



# UL 943

## STANDARD FOR SAFETY

### Ground-Fault Circuit-Interrupters

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UL Standard for Safety for Ground-Fault Circuit-Interrupters, UL 943

Fifth Edition, Dated May 17, 2016

### **Summary of Topics**

***This revision of ANSI/UL 943 dated September 5, 2023, includes the following changes in requirements:***

- ***Clarification of Auto-Monitoring Function Initiation and Detection; [5.16.2](#)***
- ***Clarification for Available Fault Current; [Table 6.17.2.2](#), [6.18.3](#) – [6.18.5](#) and [SA1.2](#)***
- ***Alternate Delivery Methods for Installation Instructions; [8.1.1](#)***
- ***Editorial Correction to Spacings; [Table 5.12.2.1](#) and [Table 5.12.2.2](#)***
- ***Revision of Requirements to Allow Remote ON and OFF switching of GFCIs; [3.19A](#), [5.14.8](#), [5.14.9](#), [7.2.8](#)***
- ***Update Annex A Ref 12 for Alternative Use of UL 60947-4-2•CSA C22.2 No 60947-4-1 for Motor Controllers; [6.14.9](#), [7.2.9](#) and Annex [A](#)***
- ***Revised Marking Requirements in Supplement SA; [SA3.1](#)***
- ***Open Neutral Protection – Extra Low Resistance Ground Fault Test and Short Circuit Test; [6.18.9](#) and [6.19.4](#)***

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated December 17, 2021 and October 7, 2022.

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Association of Standardization and Certification  
NMX-J-520-ANCE  
Third Edition



CSA Group  
CSA C22.2 No. 144.1-16  
Second Edition



Underwriters Laboratories Inc.  
UL 943  
Fifth Edition

## Ground-Fault Circuit-Interrupters

May 17, 2016

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ANSI/UL 943-2023

## Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as "CSA Group"), and ULSE Inc. (ULSE). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or ULSE at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and ULSE. CSA Group and ULSE will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and ULSE pages.

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This ANSI/UL Standard for Safety consists of the Fifth edition including revisions through September 5, 2023. The most recent designation of ANSI/UL 943 as an American National Standard (ANSI) occurred on September 5, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

The Department of Defense (DoD) has adopted UL 943 on November 30, 1994. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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## Preface

This is the harmonized ANCE, CSA Group, and ULSE standard for Ground-Fault Circuit-Interruptioners. It is the third edition of NMX-J-520-ANCE, the second edition of CSA C22.2 No. 144.1, and the fifth edition of UL 943. This harmonized standard has been jointly revised on September 5, 2023. For this purpose, CSA Group and ULSE are issuing revision pages dated September 5, 2023, and ANCE is issuing a new edition dated September 5, 2023.

This harmonized Standard was prepared by the Association of Standardization and Certification (ANCE), CSA Group, and ULSE. The efforts and support of the CANENA Technical Harmonization Subcommittee 23E, Ground-Fault Circuit-Interruptioners, are gratefully acknowledged.

This standard is considered suitable for use for conformity assessment within the stated scope of the standard.

The present Mexican standard was developed by the CT 23 Accesorios Electricos from the Comité de Normalización de la Asociación de Normalización y Certificación, A.C., CONANCE, with the collaboration of the ground fault circuit interruptioners manufacturers and users.

This Standard was reviewed by the CSA Subcommittee on Ground-Fault Circuit-Interruptioners, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

## Application of Standard

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

## Level of harmonization

This Standard uses the IEC format but is not based on, nor shall it be considered equivalent to, an IEC Standard.

This Standard is published as an identical Standard for ANCE, CSA Group, and ULSE.

An identical Standard is a Standard that is exactly the same in technical content except for national differences resulting from conflicts in codes and governmental regulations. Presentation is word for word except for editorial changes.

## Reasons for differences from IEC

This Standard provides requirements for ground-fault circuit-interruptioners for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC Standard for ground-fault circuit-interruptioners for use in accordance with these codes. Therefore, this Standard does not employ any IEC Standard for base requirements.

## Interpretations

The interpretation by the standards development organization of an identical or equivalent Standard is based on the literal text to determine compliance with the Standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

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## 1 Scope

1.1 This Standard applies to Class A, single- and three-phase, ground-fault circuit-interrupters intended for protection of personnel, for use only in grounded neutral systems in accordance with the National Electrical Code (NEC), ANSI/NFPA 70, the Canadian Electrical Code, Part I, and Electrical Installations (Use), NOM-001-SEDE. These devices are intended for use on alternating current (AC) circuits of 120 V, 208Y/120 V, 120/240 V, 127 V, or 220Y/127 V, 60 Hz circuits.

Note: In Canada, the text “intended for protection of personnel” is excluded.

1.2 These requirements do not cover ground-fault circuit-interrupters intended for use in circuits served by a transformer having windings wholly insulated from each other.

1.3 This Standard applies to all Class A ground-fault circuit-interrupters. These Class A GFCIs are permitted to be integrated into other devices, in which case, besides complying with this Standard, these devices are to comply with the corresponding applicable Standard for the device in question.

1.4 This Standard includes minimum requirements for the function, construction, performance, and markings of ground-fault circuit-interrupters included in the scope.

1.5 This Standard is intended to cover only Class A GFCI devices.

1.6 This Standard also covers GFCIs of the self contained type that are intended for installation in a counter, such as would be suitable for installation in a kitchen or bathroom counter top.

## 2 Normative References

2.1 Any normative reference to a code or Standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or Standard. See Annex A.

2.2 When a reference is made to another code or Standard, the product shall comply with the installation code or Standard of the country or countries in which the product is intended to be used.

2.3 For products intended for use in Canada general requirements are given in CSA Standard C22.2 No. 0, *Definitions and General Requirements – Canadian Electrical Code, Part II*.

## 3 Definitions

For the purposes of this Standard, the following definitions apply:

3.1 ACCESSIBLE PART – A part so located that it can be contacted by a person, either directly or by means of a probe or tool.

3.2 AUTOMATIC RECLOSURE – Denotes the act of a ground-fault circuit-interrupter resetting itself after having been tripped.

3.3 CLASS A – Class A, when applied to a ground-fault circuit-interrupter (GFCI), is an interrupter that will interrupt the circuit to the load when the ground-fault current is 6 mA or more but not when the ground-fault current is 4 mA or less.

3.4 CORD-CONNECTED – Denotes connection to a supply circuit by way of a flexible cord terminating in an attachment plug.

3.5 DOUBLE INSULATION – The insulation system resulting from a combination of functional and supplementary insulation.

3.6 ENCLOSURE – A surrounding case constructed to provide a degree of protection against incidental contact with the enclosed equipment and to provide a degree of protection to the enclosed equipment against specified environmental conditions.

3.7 ENERGIZED PART – A part at some potential with respect to another part, or to earth.

3.8 FUNCTIONAL INSULATION – The insulation necessary for the proper functioning of the device, and for basic protection against electrical shock hazard.

3.9 GFCI END OF LIFE – When a GFCI is incapable of providing ground fault protection and passing its internal test function it has reached its end of life.

3.10 GROUND FAULT – Denotes an unintentional electrical path between a part operating normally at some potential to ground, and ground.

3.11 GROUND-FAULT CIRCUIT-INTERRUPTER – In the US and Mexico, a device intended for the protection of personnel that functions to de-energize a circuit or portion of a circuit within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

In Canada, a device whose function is to interrupt, within a predetermined time, the electrical circuit to the load when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

3.12 HOUSING – The integral envelope directly surrounding the circuit components of the ground-fault circuit-interrupter.

3.13 LEAKAGE CURRENT – Denotes all currents including capacitively coupled currents which may be conveyed between energized parts of a circuit and (1) ground or (2) other parts.

3.13A MICROELECTRONICS – Monolithic, hybrid, or module circuits, where the internal circuit connections are not accessible exclusive of provided external connection pins or pads. The circuits are capable of functioning in the analogue mode, digital mode, or a combination of the two modes. Examples of microelectronics include: ASICs, ROMs, RAMs, PROMs, EPROMs, PALs, and PLDs. See [3.16A](#).

3.14 OUTLET-BOX TYPE GROUND-FAULT CIRCUIT INTERRUPTER – A permanently connected ground-fault circuit-interrupter provided with a mounting yoke for mounting in an outlet box; may or may not be provided with receptacle outlets. May be referred to as a receptacle-type GFCI.

3.15 PERMANENTLY CONNECTED – Denotes connection to a supply circuit by way of fixed electrical conductors (see cord-connected).

3.16 PORTABLE GROUND-FAULT CIRCUIT-INTERRUPTER – A plug-in type ground-fault circuit-interrupter provided with male blades for connection to a receptacle, or one that is cord-connected. (See cord-connected).

3.16A PROGRAMMABLE COMPONENT – Any microelectronic hardware that can be programmed in the design center, the factory, or in the field. Here the term "programmable" is taken to be "any manner in which one can alter the software wherein the behavior of the component can be altered". The microelectronics defined in [3.13A](#) are examples of programmable components.

3.17 RATED CURRENT – The marked value of current.

3.18 RATED VOLTAGE – Voltage assigned by the manufacturer. See [Table 7.2.1](#) for details and marked voltage.

3.19 REINFORCED INSULATION – An insulation providing protection against electrical shock hazard that is equivalent to double insulation.

3.19A REMOTE CONTROL – Denotes the use of a GFCI for switching purposes, to be actuated (on or off) from a location not at the GFCI. This does not anticipate for resetting when tripped in accordance with the provisions of [6.7.1.1](#) – [6.7.2.2](#).

3.20 ROOM TEMPERATURE – Air at  $25.0 \pm 5.0^{\circ}\text{C}$  ( $77.0 \pm 9.0^{\circ}\text{F}$ ).

3.21 SHOCK HAZARD – A shock hazard is considered to exist at a part of a ground-fault circuit-interrupter if:

- a) There would be current of 6 mA or more in a resistance of 500 ohms connected between the part in question and the grounded supply conductor, and
- b) The device would not operate to open the circuit to the 500-ohm resistor within the time allowed in [6.7.1.1](#).

3.22 SUPPLEMENTARY INSULATION – An independent insulation provided in addition to the functional insulation to insure protection against electric shock hazard in the event that functional insulation should fail.

3.23 TRIP – Denotes automatic interruption by the ground-fault circuit-interrupter of the electric circuit to the load.

## 4 General

### 4.1 Components

4.1.1 Except as indicated in [4.1.2](#), a component of a product covered by this Standard shall comply with the requirements for that component. See Annex A for a list of Standards covering components generally used in the products covered by this Standard and applicable Mexican Standards. A component shall comply with the ANCE, CSA, or UL Standards as appropriate for the country where the product is to be used. When a product is intended for use in more than one country, a component shall comply with the appropriate component Standard for the countries in which it is being used.

4.1.2 A component need not comply with a specific requirement that:

- a) Involves a feature or characteristic not needed in the application of the component in the product covered by this Standard, or
- b) Is superseded by a requirement in this Standard.

4.1.3 A component shall be used in accordance with its ratings for the intended conditions of use.

4.1.4 Specific components are accepted as being incomplete in construction features, or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as temperatures not exceeding specified limits, and shall be used only under those specified conditions for which they have been investigated.

## 4.2 Units of measurement

4.2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

## 5 Construction

### 5.1 All types

5.1.1 A ground-fault circuit-interrupter which is intended to be connected to a supply circuit having more than one ungrounded conductor shall be so designed that their intended purpose will not be defeated if any of the ungrounded conductors is not energized in the normal way.

5.1.2 An interrupter having an adjustable circuit component, the setting of which affects the clearing time or the sensitivity, shall be constructed so that:

- a) The component is not visible to the user when the interrupter is in normal use or when it is opened for connecting supply circuit and load circuit conductors; and
- b) Any cover or other part which obscures the component from view requires a tool for removal and is so secured or sealed that the removal can be readily detected. The application of a sealing material directly to the component is considered to comply with the intent of Item (b) for sealing.

5.1.3 Except as specified in [5.1.4](#), male and female contact devices such as plugs, connectors, current taps, and receptacles provided with, or as an integral part of, a ground-fault circuit-interrupter shall also comply with the applicable construction and performance requirements in the Standards referenced in Annex A, Ref. No. 1.

5.1.4 For Canada, as an alternate to the Temperature Test in Clause 7.9 of the Standard for General Use Receptacles, Attachment Plugs, and Similar Wiring Devices, C22.2 No. 42, a receptacle type GFCI may be tested as described in Section [6.28](#) of this Standard.

For Mexico, as an alternate to the Temperature Test in Clause 6.2.5 of the Standard for Wiring Devices – Safety requirements – Specifications and Test Methods, NMX-J-508-ANCE, a receptacle type GFCI may be tested as described in Section [6.28](#) of this Standard.

For the US, as an alternate to the Temperature Test in Section 111 of the Standard for Attachment Plugs and Receptacles, UL 498, a receptacle type GFCI may be tested as described in Section [6.28](#) of this Standard.

5.1.5 In Canada, a portable ground-fault circuit-interrupter:

- a) Is required to have a fixed grounding pin,
- b) Of the direct plug-in type, other than one designed solely for use in a locking type receptacle, shall not include a mounting tab which is intended to connect with a screw retaining the cover of a duplex receptacle in place, or any other means for securing the interrupter to a receptacle or its cover.

### 5.2 Resistance to corrosion

5.2.1 Parts shall be protected against corrosion if failure of such parts would be likely to result in a hazardous condition, including failure to perform with high-resistance ground faults as provided in these requirements. To verify compliance with [5.2.1](#), see the Corrosion test, Clause [6.21](#).

### 5.3 Grounding and bonding

5.3.1 All accessible parts of a permanently connected ground-fault circuit-interrupter that are likely to become energized if there should be arc-over, insulation failure, or the like, shall be connected together and to the terminals intended for the equipment grounding conductor (see [5.11.1](#)). The resistance of the circuit is not to exceed 0.1 ohm, and the circuit shall be capable of withstanding continuously a current of 25 A.

5.3.2 In Canada, the grounding and bonding shall comply with the requirements of Annex [A](#), Ref. No. 2, except the screw size shall be permitted to comply with [5.3.3](#).

5.3.3 For devices rated 15 A or 20 A the minimum screw size is 4.5 mm (No. 8).

5.3.4 In considering the provisions of [5.3.1](#), a grounded or insulating barrier may be employed to reduce the likelihood that accessible parts will become energized.

5.3.5 If provided, the equipment grounding conductor of a portable or cord-connected ground-fault circuit-interrupter shall be conductively connected to the grounding contacts of the attachment plug and of the receptacles, and shall not be connected to accessible conductive parts.

5.3.6 A ground-fault circuit-interrupter shall operate normally if there is an open circuit in the grounding conductor.

Note: In Canada, equipment grounding conductors are referred to as bonding conductors.

### 5.4 Enclosure and housing

5.4.1 A ground-fault circuit-interrupter housing shall be capable of withstanding the abuses to which it might be subjected in normal use without affecting the GFCI to the extent that the GFCI would fail to comply with the requirements of this Standard. A ground-fault circuit-interrupter intended to be incorporated into equipment having an enclosure that is subject to the requirements of the end-product \*Standard, shall be permitted to be constructed without enclosures.

\*See Annex [D](#) for a list of possible end-product Standards.

5.4.2 A device which is capable of being used as a ground-fault circuit interrupter without being installed in an additional enclosure, shall comply with the enclosure requirements as referenced in Annex [A](#), Ref. No. 3, and shall also comply with the applicable enclosure requirements for the intended environment as referenced in Annex [A](#), Ref. No. 4. See [6.3.8](#).

5.4.3 Doors and covers shall have means for securing them firmly in place. If bare live parts are exposed by the opening of such doors or covers, means requiring the use of a tool to open, or provision for locking, shall be provided to hold them in the closed position.

### 5.5 Provision for connection to permanent wiring systems

5.5.1 There shall be provision at a permanently connected ground-fault circuit-interrupter for attachment of raceway or cable and grounding in accordance with the National Electrical Code (NEC), ANSI/NFPA 70, Canadian Electrical Code (CEC), C22.1 or Electrical Installations (Use), NOM-001-SEIE-1999.

5.5.2 Interrupters shall be so constructed that:

- a) The position of the openings for conduit or cable connection is unlikely to cause confusion in connecting field-installed conductors;



b) Field-installed conductors will be separated by barriers from conductors of internal wiring; and from components of interrupters other than wiring terminals; and

c) Circuit components will be protected from damage during field installation. See Enclosure and housing – performance, Clause [6.3](#).

## 5.6 Insulation

5.6.1 Except as described in [5.6.2](#) and [5.6.3](#), a portable ground-fault circuit-interrupter shall have double insulation or reinforced insulation throughout its construction.

5.6.2 Functional insulation alone is acceptable in a portable device where, in the event that the functional insulation should fail, there would be no shock hazard at the ground-fault circuit-interrupter.

5.6.3 In performing the evaluation described in [5.6.2](#) at a manual switch in the supervisory circuit (described in [5.15.1](#)), the device need not trip if the value of current available in the event that the functional insulation of the switch should fail would not exceed the value of current employed by the supervisory circuit.

5.6.4 Functional insulation shall be interposed between grounding conductors and accessible parts of a cord-connected ground-fault circuit-interrupter. If such insulation is inherent in a receptacle:

a) There shall be instructions visible when the receptacle is being removed for replacement to replace the receptacle with only an identical replacement, and how to obtain the replacement, and

b) It shall not be possible to use a standard grounding-type receptacle as a replacement without first performing a drilling or cutting operation.

5.6.5 Except where specifically acceptable for the purpose, the jacket of the power-supply cord of the ground-fault circuit-interrupter is not considered to provide insulation. See [5.10.5](#).

## 5.7 Accessibility of energized parts

5.7.1 Parts of a ground-fault circuit-interrupter shall not be accessible when they are energized.

5.7.2 In determining compliance with the provisions of [5.7.1](#):

a) Except at a contact of an attachment-plug receptacle, a part is considered to be accessible if it can be touched with a 2.4 mm (3/32-inch) diameter rod,

b) A permanently connected device shall be mounted as intended,

c) A door or cover that can be opened or removed without the use of a separate tool is to be open or removed,

d) A door or cover that must be opened or removed in order to use a ground-fault circuit-interrupter shall be opened or removed, and

e) Material that is not acceptable as insulation is considered to be conductive.

5.7.3 Access to the trip mechanism and electronics of a portable ground-fault circuit-interrupter, not intended to be repaired, shall not be attainable with ordinary tools. Access shall be limited by use of tamper-resistant screws, rivets, welding or other equivalent means.



## 5.8 Internal wiring

5.8.1 The gauge and insulation of wires shall withstand the mechanical and electrical stresses of service. Particular consideration should be given to the effect of vibration and user servicing where wire smaller than 0.205 mm<sup>2</sup> (24 AWG) is employed. Compliance shall be determined by completion of the impact test and drop test as described in Enclosure and housing – performance, Clause [6.3](#), and conducting the Visual inspection test, Clause [6.22](#).

5.8.2 In a portable cord-connected ground-fault circuit-interrupter, at a wire termination or splice there shall be at least one independent means provided which alone could prevent the conductor from becoming free to bridge supplementary or reinforced insulation in the event that the wire should break at the termination or splice. A wire-binding screw or nut shall be suitably prevented from loosening such as with a spring-type lockwasher or equivalent, if such loosening could allow the attached conductor to become free to bridge supplementary or reinforced insulation. Compliance shall be determined by conducting the Visual inspection test, Clause [6.22](#).

5.8.3 Insulated conductors shall be suitable for the temperature, voltage, and the intended use in accordance with the applicable requirements of relevant component Standards (see also Separation of circuits, subclause [5.12.4](#)).

5.8.4 All joints and connections shall be made mechanically secure and shall provide adequate and reliable contact without strain on connections and terminals. Compliance shall be determined by conducting the Visual inspection test, Clause [6.22](#).

5.8.5 All joints shall be provided with insulation suitable for the temperature, voltage, and intended use of the conductors themselves, in accordance with applicable requirements of the relevant component Standards listed in Annex A, Ref. No. 5, or shall comply with Spacings, Clause [5.12](#), or Alternate spacings – clearances and creepage distances, Clause [5.13](#). Compliance shall be determined by conducting the Visual inspection test, Clause [6.22](#).

## 5.9 Field wiring

5.9.1 A ground-fault circuit-interrupter intended for permanent connection to the branch circuit shall be provided with means for the connection of wires having an ampacity in accordance with the National Electrical Code ANSI/NFPA 70, and the Canadian Electrical Code, C22.1, and Electrical Installations (Use), NOM-001-SEDE.

5.9.2 In a permanently connected ground-fault circuit-interrupter, either:

- a) Acceptable barriers shall be employed to separate load-circuit conductors and terminals from terminals and conductors of any other circuit, or
- b) All such parts shall be insulated for the maximum voltage of either circuit.

5.9.3 If a ground-fault circuit-interrupter is provided with leads for connection to the branch circuit, the leads shall not be more than two sizes smaller than the size referred to in [5.9.1](#) and shall not be smaller than 2.082 mm<sup>2</sup> (14 AWG).

5.9.4 A lead-type terminal shall be so constructed as to withstand the stress of normal handling without damage to the ground-fault circuit-interrupter. To determine compliance, each terminal lead shall be subjected to the force described in [6.1.5](#).

5.9.5 Green coloring with or without one or more yellow stripes and white or gray coloring shall not be used for the covering of a terminal lead unless intended for connection to grounding and grounded conductors respectively. See also [8.2.4](#).

In Canada, an equipment grounding conductor is referred to as a bonding conductor and the grounded conductor is referred to as the identified conductor.

5.9.6 The free length of a terminal lead shall be at least 100 mm (4 inches).

5.9.7 A terminal connector shall be prevented from moving so as to strain factory connections or reduce spacings to unacceptable values. Friction alone is not to be depended upon to prevent such movement.

5.9.8 At a terminal that is not considered to be a pressure terminal connector, it shall not be necessary to assemble or adjust parts other than loosening or tightening a screw, bolt, or nut. In order to determine compliance with the provisions of [5.9.8](#), a wire-binding screw or nut is to be tested in accordance with [6.1.8](#).

5.9.9 A terminal connector of the wire-binding type is permitted to terminate conductors no larger than 5.26 mm<sup>2</sup> (10 AWG).

## 5.10 Power-supply cord

5.10.1 A cord-connected ground-fault circuit-interrupter shall be provided with an attachment plug for connection to the supply circuit. The rating of the attachment plug is to be equal to the rating of the ground-fault circuit-interrupter.

5.10.2 The flexible cord shall be of a type, which complies with the requirements for:

- a) Hard usage or extra-hard usage in accordance with Table 11 of the Canadian Electrical Code, Part I, or
- b) Hard service or junior hard service cords in accordance with Flexible Cords and Cables, Table 400-4 of the National Electrical Code, ANSI/NFPA 70, or
- c) Extra-hard service or hard service in accordance with Electrical Products, Wire and Cables, Heavy Duty and Extra Heavy Duty Flexible Cords, Up to 600 V, NMX-J-436.

5.10.3 Strain on the power-supply cord that may occur by way of pulling, twisting, or pushing into the ground-fault circuit-interrupter housing shall not be transmitted to cord-conductor terminations.

5.10.4 In order to determine that the strain of pulling on the supply cord will not be transmitted to the cord terminations as provided in [5.10.3](#), the power supply cord is to be subjected to be the test in [6.1.6](#).

5.10.5 A clamp or similar device of conductive material applied to the power-supply cord shall have supplementary insulation interposed between the cord and the clamping device or shall not be accessible.

5.10.6 A surface of a ground-fault circuit-interrupter against which a flexible cord is likely to bear shall be smooth and well-rounded.

5.10.7 Unless protection is provided in a ground-fault circuit-interrupter to prevent overloading of the supply-cord conductors, the current rating of the supply cord shall not be less than the current rating of the attachment plug on the supply cord.

5.10.8 The points within the ground-fault circuit-interrupter intended for the termination of power-supply-cord conductors shall be plainly identified as detailed in [7.4.3](#).

5.10.9 The attachment plug of a ground-fault circuit-interrupter shall be a molded-on type or shall have the cord-conductor terminations sealed, or shall be provided with other means to prevent accidental contact between the grounding conductor and either or both of the power conductors, within the attachment plug.

5.10.10 A portable ungrounded ground-fault circuit-interrupter shall be provided with a polarized attachment plug cap.

5.10.11 If a 3-wire grounding-type attachment plug or a 2-wire polarized attachment plug is provided, the attachment plug connections shall comply with [Figure 5.10.1](#), and the polarity identification of the flexible cord shall comply with [Table 5.10.1](#).

5.10.12 The power supply cord of a portable GFCI having a permanently attached cord shall be subjected to the test in [6.1.7](#).

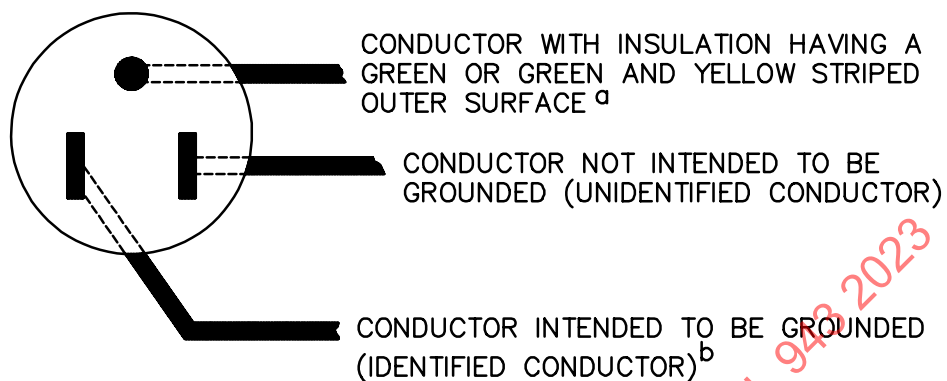
5.10.13 The power-supply cord shall be separately insulated from exposed metal parts at the point where it enters the equipment. The jacket on a cord is not considered as supplementary insulation.

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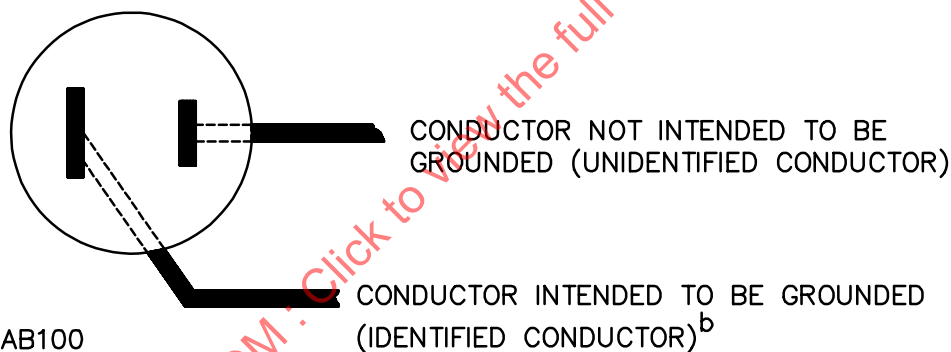
Figure 5.10.1

## Connection to attachment plug

CONNECTIONS OF CORD CONDUCTORS TO GROUNDING – TYPE ATTACHMENT PLUG (FACE OF PLUG REPRESENTED)



CONNECTIONS OF CORD CONDUCTORS TO POLARIZED ATTACHMENT PLUG (FACE OF PLUG REPRESENTED)



AB100

<sup>a</sup> In the above illustration, the blade to which the green conductor is connected may have a U-shaped or circular cross section.<sup>b</sup> Signifies a conductor identified in accordance with [Table 5.10.1](#) as wire intended to be grounded.

**Table 5.10.1**  
**Polarity identification of flexible cords**

Method of Identification	Acceptable combinations	
	Wire intended to be grounded <sup>b,c</sup>	All other wires <sup>b</sup>
Color of braids on individual conductors	A Solid white or gray – without tracer	Solid color other than white or gray – without tracer
	B Color other than white or gray, with tracer in braid	Solid color other than white or gray – without tracer
Color of insulation <sup>a</sup> on individual conductors	C Solid white or gray	Solid color other than white, or gray
	D Light blue	Solid color other than light blue, white
Note: In Canada, an equipment grounding conductor is referred to as a bonding conductor and the grounded conductor is referred to as the identified conductor.		
<sup>a</sup> Only for cords having no braid on any individual conductor.		
<sup>b</sup> Wire finished to show a green color with or without one or more yellow stripes or tracers is to be used only as an equipment-grounding conductor. See <a href="#">Figure 5.10.1</a> .		
<sup>c</sup> The color blue or use of a tracer braid is not permitted for this use in Canada.		

## 5.11 Receptacles

5.11.1 A receptacle of a ground-fault circuit-interrupter shall be of the grounding type with the grounding terminal conductively connected to the grounding conductor of the power-supply cord, except as noted in [5.11.2](#).

5.11.2 A portable ground-fault circuit-interrupter that is not provided with an equipment ground shall not be provided with a receptacle or cord connector of the grounding type, but shall be provided with a polarized receptacle or cord connector. See [5.5](#).

5.11.3 The ampere rating of the receptacle of a ground-fault circuit-interrupter that has only a single receptacle shall be equal to the rating of the attachment plug of the supply cord.

5.11.4 The rating of any receptacle not having individual overcurrent protection, provided on a ground-fault circuit-interrupter having more than one receptacle outlet, shall be one of those shown in [Table 5.11.1](#).

5.11.5 The face of a two-conductor ungrounded receptacle or cord connector shall obstruct the insertion of a 2-pole 3-wire grounding type attachment plug cap.

**Table 5.11.1**  
**Receptacle current rating in amperes**

Supply – Cord Cap Amperes	15	20	30
Receptacle	15	15 or 20	30

## 5.12 Spacings

### 5.12.1 General

5.12.1.1 A through-air spacing between bare, current-carrying parts shall be considered to be the shortest distance measured around any insulating barriers between them, except that any joint in a barrier

shall be treated as a gap in the barrier, unless the joint has been shown to have an effective dielectric strength equivalent to that of the barrier.

5.12.1.2 An over-surface spacing between bare, current-carrying parts shall be considered to be the shortest distance measured along the surface of the insulating material between them, except that the following distances shall not be included:

- a) The length of the contour of a slot or groove where the width of the slot or groove in the surface is less than 0.8 mm (1/32 inch) wide.
- b) The distance measured around an insulating barrier which is not integral with its supporting base and not otherwise joined to it so that the dielectric strength of the joint is effectively equivalent to that of the barrier.

5.12.1.3 In determining spacings, film-coated magnet wire is considered to be un-insulated.

5.12.1.4 Parts not locked in position, parts subject to random orientation (such as non-circular heads of screws), and the like are to be moved to the most adverse position for spacing measurement.

5.12.1.5 The spacing at wiring terminals shall be measured with appropriate wires in place and connected to the terminals as in actual service.

5.12.1.6 All bare current-carrying parts connected to different circuits shall be spaced from each other as though they were parts of opposite polarity and spacing requirements shall be judged on the basis of the voltage involved. In the case of isolated circuits, the polarity and spacing between the adjacent bare conductors of the two circuits shall be consistent with the requirements of the highest voltage involved.

5.12.1.7 In determining spacings through openings in a housing of insulated material, tightly drawn metal foil may be used to bridge the opening, but is not to be pressed into the opening.

## **5.12.2 Requirements – other than field-wiring terminals**

5.12.2.1 Through-air and over-surface spacings shall not be less than the values shown in [Table 5.12.2.1](#) and [Table 5.12.2.2](#).

## **5.12.3 Requirements – field-wiring terminals**

5.12.3.1 The spacings between field-wiring terminals not operating at the same potential shall not be less than those shown in [Table 5.12.3.1](#).

## **5.12.4 Separation of circuits**

5.12.4.1 Unless supplied with insulation suitable for the highest voltage, insulated conductors of different circuits (internal wiring) shall be separated by barriers or shall be segregated; and shall be separated or segregated from bare live parts connected to different circuits. Clamping, routing, or equivalent means of permanent separation from insulated or bare live parts of a different circuit may be considered as appropriate segregation of the insulated conductors.

**Table 5.12.2.1**  
**Spacing in mm (inches)<sup>e</sup>**

Parts separated by	Operating potential between parts							
	70 V peak or less				71 – 200 V peak			
	Through air		Over surface		Through air		Over surface	
	Open <sup>a</sup>	Closed-in <sup>b</sup>	Open <sup>a</sup>	Closed-in <sup>b</sup>	Open <sup>a</sup>	Closed-in <sup>b</sup>	Open <sup>a</sup>	Closed-in <sup>b</sup>
Functional insulation <sup>c</sup>	1.6 (1/16 <sup>d</sup> )	1.6 (1/16 <sup>d</sup> )	1.6 (1/16 <sup>d</sup> )	1.6 (1/16 <sup>d</sup> )	3.2 (1/8)	1.6 (1/16)	6.4 (1/4)	1.6 (1/16)
Supplementary insulation	3.2 (1/8)	1.6 (1/16)	6.4 (1/4)	1.6 (1/16)	3.2 (1/8)	1.6 (1/16)	6.4 (1/4)	3.2 (1/8)
Double or Reinforced insulation	6.4 (1/4)	3.2 (1/8)	12.7 (1/2)	3.2 (1/8)	6.4 (1/4)	3.2 (1/8)	12.7 (1/2)	6.4 (1/4)

<sup>a</sup> A space that is not specially protected from deposition of dirt.

<sup>b</sup> A space that is specially protected from deposition of dirt; i.e., a sealed housing that meets the requirements of the dust test outlined in Clause 6.20.

<sup>c</sup> Smaller spacings may be acceptable where they are inherent in a suitable component.

<sup>d</sup> May be less than 1.6 mm (1/16 in), but not less than 0.8 mm (1/32) at a printed wiring board without conformal coating.

<sup>e</sup> For printed wiring boards with suitable conformal coating which has been determined to comply with the requirements in Annex A, Ref. No. 6 spacings may be reduced to 0.8 mm (1/32 in), and may be further reduced if the coating is determined to be suitable and a special dielectric withstand test is performed between the conductors.

**Table 5.12.2.2**  
**Spacing in mm (inches)<sup>e</sup>**

Parts separated by	Operating potential between parts			
	201 – 400 V peak			
	Through air		Over surface	
	Open <sup>a</sup>	Closed-in <sup>b</sup>	Open <sup>a</sup>	Closed-in <sup>b</sup>
Functional insulation <sup>c</sup>	6.4 (1/4)	3.2 (1/8)	9.5 (3/8)	3.2 (1/8)
Supplementary insulation	6.4 (1/4)	1.6 (1/16)	9.5 (3/8)	3.2 (1/8)
Double or Reinforced insulation	12.7 (1/2)	6.4 (1/4)	19 (3/4)	6.4 (1/4)

<sup>a</sup> A space that is not specially protected from deposition of dirt.

<sup>b</sup> A space that is specially protected from deposition of dirt; i.e., a sealed housing that meets the requirements of the dust test outlined in Clause 6.20.

<sup>c</sup> Smaller spacings may be acceptable where they are inherent in a suitable component.

<sup>d</sup> May be less than 1.6 mm (1/16 in), but not less than 0.8 mm (1/32) at a printed wiring board without conformal coating.

<sup>e</sup> For printed wiring boards with suitable conformal coating which has been determined to comply with the requirements in Annex A, Ref. No. 6 spacings may be reduced to 0.8 mm (1/32 in), and may be further reduced if the coating is determined to be suitable and a special dielectric withstand test is performed between the conductors.

**Table 5.12.3.1**  
**Minimum spacing at field wiring terminals**

Voltage peak	Spacing, mm (inches)		
	Through air (between opposite polarities)	Over surface in air (between opposite polarities)	Through air or over surface (between live parts to ground)
up to 200	6.4 (1/4)	6.4 (1/4)	6.4 (1/4)
201 – 400	9.5 (3/8)	9.5 (3/8)	12.7 (1/2)

### 5.13 Alternative spacings – clearances and creepage distances

5.13.1 As an alternative to the measurement method specified in Spacings, Clause 5.12, for functional insulation, the minimum acceptable clearances (through air spacings) and creepage distances (over surface spacings) for a printed wiring board assembly shall be evaluated as specified in 5.13.2 – 5.13.4 using the applicable requirements in Annex A, Ref. No. 7.

5.13.2 When applying the requirements in Annex A, Ref. No. 7, the environment for a printed wiring board assembly within a ground-fault circuit-interrupter is considered to be:

- a) Pollution degree 3 for an assembly without a conformal coating,
- b) Pollution degree 2 for
  - 1) an assembly with a conformal coating, or
  - 2) an assembly without a conformal coating when the printed wiring board is contained in a sealed housing that complies with the Dust test, Clause 6.20, or
- c) Pollution degree 1 for an assembly with a conformal coating complying with the Printed Wiring Board Coating Performance Test in Annex A, Ref. No. 7.

5.13.3 When applying Clearance B (controlled overvoltage) construction requirements from Annex A, Ref. No. 7, the applicable overvoltage category for line voltage circuits is Category III. Category I is applicable to low voltage circuits if a short circuit between the parts involved results in operation of the controlled equipment which increases the risk of fire, the risk of electric shock, or both. Any overvoltage protection device needed to achieve these categories shall be provided as an integral part of the ground-fault circuit-interrupter.

5.13.4 Where measurement of clearances and creepage distances is involved to establish the minimum spacings, the methods specified for measurement of clearance and creepage distances in Annex A, Ref. No. 7, shall be used.

### 5.14 Operating mechanism

5.14.1 Compliance with the provisions of 6.7.1.1 – 6.7.2.2 shall not be prevented by manipulation or restraint of accessible control levers, knobs, and the like of a ground-fault circuit-interrupter. To verify compliance with 5.14.1, see Operating mechanism test, Clause 6.26.

5.14.2 A ground-fault circuit-interrupter that has tripped in accordance with the provisions of 6.7.1.1 – 6.7.2.2 shall not be capable of automatic reclosure.

5.14.3 If a permanently connected ground-fault circuit-interrupter trips because of a loss of power on the line side, it shall be capable of automatic reclosure when power is restored.



5.14.4 A portable ground-fault circuit-interrupter which trips due to a loss of power on the line side is not prohibited from being provided with the capability of automatic reclosure when power is restored.

5.14.5 A receptacle Type GFCI that contains separate line and load terminals, and that is powered through its load terminals, shall not reset and supply power to its receptacle face or line terminals. See Reverse line-load miswire test, Clause [6.23](#).

5.14.6 A receptacle type GFCI that contains separate line and load terminals shall comply with [5.14.5](#) during its initial installation and after reinstallation following a correctly wired installation. If the device is provided with special instructions for removal and reinstallation, the instructions shall be followed during testing. See Clause [6.24](#).

5.14.7 The requirement of [5.14.6](#) does not apply to a receptacle type GFCI marked in accordance with [7.3.7](#).

5.14.8 A GFCI with an electronic mechanism to comply with [5.14.2](#) to allow for remote control shall be evaluated to the following as applicable:

- a) If a programmable circuit has a component such as a microprocessor, that portion of the device shall be investigated in accordance with the requirements of Annex A, Ref. No. 15.
- b) Failure-Mode and Effect Analysis (FMEA) simulation, where a single component failure of the electronic interlock circuit shall not result in loss of protective control to comply with [5.14.2](#).
- c) Same device subject to [6.14](#) with interrupting contacts responsible for both GFCI trip and remote ON and OFF function shall be subject to an additional 3000 cycles via remote ON and OFF function. For devices with separate GFCI trip, the interrupting contacts responsible for Remote ON and OFF function shall be subject to 6000 cycles to [6.14](#) via remote ON and OFF function.
- d) When agreed upon by all concerned parties, a GFCI with a mechanical interlock prohibiting remote-control function per [5.14.2](#) is exempt from [5.14.8\(a\)](#) and [5.14.8\(b\)](#) but shall meet the requirements in [5.14.8\(c\)](#).

5.14.9 Restoration of the remote control function is prohibited after the GFCI has interrupted in accordance with [5.14.2](#). In addition to [5.14.3](#) or [5.14.4](#), restoration of remote control function requires local manual RESET of the tripped GFCI.

## 5.15 Supervisory circuit

5.15.1 A ground-fault circuit-interrupter shall be provided with a supervisory circuit that will conveniently allow for periodic, manual testing of the ability of the device to trip by way of a simulated ground fault.

5.15.2 If it is necessary to employ a separate tool in order to operate the supervisory circuit, operation is considered not to be convenient within the intent of these requirements.

5.15.3 The supervisory circuit shall operate to create a current imbalance of the sensing toroid, but shall not rely on the equipment grounding conductor to operate.

5.15.4 The results of the test shall be made known by means of an audible or visual indication.

5.15.5 When the reset is operated, a ground-fault circuit-interrupter that has reached its end of life shall comply with Clause [6.27](#).

5.15.6 The current imbalance employed by the supervisory circuit shall be sufficient to cause tripping at 85 percent of rated voltage, provided that at rated voltage the current imbalance shall not exceed 9 mA.

## 5.16 Auto-monitoring function

5.16.1 In addition to the Supervisory circuit specified in [5.15](#), a ground-fault circuit interrupter shall be provided with an auto-monitoring function that will allow for periodic, automatic testing of the ability of the device to respond to a ground fault. This testing shall be done without opening the circuit interrupter contacts.

5.16.2 With the GFCI wired normally (not reversed), the auto-monitoring function shall perform the automatic test each time power becomes available to the load terminal(s) or, alternatively, line terminal(s) of a properly wired GFCI. The automatic test shall be initiated and meet the requirements of [5.16.4](#) with the simulated auto-monitor fault conditions present within five seconds of power availability to the line or load terminals. The automatic test shall be repeated at least every three hours.

5.16.3 The auto-monitoring function shall not compromise the ability of the GFCI to respond to a ground fault or a grounded neutral fault. Compliance is determined by the test of [6.31.6](#).

5.16.4 The consequence of the auto-monitoring test detection of a problem shall be one or more of the following:

- a) Power denial (trip with the inability to reset);
- b) Trip with the ability to reset, subject to the next auto-monitoring test cycle or repeatedly trip;
- c) Visual and/or audible indication as permitted by [6.31.8](#).

## 5.17 Programmable circuit components

5.17.1 If a programmable circuit component such as a microprocessor is employed in a device, that portion of the device shall be investigated in accordance with the requirements of Annex A, Ref. No. 15 as defined in [5.17.2](#). Discrete components such as resistors, capacitors, and transistors, including simple integrated circuits that are not programmable such as logic gates and operational amplifiers, do not fall within the scope of the requirements of Annex [A](#), Ref. No. 15.

5.17.2 The risks to be considered in the investigation mentioned in [5.17.1](#) shall include the following scenarios as applicable:

- a) Unwanted tripping;
- b) Failure to trip under conditions where tripping should occur;
- c) Tripping at the wrong trip threshold value;
- d) Failure of supervisory circuit to complete evaluation;
- e) Failure of the end of life function;
- f) Failure of the auto-monitoring function; and
- g) Failure of the line load miswire function.

## 6 Tests

### 6.1 General

6.1.1 When evaluated in accordance with [6.1.2](#), a product having integral blades for direct insertion into a receptacle shall comply with the specifications in [Table 6.1.1](#).

6.1.2 The limits specified in [Table 6.1.1](#) shall be determined as follows:

- a) For units with an output cord, the cord is to be cut off at the enclosure, or at the strain relief means if the strain relief means is outside the enclosure.
- b) For units with integrally mounted accessories or optional components, the values are to be measured with the accessories or components in place.
- c) A removable part is to be in place.
- d) A mounting tab is not to be included in the measurement of linear dimensions for the purpose of determining moments unless:
  - 1) There is no deformation of the tab and enclosure after being subjected to the impact described in Enclosure and housing – performance, [Clause 6.3](#), and
  - 2) For a polymeric-enclosed product having an integral tab, there is no distortion at temperatures to which the polymeric material may be subjected under conditions of normal and abnormal use as determined by subjecting the product to the applicable mold stress-relief distortion test requirements in Annex [A](#), Ref. No. 8.

6.1.3 When the integral blades are inserted into a parallel-blade duplex receptacle, no part of the product, including a mounting tab, shall interfere with the full insertion of an attachment plug into the adjacent receptacle, except as noted in [6.1.4](#). See [Figure 6.1.2](#).

6.1.4 A unit that renders the adjacent receptacle completely unusable in any one mounting position is acceptable.

**Table 6.1.1**  
**Specifications for plug-in GFCIs**

Algebraic Quantity	Maximum acceptable value	
W	(7.78 N)	28 ozf
WY/Z	(13.34 N)	48 ozf
WY/S	(13.34 N)	48 ozf
WX	(0.56 N·m)	80 ozf-in.

In this table the variables are defined as follows:

W is the weight of the product in N (ozf) and is considered to be a force equal to the product mass in kg (oz) as measured on a scale or balance.

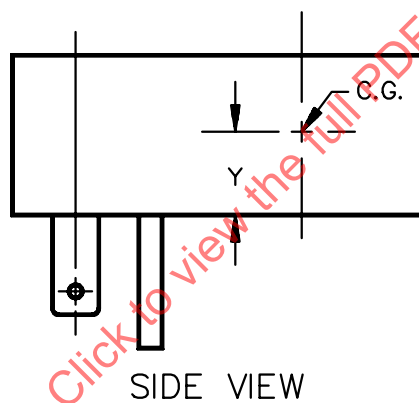
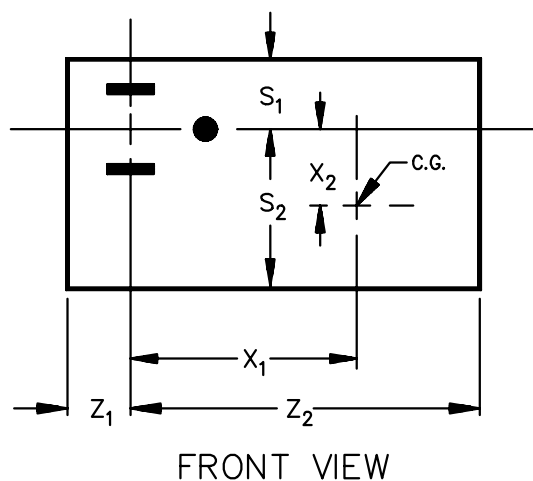
Y is the distance, in mm (inches), illustrated in [Figure 6.1.1](#).

Z is the shorter distance, in mm (inches), of Z<sub>1</sub> or Z<sub>2</sub> illustrated in [Figure 6.1.1](#).

S is the shorter distance, in mm (inches), or S<sub>1</sub> or S<sub>2</sub> illustrated in [Figure 6.1.1](#).

X is the shorter distance, in mm (inches), of X<sub>1</sub> or X<sub>2</sub> illustrated in [Figure 6.1.1](#).

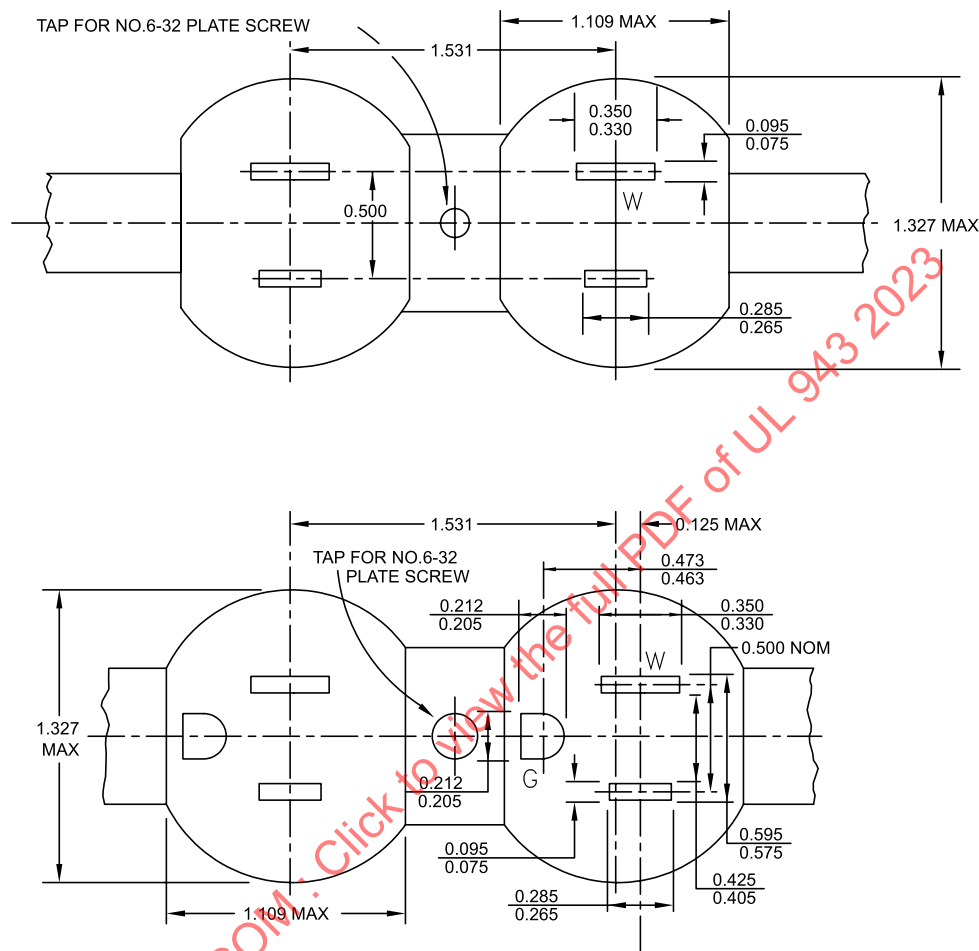
Figure 6.1.1  
Dimensions of a plug-in product



C.G. = Center of Gravity

CP100A

**Figure 6.1.2**  
**Parallel duplex receptacle**



s3076

6.1.5 Each field wiring terminal lead mentioned in [5.9.4](#) is to withstand a tensile force increased gradually to 89 N (20 lbf), and maintained at that value for five minutes.

6.1.6 In order to determine that the strain of pulling on the power-supply cord mentioned in [5.10.4](#) will not be transmitted to the cord terminations, a tensile force is to be applied to the cord and increased gradually to 156 N (35 lbf). The force is to be maintained at 156 N (35 lbf) for one minute.

6.1.7 The power-supply cord of a portable GFCI having a permanently attached cord mentioned in [5.10.12](#) shall be subjected to a pull equal to three times the weight of the equipment. The test shall be repeated ten times with the pull being applied each time for 1 s without jerks. The strain relief shall be judged to comply with the Standard if the cord has not been displaced by more than 2.4 mm (0.094 in) and there is no evidence of any strain being imposed on the wiring connections.

6.1.8 In order to determine compliance with the provisions of [5.9.8](#), a wire-binding screw or nut is to be tightened on a conductor selected in accordance with the provisions of [5.9.1](#) to a torque of 2.3 N·m (20 lbf-in) without causing displacement of the wire or damage to the terminal assembly of the wire. Except where the configuration of the terminal assembly does not permit it, or markings allow the use of unformed wire, the wire is to be formed into a 3/4 loop that will just be accommodated by the assembly, before tightening.

## 6.2 Polymeric enclosures

### 6.2.1 General

6.2.1.1 A polymeric enclosure, or a polymeric part of an enclosure of a ground-fault circuit-interrupter shall comply with the Standard for the polymeric enclosure as specified in Annex [A](#), Ref. No. 9, except as noted in [6.2.1.2](#).

6.2.1.2 For a direct plug-in ground-fault circuit-interrupter, the crushing test shall be conducted in accordance with Annex [A](#), Ref. No. 1.

6.2.1.3 An adhesive used in the assembly of a ground-fault circuit-interrupter shall comply with the applicable requirements for adhesives in accordance with the applicable requirements in Annex [A](#), Ref. No. 10, except as noted in [6.2.1.4](#).

6.2.1.4 Methods utilizing fusion techniques, such as solvent cementing, ultrasonic welding, electromagnetic induction, and thermal welding need not be investigated.

### 6.2.2 Thermal stability – enclosures made of nonmetallic material

6.2.2.1 Enclosures or parts thereof of nonmetallic material shall comply also with the requirements of the thermal stability test in [6.2.2.2](#) – [6.2.2.3](#).

6.2.2.2 A sample of the enclosure shall be subjected to a temperature 10°C higher than that attained by the enclosure under normal operating conditions, but in no case less than 70°C for a period of 7 h.

6.2.2.3 The enclosure shall be judged to comply with the requirements if any distortion of the enclosure neither impairs the operation of the interrupter nor results in failure to comply with requirements for Accessibility of energized parts, Clause [5.7](#).

### 6.3 Enclosure and housing – performance

6.3.1 Except as specified in [6.3.2](#), a permanently connected ground-fault circuit-interrupter is to be subjected to an externally applied impact of 6.8 J (5 ft-lbs) applied by way of a solid, smooth, steel sphere 50.8 mm (2 inches) in diameter.

6.3.2 Receptacle-type ground-fault circuit-interrupters are to be subjected to a 0.91-m (3-ft) drop test onto a concrete floor. The method of doing the test shall be in accordance with the provisions of [6.3.5](#).

6.3.3 The sphere mentioned in [6.3.1](#) is to be allowed to fall freely from rest through the distance required to cause the specified impact upon the surface under test. For surfaces other than horizontal, the sphere may be suspended by a cord and allowed to fall as a pendulum through the required distance. The ground-fault circuit-interrupter is to be placed against a vertical wall with the surface to be tested in the same vertical plane as the point of support of the pendulum.

6.3.4 The ground-fault circuit-interrupter shall be judged to comply with the requirements if the enclosure still complies with the requirements for Accessibility of live parts, Clause [5.7](#); there is no damage to prevent the normal use of switches, spacings specified have not been reduced below the minimum specified by Spacings, Clause [5.12](#), and actuation of the test means or the external application of a fault indicates that the interrupter operates correctly.

6.3.5 A cord-connected or portable device is to be allowed to fall from a height of 0.91 m (3 ft) such that a different part will strike a hardwood surface in each of three drops. Doors or covers are to be moved to any position likely in normal service providing that a captive door or cover is not forced to remain in any position by some means not part of the ground-fault circuit-interrupter.

6.3.6 The hardwood surface mentioned in [6.3.5](#) is to consist of a layer of nominal 1-inch tongue-and-groove oak flooring mounted on two layers of 19 mm (3/4-inch) plywood. The surface is to be a square 1.2 m (4 ft.) on a side. The assembly is to rest on a concrete floor or the equivalent.

6.3.7 Device compliance shall be verified by the test sequence in Representative devices, Clause [6.4](#).

6.3.8 A representative device which is capable of being used as a ground-fault circuit-interrupter without being installed in an additional enclosure, shall be tested in accordance with the applicable enclosure requirements in Annex [A](#), Ref. No. 4 and Annex [A](#), Ref. No. 3. See [5.4.2](#).

6.3.9 In addition to the requirements of [6.3.8](#), a GFCI that is capable of being used without being installed in an additional enclosure, and is intended for installation in a countertop shall additionally comply with the Spill Test of Clause [6.30](#).

6.3.10 If a GFCI as mentioned in [6.3.9](#) is retractable into its enclosure, the device shall be subjected to the Mechanical Endurance Test of Clause [6.29](#) prior to being subjected to the Spill Test of Clause [6.30](#).

6.3.11 Gaskets, seals or similar devices used to prevent the entry of spilled liquids shall be tested in accordance with the applicable requirements for gaskets and seals in Annex [A](#), Ref. No 4.

### 6.4 Representative devices

6.4.1 A representative ground-fault circuit-interrupter that has been conditioned as described in [6.5.7](#) and then subjected to the Leakage current test, Clause [6.5](#), shall at any convenient time and in the following order comply with the requirements for impact as described in [6.3.1](#) or [6.3.5](#), Voltage surge, Clause [6.6](#), High-resistance ground-fault, Clause [6.7](#), and Dielectric voltage withstand, Clause [6.11](#).

6.4.2 Separate, unconditioned representative ground-fault circuit-interrupters shall be subjected to each of the tests in Clause 6, except as noted in 6.4.1. For tests and test sequences, see Table 6.4 for typical test program.

**Table 6.4**  
**Representative device test program<sup>a</sup>**

Test	Clause	Representative device number	
		Portable GFCI	Permanently connected GFCI
Visual inspection	<a href="#">6.22</a>	1 <sup>b</sup>	1 <sup>b</sup>
Humidity	<a href="#">6.5.7</a>	1	1
Leakage current	<a href="#">6.5</a>	1	1
Ball impact	<a href="#">6.3.1</a>	—	1 <sup>d</sup>
Drop impact	<a href="#">6.3.5</a>	1	—
Voltage surge	<a href="#">6.6</a>	1	1
High resistance ground fault	<a href="#">6.7</a>	1	1
Open neutral	<a href="#">6.7.2.1(c)</a>	1 <sup>b</sup>	—
Most adverse	<a href="#">6.7.3.4</a>	1 <sup>b</sup>	1 <sup>b</sup>
Trip threshold	<a href="#">6.7</a>	1	1
Trip times	<a href="#">6.7</a>	1	1
Grounded neutral	<a href="#">6.7.4</a>	1	1
False tripping	<a href="#">6.8</a>	1 <sup>b</sup>	1 <sup>b</sup>
Dielectric	<a href="#">6.11</a>	1	1
Overload	<a href="#">6.12</a>	2	2
Low resistance ground fault	<a href="#">6.13</a>	3	3
Endurance	<a href="#">6.14</a>	4	4
Dielectric	<a href="#">6.11</a>	4	4
Abnormal	<a href="#">6.15</a>	c	c
Extra low resistance ground fault	<a href="#">6.18</a>	5, 6	5, 6
Short circuit	<a href="#">6.19</a>	7	7
Dielectric	<a href="#">6.11</a>	5 – 7	5 – 7
Normal temperature	<a href="#">6.10</a>	8	8
Immunity to conducted disturbances, induced by RF fields	<a href="#">6.9</a>	9	9
Surge current	<a href="#">6.16</a>	10 – 12	10 – 12
Abnormal overvoltage	<a href="#">6.17</a>	13 – 17	13 – 17
Corrosion	<a href="#">6.21</a>	18	18
Reverse line-load miswire	<a href="#">6.23</a>	—	19 <sup>e</sup>
Reverse line-load miswire – repeated	<a href="#">6.24</a>	—	19 <sup>b, e</sup>
Supplemental voltage surge immunity	<a href="#">6.25</a>	19 <sup>b</sup>	20 <sup>b</sup>
Operating mechanism	<a href="#">6.26</a>	20	21
GFCI end of life	<a href="#">6.27</a>	21	22

Table 6.4 Continued on Next Page



Table 6.4 Continued

Test	Clause	Representative device number	
		Portable GFCI	Permanently connected GFCI
GFCI receptacle temperature	<a href="#">6.28</a>	–	23 <sup>e</sup>
Auto-monitoring function	<a href="#">6.31</a>	–	24 – 30 <sup>c</sup>
Mechanical endurance	<a href="#">6.29</a>	–	31 <sup>f</sup>
Spill	<a href="#">6.30</a>	–	32 – 37 <sup>f</sup>
<p><sup>a</sup> This table does not include construction requirements or enclosure tests. With the agreement of all concerned, fewer representative devices may be used, except where tests are required to be performed on a previously untested representative device.</p> <p><sup>b</sup> Separate representative devices may be used for these tests</p> <p><sup>c</sup> As many representative devices as necessary</p> <p><sup>d</sup> Receptacle type ground-fault circuit interrupters are subjected only to the drop impact test per <a href="#">6.3.2</a></p> <p><sup>e</sup> Receptacle type ground-fault circuit interrupters only</p> <p><sup>f</sup> Countertop type retractable ground-fault circuit interrupters only</p>			

## 6.5 Leakage current test

6.5.1 The leakage current of a ground-fault circuit-interrupter is to be tested in accordance with [6.5.2](#) – [6.5.7](#).

a) The leakage current with the test voltage applied between the supply circuit and accessible surfaces shall be no more than 0.5 mA. In the U.S., transient voltage surge suppressor circuits may have higher leakage if they comply with the performance and marking requirements of Annex A, Ref. No. 11.

b) If a portable GFCI has electronic components (e.g. a transient voltage surge suppressor) connected between line and ground, the leakage current shall be measured through these components.

6.5.2 All accessible parts of a ground-fault circuit-interrupter are to be tested for leakage currents. The accessible parts are to be tested individually, collectively, and from one part to another.

6.5.3 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using metal foil with an area of 10 cm (3.94 inches) by 20 cm (7.87 inches) in contact with the surface. Where the surface is less than 10 cm (3.94 inches) by 20 cm (7.87 inches), the metal foil is to be the same size as the surface. The metal foil is not to be pressed into openings and is not to remain in place long enough to affect the temperature of the sample.

6.5.4 The measurement circuit for leakage current of a cord-connected device is to be as shown in [Figure 6.5.4.1](#). The measurement instrument is defined in items a – d of this paragraph. The meter that is actually used for a measurement need only indicate the same numerical value for a measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

a) The meter is to have an input impedance of 1500 Ohms resistive shunted by a capacitance of 0.15 µF.

b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistance or current through the resistance.

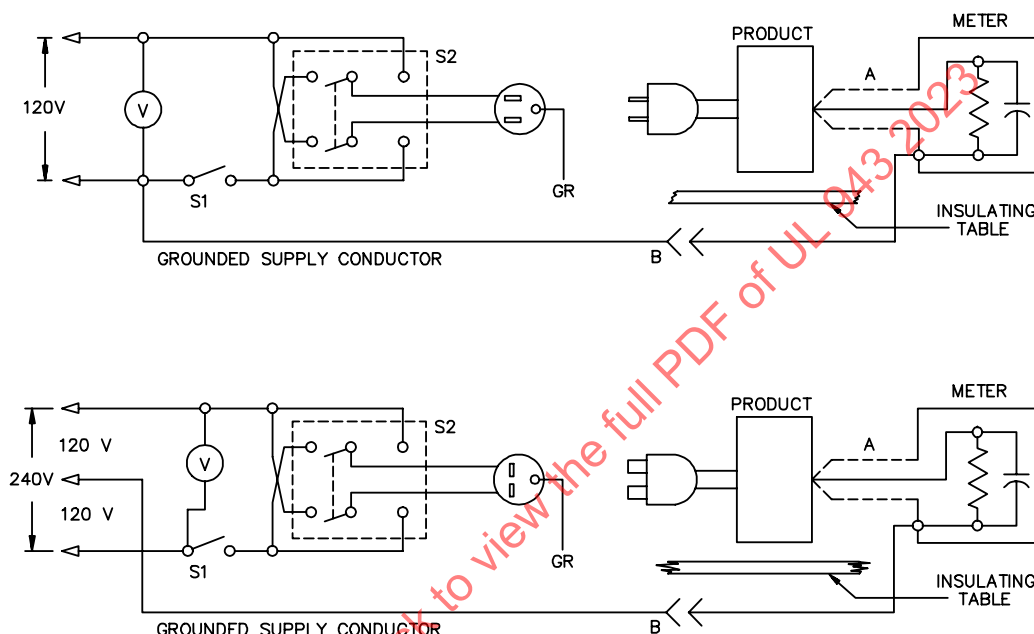
c) Over a frequency range of 0 – 100 kHz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) that is to the ratio of the impedance of a

1500-Ohm resistance, shunted by a 0.15- $\mu$ F capacitance, to 1500 Ohms. At an indication of 0.5 mA, the measurement is to have an error of not more than five percent at any frequency within the range of 0 – 100 kHz.

d) Unless the meter is being used to measure leakage from one part of the sample to another, the meter is to be connected between the accessible parts and the ground supply conductor.

**Figure 6.5.4.1**

**Leakage-current measurement circuits**



**NOTE:**

A – Probe with shielded lead.

B – Separated and used as clip when measuring currents from one part of the device to another.

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6.5.5 A permanently connected ground-fault circuit-interrupter is to be connected to the supply by way of the line terminals of the device, and tested in the same manner as a cord-connected device.

6.5.6 A sample of the ground-fault circuit-interrupter is to be tested for leakage current after the conditioning described in 6.5.7. If removed from the humidity chamber the testing is to start within one minute after its removal. The grounding conductor of a cord-connected unit is to be open at the supply receptacle and the grounding conductor of a permanent connected unit is not to be used. The supply voltage is to be adjusted to 110 percent of the rated voltage. The test sequence, with reference to the measuring circuit in Figure 6.5.4.1, is as follows:

a) With switch S1 open, the sample is to be connected to the measurement circuit. The leakage current is to be measured using both positions of switch S2 and if physically possible with the sample switching devices in all their positions.

b) Switch S1 is then to be closed, energizing the sample, and within a period of five seconds, the leakage current is to be measured using both positions of switch S2 and with the control settings varied throughout the operating range.

c) Leakage current is to be monitored at intervals necessary to determine the maximum leakage current, with additional measurements being taken until such time as thermal equilibrium is attained. Both positions of switch S2 are to be used in determining this measurement.

6.5.7 The conditioning mentioned in [6.5.6](#) and [6.4.1](#) is exposure to air at a relative humidity of  $93 \pm 2$  percent at a temperature of  $32.0 \pm 2.0^{\circ}\text{C}$  ( $89.6 \pm 3.6^{\circ}\text{F}$ ). The ground-fault circuit-interrupter is to be exposed to ambient air at a temperature of at least  $30^{\circ}\text{C}$  ( $86^{\circ}\text{F}$ ) until thermal equilibrium is attained before placed in the test chamber. Devices are kept in the chamber for 168 hours, except as noted in [6.5.8](#).

6.5.8 Devices restricted for indoor use are kept in the chamber for 48 hours.

## 6.6 Voltage surge test

### 6.6.1 General

6.6.1.1 The line side terminals of the Line-Neutral and Line-Line terminals that are protected by the representative ground-fault circuit-interrupter shall be subjected to the following surge tests in accordance with the sequence described in Clause [6.4.1](#): Unwanted tripping test, Clause [6.6.2](#) and the Surge immunity test, Clause [6.6.3](#). Previously untested representative ground-fault circuit-interrupters shall be tested as specified in the Surge current test, Clause [6.16](#), the Abnormal overvoltage test, Clause [6.17](#), and the Supplemental voltage surge immunity test, Clause [6.25](#).

6.6.1.2 The ground-fault circuit-interrupter is to be connected to a supply of rated voltage. The grounding lead or terminal of the ground-fault circuit-interrupter (if provided) is to be connected to the supply conductor serving as the neutral. The ground-fault circuit interrupter is to be in the "on" condition with no load connected. GFCI's that are intended only for use in enclosures shall be tested in their intended enclosure for the tests referenced in [6.6.1.1](#). The enclosure shall be representative of the worst case situation for the tests.

### 6.6.2 Unwanted tripping test (ring wave)

6.6.2.1 One representative ground-fault circuit interrupter shall not trip after being subjected to ten random applications or three controlled applications of a 3 kV surge applied at 60 second intervals. When three controlled applications are employed, one application is to be essentially at zero of the supply voltage wave, one at the positive peak, and one at the negative peak.

6.6.2.2 The surge generator is to have a surge impedance of 50 ohms. When there is no load on the generator, the waveform of the surge is to be essentially as follows:

- a) Initial rise time, 0.5 microseconds between 10 percent and 90 percent of peak amplitude,
- b) The period of the following oscillatory wave, 10 microseconds, and
- c) Each successive peak, 60 percent of the preceding peak.

6.6.2.3 [Figure 6.6.1](#) and [Figure 6.6.2](#) show a typical surge generator and control relay.

### 6.6.3 Surge immunity test (combination wave)

6.6.3.1 The GFCI subjected to the Unwanted tripping test shall be subjected to the Surge immunity test without demonstrating, either during or after testing:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (preexisting or created as a result of the test) in the product,

b) Ignition of the enclosure, or

c) Creation of any opening in the enclosure that results in accessibility of energized parts, when judged in accordance with Accessibility of energized parts, Clause [5.7](#).

6.6.3.2 The test method is to be conducted in accordance with the testing methods described in IEC 61000-4-5 Electromagnetic Compatibility (EMC) Part 4-5: Testing and Measurements Techniques – Surge Immunity Test.

6.6.3.3 The surges shall be applied at phase angles of 90 and 270 electrical degrees.

6.6.3.4 Only the surge impulse test levels in [Table 6.6.3.1](#) shall be used.

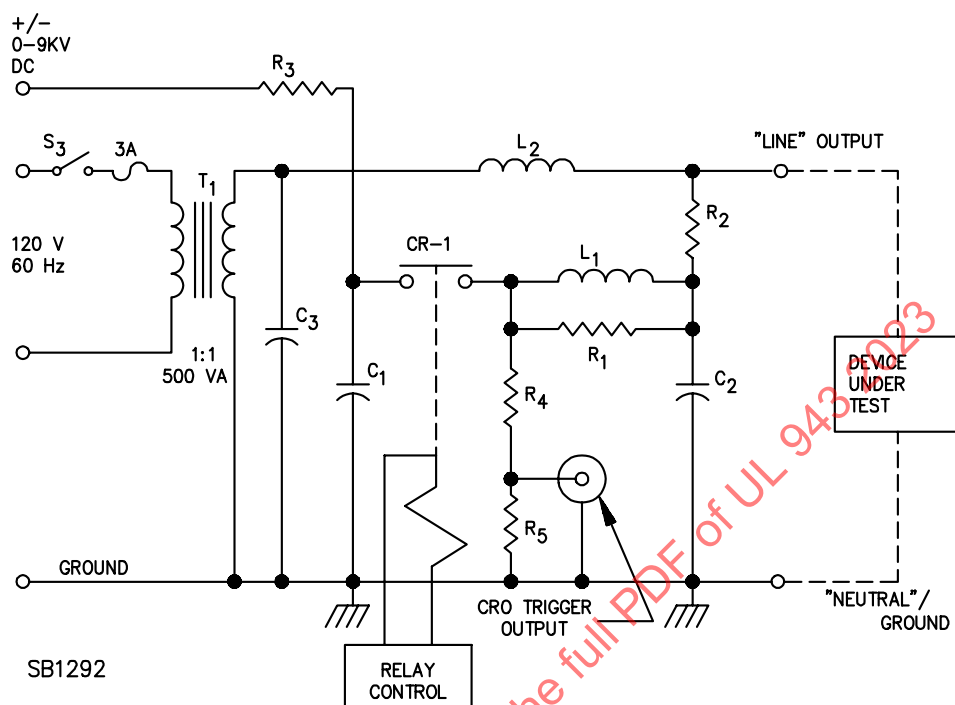
**Table 6.6.3.1**  
**Surge impulse test level**

Impulse <sup>a</sup>	
Peak voltage (kV <sub>p</sub> )	Peak current (kA <sub>p</sub> )
4	2
<sup>a</sup> Combination 1.2/50 µs, 8/20 µs Voltage/Current surge waveform. For specifications and tolerances, refer to IEC 61000-4-5, Electromagnetic Compatibility (EMC) – Part 4-5: Testing and Measurements Techniques – Surge Immunity Test.	

6.6.3.5 The GFCI is permitted to trip during surge immunity testing. If the GFCI trips, it is to be reset prior to the next surge application.

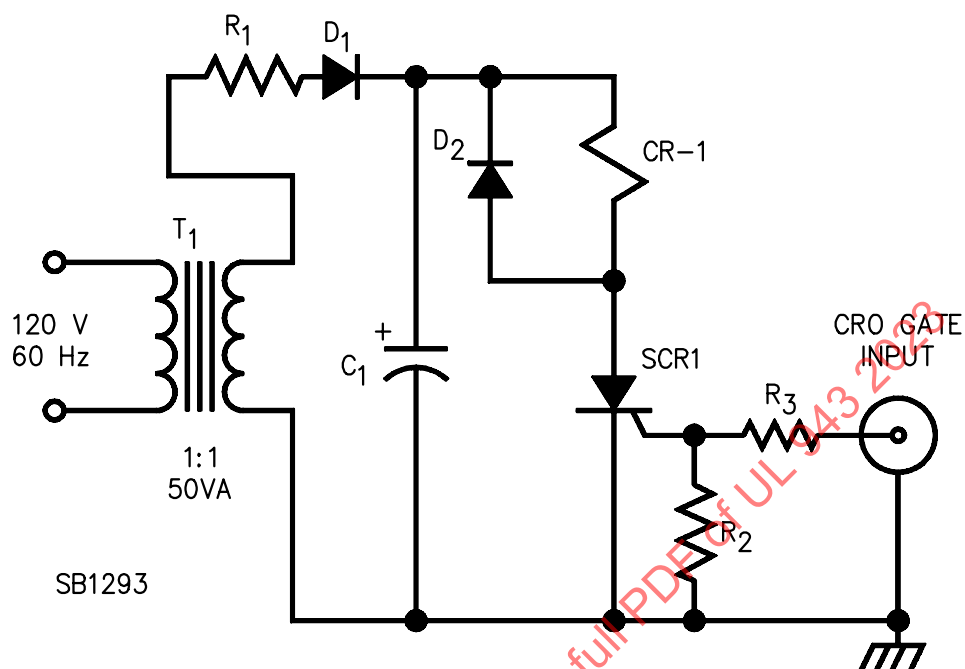
6.6.3.6 After this test the same GFCI shall comply with the High-resistance ground fault and the Dielectric voltage withstand tests.

**Figure 6.6.1**  
**Surge generator circuit**



C1	=	0.025 $\mu$ f, 10 Kv	R1	=	22 Ohmw, 1 W, composition
C2	=	0.02 $\mu$ f, 10 Kv	R2	=	12 Ohms, 1W, composition
C3	=	4 $\mu$ f, 400v	R3	=	1.3M Ohms (12 x 110K Ohms, 1/2 W)
			R4	=	47K Ohms (10 x 4.7K Ohms, 1/2 W)
L1	=	15 $\mu$ H [23 turns, 0.258 mm <sup>2</sup> (23 AWG wire), 18 mm (0.7 inch) diameter air core]	R5	=	200 Ohms, 1/2 W
L2	=	70 $\mu$ H [28 turns, 0.258 mm <sup>2</sup> (23 AWG) wire, 66 MM (2.6 inch) diameter air core]	CR-1	=	Relay

Figure 6.6.2  
Relay control circuit for surge generator



R1	=	10K Ohms, 1 W
R2	=	1K Ohms, 1/2 W
R3	=	1K Ohms, 1/2 W
C1	=	32 $\mu$ F, 250 V
D1	=	IN5060 or equivalent
D2	=	IN5060 or equivalent
SCR1	=	GE C122B or equivalent
CR-1	=	Relay GE CR 2790 E 100 A2 or equivalent
T1	=	Triad N4S X or equivalent

## 6.7 High-resistance ground fault

### 6.7.1 General

6.7.1.1 A Class A ground-fault circuit-interrupter shall be capable of interrupting the electric circuit to the load when the fault current to ground  $I$  is within the range of a minimum of 6 mA through a maximum of (110% of rated  $V$  to ground)  $X$  (1000/500) mA within the time interval  $T$  in accordance with the relationship:

$$T = \left( \frac{20}{I} \right)^{1.43}$$

in which:

$T$  is expressed in seconds, and

$I$  is expressed in milliamperes.

6.7.1.2 The time relationship in [6.7.1.1](#) shall also be met if the grounded conductor becomes grounded at a point in the load circuit of the ground-fault circuit-interrupter.

6.7.1.3 Interruption of the electric circuit to the load shall not take place if the fault current is less than 4 mA, or 3.5 mA if the ambient air temperature is less than -5°C (23°F) or more than 40°C (104°F).

6.7.1.4 The performance of any ground-fault circuit-interrupter shall not be impaired by any of the following:

- a) Any mounting positions.
- b) Any cover position likely to occur.
- c) Any electrical load within the rating of the interrupter.
- d) Any ambient temperature between -35°C (-31°F) and 66°C (151°F).
- e) Omission of grounding conductor.

### 6.7.2 GFCI characteristics

6.7.2.1 A portable ground-fault circuit-interrupter shall comply with the provisions of [6.7.1.1](#) with and without one or more of the following defects in its power-supply cord:

- a) The ungrounded and grounded conductors transposed at the attachment plug terminals.
- b) An open circuit in the grounding conductor.
- c) An open circuit in any one power conductor.
- d) Except if normal operation of the supervisory circuit would provide an indication of trouble, the ungrounded and grounding conductors of the power-supply cord transposed at the attachment plug terminals.
- e) For devices having more than one ungrounded conductor, an open circuit in any one ungrounded conductor.

6.7.2.2 A permanently connected ground-fault circuit-interrupter shall comply with the provisions of [6.7.1.1](#) with and without one or more of the following defects in its power-supply:

- a) The ungrounded and grounded conductors transposed at the line terminals.
- b) An open circuit in the grounding conductor.
- c) For devices having more than one ungrounded conductor, an open circuit in any one ungrounded conductor.

6.7.2.3 In order to determine compliance with the provisions of [6.7.1.1](#) – [6.7.2.2](#), a ground-fault circuit-interrupter is to be connected as shown in [Figure 6.7.2.1](#) and tested as described in [6.7.3.1](#), in the sequence of steps described in [Table 6.7.2.1](#).

**Table 6.7.2.1**  
**Test sequence for high-resistance ground faults and false tripping**

Ambient air temperature <sup>a</sup>		Operating parameters	Remarks
1.	25.0 ±5.0°C (77.0 ±9.0°F)	No voltage applied	Establish thermal equilibrium with at least two hours of exposure. Do not test.
2.	25.0 ±2.0°C (77.0 ±3.6°F)	Most adverse <sup>e</sup>	Test per <a href="#">6.7.2.3</a> and <a href="#">6.8.2</a> as soon as possible to minimize self-heating.
3. <sup>b</sup>	66.0 ±2.0°C (150.8 ±3.6°F)	Rated voltage <sup>f</sup> and current	Establish thermal equilibrium with at least two hours of exposure. Do not test.
4. <sup>b</sup>	66.0 ±2.0°C (150.8 ±3.6°F)	Most adverse <sup>e</sup>	Test per <a href="#">6.7.2.3</a> and <a href="#">6.8.2</a> .
5. <sup>c</sup>	40.0 ±2.0°C (104.0 ±3.6°F)	Rated voltage <sup>f</sup> and current	Establish thermal equilibrium with at least two hours of exposure. Do not test.
6. <sup>c</sup>	40.0 ±2.0°C (104.0 ±3.6°F)	Most adverse <sup>e</sup>	Test per <a href="#">6.7.2.3</a> and <a href="#">6.8.2</a> .
7.	25.0 ±5.0°C (77.0 ±9.0°F)	No voltage applied	Establish thermal equilibrium with at least two hours of exposure. Do not test.
8.	-35.0 ±2.0°C (-31 ±3.6°F)	No voltage applied	Establish thermal equilibrium with at least two hours of exposure. Do not test.
9.	-35.0 ±2.0°C (-31 ±3.6°F)	Most adverse <sup>e</sup>	Tests per <a href="#">6.7.2.3</a> and <a href="#">6.8.2</a> as soon as possible to minimize self-heating.
10. <sup>d</sup>	-5.0 ±2.0°C (23 ±3.6°F)	No voltage applied	Establish thermal equilibrium with at least two hours of exposure. Do not test.
11. <sup>d</sup>	-5.0 ±2.0°C (23 ±3.6°F)	Most adverse <sup>e</sup>	Tests per <a href="#">6.8.2</a> as soon as possible to minimize self-heating.
12.	25.0 ±5.0°C (77.0 ±9.0°F)	Rated voltage <sup>f</sup> and current	Establish thermal equilibrium with at least two hours of exposure. Do not test.
13.	25.0 ±5.0°C (77.0 ±9.0°F)	Most adverse <sup>e</sup>	Test per <a href="#">6.7.2.3</a> and <a href="#">6.8.2</a> .

<sup>a</sup> The ambient air temperature is to be changed to each value shown without intentional delay.

<sup>b</sup> In the event that a ground-fault circuit-interrupter is self-protecting such that it trips at this ambient temperature, lower values of load current are to be employed, until the device just continues to operate. The thermal protection may be circumvented for the purposes of this test.

<sup>c</sup> This test is not to be performed if steps 3 and 4 have been performed employing rated current.

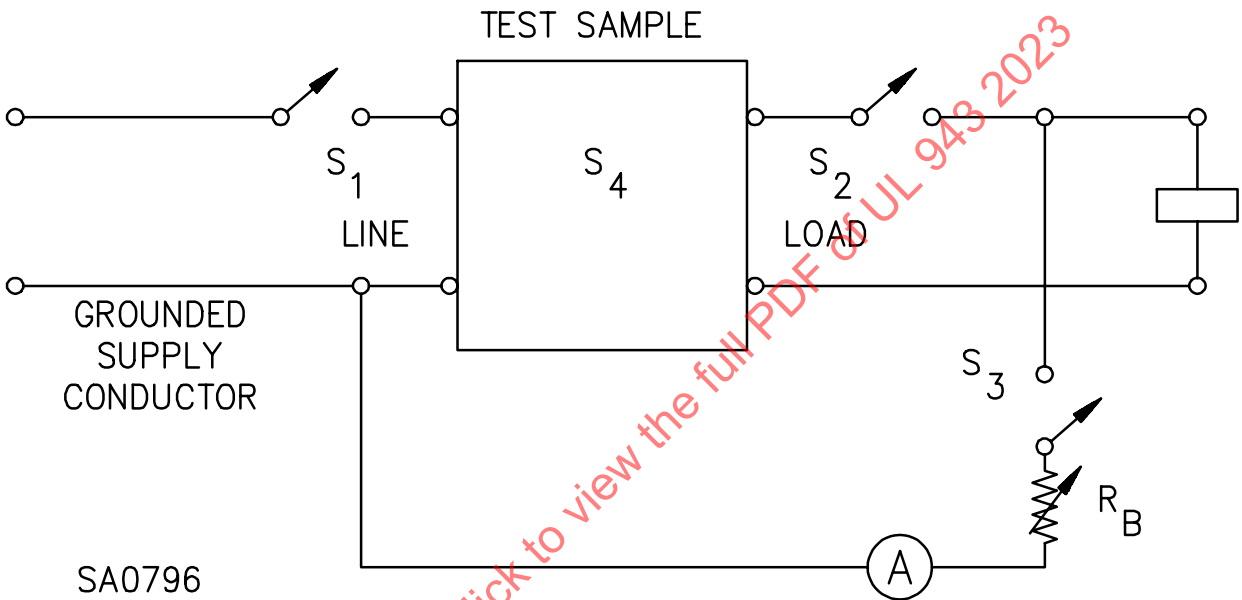
**Table 6.7.2.1 Continued on Next Page**



Table 6.7.2.1 Continued

Ambient air temperature <sup>a</sup>	Operating parameters	Remarks
<sup>d</sup> This test is not to be performed if product does not trip with less than 4 mA in step 9.		
<sup>e</sup> For "most adverse" operating parameters, see <a href="#">6.7.3.3</a> and <a href="#">6.7.3.4</a> .		
<sup>f</sup> See <a href="#">Table 7.2.1</a> for rated voltage and corresponding marked values.		

Figure 6.7.2.1  
High-resistance ground-fault test circuit



S<sub>4</sub> – Integral on-off or other operating switch (not test switch)

6.7.3 High-resistance ground fault test

6.7.3.1 In performing the test mentioned in [6.7.2.3](#), the resistance R<sub>B</sub> is to be varied to obtain the test values of current to be indicated by meter A. The sum of R<sub>B</sub> and the resistance of meter A is to be not less than 500 ohms. The test values of current are to include the minimum specified and the maximum possible and one or two additional values as may be considered necessary to assure compliance with the provisions of [6.7.1.1](#) – [6.7.2.2](#). Ten measurements of current duration are to be made for each mode of operation described and for each value of test current selected. The average of each group of ten is not to exceed the time allowed. Individual measurements may exceed the time allowed provided that such measurements do not exceed 125 percent of the time allowed. The modes of operation noted in are to be performed. For ground-fault circuit-interrupters intended to be used on 120/240 V circuits or 127/220V, the resistance is to be connected between each ungrounded load terminal, in turn, and the grounded conductor of the supply.

**Table 6.7.3.1**  
**Modes of operation**

Precondition of circuit		Action that starts ground-fault current
A	Switch S <sub>1</sub> closed Switch S <sub>2</sub> closed Switch S <sub>3</sub> closed Switch S <sub>4</sub> open	Switch S <sub>4</sub> is to be moved (1) in one continuous motion to its extreme position, and (2) to the position at which the current just starts, and the operating handle held in that position.
B	Switch S <sub>1</sub> open Switch S <sub>2</sub> closed Switch S <sub>3</sub> closed Switch S <sub>4</sub> closed	Switch S <sub>1</sub> closed.
C	Switch S <sub>1</sub> closed Switch S <sub>2</sub> open Switch S <sub>3</sub> closed Switch S <sub>4</sub> closed	Switch S <sub>2</sub> closed.
D	Switch S <sub>1</sub> closed Switch S <sub>2</sub> closed Switch S <sub>3</sub> open Switch S <sub>4</sub> closed	Switch S <sub>3</sub> closed <sup>a</sup>
<sup>a</sup> In obtaining the minimum value of current specified for the rated class, R <sub>B</sub> is to be (1) decreased gradually until tripping occurs, and (2) preset for the desired value.		

6.7.3.2 It may be necessary to prevent tripping of the device under test while adjusting for various values of current in resistance R<sub>B</sub>. Care should then be taken to assure that components that are not continuously energized in normal operation should not be caused to be continuously energized during the adjustment procedure. Attempts to bypass one or more poles of the device will usually produce the condition described.

6.7.3.3 In determining the "most adverse" conditions mentioned in [Table 6.7.2.1](#), each of the operating parameters described in items (a) – (d) of this clause is to be varied as described in [6.7.3.4](#) so as to obtain a combination, if any, considered to be most adverse to the tested function of the ground-fault circuit-interrupter, at room-temperature ambient. The "most adverse" condition of an operating parameter is to be learned from operating a representative device. This representative device need not be subjected to any other tests.

a) **LINE VOLTAGE** – The closed-circuit line voltage is to be adjusted within the range of 85 – 110 percent of rated voltage, at rated load, with the cover(s), if any, of the device closed, and with the device supported in its marked mounting position. If no mounting position is marked on the device, any one position that is considered normal for the device is to be arbitrarily selected. The line voltage to the device is to be obtained from a source having sinusoidal waveform and free from any measurable transient voltage rises or dips.

b) **LOAD** – The load may have any value of current up to rated and is to be resistive.

c) **SUPPLY POLARITY** – "Normal polarity" is when the representative device is connected as intended. For a 120 volt device the ungrounded supply conductor is connected to the hot terminal, the grounded supply conductor is connected to the white terminal. "Reverse polarity" would be when these connections are transposed.

d) **MOUNTING POSITION** – Except for a permanently connected ground-fault circuit-interrupter marked to specify a mounting position, the device is to be placed in different positions. The

mounting position of a permanently connected device that is marked to specify a mounting position is to be varied from the marked mounting position by no more than 10 degrees (for a total range of 20 degrees). Rated load is to be connected and the cover(s), if any, of the device are to be closed.

#### 6.7.3.4 Procedure for determining the "most adverse" parameters in a 25°C ambient:

- a) Step 1 – Establishing most adverse "Line Voltage" – Start with the device in a normal mounting position, no load, normal supply polarity. Make ten readings of trip time for each of the following conditions. Use switch  $S_1$  (Table 6.7.3.1 mode B) to turn on the power. Set line voltage at 85% of rated. Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault. Set line voltage at 100% of rated. Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault. Set line voltage at 110% of rated. Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault.
- b) Step 1a – Average the trip times for each condition. The "most adverse" condition will be the highest average percentage of the allowable trip time (see equation in 6.7.1.1) for the fault that was used.
- c) Step 2 – Establishing most adverse "Load Condition" – Start with the device in a normal mounting position, most adverse line voltage condition determined from step 1, normal supply polarity. Make ten readings of trip time for each of the following conditions. Use switch  $S_1$  (Table 6.7.3.1 mode B) to turn on the power. Connect maximum rated load. Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault. Disconnect load. Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault.
- d) Step 2a – Average the trip times for each condition. The "most adverse" condition will be the highest average percentage of the allowable trip time for the fault that was used.
- e) Step 3 – Establishing most adverse "Supply Polarity" – Start with the device in a normal mounting position, most adverse line voltage condition determined from step 1, most adverse load condition from step 2. Make ten readings of trip time for each of the following conditions. Use switch  $S_1$  (Table 6.7.3.1 mode B) to turn on the power. Connect with "Normal supply polarity" – Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault. Connect with "Reverse supply polarity" – Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault.
- f) Step 3a – Average the trip times for each condition. The "most adverse" condition will be the highest average percentage of the allowable trip time for the fault that was used.
- g) Step 4 – Establishing most adverse Mounting Position – Start with the device in a normal mounting position, most adverse line voltage condition determined from step 1, most adverse load condition from step 2, most adverse supply polarity from step 3. Make ten readings of trip time for each of the following conditions. Use switch  $S_1$  (Table 6.7.3.1 mode B) to turn on the power. With sample in "Normal Mounting Position" No. 1 – Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault. With sample in each possible mounting position No. 2, 3, 4, 5, and 6 as necessary – Test ten times with a 6 mA fault. Test ten times with a 500 ohm fault.
- h) Step 4a – Average the trip times for each condition. The "most adverse" condition will be the highest average percentage of the allowable trip time for the fault that was used. At this point the most adverse voltage, load, polarity, and mounting position have been determined. Other variables, such as cover position and grounding may also be considered in the same manner.

#### 6.7.4 Grounded neutral test

6.7.4.1 In determining compliance with the provisions of 6.7.1.2, the representative device is to be connected as shown in Figure 6.7.4.1 and tested in the sequence of steps described in Table 6.7.2.1 as described in 6.7.4.3 for the highest and lowest values of  $R_N$  and  $R_G$  (see Table 6.7.4.1) which are appropriate for the ratings of the representative device. For example, for a representative device rated maximum 20 A, minimum 15 A, 3.307 mm<sup>2</sup> (12 AWG) or 2.082 mm<sup>2</sup> (14 AWG) wire may be used so the

lowest value of  $R_N$  and  $R_G$  is 0.008 ohms. The highest value of  $R_N$  and  $R_G$  would be 0.4 and 1.6 ohms. These are the values that would be used for testing. The tests are to be conducted both with  $R_L$  open and with  $R_L$  adjusted for rated current. The test voltage shall be the most adverse as determined in [6.7.3.3](#) – [6.7.3.4](#).

6.7.4.2 When testing as described in [6.7.4.3](#), additional values of current indicated by meter A and in resistance  $R_L$  and other values of resistances  $R_N$  and  $R_G$  may be employed if necessary to determine compliance with the provisions of [6.7.4.1](#). Such other values are to be in accordance with the rating of the product and the cable constructions represented in [Table 6.7.4.1](#). Ground fault current values of 6 mA and most adverse voltage divided by 500 ohms are suggested.

6.7.4.3 Grounded neutral trip test procedure (Except as noted in [6.7.4.4](#)):

- a) Select the combination of  $R_G$  and  $R_N$  from [Table 6.7.4.1](#) as required.
- b) Open  $S_3$  and  $S_4$ . Close  $S_1$  and  $S_2$ .
- c) Using ammeter (A), set the current to 6.0 mA by adjusting  $R_B$ .
- d) With  $S_2$  and  $S_4$  open and  $S_3$  closed, close  $S_1$ . If the device trips, trip time need not be recorded. If the device does not trip close  $S_2$  and record trip time. Repeat 10 times.
- e) Repeat step (d) with  $S_2$  closed,  $S_3$  closed, and close  $S_1$  and record trip time.
- f) With  $S_2$  and  $S_4$  open and  $S_1$  closed, close  $S_3$  and if the device trips, trip time need not be recorded. If the device does not trip close  $S_2$  and record trip time. Repeat 10 times.
- g) Repeat procedure (a) – (f) for the combinations of resistors from [Table 6.7.4.1](#) which apply.
- h) Repeat procedure (a) – (g) with  $S_4$  closed (which would switch on the load) and with  $R_L$  = to full load current.

6.7.4.4 When testing devices which require that manual setting be activated, the manual setting means will be considered as  $S_1$ .

Figure 6.7.4.1  
Supplementary high-resistance test circuit

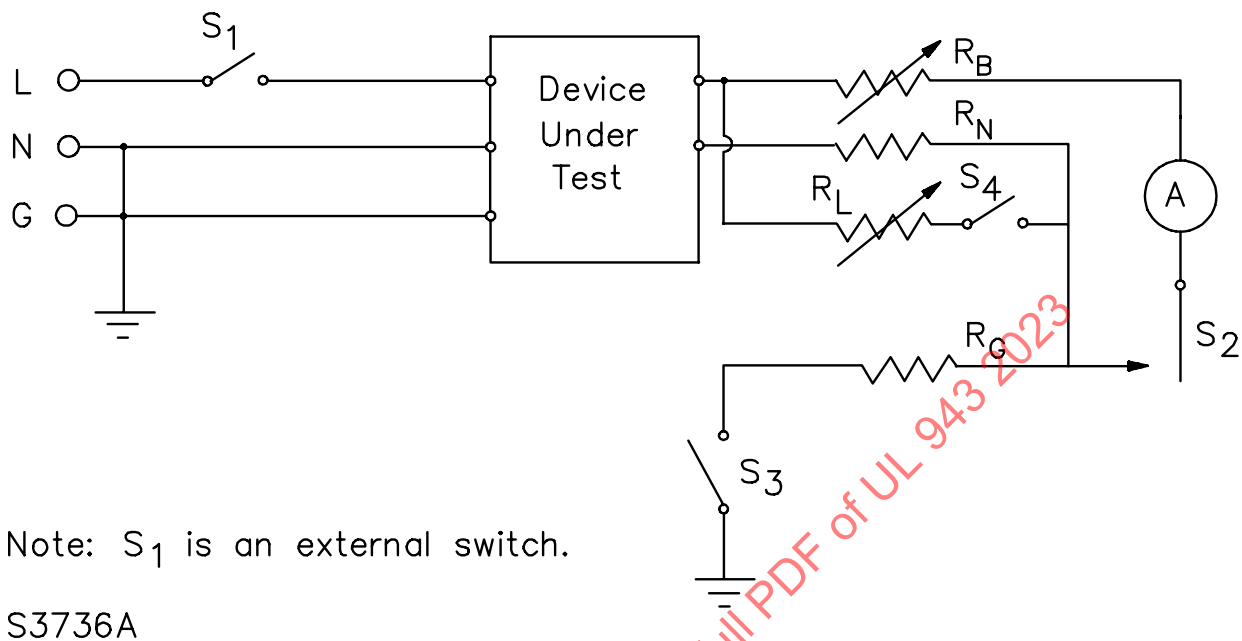


Table 6.7.4.1  
Resistance in OHMS<sup>a</sup>

AWG copper wire size of field wiring <sup>b</sup>										
Combination	2.082 mm <sup>2</sup> (14 AWG) – 3.307 mm <sup>2</sup> (12 AWG)		5.26 mm <sup>2</sup> (10 AWG)		8.367 mm <sup>2</sup> (8 AWG)		13.30 mm <sup>2</sup> (6 AWG)		21.15 mm <sup>2</sup> (4 AWG)	
	R <sub>N</sub>	R <sub>G</sub>	R <sub>N</sub>	R <sub>G</sub>	R <sub>N</sub>	R <sub>G</sub>	R <sub>N</sub>	R <sub>G</sub>	R <sub>N</sub>	R <sub>G</sub>
1	0.008	0.008	0.005	0.005	0.0032	0.0032	0.002	0.002	0.0013	0.0013
2	0.08	0.20	0.05	0.13	0.0320	0.0833	0.021	0.053	0.013	0.0337
3	0.4	1.0	0.25	0.65	0.1601	0.4163	0.103	0.267	0.065	0.168
4	0.008	0.032	0.005	0.028	0.0032	0.0179	0.0021	0.0115	0.0013	0.0073
5	0.08	0.32	0.05	0.28	0.0320	0.179	0.021	0.115	0.013	0.073
6	0.4	1.6	0.25	1.4	0.1601	0.897	0.103	0.574	0.065	0.363

<sup>a</sup> The combinations shown represent discrete lengths and constructions of cable or flexible cord. Resistances R<sub>N</sub> and R<sub>G</sub> represent respectively the resistance of the grounded and the grounding conductors of the cable or cord.

<sup>b</sup> See 5.8.1.

6.8 Resistance to false tripping test

6.8.1 A ground-fault circuit-interrupter shall have necessary resistance to tripping when connected to load circuits that have:

- a) Values of leakage current anticipated in normal service, and

b) Normal transient electrical disturbances such as those caused by switching.

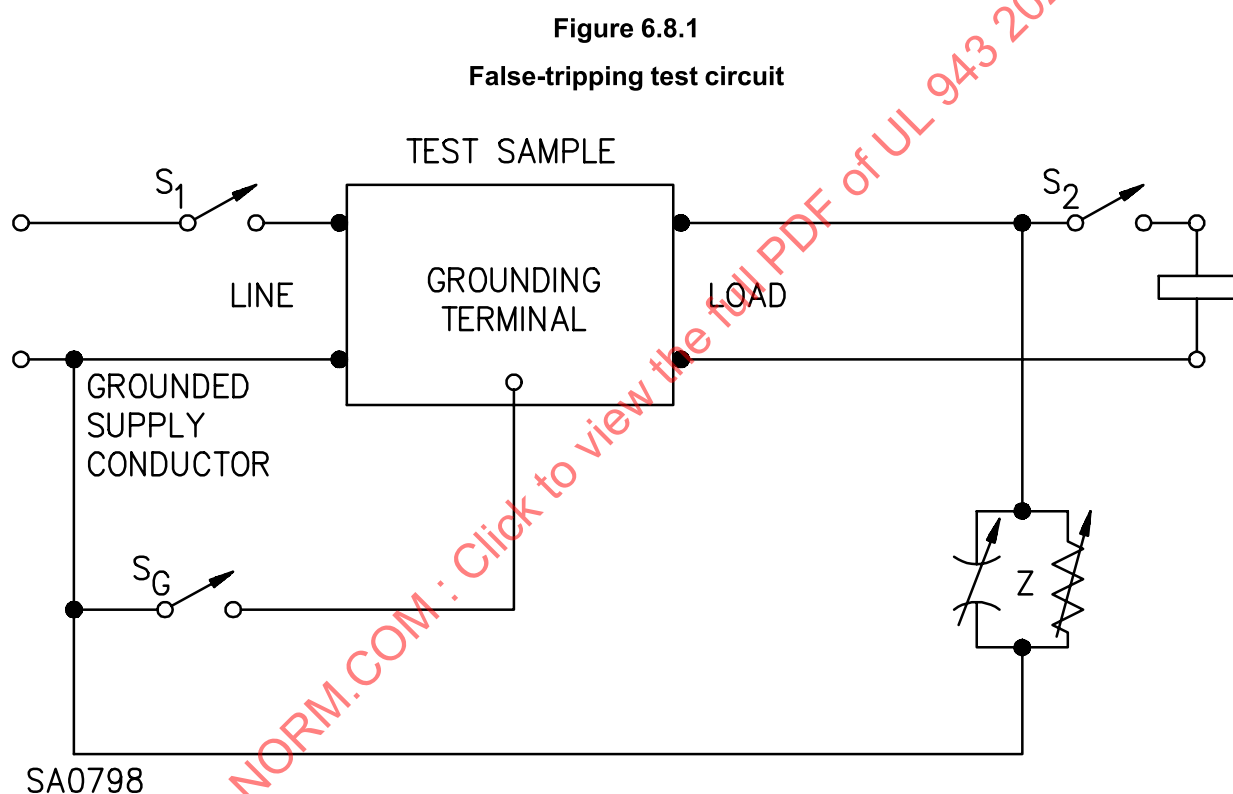
6.8.2 In order to determine compliance with the provisions of 6.8.1, a ground-fault circuit-interrupter is to be connected as shown in Figure 6.8.1 with the impedance  $Z$  described in 6.8.3 and tested:

a) As described in 6.8.4, in each of the steps shown in Table 6.7.2.1, and

b) As described in 6.8.5.

Switches  $S_1$  and  $S_2$  shown in Figure 6.8.1 are to be capable of closing with minimum contact bounce, and opening with minimum clearing time. They may control both conductors if that is more adverse.

6.8.3 Components of impedance  $Z$  are to be as indicated in Table 6.8.1.



**Table 6.8.1**  
**Impedance ( $Z$ )**

Ground-fault circuit-interrupter	Components of $Z$	
	Resistance in ohms	Capacitance in microfarads
Portable	80,000	0.012 or none
Permanent	64,000	0.015 or none

6.8.4 The tests mentioned in 6.8.2 are as follows:

- a) Under the "most adverse" conditions described in [6.8.7](#), the device is not to trip while operating continuously,
- b) Under the "most adverse" conditions described in [6.8.7](#), the device is not to trip more than three times in ten operations of each switch  $S_1$  and switch  $S_2$ , and
- c) Under the "most adverse" conditions described in [6.8.7](#), a device is not to trip below the fault current mentioned in [6.7.1.3](#). The impedance  $Z$  is gradually reduced until the ground-fault circuit-interrupter trips. The capacitive component of  $Z$  is to be disconnected and switches  $S_1$  and  $S_2$  are to be closed. The procedure is to be conducted three times under each of the "most adverse" conditions.

6.8.5 The tests mentioned in [6.8.2](#) are as follows:

- a) Under the "normal" conditions described in [6.8.6](#), the device is not to trip more than three times in 100 operations of each switch  $S_1$  and  $S_2$ , and
- b) Under the "normal" conditions described in [6.8.6](#), the device is not to trip more than one time in ten operations of any switch that is an integral part of the device and that controls the electric supply to the load.

6.8.6 Normal conditions are to include rated voltage, ground-lead switch  $S_G$  closed, normal mounting position, all doors closed and rated load. The voltage waveform is to be sinusoidal and free from any measurable transient rises or dips.

6.8.7 The "most adverse" conditions for this test are different than those determined in [6.7.3.3](#) – [6.7.3.4](#). For this test the "most adverse" conditions are those that cause the test sample to trip the fastest. The trip times recorded in [6.7.3.4](#) can be used for this test but for each step, the most adverse condition will be the one with the lowest average percentage of allowable trip time. One additional parameter exists for this test, capacitive leakage for which a value of capacitance may be connected or omitted. See [Table 6.8.1](#).

## 6.9 Immunity to conducted disturbances, induced by RF fields

6.9.1 The GFCI shall operate normally (test and reset) after completion of this test and there shall not be any evidence of a risk of fire or risk of electrical shock. The GFCI shall not trip when subjected to the applied frequency. The test method described in the Standard for Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques – Clause 6, Immunity to conducted disturbances, induced by radio-frequency fields, IEC 61000-4-6, is to be followed. The representative ground-fault circuit-interrupter is to be subjected to a conducted disturbance at 0.5 V over a frequency range of 150 kHz to 230 MHz.

## 6.10 Normal temperature test

6.10.1 When carrying rated current and with rated voltage applied, a ground-fault circuit-interrupter shall not attain a temperature at any point that is sufficiently high to (1) constitute a fire hazard, (2) affect injuriously any materials used in the device, or (3) exhibit greater rises in temperature at specific points than indicated in [Table 6.10.1](#), based on an assumed average ambient temperature in normal service of 25°C (77°F). A 120/240 V ground-fault circuit-interrupter is to be connected to a 120/240 V supply, or two phases of a 120/208 V supply, adjusted to rated voltage of the supply. A 127/220 V ground-fault circuit-interrupter is to be connected to a 127/220 V supply, adjusted to rated voltage of the supply. Loads are to be connected to the load terminals to cause the load conductors, including the neutral conductor, to carry rated current.



6.10.2 In performing the test described in 6.10.1, parts and circuits that are heated only when there is ground-fault current are to be continuously heated by providing a value of ground-fault current just low enough not to cause tripping.

6.10.3 Coil or winding temperatures are to be measured by thermocouples unless access cannot be gained for mounting a thermocouple (for example, a coil enclosed in sealing compound).

6.10.4 Except at coils, temperature readings are to be obtained by means of thermocouples consisting of wires not larger than 0.2051 mm<sup>2</sup> (24 AWG), and a temperature is considered to be constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5-minute intervals, indicate no change. When thermocouples are used in the determination of temperatures in connection with the heating of electrical devices, it is common practice to employ thermocouples consisting of 0.0507 mm<sup>2</sup> (30 AWG) iron and constantan wires and a potentiometer type of indicating instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

6.10.5 Ambient air is to be at any convenient temperature within the range of 20 – 30°C (68 – 86°F).

**Table 6.10.1**  
**Maximum acceptable temperature rises**

Materials and components		Degrees	
		°C	°F
1.	Varnished-cloth insulation	60	108
2.	Fuses	65	117
3.	Fiber employed as electrical insulation	65	117
4.	Wood and other combustible material	65	117
5.	Surfaces likely to contact the insulation of field wiring	35	63
6.	A surface upon which a permanently wired unit might be mounted in service and surfaces that might be adjacent to the unit when it is so mounted	65	117
7.	Class 105 insulation systems on windings of coils:		
	Thermocouple method	65 <sup>a</sup>	117 <sup>a</sup>
	Resistance method	85 <sup>a</sup>	153 <sup>a</sup>
	Class 130 insulation systems on windings of coils:		
	Thermocouple method	85	153
	Resistance method	105	189
8.	Molded phenolic composition	100 <sup>b</sup>	180 <sup>b</sup>
9.	Rubber- or thermoplastic-insulated wires and cords	35 <sup>b</sup>	63 <sup>b</sup>
10.	Accessible surfaces	35	63
11.	Semiconductor junction	c	c
12.	Electrolytic capacitor <sup>d</sup>	40	72

<sup>a</sup> See 6.10.3.

<sup>b</sup> The limitations on phenolic composition and on rubber and thermoplastic insulations do not apply to compounds that have been found suitable for higher temperatures.

<sup>c</sup> The temperature  $T_J$  at a semiconductor junction is related to the power  $P_J$  dissipated at the junction, the thermal resistance  $K_{THE}$  from the junction to the cooling medium (generally, the specifications for the semiconductor device will include the thermal resistance), and the temperature  $T_M$  of that cooling medium, as shown:

$$T_J = T_M + (K_{THE}) P_J$$

<sup>d</sup> A capacitor operating at a higher temperature may be accepted on the basis of its marked temperature rating.



## 6.11 Dielectric voltage withstand test

6.11.1 A ground-fault circuit-interrupter shall be capable of withstanding without breakdown the application of 48 – 62 Hz essentially sinusoidal potential as indicated in [Table 6.11.1](#).

**Table 6.11.1**  
**Dielectric voltage-withstand**

Points of application	Potential (volts rms)
<b>For all GFCIs including portable</b>	
Opposite polarity where operating voltage does not exceed 70 V peak	500
Opposite polarity above 70 V peak (FI)	1000 + (2 x Rated V)
Between line and load circuits with GFCI tripped (FI)	1000 + (2 x Rated V)
Between all live parts and all accessible metal parts including the ground terminal (FI)	1000 + (2 x Rated V)
<b>For portable GFCIs</b>	
Between line circuits and grounding circuit (SI)	2500
Between load circuit and grounding circuit (SI)	2500
Between line circuit and enclosure or foil (RI)	4000
Between load circuit and enclosure or foil (RI)	4000
Between grounding circuit and enclosure or foil (FI)	1000 + (2 x Rated V)
(FI) = Functional insulation (SI) = Supplementary insulation (RI) = Reinforced insulation Note: Opposite polarity testing will not be possible if electronic circuits are connected to the points in question.	

6.11.2 Functional insulation and spacings inherent in a component need not withstand the test potentials mentioned in [6.11.1](#) if the component in question complies with the requirements applicable to the component.

6.11.3 In order to determine compliance with the provisions of [6.11.1](#), the insulation and spacings are to be subjected to potentials increased from zero to the values specified and maintained for a period of one minute. The increase in the applied potential is to be at a substantially uniform rate and as rapid as is consistent with the value of the applied potential being correctly indicated by the voltmeter.

6.11.4 Where the construction of the ground-fault circuit-interrupter is such as to deny access to the insulation to be tested, suitable subassemblies may be employed.

6.11.5 In the application of test potentials to insulating surfaces, metal foil may be used providing that care is taken to avoid flashover at the edge of the insulation.

## 6.12 Overload and motor starting test

6.12.1 A ground-fault circuit-interrupter shall have necessary interrupting capacity and shall not trip as a result of motor starting.

6.12.2 In order to determine compliance with the provisions of [6.12.1](#), a ground-fault circuit-interrupter shall be caused to switch an inductive impedance adjusted for a value of load current equal to six times the ampere rating of the device and a power factor within the range of 0.45 – 0.50.

6.12.3 Reactive components of the impedance mentioned in [6.12.2](#) may be paralleled with each other if they are of the air-core type. An air-core reactor is to be paralleled with resistance adjusted to dissipate approximately one percent of the total power dissipated in the impedance without such resistance.

6.12.4 The value of paralleled resistance R in ohms mentioned in [6.12.3](#) may be obtained by calculation from the relationship in which E is the closed-circuit voltage at the load and I is the load current in amperes, without resistance R.

$$R = \frac{163E}{I}$$

6.12.5 The supply circuit for the test mentioned in [6.12.2](#) is to have the capacity to provide a closed-circuit voltage not less than 85 percent of the rated voltage of the ground-fault circuit-interrupter. The open-circuit voltage is to be in the range of 100 – 105 percent of the rated voltage of the ground-fault circuit-interrupter except when a higher value is agreed upon by those concerned. A 1-A fuse is to be connected between the grounded conductor of the supply circuit and accessible conductive parts of the ground-fault circuit-interrupter. This fuse shall not operate to open the circuit.

6.12.6 In performing the test mentioned in [6.12.2](#) the device is to be switched "on" and, after one second, switched "off", except as noted in [6.12.8](#), at a rate of six cycles per minute for a total of 25 cycles of operation, except as noted in [6.12.7](#).

6.12.7 If the device operation will not permit these cycle times, times as close as possible to these are to be used.

6.12.8 If it is determined that for a duration less than one second:

- a) the device conducts the test current without interrupting the circuit or being adversely affected by heat, and
- b) the device contacts are properly seated before the break is initiated as confirmed by oscilloscopic or oscillographic measurements,

the "on" time may be reduced to that duration, provided the duration is not less than one-half second.

### 6.13 Low-resistance ground fault test

6.13.1 A ground-fault circuit-interrupter shall operate to interrupt the circuit when a low resistance ground fault is present.

6.13.2 In order to determine compliance with the provisions of [6.13.1](#) the circuit is to be as described in [6.12.5](#). The resistance R is to be adjusted for a value of current equal to six times the rating of the ground-fault circuit-interrupter and connected as shown in [Figure 6.13.1](#) so as to simulate a ground fault. The current is to be initiated 25 times, at intervals of 10 seconds, or longer if necessary to reset the device. The 1-A fuse (shown in [Figure 6.13.1](#)) connected to accessible conductive parts of the device shall not open. Automatic interruption of the fault current is to occur each time in not more than T seconds as determined in accordance with the equation

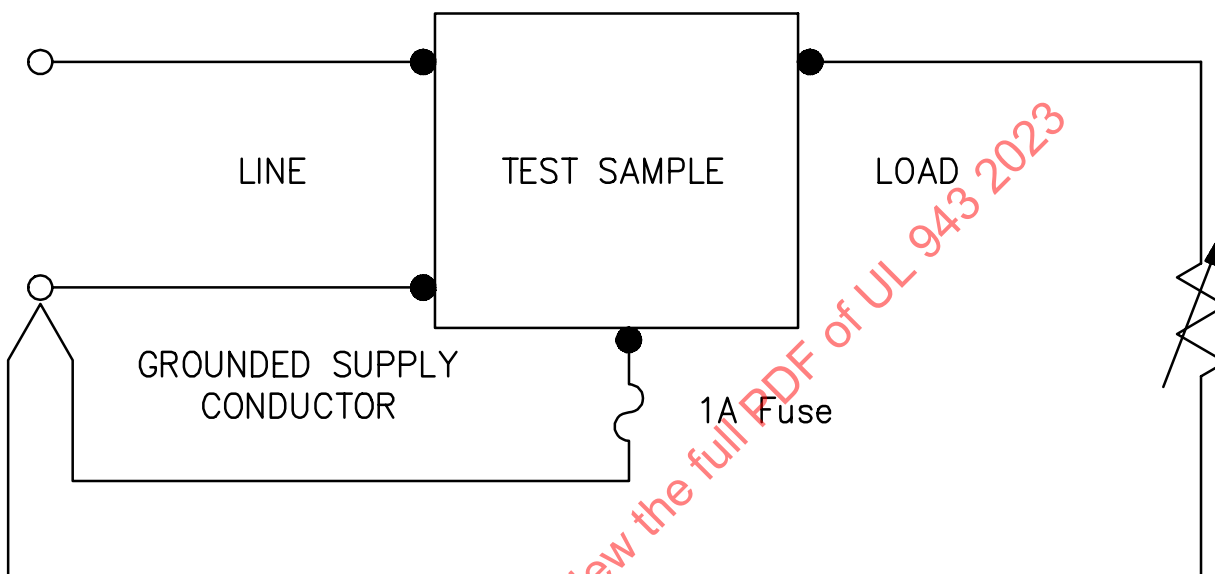
$$T = 1.25 \left( \frac{10}{V} \right)^{1.43}$$

and the average value of time for the 25 operations is not to exceed

$$T = \left( \frac{10}{V} \right)^{1.43}$$

The quantity V is the value of closed circuit voltage at the line terminals of the device.

**Figure 6.13.1**  
**Low-resistance ground-fault test circuit**



SA0799B

## 6.14 Endurance test

6.14.1 A ground-fault circuit-interrupter shall have the necessary capacity for normal operation.

6.14.2 In order to determine compliance with [6.14.1](#), a ground-fault circuit-interrupter is to be caused to switch an inductive load adjusted for a value of load current equal to the ampere rating of the device and a power factor within the range of 0.75 – 0.80.

6.14.3 In performing the test described in [6.14.2](#), the device is to be switched "on" and, after one second, switched "off" at a rate of approximately 6 cycles of operation per minute for 3000 cycles. This test shall be performed using the supervisory circuit to operate the device. If the GFCI has a manual switching means, it shall be caused to operate an additional 3000 operations.

6.14.4 Reactive components of the load mentioned in [6.14.2](#) may be paralleled with each other if they are of the air-core type. An air-core reactor is to be paralleled with resistance adjusted to dissipate approximately one percent of the total power dissipated in the load without such resistance.

6.14.5 The value of paralleled resistance R in ohms mentioned in [6.14.4](#) may be obtained by calculation from the relationship

$$R = \frac{52E}{I}$$

in which E is the closed-circuit voltage at the load and I is the load current in amperes without resistance R.

6.14.6 In performing the test described in [6.14.2](#), the capacity of the supply circuit is to be such as to allow a closed-circuit voltage not less than 97.5 percent of the rated voltage of the ground-fault circuit-interrupter. Except when a higher value is agreed to by those concerned, the open-circuit voltage is to be in the range of 100 – 105 percent of the rated voltage of the ground-fault circuit-interrupter. A 1-A fuse is to be connected between the grounded conductor of the supply circuit and accessible conductive parts of the ground-fault circuit-interrupter. This fuse shall not operate to open the circuit.

6.14.7 A ground-fault circuit-interrupter shall withstand being tripped by means of the supervisory circuit and reset, at rated voltage without load, 25 times in as rapid succession as practicable.

6.14.8 A representative device that has been subjected to an endurance test shall also be subjected to the dielectric withstand test of [6.11](#). No other tests are necessary on this representative device.

6.14.9 A ground-fault circuit-interrupter intended to be used as an "ON" "OFF" controller shall be additionally investigated to requirements for manual motor controllers. The device shall comply with overload, endurance, and dielectric tests in accordance with the applicable requirements of the relevant Standard listed in Annex A, Ref. No. 12. A GFCI in compliance with these requirements is permitted to be marked in accordance with [7.2.9](#).

## 6.15 Abnormal operation test

6.15.1 A ground-fault circuit-interrupter shall not become a shock or fire hazard when operating while in an abnormal condition, such as with a short-circuited or open-circuited component. Each component which has a likelihood of risk of electric shock, risk of fire, or both, shall be tested by imposing a fault on the component which simulates the typical failure mode for the component. Examples of failure modes may include: transistors fail with an emitter to collector short circuit, diodes fail open or short circuit, electrolytic capacitors fail open circuit, or partial short circuit.

6.15.2 A single layer of cheesecloth is to be loosely draped over the ground-fault circuit-interrupter. In addition, a cord-connected device is to rest on white tissue paper supported by a softwood surface. A 1-A fuse is to be connected between the grounded supply conductor and accessible conductive parts of the device.

6.15.3 The cheesecloth mentioned in [6.15.2](#) is to be bleached cheesecloth running approximately 26 – 28 square meters per kilogram mass (14 – 15 square yards per pound mass), and having for any square centimeter, 13 threads in one direction and 11 in the other direction (what is known in the trade as a "count of 32 by 28", that is, for any square inch, 32 threads in one direction and 28 threads in the other direction).

6.15.4 A ground-fault circuit-interrupter operating under abnormal conditions will be considered to have become a hazard if:

- a) There is glowing or flaming of the cheesecloth or tissue paper mentioned in [6.15.2](#), or
- b) There is emission of molten metal, or
- c) The fuse mentioned in [6.15.2](#) operates to open the circuit, or
- d) Except if the device is likely to be removed from service, there is dielectric failure (see Dielectric voltage withstand test, Clause [6.11](#)), or

e) It is possible to touch a part testing with the articulated probe shown in [Figure 6.15.1](#) while there is a shock hazard at that part (for U.S. and Canada), or (for Mexico, to determine compliance with [6.15.4](#) item e the articulated probe of [Figure 6.15.2](#) or [Figure 6.15.1](#) shall be used), or

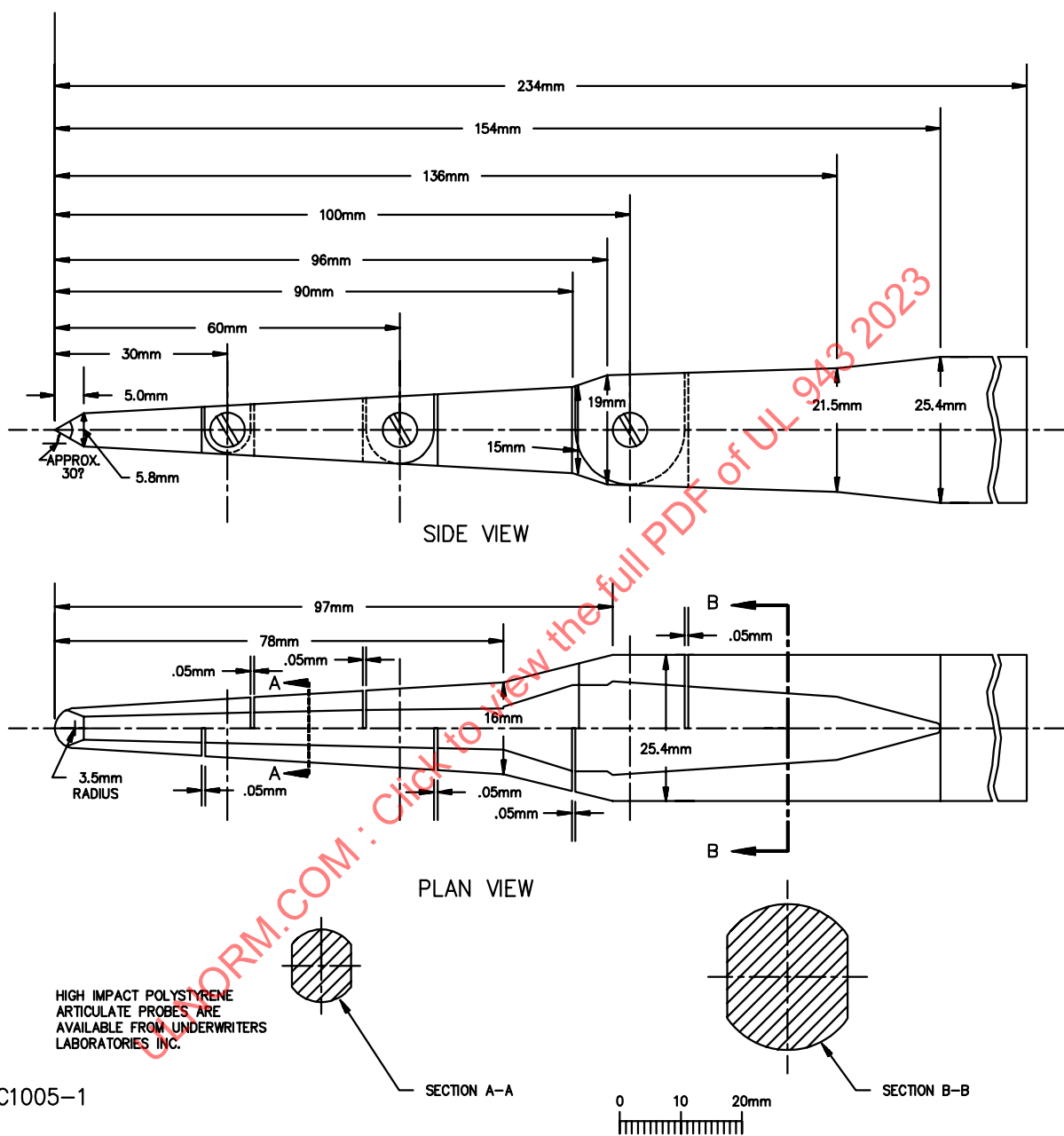
f) There is any other evidence of hazard.

6.15.5 If normal operation of the supervisory circuit after abnormal operation provides an indication of proper functioning of the ground-fault circuit-interrupter, the device shall be capable of complying with the applicable provisions of [6.7.1.1](#) – [6.7.2.2](#).

6.15.6 A device that is no longer able to complete the electric circuit to the load will be considered likely to be removed from service.

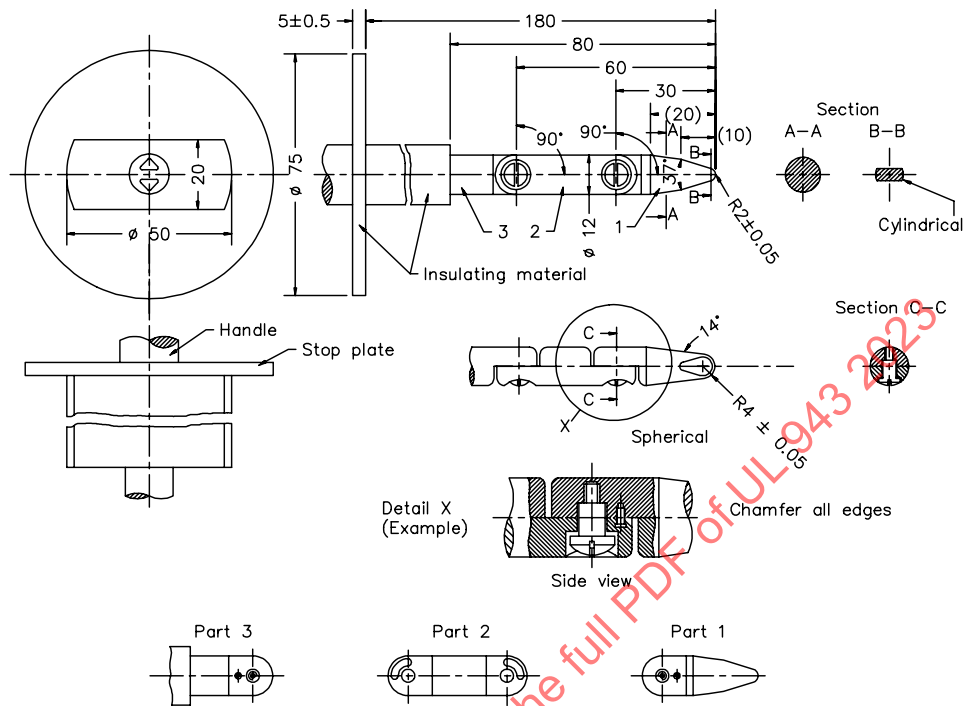
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Figure 6.15.1  
Articulated probe



SC1005-1

**Figure 6.15.2**  
**IEC articulated probe**



SA1788A

Dimensions shown in millimeters

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## 6.16 Surge current test

### 6.16.1 General

6.16.1.1 Each of three previously untested representative devices of the GFCI are to be subjected to the Surge current test in [6.16.2.1](#) – [6.16.4.1](#) without demonstrating, either during or after testing:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (preexisting or created as a result of the test) in the product.
- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.
- c) Ignition of the enclosure.
- d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of energized parts, Clause [5.7](#).

### 6.16.2 Mounting and installation

6.16.2.1 A GFCI shall be placed on a softwood surface covered with a double layer of white tissue paper. Each GFCI is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles are not prohibited from being expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings. GFCI's that are intended only for use in enclosures shall be tested in their intended enclosure. The enclosure shall be representative of the worst case situation for this test.

### 6.16.3 Surge parameters

6.16.3.1 A plug-in type ground-fault circuit-interrupter is to be subjected to a surge of 6 kV at 3 kA. A permanently-connected ground-fault circuit-interrupter is to be subjected to a minimum surge of 6 kV at 10 kA. The surge shall be a combination 1.2/50µs, 8/20µs voltage/current surge waveform.

### 6.16.4 Surge polarity

6.16.4.1 The polarity of the impulses shall be one positive applied at a phase angle of 90 degrees (+0, -15) and one negative applied at a phase angle of 90 degrees (+0, -15).

## 6.17 Abnormal overvoltage tests

### 6.17.1 General

6.17.1.1 After being tested as described in Full phase voltage-high current abnormal overvoltage test, Clause [6.17.2](#) and Limited current abnormal overvoltage test, [6.17.3](#), a ground-fault circuit-interrupter shall not result in any of the following conditions:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (preexisting or created as a result of the test in the product),
- b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth,
- c) Ignition of the enclosure, and
- d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of energized parts, Clause [5.7](#).



6.17.1.2 The representative devices used for each of the tests described in [6.17.2.1](#) – [6.17.3.2](#) are to be previously untested.

6.17.1.3 The representative GFCI's shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative GFCI is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings and any other similar openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

6.17.1.4 Cord-connected, direct plug-in, permanently-connected receptacle, and other ground-fault circuit-interrupter types intended for connection to common outlet boxes (such as raceways, multiple outlet assembly types) shall be tested in accordance with Limited current abnormal overvoltage test, Clause [6.17.3](#) in both normal and reversed polarity.

6.17.1.5 When agreed upon by all concerned parties, fewer representative ground-fault circuit-interrupters than those specified in [6.17.2.1](#) – [6.17.3.2](#) shall be used for testing.

6.17.1.6 Following the tests described in Full phase voltage – high current abnormal overvoltage test, Clause [6.17.2](#) and Limited current abnormal overvoltage test, Clause [6.17.3](#), the same representative devices are to be subjected to and comply with the Leakage current test, Clause [6.5](#), for cord-connected and direct plug-in GFCIs, and Grounding, Clause [5.3](#), for cord-connected, direct plug-in, and permanently-connected receptacle-type GFCIs. The leakage current test shall be conducted within five minutes of the end of the abnormal overvoltage tests.

6.17.1.7 Operation of the ac-power-line circuit breaker, fuse internal or external to the ground-fault circuit-interrupter, or operation of an acceptable overcurrent or overtemperature protective device provided as part of the ground-fault circuit-interrupter is considered acceptable.

6.17.1.8 Following the tests described Full phase voltage – high current abnormal overvoltage test, Clause [6.17.2](#) and Limited current abnormal overvoltage test, Clause [6.17.3](#), the same representative devices are to be subjected to and comply with Grounding, Clause [5.3](#), for permanently-connected, other than receptacle type, ground-fault circuit-interrupters.

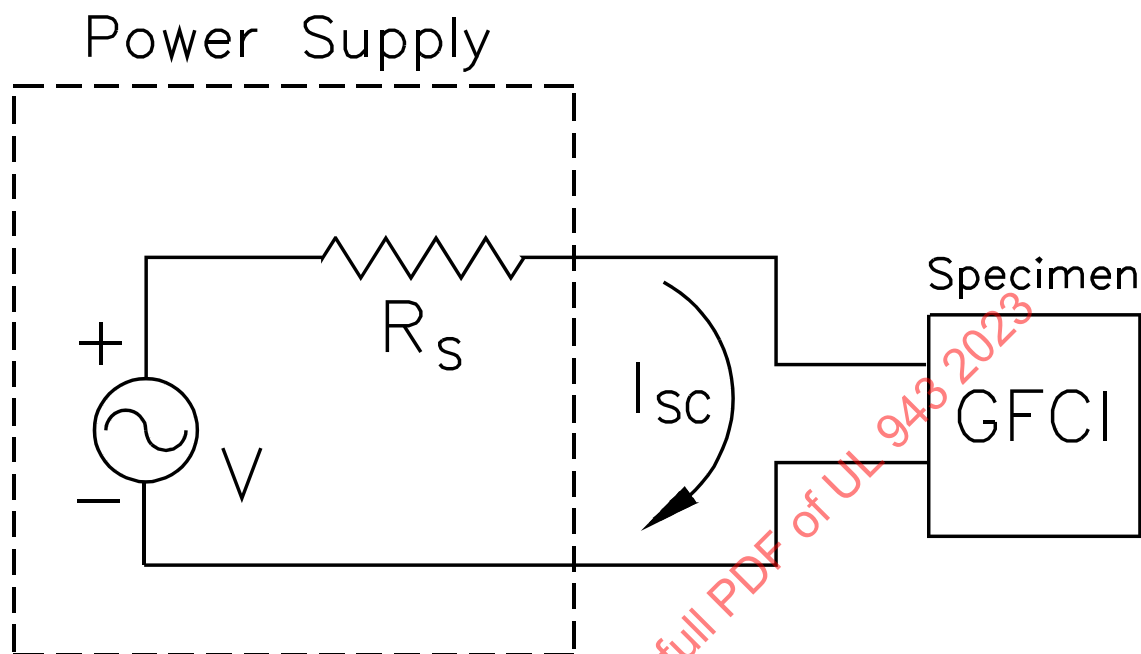
## **6.17.2 Full phase voltage – high current abnormal overvoltage test**

6.17.2.1 Except as noted in [6.17.2.2](#), after being tested as described in this Clause, a ground-fault circuit-interrupter shall comply with the requirements in [6.17.1.1](#). One previously untested ground-fault circuit-interrupter, for each combination of conductor pairs that were tested in accordance with the Voltage surge test, Clause [6.6](#), is to be subjected to the application of the test voltage as specified in [Table 6.17.2.2](#) with a power factor as specified in [Table 6.17.2.3](#). The ac power source shall have an available short-circuit (fault) current (Isc) as specified in [Table 6.17.2.2](#). For each representative device, the overvoltage is to be applied for 7 hours, or until current to, or temperatures within the GFCI attain equilibrium, or until the GFCI becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device). See [Figure 6.17.2.1](#).

6.17.2.2 The testing of [6.17.2.1](#) is not required for an end-product employing a component or components that have been previously tested and shown not to conduct current nor to exhibit any condition in [6.17.1.6](#) when subjected to the maximum phase voltage or twice the conductor pair voltage rating as specified in [Table 6.17.2.1](#) for the end-product.

Figure 6.17.2.1

High current abnormal overvoltage



S3765A

6.17.2.3 Permanently-connected receptacle and other type GFCIs intended for mounting in boxes shall be tested in the smallest standard metal box in accordance with the National Electrical Code, ANSI/NFPA 70.

**Table 6.17.2.1**  
Test voltage selection table

Device rating <sup>a</sup>	Phase	Test voltage (Vac) <sup>a</sup>	Voltage rating of conductor pair to which the test voltage is to be applied
110 – 120 V	Single	240	All
110 – 120V/220 – 240V	Split	240	110 – 120V
120/208V	3-Wye	208	120V

<sup>a</sup> For device ratings not specified in this table, the test voltage shall be the maximum phase voltage (if available) or twice the conductor pair voltage rating.

**Table 6.17.2.2**  
**Available fault current from source of supply**

Permanently connected devices		Cord connected or direct plug-in devices		
Rating A	Available fault current, amperes	Rating volts	Rating, volts times amperes	Available fault current, rms symmetrical amperes
100 A or less	5,000	250 ac or less	1175 or less	200
101 – 400 A	10,000		1176 to 1920	1000
Over 400 A	25,000		1921 to 4080	2000
			4081 to 9600	3500
			More than 9600	5000
		More than 250 ac	1920 or less	1000
			More than 1920	5000
Note: Calibration of one complete sinusoidal cycle is the available rms symmetrical fault current.				

**Table 6.17.2.3**  
**Power factor**

Available fault current	Power factor
200 A	0.80 – 1.0
1000 A	0.70 – 0.80
2000 – 10,000 A	0.40 – 0.50
10,001 – 20,000 A	0.25 – 0.30
>20,000 A	0.20

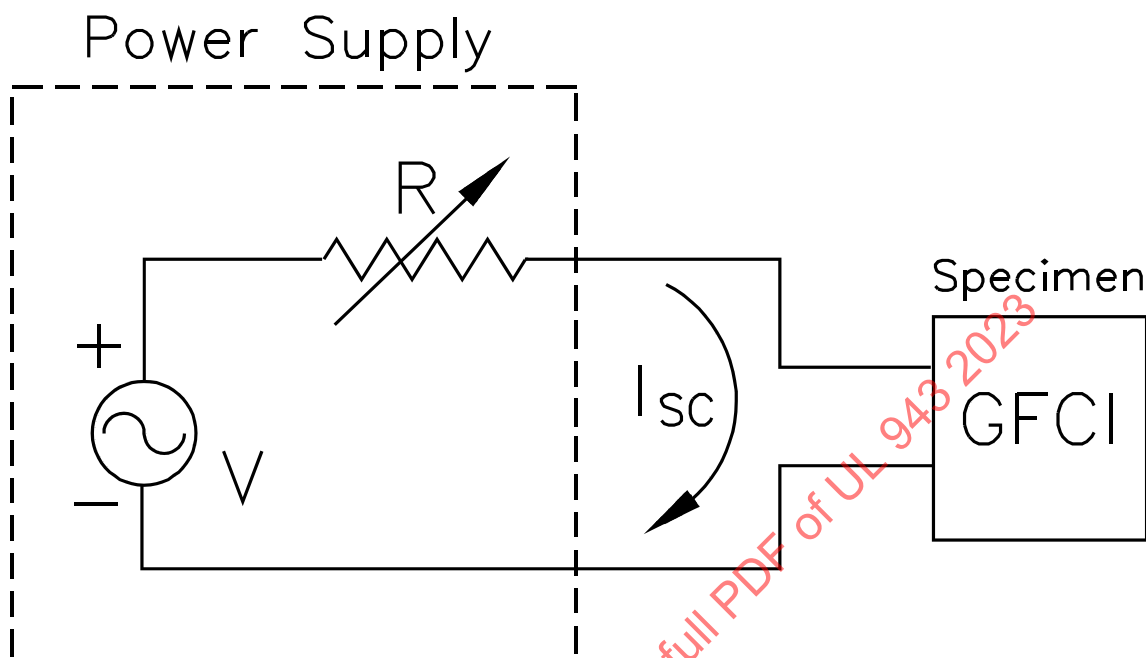
6.17.2.4 Connection of the test circuit in series with a circuit breaker or time delay non-current limiting fuse rated for the maximum ampacity of the circuit in which the GFCI is to be installed, as specified in the National Electrical Installation Code for the country in which the product is to be used, is permitted.

### 6.17.3 Limited current abnormal overvoltage test

6.17.3.1 Except as noted in [6.17.3.2](#), after being tested as described in this Clause, a ground-fault circuit-interrupter shall comply with the requirements in [6.17.1.1](#). Each of four previously untested representative GFCIs for each combination of conductor pairs is to be connected to an ac power supply having an open circuit voltage equal to the test voltage specified in [Table 6.17.2.1](#). The power supply is to incorporate a series variable resistor that can be adjusted to obtain the short-circuit current ( $I_{sc}$ ) specified below. See [Figure 6.17.3.1](#). No load is to be connected. Except as noted in [6.17.3.3](#), the variable resistor is to be adjusted such that  $I_{sc}$  equals 5 A for the first representative device, 2.5 A for the second, 0.5 A for the third, and 0.125 A for the fourth. The four representative devices are to be energized for 7 hours, or until current to, or temperatures within the GFCI attain equilibrium, or until the GFCI becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device). See [Figure 6.17.3.1](#).

Figure 6.17.3.1

## Limited current abnormal overvoltage test circuit



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6.17.3.2 This test is not required for an end-product employing a component or components that have been previously tested and shown not to conduct current nor to exhibit any condition in [6.17.1.1](#) when subjected to the maximum phase voltage or twice the conductor pair voltage rating as specified in [Table 6.17.2.1](#) for the end-product.

6.17.3.3 When this test is performed at a current level specified above and results in neither:

- a) Any condition specified in [6.17.1.1](#); nor
- b) Operation of any overcurrent or thermal device

then the test results are also representative of testing of the device at lower current levels.

6.17.3.4 Permanently-connected receptacle and other type GFCIs intended for mounting in boxes are to be mounted in the smallest standard non-metallic box with faceplate in accordance with the National Electrical Installation Code for the country in which the product is to be used.

## 6.18 Extra-low-resistance ground faults test

6.18.1 A ground-fault circuit-interrupter shall withstand extra-low-resistance ground faults followed by the dielectric withstand test of Clause [6.11.1](#).

6.18.2 In order to determine compliance with the provisions of [6.18.1](#), the supply circuit is to have an open-circuit voltage in the range of 100 – 105 percent of the rating of the ground-fault circuit-interrupter. The impedance of the supply is to be such as to provide a prospective current (the current that would

result from short-circuiting the supply terminals) shown in [6.18.3](#), [6.18.4](#) or [6.18.5](#). The 1-A fuse shall not operate to open the circuit, and there shall be no flaming of the cotton.

6.18.3 Except as described in [6.18.4](#), in testing a permanently connected ground-fault circuit-interrupter, the prospective current is to be 5000 A rms symmetrical and the power factor is to be within the range of 0.45 – 0.50.

6.18.4 In testing a receptacle type ground-fault circuit-interrupter, the prospective current is to be 2000 A rms symmetrical and the power factor is to be within the range of 0.90 – 1.0.

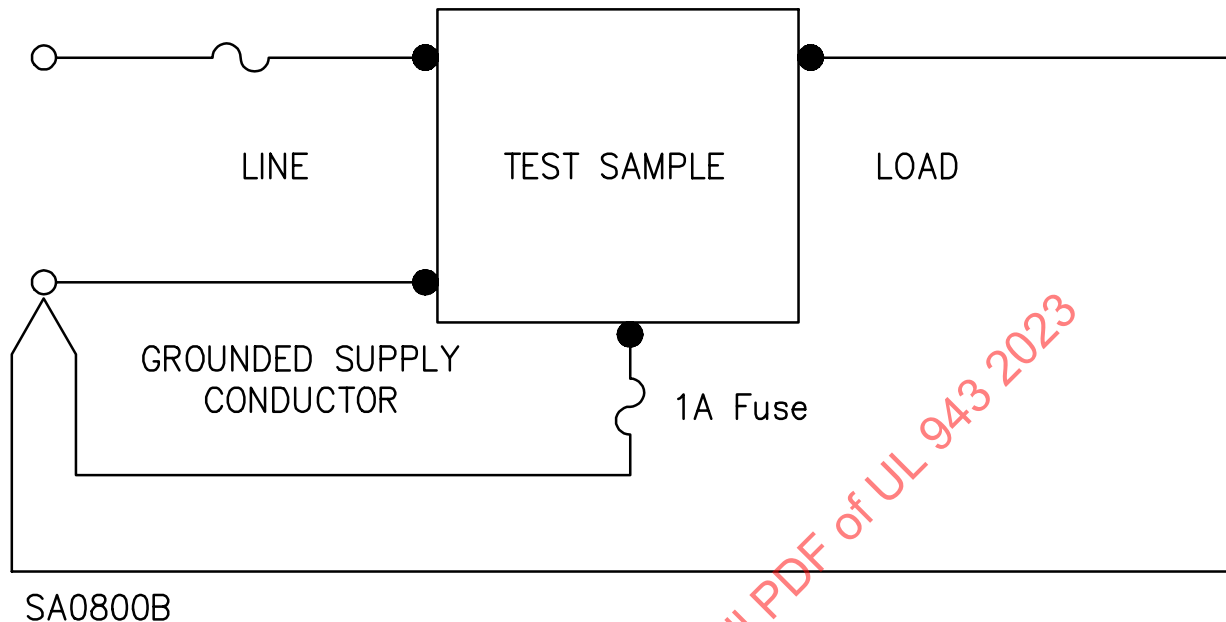
6.18.5 In testing a portable ground-fault circuit-interrupter, the prospective current is to be 2000 A rms symmetrical and the power factor is to be within the range of 0.9 – 1.0.

6.18.6 Each line terminal of a ground-fault circuit-interrupter is to be connected to the supply mentioned in [6.18.2](#) using 1.2 m (4 ft) of insulated wire, both selected in accordance with [Table 6.18.1](#). A fuse is to be connected in series with the ungrounded line conductor. An identical conductor 1.2 m (4 ft) in length is to be connected between a load terminal and a terminal of the supply so as to represent a ground fault. The device is to be in any position considered to be normal in service. A 1-A fuse is to be connected between the supply terminal representing the grounded circuit conductor and accessible conductive parts of the ground-fault circuit-interrupter. Surgical cotton is to cover openings of the ground-fault circuit-interrupter where flame may be emitted. See [Figure 6.18.1](#).

**Table 6.18.1**  
**Fuse and wire**

Ground-fault circuit-interrupter rating, amperes		Series fuse amperes	(mm <sup>2</sup> ) AWG conductor size
Cord-connected	Permanently connected		
—	15	15	(2.082) 14
15 or 20	20	20	(3.307) 12
30	30	30	(5.26) 10

**Figure 6.18.1**  
**Extra-low-resistance ground-fault test circuit**



6.18.7 For a portable ground-fault circuit-interrupter, conductors are to be attached to the attachment plug blades of the device and to a terminal of a receptacle of the device so as not to be dislodged during the test.

6.18.8 The prospective current is to be initiated once by means of a switch in the supply circuit, and once by means of any control of the ground-fault circuit-interrupter, providing that a single sample need not experience more than one current initiation. The 1-A fuse shall not operate to open the circuit, and there shall be no flaming of the cotton, both mentioned in [6.18.6](#).

6.18.9 For GFCIs that employ interrupting contacts that meet [6.7.2.1](#) (c) and/or (e), where the prospective current that is to be initiated by means of a switch in the supply circuit, a contactor with a rated voltage, 100 A, and a short circuit current rating (SCCR) equal or greater than prospective current in [6.18.4](#) is to be placed in series in the middle of the fault wire. With the supply circuit ON, the GFCI interrupting contact closed by “reset” by means of control, the external shorting contactor is to be remotely closed to introduce the prospective fault current.

## 6.19 Short circuit test

6.19.1 A ground-fault circuit-interrupter shall withstand short circuits followed by the dielectric withstand test of Clause [6.11.1](#).

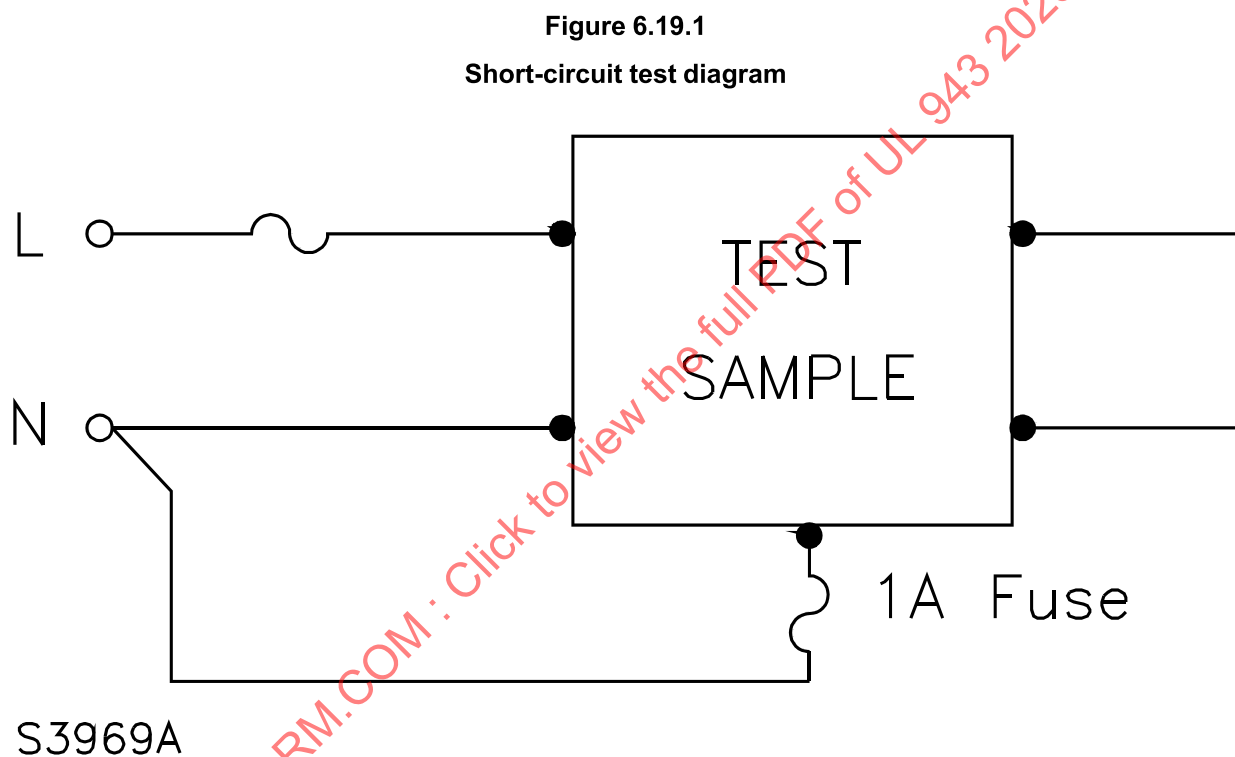
6.19.2 In order to determine compliance with the provisions of [6.19.1](#), conditions are to be as described in [6.18.2](#) – [6.18.6](#), except that:

- a) The ground fault described in [6.18.6](#) is not to be connected, and

b) A 0.51 m (20 inch) length of wire of the same construction as the line conductors is to be connected between load terminals. See Short-circuit test diagram, [Figure 6.19.1](#).

6.19.3 The test current is to be initiated by means of a switch in the supply circuit. The 1-A fuse shall not operate to open the circuit and there shall be no flaming of the cotton, both mentioned in [6.18.6](#).

6.19.4 For GFCIs that employ interrupting contacts that meet [6.7.2.1](#) (c) and/or (e), where the prospective current that is to be initiated by means of a switch in the supply circuit, a contactor with a rated voltage, 100 A, and a short circuit current rating (SCCR) equal or greater than prospective current in [6.18.4](#) is to be placed in series in the middle of the shorting wire. With the supply circuit ON, the GFCI interrupting contact closed by “reset” by means of control, the external shorting contactor is to be remotely closed to introduce the prospective fault current.



## 6.20 Dust test

6.20.1 To determine compliance with footnote b in [Table 5.12.2.1](#) and [Table 5.12.2.2](#), six samples, each mounted in a different mounting orientation, are to be placed, deenergized, in an air-tight chamber having an internal volume of at least 0.09 m<sup>3</sup> (3 cubic feet).

6.20.2 A 0.06 kg (two oz) quantity of cement dust, maintained at a relative humidity of 20 – 50 percent and capable of passing through a 200 mesh screen, is to be circulated for 15 minutes by means of compressed air or a blower so as to completely envelop the sample in the chamber. The air flow is to be maintained at an air velocity of approximately 0.25 m/s (50 fpm).

6.20.3 Following the exposure to dust, the sample exterior shall be carefully cleaned. The sample is then to be opened and examined for the presence of dust. If there is no evidence of dust within the interior, the sample can be considered "closed-in" for spacing purposes. See [Table 5.12.2.1](#) and [Table 5.12.2.2](#).

6.20.4 As an alternative to the dust test procedure (cement dust) in [6.20.1](#) – [6.20.3](#), a ground-fault circuit-interrupter may be subjected to the dust test (talcum) for first characteristic numeral 5 as specified in Table VII Annex A, reference item No. 14.

## 6.21 Corrosion test

6.21.1 A ground-fault circuit-interrupter shall operate as intended after being subjected to the corrosive atmosphere test described in [6.21.2](#) – [6.21.3](#). The representative ground-fault circuit-interrupter is to be tested for trip threshold prior to exposure to the corrosive atmosphere.

6.21.2 One representative GFCI is to be placed in a 200 liter or larger test chamber on a platform approximately 50.8 mm (2 inches) above the bottom of the chamber. The temperature in the chamber is to be maintained at  $30 \pm 2^{\circ}\text{C}$  ( $86 \pm 3^{\circ}\text{F}$ ) and the relative humidity at  $70 \pm 2$  percent (measured directly in the chamber). The temperature and humidity are to be checked daily. Because of the corrosive atmosphere a set of wet and dry bulb thermometers shall be used for measurement of relative humidity.

6.21.3 The following gas mixture in air is to be supplied to the chamber at a rate sufficient to achieve an air exchange in the chamber of about five times per hour, for a period of 3 weeks:  $100 \pm 10$  parts per billion (ppb) (parts per billion = parts per  $10^9$  by volume) hydrogen sulfide ( $\text{H}_2\text{S}$ ) plus  $20 \pm 5$  ppb chlorine ( $\text{Cl}_2$ ) plus  $200 \pm 50$  ppb nitrogen dioxide ( $\text{NO}_2$ ). The air inside the chamber is to be circulated by a single fan, with flow upwards from the bottom. See [6.21.4](#).

6.21.4 Trip threshold measurements following the exposure to the corrosive atmosphere shall not cause false tripping and shall comply with the trip threshold requirements of this Standard. The trip threshold levels are to be measured in accordance with High-resistance ground fault test, Clause [6.7](#) and Resistance to false tripping test, Clause [6.8](#), giving consideration to the most adverse conditions described in [6.7.2.3](#). The measurements are to be performed at room temperature.

## 6.22 Visual inspection test

6.22.1 To determine compliance with internal wiring construction requirements in Clause [5](#), representative ground-fault circuit-interrupters shall be examined. This may require disassembly of the ground-fault circuit-interrupter or obtaining representative subassemblies from the manufacturer.

## 6.23 Reverse line-load miswire test

6.23.1 A receptacle type ground-fault circuit-interrupter that has been dropped in accordance with [6.23.2](#) – [6.23.4](#) shall interrupt the electric circuit to the receptacle face and line terminals when a supply circuit is wired to the load terminals of the device.

6.23.2 A previously untested receptacle type ground-fault circuit-interrupter shall be allowed to fall from a height of 0.91 m (3 ft) such that a different part will strike a hardwood surface in each of three drops.

6.23.3 The hardwood surface mentioned in [6.23.2](#) shall consist of a layer of nominal 1-inch tongue-and-groove oak flooring mounted on two layers of 19 mm (3/4-inch) plywood. The surface shall be a square 1.2 m (4 ft.) on a side. The assembly shall rest on a concrete floor or the equivalent.

6.23.4 The same device shall then be subjected to the test described in [6.23.5](#) – [6.23.7](#).



6.23.5 Under the conditions described in [6.23.6](#) and [6.23.7](#) the ground-fault circuit-interrupter shall interrupt the electric circuit to the receptacle face and line terminals or not permit power to be applied to the receptacle face and line terminals when the power is first applied to the load terminals, and each time the reset is operated.

6.23.6 For this test, the supply line voltage is to be set at 85 percent of the rated voltage. The ground-fault circuit-interrupter is to be switched on unless it is shipped from the manufacturer in the tripped condition and cannot be reset until properly installed. If shipped in the tripped condition, to verify the ground-fault circuit-interrupter cannot be reset until properly installed, attempt to engage reset by first pressing the reset button and then by pressing the test and reset buttons simultaneously. This is to be performed before and after load terminals are connected to supply voltage. Power is to be applied to the load terminals, and the reset shall be operated ten times in rapid succession.

6.23.7 The test described in [6.23.5](#) is to be repeated on the same device, with the supply line voltage set at 110 percent of the rated voltage.

#### **6.24 Reverse line-load miswire test – repeated**

6.24.1 When a supply circuit is wired to the load terminals of a receptacle GFCI after reinstallation following a correctly wired installation, the same device subjected to the test described in Clause [6.23](#) shall interrupt the electric circuit to the receptacle face and line terminals or not permit power to be applied to the receptacle face and line terminals when the power is first applied and each time the reset is operated. Compliance shall be determined by the test described in [6.24.2](#).

6.24.2 The same device subjected to the test described in Clause [6.23](#) shall be correctly wired to a supply of rated voltage. The test and reset button shall be actuated to verify the proper functioning of the device when wired correctly. Following any specific instructions for the rewiring or reuse of the device, if provided, the device shall be removed from the supply source, and then reinstalled with its load terminals connected to a supply of rated voltage. The reset shall be operated ten times in rapid succession.

#### **6.25 Supplemental voltage surge immunity test**

##### **6.25.1 General**

6.25.1.1 The line side terminals of the Line-Neutral and Line-Line terminals that are protected by the representative ground-fault circuit-interrupter shall be subjected to this test.

6.25.1.2 The ground-fault circuit-interrupter is to be connected to a supply of rated voltage. The grounding lead or terminal of the ground-fault circuit-interrupter (if provided) is to be connected to the supply conductor serving as the neutral. The ground-fault circuit-interrupter is to be in the "ON" condition with no load connected. GFCIs that are intended only for use in enclosures shall be tested in their intended enclosure for the tests referenced in [6.25.1.1](#). The enclosure shall be representative of the worst case situation for the tests.

##### **6.25.2 Surge immunity test (combination wave)**

6.25.2.1 The GFCI shall be subjected to the Surge immunity test without demonstrating, either during or after testing:

- a) Emission of flame, molten metal, glowing or flaming particles through any openings (preexisting or created as a result of the test) in the product,
- b) Ignition of the enclosure, or

c) Creation of any opening in the enclosure that results in accessibility of energized parts, when judged in accordance with Accessibility of energized parts, Clause [5.7](#).

6.25.2.2 The test method is to be conducted in accordance with the testing methods described in IEC 61000-4-5 Electromagnetic Compatibility (EMC) Part 4-5: Testing and Measurements Techniques – Surge Immunity Test.

6.25.2.3 The surges shall be superimposed on the ac power with the GFCI energized and applied at phase angles of 90 and 270 electrical degrees.

6.25.2.4 Only the surge impulse test levels in [Table 6.25.2.1](#) shall be used. Using a separate representative GFCI for each surge impulse test level meets the intent of the requirement.

**Table 6.25.2.1**  
**Surge impulse test level impulse<sup>a</sup>**

Peak voltage (kV p)	Peak current (kA p)
2	1
6	3
<sup>a</sup> Combination 1.2/50 s, 8/20 s Voltage/Current surge waveform. For specifications and tolerances, refer to IEC 61000-4-5 Electromagnetic Compatibility (EMC) – Part 4-5: Testing and Measurements Techniques – Surge Immunity Test.	

6.25.2.5 The GFCI is permitted to trip during surge immunity testing. If the GFCI trips, it is to be reset prior to the next surge application.

6.25.2.6 After the 2 kV test the same GFCI shall be in condition to comply with the High-resistance ground fault and the Dielectric voltage withstand tests.

6.25.2.7 After the 6 kV test, the same GFCI shall comply with either a or b:

- a) The GFCI shall be in condition to comply with the High-resistance ground fault test, Clause [6.7](#), and the Dielectric voltage withstand test, Clause [6.11](#), or
- b) The GFCI shall trip as a result of the surge test and render itself incapable of delivering power after attempting reset. Reset shall be attempted 5 times as fast as possible with rated voltage applied.

## 6.26 Operating mechanism test

6.26.1 Unless the electronics are connected to the line side of the contacts it will be necessary to verify compliance with [5.14.1](#) by testing the ground-fault circuit-interrupter as follows:

- a) The ground-fault circuit-interrupter is to be connected as shown in [Figure 6.7.2.1](#),
- b) The resistance  $R_B$  is to be adjusted to obtain a ground fault current of 6 mA,
- c) Switches  $S_1$ ,  $S_2$ , are closed, and switch  $S_3$  is open,
- d) The 6 mA current is passed by closing switch  $S_3$  the GFCI having been closed and the operating means being held in the closed position. The GFCI shall trip.

6.26.2 The test in [6.26.1](#) is then repeated by moving the operating means of the GFCI slowly over a period of approximately 1 second to a position where the current starts to flow. Tripping shall occur without further movement of the operating means.

6.26.3 Both the test in [6.26.1](#) and [6.26.2](#) are to be performed three times, at least once on each pole intended to be connected to a phase.

## **6.27 GFCI end of life test**

### **6.27.1 General**

6.27.1.1 A ground-fault circuit-interrupter that has reached its end of life shall meet the requirements of [5.15.5](#).

### **6.27.2 GFCI end of life simulation**

6.27.2.1 In order to determine compliance with the provisions of [6.27.1.1](#), one representative GFCI is to be subjected to an end of life simulation in accordance with [6.27.2.2](#) or [6.27.2.3](#).

6.27.2.2 One representative GFCI shall be altered with a single modification to the GFCI circuitry in the form of a short circuit or open circuit such that the GFCI is incapable of responding in the normal manner to a line to ground, ground-fault. The representative GFCI shall then be evaluated in accordance with [6.27.2.4](#).

6.27.2.3 If the GFCI is designed to repeatedly trip at end of life, the following end of life simulation may be used as an alternative to [6.27.2.2](#). One representative GFCI shall be altered with a single modification to the GFCI that results in the trip solenoid being in an energized state. The single modification can be a short circuit connected across an appropriate electrical component, or an appropriate electrical component is to be open circuited. The representative GFCI shall then be evaluated in accordance with [6.27.2.4](#).

6.27.2.4 The representative GFCI, having been placed in the open or tripped position, is to be correctly connected to rated line voltage and allowed to stabilize. The reset is to be operated. Each representative GFCI shall be considered as meeting the requirements of [5.15.5](#) if the GFCI:

- a) Does not permit power to be applied to any load when reset is attempted; or
- b) Repeatedly trips when reset is attempted.

## **6.28 GFCI receptacle temperature tests**

### **6.28.1 General**

6.28.1.1 For Canada, when conducting the CSA C22.2 No. 42 test sequence on a GFCI receptacle, the following Temperature Tests may be conducted in place of the test in Clause 7.9 of CSA C22.2 No. 42.

For Mexico, when conducting the NMX-J-508-ANCE test sequence on a GFCI receptacle, the following Temperature Tests may be conducted in place of the test in Clause 6.2.5 of NMX-J-508-ANCE.

For the US, when conducting the UL 498 test sequence on a GFCI receptacle, the following Temperature Tests may be conducted in place of the test in Section 111 of UL 498.

6.28.1.2 The temperature tests shall be conducted following the overload test on six receptacles and shall continue until stabilized temperatures are attained. A temperature is considered to be stabilized when three consecutive readings, taken at 5-minute intervals, indicate no further rise above the ambient temperature. The contact temperatures shall be measured at the contacts previously subjected to the overload test.

6.28.1.3 Wire binding terminal screws and screw actuated clamp type terminals on the GFCI receptacle under test shall be tightened using a torque of 1.0 N·m (9 in-lbf) for receptacles wired with 2.1 mm<sup>2</sup> (14 AWG) conductor and 1.6 N·m (14 in-lbf) for receptacles wired with 3.3 mm<sup>2</sup> (12 AWG) conductor.

6.28.1.4 It shall be permissible for the electronic circuitry in the GFCI to be removed or deenergized to eliminate it as a source of heat when conducting the temperature tests specified in [Clauses 6.28.1 – 6.28.4](#). Internal components of the switches, including the switching mechanism, may be short-circuited by means of a soldered shunt.

## 6.28.2 Contact temperature test

6.28.2.1 The contact temperature rise of a GFCI receptacle shall not be more than 30°C (54°F) when the receptacle is carrying its maximum rated current.

6.28.2.2 The temperature measurement mentioned in [Clause 6.28.2.1](#) shall be taken at points as close to the face of the receptacle as possible on the male blades of an attachment plug inserted in the outlet.

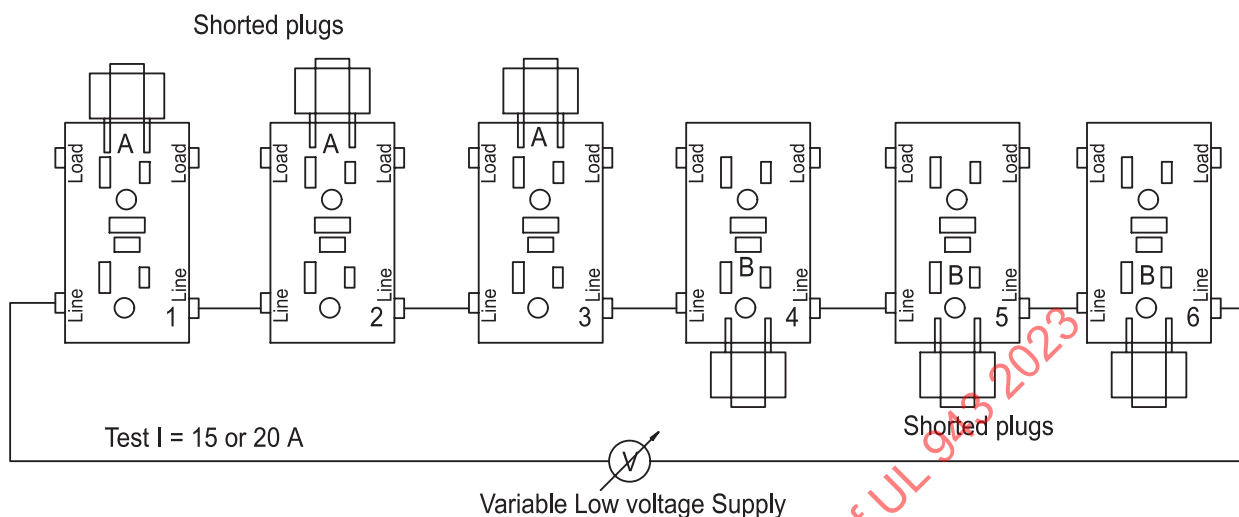
6.28.2.3 The overloaded contacts of individual receptacles shall be connected together by means of a shorted attachment plug of the configuration shown in Table 111.1 of UL 498. A standard solid blade attachment plug shall be used. The terminals of the plug shall be short-circuited by means of the shortest feasible length of wire that has an ampacity at least equal to that of the receptacle. It shall be permissible for the shorting wire to be soldered to the plug terminals in order to minimize the generation of heat from sources other than the contacts.

6.28.2.4 GFCI receptacles having a T-slot configuration (5-20 configuration) shall be tested at 20 A using three 20 A rated attachment plugs and three 15 A rated attachment plugs. The 20 A rated attachment plugs shall be inserted in two top receptacles and one bottom receptacle. The 15 A rated attachment plugs shall be inserted in two bottom receptacles and one top receptacle.

6.28.2.5 The receptacles under test shall be connected in series in the test circuit shown in [Figure 6.28.2.1](#) with solid or stranded copper building wire as specified in [Clause 6.28.2.6](#) using lengths of no less than 500 mm (20 inches).

6.28.2.6 GFCI receptacles having a 15-A configuration shall be wired with 2.1 mm<sup>2</sup> (14 AWG) wire. The test shall be conducted at a current of 15 A. GFCI receptacles having a 20-A configuration shall be wired with 3.3 mm<sup>2</sup> (12 AWG) wire and tested at a current of 20 A. The test current shall be obtained by adjusting the variable low voltage supply shown in [Figure 6.28.2.1](#) to obtain the specified current.

**Figure 6.28.2.1**  
**Contact temperature test circuit**



Six samples with shorted plugs, 3 in top receptacle (A), 3 in bottom (B)

su0200

### 6.28.3 Terminal temperature test

6.28.3.1 Each GFCI receptacle provided with means for through-wiring on a branch circuit shall also be subjected to a terminal temperature test at a current of 20 A. The temperature rise on the terminals shall not be more than 35°C (63°F).

6.28.3.2 The temperature measurement mentioned in Clause [6.28.3.1](#) shall be made on the wiring terminals of the GFCI receptacle if they are accessible for the mounting of thermocouples.

6.28.3.3 When testing GFCI receptacles with wire binding screws or screw actuated clamp type terminations, the terminal temperature shall be measured on the terminations in a manner such that the thermocouple does not interfere with the termination.

6.28.3.4 When testing GFCI receptacles with wire leads that are intended for through-wiring on a branch circuit or with terminals that are inaccessible for mounting thermocouples, the terminal temperature shall be measured on the conductor as close as possible to the entry (exit) of the conductor to (from) the receptacle.

6.28.3.5 The receptacles under test shall be connected in the test circuit shown in [Figure 6.28.3.1](#) or [Figure 6.28.3.2](#) with 3.3 mm<sup>2</sup> (12 AWG) solid or stranded copper building wire using lengths of no less than 500 mm (20 inches). Alternate test circuits shall be permitted if it can be demonstrated that they result in the same current path through the devices under test.

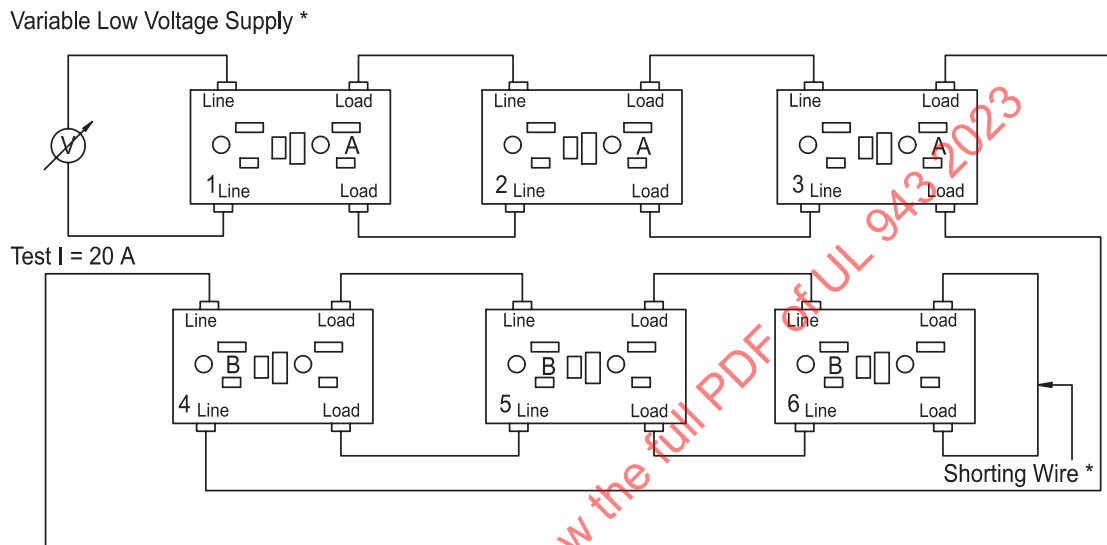
6.28.3.6 If the test circuit of [Figure 6.28.3.1](#) is used, the test current of 20 A shall be obtained by adjusting the variable low voltage supply. It shall also be permitted to conduct this test using rated voltage

if the shorting wire on the load terminals of the last sample (sample 6 in [Figure 6.28.3.1](#)) is replaced by a variable load adjusted to produce the 20 A test current.

6.28.3.7 If the test circuit of [Figure 6.28.3.2](#) is used, the test current of 20 A shall be obtained by adjusting the variable low voltage supply.

**Figure 6.28.3.1**

**Terminal temperature test circuit – 1**

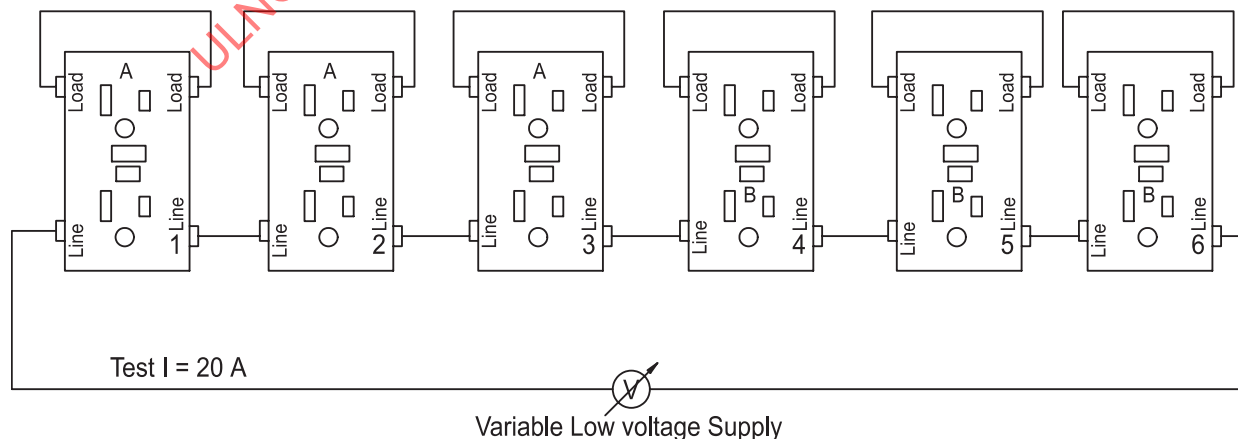


su0202

\* See [6.28.3.6](#)

**Figure 6.28.3.2**

**Terminal temperature test circuit – 2**



su0203

#### 6.28.4 Split load temperature test

6.28.4.1 Each GFCI receptacle provided with means for through-wiring on a branch circuit shall also be subjected to a split load temperature test at a total test current of 20 A with the load current divided between the GFCI receptacle contacts previously subjected to the Overload test, and the through wiring terminals. The contact temperature rise shall not be more than 30°C (54°F), and the temperature rise on the terminals shall not be more than 35°C (63°F).

6.28.4.2 The contact temperature measurement mentioned in Clause [6.28.4.1](#) shall be taken at points as close to the face of the receptacle as possible on the male blades of an attachment plug inserted in the outlet.

6.28.4.3 The terminal temperature measurement mentioned in Clause [6.28.4.1](#) shall be made on the wiring terminals of the GFCI receptacle if they are accessible for the mounting of thermocouples.

6.28.4.4 When testing GFCI receptacles with wire binding screws or screw actuated clamp type terminations, the terminal temperature shall be measured on the terminations in a manner such that the thermocouple does not interfere with the termination.

6.28.4.5 When testing GFCI receptacles with wire leads that are intended for through-wiring on a branch circuit or with terminals that are inaccessible for mounting thermocouples, the terminal temperature shall be measured on the conductor as close as possible to the entry (exit) of the conductor to (from) the receptacle.

6.28.4.6 The overloaded contacts of each individual GFCI receptacles shall be loaded by means of an attachment plug of the configuration shown in Table 111.1 of UL 498. A standard solid blade attachment plug shall be used. The terminals of the plug shall be connected to the load indicated in [Table 6.28.4.1](#) using lengths of wire having ampacity at least equal to that of the receptacle. It shall be permissible for the wires to the load to be soldered to the plug terminals in order to minimize the generation of heat from sources other than the contacts.

6.28.4.7 GFCI receptacles having a T-slot configuration (5-20 configuration) shall be tested using three 20 A rated attachment plugs and three 15 A rated attachment plugs. The 20 A rated attachment plugs shall be inserted in two top receptacles and one bottom receptacle. The 15 A rated attachment plugs shall be inserted in two bottom receptacles and one top receptacle.

6.28.4.8 The through wiring terminals of each individual GFCI receptacle under test shall be connected to the load indicated in [Table 6.28.4.1](#) using lengths of 3.3 mm<sup>2</sup> (12 AWG) solid or stranded copper building wire.

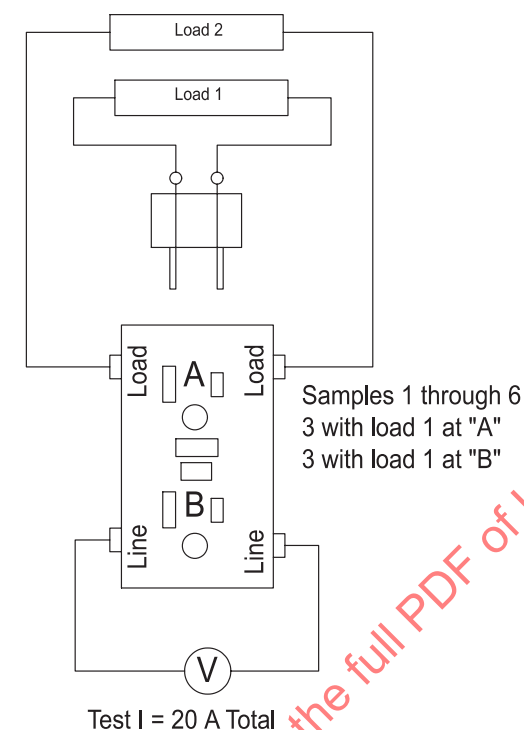
6.28.4.9 The test currents shall be obtained by the use of either a low voltage source or rated voltage source, and adjustment of the individual loads to obtain the currents specified in [Table 6.28.4.1](#).

**Table 6.28.4.1**  
**Load currents – split load temperature test**

Test Number	Receptacle (Load 1) (A)	Through Wiring (Load 2) (A)
1	5	15
2	10	10
3	15	5



**Figure 6.28.4.1**  
**Split load temperature test circuit**



su0201

## 6.29 Mechanical endurance test

6.29.1 This test shall be conducted on a representative retractable GFCI that is capable of being used without being installed in an additional enclosure, and is intended for installation in a countertop. See [6.3.10](#).

6.29.2 A representative GFCI shall be mounted in a counter surface in accordance with the installation instructions. Power shall not be applied to the device. The retractable assembly shall initially be retracted and locked. The retractable assembly shall then be released, fully extended and then fully retracted for one cycle of operation. The above extension and retraction cycle shall be repeated for a total of 6000 cycles at as fast a cycling rate as permitted by the construction of the unit.

6.29.3 At the conclusion of the cycling, the device shall be connected to a rated source of supply. Power shall be available at the receptacle outputs as determined by the use of a test light or equivalent means. The GFCI shall still function as determined by the use of the test and reset buttons.

6.29.4 The sample shall then be subjected to and comply with the Leakage Current Test of Clause [6.5](#) with no humidity conditioning, and the Dielectric Withstand Test of Clause [6.11](#).

6.29.5 The same representative device shall then be subjected to the Spill Test of Clause [6.30](#).

## 6.30 Spill test

6.30.1 This test shall be conducted on a representative GFCI that is capable of being used without being installed in an additional enclosure, and is intended for installation in a countertop. If the device



incorporates a retractable construction, the representative device that was used for the Mechanical Endurance Test shall also be used for this test. See [6.3.9](#), [6.3.10](#), and [6.29.5](#).

6.30.2 A representative GFCI shall be mounted to a counter surface in accordance with the installation instructions. The pop-up assembly shall be fully extended. Any covers provided shall be opened to their most disadvantageous position. Covers that tend to close themselves shall be allowed to fall to their natural resting position. If more than one power receptacle is enclosed by such a self-closing cover, a single power supply cord shall be mated with one of the receptacles and the cord shall exit from behind the cover.

6.30.3 A container measuring 181 mm (7-1/8 inch) I.D. by 251 mm (9-7/8 inch) tall shall be filled with 1.9 L (1/2 gallon) of saline solution, consisting of 8 grams (0.28 ounce) of table salt per liter (0.264 gallon) of distilled water. The container shall be placed on the counter surface with its base 305 mm (12 inch) from the sample, and facing the convenience receptacles. The container shall then be tipped over all at once. An effort shall be made to direct the spill toward the most disadvantageous area of the assembly.

6.30.4 One minute after the container of water is tipped over, the sample shall be subjected to and comply with the Leakage Current Test of Clause [6.5](#) with no humidity conditioning, and the Dielectric Withstand Test of Clause [6.11](#).

6.30.5 The test shall be repeated with the pop-up assembly fully retracted.

### 6.31 Auto-monitoring function tests

6.31.1 The results of the Auto-Monitoring Function Tests shall meet the requirements of Clause [5.16](#).

6.31.2 In order to determine compliance with the provisions of Clause [5.16](#), separate samples shall be modified to represent those single component failure modes that can cause the GFCI to become unable to respond to a ground fault per this standard. Welded power contacts need not be considered. Except as noted in [6.31.3](#), each sample shall be altered with a single modification that represents either an open or a shorted component (unless otherwise specified) as described in [6.31.2](#) (a) – (g) below.

- a) Open circuit or short circuit the ground fault sensing component (transformer);
- b) Alter the integrated circuit responsible for the ground fault detection by one of the following modifications selected by the manufacturer and agreeable to all parties concerned:
  - 1) Disconnect the power supply pin of the IC;
  - 2) Disable the “clock” circuit;
  - 3) Open the signal path at the subject IC pin;
  - 4) Short the signal path pin to one of the adjacent pins one at a time.
- c) Open circuit the current limiter (for example, dropping resistor) of the power supply of the ground fault detection circuit.
- d) Open-circuit the trip solenoid. See [6.31.8](#).
- e) Open the switching semiconductor supplying the trip solenoid. See [6.31.8](#).
- f) Short circuit the switching semiconductor supplying the trip solenoid.
- g) Open circuit or short circuit a single rectifier diode in the ground fault detection power supply circuit. Short circuit a single diode in the case of a bridge rectifier package.

6.31.3 Certain failure modes in [6.31.2](#) need not be tested if, based on an engineering analysis of the circuit, one or both of the following criteria are met. The results of the engineering analysis shall be agreeable to all parties concerned.

- a) The failure mode does not interfere with the ability of the GFCI to respond to a line to ground fault.
- b) The failure mode results in [5.16.4](#) being met automatically, without assistance from the auto-monitoring function.

6.31.4 Failure modes that need to be investigated may, at the option of the manufacturer, be tested on previously tested samples if agreeable to all parties concerned.

6.31.5 The device power contacts shall be in the closed position at the start of the test. Power shall be applied externally by closing a switch in the supply. Each GFCI shall comply with [5.16.4](#) within the timing requirements of [5.16.2](#).

6.31.6 Trip time during auto-monitoring. The trip time relationship of [6.7.1.1](#) shall continue to be met during an automatic test interval. One sample shall be subjected to a limited high-resistance ground fault test in accordance with [6.31.7](#).

6.31.7 The test of [6.7.3](#) shall be conducted with  $R_b = 500$  Ohms, at room temperature and at rated line voltage. Preconditioning by humidity, surge, drop or leakage current tests is not required to be conducted. The ground fault shall be applied when the auto monitoring function is active. It shall be permissible for the auto-monitoring function to be altered such that the auto-monitoring signal is being applied in the normal manner but continuously in order to test the GFCI.

6.31.8 As an alternative to meeting the requirements described in [6.31.5](#) – [6.31.6](#), failure modes in [6.31.2](#) that reference [6.31.8](#) may comply with the requirements listed below. A representative GFCI, having been subjected to a failure mode simulation, shall be correctly connected to rated line voltage and allowed to stabilize. The manually operated supervisory test function shall be performed, after which the reset button shall be operated. Each representative GFCI shall be considered as meeting the requirements of Clause [6.31.1](#) if one of the following conditions is met:

- a) The GFCI visually or audibly indicates if it does not interrupt the electric circuit to all loads; or
- b) The GFCI interrupts the electric circuit to all loads or does not permit power to be applied to any loads, each time the reset is operated when reset is attempted.

## 7 Markings

### 7.1 Permanence of marking

7.1.1 A label as mentioned in [8.1.4](#) shall comply with the requirements specified in Annex [A](#), Ref. No. 13.

7.1.2 Labels that come in contact with uninsulated live parts shall be of a nonconductive material that complies with requirements for polyvinyl chloride, polyethylene, and rubber insulating tape in Annex [A](#), Ref. No. 5.

7.1.3 For the purpose of these requirements, a water transfer or the equivalent located in a depression at least 0.8 mm (0.031 inch) deep may be considered as permanent subject to investigation.

## 7.2 Marking

*Advisory Note: For products intended for use in Canada, markings shall be at least in English and caution and warning markings shall be at least in French and English. For products intended for use in Mexico, all markings shall be at least in Spanish. For products intended for use in the United States, all markings shall be at least in English. See Annex B and Annex C for suitable translations.*

7.2.1 All interrupters shall be plainly marked in a permanent manner with at least the following:

- a) Manufacturer's name, trademark, tradename, or other recognized symbol of identification;
- b) Amperes or other necessary indication of current-carrying capacity, the load-capacity marking of a cord connected ground-fault circuit-interrupter shall include watts;
- c) Except as noted in 7.2.1(d), voltage and frequency shall be marked as follows: rated voltage followed by V ~ 60Hz. Alternative markings are rated voltage followed by ~ 60 Hz, by V 60Hz, or by VAC, 60 Hz. See 7.2.7.
- d) In Mexico, acceptable markings are rated voltage followed by V ~ 60Hz, V 60 Hz, or Vc.a. 60 Hz.
- e) The basic catalog number, or type designation. Prefixes and suffixes that indicate features such as color, indicator lamps, shutters, or other construction variations shall not be required. For Canada, the catalogue number or type must appear on the product or the smallest unit of packaging.

7.2.2 All terminals to which line, load or grounding conductors are intended to be connected shall be clearly identified.

7.2.3 A ground-fault circuit-interrupter shall be legibly and permanently marked with the date or other dating period of manufacture not exceeding any three consecutive months. The date of manufacture may be abbreviated, or may be in a conventional code, or in a code affirmed by the manufacturer, provided that the code does not repeat in less than 20 years, and does not require reference to the production records of the manufacturer to determine when the product was manufactured.

7.2.4 If the enclosure has been suitably evaluated for environmental Types 2, 3, 3R, 3S, 4, 4X, 5, 6, 6P, 12, 12K, or 13, it shall be marked in accordance with the requirements for enclosures, Annex A, Ref. No. 4.

7.2.5 Class A interrupters shall be marked in a permanent manner where the marking will be readily visible after installation (e.g., with a cover plate removed) with the following wording or a suitable equivalent: "GROUND FAULT CIRCUIT INTERRUPTER CLASS A". Note: Except as noted in 7.2.6, an abbreviation of this marking such as "GFCI CL A", "Class A", "CL A", or "GFCI A" is considered to be a suitable equivalent in those cases where the areas available for marking make the complete text impracticable.

7.2.6 The abbreviation "ICFT" is considered a suitable equivalent marking for a GFCI intended for use in Mexico only.

7.2.7 A ground-fault circuit-interrupter shall be legibly and permanently marked with the voltage as indicated in Table 7.2.1 below.

**Table 7.2.1**  
**Rated voltage and corresponding marked voltage(s)**

Rated Voltage	Marked Voltage(s)
120 V	120 V or 125 V <sup>a</sup>
127 V	127 V
120-127 V	120, 127 V
120/240 V	120/240 V
208 Y/120 V	208 Y/120 V
220 Y/120-127 V	220 Y/120-127 V
208 Y/120, 220 Y/127 V	208 Y/120, 220 Y/127 V

<sup>a</sup> 125V based on configuration rating of plug or receptacle GFCI.

7.2.8 The remote control function of a GFCI shall be marked and identified on the smallest package and instructions. The device shall be permanently marked with the word "CONTROLLED" on the device where visible after installation.

7.2.9 A ground-fault circuit-interrupter that is intended to be used as an "ON" "OFF" controller and that is in compliance with the requirements of [6.14.9](#) is permitted to be marked with the applicable horsepower rating on the product and the area near the "TEST" and "RESET" buttons is permitted to be marked "OFF" and "ON" respectively.

### 7.3 Permanently connected ground-fault circuit-interrupters

7.3.1 Except as noted in [7.3.2](#), a ground-fault circuit-interrupter employing terminal leads shall be marked with the gauge of the leads on the device.

7.3.2 A GFCI with suitable wire connectors need not comply with the requirement in [7.3.1](#).

7.3.3 Unless a permanently connected ground-fault circuit-interrupter has been found suitable for use where it may be exposed to rain, it shall be marked where visible during installation in letters 3.2 mm (1/8 inch) high with the words: "Do not use where exposed to rain", or the equivalent, except as noted in [7.3.4](#).

7.3.4 The marking specified in [7.3.3](#) is not required on a receptacle type GFCI provided with installation instructions specified in [8.1.2](#).

7.3.5 A ground-fault circuit-interrupter that has been found suitable for connection to a conduit which extends directly to an underwater pool light forming shell may be so marked.

7.3.6 A permanently connected ground-fault circuit-interrupter shall have its terminals legibly and permanently marked "Line" (Linea) and "Load" (Carga), and "Hot" (Fase) and "White" (Neutral) as appropriate for the country it is intended to be used. If a permanently connected ground-fault circuit-interrupter is provided with leads, the location where the leads exit the ground-fault circuit-interrupter, shall be legibly and permanently marked "Line" (Linea) and "Load" (Carga), and "Hot" (Fase) and "White" (Neutral) or "Gray" (Gris) as appropriate for the country it is intended to be used.

7.3.7 A receptacle type GFCI not intended to be removed and reinstalled shall be marked "Warning – Risk of electric shock- Do not reinstall this device after removal" in letters min. 1.6 mm (1/16 in.) high. The marking shall be located where exposed to view when the field-wiring terminals are exposed to view.