

UL 943

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Ground-Fault Circuit- Interrupters

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

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Page	Date
1	April 15, 2002
2-3	September 18, 2000
4-5	April 15, 2002
6-8A	September 18, 2000
8B	May 13, 1998
9	August 27, 1993
10	December 16, 1994
11-14	August 27, 1993
15-16	March 24, 1997
16A	September 18, 2000
16B	May 13, 1998
17	January 4, 1995
18	September 18, 2000
19	August 27, 1993
20	May 13, 1998
21-24	September 18, 2000
25-26B	May 13, 1998
27	September 18, 2000
28	August 27, 1993
29	September 18, 2000
30	May 13, 1998
30A	September 18, 2000
30B	May 13, 1998
31	September 3, 1996
32	January 4, 1995
33-34	August 27, 1993
35	April 2, 1996
36	August 27, 1993
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52B	April 15, 2002
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1

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This edition of UL 943, including all revisions, is approved as an American National Standard. Approval of UL 943 as an American National Standard is maintained using the continuous maintenance process. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Written comments are to be sent to UL-Melville Standards Department, 1285 Walt Whitman Road, Melville, L.I., NY 11747.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Approved as ANSI/UL 943-2002, March 12, 2002

The Department of Defense (DoD) has adopted UL 943 on November 30, 1984. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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No Text on This Page

CONTENTS

FOREWORD 4

INTRODUCTION

1 Scope 5
 2 Glossary 5
 3 Components 6A
 4 Units of Measurement 6A
 5 References 6A

CONSTRUCTION

6 General 6B
 7 Resistance to Corrosion 6B
 8 Rainproof Enclosures 6B
 9 Grounding 9
 10 Frame and Enclosure 9
 10.1 General 9
 10.2 Polymeric enclosures 14
 11 Provision for Wiring Systems 14
 12 Connections 14
 13 Accessibility of Energized Parts 15
 14 Internal Wiring 15
 15 Field Wiring 16
 16 Power-Supply Cord 17
 17 Receptacles 19
 18 Spacings 19
 18A Alternate Spacings - Clearances and Creepage Distances 21
 19 Operating Mechanism 22
 20 Supervisory Circuit 22

PERFORMANCE

21 General 22
 22 Leakage Current Test 22A
 23 Voltage Surge Test 23
 24 High-Resistance Ground Faults Test 26A
 24.1 General 26A
 24.2 High-resistance ground fault test 27
 25 Resistance to False Tripping Test 31
 26 Resistance to Environmental Noise Test 34
 27 Regulation Test 40
 28 Normal Temperature Test 40
 29 Dielectric Voltage-Withstand Test 41
 30 Overload and Motor Starting Test 42
 31 Low-Resistance Ground Fault Test 43
 32 Endurance Test 45
 33 Abnormal Operation Test 46
 34 Extra-Low-Resistance Ground Faults Test 48
 35 Short Circuit Test 49

36 Chromic Acid Dropping Test50
 37 Dust Test51
 37A Permanence of Marking52

MARKINGS

38 Details52
 38.1 General52
 38.2 Permanently connected ground-fault circuit-interrupters52A
 38.3 Portable ground-fault circuit-interrupters52B
 39 Installation Instructions53
 39.1 General53
 39.2 Permanently connected ground-fault circuit-interrupters56

SUPPLEMENT SA - OPTIONAL 10 KA SHORT CIRCUIT CURRENT TEST FOR OUTLET-BOX TYPE GROUND-FAULT CIRCUIT-INTERRUPTERS.

INTRODUCTION

SA1 ScopeSA1

PERFORMANCE

SA2 GeneralSA1

MARKINGS

SA3 GeneralSA2

APPENDIX A

Standards for Components..... A1

No Text on This Page

FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

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F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 These requirements cover ground-fault circuit-interrupters intended for use only in alternating-current circuits wherein one of the wires is grounded in accordance with the National Electrical Code. These devices are intended for use on 120 Vac or 120/240 Vac, 60 Hz circuits.

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 A ground-fault circuit-interrupter as covered by these requirements is a device whose function is to interrupt the electric circuit to the load when a fault current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

1.4 *Deleted April 15, 2002*

2 Glossary

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

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

2.3 CLASS A – Denotes a ground-fault circuit-interrupter that will trip when a fault current to ground is 6 mA or more.

2.4 CLASS B – Denotes a ground-fault circuit-interrupter that will trip when a fault current to ground is 20 mA or more.

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

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

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

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

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

2.10 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.

2.10.1 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.

2.10.1 added March 24, 1997

2.11 PERMANENTLY CONNECTED – Denotes connection to a supply circuit by way of fixed electrical conductors.

2.12 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 2.5).

2.13 RAINPROOF – Denotes a ground-fault circuit-interrupter so constructed as to prevent rain from interfering with its successful operation.

2.14 RATED CURRENT – The marked value of current.

2.15 RATED VOLTAGE – For devices with a marked voltage within the range of 110– 125 V, the rated voltage is to be considered to be 120 V. For devices with an additional marked voltage within the range of 190 – 250 V, the rated voltage is considered to be 120/240 V.

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

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

2.18 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 24.1.1

2.19 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.

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

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components used in the products covered by this standard.

3.1 revised September 18, 2000

3.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

3.2 revised September 18, 2000

3.3 A component shall be used in accordance with its rating established for the intended conditions of use.

3.3 revised September 18, 2000

3.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits and shall be used only under those specific conditions.

3.4 revised September 18, 2000

4 Units of Measurement

4.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4.1 revised September 18, 2000

5 References

5.1 Any undated 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.

CONSTRUCTION

6 General

6.1 The design, workmanship, and degree of production uniformity shall be such that the reliability of the ground-fault circuit-interrupter to perform the functions evaluated by the requirements will be high.

6.2 A ground-fault circuit-interrupter intended to serve also as a junction box for swimming-pool equipment shall comply with the applicable requirements covering swimming-pool junction boxes, UL 1241.

6.3 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 from the Standard for Attachment Plugs and Receptacles, UL 498.

Added 6.3 effective July 4, 1998

7 Resistance to Corrosion

7.1 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.

8 Rainproof Enclosures

8.1 A rainproof enclosure shall be so constructed as to exclude a beating rain. The enclosure shall be provided with external means for mounting, except that internal means for mounting may be employed if so designed as to prevent water from entering the enclosure. Metals shall not be used in combination such as to cause galvanic action which will affect adversely any part of the device.

8.2 A rainproof ground-fault circuit-interrupter is to be attached to a vertical clapboard surface as in actual service. If there is provision for conduit connection at points above the lowest insulation or live part of the ground-fault circuit-interrupter, an unspecified length of conduit is to be attached with the torque specified in 11.4. The unattached end of the conduit is to be covered to prevent entry of water during this test. A water spray is to be applied from three nozzles so located as to direct the spray against all surfaces that would be exposed to a beating rain. The device is considered to comply with the provisions of 8.1 if there is no entry of water above the lowest insulation or live part of the ground-fault circuit-interrupter.

8.3 An elastomeric material, employed to obtain compliance with the provisions of 8.1 shall be adequately resistant to deterioration.

8.4 In order to determine compliance with the provisions of 8.3, a gasket of rubber or neoprene or a composition thereof is to be exposed for 96 hours to oxygen at a gauge pressure of 300 ± 10 psi (2.07 ± 0.07 MN/m²) gauge and a temperature of $70.0 \pm 1.0^\circ\text{C}$ ($158.0 \pm 1.8^\circ\text{F}$). There is to be no visible evidence of deterioration, or change in hardness of more than 5 numbers (0.0005 inch or 0.013 mm).

8.4 revised December 16, 1994

8.5 Except for threaded holes, there shall not be provision for conduit located above any live part or insulation of the ground-fault circuit-interrupter.

8.6 There shall be provision for drainage of the enclosure, provided that holes for this purpose are to be no larger than 1/4 by 1/4 inch (6.4 by 6.4 mm).

8.7 A rainproof enclosure made of sheet steel having a thickness of 0.120 inch (3.05 mm) or more shall be protected against corrosion by one of the following coatings:

a) Hot dipped mill galvanized sheet steel conforming with the coating designation G60 or A60 in Table 1 of the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M-94, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM Specification. The weight of zinc coating may be determined by any acceptable method; however, in case of question the weight of coating shall be established in accordance with the test method of ASTM A90-81(1991). An A60 (alloyed) coating shall also comply with 8.10.

b) A zinc coating, other than that provided on hot dipped mill galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.010 mm) on each surface with a minimum thickness of 0.00034 inch (0.009 mm). The thickness of the coating shall be established by the Chromic Acid Dropping Test, Section 36. An annealed coating shall also comply with 8.10.

c) Two coats of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on both surfaces. The suitability of the paint may be determined by consideration of its composition or by corrosion tests if these are considered necessary.

8.7 revised April 2, 1996

8.8 A rainproof enclosure made of sheet steel having a thickness of less than 0.120 inch (3.05 mm) shall be protected against corrosion by one of the following coatings:

a) Hot dipped mill galvanized sheet steel conforming with the coating Designation G90 in Table 1 of the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M-94, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM Specification. The weight of zinc coating may be determined by any suitable method; however, in case of question the weight of coating shall be established in accordance with the test method of ASTM A90-81(1991).

b) A zinc coating, other than that provided on hot dipped mill galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 inch (0.015 mm) on each surface with a minimum thickness of 0.00054 inch (0.014 mm). The thickness of the coating shall be established by the Chromic Acid Dropping Test, Section 36. An annealed coating shall also comply with 8.10.

c) A cadmium coating not less than 0.001 inch (0.025 mm) thick on both surfaces. The thickness of coating shall be established by the Chromic Acid Dropping Test, Section 36.

d) A zinc coating conforming with item a) or b) of 8.7 with one coat of outdoor paint as specified in item c of 8.7.

e) A cadmium coating not less than 0.00075 inch (0.019 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established by the Chromic Acid Dropping Test, Section 36 and the paint shall be as specified in item c of 8.7.

8.8 revised April 2, 1996

8.9 With reference to 8.7 and 8.8, other finishes, including paints, special metallic finishes and combinations of the two may be accepted when comparative tests with galvanized sheet steel (without annealing, wiping, or other surface treatment) conforming with item a of 8.7 or 8.8, as applicable, indicate they provide equivalent protection. Among the factors which are taken into consideration when judging the suitability of such coating systems are exposure to salt spray, moist carbon dioxide sulphur dioxide-air mixtures, moist hydrogen sulphide-air mixtures, ultraviolet light and water.

8.10 A hot dipped mill-galvanized A60 (alloyed) coating or an annealed coating on sheet steel which is bent or similarly formed or extruded or rolled at edge of holes after annealing shall additionally be painted in the bent or formed area if the bending or forming process damages the zinc coating.

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8.11 If flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification, the zinc coating is considered damaged. Simple sheared or cut edges and punched holes are not considered to be formed.

9 Grounding

9.1 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 15.1). 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.

9.2 In considering the provisions of 9.1, a grounded or insulating barrier may be employed to reduce the likelihood that accessible parts will become energized.

9.3 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.

10 Frame and Enclosure

10.1 General

10.1.1 A ground-fault circuit-interrupter shall be so formed and assembled that it can withstand the abuses to which it might be subjected without affecting spacings, insulation, accessibility of live parts, performance with high-resistance ground faults, or grounding, to the extent that the device would fail to comply with these requirements.

10.1.2 Opening or removal of a door or cover, with or without the use of a separate tool, that must be opened or removed in order to properly use or install a ground-fault circuit-interrupter shall not increase the likelihood of accidental injury to any part depended upon for the proper functioning of the device. The likelihood of such injury will not be considered to have increased if the part in question has not become accessible. See items a and b of 13.2.

10.1.3 Among the factors taken into consideration when the acceptability of enclosure material is being determined, are (1) physical strength, (2) resistance to moisture absorption, (3) combustibility, (4) resistance to corrosion, and (5) resistance to distortion at temperatures to which the enclosure may be subjected under conditions of normal or abnormal use. For a nonmetallic enclosure, all of these factors are considered with respect to thermal aging.

10.1.4 An enclosure of sheet metal having the construction indicated in Table 10.1 or 10.2 will generally be considered to have an acceptable level of the factors shown in 10.1.3.

10.1.5 In determining compliance with the provisions of 10.1.1, a permanently connected ground-fault circuit-interrupter is to be subjected to an externally applied impact of 5 ft-lbs (6.8 J) applied by way of a solid, smooth, steel sphere 2 inches (50.8 mm) in diameter.

Exception: Receptacle-type ground-fault circuit-interrupters are to be subjected to a 3-ft (0.91 m) drop test onto a concrete floor. The method of doing the test shall be in accordance with the provisions of 10.1.8.

10.1.6 The sphere mentioned in 10.1.5 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.

Table 10.1
Thickness of sheet metal for enclosures – carbon steel or stainless steel^a

Table 10.1 revised December 16, 1994

Without supporting frame ^b		With supporting frame or equivalent reinforcing ^b		Minimum thickness inches (mm)	
Maximum width ^c	Maximum length ^d	Maximum width ^c	Maximum length ^d	Uncoated	Metal coated
Inches (cm)	Inches (cm)	Inches (cm)	Inches (cm)		
4.0 (10.2)	Not limited	6.25 (15.9)	Not limited	0.020 ^{e,f} (0.51)	0.023 ^{e,f} (0.58)
4.75 (12.1)	5.75 (14.6)	6.75 (17.1)	8.25 (21.0)		
6.0 (15.2)	Not limited	9.5 (24.1)	Not limited	0.026 ^{e,f} (0.66)	0.029 ^{e,f} (0.74)
7.0 (17.8)	8.75 (22.2)	10.0 (25.4)	12.5 (31.8)		
8.0 (20.3)	Not limited	12.0 (30.5)	Not limited	0.032 (0.81)	0.034 (0.86)
9.0 (22.9)	11.5 (29.2)	13.0 (33.0)	16.0 (40.6)		
12.5 (31.8)	Not limited	19.5 (49.5)	Not limited	0.042 (1.07)	0.045 (1.14)
14.0 (35.6)	18.0 (45.7)	21.0 (53.3)	25.0 (63.5)		
18.0 (45.7)	Not limited	27.0 (68.6)	Not limited	0.053 (1.35)	0.056 (1.42)
20.0 (50.8)	25.0 (63.5)	29.0 (73.7)	36.0 (91.4)		
22.0 (55.9)	Not limited	33.0 (83.8)	Not limited	0.060 (1.52)	0.063 (1.60)
25.0 (63.5)	31.0 (78.7)	35.0 (88.9)	43.0 (109.2)		
25.0 (63.5)	Not limited	39.0 (99.1)	Not limited	0.067 (1.70)	0.070 (1.78)
29.0 (73.7)	36.0 (91.4)	41.0 (104.1)	51.0 (129.5)		
33.0 (83.8)	Not limited	51.0 (129.5)	Not limited	0.080 (2.03)	0.084 (2.13)
38.0 (96.5)	47.0 (119.4)	54.0 (137.2)	66.0 (167.6)		
42.0 (106.7)	Not limited	64.0 (162.6)	Not limited	0.093 (2.36)	0.097 (2.46)
47.0 (119.4)	59.0 (149.9)	68.0 (172.7)	84.0 (213.4)		
52.0 (132.1)	Not limited	80.0 (203.2)	Not limited	0.108 (2.74)	0.111 (2.82)
60.0 (152.4)	74.0 (188.0)	84.0 (213.4)	103.0 (261.6)		
63.0 (160.0)	Not limited	97.0 (246.4)	Not limited	0.123 (3.12)	0.126 (3.20)
73.0 (185.4)	90.0 (228.6)	103.0 (261.6)	127.0 (322.6)		

^a Tables 10.1 and 10.2 are based upon the initial deflection of an enclosure surface with a concentrated load at the center of the surface.

^b A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes: (1) single sheet with single-formed flanges (formed edges), (2) a single sheet which is corrugated or ribbed, and (3) an enclosure surface loosely attached to a frame, for example, with spring clips.

^c The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

^d For panels which are supported along one side (for example, side panels of boxes) the length of the unsupported side shall be limited to the dimensions specified.

^e Sheet steel for a rainproof enclosure is to be not less than 0.034 inch thick if zinc-coated and not less than 0.032 inch thick if uncoated.

^f Sheet steel is to be not less than 0.032 inch thick if uncoated and not less than 0.034 inch thick if zinc-coated at points to which a wiring system is to be attached.

Table 10.2
Thickness of sheet metal for enclosures – aluminum, copper, or brass^a

Without supporting frame ^b		With supporting frame or equivalent reinforcing ^b							
Maximum width ^c		Maximum length ^d		Maximum width ^c		Maximum length ^d		Minimum acceptable thickness	
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited		0.023 ^{e,f}	(0.58)
3.5	(8.9)	4.0	(10.2)	8.5	(21.6)	9.5	(24.1)	0.029 ^f	(0.74)
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited			
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.3)	0.036 ^f	(0.91)
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited			
6.5	(16.5)	8.0	(20.3)	15.0	(38.1)	18.0	(45.7)	0.045	(1.14)
8.0	(20.3)	Not limited		19.0	(48.3)	Not limited			
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)	0.058	(1.47)
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited			
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)	0.075	(1.91)
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited			
20.0	(50.8)	25.0	(63.4)	45.0	(114.3)	55.0	(139.7)	0.095	(2.41)
25.0	(63.5)	Not limited		60.0	(152.4)	Not limited			
29.0	(73.7)	36.0	(91.4)	64.0	(162.6)	78.0	(198.1)	0.122	(3.10)
37.0	(94.0)	Not limited		87.0	(221.0)	Not limited			
42.0	(106.7)	53.0	(134.6)	93.0	(236.2)	114.0	(289.6)	0.153	(3.89)
52.0	(132.1)	Not limited		123.0	(312.4)	Not limited			
60.0	(152.4)	74.0	(188.0)	130.0	(330.2)	160.0	(406.4)		

^{a-d} See notes a–d to Table 10.1.
^e Sheet copper, brass, or aluminum for a raintight enclosure is to be not less than 0.029 inch in thickness.
^f Nonferrous metal is to be not less than 0.045 inch thick at points to which a wiring system is to be attached.

10.1.7 The surfaces mentioned in 10.1.6 are those exposed during normal service, including operating handles, pushbuttons, and the like. Doors that are hinged or sliding or otherwise captive, and covers that cannot be removed without tools, are to be closed. Other doors or covers are to be opened or removed. A sample that has been struck is not required to withstand another blow. However, if more than one blow is applied to a single sample, a failure after the first blow is to be disregarded provided that the same surface withstands a blow on another sample. If a device fails during the first test, the device is considered to have failed.

10.1.8 A cord-connected or portable device is to be allowed to fall from a height of three feet 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.

10.1.9 The hardwood surface mentioned in 10.1.8 is to consist of a layer of nominal 1-inch tongue-and-groove oak flooring mounted on two layers of 3/4-inch (19 mm) plywood. The surface is to be a square 4 ft (1.2 m) on a side. The assembly is to rest on a concrete floor or the equivalent.

10.1.10 The maximum acceptable moment, center of gravity, dimensions, and weight of a direct plug-in unit shall comply with the requirements specified in Items a, b, c and d. See Figure 10.1 and 10.1.11 and 10.1.12.

- a) The quotient of WY/Z shall not exceed 48 ounces (1361 g).
- b) The quotient of WY/S shall not exceed 48 ounces (1361 g).
- c) The product of WX shall not exceed 80 ounce-inches (0.56 N-m).
- d) The weight of a unit shall not exceed 28 ounces (794 g).

10.1.11 Definitions for the symbols used in 10.1.10 are as follows:

W is the weight of the unit in ounces (g).

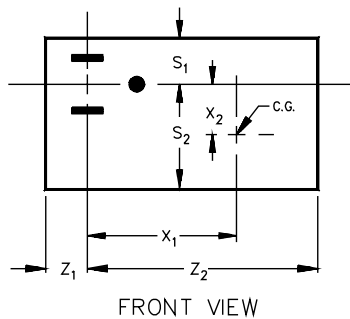
Y is the distance illustrated in Figure 10.1 in inches (mm).

Z is the lesser of the two distances, Z_1 or Z_2 , as illustrated in Figure 10.1, in inches (mm).

S is the lesser of the two distances, S_1 or S_2 , as illustrated in Figure 10.1, in inches (mm).

X is the greater of the two distances X_1 or X_2 , as illustrated in Figure 10.1, in inches (mm).

Figure 10.1
Dimensions of a direct plug-in unit



C.G. = Center of Gravity

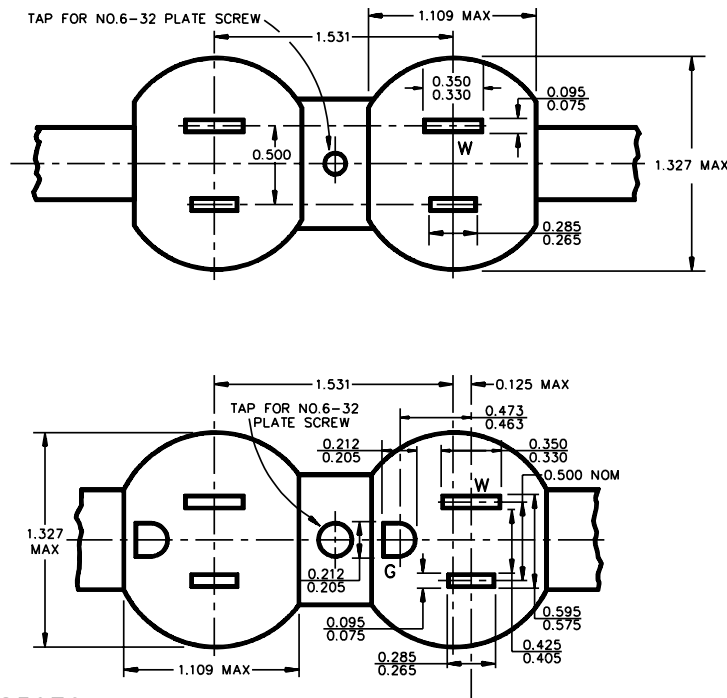
10.1.12 The moment and weight specified in 10.1.10 are to be determined as follows:

- 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.

10.1.13 When inserted in a parallel-bladed duplex receptacle, any part of a unit, including output wiring, shall not interfere with full insertion of an attachment plug into the adjacent receptacle. See Figure 10.2.

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

Figure 10.2
Parallel duplex receptacle



S3076

10.2 Polymeric enclosures

10.2.1 A polymeric enclosure, or a polymeric part of an enclosure, shall comply with the applicable requirements for enclosures as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: For a direct plug-in ground-fault circuit-interrupter, the crushing test shall be conducted in accordance with 71 of the Standard for Attachment Plugs and Receptacles, UL 498.

10.2.2 An adhesive used in the assembly of a ground-fault circuit-interrupter shall comply with the applicable requirements for adhesives as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

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

11 Provision for Wiring Systems

11.1 There shall be provision at a permanently connected ground-fault circuit-interrupter for attachment of raceway or cable in accordance with the National Electrical Code, ANSI/NFPA 70.

11.2 A knockout in a sheet-metal enclosure shall be secure but shall be capable of being removed without significant deformation of the enclosure, or dislocating larger sizes of a multiple knockout. A knockout likely to be used during installation shall be surrounded by a flat surface for effective seating of a conduit bushing and shall be so located that installation of a bushing will not result in spacings smaller than those allowed in these requirements.

11.3 A hole tapped for the attachment of threaded rigid conduit shall be so constructed as to permit:

- a) The attachment of a conduit bushing, or there is to be a smooth, well-rounded passage for wires equivalent to that presented by a bushing, and
- b) For raintight equipment, the application of tightening torque as specified in 11.4.

11.4 The torque mentioned in 8.2 and 11.3 is to be applied to the conduit in such a manner as to prevent the application of a bending movement to the assembly. The value of torque is to be 800 lbf-in (90 N·m) for 3/4-inch (19-mm) and smaller trade sizes of conduit, 1000 lbf-in (113 N·m) for sizes larger than 3/4 inch (19 mm) up to 1-1/2 inches (38 mm), and 1600 lbf-in (181 N·m) for sizes larger than 1-1/2 inches (38 mm).

12 Connections

12.1 Except as described in 12.2 and 12.3, a portable cord-connected ground-fault circuit-interrupter provided with an equipment grounding conductor shall have double insulation or reinforced insulation throughout its construction, or if not provided with an equipment grounding conductor shall have double insulation or reinforced insulation on the line side of the device.

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

12.3 In performing the evaluation described in 12.2 at a manual switch in the supervisory circuit (described in 20.1), 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.

12.4 The equivalent of functional insulation shall be interposed between the grounding conductor of the power-supply cord 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.

12.5 The dielectric of a capacitor is not acceptable as supplementary insulation.

12.6 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 16.5.

13 Accessibility of Energized Parts

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

13.2 In determining compliance with the provisions of 13.1:

- a) Except at a contact of an attachment-plug receptacle, a part is considered to be accessible if it can be touched with a 3/32-inch (2.4 mm) diameter rod.
- b) A permanently connected device is to 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, and
- d) A door or cover that must be opened or removed in order to use a ground-fault circuit-interrupter is to be opened or removed.
- e) Material that is not acceptable as insulation is considered to be conductive.

13.3 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.

Added 13.3 effective July 4, 1998

14 Internal Wiring

14.1 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 No. 24 AWG is employed.

14.2 In a 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.

14.3 Electrical splices, terminations, and the like shall provide effective, continuous conductivity.

14.4 In determining compliance of a clamped splice or termination with the provisions of 14.3, consideration is to be given to the likelihood of permanent deformation under mechanical load (creep).

15 Field Wiring

15.1 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, at least two equipment-grounding terminals. See 9.1.

15.2 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.

15.3 Lead-type terminals shall not differ by more than two wire sizes from the size referred to in 15.1, providing that wire smaller in cross-section than No. 14 AWG shall not be used.

15.4 The insulation of lead-type terminals shall be for the intended purpose, such as 0.030-inch (0.76-mm) thick minimum rubber or thermoplastic material.

15.5 A lead-type terminal shall be so constructed as to withstand the stress of normal handling without damage to the ground-fault circuit-interrupter.

15.6 In order to determine compliance with the provisions of 15.5, each terminal lead is to withstand a tensile force increased gradually to 20 lbf (89 N), and maintained at that value for five minutes.

15.7 Green coloring with or without one or more yellow stripes and white or natural grey coloring shall not be used for the covering of a terminal lead unless intended for connection to grounding and grounded conductors respectively. See also 39.2.6.

15.7 revised January 4, 1995

15.8 The free length of a terminal lead shall be at least 6 inches (152 mm).

15.9 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.

15.10 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.

15.11 A terminal connector of the wire-binding type may be used to terminate conductors no larger than No. 10 AWG (5.3 mm²).

15.12 In order to determine compliance with the provisions of 15.10, a wire-binding screw or nut is to be tightened on a conductor selected in accordance with the provisions of 15.1 to a torque of 20 lbf-in (2.3 N-m) without causing displacement of the wire or damage to the terminal assembly or 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.

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16 Power-Supply Cord

16.1 A cord-connected ground-fault circuit-interrupter shall be provided with not less than 6 ft (1.83 m) of flexible cord and 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.

Exception: A ground-fault circuit-interrupter may be provided with less than 6 ft (1.83 m) of permanently attached flexible cord or with a motor-attachment plug if the ground-fault circuit-interrupter is marked as indicated in 38.3.3.

16.1 revised January 4, 1995

16.2 The flexible cord shall be of Type S, ST, SO, STO, SJ, SJT, SJO, or SJTO.

16.3 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.

16.4 In order to determine that the strain of pulling on the supply cord will not be transmitted to the cord terminations as provided in 16.3, a tensile force is to be applied to the cord and increased gradually to 35 lbf (156 N). The force is to be maintained at 35 lbf (156 N) for one minute.

16.5 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.

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

16.7 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.

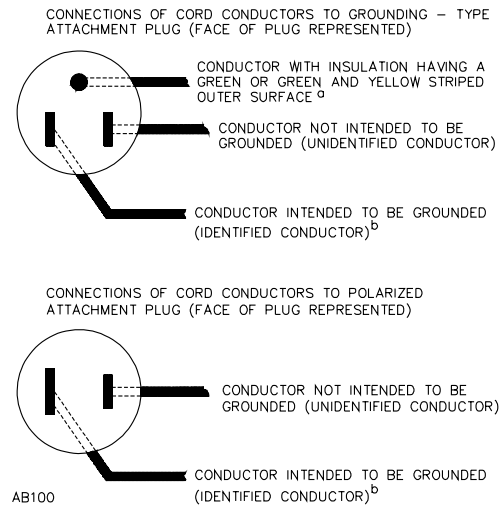
16.8 The points within the ground-fault circuit-interrupter intended for the termination of power-supply-cord conductors shall be plainly identified to show the proper connection of the conductors of a replacement cord, and to indicate that the grounding conductor shall not be connected to accessible metal parts of the unit. This marking is to be discernible only after access is obtained to the terminations, except that if there is safe, convenient provision for cord replacement, reference to such replacement may be discernible from outside the ground-fault circuit-interrupter also.

16.9 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.

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

16.11 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 16.1, and the polarity identification of the flexible cord shall comply with Table 16.1.

Figure 16.1
Connection to attachment plug



^a In the above illustration, the blade to which the green conductor is connected may have a U-shaped or circular cross section.

^b Signifies a conductor identified in accordance with Table 16.1 as wire intended to be grounded.

Table 16.1
Polarity identification of flexible cords

Method of identification	Acceptable combinations		
		Wire intended to be grounded ^b	All other wires ^b
Color of braids on individual conductors	A	Solid white or natural gray – without tracer	Solid color other than white or natural gray – without tracer
	B	Color other than white or natural gray, with tracer in braid	Solid color other than white or natural gray – without tracer
Color of insulation ^a on individual conductors	C	Solid white or natural gray	Solid color other than white, or natural gray
	D	Light blue	Solid color other than light blue, white

^a Only for cords having no braid on any individual conductor.

^b 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 Figure 16.1

17 Receptacles

17.1 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.

Exception: 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.

17.2 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.

17.3 The rating of any receptacle not having individual overcurrent protection, provided on a ground-fault circuit-interrupter having more than one receptacle, shall be one of those shown in Table 17.1.

17.4 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 17.1
Receptacle current rating in amperes

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

18 Spacings

18.1 Except at field-wiring terminals, the through-air and over-surface spacings between conductive parts shall not be less than the values shown in Table 18.1.

18.2 The spacing shall not be less than 1/4 inch (6.4 mm) between field-wiring terminals not operating at the same potential for devices rated up to 200 v peak, and 3/8 inch (9.5 mm) for devices rated up to 400 v peak.

18.3 Except as permitted in note c to Table 18.1, if a groove or a slot in insulating material is less than 1/64 inch (0.4 mm) wide, the contour of the slot or groove is to be disregarded in measuring spacings over the surface.

18.4 Spacings measured along the boundary of insulating materials that have been joined together are considered to be spacings over surface unless it can be shown that the dielectric strength of the boundary is not less than that of any of the materials joined.

18.5 In determining compliance with the provisions of 18.1 or 18.2, parts not locked in position, parts subject to random orientation (such as noncircular heads of screws), adjustable parts of terminal connectors, and the like are to be moved to the most adverse position.

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

18.7 Film-coated magnet wire is considered to be uninsulated in determining spacings.

Table 18.1
Spacing in inches (mm)^{a,e}

Table 18.1 revised May 13, 1998

Parts separated by	Operating potential between parts									
	70 V peak or less		71 – 200 V peak				201 – 400 V peak			
	Through air	Over surface	Through air	Over surface	Through air	Over surface	Through air	Over surface	Through air	Over surface
	Open ^a	Closed-in ^b	Open ^a	Closed-in ^b	Open ^a	Closed-in ^b	Open ^a	Closed-in ^b	Open ^a	Closed-in ^b
Functional insulation ^c	1/16 ^d (1.6)	1/16 ^d (1.6)	1/16 ^d (1.6)	1/16 ^d (1.6)	1/8 (3.2)	1/16 (1.6)	1/4 (6.4)	1/16 (1.6)	1/4 (6.4)	1/8 (3.2)
Supplementary insulation	1/8 (3.2)	1/16 (1.6)	1/8 (3.2)	1/16 (1.6)	1/8 (3.2)	1/8 (3.2)	1/4 (6.4)	1/8 (3.2)	1/4 (6.4)	1/8 (3.2)
Double or Reinforced insulation	1/4 (6.4)	1/8 (3.2)	1/2 (12.7)	1/8 (3.2)	1/4 (6.4)	1/8 (3.2)	1/2 (12.7)	1/4 (6.4)	1/2 (12.7)	1/4 (6.4)

^a A space that is not specially protected from deposition of dirt.

^b 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 Section 37.

^c Smaller spacings may be acceptable where they are inherent in a suitable component.

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

^e For printed wiring boards with suitable conformal coating which has been determined to comply with the requirements for conformal coatings in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, spacings may be reduced to 1/32 in (0.8 mm), and may be further reduced if the coating is determined to be suitable and a special dielectric withstand test is performed between the conductors.

18A Alternate Spacings - Clearances and Creepage Distances

Section 18A added September 18, 2000

18A.1 When applying requirements in Alternate Spacings - Clearances and Creepage Distances, Section 18A, as an alternative to the measurement method specified in Spacings, Section 18, 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 18A.2 – 18A.4 using the applicable requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

18A.2 When applying the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, 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, or
- b) Pollution degree 2 for
 - i) an assembly with a conformal coating,
 - ii) an assembly without a conformal coating when the printed wiring board is contained in a sealed housing that complies with the Dust Test, Section 37 or,
- c) Pollution degree 1 for an assembly with a conformal coating complying with the Printed Wiring Board Coating Performance Test in UL 840.

18A.3 When applying Clearance B (controlled overvoltage) construction requirements from the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment UL 840, the applicable overvoltage category for line voltage circuits is Category III for permanently connected GFCIs and Category II for portable and cord connected GFCIs. 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.

18A.4 Where measurement of clearances and creepage distances is involved to establish the minimum spacings, the methods specified in Measurement of Clearance and Creepage Distances, Section 7, of the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment UL 840, shall be used.

19 Operating Mechanism

19.1 Compliance with the provisions of 24.1.1 – 24.1.4 shall not be prevented by manipulation or restraint of accessible control levers, knobs, and the like of a ground-fault circuit-interrupter.

19.2 A ground-fault circuit-interrupter that has tripped in accordance with the provisions of 24.1.1 – 24.1.4 shall not be capable of automatic reclosure.

19.3 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.

19.4 In a permanently connected ground-fault circuit-interrupter that cannot trip without power from the line, the grounded circuit conductor shall be electrically continuous during normal operation of the device.

19.5 A 120/240 V ground-fault circuit-interrupter shall function to provide protection with one or both ungrounded line terminals energized.

20 Supervisory Circuit

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

20.2 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.

20.3 The supervisory circuit shall be connected to the grounded supply-circuit conductor and the ungrounded load-circuit conductor.

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

20.5 The current employed by the supervisory circuit shall be sufficient to cause tripping at 85 percent of rated voltage, provided that at rated voltage the current shall not exceed 9 mA in a Class A device and 32 mA in a Class B device.

PERFORMANCE

21 General

21.1 A sample that has been struck as described in 10.1.5 or 10.1.8 and conditioned as described in 22.7 shall at any convenient time after removal from the conditioning atmosphere, and in the following order, comply with the provisions of these requirements for voltage surge, high-resistance ground faults and dielectric voltage withstand tests.

21.2 Except as noted in 21.1, a separate, unconditioned representative ground-fault circuit-interrupter shall be subjected to each of the following tests.

Exception: The same representative device may be used for more than one test if agreeable to all concerned.

21.2 added April 2, 1996

22 Leakage Current Test

22.1 The leakage current of a ground-fault circuit-interrupter, when tested in accordance with 22.2 – 22.7, shall be no more than 0.5 mA.

22.2 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.

22.3 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 by 20 cm in contact with the surface. Where the surface is less than 10 by 20 cm, 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.

22.4 The measurement circuit for leakage current of a cord-connected device is to be as shown in Figure 22.1. 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.

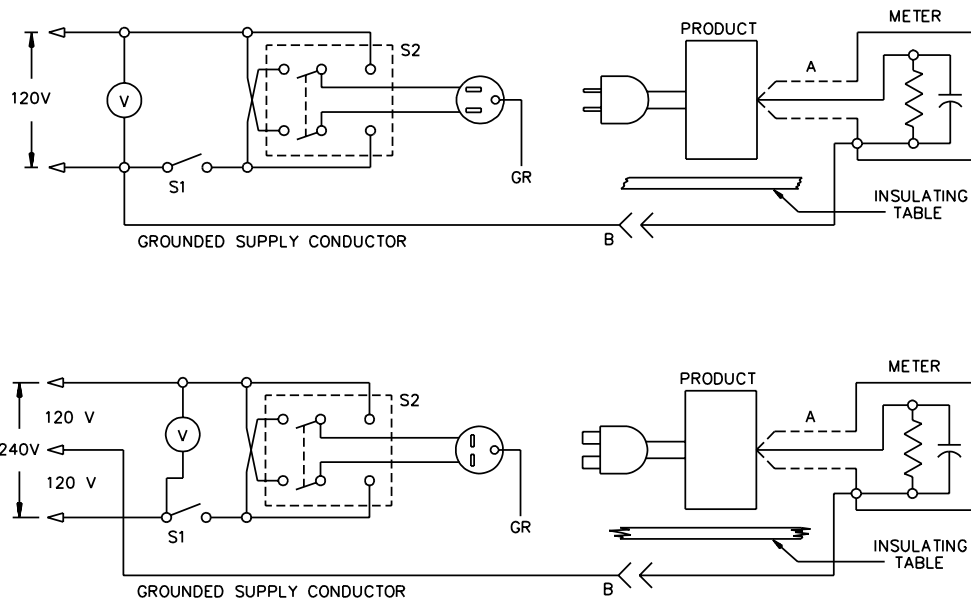
- a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 μ F.
- b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistance or current through the resistance.
- c) Over a frequency range of 0 – 100 kHz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) that is equal to the ratio of the impedance of a 1500-ohm resistance, shunted by a 0.15- μ 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.

22.5 A permanently connected ground-fault circuit-interrupter is to be connected to the supply by way of the terminals of the device, and tested in the same manner as a cord-connected device except that switches S1 and S2 are not to be employed.

22.6 A sample of the ground-fault circuit-interrupter is to be tested for leakage current after the conditioning described in 22.7. 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 permanently 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 22.1, 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 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.

Figure 22.1
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.

LC201E

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.

22.7 The conditioning mentioned in 22.6 and 21.1 is exposure to air at a relative humidity of 93 ± 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°C (86°F) until thermal equilibrium is attained before placed in the test chamber. A rainproof device is to be kept in the chamber for 168 hours. Other devices are to be kept in the chamber for 48 hours.

23 Voltage Surge Test

23.1 The sample shall be subjected to the following surge voltage impulses in the order given:

- a) Ten random applications or three controlled applications of a 6 kV surge impulse at 60 second intervals. Tripping of the ground-fault circuit-interrupter may result but there shall be no fire or shock hazard.
- b) Ten random applications or three controlled applications of a 3 kV surge impulse at 60 second intervals. Tripping of the ground-fault circuit-interrupter is not acceptable.

23.2 The sample is to be connected to a supply of rated voltage. The grounding lead or terminal of the sample is to be connected to the supply conductor serving as the neutral. The sample is to be in the "on" condition with no load connected. For each application, the voltage is to have the specified initial peak amplitude of 6 or 3 kV when applied to the 60 Hz supply to the unit under test. Each of the ten applications is to be random with respect to the phase of the 60 Hz supply voltage. If three controlled applications are employed, one application is to be at essentially zero of the supply voltage wave, one at positive peak and one at negative peak.

23.2 revised September 18, 2000

23.3 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:

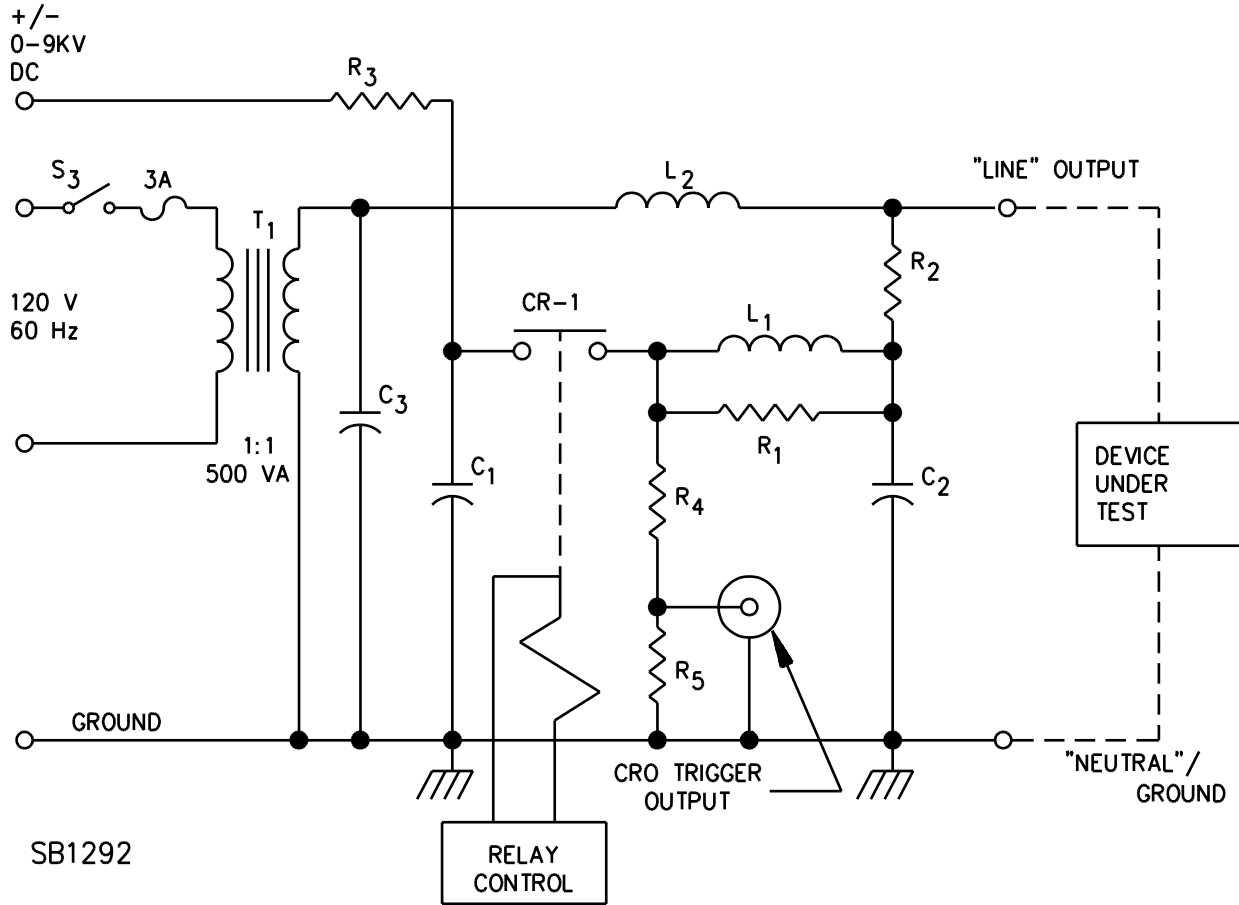
- a) Initial rise time, 0.5 microseconds between 10 percent and 90 percent of peak amplitude,
- b) The period of the following oscillatory wave, 10 microseconds, and
- c) Each successive peak, 60 percent of the preceding peak.

23.4 Figures 23.1 and 23.2 show a typical surge generator and control relay.

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Figure 23.1
Surge generator circuit

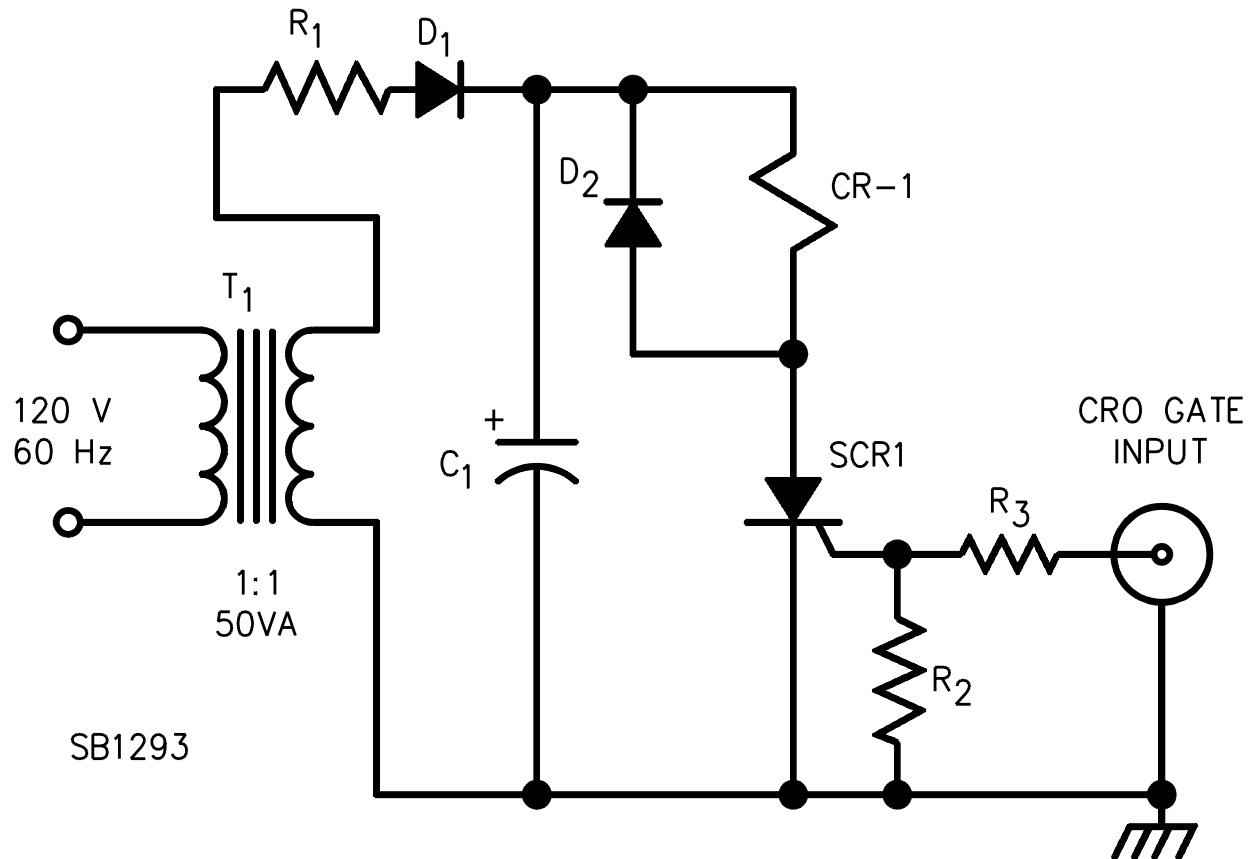
Figure 23.1 revised May 13, 1998



C1 =	0.025 μ F, 10 Kv	R1 =	22 Ohms, 1 W, composition
C2 =	0.01 μ F, 10 Kv	R2 =	12 Ohms, 1 W, composition
C3 =	4 μ F, 400 v	R3 =	1.3M Ohms (12 \times 110X Ohms, 1/2 W)
L1 =	15 μ H [23 turns, No. 23 AWG wire, 0.7 inch (18 mm) diameter air core]	R4 =	47K Ohms (10 \times 4.7 Ohms, 1/2 W)
L2 =	70 μ H [28 turns, No. 23 AWG wire, 2.6 inch (66 mm) diameter air core]	R5 =	200 Ohms, 1/2 W
		CR-1 =	Relay

Figure 23.2
Relay control circuit for surge generator

Figure 23.2 revised May 13, 1998



R1	=	10K Ohms, 1 W
R2	=	1K Ohms, 1/2 W
R3	=	1K Ohms, 1/2 W
C1	=	32 μ 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

24 High-Resistance Ground Faults Test

24.1 General

24.1.1 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 6 – 264 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.

24.1.2 A Class B 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 20 – 1,056 mA within the time interval T in accordance with the relationship:

$$T = \left(\frac{80}{I} \right)^{1.43}$$

in which T is expressed in seconds and I is expressed in milliamperes.

24.1.3 The trip times indicated in 24.1.1 and 24.1.2 correspond to a maximum nominal voltage to ground of 125 V.

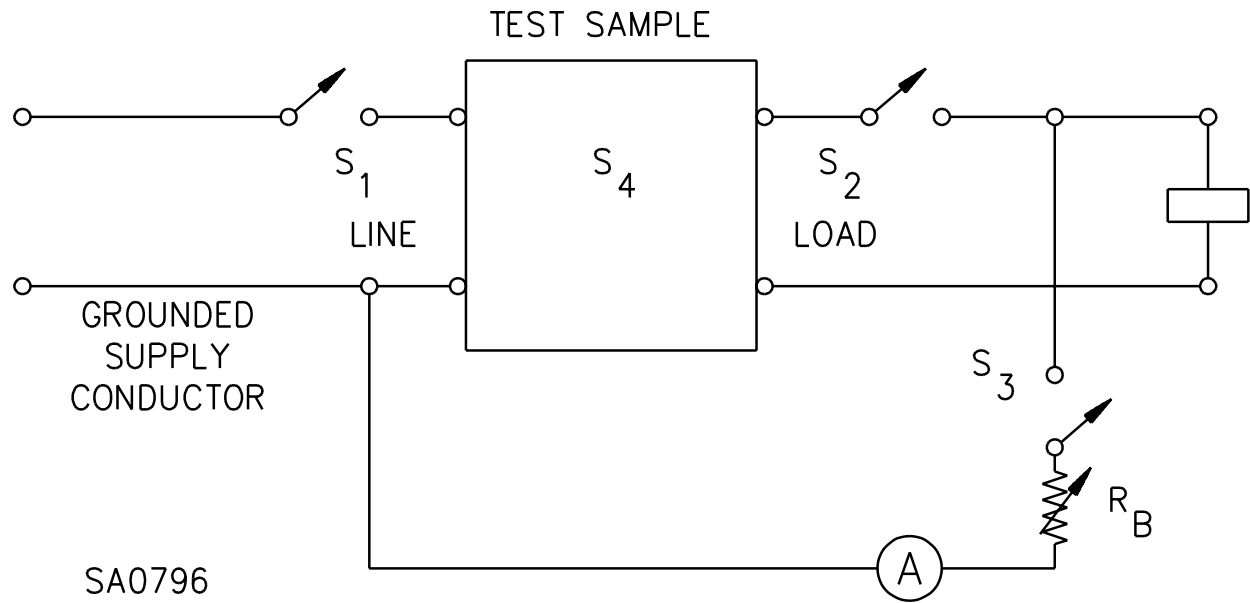
24.1.4 A cord-connected ground-fault circuit-interrupter shall comply with the provisions of 24.1.1 with and without one or more of the following defects in its power-supply cord:

- 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.

24.1.5 In order to determine compliance with the provisions of 24.1.1 – 24.1.4, a ground-fault circuit-interrupter is to be connected as shown in Figure 24.1 and tested as described in 24.2.1, in the sequence of steps described in Table 24.2.

Figure 24.1
High-resistance ground-fault test circuit

Figure 24.1 revised May 13, 1998



S₄ – Integral on-off or other operating switch (not test switch)

24.2 High-resistance ground fault test

24.2.1 In performing the test mentioned in 24.1.5, the resistance R_B is to be varied to obtain the test values of current to be indicated by meter A. The sum of R_B and the resistance of meter A is to be not less than (1) 500 ohms for a Class A and for a cord-connected ground-fault circuit-interrupter, and (2) 125 ohms for a Class B ground-fault circuit-interrupter. The test values of current are to include the minimum specified and the maximum possible according to the class and one or two additional values as may be considered necessary to assure compliance with the provisions of 24.1.1 – 24.1.4. 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 for the rated class. Individual measurements may exceed the time allowed for the rated class provided that such measurements do not exceed 125 percent of the time allowed for the rated class. The modes of operation noted in Table 24.1 are to be performed. For ground-fault circuit-interrupters intended to be used on 120/240 V circuits, the resistance is to be connected between each ungrounded load terminal, in turn, and the grounded conductor of the supply.

**Table 24.1
Modes of operation**

Table 24.1 revised April 2, 1996

Precondition of circuit		Action that starts ground-fault current
A	Switch S ₁ closed Switch S ₂ closed Switch S ₃ closed Switch S ₄ open	Switch S ₄ 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 ₁ open Switch S ₂ closed Switch S ₃ closed Switch S ₄ closed	Switch S ₁ closed.
C	Switch S ₁ closed Switch S ₂ open Switch S ₃ closed Switch S ₄ closed	Switch S ₂ closed.
D	Switch S ₁ closed Switch S ₂ closed Switch S ₃ open Switch S ₄ closed	Switch S ₃ closed ^a .
^a In obtaining the minimum value of current specified for the rated class, R_B is to be (1) decreased gradually until tripping occurs, and (2) preset for the desired value.		

24.2.2 It may be necessary to prevent tripping of the device under test while adjusting for various values of current in resistance R_B . 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.

24.2.3 In determining the "most adverse" conditions mentioned in Table 24.2, each of the operating parameters described in items a – e of this paragraph is to be varied 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 (1) a study of the design and, (2) if necessary, from operating the sample, provided that if it is necessary to operate the sample, that sample need not be subjected to any of the tests described in these requirements.

- 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) **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.
- c) **COVER POSITION** – Any cover or door normally moved or removed during operation or functioning of the device, or that can be moved or removed without the use of a tool, may be so moved or removed. Rated load is to be connected.
- d) **LOAD** – The load may have any value of current up to rated and is to be resistive.
- e) **GROUNDING** – A cord-connected device, and a permanently connected device not marked to indicate that it must be grounded, may be either grounded or ungrounded, whichever is more adverse.

Table 24.2
Test sequence for high-resistance ground faults and false tripping

Ambient air temperature ^a		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	Test per 24.1.5 and 25.2 as soon as possible to minimize self-heating.
3. ^b	66.0 ±2.0°C (150.8 ±3.6°F)	Rated voltage and current	Establish thermal equilibrium with at least two hours of exposure. Do not test.
4. ^b	66.0 ±2.0°C (150.8 ±3.6°F)	Most adverse	Test per 24.1.5 and 25.2.
5. ^c	40.0 ±2.0°C (104.0 ±3.6°F)	Rated voltage and current	Establish thermal equilibrium with at least two hours of exposure. Do not test.
6. ^c	40.0 ±2.0°C (104.0 ±3.6°F)	Most adverse	Test per 24.1.5 and 25.2.
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	Tests per 24.1.5 and 25.2 as soon as possible to minimize self-heating
10. ^d	-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. ^d	-5.0 ±2.0°C (23 ±3.6°F)	Most adverse	Tests per 25.2 as soon as possible to minimize self-heating
12.	25.0 ±5.0°C (77.0 ±9.0°F)	Rated voltage 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	Test per 24.1.5 and 25.2

^a The ambient air temperature is to be changed to each value shown without intentional delay.

^b 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, if possible.

^c This test is not to be performed if steps 3 and 4 have been performed employing rated current.

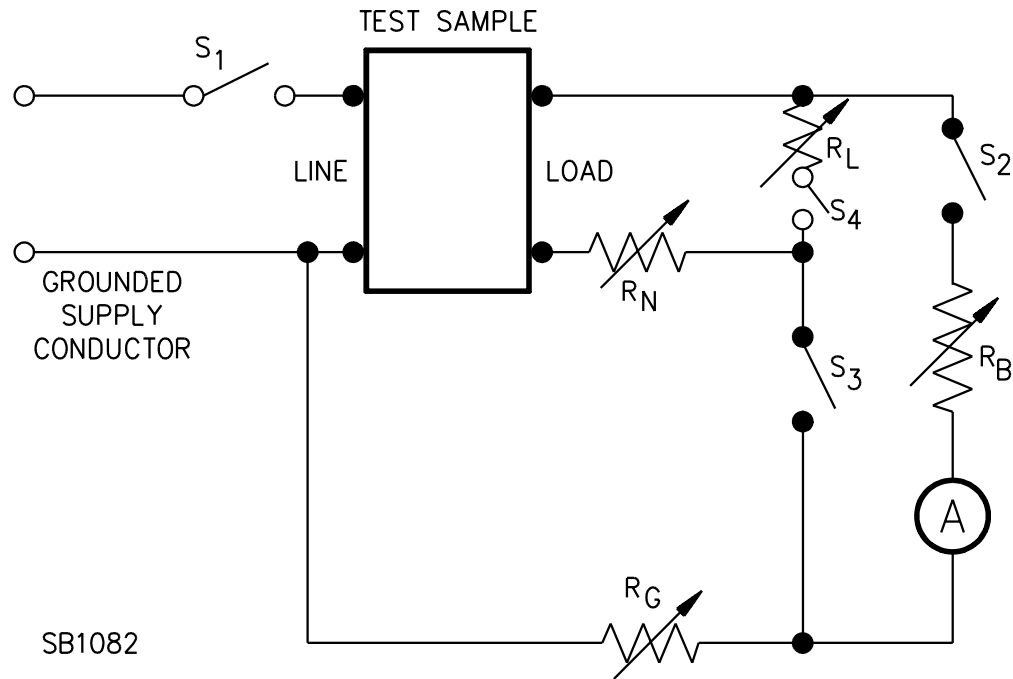
^d This test is not to be performed if product does not trip with less than 4 mA in step 9.

24.2.4 A ground-fault circuit-interrupter shall comply with the provisions of 24.1.1 – 24.1.4 when the circuit conductor that is normally grounded at the service only, is also grounded at a point in the load circuit of the ground-fault circuit-interrupter.

24.2.5 In determining compliance with the provisions of 24.2.4, the sample is to be connected as shown in Figure 24.2 and tested as described in 24.2.7 for each combination of R_N and R_G as indicated in Table 24.3. The tests are to be conducted both with R_L open and with R_L adjusted for rated current.

Figure 24.2
Supplementary high-resistance test circuit

Figure 24.2 revised May 13, 1998



SB1082

24.2.6 When testing as described in 24.2.7, 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 24.2.4. Such other values are to be in accordance with the rating of the product and the cable constructions represented in Table 24.3. The product is to trip within the time interval prescribed in 24.1.1 or 24.1.2.

24.2.7 The sample is to be tested following the procedure indicated in items a – c.

a) Close switch S1 and then switch S3. If the device does not trip, adjust resistance R_B to any value that will not cause tripping and close switch S2. Decrease resistance R_B until meter A reads 20 mA for a Class B device or 6 mA for other than a Class B device or the device trips. The device may trip with meter A indicating less than the specified values of current. Conduct procedures ten times.

b) Close switch S3 and then switch S1. If the device does not trip, adjust resistance R_B to any value that will not cause tripping and close switch S2. Decrease resistance R_B until meter A reads 20 mA for a Class B device or 6 mA for other than a Class B device or the device trips. The device may trip with meter A indicating less than the specified values of current. Conduct procedures ten times.

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c) With resistance R_B adjusted to cause 20 mA for a Class B device or 6 mA for other than a Class B device, close switches S2 and S3. Close switch S1. Conduct procedures ten times.

Table 24.3
Resistance in OHMS^a

Table 24.3 revised September 3, 1996

AWG copper wire size of field wiring ^b										
Combi- nation	Nos. 14 – 12		No. 10		No. 8		No. 6		No. 4	
	R_N	R_G	R_N	R_G	R_N	R_G	R_N	R_G	R_N	R_G
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

^a The combinations shown represent discrete lengths and constructions of cable or flexible cord. Resistances R_N and R_G represent respectively the resistance of the grounded and the grounding conductors of the cable or cord.

^b See paragraph 14.1.

25 Resistance to False Tripping Test

25.1 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.

25.2 In order to determine compliance with the provisions of 25.1, a ground-fault circuit-interrupter is to be connected as shown in Figure 25.1 with the impedance Z described in 25.3 or 25.4, and tested as described in (1) 25.6, in each of the steps shown in Table 24.2 and (2) 25.7. Switches S1 and S2 shown in Figure 25.1 are to be of the mercury-contact type or otherwise capable of (1) closing with minimum contact bounce and (2) opening with minimum clearing time. They may control both conductors if that is more adverse.

25.3 With a Class B ground-fault circuit-interrupter, the impedance Z indicated in Table 25.1 is to be employed.

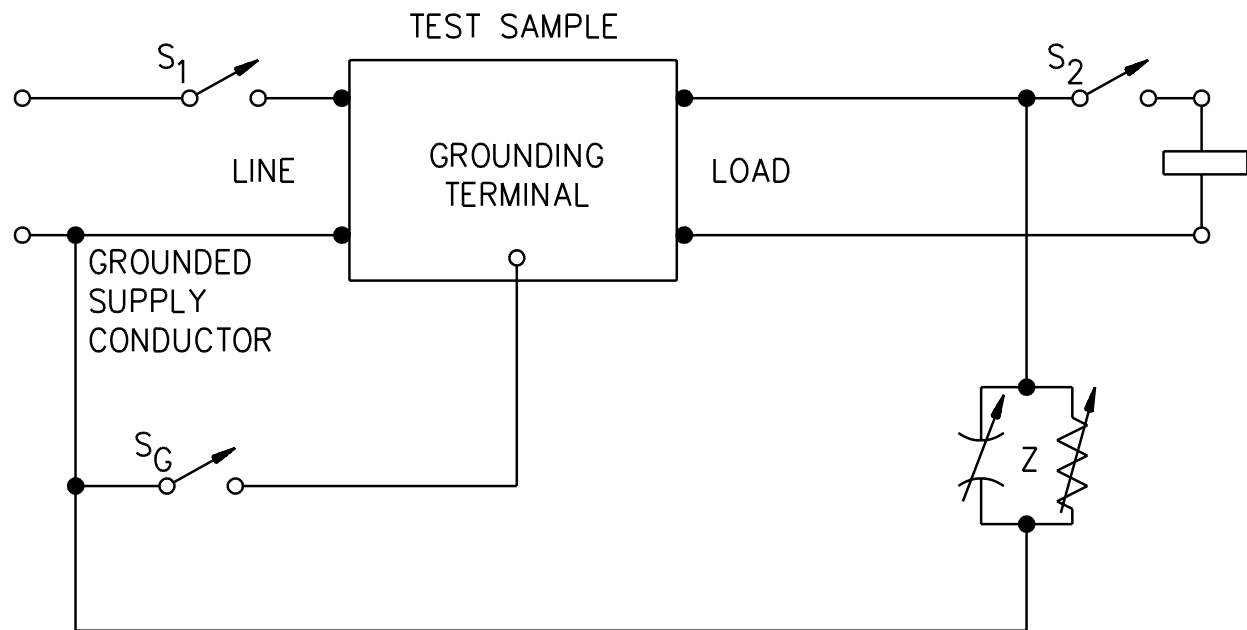
Table 25.1
Impedance

Table 25.1 revised January 4, 1995

Marked length ^a of conductor run in feet (meters)	Components of Z	
	Class B	
	Minimum resistance in ohms	Capacitance in microfarads
Not over 100 (30)	20,000	0.010 or none
Over 100 but not over 150 (46)	13,300	0.015 or none
Over 150 but not over 175 (53)	11,400	0.0175 or none
Over 175 but not over 200 (61)	10,000	0.020 or none
Over 200 but not over 250 (76)	8,000	0.025 or none

^a Marked length to comply with the provisions of 39.2.3 item 2. The length of conductor run is the total one-way length of the conductors from the ground-fault circuit interrupter at every part of the load circuit.

Figure 25.1
False-tripping test circuit



SA0798

25.4 With a device other than Class B, the components of impedance Z are to be as indicated in Table 25.2.

Table 25.2
Impedance (Z)

Ground-fault circuit-interrupter	Components of Z	
	Resistance in ohms	Capacitance in microfarads
Plug Connected	80,000	0.012 or none
Class A	64,000	0.015 or none

25.5 A ground-fault circuit-interrupter with an adjustable control shall comply with the provisions of 25.1 for at least one setting of the control.

25.6 The tests mentioned in 25.2 are as follows:

- a) Under the "most adverse" conditions described in 25.9, the device is not to trip while operating continuously,
- b) Under the "most adverse" conditions described in 25.9, the device is not to trip more than three times in ten operations of each switch S1 and switch S2, and
- c) Under the "most adverse" conditions described in 25.9, a device other than Class B is not to trip at less than 4 mA. The device may trip at less than 4 mA but not less than 3.5 mA when the temperature of the ambient air is less than minus 5°C (plus 23°F) or more than 40°C (104°F). The impedance Z is gradually reduced until the ground-fault circuit-interrupter trips. The capacitive component of Z is to be disconnected and switches S1 and S2 are to be closed. The procedure is to be conducted three times under each of the "most adverse" conditions.

25.7 The tests mentioned in 25.2 are as follows:

- a) Under the "normal" conditions described in 25.8, the device is not to trip more than three times in 100 operations of each switch S1 and S2, and
- b) Under the "normal" conditions described in 25.8, 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.

25.8 Normal conditions called for in 25.7 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.

25.9 In determining the "most adverse" conditions mentioned in Table 24.2, each of the operating parameters described in items a – f of this is to be varied 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 (1) a study of the design and, (2) if necessary from operating the sample, provided that if it is necessary to operate the sample, that sample need not be subjected to any of the tests described in these requirements. An adjustable control, if provided, is not to be adjusted after having started the tests specified in 25.2.

- a) **LINE VOLTAGE** – The voltage is to be adjusted within the range of 85 – 110 percent of rated voltage, with the covers (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) **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 which 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.
- c) **COVER POSITION** – Any cover or door normally moved or removed during operation or functioning of the device, or that can be moved or removed without the use of a tool, may be so moved or removed. Rated load is to be connected.
- d) **LOAD** – The load may have any value of steady-state current up to rated. For a Class A device, the load may be appliances, tools, underwater swimming-pool lighting fixtures or other utilization equipment. For a Class B device, the load is to be underwater swimming-pool lighting fixtures or the equivalent. See 32.8.
- e) **CAPACITIVE LEAKAGE** – The value of capacitance (selected from Table 25.1) may be connected or omitted.
- f) **GROUNDING** – If a permanently connected device is not marked to indicate that it must be grounded, ground-lead switch SG may be open or closed.

26 Resistance to Environmental Noise Test

26.1 A ground-fault circuit-interrupter shall resist tripping from the effects of an RF signal varied from 10-450 MHz and function properly when tested in accordance with 26.2 – 26.5.

26.2 The test circuit for environmental electrical noise is to be as shown in Figure 26.1. The test equipment is defined in Items a – d of this paragraph.

a) RF Signal Generator

Frequency Range: 10 to 450 MHz min

Accuracy: $\pm 3\%$ after warm-up

Modulation: Continuous Wave (CW)

Adjustable Output Attenuator

Spectral Purity:

Harmonic distortion (output power $\pm + 3$ dBm): < -20 dBc.

Spurious output signals, subharmonically and nonharmonically related (excluding line related): <-100 dBc.

Residual AM (average rms): -55 dBc in a 50 Hz to 15 kHz post-detection noise bandwidth.

Residual FM on CW (averaged rms deviation): <0.3 ppm in a 0.3 to 3 kHz post-detection noise bandwidth: <0.5 ppm in a 50 Hz to 15 kHz post-detection noise bandwidth.

Output Voltage: Is to be capable of delivering 0.5 V rms min across a 51 ohm resistive load.

b) High Frequency Voltmeter

Frequency Range: 10 to 450 MHz min

Voltage Range: Is to have a range suitable for measuring a value of 0.5 V rms to an accuracy of $\pm 3\%$.

Input Impedance: $>10M$ ohm shunted by 1.5 pF or less capacitance.

c) RF Coupling Fixture

The RF coupling fixture is to be constructed in accordance with Figure 26.2. Modifications to the Coupling Fixture which may be required by the product configuration are to comply with 26.3. The bill-of-materials for the fixture appears in Table 26.1.

d) Isolation Transformer

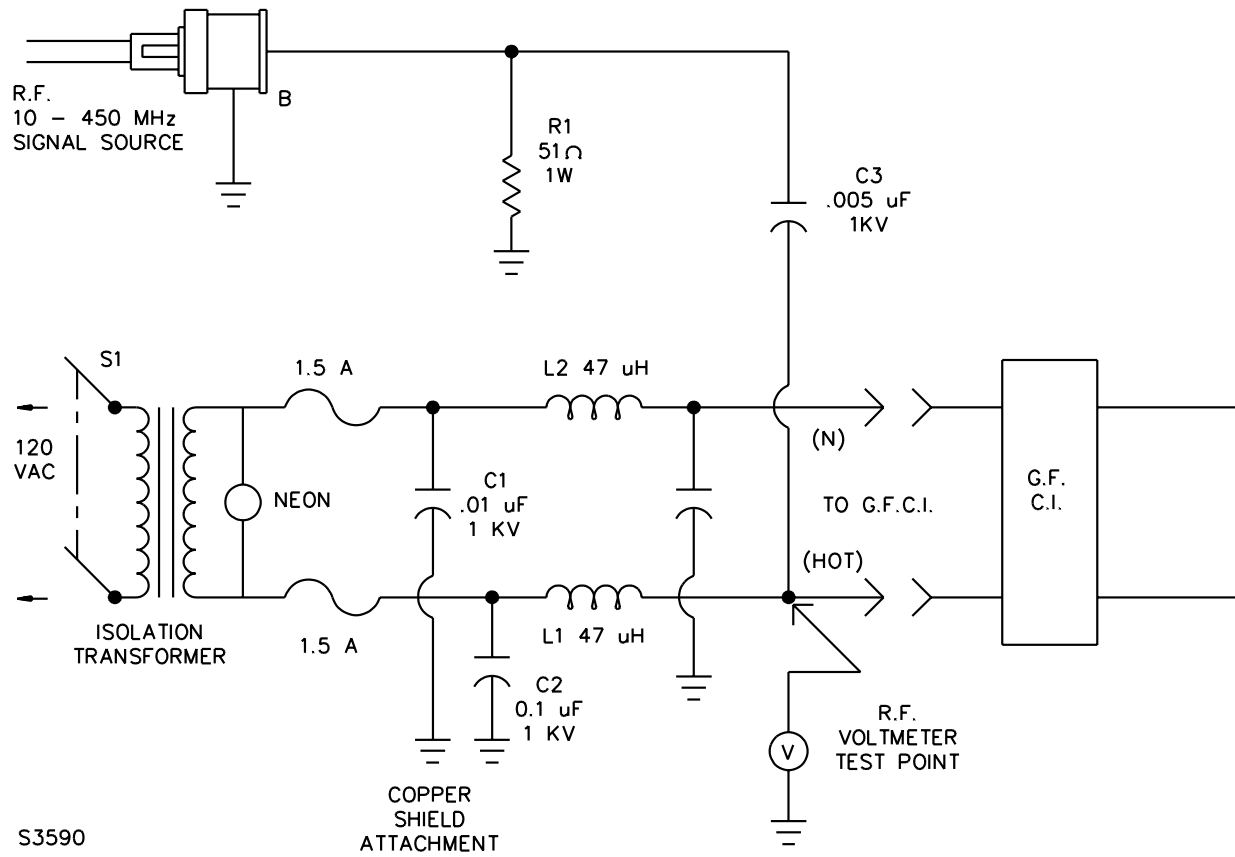
Secondary Voltage: Rated voltage for the GFCI under test.

Frequency: 50/60 Hz

VA: 225 min

Triad-Utrad N55M or equivalent

Figure 26.1
Environmental electrical noise test schematic diagram



S3590

Figure 26.2
RF coupling fixture

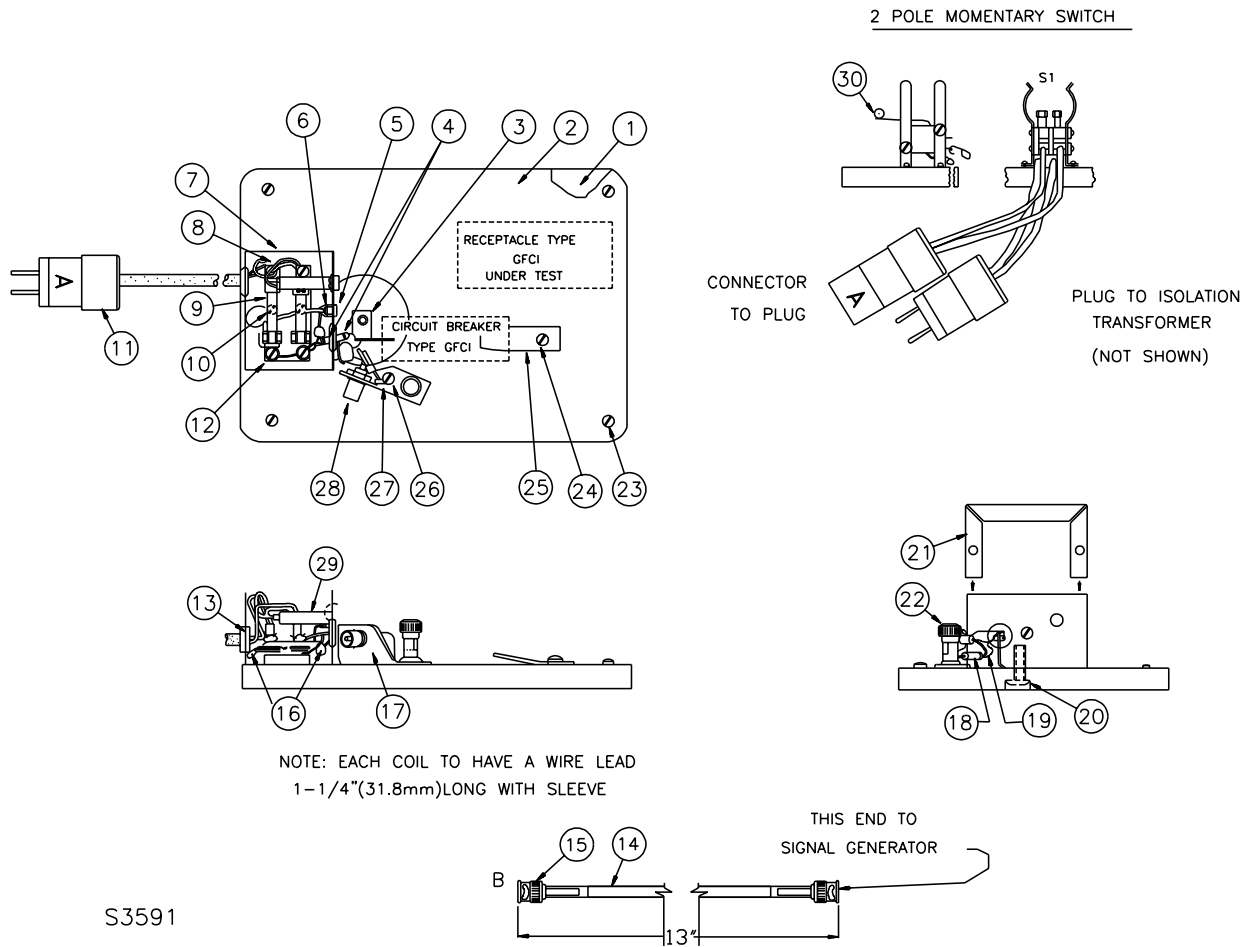


Table 26.1
Bill of materials

Item	Material or part no. All dimensions in inches (mm)	Reference	Qty.	Description
1	Lexan 8.75 × 6.12 × .50 (222 × 155 × 12.7)			Base
2	Copper, 8.75 × 6.12 × 0.31 (222 × 155 × 0.8)			Base Plate
3	Copper, .075 (1.9) Thick			Stab
4	.170 dia × .400 (4.3 × 10.2)	L1 & L2	2	Coil 47 μh
5	#6-40 × 0.37 (3.5 – 0.5) Long			Screw and Nut
6	Copper			Terminal Solder
7	Aluminum, 2.26 × 2.00 × 1.60 (66.5 × 50.8 × 40.6)			Lug Box
8	Quick disconnect terminal		2	Terminal Lug
9	3 AMP/125V S.B.		2	Fuse
10	#10-32 (4.8 – 0.08)		2	Mounting Screw
11	120V Polarized			Plug & Cord (2 Wire)
12	Fuse Block			Fuse Block (2 Fuse)
13	Rubber		2	Grommet
14	RG-58 C/U Coaxial Cable × 13 (330) Long			Wire
15	BNC Connector, Male		2	Coax Connector (Male)
16	0.1 μf/1 kV Ceramic Disc	C1, C2	2	Capacitor
17	Aluminum			Bracket
18	51 ohm 1 W Carbon Composition	R1		Resistor
19	.005 μf/1 kV	C3		Capacitor
20	Brass .25-20 × .75 (6.35 – 20 × 19.1) Long			Screw
21	2.75 × 2.15 × 1.65			Cover, Box
22	Fast clamp			Terminal
23	#8 × 0.37 (4.2 × 9.5) Long		4	Screw
24	#8 × 0.50 (4.2 × 12.7) Long			Screw
25	Aluminum, 1.75 × .540 × .070 (45.2 × 13.7 × 1.8)			Hold down for Breaker Type GFCI
26	#10-32 (4.8 – 0.8)			Screw
27	#8 (4.2)			Solder Lug
28	BNC Connector, Female			Coax Connector (Female)
29	125V, 1/3 W Neon			Light & Clip
30	2-Pole 125V, Normally Open	S1		Momentary Switch

26.3 If the ground-fault circuit-interrupter contains integral wire connections, they are not to be shortened, lengthened, or altered in any way when connected to the test equipment. GFCI's employing field wiring terminals are to be connected to the fixture with No. 14 AWG (2.1 mm²) solid wire leads, 6 ±1/2 inches (152 ±13 mm) long.

26.4 Prior to initiation of the test, the signal generator and amplifier are to warm up and stabilize.

26.5 The test sequence, with reference to the test circuit in Figure 26.1, is as follows:

- a) With switch S1 open, the line terminals of the test GFCI are to be connected to the test fixture of Figure 26.2, observing proper polarity.
- b) Set the signal generator to the first test frequency. Connect the voltmeter to the voltmeter test point. The GFCI under test is to be in the "tripped" or "off" position while setting up the RF Voltage to prevent loading effect on the RF generator. (If necessary the test GFCI may be removed from the test fixture while setting the RF voltage).
- c) Adjust the output of the amplifier until the voltmeter reads 0.5 V rms $\pm 5\%$. Disconnect the voltmeter from the voltmeter test point.
- d) Turn "on" or reset the GFCI under test. Close switch S1 to apply rated voltage to the GFCI. The GFCI's shall not trip for a period of 30 s after application of the ac voltage and RF signal.
- e) Depress the test switch to energize the supervisory circuit of the GFCI under test. The GFCI shall trip.
- f) Open switch S1, and set the signal generator to the next test frequency given in Table 26.2. Repeat steps b – e until the GFCI has been evaluated at each of the test frequencies given in Table 26.2.

Table 26.2
Test frequencies

Test no.	Frequency mHz ± 5 percent
1	10
2	12
3	14
4	18
5	20
6	25
7	30
8	35
9	45
10	50
11	60
12	75
13	90
14	100
15	120
16	150
17	175
18	200
19	250
20	300

Table 26.2 Continued on Next Page

Table 26.2 Continued

Test no.	Frequency mHz \pm 5 percent
21	350
22	450

27 Regulation Test

27.1 The inherent regulation of a ground-fault circuit-interrupter at rated input voltage shall be such that the difference between output voltage at no load and output voltage at maximum rated current shall not be more than two percent of the output voltage at rated current.

28 Normal Temperature Test

28.1 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 28.1, 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. Loads are to be connected to the load terminals to cause the load conductors, including the neutral conductor, to carry rated current.

28.2 In performing the test described in 28.1, 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.

28.3 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) or unless the coil wrap includes thermal insulation, such as asbestos, or more than two layers (1/32 inch or 0.8 mm maximum) of cotton, paper, rayon, or the like. At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise measured by means of a thermocouple may be 10°C (18°F) more than the indicated maximum, provided that the temperature rise of the coil, as measured by the resistance method is no more than that specified in Table 28.1.

28.4 Except at coils, temperature readings are to be obtained by means of thermocouples consisting of wires not larger than No. 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 No. 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.

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

28.6 The thermocouples and related instruments are to be accurate and calibrated in accordance with accepted laboratory practice. The thermocouple wire is to conform with the requirements specified in the Initial Calibration Tolerances for Thermocouples table in "Temperature-Measurement Thermocouples", ANSI/ISA MC96.1(1982).

Table 28.1
Maximum acceptable temperature rises

Table 28.1 revised May 13, 1998

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 ^a	117 ^a
Resistance method	75 ^a	135 ^a
8. Molded phenolic composition	100 ^b	180 ^b
9. Rubber- or thermoplastic-insulated wires and cords	35 ^b	63 ^b
10. Accessible surfaces	35	63
11. Semiconductor junction	c	c
12. Electrolytic capacitor ^d	40	72

^a See 28.3

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

^c The temperature T_J at a semiconductor junction is related to the power P_J dissipated at the junction, the thermal resistance K_{TH} 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:

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

^d A capacitor operating at a higher temperature may be accepted on the basis of its marked temperature rating.

29 Dielectric Voltage-Withstand Test

29.1 In a ground-fault circuit-interrupter, except as described in 29.2, the insulation and spacings between (1) line-connected circuits, and (2) other circuits and accessible parts shall withstand without breakdown the test potentials shown in Table 29.1. The functional insulation and spacings of other circuits too shall withstand without breakdown the test potentials shown in Table 29.1, except that where the potential does not exceed 70 V peak in normal service, the test potential is to be 500 V. See 21.1.

Table 29.1
Dielectric voltage-withstand

Insulation tested	Potential (Volts)
Functional	1500a
Supplementary	2500
Reinforced	4000

^a 900 V across the dielectric of a capacitor.

29.2 Functional insulation and spacings inherent in a component need not withstand the test potentials mentioned in 29.1 if the component in question complies with the requirements applicable to the component.

29.3 In order to determine compliance with the provisions of 29.1, the insulation and spacings are to be subjected to 60 Hz essentially sinusoidal 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.

29.4 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.

29.5 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.

30 Overload and Motor Starting Test

30.1 A ground-fault circuit-interrupter shall have necessary interrupting capacity. In addition, a Class A and a cord-connected device shall not trip as a result of motor starting.

30.2 In order to determine compliance with the provisions of 30.1, a Class A or a cord-connected device is to 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.

30.3 Reactive components of the impedance mentioned in 30.2 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.

30.4 The value of paralleled resistance R in ohms mentioned in 30.3 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.

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

30.5 The supply circuit for the test mentioned in 30.2 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. 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.

30.6 In performing the test mentioned in 30.2 the device is to be switched "on" and, after one second, switched "off", for a total of 25 cycles of operation, at the rate of six cycles per minute.

Exception No. 1: If the device operation will not permit these cycle times, times as close as possible to these are to be used.

Exception No. 2: If it is determined that for a duration less than one second, (1) the device conducts the test current without interrupting the circuit or being adversely affected by heat, and (2) 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.

30.7 A Class B ground-fault circuit-interrupter is to be caused to switch 25 times a tungsten-filament lamp load, or the equivalent, adjusted for 150 percent of rated current. The number of lamps is to be the smallest possible, using lamps of standard wattage ratings, providing that no lamp used is to be rated more than 500 W without the agreement of the submitter. The ground-fault circuit-interrupter is to be operated at a rate not to exceed ten times per minute provided that lamps, if used, are to be allowed to be "off" at least 55 seconds before being energized. Tripping is allowed. See 32.8.

31 Low-Resistance Ground Fault Test

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

31.2 In order to determine compliance with the provisions of 31.1 the circuit is to be as described in 30.5. 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 31.1 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 31.1) 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

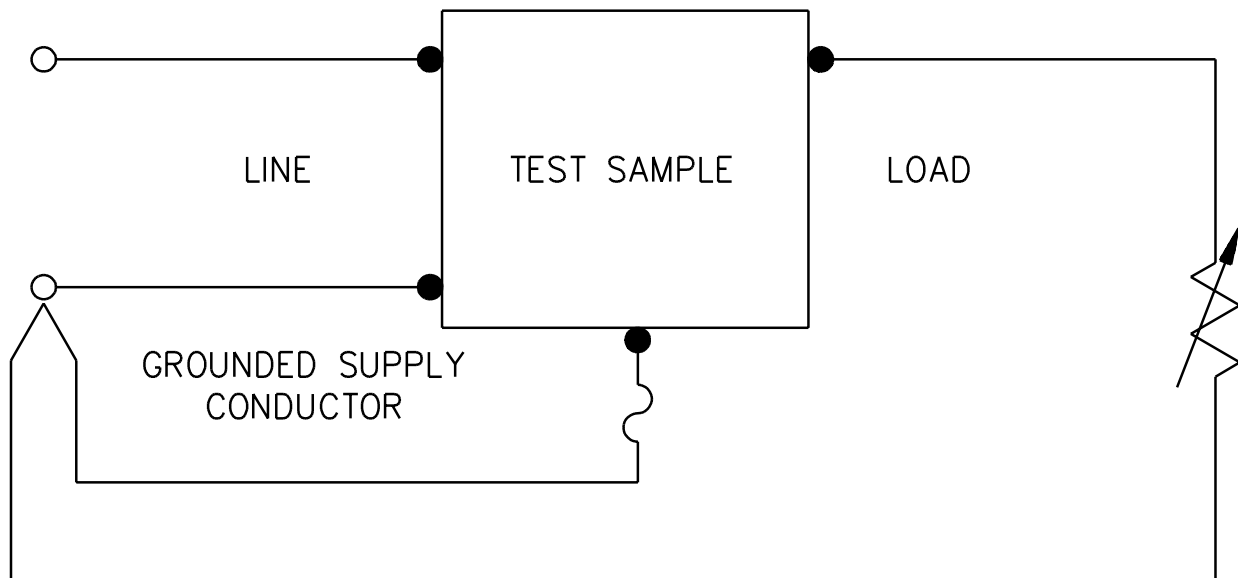
$$T = 1.25 \left(\frac{10}{V} \right)^{1.43}$$

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 31.1
Low-resistance ground-fault test circuit



SA0799

32 Endurance Test

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

32.2 Except as permitted in 32.7, in order to determine compliance with 32.1, 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.

32.3 In performing the test described in 32.2, 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. An additional 3000 cycles are to be performed with automatic tripping by way of the supervisory circuit.

32.4 Reactive components of the load mentioned in 32.2 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.

32.5 The value of paralleled resistance R in ohms mentioned in 32.4 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.

32.6 In performing the test described in 32.2, 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.

32.7 A Class B ground-fault circuit-interrupter need be tested only with a tungsten-filament lamp or equivalent load adjusted for rated current under steady-state conditions. The number of lamps is to be the smallest possible using lamps of standard wattage ratings, provided that no lamp is rated more than 500 W without agreement of the submitter. Lamps are to be "off" at least 55 seconds.

32.8 In performing the test mentioned in 25.9, 30.7, and 32.7, the supply circuit shall be capable of providing a peak current not less than 14.1 times the rms value of steady-state current in the load, within 1/240 second after the current is initiated. The voltage is to be as described in 32.6.

32.9 A sample that has been subjected to an endurance test need not withstand any other of the tests described in these requirements.

32.10 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.

33 Abnormal Operation Test

33.1 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.

33.2 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.

33.3 The cheesecloth mentioned in 33.2 is to be bleached cheesecloth running 14–15 square yards per pound mass, (approximately 26–28 square meters per kilogram mass), and having 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 (for any square centimeter, 13 threads in one direction and 11 in the other direction.)

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

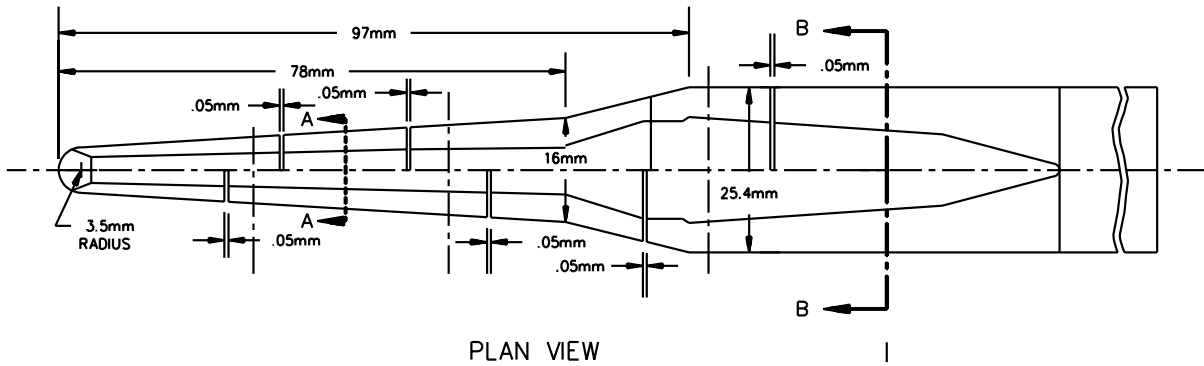
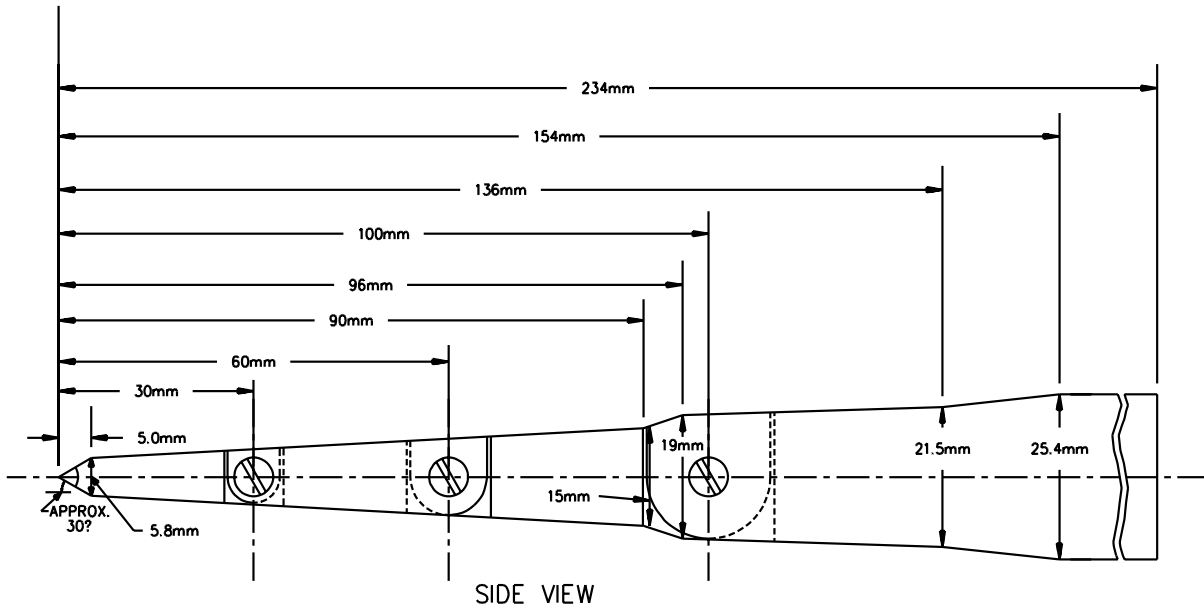
- a) There is glowing or flaming of the cheesecloth or tissue paper mentioned in 33.2, or
- b) There is emission of molten metal, or
- c) The fuse mentioned in 33.2 operates to open the circuit, or
- d) Except if the device is likely to be removed from service, there is dielectric failure (see 33.6 and 33.7), or
- e) It is possible to touch a part with the articulated probe shown in Figure 33.1 while there is a shock hazard at that part, or
- f) There is any other evidence of hazard.

33.5 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 24.1.1 – 24.1.4.

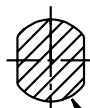
33.6 Failure to comply with the provisions of 29.1 will be considered to be dielectric failure.

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

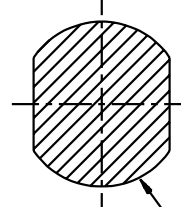
Figure 33.1
Articulated probe



HIGH IMPACT POLYSTYRENE
ARTICULATE PROBES ARE
AVAILABLE FROM UNDERWRITERS
LABORATORIES INC.

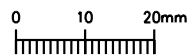


SECTION A-A



SECTION B-B

SC1005-1



34 Extra-Low-Resistance Ground Faults Test

34.1 A ground-fault circuit-interrupter shall withstand extra-low-resistance ground faults.

34.2 In order to determine compliance with the provisions of 34.1, 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 34.3 or 34.4.

34.3 In testing a permanently connected ground-fault circuit-interrupter, the prospective current is to be 5000 A and the power factor is to be within the range of 0.45 – 0.50.

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

34.3 revised December 16, 1994

34.4 In testing a cord-connected ground-fault circuit-interrupter, the prospective current is to be 2000 A and the power factor is to be within the range of 0.9 – 1.0.

34.5 Each line terminal of a ground-fault circuit-interrupter is to be connected to the supply mentioned in 34.2 using 4 ft (1.2 m) of insulated wire, both selected in accordance with Table 34.1. A fuse is to be connected in series with the ungrounded line conductor. An identical conductor is to be connected between a load terminal and a line terminal of the device 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 34.1.

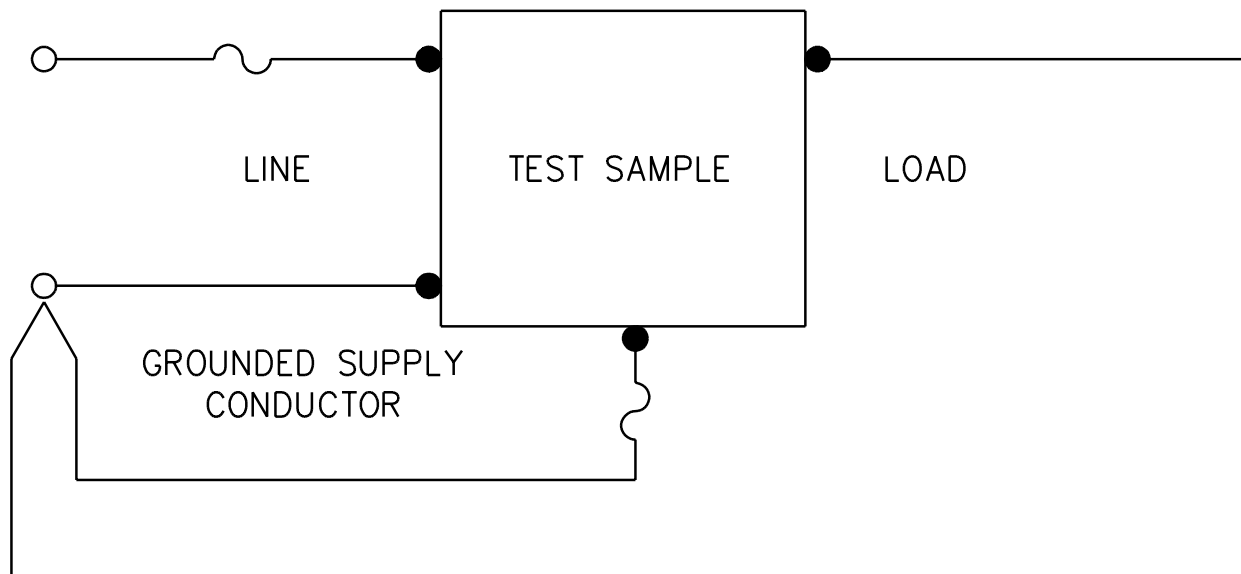
Table 34.1
Fuse and wire

Ground-fault circuit interrupter rating, amperes		Series fuse amperes	AWG conductor size
Cord-connected	Permanently connected		
–	15	15	14
15 or 20	20	20	12
30	30	30	10

34.6 For a cord-connected 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.

34.7 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 34.5.

Figure 34.1
Extra-low-resistance ground-fault test circuit



SA0800

35 Short Circuit Test

35.1 A ground-fault circuit-interrupter shall withstand short circuits.

35.2 In order to determine compliance with the provisions of 35.1, conditions are to be as described in 34.2 – 34.5, except that:

- a) The ground fault described in 34.5 is not to be connected, and
- b) A 20 inch (0.51 m) length of wire of the same construction as the line conductors is to be connected between load terminals.

35.3 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 34.5.

36 Chromic Acid Dropping Test

36.1 The solution to be used for the chromic acid dropping test is to be made from distilled water and is to contain 200 grams per liter of reagent grade chromic acid (CrO_3) and 50 grams per liter of reagent grade concentrated sulfuric acid (H_2SO_4). (The latter is equivalent to 27 milliliters per liter of reagent grade concentrated sulfuric acid, specific gravity of 1.84, containing 96 percent of H_2SO_4 .)

36.2 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube of approximate 0.025 inches (0.64 mm) inside bore and 5.5 inches (140 mm) long. The lower end of the capillary tube is tapered to form a tip, the drops from which are about 0.05 mL each. To preserve an effectively constant level, a small glass tube is inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that, when the stopcock is open, the rate of dropping is 100 ± 5 drops per minute. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

36.3 The sample and the test solution should be kept in the test room long enough to acquire the temperature of the room, which should be noted and recorded. The test is to be conducted at a room temperature of 70 – 90°F (21 – 32°C).

36.4 Each sample is to be thoroughly cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings are to be removed completely by means of acceptable solvents. Samples are then to be thoroughly rinsed in water and dried with clean cheesecloth. Care should be exercised to avoid contact of the cleaned surface with the hands or any foreign material.

36.5 The sample to be tested is to be supported 0.7 – 1 inch (17 – 25 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested should be inclined about 45 degrees from horizontal.

36.6 After cleaning, the sample to be tested is to be put in place under the orifice. The stopcock is to be opened and the time in seconds is to be measured with a stop watch until the dropping solution dissolves off the protective metal coating, exposing the base metal. The end point is the first appearance of the base metal recognizable by the change in color at that point.

36.7 Each sample of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface, at places where the metal coating may be expected to be the thinnest. On enclosures made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

36.8 To calculate the thickness of the coating being tested, select from Table 36.1 the thickness factor appropriate for the temperature at which the test was conducted and multiply by the time in seconds required to expose base metal as noted in 36.6.

Table 36.1
Coating thickness factors

Temperature,		Thickness factors, 0.00001 inch (0.00025 mm) per second	
°F	(°C)	Cadmium platings	Zinc platings
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

37 Dust Test

37.1 To determine compliance with footnote b in Table 18.1, 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 3 cubic feet (0.09 m³).

37.2 Two oz (0.06 kg) 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 50 fpm (0.25 m/s).

37.3 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 18.1.

37A Permanence of Marking

Added Section 37A effective July 4, 1995

37A.1 An adhesive backed label as mentioned in 39.1.2 and 39.2.2 shall comply with the Standard for Marking and Labeling Systems, UL 969.

37A.2 Labels required by 39.2.2 that come in contact with uninsulated live parts shall be of a nonconductive material that complies with the Dielectric Breakdown Test, Section 8, the Moisture Absorption Test, Section 10 and the Test for Indirect Measurement of Conductor Corrosion, Section 15, of the Standard for Electrical Insulating Tape, UL 510.

MARKINGS

38 Details

Section 38 Title revised January 4, 1995

38.1 General

Sub-heading 38.1 added and replaces 38.1 which has been relocated as added 39.1.1 January 4, 1995

38.1.1 A ground-fault circuit-interrupter shall be marked with the manufacturer's name, trademark, or other suitable means of identification and the electrical ratings in voltage, frequency, and load capacity in amperes. The load-capacity marking of a cord-connected ground-fault circuit-interrupter shall include watts.

38.13 relocated as added 38.1.1 January 4, 1995

38.1.2 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.

Exception: The date of manufacture may be abbreviated, or may be in a nationally accepted conventional code, or in a code affirmed by the manufacturer, provided that the code:

- a) Does not repeat in less than 20 years, and*
- b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.*

38.18 relocated as added 38.1.2 January 4, 1995

38.1.3 An enclosure that has been found to be rainproof may be marked "Rainproof".

39.9 relocated as added 38.1.3 January 4, 1995

38.2 Permanently connected ground-fault circuit-interrupters

Sub-heading 38.2 added and replaces 38.2 which has been relocated as added 39.2.9 January 4, 1995

38.2.1 Except if suitable wire connectors are packed with a ground-fault circuit-interrupter employing terminal leads, the gauge of the terminal leads shall be marked on the device.

39.8 relocated as added 38.2.1 January 4, 1995

38.2.2 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 1/8 inch (3.2 mm) high with the words: "Do not use where exposed to rain", or the equivalent.

39.7 relocated as added 38.2.2 January 4, 1995

38.2.3 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.

39.10 relocated as added 38.2.3 January 4, 1995

38.2.4 A permanently connected ground-fault circuit-interrupter shall have its terminals legibly and permanently marked "Line" and "Load", and "Hot" and "White" as appropriate. 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" and "Load", and "Hot" and "White" or "Gray" as appropriate.

Added 38.2.4 effective November 13, 1998

38.2.5 A permanently connected ground-fault circuit-interrupter shall be marked in letters at least 1/8 inch (3.2 mm) high:

"For use on grounded circuits".

For a Class A device:

"To minimize false tripping do not connect to swimming-pool equipment installed before adoption of the 1965 National Electrical Code," and

For a Class B device:

"1. Use only with underwater swimming-pool lighting fixtures installed before adoption of the 1965 National Electrical Code. CAUTION – To prevent electrical shock, disconnect power before servicing fixtures.

"2. To minimize false tripping: Do not connect to more than (____) feet (and/or ____ meters) of load conductor for the total one-way run". The blank shall be filled in with the appropriate length, in accordance with Table 39.1. See also 25.3.

39.2.3 relocated as added 38.2.5 May 13, 1998

38.2.6 Marking of a permanently connected ground-fault circuit-interrupter shall include the Class.

39.2.12 relocated as added 38.2.6 May 13, 1998

38.3 Portable ground-fault circuit-interrupters

Sub-heading 38.3 added and replaces 38.3 which has been revised and relocated as added 39.1.2 January 4, 1995

38.3.1 A cord-connected ground-fault circuit-interrupter shall be marked in letters at least 1/8 inch (3.2 mm) high, with the word "WARNING" and the following or equivalent wording, "To reduce the risk of electric shock the supervisory circuit must be operated before an appliance is plugged into any receptacle on the device. The marking shall describe the indication given by operation of the supervisory circuit and inform the user that, in the event of an indication of improper functioning, the cause of the malfunction is to be corrected before further use of the device.

38.11 relocated as added 38.3.1 January 4, 1995

38.3.2 A cord-connected device shall be marked with a statement to the effect that the device does not guard against electric shock resulting from:

- a) Some possible defects or faults in an extension cord or other wiring supplying the ground-fault circuit-interrupter, or
- b) Contact with both circuit conductors.

38.16 relocated as added 38.3.2 January 4, 1995

38.3.3 A cord connected ground-fault circuit-interrupter not provided with a permanently attached cord 6 ft (1.83 m) or longer in length, shall be marked with the following or equivalent wording "This product should be used only with a three-conductor, 120 volt, ____ ampere (15, 20, or 30 A) supply cord set employing Type ST, SO, STO, SJT, SJO, or SJTO cord. In event of cord set damage, it should be replaced only with an equivalent cord set".

38.17 relocated as added 38.3.3 January 4, 1995

38.3.4 Unless a cord-connected ground-fault circuit-interrupter has been found suitable for use in wet locations, it shall be marked "Do not use where water is likely to enter case" or the equivalent.

38.15 relocated as 38.3.4 January 4, 1995

38.4 Deleted effective July 4, 1995

38.5 Deleted effective July 4, 1995

38.6 Deleted effective July 4, 1995

38.7 Deleted effective July 4, 1995

38.8 Revised and relocated as added 39.2.10 January 4, 1995

38.9 Revised and relocated as added 39.2.11 January 4, 1995

38.10 Relocated as added 39.2.12 January 4, 1995

38.11 Relocated as added 38.3.1 January 4, 1995

38.12 Relocated as added 39.2.13 January 4, 1995

38.13 Relocated as added 38.1.1 January 4, 1995

38.14 Relocated as added 39.2.8 January 4, 1995

38.15 Relocated as added 38.3.4 January 4, 1995

38.16 Relocated as added 38.3.2 January 4, 1995

38.17 Revised and relocated as added 38.3.3 January 4, 1995

38.18 Relocated as added 38.1.2 January 4, 1995

39 Installation Instructions

39.1 General

Sub-heading 39.1 added and replaces 39.1 which has been relocated as added 39.2.1 January 4, 1995

39.1.1 There shall be plain, legible, and durable instructions for effective use of a ground-fault circuit-interrupter. Whenever possible, such instructions are to appear on the device, and be so located that they may be readily viewed without the use of tools, and while a permanently-connected device is operating normally. A GFCI that can not accommodate legible instructions, due to the size of the instructions, the size of the device, or both, may have the required instructions supplied on "stuffer sheets" provided with the GFCI. A receptacle-type GFCI shall be provided with an installation instruction sheet as specified in 39.1.1.1.

Revised 39.1.1 effective November 13, 1998

39.1.1.1 Each receptacle-type GFCI shall be provided with the installation instructions shown in Figures 39.1 – 39.6. The installation instruction sheet, containing the detail of all six figures, shall not be smaller than 8 – 1/2 inches (215.9 mm) high × 16 – 1/2 inches (419.1 mm) long, consisting of 12 panels (for folding), each no smaller than 4 – 1/4 inches (108 mm) high × 2 – 3/4 inches (69.9 mm) long. The front of the installation instructions shall contain the manufacturer's name, cautionary note, and steps 1 – 6 as shown in Figures 39.1 – 39.3. The back of the installation instruction sheet shall contain steps 7 and 8 as shown in Figures 39.4 – 39.6. The only modifications that may be made to the content of the instructions are those necessary for including the manufacturer's name, model, and warranty information, and any product configurations different from those represented in the figures. A GFCI that is provided with these installation instructions need not additionally be provided with the instructions detailed in 39.2.4, 39.2.8, or 39.2.10.

Added 39.1.1.1 effective November 13, 1998

39.1.2 If the instructions in 39.1.1 are included on an adhesive-backed label, the label shall comply with the requirements of 37A.1.

38.3 revised and relocated as added 39.1.2 effective July 4, 1995

Figure 39.1
Installation instructions

Added Figure 39.1 effective November 13, 1998

**Manufacturer's
Name**

**Installing and
Testing a GFCI
Receptacle**

**Please read this leaflet
completely before
getting started.**

⚠ CAUTION

- To prevent severe shock or electrocution, always turn the power OFF at the service panel before working with wiring.
- Use this GFCI receptacle with copper or copper-clad wire. Do not use it with aluminum wire.
- Do not install this GFCI receptacle on a circuit that powers life support equipment because if the GFCI trips it will shut down the equipment.
- For installation in wet locations, protect the GFCI receptacle with a weatherproof cover that will keep both the receptacle and any plugs dry.
- Must be installed in accordance with national and local electrical codes.

3. Should you install it?

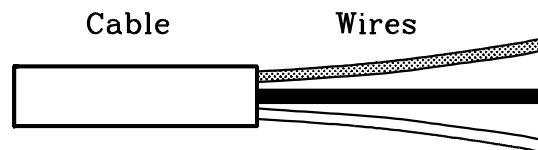
Installing a GFCI receptacle can be more complicated than installing a conventional receptacle.

Make sure that you:

- Understand basic wiring principles and techniques
- Can interpret wiring diagrams
- Have circuit wiring experience
- Are prepared to take a few minutes to test your work, making sure that you have wired the GFCI receptacle correctly

4. LINE vs. LOAD

A cable consists of 2 or 3 wires.



LINE cable:

Delivers power from the service panel (breaker panel or fuse box) to the GFCI. If there is only one cable entering the electrical box, it is the LINE cable. This cable should be connected to the GFCI's LINE terminals only.

LOAD cable:

Delivers power from the GFCI to another receptacle in the circuit. This cable should be connected to the GFCI's LOAD terminals only. The LOAD terminals are under the yellow sticker. Do not remove the sticker at this time.

Figure 39.2
Installation instructions

Added Figure 39.2 effective November 13, 1998

1. What is a GFCI?

A GFCI receptacle is different from conventional receptacles. In the event of a ground fault, a GFCI will trip and quickly stop the flow of electricity to prevent serious injury.

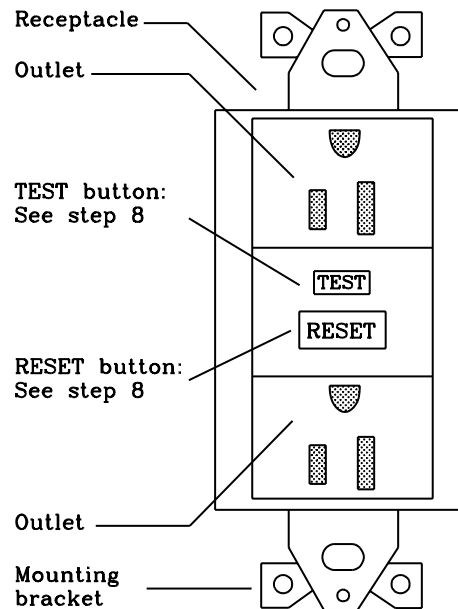
Definition of a ground fault:

Instead of following its normal safe path, electricity passes through a person's body to reach the ground. For example, a defective appliance can cause a ground fault.

A GFCI receptacle does not protect against circuit overloads, short circuits, or shocks. For example, you can still be shocked if you touch bare wires while standing on a non-conducting surface, such as a wood floor.

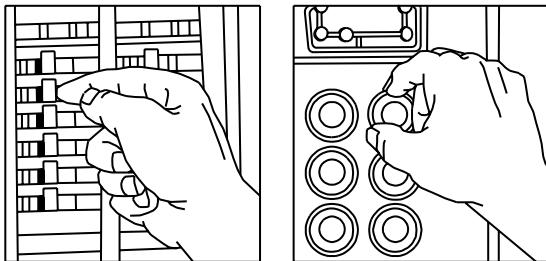
2. The GFCI's features —

FRONT VIEW



5. Turn the power OFF

Plug an electrical device, such as a lamp or radio, into the receptacle on which you are working. Turn the lamp or radio on. Then, go to the service panel. Find the breaker or fuse that protects that receptacle. Place the breaker in the OFF position or completely remove the fuse. The lamp or radio should turn OFF.



Next, plug in and turn ON the lamp or radio at the receptacle's other outlet to make sure the power is OFF at both outlets. If the power is not OFF, stop work and call an electrician to complete the installation.

6. Identify cables/wires —

Important:

Do not install the GFCI receptacle in an electrical box containing (a) more than 4 wires (not including the grounding wires) or (b) cables with more than two wires (not including the grounding wire). Contact a qualified electrician if either (a) or (b) is true.

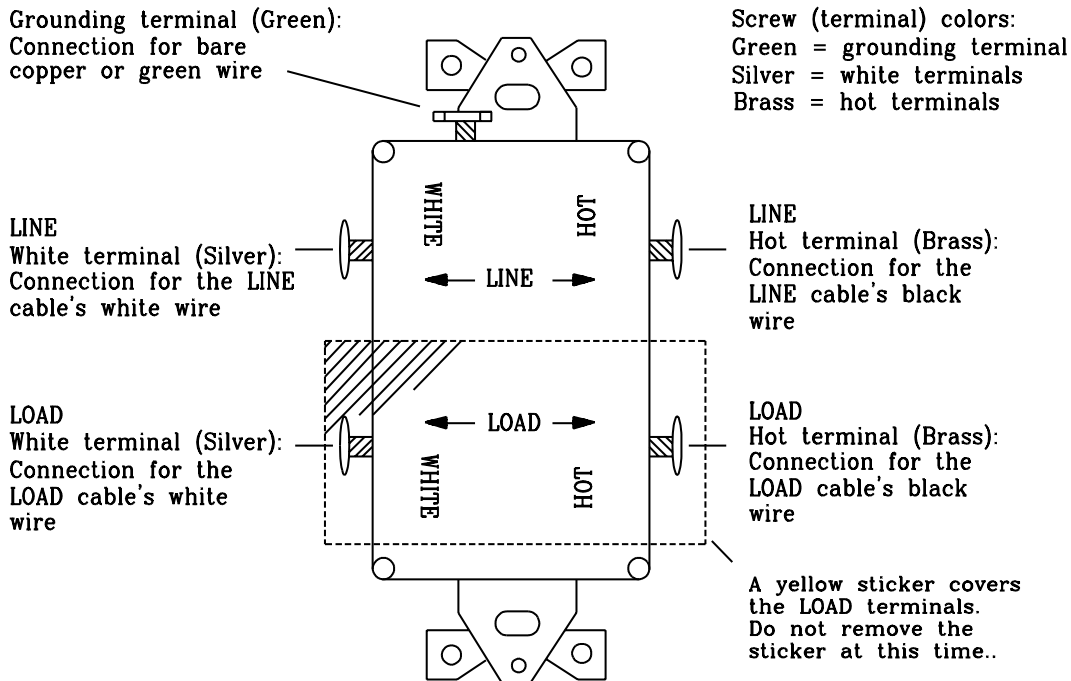
If you are replacing an old receptacle, pull it out of the electrical box without disconnecting the wires.

- If you see one cable (2-3 wires), it is the LINE cable. The receptacle is probably in position C (see diagram to the right). Remove the receptacle and go to step 7A.
- If you see two cables (4-6 wires), the receptacle is probably in position A or B (see diagram to the right). Follow steps a-e of the procedure to the right.

Figure 39.3
Installation instructions

Added Figure 39.3 effective November 13, 1998

BACK VIEW



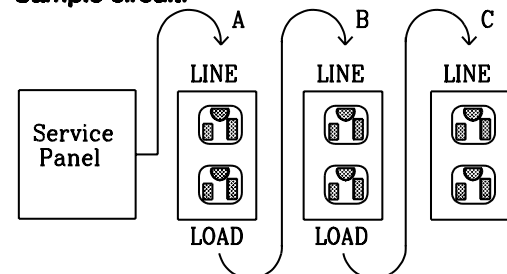
Procedure: box with two cables (4-6 wires)

- (a) Detach one cable's white and hot wires from the receptacle and cap each one separately with a wire connector. Make sure that they are from the same cable.
- (b) Re-install the receptacle in the electrical box, attach the faceplate, then turn the power ON at the service panel.
- (c) Determine if power is flowing to the receptacle. If so the capped wires are the LOAD wires. If not the capped wires are the LINE wires.
- (d) Turn the power OFF at the service panel, label the LINE and LOAD wires, then remove the receptacle.
- (e) Go to step 7B.

Placement in circuit:

The GFCI's place in the circuit determines if it protects other receptacles in the circuit.

Sample circuit:



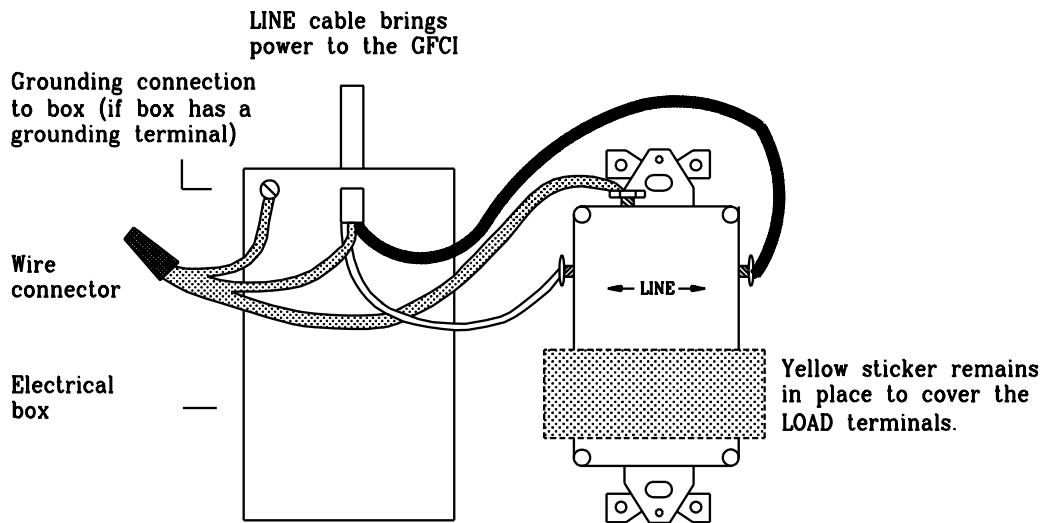
Placing the GFCI in position A will also provide protection to "load side" receptacles B and C. On the other hand, placing the GFCI in position C will not provide protection to receptacles A or B. Remember that receptacles A, B and C can be in different rooms.

Figure 39.4
Installation instructions

Added Figure 39.4 effective November 13, 1998

7. Connect the wires (choose A or B) ... only after

A: One cable (2 or 3 wires) entering the box



About wire connections:



Connect the LINE cable wires to the LINE terminals:

- The white wire connects to the White terminal (Silver)
- The black wire connects to the Hot terminal (Brass)

Connect the grounding wire (only if there is a grounding wire):

- For a box with no grounding terminal: (diagram not shown) Connect the LINE cable's bare copper (or green) wire directly to the grounding terminal on the GFCI receptacle.
- For a box with a grounding terminal: (diagram shown above) Connect a 6-inch bare copper (or green) 12 or 14 AWG wire to the grounding terminal on the GFCI. Also connect a similar wire to the grounding terminal on the box. Connect the ends of these wires to the LINE cable's bare copper (or green) wire using a wire connector. If these wires are already in place, check the connections.

Complete the installation:

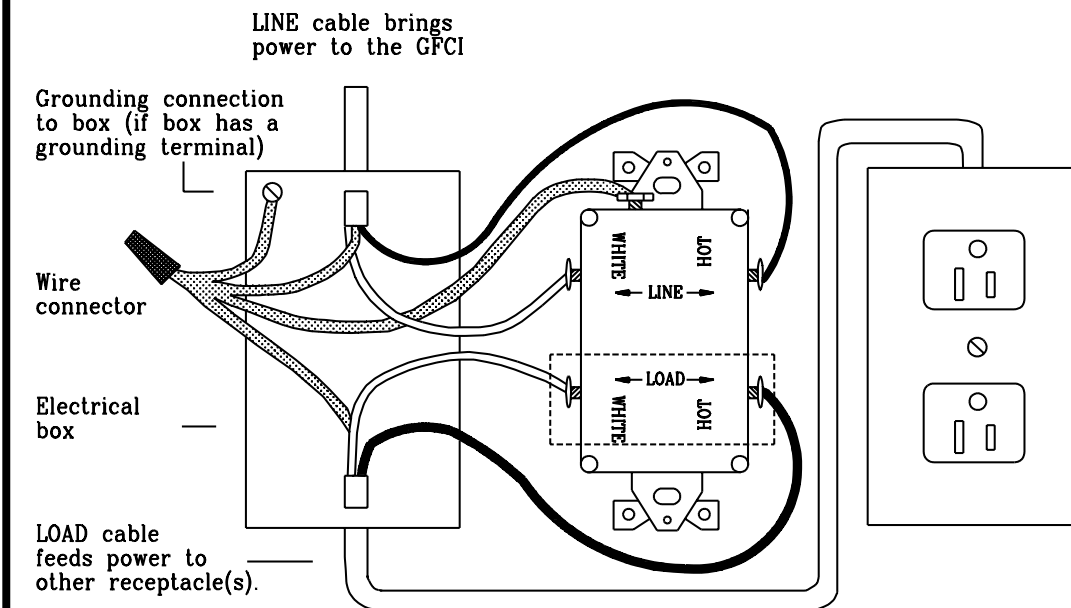
- Fold the wires into the box, keeping the grounding wire away from the White and Hot terminals. Screw the receptacle to the box and attach the faceplate.
- Go to step 8.

Figure 39.5
Installation instructions

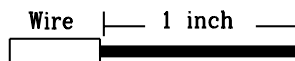
Added Figure 39.5 effective November 13, 1998

reading other side completely

R) B: Two cables (4 or 6 wires) entering the box



About wire connections:



Clockwise, 2/3 of the way around screw

Connect the LINE cable wires to the LINE terminals:

- The white wire connects to the White terminal (Silver)
- The black wire connects to the Hot terminal (Brass)

Connect the LOAD cable wires to the LOAD terminals:

- Remove the yellow sticker to reveal the LOAD terminals
- The white wire connects to the White terminal (Silver)
- The black wire connects to the Hot terminal (Brass)

Connect the grounding wires as shown above (only if there is a grounding wire):

- Connect a 6-inch bare copper (or green) 12 or 14 AWG wire to the grounding terminal on the GFCI. If the box has a grounding terminal, also connect a similar wire to the grounding terminal on the box. Connect the ends of these wires to the LINE and LOAD cable's bare copper (or green) wire using a wire connector. If these wires are already in place, check the connections.

Complete the installation:

- Fold the wires into the box, keeping the grounding wire away from the White and Hot terminals. Screw the receptacle to the box and attach the faceplate.
- Go to step 8.

Figure 39.6 Installation instructions

Added Figure 39.6 effective November 13, 1998

8. Test your work

Why perform this test?

- If you miswire the GFCI it may not prevent personal injury or death due to a ground fault (electrical shock).
- If you mistakenly connect the LINE wires to the LOAD terminals, the GFCI will still operate like an ordinary receptacle, but it will not interrupt a ground fault.

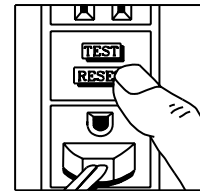
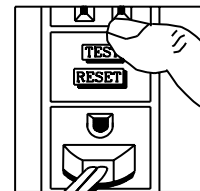
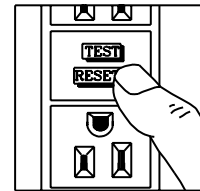
Procedure:

(a) Turn the power ON at the service panel. Press the RESET button fully. Plug a lamp or radio into the GFCI (and leave it plugged-in) to verify that the power is ON. If there is no power, go to Troubleshooting.

(b) Press the blue TEST button in order to trip the device. This should stop the flow of electricity, making the radio or lamp shut OFF. Note that the red RESET button will pop-out. If the power stays ON, go to Troubleshooting. If the power goes OFF, you have installed the GFCI receptacle correctly. To restore power, press the RESET button.

(c) If you installed your GFCI using step 7B, plug a lamp or radio into surrounding receptacles to see which one(s), in addition to the GFCI, lost power when you pressed the TEST button. Do not plug life saving devices into any receptacles that lost power. Place a "GFCI Protected" sticker on every receptacle that lost power.

(d) Press the TEST button (then RESET button) every month to assure proper operation.



TROUBLESHOOTING

Turn the power OFF and check the wire connections against the appropriate wiring diagram in step 7A or 7B. Make sure that there are no loose wires or loose connections. Also, it is possible that you reversed the LINE and LOAD connections. LINE/LOAD reversal will be indicated by power remaining ON at the GFCI after you press the GFCI's TEST button. Reverse the LINE and LOAD connections if necessary. Start the test from the beginning of step 8 if you rewired any connections to the GFCI.

General Information

GFCI receptacle rating:
The receptacle's ratings go here.

Contact:
The manufacturer's address and telephone number go here.

Warranty:
A condensed manufacturer's warranty statement goes here.

39.2 Permanently connected ground-fault circuit-interrupters

Sub-heading 39.2 added and replaces 39.2 which has been relocated as added 39.2.3 January 4, 1995

39.2.1 Those installation instructions required to be on a permanently connected ground-fault circuit-interrupter shall be either continuously exposed to view, or shall become exposed to view when the field-wiring terminals are exposed to view.

39.1 relocated as added 39.2.1 January 4, 1995

39.2.2 A receptacle type GFCI shall be provided with an adhesive label that either covers the load terminals or is wrapped around the load leads. The label shall be safety yellow in accordance with the Standard for Product Safety Signs and Labels, ANSI Z535.4 or an equivalent yellow, with black lettering and shall contain the following wording or equivalent: "ATTENTION [in letters at least 3/32 inch (2.4 mm) high]" The load terminals under this label are for feeding additional receptacles. Miswiring can leave this outlet without ground fault protection. Read instructions prior to wiring."

Added 39.2.2 effective July 4, 1995

39.2.3 Relocated as added 38.2.5 May 13, 1998

39.2.4 A permanently connected ground-fault circuit-interrupter shall be provided with installation instructions that include the following either in written text or pictorial form:

- a) A description of how to differentiate "Line" conductors from "Load" conductors, and a description of the proper method of connecting the conductors to the GFCI, and
- b) A description of how to determine whether the GFCI has been wired properly and how to determine whether it functions properly after it has been wired.

Added 39.2.4 effective July 4, 1995

39.2.5 Deleted May 13, 1998

39.2.6 A permanently connected ground-fault circuit-interrupter shall be clearly marked so as to minimize the occurrence of miswiring of the conductors to the means of termination provided. See 15.7.

39.5 revised and relocated as added 39.2.6 January 4, 1995

39.2.7 In determining compliance with the provisions of 39.2.6, consideration is to be given to:

- a) Wire gauge,
- b) Whether conductors are copper or aluminum,
- c) Whether terminals are for grounded, grounding, line, or load connection, and
- d) Whether conductors are solid or stranded.

39.6 revised and relocated as added 39.2.7 January 4, 1995

39.2.8 A statement to the effect that the device does not guard against electric shock resulting from contact with both circuit conductors shall appear on a permanently connected ground-fault circuit-interrupter or in literature packed with the device.

38.14 relocated as added 39.2.8 January 4, 1995

39.2.9 There is to be suitable reference on a ground-fault circuit-interrupter to the location of any of the instructions mentioned in 39.1.1, that are not on the device.

38.2 revised and relocated as added 39.2.9 January 4, 1995

39.2.10 For a permanently connected ground-fault circuit-interrupter, there shall be instructions to operate the supervisory circuit upon installation and at least as frequently as monthly. Part of these instructions may be omitted from the device when complete instructions are provided on literature packaged with the device.

38.8 relocated as 39.2.10 January 4, 1995

39.2.11 The instructions mentioned in 39.2.10 shall include on the device a description of the indication given by instructions for the normal operation of the supervisory circuit.

38.9 revised and relocated as added 39.2.11 January 4, 1995

39.2.12 Relocated as added 38.2.6 May 13, 1998

39.2.13 Deleted May 13, 1998

39.3 Deleted January 4, 1995

Table 39.1
Marked length

Volt-ampere rating of interrupter	Marked length of load conductor run in feet, (meters) minimum
Not over 600	100
Over 600 but not over 1200	150
Over 1200 but not over 1800	175
Over 1800 but not over 2400	200
Over 2400 but not over 3600	250

39.4 Revised and relocated as added 39.2.5 January 4, 1995

39.5 Revised and relocated as added 39.2.6 January 4, 1995

39.6 Revised and relocated as added 39.2.7 January 4, 1995

39.7 Relocated as added 39.2.2 January 4, 1995

39.8 Relocated as added 38.2.1 January 4, 1995

39.9 Relocated as added 38.1.3 January 4, 1995

39.10 Relocated as added 38.2.3 January 4, 1995

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SUPPLEMENT SA - OPTIONAL 10 KA SHORT CIRCUIT CURRENT TEST FOR OUTLET-BOX TYPE GROUND-FAULT CIRCUIT-INTERRUPTERS.

INTRODUCTION

SA1 Scope

Section SA1 added March 24, 1997

SA1.1 These requirements in this supplement cover an optional test procedure for a ground-fault circuit-interrupter.

SA1.2 These requirements are intended to verify the optional 10kA short circuit current capabilities for a ground-fault circuit-interrupter employed in applications such as power outlets, where higher currents are available.

SA1.3 The ground-fault circuit-interrupter mentioned in SA1.2 shall comply with the applicable requirements of this standard, UL 943, except as modified by the requirements contained in this supplement.

SA1.4 The requirements of this supplement do not apply to a portable ground-fault circuit-interrupter.

PERFORMANCE

SA2 General

Section SA2 added March 24, 1997

SA2.1 Representative outlet-box type ground-fault circuit-interrupters shall be subjected to the Extra-Low-Resistance Ground Fault Test in Section 34 and the Short Circuit Test in Section 35 except the prospective current is to be 10,000 rms Symmetrical Amperes and the power factor in the range of 0.45 to 0.50.

SA2.2 In the tests mentioned in SA2.1 each representative device tested shall be operational after each test. Operation shall be verified by the supervisory circuit remaining operable upon completion of each test. The representative devices tested shall also comply with Dielectric Voltage-Withstand Test, Section 29. See also 21.2 for representative device selection.

MARKINGS

SA3 General

Section SA3 added March 24, 1997

SA3.1 A ground-fault circuit-interrupter that complies with SA2.1 and SA2.2 shall not be marked to indicate the ability to withstand a 10kA short circuit current as a result of these tests.

APPENDIX A

Standards for Components

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard – UL Standard Designation

Attachment Plugs and Receptacles – UL 498
Boxes, Junction, for Swimming Pool Lighting Fixtures – UL 1241
Cord Sets and Power-Supply Cords – UL 817
Double Insulation Systems for Use in Electrical Equipment – UL 1097
Flexible Cord and Fixture Wire – UL 62
Fuseholders – UL 512
Industrial Control Equipment – UL 508
Optical Isolators – UL 1577
Plastic Materials for Parts in Devices and Appliances, Tests for Flammability of – UL 94
Polymeric Materials – Long Term Property Evaluations – UL 746B
Polymeric Materials – Short Term Property Evaluations – UL 746A
Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C
Printed-Wiring Boards, Electrical – UL 796
Semiconductor Devices, Electrically Isolated – UL 1557
Sharpness of Edges on Equipment, Determination of – UL 1439
Switches, Special-Use – UL 1054
Systems of Insulating Materials – General – UL 1446
Tape, Insulating – UL 510
Terminal Blocks, Electrical – UL 1059
Terminals, Electrical Quick-Connect – UL 310
Tubing, Extruded Insulating – UL 224
Wire Connectors and Soldering Lugs for Use With Copper Conductors – UL 486A
Wire Connectors for Use With Aluminum Conductors – UL 486B
Wire Connectors, Splicing – UL 486C
Wires and Cables, Rubber-Insulated – UL 44
Wires and Cables, Thermoplastic-Insulated – UL 83
Wiring Terminals, Equipment, for Use With Aluminum and/or Copper Conductors – UL 486E

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