



UL 1699

STANDARD FOR SAFETY

Arc-Fault Circuit-Interrupters

UL Standard for Safety for Arc-Fault Circuit-Interrupters, UL 1699

Third Edition, Dated May 3, 2017

SUMMARY OF TOPICS

This revision of ANSI/UL 1699 dated September 26, 2023 is issued to include a patent claim on the title page.

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MAY 3, 2017
(Title Page Reprinted: September 26, 2023)



ANSI/UL 1699-2022

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UL 1699

Standard for Arc-Fault Circuit-Interrupters

First Edition – February, 1999
Second Edition – April, 2006
Third Edition – May, 2017

Third Edition

May 3, 2017

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through September 26, 2023.

The most recent designation of ANSI/UL 1699 as an American National Standard (ANSI) occurred on February 8, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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INTRODUCTION

1 Scope

1.1 The requirements of this Standard cover arc-fault circuit-interrupters (AFCIs) of the branch/feeder, outlet circuit, portable, and cord type intended for use in dwelling units. These devices are intended to mitigate the effects of arcing faults that may pose a risk of fire ignition under certain conditions if the arcing persists.

1.2 AFCIs have a maximum rating of 20 A and are intended for use in 120-V ac, 60-HZ circuits. Cord AFCIs are rated up to 30 A.

1.3 These devices are not intended to detect glowing connections.

1.4 In these requirements the term device is used generically to apply to all of the devices covered by these requirements and is modified when the requirement does not apply to all types.

1.5 An AFCI that is also intended to perform other functions, such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable Standard or Standards that cover devices that provide those functions.

1.6 This standard contains a supplement covering the requirements for Leakage-Current Detector-Interrupters.

2 Glossary

2.1 For the purposes of this Standard, the following definitions apply.

2.2 **ARCING** – A luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes.

2.3 **ARCING FAULT** – An unintentional arcing condition in a circuit.

2.4 **ARC-FAULT CIRCUIT-INTERRUPTER (AFCI)** – A device intended to mitigate the effects of arcing faults by functioning to deenergize the circuit when an arc-fault is detected.

2.5 **BRANCH/FEEDER ARC-FAULT CIRCUIT-INTERRUPTER** – A device intended to be installed at the origin of a branch circuit or feeder, such as at a panelboard. It is intended to provide protection of the branch circuit wiring, feeder wiring, or both, against unwanted effects of arcing. This device also provides limited protection to branch circuit extension wiring. It may be a circuit-breaker type device or a device in its own enclosure mounted at or near a panelboard.

2.6 **CARBONIZED PATH** – A conductive carbon path formed through or over the surface of a normally insulating material.

2.7 **COMBINATION ARC-FAULT CIRCUIT-INTERRUPTER** – An AFCI which complies with the requirements for both branch/feeder and outlet circuit AFCIs. It is intended to protect downstream branch circuit wiring and cord sets and power-supply cords.

2.8 **CORD ARC-FAULT CIRCUIT-INTERRUPTER** – A plug-in device intended to be connected to a receptacle outlet. It is intended to provide protection to the power-supply cord connected to it against the unwanted effects of arcing. The cord may be integral to the device. The device has no additional outlets.

2.9 MICROELECTRONICS – Monolithic, hybrid, or module circuits, where the internal circuit connections are not accessible exclusive of provided external connection pins or pads. The circuits are capable of functioning in the analogue mode, digital mode, or a combination of the two modes. Examples of microelectronics include: ASICs, ROMs, RAMs, PROMs, EPROMs, PALs, and PLDs. See [2.13](#).

2.10 OPERATION INHIBITION – Denotes the concealment of an arcing fault by the normal operation of certain circuit components.

2.11 OUTLET CIRCUIT ARC-FAULT CIRCUIT-INTERRUPTER – A device intended to be installed at a branch circuit outlet, such as at an outlet box. It is intended to provide protection of cord sets and power-supply cords connected to it (when provided with receptacle outlets) against the unwanted effects of arcing. This device may provide feed-through protection of the cord sets and power-supply cords connected to downstream receptacles.

2.12 PORTABLE ARC-FAULT CIRCUIT-INTERRUPTER – A plug-in device intended to be connected to a receptacle outlet and provided with one or more outlets. It is intended to provide protection to connected cord sets and power-supply cords against the unwanted effects of arcing.

2.13 PROGRAMMABLE COMPONENT – Any microelectronic hardware that can be programmed in the design center, the factory, or in the field. Here the term "programmable" is taken to be "any manner in which one can alter the software wherein the behavior of the component can be altered." The microelectronics defined in [2.9](#) are examples of programmable components.

2.14 UNWANTED TRIP – A tripping function in response to a condition that is not an arcing fault but a condition that occurs as part of the normal or anticipated operation of circuit components.

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 generally used in the products covered by this standard.

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.

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

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.

4 Units of Measurement

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

5 Undated 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

ALL DEVICES

6 General

6.1 An AFCI shall comply with the construction requirements in Sections [6](#) – [15](#).

7 Accessibility of Energized Parts

7.1 Parts of a device shall not be accessible when they are installed as intended and energized.

7.2 Parts are considered to be accessible if they can be touched using the articulated probe. See [Figure 7.1](#).

7.3 Access to the trip mechanism shall not be attainable with ordinary tools. Access to internal parts of portable devices shall be limited by use of tamper-resistant screws, rivets, welding or other equivalent means.

8 Corrosion Protection

8.1 Parts, in addition to enclosures, shall be protected against corrosion if failure of such parts would be likely to result in a hazardous condition such as the inability of the device to perform its intended function.

9 Current Carrying Parts

9.1 Current-carrying parts shall be of silver, a silver alloy, copper, a copper alloy or other metal acceptable for the application. Screws, nuts, or wire binding screws made of iron or steel and corrosion protected, shall be permitted to be used to secure live parts, but shall not be depended upon to carry current.

10 Internal Wiring

10.1 The gauge and insulation of wires shall withstand the mechanical and electrical stresses of service. Wires smaller than 24 AWG (0.21 mm²) shall be investigated for the application.

11 Insulation

11.1 A device shall have at least functional insulation throughout. Materials shall be suitable for the temperature, voltage and conditions of service.

12 Spacings

12.1 A device shall comply with the requirements shown in [Table 12.1](#) except that at field-wiring terminals the spacings shall be not less than 1/4 inch (6.4 mm) between terminals not operating at the same potential for either a branch/feeder AFCI, or a cord AFCI without an integral cord, rated up to 200 V peak.

Table 12.1
Spacing in inches (mm)^{a,b}

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
1/16 (1.6)	1/16 (1.6)	1/8 (3.2)	1/4 (6.4)	1/4 (6.4)	3/8 (9.5)
^a Smaller spacings may be acceptable where they are inherent in a suitable component. ^b For printed wiring boards with suitable conformal coating which have 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 inch (0.8 mm), and may be reduced further if the coating is determined to be suitable and it is evaluated in accordance with UL 746C for the reduced spacing.					

12.2 Except as permitted in note a to [Table 12.1](#), 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.

12.3 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.

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

12.5 As an alternative to the measurement method specified in [12.1](#) – [12.4](#), the minimum acceptable clearances (through air spacings) and creepage distances (over surface spacings) for a printed wiring board assembly may be evaluated as specified in [12.6](#) – [12.8](#) using the applicable requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

12.6 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 an arc fault circuit-interrupter is considered to be:

- a) Pollution degree 3 for an assembly without a conformal coating;
- b) Pollution degree 2 for
 - 1) An assembly with a coating,
 - 2) An assembly without a coating when the printed wiring board is contained in a sealed housing that complies with the Dust Test, Section [57](#), or
- c) Pollution degree 1 for an assembly with a conformal coating complying with the Printed Wiring Board Coating Performance Test, in UL 840.

12.7 For Clearance B (controlled overvoltage) requirements in 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 branch/feeder and outlet circuit AFCIs and Category II for portable and cord AFCIs. Category I is applicable to low-voltage circuits if short circuit between the parts involved may result in operation of the controlled equipment that increases the risk of fire or electric shock. Any overvoltage protection device needed to achieve these categories shall be provided as an integral part of the arc fault circuit-interrupter.

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

13 Operating Mechanism

13.1 Compliance with the provisions of arcing fault interruption shall not be prevented by manipulation or restraint of accessible levers, knobs, and the like of a device.

13.2 A device that has tripped in accordance with the provisions of arcing fault interruption shall not be capable of automatic reclosure.

13.3 Except for an AFCI that is intended to be mounted in a panelboard, an AFCI shall operate to open both the ungrounded and grounded circuit conductors in the event of a fault.

13.4 An AFCI device that contains separate line and load terminals, intended for mounting in an outlet box, and that is powered through its load terminals, shall not reset and supply power to its line terminals. See Reverse Line – Load Miswire Test, Section [59](#).

14 Programmable Components

14.1 An arc-fault circuit-interrupter that employs a programmable component such as a microprocessor shall be investigated in accordance with the Standard for Software in Programmable Components, UL 1998, as defined in [14.2](#) – [14.8](#).

14.2 All of the requirements of the Standard for Software in Programmable Components, UL 1998, apply to programmable components employed in an arc-fault circuit-interrupter, except as modified by [14.3](#) – [14.9](#).

14.3 The risks to be considered for the Risk Analysis portion of UL 1998 include the following scenarios:

- a) Unwanted tripping;
- b) Failure to trip under conditions where tripping should occur; and
- c) Failure of test circuit to complete evaluation.

14.4 The Tool Qualification requirements from UL 1998 are modified in [14.5](#) and [14.6](#).

14.5 All tools used in the design, implementation, and verification of software shall be documented. The documentation shall include:

- a) The name of the tool supplier or developer;
- b) The model, application, or trade name of the tool;
- c) The tool version identification;
- d) A description of the purpose for which the tool is used; and
- e) A list of known errors, faults or failures of the tool performance, such as a "bug list".

14.6 Software tools are defined as software or hardware used in the development, testing, analysis, or maintenance of a program or its documentation. Examples include compilers, assemblers, timing analyzers, logic analyzers, test case generators, simulators, emulators, and similar tools.

14.7 Means shall be employed to address all microelectronic hardware failure modes identified in the Risk Analysis of [14.3](#). The analysis shall consider all possible combinations of microelectronic hardware failures, software faults, and other events that are capable of resulting in a risk. This includes, for example, microelectronic hardware failures that cause software faults that are capable of resulting in a risk. Detection of failure modes shall be at a frequency and adequacy suitable for the application.

14.8 One approach to comply with [14.7](#) is for the manufacturer to:

- a) Identify failure modes;
- b) Determine safety impact of failure modes;
- c) Design and provide means to detect the failure modes that have an impact on safety;
- d) Demonstrate that coverage provided by detection means is at a frequency and effective level suitable for the application; and
- e) Provide evidence that the failure rate of microelectronic components is suitable for the application.

14.9 The requirements in UL 1998 addressing User Interfaces do not apply.

15 Test Circuit

15.1 An AFCI shall be provided with a test circuit that simulates an arc such that the arc detection circuit or software is caused to detect the simulated arc. An AFCI that also incorporates features of other devices that require a supervisory circuit, such as GFCIs, shall be provided with one or more test circuits that simulate the arc detection portion of the device as described in this Section, and comply with the test or supervisory circuit requirements for the additional device or features provided with the AFCI.

15.2 Operation of the test circuit shall cause the contacts of the device to open. The results of the test shall be made known to the user by a positive visual indication.

BRANCH/FEEDER ARC-FAULT CIRCUIT-INTERRUPTER

16 General

16.1 In addition to the construction requirements in Sections [6](#) – [15](#), a branch/feeder AFCI shall comply with the construction requirements in Sections [17](#) – [19](#).

17 Terminals

17.1 General

17.1.1 A device shall have terminals suitable for the application. Terminals that are intended to be wired in the field shall be in the form of terminal leads, wire binding screws or pressure-wire terminals.

17.2 Terminal leads

17.2.1 Terminal leads shall differ by no more than two wire sizes from the size that would have an ampacity in accordance with the National Electrical Code (NEC), ANSI/NFPA 70 for the rating of the device.

17.2.2 The insulation of lead type terminals shall be rated for the application and be of a color that conforms with the requirements of the NEC, that is white or gray for the grounded conductor and green or green with a yellow stripe for the grounding conductor.

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

17.2.4 A conductor shall be constructed so as to withstand the stress of normal handling without damage to itself or the device. See Mechanical Tests, Section [55](#).

17.3 Wire binding screw terminals

17.3.1 A wire binding screw shall be permitted to be used at a field wiring terminal intended for the connection of a 10 AWG (5.3 mm²) or smaller wire if upturned lugs or the equivalent are provided to retain the wire under the head of the screw even though the screw becomes loosened.

17.3.2 A screw and washer construction used at a field wiring terminal shall not be smaller than No. 10 (4.8 mm) with no more than 32 threads per inch (25.4 mm).

17.3.3 A terminal plate tapped for a wire binding screw shall be of metal not less than 0.05 inch (1.27 mm) thick and shall have not less than 2 full threads in the metal; except that a plate made of a special alloy not less than 0.03 inch (0.76 mm) thick shall be permitted if the tapped threads have the necessary mechanical strength.

17.3.4 A terminal plate shall be permitted to have the metal extruded at the tapped hole so as to give the thickness necessary for at least 2 full threads provided that the thickness for the unextruded metal is not less than the pitch of the thread.

17.4 Pressure wire terminals

17.4.1 Pressure wire terminals provided with a device shall comply with the Standard for Wire Connectors, UL 486A-486B or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

17.4.2 The tightening torque for a field wiring terminal shall be in accordance with the Standard for Wire Connectors, UL 486A-486B, the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, or as specified by the device manufacturer and the device shall be marked as required by [63.5](#). The specified tightening torque shall not be less than 90 percent and not more than 100 percent of the value used in the static heating test as specified in UL 486A-486B or UL 486E, for the wire size corresponding to the ampere rating of the device. See Mechanical Tests, Section [55](#). Torque values shall be permitted to be less than 90 percent if the connector is investigated in accordance with the lesser assigned torque value.

17.4.3 A pressure wire connector shall be prevented from moving (rotating) so as to strain connections or reduce spacings to unacceptable values.

18 Enclosure

18.1 When a branch/feeder AFCI that is not intended to be mounted in a panelboard is provided with its own enclosure, the enclosure shall comply with the requirements in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, and the applicable enclosure requirements for the intended environment in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E. There shall not be any unused openings.

19 Grounding

19.1 All accessible parts of a branch/feeder AFCI 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.

OUTLET CIRCUIT ARC-FAULT CIRCUIT-INTERRUPTER

20 General

20.1 In addition to the construction requirements in Sections [6](#) – [15](#), an outlet circuit AFCI shall comply with the construction requirements in Sections [20](#) – [23](#).

20.2 An outlet circuit AFCI shall also comply with the construction requirements for receptacles, including the enclosure requirements, in the Standard for Attachment Plugs and Receptacles, UL 498.

21 Terminals

21.1 An outlet circuit AFCI shall comply with the terminal requirements in Terminals, Section [17](#), except that the minimum wire binding screw size is No. 8 (4.2 mm).

22 Housings

22.1 An outlet circuit AFCI shall comply with the materials requirements in 8.1 – 8.5 of the Standard for Attachment Plugs and Receptacles, UL 498.

23 Grounding

23.1 An outlet circuit AFCI shall comply with the grounding requirements in Grounding, Section [19](#).

PORTABLE ARC-FAULT CIRCUIT-INTERRUPTER

24 General

24.1 In addition to the construction requirements in Sections [6](#) – [15](#), a portable AFCI shall comply with the construction requirements in Sections [24](#) – [30](#).

24.2 A portable AFCI shall provide protection in the event that the grounded conductor becomes open circuited.

25 Plugs/Receptacles

25.1 An outlet provided with a portable AFCI shall be either of the grounding or non-grounding type but in any case shall have the same configuration as the attachment plug of the AFCI. When the outlet is of the grounding type, the grounding terminal shall be conductively connected to the grounding circuit.

25.2 The attachment plug and any outlets provided with a portable AFCI shall comply with the dimensions and other appropriate construction requirements of the Standard for Attachment Plugs and Receptacles, UL 498.

25.3 The ampere rating of an outlet of a cord-connected portable AFCI shall not exceed the rating of the attachment plug.

25.4 The ampere rating of the outlet of a portable (direct plug-in or cord-connected) AFCI that has only a single outlet shall be equal to the ampere rating of the attachment plug.

26 Cords

26.1 A cord that is provided with a device shall be a type that has the number of conductors, insulation and electrical ratings suitable for the application.

26.2 Strain on the cord that may occur by way of pulling, pushing or twisting shall not be transmitted to cord-conductor termination in the device. See the Power-Supply Cord Strain Relief Test, Section [54](#).

26.3 A flexible cord, provided as an input power-supply cord or an output cord, shall comply with the requirements of the Standard for Flexible Cords and Cables, UL 62. Constructions employing molded-on fittings shall comply with the applicable requirements of the Standard for Cord Sets and Power-Supply Cords, UL 817.

27 Direct Plug-In

27.1 A device that is intended to plug directly into a receptacle shall comply with the weight and moment requirements in [27.2](#) – [27.5](#).

27.2 The maximum acceptable moment, center of gravity, dimensions, and weight of a direct plug-in unit shall comply with the requirements specified in (a), (b), (c) and (d). See [27.3](#) and [27.4](#) and [Figure 27.1](#).

- 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).

27.3 Definitions for the symbols used in [27.2](#) are as follows:

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

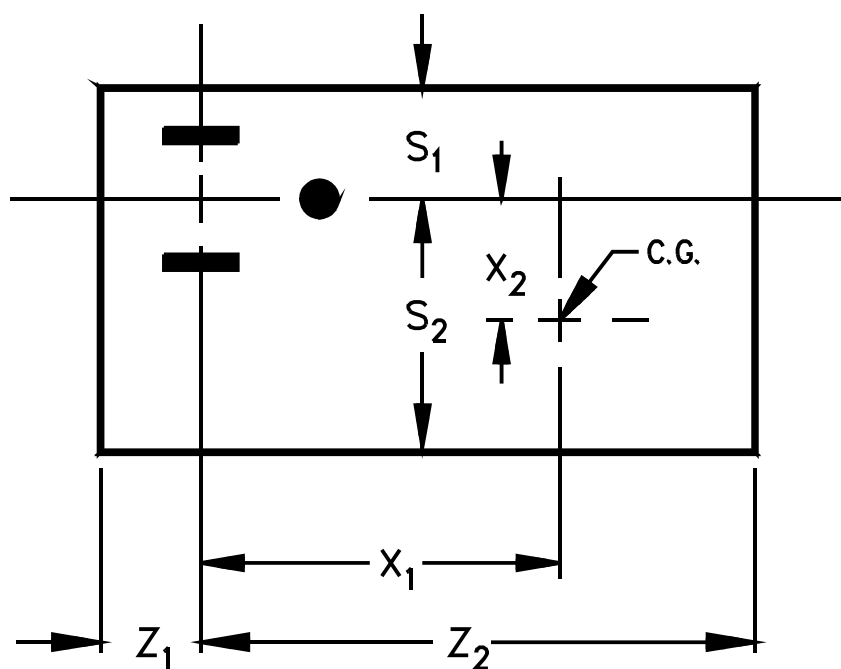
Y is the distance illustrated in [Figure 27.1](#) in inches (mm).

Z is the lesser of the two distances, Z1 or Z2, as illustrated in [Figure 27.1](#), in inches (mm).

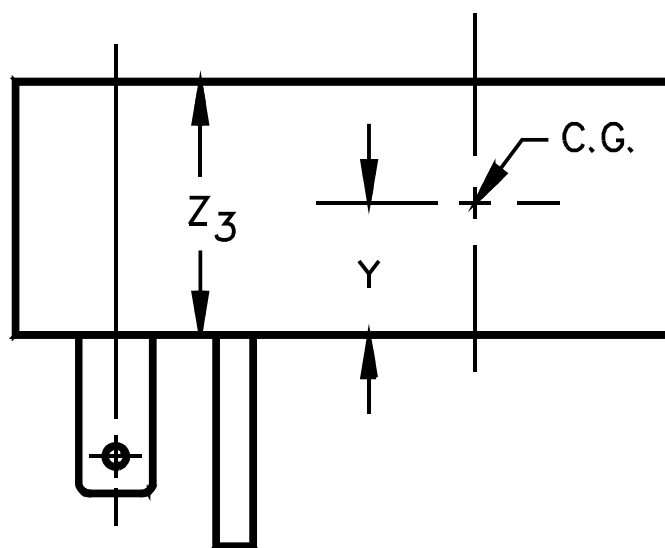
S is the lesser of the two distances, S1 or S2, as illustrated in [Figure 27.1](#), in inches (mm).

X is the greater of the two distances X1 or X2, as illustrated in [Figure 27.1](#), in inches (mm).

Figure 27.1
Dimensions of a direct plug-in unit



FRONT VIEW



SIDE VIEW

C.G. = Center of Gravity

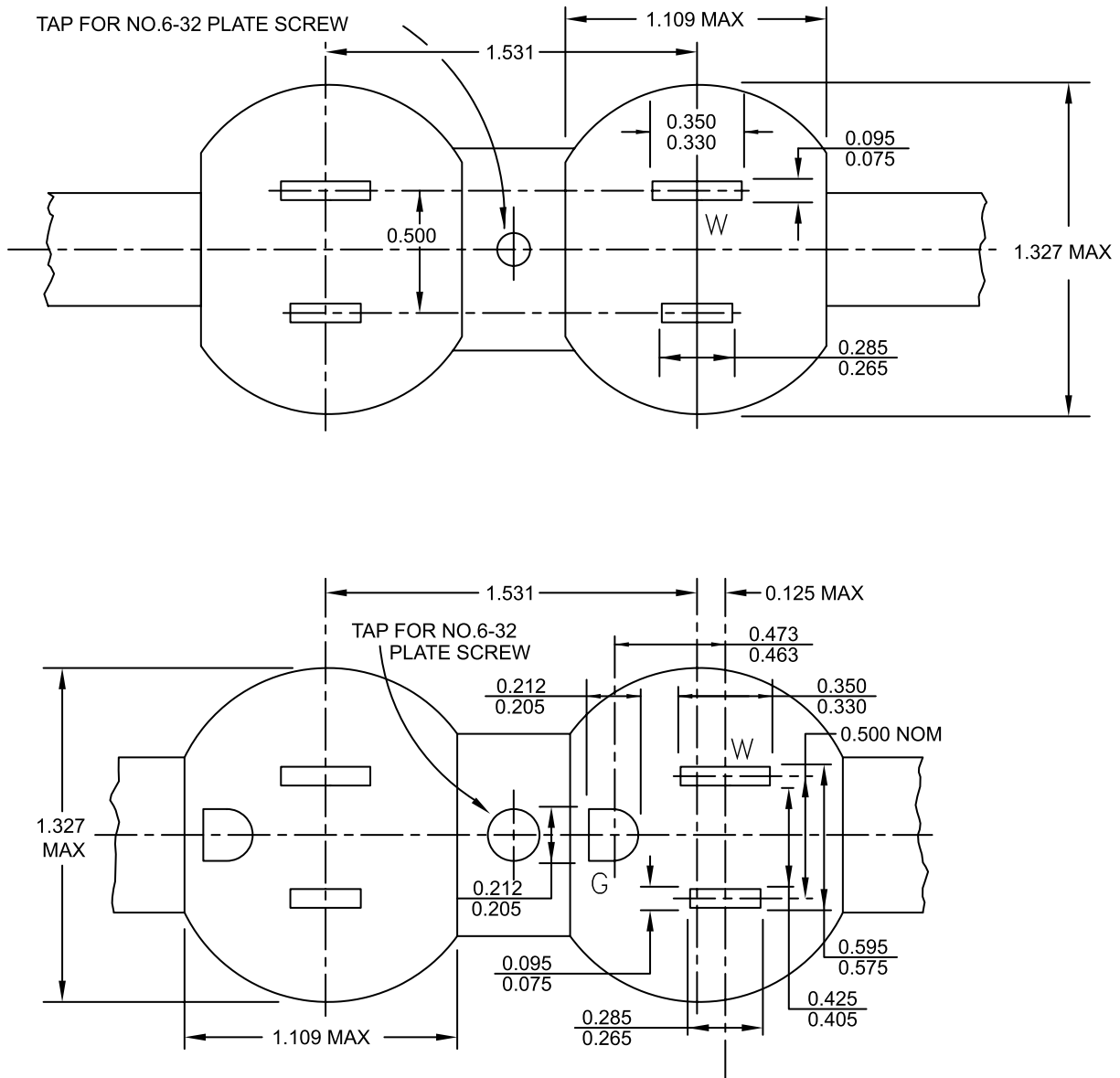
27.4 The moment and weight specified in [27.2](#) are to be determined as follows:

- 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.

27.5 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 27.2](#).

Exception: A unit that renders the adjacent receptacle completely unusable in any one mounting position meets the intent of the requirement.

Figure 27.2
Parallel duplex receptacles



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28 Grounding

28.1 When a portable AFCI is provided with a grounding-type attachment plug, the accessible conductive parts and the equipment grounding conductor of a cord-connected portable AFCI shall be conductively connected to the grounding contacts of the attachment plug and any of the receptacle outlets.

29 Enclosures

29.1 The polymeric enclosure of a portable AFCI shall comply with the requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

CORD ARC-FAULT CIRCUIT-INTERRUPTERS

30 General

30.1 In addition to the construction requirements in Sections [6](#) – [15](#), and Cords, Section [26](#) and Direct Plug-In, Section [27](#), a cord AFCI shall comply with the construction requirements in Sections [30](#) – [33](#).

30.2 A cord AFCI need not be provided with an integral cord.

30.3 A cord AFCI shall provide protection in the event that the grounded conductor becomes open circuited.

Exception: A cord AFCI constructed with arc fault protection circuitry integral to the attachment plug and intended for a dedicated load need not comply with the requirements of [30.3](#).

31 Plugs/Receptacles

31.1 A cord AFCI shall not be provided with any outlets.

31.2 The attachment plug provided with a portable AFCI shall comply with the dimensions and other appropriate construction requirements of the Standard for Attachment Plugs and Receptacles, UL 498.

32 Grounding

32.1 The accessible conductive parts and the equipment grounding conductor of a cord AFCI provided with a cord shall be conductively connected to the grounding contacts of the attachment plug.

33 Enclosures

33.1 The polymeric enclosure of a direct plug-in device shall comply with the requirements of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C and with the Crushing Test, Section [56](#).

PERFORMANCE

34 General

34.1 An AFCI shall comply with the performance requirements in Sections [34](#) – [58](#) as detailed in [Table 34.1](#) and [Table 34.2](#).

Table 34.1
Test sequence

Test name	Conditioning/environmental ^a	Overload/endurance ^b	Other ^c
Conditioning			
Impact	X		
Drop	X		
Humidity	X		
Leakage	X		
Voltage surge	X		
Environmental sequence	X		
Arc fault detection	X		
Unwanted tripping			X
Inhibition			X
Temperature			X
Overvoltage		X	
Overload		X	
Endurance		X	
Dielectric withstand	X	X	X
Abnormal			X
Short circuit			X
Crushing			X
Strain relief			X
Mechanical			X
^a The same representative AFCI shall be subject to the tests in the sequence shown.			
^b A new representative AFCI shall be subject to all of the tests in the sequence shown.			
^c These tests need not be conducted in the sequence shown and may be conducted on new representative AFCIs, except when the dielectric voltage withstand is required as part of another test.			

Table 34.2
Arc fault detection tests table

Tests		Branch/ feeder AFCI	Combina tion AFCI	Outlet circuit AFCI		Portable AFCI	Cord AFCI
				With feed	Without feed		
40.2	Carbonized path arc ignition test						
	NM-B conductor cut	X	X				
40.3	Carbonized path arc interruption test						
	SPT-2 insulation cut	X	X				
	NM-B insulation cut	X	X				
40.4	Carbonized path arc clearing time test						
	SPT-2 insulation cut		X	X	X	X	X

Table 34.2 Continued on Next Page

Table 34.2 Continued

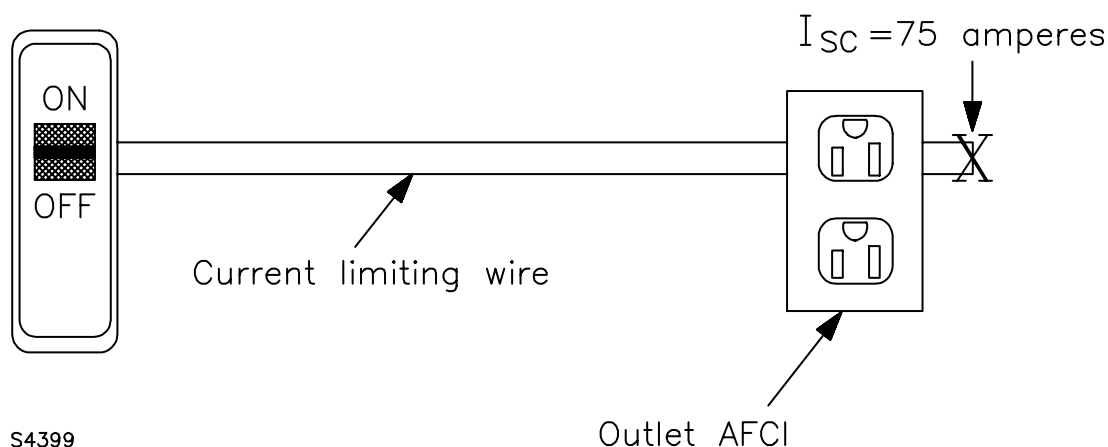
Tests	Branch/ feeder AFCI	Combina tion AFCI	Outlet circuit AFCI		Portable AFCI	Cord AFCI
			With feed	Without feed		
40.5 Point contact arc test						
SPT-2 insulation cut	X	X	X	X	X	X
NM-B insulation cut	X	X				
41 Unwanted tripping tests						
41.2 Load condition I – inrush current	X	X	X	X	X	X
41.3 Load condition II – normal operation arcing						
conditions a – c	X	X	X	X	X	X
conditions d – g	X	X	X			
41.4 Load condition III – non- sinusoidal waveform	X	X	X	X	X	X
41.5 Load condition IV – cross talk	X	X	X			
41.6 Load condition V – multiple load	X	X	X	X	X	
41.7 Load condition VI – lamp burnout	X	X	X			
42 Operation inhibition						
42.2 Masking	X	X	X	X	X	X
42.3 EMI filter	X	X	X	X	X	
42.4 Line impedance	X	X	X			
NOTE – All SPT-2 wire specimens shall have insulation rated 60°C.						

34.2 The available short-circuit current for the tests in Sections [39](#) – [42](#) shall be 500 A RMS ± 10 percent.

34.3 When test currents of less than 500 A are required, the current shall be limited by adding lengths of wire for currents of 75 A and higher and by adding resistances for currents less than 75 A. For branch/feeder and combination AFCIs, the wire or resistances shall be inserted into the test circuit on the load side of the device under test. For outlet circuit AFCIs, the wire shall be inserted into the test circuit on the line side of the device under test, and the resistances shall be inserted into the test circuit on the load side of the device under test. See [Figure 34.1](#).

Figure 34.1

Test for outlet circuit operation with "Current-Limiting Wire" upstream of outlet



35 Drop and Impact Tests

35.1 General

35.1.1 After being tested as described in this Section, an AFCI shall not have any exposed live parts as determined by using the accessibility probe, [Figure 7.1](#) and shall continue to function as intended.

35.2 Impact test

35.2.1 An outlet circuit AFCI with receptacle outlets shall be subjected to a 5 ft-lb impact imparted from a solid, smooth, steel sphere 2 inches (50.8 mm) in diameter. The sphere is to be allowed to fall freely from rest through the distance required to cause the specified impact upon the surface under test. The device under test is to be mounted in a box as intended. The surfaces to be tested are those exposed during normal service. When it is necessary to test more than one surface, the same or an additional device is to be used.

35.3 Drop test

35.3.1 A cord or portable AFCI is to be allowed to fall from a height of 3 feet (0.9 m) such that a different part will strike a hardwood surface in each of three drops.

35.3.2 The hardwood surface mentioned in [35.3.1](#) 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.

36 Humidity Conditioning

36.1 A representative AFCI is to be exposed for 168 hours 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 device is to be exposed to ambient air at a temperature of at least 30°C (86°F) until thermal equilibrium is attained before being placed in the test chamber.

37 Leakage Current Measurement

37.1 The leakage current of an AFCI, when tested in accordance with [37.2](#) – [37.6](#), shall not be more than 0.5 mA.

37.2 All accessible parts of an AFCI are to be tested for leakage currents. The accessible parts are to be tested individually, collectively, and from one part to another.

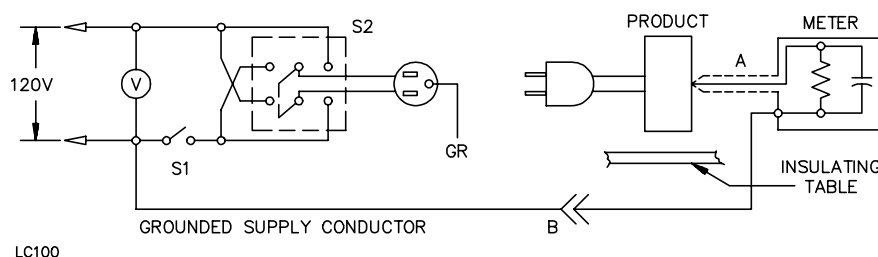
37.3 If a surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using metal foil with an area of 10 by 20 cm in contact with the surface. Where the surface is less than 10 by 20 cm, the metal foil is to be the same size as the surface. The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

37.4 The measurement circuit for leakage current of a portable or cord AFCI is to be as shown in [Figure 37.1](#). The measurement instrument is defined in (a) – (d) below. The meter that is actually used for a measurement need only indicate the same numerical value for a measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

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

Figure 37.1

Leakage-current measurement circuits



NOTES:

A – Probe with shielded lead.

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

37.5 A branch/feeder, combination, or outlet circuit AFCI is to be connected to the supply by way of the terminals of the device, and tested in the same manner as a portable or cord AFCI except that switches S1 and S2 are not to be employed.

37.6 A representative device is to be tested for leakage current after the conditioning described in Humidity Conditioning, Section [36](#). If removed from the humidity chamber, the testing is to start within one minute after its removal. The grounding conductor of a portable or cord AFCI is to be open at the supply receptacle and the grounding conductor of a branch/feeder or outlet circuit device 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 37.1](#), is as follows:

- a) With switch S1 open, the device 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 device, and within a period of five seconds, the leakage current is to be measured using both positions of switch S2 and with the control settings varied throughout the operating range.
- c) Leakage current is to be monitored at intervals necessary to determine the maximum leakage current, with additional measurements being taken until such time as thermal equilibrium is attained. Both positions of switch S2 are to be used in determining this measurement.

38 Voltage Surge Test

38.1 General

38.1.1 The line side terminals of the arc-fault circuit-interrupter, including both Line-Neutral and Line-Line terminals, as provided, shall be subjected to the following surge tests: Unwanted Tripping Test, Section [38.2](#), the Surge Immunity Test, Section [38.3](#), the Surge Current Test, Section [50](#), the Abnormal Overvoltage Test, Section [51](#), and the Supplemental Voltage Surge Immunity Test, Section [60](#). The intent of the requirements is met by using separate representative devices for each test.

38.1.2 The arc-fault circuit-interrupter is to be connected to a supply of rated voltage. The grounding lead or terminal of the arc-fault circuit-interrupter is to be connected to the supply conductor serving as the neutral. The arc-fault circuit-interrupter is to be in the "on" condition with no load connected.

38.2 Unwanted tripping test (Ring wave)

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

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

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

38.2.3 [Figure 38.1](#) and [Figure 38.2](#) show a typical surge generator and control relay, respectively.