Clinton
INSTRUMENT COMPANY

Model FL-20A Cable Fault Locator
Instruction Manual

Clinton Instrument Company

295 East Main Street
Clinton, CT 06413 USA
Telephone: 860.669.7548 Fax: 860.669.3825
www.clintoninstrument.com

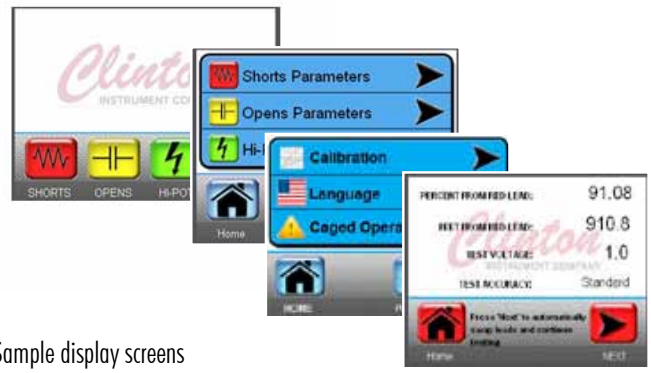
MODEL FL-20A

Cable Fault Locator

- >> Quickly locates opens, shorts and high voltage shorts in cable lengths
- >> Fully automated testing
- >> Simple to operate
- >> Color touch screen
- >> Compact, lightweight unit
- >> CE approved

Reels of rejected multi-conductor and shielded cable sitting on the production floor are an expensive problem. Until now, finding opens and shorts with an analog cable fault locator took expertise and patience, since the procedure required tedious meter and sensitivity adjustments as well as mathematical calculation once the test was completed.

The digital FL-20A automates cable fault detection, greatly reducing the time and training required to find these problems. Opens, metallic shorts, or high voltage shorts between conductors or between conductor and shield are pinpointed quickly and with ease. The operator simply connects the FL-20A test probes to each end of the cable under test, enters the cable length on the digital touch screen, and selects "Shorts" or "Opens" to begin the test. The unit quickly calculates the distance of the fault site from each test probe, displays the location in feet or meters, and provides a suggested trim area. The failure can then be cut out or repaired and the remaining good product salvaged, resulting in great savings to the producer.



Sample display screens

The FL-20A Cable Fault Locator, a compact 15"W x 14"D x 10"H weighing only 38 lbs., is significantly smaller and lighter than its predecessors. It promises a great return on investment by salvaging expensive cable assemblies and lowering the costs associated with salvage.

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FL-20A
SPECIFICATIONS

Fault Definitions:

Open.....A condition where a single conductor has no continuity from one end to the other.

Metallic Short.....Two conductors without insulation or a conductor and a shield which physically come into contact with one another.

High Voltage Short.....Two conductors or a conductor and a shield which have no insulation between them but do not contact one another.

Voltage Test Range.....0-20KV D.C.

Display.....6-inch backlit color TFT touch screen.

Output Current.....6 ma. maximum.

Equipment Accuracy.....Better than 1% of total cable length (dependent on accuracy of actual cable footage and product uniformity).

Cable Loop Resistance

Metallic Short.....50 milliohms minimum.

High Voltage Short.....300 milliohms minimum.

Dimensions:

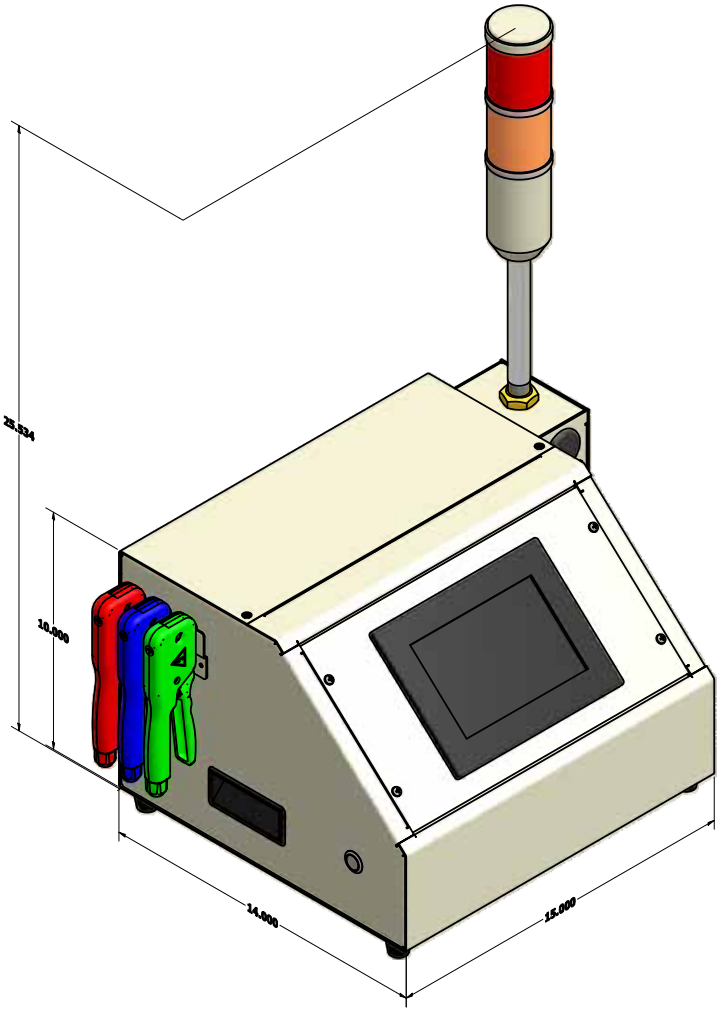
FL-20A.....15"W x 14"D x 10"H.

FL-20A with X3F.....15"W x 14"D x 25.5"H.

Test Leads.....10' standard, 20 & 30 ft. available.

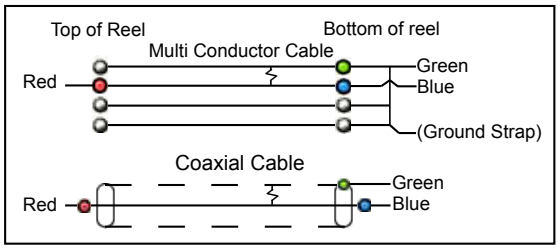
Weight.....38 lbs. (17.3kg.).

Power Requirements.....100 - 240 volts AC, 50/60 Hz 2 amps.

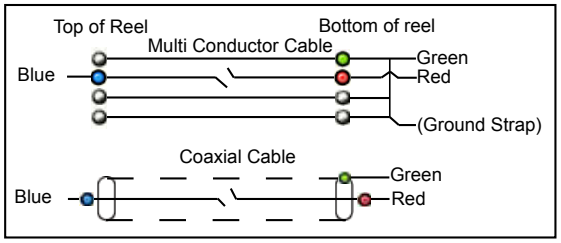


Typical Lead Connections

Shorts



Opens



Clinton INSTRUMENT COMPANY 295 East Main St. • Clinton, CT 06413 USA • Tel: 860.669.7548 • Fax: 860.669.3825 • www.clintoninstrument.com

Table of Contents

Declaration of Conformity

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

Herewith declares that
The Cable Fault Locator
Type FL-20A
is in conformity with the provisions of the following EEC directives:

89/236/EEC
73/23/EED

Conforms with the emissions requirements of EN 61326-1:2006; Clause 7.2:
CISPR 11 Edition 4:2003 .....Conducted Emissions, Class A
CISPR 11 Edition 4:2003 .....Radiated Emissions, Class A
IEC 61000-3-2:2000 .....Harmonics
IEC 61000-3-3:2002 .....Flicker

Conforms with the immunity requirements of EN 61326:2006; Table 1:
IEC 61000-4-2:2001 .....Electrostatic Discharge
IEC 61000-4-3:2002 .....Radiated Immunity
IEC 61000-4-4:2004 .....EFT/Burst, Power and I/O Leads
IEC 61000-4-5:2001 .....Surge Immunity
IEC 61000-4-6:2003 .....Conducted Immunity, Power and I/O Cables
IEC 61000-4-11:2004 .....Voltage Dips and Interrupts

Conforms to the safety requirements of EN61010.

Clinton, CT USA February 2010

Marianne Szreders
President

Ted P. Lane
Chief Engineer

Safety

Danger! High Voltage Safety Hazards

Caution--Read before using this equipment.

DISCHARGE ALL CONDUCTORS OF THE TEST CABLE PRIOR TO CONNECTING TO THE FL-20A. YOU MUST REMOVE ANY STORED CHARGE FROM THE PREVIOUS OPERATION, SUCH AS A HI-POT TEST. A STORED CHARGE IN THE CABLE CAN KILL!!!

The FL-20A employs high voltage to locate cable faults. It is imperative that only personnel trained in the dangers of high voltage operate this equipment. **A stored charge in the TEST PRODUCT can be lethal,** even when the cable is no longer attached to the FL-20A. Please read and understand the manual prior to operating this equipment.

A Warning to Supervisors!

The FL-20A is equipped with such safety features as external and internal safety interlocks, a red high voltage warning light, grounding sensors, and password protection. Do not attempt to defeat or bypass any safety feature. Failure to observe proper safety precautions can result in severe injury or death!

Supervisory personnel are strongly advised to use the built-in password protection feature to prevent unauthorized persons from defeating safety features or changing test parameters. Read the section in Installation entitled, "Password Protection," for further information.

A Warning Note to Operators!

When cables are being tested with this or any high voltage equipment, the possibility of leaving a dangerous charge in the cable is always present. Always bunch together and ground all conductors not under test, including to the cable shield and to the earth ground, using the provided ground probe. Make sure the test is complete, that the high voltage indicator lamp is off, and that **all leads are shorted to ground before touching any part of the cables.**

Although the high voltage output of the FL-20A is not in itself capable of delivering a truly dangerous shock, a stored charge in the cable can, if proper safety precautions are not taken. For this reason, operators and supervisors should establish rigid safety procedures for the use of this and all high voltage equipment.

High Voltage Facts

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.

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.

Safety Symbols

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

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

Risk of electric shock symbol.

Earth (ground) symbol.

Environmental Conditions

The Model FL-20A Cable Fault Locator 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.

Installation

Unpacking

The following items are included in the shipment:

- FL-20A Cable Fault Locator, with a set of 3 test probes (red, blue and green) connected to the back of the unit
- A green 2-position connector, to be used as a safety interlock if products will be tested in a cage. This will also be used during calibration.
- X3F Light Tower
- A 4-conductor cable with a 4-pin connector on one end, and a 10-pin connector on the other, to connect the FL-20A to the X3F
- 4 bolts to mount the X3F to the FL-20A
- A Y- power cord
- 91785 FL Test Box
- (3) 92100 Probe Clip Assemblies (other sizes available)
- An instruction manual

If a printer was ordered, the following items are included:

- Printer
- Printer cable
- Power adapter
- Roll of paper, part no. 91901

Remove the FL-20A and accessories from the carton. Retain the packing material in the event that the unit is returned for calibration or service at some future time.

Site Preparation

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 damage to equipment.

Caged Operation

Cables under high voltage test can build up a deadly charge. It is common practice to enclose cables under test in a caged area to protect workers, with the FL-20A located outside the cage. When the FL-20A Caged

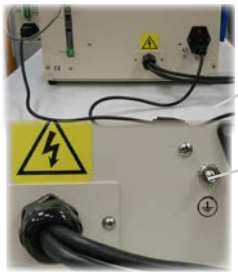
Operation mode is selected, the equipment operator can perform a cable test by momentarily pressing the safety buttons on the side of the fault locator, rather than having to press the buttons for the duration of the test. Caged Operation requires that the high voltage safety interlock on the back of the unit be connected to the cage door interlock. See "Wiring Requirements" for external safety interlock wiring instructions.

Wiring Requirements

Mount the X3F Light Tower

Be sure the FL-20A is OFF. Mount the X3F to the right side of the FL-20A, using the 4 bolts provided.

Locate the 10-pin green terminal block on the back of the X3F, the 4-pin terminal block on the back of the fault locator, and the 4-conductor cable supplied with the unit. Plug the 10-pin connector into the X3F 10-pin terminal block and the 4-pin connector into the 4-pin block on the rear panel of the FL-20A.



When the wiring is complete, plug the Y-power cord into the X3F and the fault locator.

Ground the chassis

Connect a ground wire to the ground terminal on the rear of the FL-20A chassis. Connect the other end to earth ground. Use 22 gauge wire or larger. This is an important safety task that must not be neglected.

Wire the external safety interlock (Caged Operation)

Wire the green 2-position connector to 22 ga. or larger wire and connect to the 2-pin FL-20A external safety interlock terminal block, found on the rear of the FL-20A. Connect the other end of the wire to the cage door. If you will not be using Caged Operation, skip this step.

Printer Installation

1. Plug the power adapter into the connector located on the back right of the Thermal Receipt Printer.
2. Connect the male end of the printer cable into the back of the printer and the female end of the printer cable into the FL-20A connector labelled "Printer," located on the rear of the unit.
3. Make sure paper (Part # 90901) is inserted and fed through the printer.
4. Press the switch on the back left of the printer to turn ON. The

printer is ready when a green power light shows on front of printer.

5. Printing occurs when the final test page (results page) appears on the FL-20A display screen, as shown in the picture to the left.

Password Protection

The FL-20A offers password protection that can prevent unauthorized individuals from defeating safety features and changing voltage settings and test parameters. Using password protection will make your work-place safer.

After making necessary changes in the Settings menu, go to the Set Admin Password setting. The default password is 1111. To change it, press the displayed password to access a keypad. Enter a new 4-digit password and press OK.

After entering a new password, go to the Lock Settings Menu function and turn it ON. This will restrict unauthorized personnel from accessing the Settings menu. If the new password should be lost, contact the factory.

Definitions

Shorts

Metallic short

A condition where there is direct metal-to-metal contact between two conductors.

High voltage short

Two conductors without insulation, or a conductor and a shield with no insulation between them, where there is no direct contact. The condition is detected only at high voltage when arcing occurs between conductors.

Intermittent arc

An intermittent arc is a high voltage short present that breaks down marginally at the selected hi-pot voltage.

Opens

An open is a condition where a single conductor has no continuity from one end to the other.

Hi-Pot Test

Also called a dielectric withstand test. The purpose of this test is to charge one conductor to determine if high voltage at a predetermined level will discharge to ground through the insulation. If too much current flows, the conductor is not well insulated and it fails the test.

Loop Resistance

Conductor resistance to the flow of electrical current, measured in ohms/1,000 feet. Resistance is inversely proportional to the cross-sectional area of the conductor, so when the diameter of the conductor is doubled, the resistance declines 50 percent. FL-20A tests for metallic shorts are accurate on conductors with loop resistances of 50 milliohms or greater. Tests for high voltage shorts are effective on conductors with resistances of 200-250 milliohms or greater.

Accuracy

The accuracy of the test performed. Ratings are influenced by cable characteristics such as low loop resistance. Accuracy is reported as follows:

Low

There may be multiple faults in the cable, the cable may have low loop resistance, or the fault is judged to be close to either end.

Standard

The test is considered good, with good results.

Exceptional

The fault location was easily located, and test results are accurate within 1% of the cable length.

FL-20A Controls

ON/OFF power switch

This switch is located on the rear panel of the unit.

Ground connection

A 10-32 grounding stud located on the rear panel of the FL-20A chassis. Wire to earth ground as directed in the Installation section.

External safety interlock (for Caged Operation)

If cables are to be tested in a caged area with the FL-20A located outside, the FL-20A external safety interlock must be wired to the cage door so that cables may be tested only when the cage door is closed. When the external interlock is engaged and the Caged Operation setting, found in the Settings menu, is ON, the operator will be required to momentarily press the FL-20A safety buttons during a test, rather than press them for the full test. Refer to the section of Caged Operation for wiring details.

The safety interlock is also required for calibration. A two-position connector is supplied for this purpose. Refer to the Calibration section for instructions.

Front panel touch screen

The touch screen is used to set test parameters, run tests, and view test results. Never press the touch screen with a tool or sharp object.

Safety buttons

Located on each side of the FL-20A, the safety buttons must be held in during a shorts or hi-pot test. This is a safety feature that prevents the operator from touching the charged test cable during a test.

Red and blue test probes

The red probe will connect to one end of a test conductor, and the blue probe to the opposite end. Review the instructions in the Installation section on how to properly strip back the conductors and insert them into the probes. This is an important safety procedure.

Green ground probe

The green ground probe is used to make connections to the reference

conductor and to ground the test cable. Review the instructions in the test sections on how to properly strip back the conductors and insert them into the probe. This is an important safety procedure.

X3F Light Tower

When the X3F is properly installed, the red High Voltage light will go ON when high voltage is present on the FL-20A test probes.

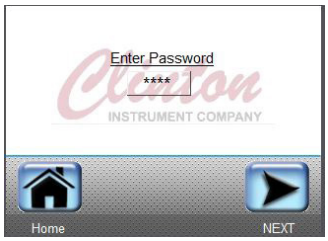
The yellow Test In Progress light will flash during a test.

Warning: when the red High Voltage light on the X3F is illuminated, do not touch the red and blue probes or the test cable, because a charge is present. If the cable capacitance is large, the light may be illuminated for several seconds after the test is complete.

Settings Menu

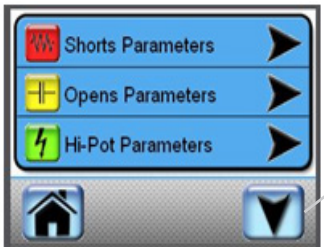
Test parameters are found on the touch screen Settings menu. They are saved in memory even when the FL-20A is off. To view or change test parameters, turn on the FL-20A power switch, which is located on the back of the unit. The FL-20A will take a few moments to boot up. Do not touch the screen until the Clinton logo appears. The main menu will appear.

Press the Settings button.



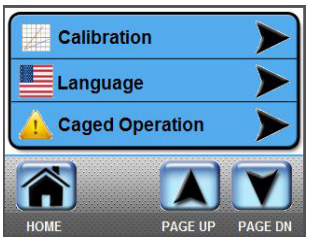
The Password Entry screen will appear. Click inside the Password box and enter the password on the keypad and press OK. The default password is 1111. Press NEXT. (If you wish to change the password, go to Set Admin Password, on a later page of the Settings menu.)

The first page of the Settings menu will appear.



Press Pg Down to the next few pages of the Settings menu to access the following global settings: Calibration, Language, Caged Operation and Unit of Measure. These settings apply to all Opens, Shorts and Hi-Pot Testing.

Global Settings



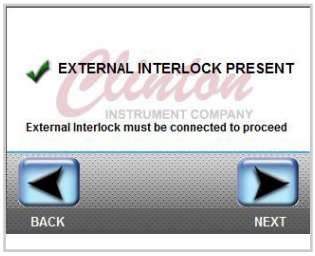
Global settings such as Calibration, Language, Caged Operation, and Unit of Measure apply to Opens, Shorts and Hi-Pot tests. They are found in the several pages of the Settings Menu. To view or modify a setting, press the appropriate button to access the subscreen. Addtional screens such as System Information, System Errors, Set System Defaults, and Set Admin Password are also included in the Settings menu.

Calibration

This setting allows the user to calibrate the FL-20A output voltage and voltage reporting. Refer to the section entitled,"Calibration," for specific instructions.

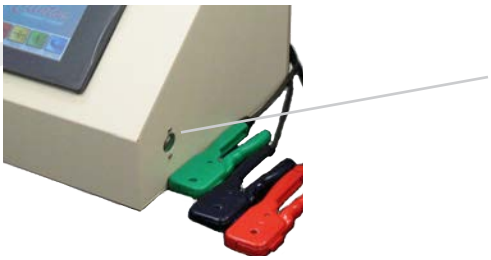
Language

Flag icons representing the languages that are available on the FL-20A are displayed here. The languages are English, Japanese, Spanish, German, French, Italian, Swedish, and Chinese. Press the flag icon of your choice. The default setting is English.



Caged Operation

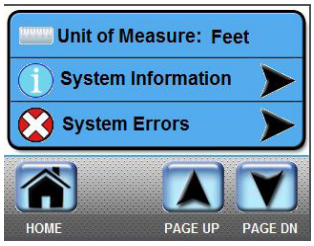
Cables under high voltage test can build up a deadly charge that remains



until the conductors are intentionally discharged. For this reason, an operator using the FL-20A in an open area is required to hold in the safety buttons on each side of the fault locator. This is a safety precaution to prevent him or her from touching the test cable while it is charged. In this situation, Caged Operation is OFF. This is the default setting.

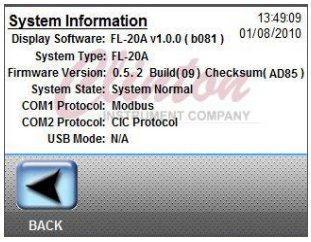
Do not attempt to defeat the safety buttons. Failure to observe proper safety precautions can result in severe injury or death!

Because it is common practice to use a fault locator in a caged area to protect workers, the Caged Operation setting can be changed to ON, and the FL-20A operator can perform a test without pressing in the safety buttons on each side of the fault locator. To turn ON the Caged Operation setting, the external interlock on the back of the FL-20A unit must be connected to the cage door. Press NEXT to access the next screen. Then press the ON/OFF area of the screen to change Caged Operation to ON. Press ACCEPT.



Unit of Measure

Test cable lengths may be displayed in feet or meters. The unit of measure cannot be changed during a test. Press the displayed choice to toggle between Feet or Meters.



System Information

FL-20A firmware and software version numbers are stored here. During troubleshooting, you may be asked for this information by a Clinton technician.

System Errors

System error information is stored here. A Clinton technician may request that you access this information during troubleshooting if the yellow or red lights on the back of the FL-20A are flashing.

Set System Defaults

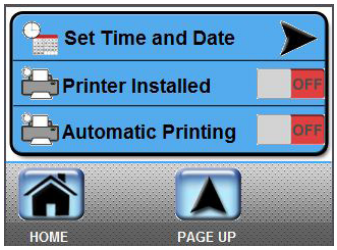
The Set System Defaults RESTORES system defaults. Restoring System Defaults does not affect calibration.

Set Admin Password

When Lock Settings is ON, a password is required to access the Settings menu. Reserving global setting access to supervisory personnel prevents unauthorized individuals from changing test parameters or defeating safety features. The default password is 1111. To change it, press the displayed password to access a keypad. Enter a new 4-digit password and press the check mark/accept button.

After changing the password, turn Locked Settings Menu ON to prevent unauthorized access to the Settings menu.

Note: change the Password before you turn ON the Lock Settings Menu option.



Lock Settings Menu

When Lock Settings Menu is ON, you will be required to enter the admin password to access the Settings menu. If the password is lost, contact the factory. The default setting is OFF.

Set Date and Time

If printed report information with date and time is required, enter the current date and time. The FL-20A will retain this setting in memory, even when it is turned OFF.

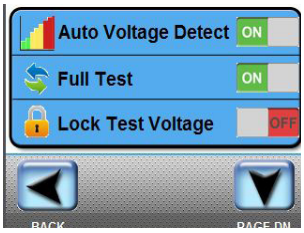
Printer Installed

Turn ON this setting if a thermal printer is attached to the FL-20A.

Automatic Printing

When this setting is ON, it will force printing at the end of each test, rather than prompting the operator.

Shorts Parameters



Shorts Parameters are accessed from the Settings menu. The first page of the Shorts Parameters settings will appear. These settings will apply to all shorts tests that will be done. They are saved in memory even when the FL-20A is off.

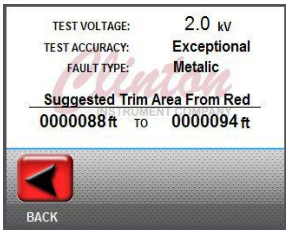
Auto Voltage Detect

During the shorts test, the optimum voltage level is the test voltage required to cause a fault to arc to ground, not higher. When Auto Voltage Detect is ON, the fault locator will begin testing the conductor at 10% of the Shorts Max Voltage and increase it by 10% increments until a short is found. For example, if Shorts Max Voltage is set at 10KV, the test voltage begins at 1KV and rises by 1KV until a short is found.

This feature may prevent damage to the cable by testing at the lowest possible voltage. It also may be useful when multiple high voltage shorts are present, since one short may arc at a lower test voltage than another. When the first short is detected, it can be cut out of the cable, and the test can be resumed to locate the second short.

Full Test

When this setting is ON, the equipment will first locate the distance of



the short from the red probe, and then find its distance from the blue probe. A summary screen showing the distance of the fault from each probe will display. The total of the two distances should equal the length of the test cable. By pressing MORE, the operator may view the rated accuracy of the results as well as a suggested cable area to remove. The full report may be printed.

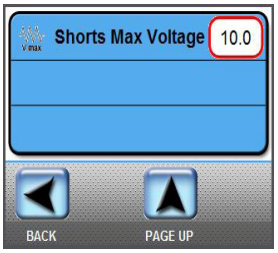
When the setting is OFF, the FL-20A performs only a partial test, finding the distance of the short from the red probe and then pausing to display a report. You may press BACK to terminate the test, but the test's accuracy is, at this point, unknown. If you instead press NEXT, the FL-20A will then proceed to ind the distance of the short from the blue probe. A summary screen showing the short's location from the red and blue probes, as well as the rated accuracy of the test and the suggested trim area, will display.

The default for Full Test is ON. Experienced operators working with a particular cable type are sometimes confident that a partial test is accurate and choose it to reduce test time. However, this is not recommended without the advice of a Clinton technician.

Lock Test Voltage

When this setting is ON, the Shorts Max Voltage setting cannot be changed at test time, although the voltage setting is displayed during the test.

Shorts Max Voltage



This setting is found on the second page of the Shorts Parameters settings. This is the maximum voltage that will be applied during the shorts test. An entry of 10.0 represents 10KV DC. To change the setting, press the existing value to view a keypad. Enter the new value, using the decimal point and press OK.

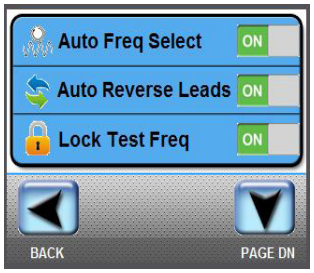
If this value is set too high, damage to the cable may result.

If the maximum voltage is set too low, a high voltage short may not arc and cannot be located.

Shorts Max Voltage can be changed at the time of test if Lock Test Voltage is OFF.

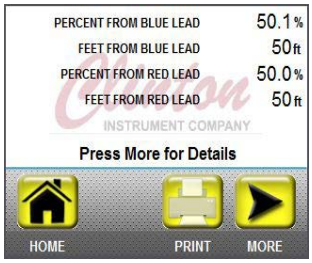
Opens Parameters

Access the Open Parameters settings from the Settings menu. They apply to opens tests that will be done. They are saved in memory even when the FL-20A is off. The default settings are usually optimum for opens testing. It is not advisable to change them, except the Auto Reverse Leads setting, without factory advice.



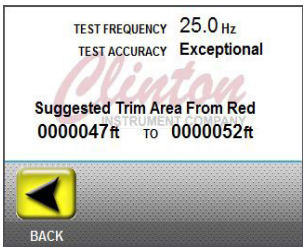
Auto Frequency Select

When this setting is ON, the FL-20A will automatically find the optimum frequency at which to test. When the setting is OFF, it will test at the Set Frequency, which may not give you correct results. The default setting is ON.



Full Test

When this setting is ON, the equipment will first locate the distance of the open from the blue probe, and then find its distance from the red probe. A summary screen showing the distance of the fault from each probe will display. The total of the two distances should equal the length of the test cable. By pressing MORE, the operator may view the rated accuracy of the results as well as a suggested cable area to remove. The full report may be printed.

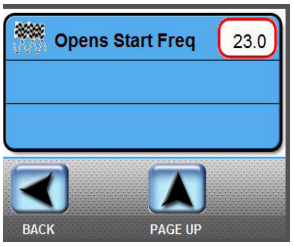


When the setting is OFF, the FL-20A performs only a partial test, finding the distance of the open from the blue probe and then pausing to display a report. You may press BACK to terminate the test, but the test's accuracy is, at this point, unknown. If you instead press NEXT, the FL-20A will then proceed to ind the distance of the short from the red probe. A summary screen showing the open's location from the red and blue probes, as well as the rated accuracy of the test and the suggested trim area, will display.

The default for Full Test is ON. Experienced operators working with a particular cable type are sometimes confident that a partial test is accurate and choose it to reduce test time. However, this is not recommended without the advice of a Clinton technician.

Lock Test Frequency

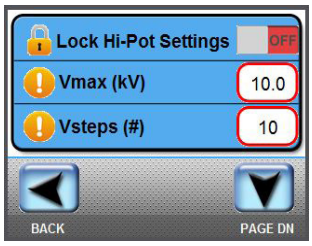
When this setting is ON, the FL-20A will not prompt the user to enter a test frequency before the Opens test. The default setting is ON.



Opens Start Frequency

This setting is found on Page 2 of the Opens Parameters menu. It is the frequency applied during the Opens test. The default setting is 23.0 Hz. Do not change this frequency without factory advice.

Hi-Pot Parameters



Access Hi-Pot parameters from the Settings menu.

Lock Hi-Pot Settings

When Lock Hi-Pot Settings is OFF, the user can change the values that are entered in the Hi-Pot Parameters menu during a Hi-Pot test. When Lock Hi-Pot Settings is ON, the operator cannot change the parameters

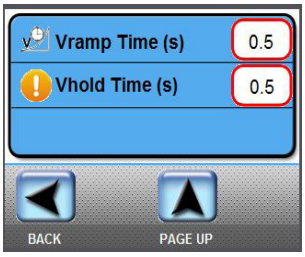
during the test. The default setting is OFF.

Vmax (kV)

This is the maximum Hi-Pot test voltage. The range is 1.0kV to 20.0kV. This setting can be changed here to affect all Hi-Pot tests, or at the time of test if Lock Hi-Pot Settings is OFF.

Vsteps (#)

This is the number of steps the Hi-Pot test will take to get to Vmax (kV), the maximum Hi-Pot voltage. The number is between 2 and 20. This setting can be changed here to affect all Hi-Pot tests, or at the time of test if Lock Hi-Pot Settings is OFF.



Vramp Time (s)

This setting is found on page 2 of the Hi-Pot parameters menu. This is the time, in seconds, up to 60 seconds, that the FL-20A will take to perform each Vstep to get to the preset maximum Hi-Pot voltage (Vmax (kV)). This setting can be changed here to affect all Hi-Pot tests, or at the time of test if Lock Hi-Pot Settings is OFF.

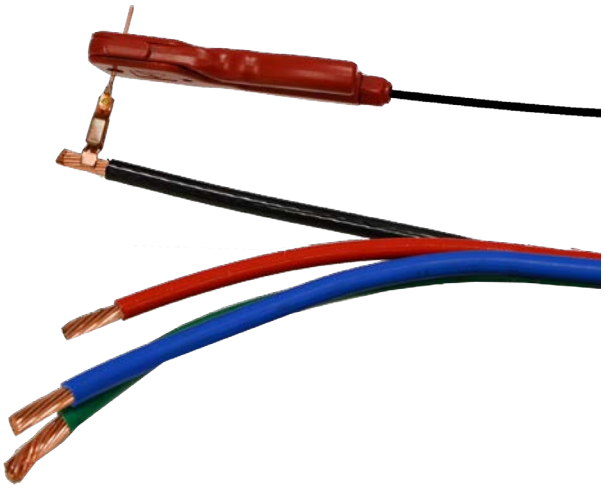
Vhold Time (s)

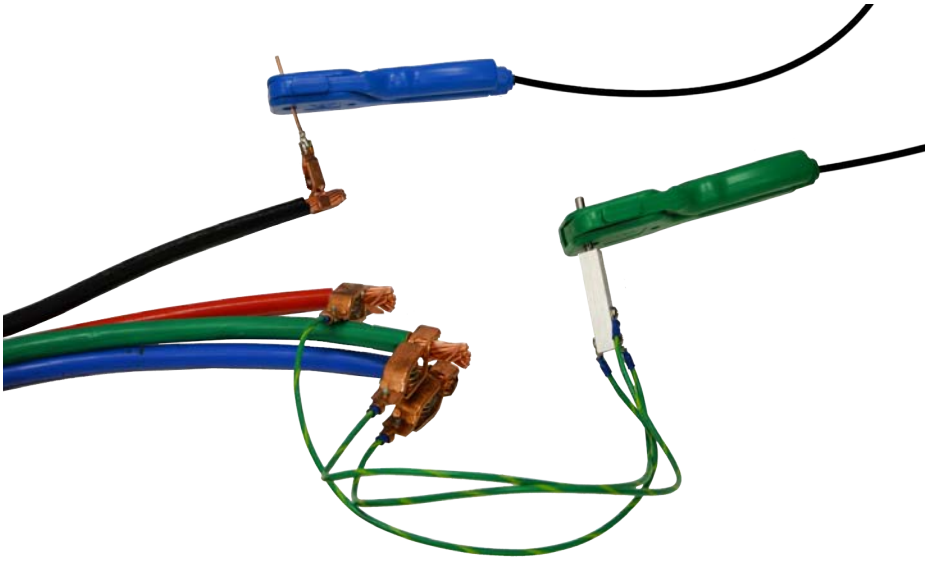
This is the time, in seconds, that the FL-20A will stay at Vmax (kV), the maximum test voltage, before the test ends. The maximum Vhold Time (s) is 60 seconds. This setting can be changed here to affect all Hi-Pot tests, or at the time of test if Lock Hi-Pot Settings is OFF.

Testing Large Cables with the FL-20A

If conductors are too large to insert into the probes, special attention must be paid to insure that proper connections are made. Poor connections can be dangerous to personnel. Additionally, the FL-20A graphics display may not function correctly due to excess electrical noise created by improper grounding.

Alligator clip assemblies similar to those shown in the photos below are highy recommended when cables to be tested are too large to fit properly in the probes. These items are available for purchase. Smaller cable sizes can use the enclosed 3 probe clip assemblies part number 92100. Larger cables may require part number 92113.





Performing a Shorts Test

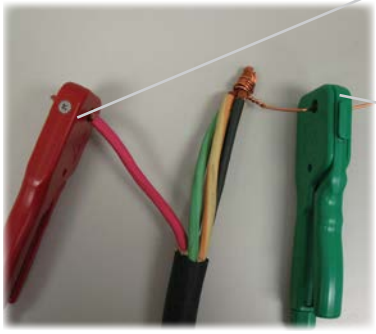
Caution. DANGER!!!

It is imperative that only personnel trained in the dangers of high voltage operate this equipment. A stored charge in a test cable can kill! A charge can remain in a cable if the cable has not been properly discharged, even when it is no longer attached to the FL-20A.

Discharge all conductors of the test cable prior to connecting to the FL-20A to remove any stored charge from a previous operation. A stored charge in the cable can be lethal.

Note: to determine the accuracy of the Shorts test that you can expect on your test product, please refer to the chart entitled, "Cable Loop Resistance Chart."

1. Review the Shorts Parameters settings that have been entered before proceeding with the test. They are found in the Settings menu.
2. Select the first conductor to be tested. Strip back by 1" and insert the exposed conductor into the red test probe. Be sure that insulation does not obstruct the connection between the metal in the probe and the exposed conductor. Strip the other end of the conductor and insert into the blue test probe.

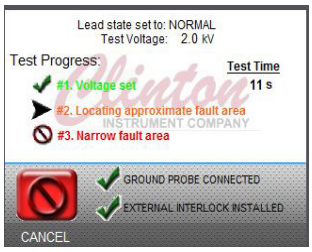


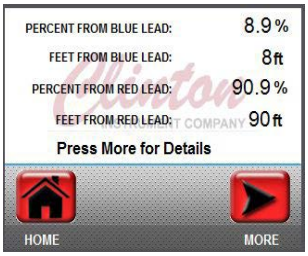
3. Ground all untested conductors. On one end of the test cable, strip back all conductors not under test by 1", carefully bunch them together with the cable shield so that they make a good connection with one another, and insert into the green ground probe. Be sure that insulation does not obstruct the connection between the metal in the probe and the exposed conductors. Do not attempt to bypass this safety procedure. Failure to observe safety precautions can result in severe injury or death!

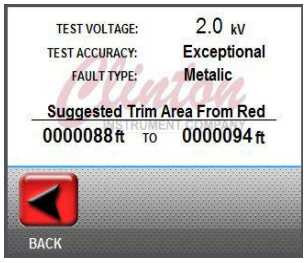
> **NOTE:** If conductors are too large to insert into the probes, see the section entitled, "Testing Large Cables with the FL-20A." It is critical that conductors be connected properly. Poor connections can be dangerous to personnel; additionally, the FL-20A graphics display may not function correctly due to noise.

4. At the main menu, press the Shorts button to begin a test for high voltage shorts or metallic shorts. The screen will guide you through the test.
5. Enter the maximum test voltage. (If the Lock Test Voltage setting is ON, this screen will not be displayed.)

6. If the Printer Installed setting is ON, a screen will appear allowing you to enter a reel description. The reel description will appear on a printed test report, if one is desired.








```
*****************************
***** FL-20A Test Receipt *****
*****************************
*          Reel ID          *
*          DEFAULT          *
*****************************
*     Test Type: Shorts     *
*      Date: 03/02/2010     *
*      Time: 02:12:59       *
*****************************
*  Test Voltage:      1.0kV *
*    Short Type:   Metallic *
*     Accuracy:   Standard  *
*     Test Time:       40s  *
*****************************
* Test Results:             *
*     9.4% from Red         *
*    91.3% from Blue        *
*****************************
* Total Reel Footage: 0000100 *
*      ft from Red: 0000009 *
*     ft from Blue: 0000091 *
*****************************
* Suggested Trim Area From Red *
*   0000007ft to 0000011ft    *
*****************************
*****************************
```

7. Enter the cable length. Press the displayed number to access a key pad and enter the test cable length. Press OK. The unit of measure entered previously in the Length UOM setting will appear. Press NEXT.

   The X3F yellow light will begin to flash, indicating that a test is in progress. If the green ground probe is connected as described in step 4, the the touch screen will display, "Ground Probe Connected."

8. If the Caged Operation setting is ON and the safety interlock is open, the touch screen will note that the External Interlock is not installed.

9. When the external interlock is closed, the test can proceed. For Caged Operation, the touch screen will display: "To initiate test, momentarily press safety switches." If the Caged Operation setting is OFF, the screen will display, "Hold Safety Switches."

10. Press the safety switches as directed.

11. The FL-20A touch screen will indicate test progress as it tries to locate the fault. The X3F yellow light will flash to alert that a test is in progress, and the red High Voltage light will go on, indicating that there is high voltage on the test cable.

12. If the Full Test setting is OFF, the first test result screen, indicating the fault distance from the red probe, will appear. Press NEXT to continue the test, or press HOME to exit the test.

    If the Full Test setting is ON, the unit will proceed through both halves of the test, and a complete test summary report will appear. The fault distance from the blue probe plus the fault distance from the red probe should total the approximate length of the test cable.

13. If the test accuracy is Standard or better, a "More" button will display. Press More to view the test accuracy and suggested trim area.

WARNING: Do not touch the red and blue probes or the test cable until the red light on the X3F goes OFF. The red light indicates that there is still a charge present on the test cable and the probes. Before handling the reel under test, wait at least 10 seconds, then discharge all conductors to ground. A stored charge in the cable can be lethal.

14. A printed report showing details of the test is available if a thermal printer was attached to the FL-20A and the Printer Installed setting is ON. If the Automatic Printing setting is OFF, press the printer icon to print the report. If the Automatic Printing setting is ON, the report will print automatically.

Performing an Open Tests

Caution.

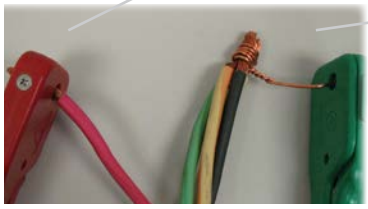
It is imperative that only personnel trained in the dangers of high voltage operate this equipment. A stored charge in a test cable can kill! A charge can remain in a cable if the cable has not been properly discharged, even when it is no longer attached to the FL-20A.

Caution. Discharge all conductors of the test cable prior to connecting to the FL-20A Fault Locator to remove any stored charge from a previous operation. A stored charge in the cable can be lethal.

Note: to determine the accuracy of the Opens test that you can expect on your test product, please refer to the chart entitled, "Cable Capacitance Chart."

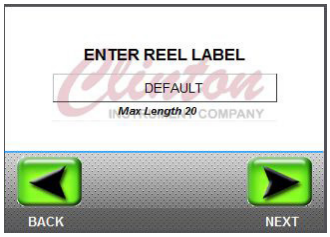
1. Review the Opens Parameters settings that have been entered before proceeding with the test. They are found in the Settings menu.

2. Select the first conductor to be tested. Strip back by 1" and insert the exposed conductor into the red test probe. Be sure that insulation does not obstruct the connection between the metal in the probe and the exposed conductor. Strip the other end of the conductor and insert into the blue test probe.



3. Ground all untested conductors. On one end of the test cable, strip back all conductors not under test by 1", carefully bunch them together with the cable shield so that they make a good connection with one another, and insert into the green ground probe. Be sure that insulation does not obstruct the connection between the metal in the probe and the exposed conductors.

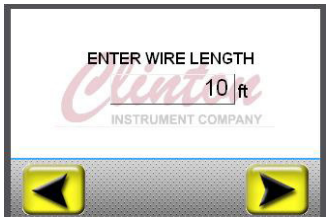
> **NOTE:** If conductors are too large to insert into the probes, see the section entitled, "Testing Large Cables with the FL-20A." It is critical that conductors be connected properly. Poor connections can be dangerous to personnel. Additionally, the FL-20A graphics display may not function correctly due to noise.

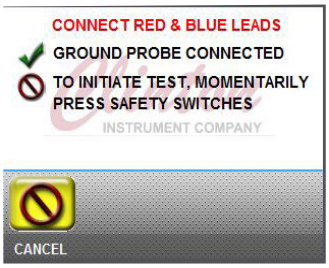


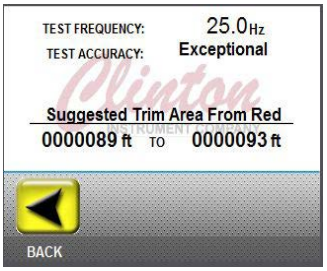
4. At the main menu, press the Opens button to begin a test for opens. The screen will guide you through the test.

5. If the Printer Installed setting is ON, a screen will appear allowing you to enter a reel description. The reel description will appear on a printed test report, if one is desired.

6. Enter the Test Frequency. If the Lock Test Frequency setting is ON, this screen will not be displayed. Under most circumstances, the Test Frequency should not be changed from the default.







7. Enter the cable length. Press the displayed number to access a key pad and enter the test cable length. Press OK. The unit of measure entered previously in the Length UOM setting will appear.

   Press NEXT. Momentarily press the safety switches on the sides of the unit. The X3F yellow light will begin to flash, indicating that a test is in progress. If the green ground probe has been connected as described in step 4, the touch screen will display, "Ground Probe Connected." The X3F yellow light will flash to alert that a test is in progress, and the FL-20A touch screen will indicate that the test has begun.

8. If the Full Test setting is OFF, the first test result screen, indicating the fault distance from the blue probe, will appear. Press NEXT to automatically reverse the leads and continue the test, or press HOME to exit the test.

9. If the Full Test setting is ON, the unit will proceed through both halves of the test, and a complete test summary report will appear. The fault distance from the blue probe plus the fault distance from the red probe should total the length of the test cable.

10. If the test accuracy is Standard or better, a "More" button will display. Press More for Details to view the test accuracy and suggested trim area from the red probe.

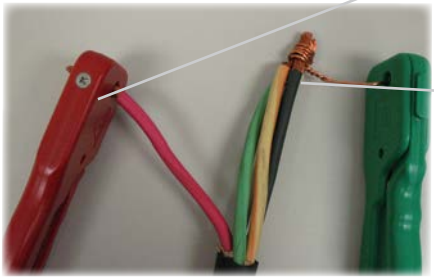
Performing a Hi-Pot Test

Caution.

It is imperative that only personnel trained in the dangers of high voltage operate this equipment. A stored charge in a test cable can kill! A charge can remain in a cable if the cable has not been properly discharged, even when it is no longer attached to the FL-20A.

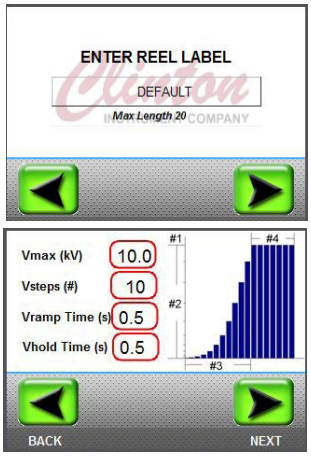
Discharge all conductors of the test cable prior to connecting to the FL-20A to remove any stored charge from a previous operation. A stored charge in the cable can be lethal.

Note: to determine the accuracy of the Hi-Pot test that you can expect on your test product, please refer to the chart entitled, "Cable Loop Resistance Chart."



1. Review the Hi-Pot Parameters settings that have been entered before proceeding with the test. They are found in the Settings menu.
2. Select the first conductor to be tested. Strip back by 1" and insert the exposed conductor into the red test probe. Be sure that insulation does not obstruct the connection between the metal in the probe and the exposed conductor. Strip the other end of the conductor and insert into the blue test probe.
3. Ground all untested conductors. On one end of the test cable, strip back all conductors not under test by 1", carefully bunch them together with the cable shield so that they make a good connection with one another, and insert into the green ground probe. Be sure that insulation does not obstruct the connection between the metal in the probe and the exposed conductors. Do not attempt to bypass this safety procedure. Failure to observe safety precautions can result in severe injury or death!

> **NOTE:** If conductors are too large to insert into the probes, see the section entitled, "Testing Large Cables with the FL-20A." It is critical that conductors be connected properly. Poor connections can be dangerous to personnel. Additionally, the FL-20A graphics display may not function correctly due to noise.

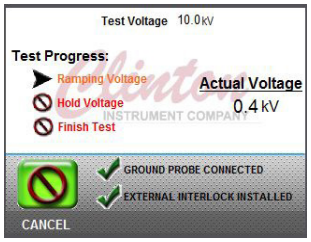


4. At the main menu, press the Hi-Pot button. If the Printer Installed setting is ON, a screen will appear allowing you to enter a reel description. The reel description will appear on a printed test report, if one is desired. Press NEXT.
5. A descriptive graph of the settings that were entered in Hi-Pot

Parameters will appear on the touch screen.

6. If Lock Hi-Pot Settings is OFF, all settings can be changed here, before the test begins. To change a setting, press on the setting value to access a keypad, enter the new value, and press OK. When all settings are correct, press NEXT.

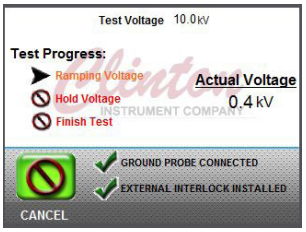
   If Lock Hi-Pot Settings is ON, settings cannot be changed. Press NEXT.



7. The touch screen will guide you through the hi-pot test. If the green ground probe is connected as described in step 4, the the touch screen will display, "Ground Probe Connected."

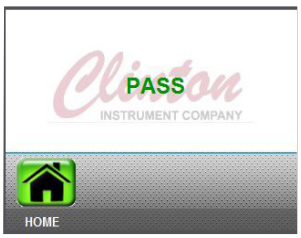
8. If the Caged Operation setting is ON and the safety interlock is open, the touch screen will note that the External Interlock is not installed. When the external interlock is closed, the test can proceed.

9. For Caged Operation, the touch screen will display: "To initiate test, momentarily press safety switches." If the Caged Operation setting is OFF, the screen will display, "Hold Safety Switches."

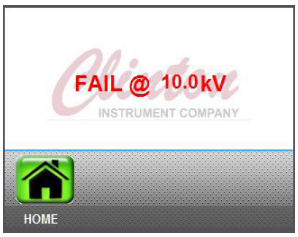


10. Press the safety switches as directed.

11. The FL-20A touch screen will indicate test progress as it tries to locate the fault. The X3F yellow light will flash to alert that a test is in progress, and the red High Voltage light will go on, indicating that there is high voltage on the test cable.



12. If the hi-pot test is successful, the touch screen will display, "Pass." A "Pass" indicates that the tested conductors were able to withstand the preselected voltage for the preselected amount of time, without any arcing. If there is an arc condition, the touch screen will display, "Fail" and the voltage at which it failed.



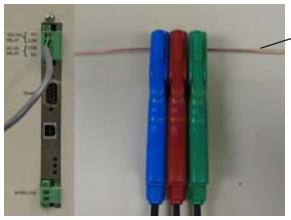
13. **WARNING: Do not touch the red and blue probes or the test cable until the red light on the X3F goes OFF. The red light indicates that there is still a charge present on the test cable and the probes. Before handling the reel under test, wait at least 10 seconds, then discharge all conductors to ground. A stored charge in the cable can be lethal.**

Calibration

A 20KV DC Voltage Divider and a DC multimeter are required to calibrate the FL-20A. Metering equipment MUST be able to withstand 20kVDC.

Caution.
It is imperative that only personnel trained in the dangers of high voltage operate this equipment. A stored charge in a test cable can kill! A charge can remain in a cable if the cable has not been properly discharged, even when it is no longer attached to the FL-20A.

Calibrate the FL-20A Output Voltage

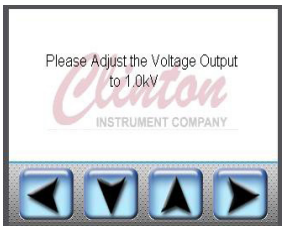


The FL-20A Output Voltage is measured on the DC multimeter.

1. Press the Calibration button, which is found on the second page of the Settings menu.
2. As directed, short all three probes (red, blue, and green) together using a piece of copper or brass rod. Locate the green 2-pin connector shipped with the FL-20A. Add a jumper between the two pins. Insert the connector into the FL-20A 2-pin external interlock terminal block, which is located on the back of the unit. You cannot proceed without installing the connector. Press NEXT.
3. The number displayed above CURRENT will be changing. Wait about 10 seconds and press the LOCK button. The CURRENT number will be saved to the CENTER number. The typical acceptable range is 12,000 to 15,000. Press NEXT.

4. Connect the shorted red and blue probes to the input of your DC multimeter.
5. Connect the green ground probe to earth ground. Check that the ground connection on the rear of the FL-20A is secure and connected to earth ground. Press NEXT.
6. The red high voltage light on the X3A will illuminate, indicating that there is high voltage on the red and blue probes.

   DANGER! Do not touch the red and blue probes for the remainder of the calibration procedure, because they are charged.

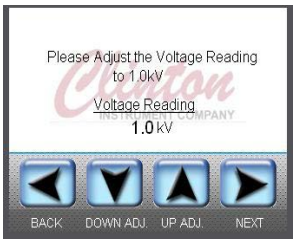


7. As directed on the touch screen, use the DOWN ADJ and UP ADJ buttons so that the multimeter displays 1.0 kV (within 2% or +/- 20 volts). Press NEXT.
8. A new screen will appear. View the reading on the multimeter. If necessary, use the DOWN ADJ and UP ADJ buttons on the touch screen until the multimeter displays 15.0 kV (+/- 2% or

300 volts). If adjustments had to be made, press BACK to the previous screen.

9. Repeat steps 11 and 12 until the multimeter screen reads 15.0 kV (+/- 2% or 300 volts) without further adjustment from the touch screen. Press NEXT.

Calibrate the FL-20A Voltage Reading



10. As directed on the touch screen, use the DOWN ADJ and UP ADJ buttons so that the Voltage Reading on the touch screen displays 1.0 kV. Press NEXT.

11. If the Voltage Reading on the touch screen is not 15.0kV, use the DOWN ADJ and UP ADJ buttons until the reading is 15.0 kV. If adjustments had to be made, press BACK to the previous screen.

12. Repeat steps 14 and 15 until the Voltage Reading reads within 2% of 15.0 kV (+/- 300 volts) without further adjustment. Press NEXT.

13. To record a calibration point, press the Voltage Reading number to access a keypad. Enter a new Voltage Reading (a number from .5kV to 20.0kV) and press OK. Record the voltage output on the multimeter. A number within 2% of the Voltage Reading is within factory tolerance. Repeat as necessary.

14. Press NEXT. The calibration is complete. Press FINISH.

Maintenance

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 is located in the ON/OFF power switch. To replace it, disconnect the power cord from power. Use a flathead screwdriver to gain access to it, as seen in the pictures below.

Cable Capacitance Chart

The accuracy of the FL-20A in Opens tests is limited by the test product's capacitance properties. Please consult the chart below to determine the results you can expect for your product.

	pF/Foot	50	Ft	100	Ft	250	FT	500	Ft	1000	Ft	2000	Ft	5000	Ft	10000	Ft	25000	Ft	50000	Ft	100000	F
Better than .5%	5	0.25	nf	0.5	nf	1.25	nf	2.5	nf	5	nf	10	nf	25	nf	50	nf	125	nf	250	nf	500	n
Better than 1.0%	10	0.50	nf	1.0	nf	2.50	nf	5.0	nf	10	nf	20	nf	50	nf	100	nf	250	nf	500	nf	1000	n
Poor Results	20	1.00	nf	2.0	nf	5.00	nf	10.0	nf	20	nf	40	nf	100	nf	200	nf	500	nf	1000	nf	2000	n
	30	1.50	nf	3.0	nf	7.50	nf	15.0	nf	30	nf	60	nf	150	nf	300	nf	750	nf	1500	nf	3000	n
	40	2.00	nf	4.0	nf	10.00	nf	20.0	nf	40	nf	80	nf	200	nf	400	nf	1000	nf	2000	nf	4000	n
	50	2.50	nf	5.0	nf	12.50	nf	25.0	nf	50	nf	100	nf	250	nf	500	nf	1250	nf	2500	nf	5000	n
	60	3.00	nf	6.0	nf	15.00	nf	30.0	nf	60	nf	120	nf	300	nf	600	nf	1500	nf	3000	nf	6000	n
	70	3.50	nf	7.0	nf	17.50	nf	35.0	nf	70	nf	140	nf	350	nf	700	nf	1750	nf	3500	nf	7000	n
	80	4.00	nf	8.0	nf	20.00	nf	40.0	nf	80	nf	160	nf	400	nf	800	nf	2000	nf	4000	nf	8000	n
	90	4.50	nf	9.0	nf	22.50	nf	45.0	nf	90	nf	180	nf	450	nf	900	nf	2250	nf	4500	nf	9000	n
	100	5.00	nf	10.0	nf	25.00	nf	50.0	nf	100	nf	200	nf	500	nf	1000	nf	2500	nf	5000	nf	10000	n
	110	5.50	nf	11.0	nf	27.50	nf	55.0	nf	110	nf	220	nf	550	nf	1100	nf	2750	nf	5500	nf	11000	n
	120	6.00	nf	12.0	nf	30.00	nf	60.0	nf	120	nf	240	nf	600	nf	1200	nf	3000	nf	6000	nf	12000	n
	130	6.50	nf	13.0	nf	32.50	nf	65.0	nf	130	nf	260	nf	650	nf	1300	nf	3250	nf	6500	nf	13000	n
	140	7.00	nf	14.0	nf	35.00	nf	70.0	nf	140	nf	280	nf	700	nf	1400	nf	3500	nf	7000	nf	14000	n
	150	7.50	nf	15.0	nf	37.50	nf	75.0	nf	150	nf	300	nf	750	nf	1500	nf	3750	nf	7500	nf	15000	n
Cat 6	9	0.45	nf	0.9	nf	2.25	nf	4.5	nf	9	nf	18	nf	45	nf	90	nf	225	nf	450	nf	900	n
Cat 5	15	0.75	nf	1.5	nf	3.75	nf	7.5	nf	15	nf	30	nf	75	nf	150	nf	375	nf	750	nf	1500	n
Cat 3	19	0.95	nf	1.9	nf	4.75	nf	9.5	nf	19	nf	38	nf	95	nf	190	nf	475	nf	950	nf	1900	n
Coax	16.2	0.81	nf	1.6	nf	4.05	nf	8.1	nf	16.2	nf	32.4	nf	81	nf	162	nf	405	nf	810	nf	1620	n
Cntrl 26Ga wire to wire	27.3	1.37	nf	2.7	nf	6.83	nf	13.7	nf	27.3	nf	54.6	nf	136.5	nf	273	nf	682.5	nf	1365	nf	2730	n
Cntrl 16ga wire to wire	51.6	2.58	nf	5.2	nf	12.90	nf	25.8	nf	51.6	nf	103.2	nf	258	nf	516	nf	1290	nf	2580	nf	5160	n
Cntrl 26Ga wire to Shield	54	2.70	nf	5.4	nf	13.50	nf	27.0	nf	54	nf	108	nf	270	nf	540	nf	1350	nf	2700	nf	5400	n
Cntrl 16ga wire to Shield	102	5.10	nf	10.2	nf	25.50	nf	51.0	nf	102	nf	204	nf	510	nf	1020	nf	2550	nf	5100	nf	10200	n

Cable Loop Resistance Chart

Better than .5%
Better than 1.0%
Poor Results

The accuracy of the FL-20A in Shorts and Hipot tests is limited by the test product's cable loop resistance properties. Please consult the chart below to determine the results you can expect for your product.

AWG-Copper	Ohms/Foot	50	100	250	500	1000	2500	5000	7500	10000	25000	50000	75000	100000
1000 MCM	0.000011	0.0006	0.0011	0.0028	0.0055	0.0110	0.0275	0.0550	0.0825	0.1100	0.2750	0.5500	0.8250	1.1000
500 MCM	0.000021	0.0011	0.0021	0.0053	0.0105	0.0210	0.0525	0.1050	0.1575	0.2100	0.5250	1.0500	1.5750	2.1000
250 MCM	0.000042	0.0021	0.0042	0.0105	0.0210	0.0420	0.1050	0.2100	0.3150	0.4200	1.0500	2.1000	3.1500	4.2000
0000	0.00005	0.0025	0.0050	0.0125	0.0250	0.0500	0.1250	0.2500	0.3750	0.5000	1.2500	2.5000	3.7500	5.0000
000	0.000063	0.0032	0.0063	0.0158	0.0315	0.0630	0.1575	0.3150	0.4725	0.6300	1.5750	3.1500	4.7250	6.3000
00	0.00008	0.0040	0.0080	0.0200	0.0400	0.0800	0.2000	0.4000	0.6000	0.8000	2.0000	4.0000	6.0000	8.0000
0	0.0001	0.0050	0.0100	0.0250	0.0500	0.1000	0.2500	0.5000	0.7500	1.0000	2.5000	5.0000	7.5000	10.0000
1	0.000127	0.0064	0.0127	0.0318	0.0635	0.1270	0.3175	0.6350	0.9525	1.2700	3.1750	6.3500	9.5250	12.7000
2	0.00016	0.0080	0.0160	0.0400	0.0800	0.1600	0.4000	0.8000	1.2000	1.6000	4.0000	8.0000	12.0000	16.0000
4	0.0002485	0.0124	0.0249	0.0621	0.1243	0.2485	0.6213	1.2425	1.8638	2.4850	6.2125	12.4250	18.6375	24.8500
6	0.0003951	0.0198	0.0395	0.0988	0.1976	0.3951	0.9878	1.9755	2.9633	3.9510	9.8775	19.7550	29.6325	39.5100
8	0.0006282	0.0314	0.0628	0.1571	0.3141	0.6282	1.5705	3.1410	4.7115	6.2820	15.7050	31.4100	47.1150	62.8200
10	0.0009989	0.0499	0.0999	0.2497	0.4995	0.9989	2.4973	4.9945	7.4918	9.9890	24.9725	49.9450	74.9175	99.8900
12	0.001588	0.0794	0.1588	0.3970	0.7940	1.5880	3.9700	7.9400	11.9100	15.8800	39.7000	79.4000	119.1000	158.8000
14	0.002525	0.1263	0.2525	0.6313	1.2625	2.5250	6.3125	12.6250	18.9375	25.2500	63.1250	126.2500	189.3750	252.5000
16	0.00402	0.2010	0.4020	1.0050	2.0100	4.0200	10.0500	20.1000	30.1500	40.2000	100.5000	201.0000	301.5000	402.0000
18	0.00639	0.3195	0.6390	1.5975	3.1950	6.3900	15.9750	31.9500	47.9250	63.9000	159.7500	319.5000	479.2500	639.0000
20	0.01015	0.5075	1.0150	2.5375	5.0750	10.1500	25.3750	50.7500	76.1250	101.5000	253.7500	507.5000	761.2500	1015.0000
22	0.01614	0.8070	1.6140	4.0350	8.0700	16.1400	40.3500	80.7000	121.0500	161.4000	403.5000	807.0000	1210.5000	1614.0000
24	0.02567	1.2835	2.5670	6.4175	12.8350	25.6700	64.1750	128.3500	192.5250	256.7000	641.7500	1283.5000	1925.2500	2567.0000
26	0.04081	2.0405	4.0810	10.2025	20.4050	40.8100	102.0250	204.0500	306.0750	408.1000	1020.2500	2040.5000	3060.7500	4081.0000
28	0.0649	3.2450	6.4900	16.2250	32.4500	64.9000	162.2500	324.5000	486.7500	649.0000	1622.5000	3245.0000	4867.5000	6490.0000
30	0.1032	5.1600	10.3200	25.8000	51.6000	103.2000	258.0000	516.0000	774.0000	1032.0000	2580.0000	5160.0000	7740.0000	10320.0000
AWG Aluminum														
6	0.000661	0.0331	0.0661	0.1653	0.3305	0.6610	1.6525	3.3050	4.9575	6.6100	16.5250	33.0500	49.5750	66.1000
4	0.000416	0.0208	0.0416	0.1040	0.2080	0.4160	1.0400	2.0800	3.1200	4.1600	10.4000	20.8000	31.2000	41.6000
2	0.000261	0.0131	0.0261	0.0653	0.1305	0.2610	0.6525	1.3050	1.9575	2.6100	6.5250	13.0500	19.5750	26.1000
1	0.000207	0.0104	0.0207	0.0518	0.1035	0.2070	0.5175	1.0350	1.5525	2.0700	5.1750	10.3500	15.5250	20.7000
0	0.000165	0.0083	0.0165	0.0413	0.0825	0.1650	0.4125	0.8250	1.2375	1.6500	4.1250	8.2500	12.3750	16.5000
00	0.00013	0.0065	0.0130	0.0325	0.0650	0.1300	0.3250	0.6500	0.9750	1.3000	3.2500	6.5000	9.7500	13.0000
000	0.000103	0.0052	0.0103	0.0258	0.0515	0.1030	0.2575	0.5150	0.7725	1.0300	2.5750	5.1500	7.7250	10.3000
0000	0.000082	0.0041	0.0082	0.0205	0.0410	0.0820	0.2050	0.4100	0.6150	0.8200	2.0500	4.1000	6.1500	8.2000
250 MCM	0.000069	0.0035	0.0069	0.0173	0.0345	0.0690	0.1725	0.3450	0.5175	0.6900	1.7250	3.4500	5.1750	6.9000
500 MCM	0.000035	0.0018	0.0035	0.0088	0.0175	0.0350	0.0875	0.1750	0.2625	0.3500	0.8750	1.7500	2.6250	3.5000
1000 MCM	0.000017	0.0009	0.0017	0.0043	0.0085	0.0170	0.0425	0.0850	0.1275	0.1700	0.4250	0.8500	1.2750	1.7000

Locating Shorts in Medium and High Voltage Cables

FL-20A Cable Fault Locator Operation

The Clinton FL-20A Cable Fault Locator's "Shorts" mode uses a resistance bridge based on the Wheatstone Bridge principle. The shorts test requires that during the bridge measurement, current must flow from the red and blue probes, which are attached to each end of the cable under test, to the reference ground conductor, connected to the green probe.

Inner conductors that make direct physical contact constitute a direct short. By contrast, an event where conductors do not touch but an arc occurs between them during hipot testing at high voltage is called a high voltage short.

The FL-20A locates high voltage faults with a 20kV high voltage generator. When shorted conductors fail at high voltages, a bridge measurement can still be made because the HV generator will allow the shorted conductor to discharge to the reference ground conductor. The bridge measurement is made only when current flows or when arcing. If insufficient current flows, the test will give inaccurate results or no results at all.

Testing Medium and High Voltage Cables

Medium and high voltage cables present unique problems in cable fault location. Some faults in medium and high voltage cables break down at low voltages. As long as the cables are high enough in total loop resistance (250 milliohms or more), the results will be accurate. It is those faults that break down at higher hipot voltage that are suspect.

In these types of cables, the physical distances between the defects causing the shorts are often relatively large, so the fault locator may not be able to produce enough voltage to flow current from one to another. In general, if the cable fails hipot testing at a test voltage of 20 kVDC or 14 kVAC, or above, the FL-20A will not have enough test voltage to generate the sustained arc necessary for shorts testing.

There are additional difficulties at these voltages. The dynamics of this current flow is complex, because arcs flashing within the inside of the cable are actually tracking along the different surfaces of the conductors. The energy of the arc causes burning and carbonization along its path, increasing surface resistivity between the shorted conductors. When the resistance becomes high enough, the arc will seek a slightly different

pathway. With enough arcing, the entire area becomes carbonized. If the resistance between the shorted conductors is high enough, arcing may stop entirely at a given test voltage.

However, while arcing may stop, current can continue to flow. In some cases, enough current will flow to cause the FL-20A to continue trying to locate the fault. In these situations the results will be inaccurate. In severe cases, the FL-20A will show an error message.

The reason the results can be inaccurate are best understood by looking at the schematic diagram of a typical fault.

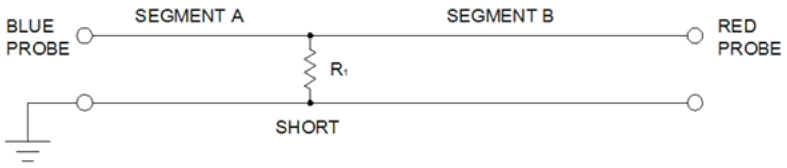


Figure 1

All Clinton cable fault locators require a high degree of consistency of resistance per unit of measure of the various conductors in order to locate short circuits. During the bridge measurement, the total resistance of Segment A plus the value of R1 equals the resistance of Segment B. This is referred to as "balancing the resistances" and is the basis of cable fault location of short circuited conductors.

When there is significant arcing and carbonization, there may be multiple current pathways, each with a different resistance. This is illustrated below in Figure 2.

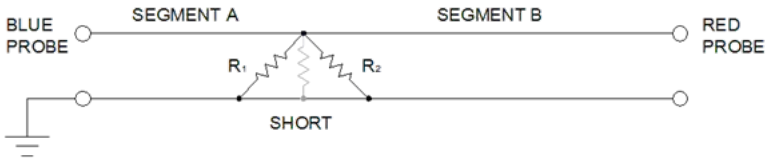


Figure 2

The FL-20A will try to balance the resistance of Segment A to Segment B first using one resistance, (R1) but then the arc will move to another site (R2) with lower resistance. The unit will then try to balance these two segments.

Regardless of which of the resistances the FL-20A balances, the result will likely not be very accurate because the carbon at the fault site adds an unknown level of resistance, making balancing the resistances difficult.

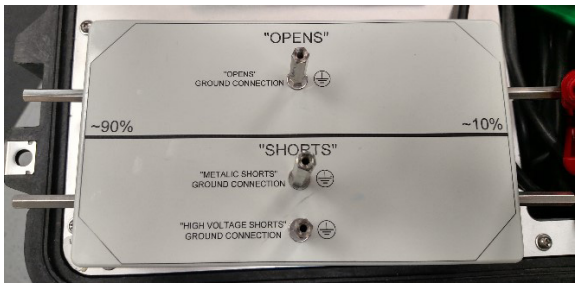
For this reason, the location of shorts revealing themselves at voltages above 15 kVDC or 10.5 kVAC should be suspect unless the FL reports "Standard" or "Exceptional" accuracy.

Recommendations

15. Record the actual voltage where a cable fails during hipot testing. Halt the test immediately after failure.
16. When hipot testing cables, do not allow the hipot tester to keep burning a fault once it is detected. This will reduce accuracy in fault location with the FL-20A.
17. When using the FL-20A on cables that failed hipot testing above 15.00 kVDC or 10.5 kVAC, regard the results as suspect unless the FL-20A reports “Standard” or “Exceptional” results.

How to Use the 91785 FL Test Box

Description



The 91785 FL Test Box is used to simulate three types of cable faults (Open, Metallic Short and High Voltage Short). The FL Test Box is useful in determining if the FL-20A or FL-8A is operating properly. Note the metal terminals, two on the left and right sides and three in the center.

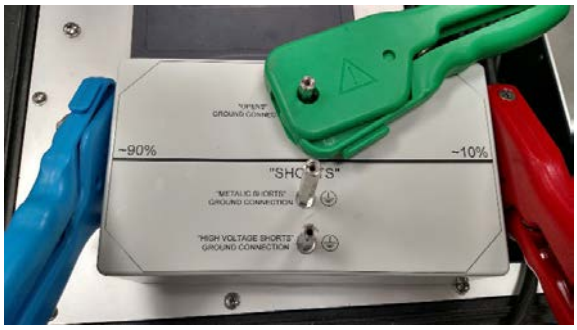
The FL Test Box is used to simulate a cable fault at a point in the cable 90% from one side and 10% from the other. The Test Box is labeled 90% on the left side and 10% on the right. If the Blue Probe is placed on the 90% side, the result should be roughly 90% from the Blue side (10% from the Red side). The opposite result would be expected if the Red Probe were placed on the 90% side.

Type of Cable Faults

Of the three types of faults that can be simulated using the FL Test Box, the first is an Open, which simulates a break in a conductor of a cable. The second is a Metallic Short which simulates a conductor directly connected to another conductor in a cable. The last is a High Voltage Short, which simulates a conductor with a break in the insulation close to a ground shield, drain wire, or another conductor with a break in the insulation. In this instance, high voltage can arc from one conductor to another conductor or ground.

Testing with the FL Test Box

Select the appropriate test and connect the Red and Blue Probes to the appropriate terminals as directed. The Green ground probe always connects to the appropriate center terminal. The Probes should be placed over the terminals so that the terminals protrude on the other side.



Testing for Opens Accuracy

For Opens, connect the Blue and Red Probes to the upper terminals and the Green Probe to the center terminal as shown. Run the Opens test on the fault locator. We would expect a result where the fault is 90% (or within our claimed accuracy) from the blue side (10% from the Red side). These two results should total approximately 100%.

Testing for Metallic Shorts Accuracy

To perform a Metallic Shorts Test, connect the probes to the Shorts terminals as shown. Note the Green ground probe connects to the terminal labeled "METALLIC SHORTS". Run the Shorts Test on the cable fault locator at a voltage of at least 1kV. We expect a result where the fault is 90% (or within our margin of accuracy) from the blue side and 10% from the Red side. These two results should total approximately 100%.

Testing for High Voltage Shorts Accuracy

For running a High Voltage Shorts Test, connect the probes to the Shorts terminals as shown. Note the Green ground probe connects to the terminal labeled "HIGH VOLTAGE SHORTS". Run the Shorts Test on the cable fault locator at a voltage of at least 8kV. We would expect a result where the fault is 90% (or within our margin of accuracy) from the blue side and 10% from the Red side. These two results should total approximately 100%.

Troubleshooting

- An error displays: "The safety switches were let go."

The two safety switches were released during the test while the Caged Operation setting was OFF. Press the CANCEL button to return to the main menu and begin the test again. Hold in the safety switches for the duration of the test.

- During a shorts test, an error displays: "Inadequate arc rate."

The voltage may not too low to cause an arc to short from the test conductor to ground. Increase the voltage.
There may be no fault in the product. Run a Hi-Pot test to confirm the presence of a fault.

- During a shorts test, an error displays: "Accuracy: Low."

When a test takes a very long time and the report screen says your accuracy is low, you may have a multiple fault condition. The FL-20A will find the first fault so it can be cut out and the cable retested to locate a second short. This setting is not recommended for low loop resistance products, because it can give false positives.

- An error displays: "Cannot Find Open."

If you run the test without attaching the red and blue probes, the error message, "Cannot Find Open" will be displayed.

- FL-20A cannot find faults.

In a situation where there are multiple direct or high voltage shorts, you may not locate any of them.

- The ground probe is connected, but it is not detected.

Insure that both contacts of the ground probe make a good connection to the ground wire.

- The external interlock is not detected in Caged Operation.

Check the connections from the door or latch on your cage to the interlock pins on the back panel of the FL-20A.

- Test accuracy is rated Low.

Insure that both contacts of each probe are making a good connection.
Insure that the ground probe is connected to all wires that are not being tested.
The test voltage may be too low.

- The X3F lights are not illuminating when expected.

Check the connections between FL-20A and X3F.
Check the continuity of the connection of each of the testing relay contacts and the connection of each of the HV ON relay contacts. If there is no connection when expected, replace fuses F1 and F2 on PC board no. 91496.

- The FL-20A will not power up.

Check the fuse contained in the ON/OFF switch. (See "Maintenance.")

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 for repair and calibration.

Part Number	Description
91501P	Touchscreen Display Color, Programmed
91526	Power Supply 24V DC 200W
91175	Power Supply 70W
91497C	Stepper Motor 4-wire
91549	Timing Belt
91498	Potentiometer 1K 10-Turn 5W
91494	PC Board Assembly High Voltage Bridge
91496	PC Board Assembly Low Voltage Main
91499	Power Supply 20kV 125W
91627C	Rotary Solenoid 10v DC w/Connector
02606	Fuse 2 amp 5x20 mm
91610	Transformer 20kV DC 115/230v
91609	Test Lead Assembly 10’
91609-20	Test Lead Assembly 20’
92100	Probe Clip Assembly (for connecting larger cables)
92113	Probe Clip Assembly (for connecting largest cables)

Optional Accessories

Part Number	Description
GND-SP	Ground Probe Assembly
PRINTER THERMAL RECEIPT	Thermal Printer
91901	Printer paper, roll

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

Perception and Startle Reaction Cont.

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.

Ventricular Fibrillation Cont.

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.

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

Burns Cont.

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

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

Grounding

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

Double Insulation

Double insulation enhances the reliability of the electrical insulation of a product to reduce the likelihood of insulation breakdown that could cause an electric shock. Each part of a double-insulation system should be independent and must be fully capable of acting as the sole insulation. If one insulation fails, the other must have all of the required attributes to prevent electric shock. It is important that the two parts of the double-insulation system are as truly independent as feasible. Both insulations should not be vulnerable to the same act (e.g., a drop on a hard surface or immersion in water) or deteriorating agent (e.g., high temperature or over-surface contamination).

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

Interlocks and "Smart" Circuits

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.

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