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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Standard for Arc-Fault Circuit-Interrupters

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Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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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

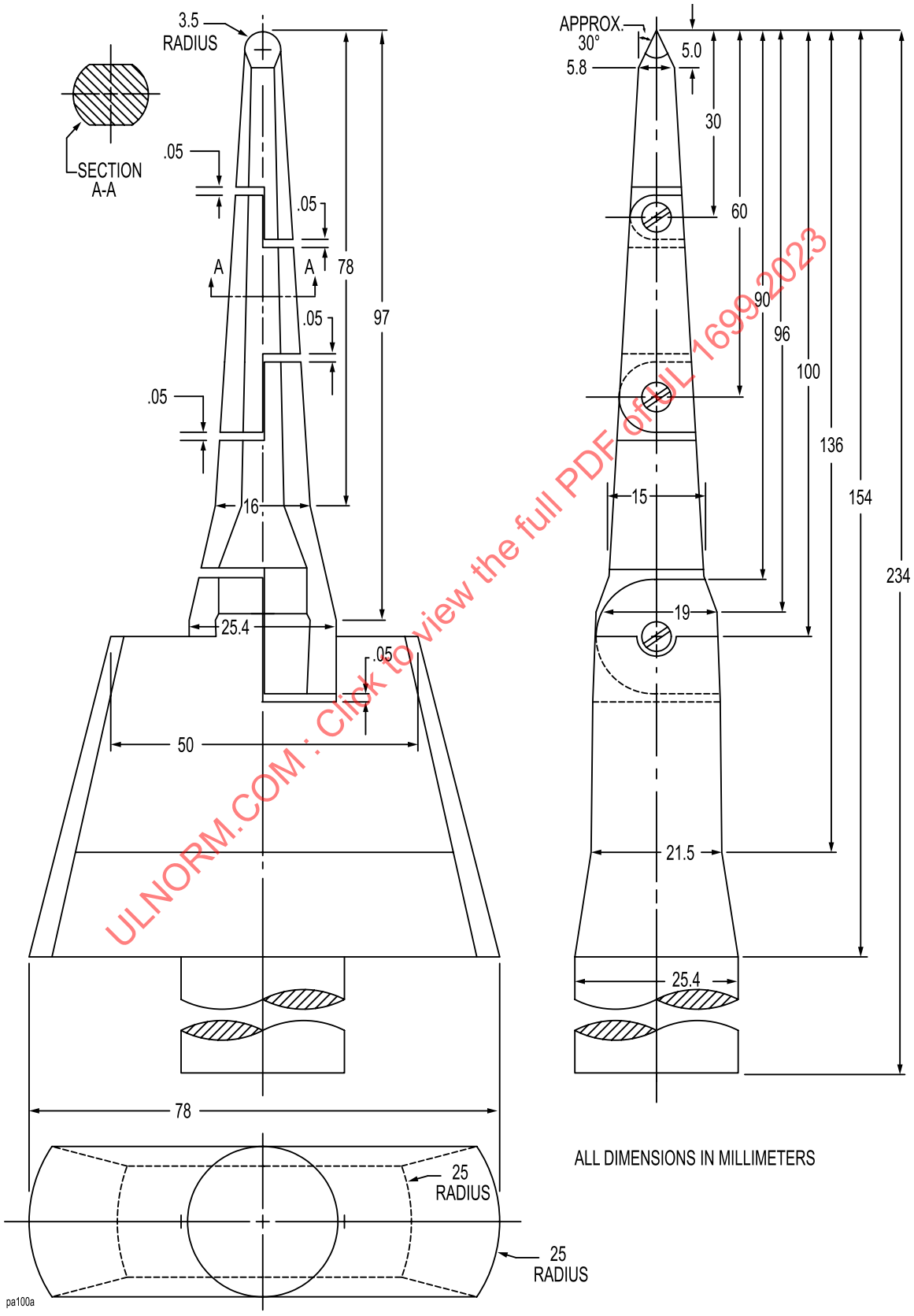
7.1 Parts of a device shall not be accessible when they are installed as intended and energized.

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.

Figure 7.1

Articulated probe



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 mm^2) 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 mm^2) 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).

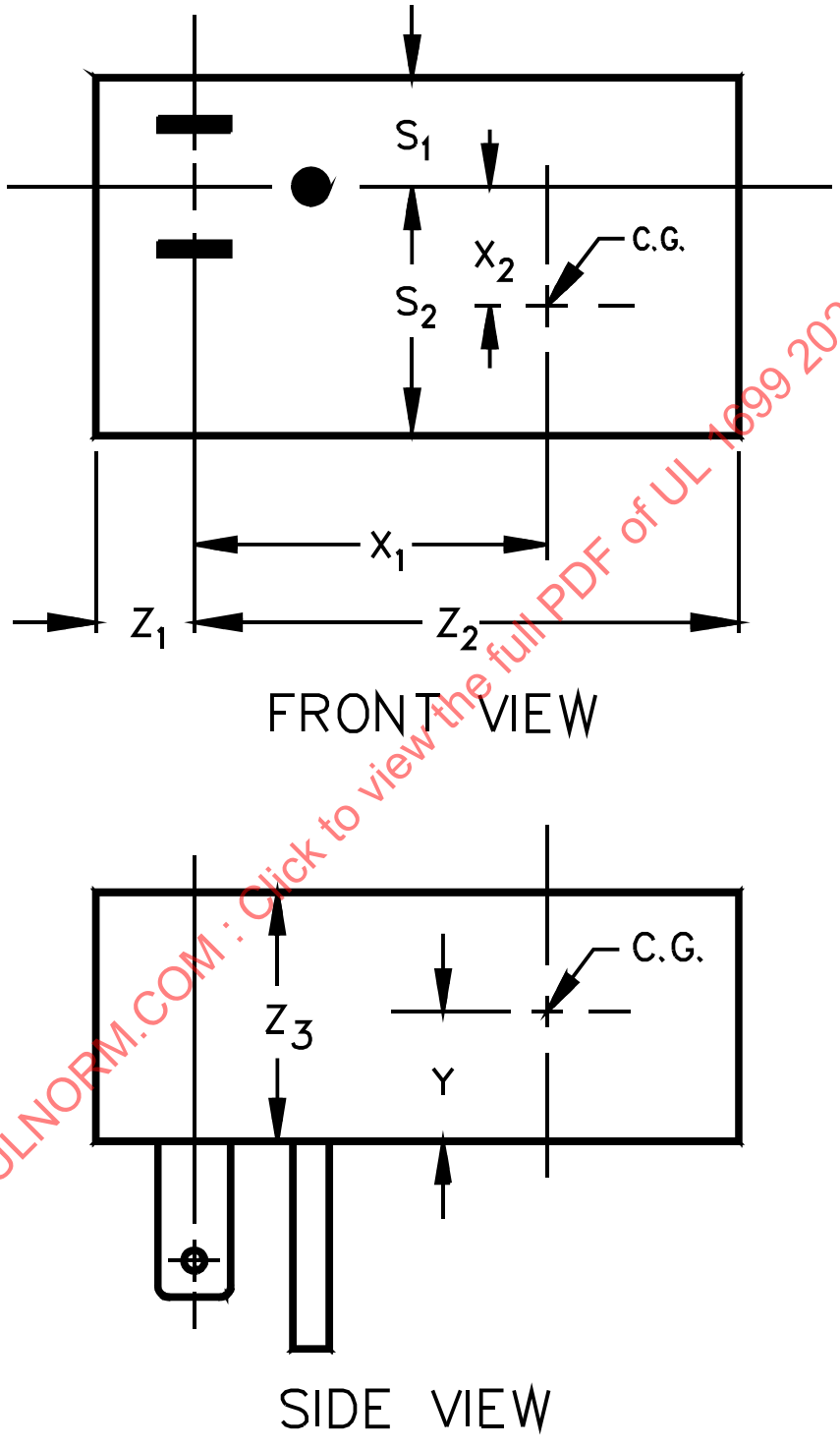
Z is the lesser of the two distances, Z1 or Z2, as illustrated in Figure 27.1, in inches (mm).

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



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.

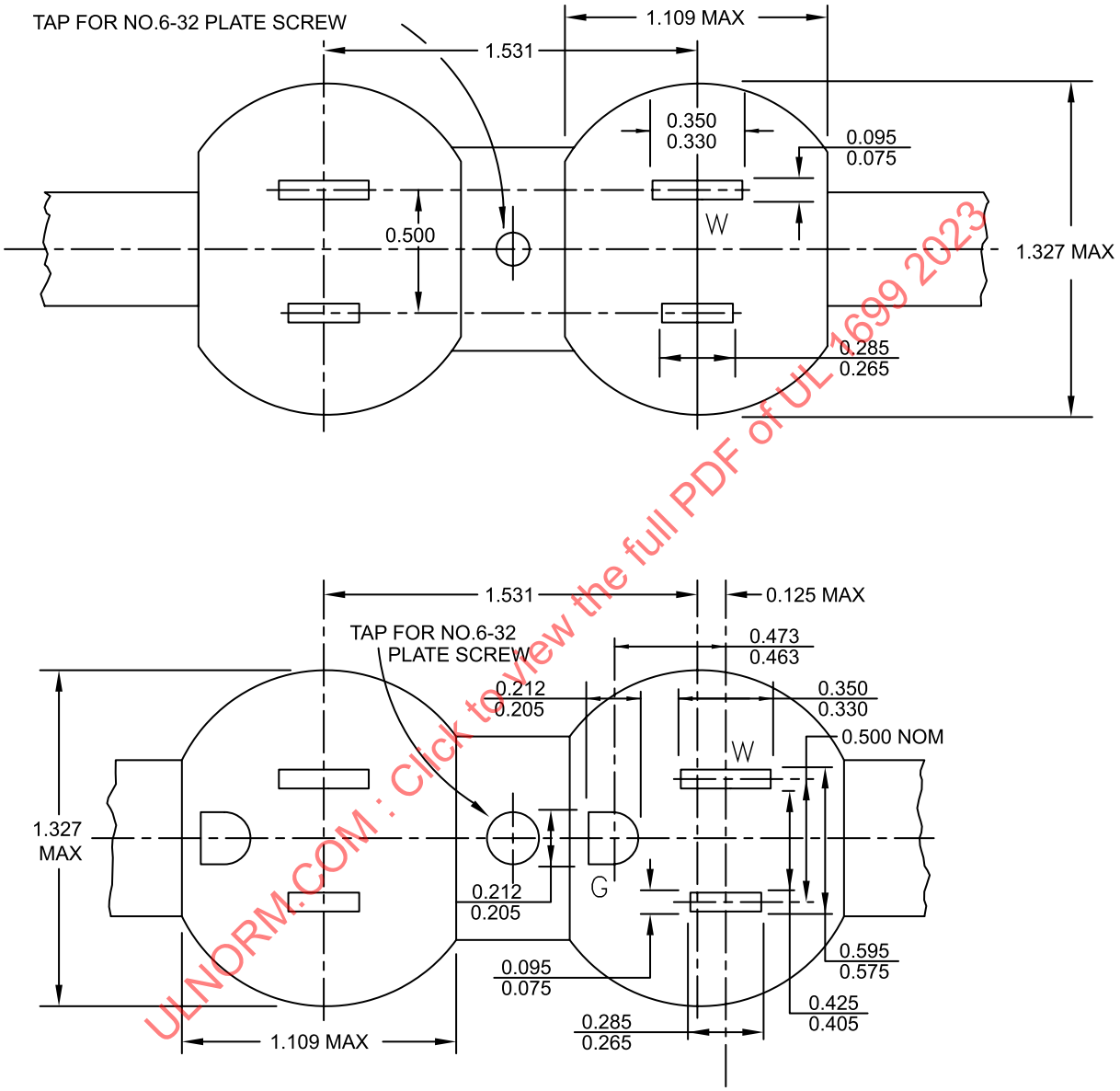
b) For units with integrally mounted accessories or optional components, the values are to be measured with the accessories or components in place.

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



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	Combination 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	Combination 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			

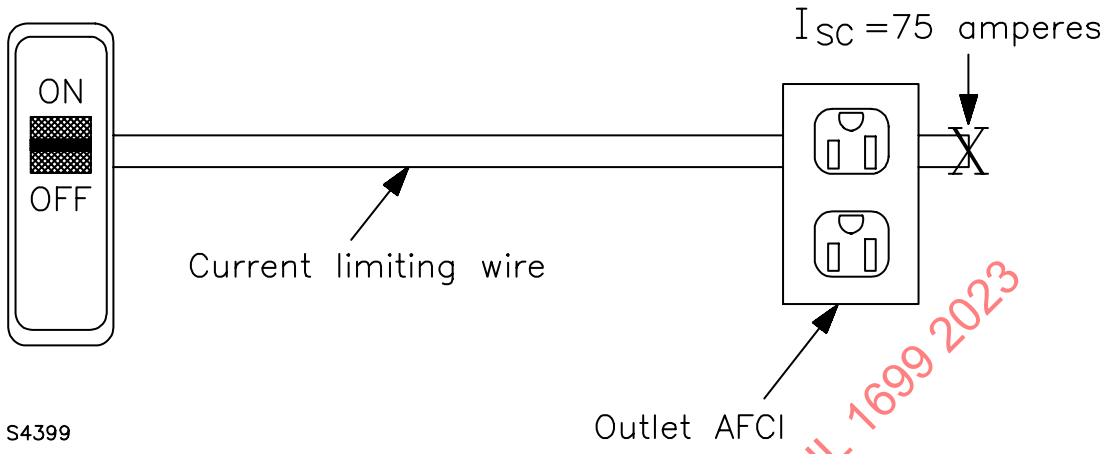
NOTE – All SPT-2 wire specimens shall have insulation rated 60°C.

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 ±2.0°C (89.6 ±3.6°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.

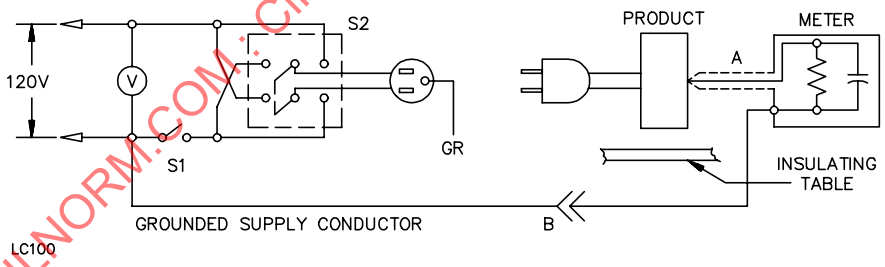
b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistance or current through the resistance.

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;

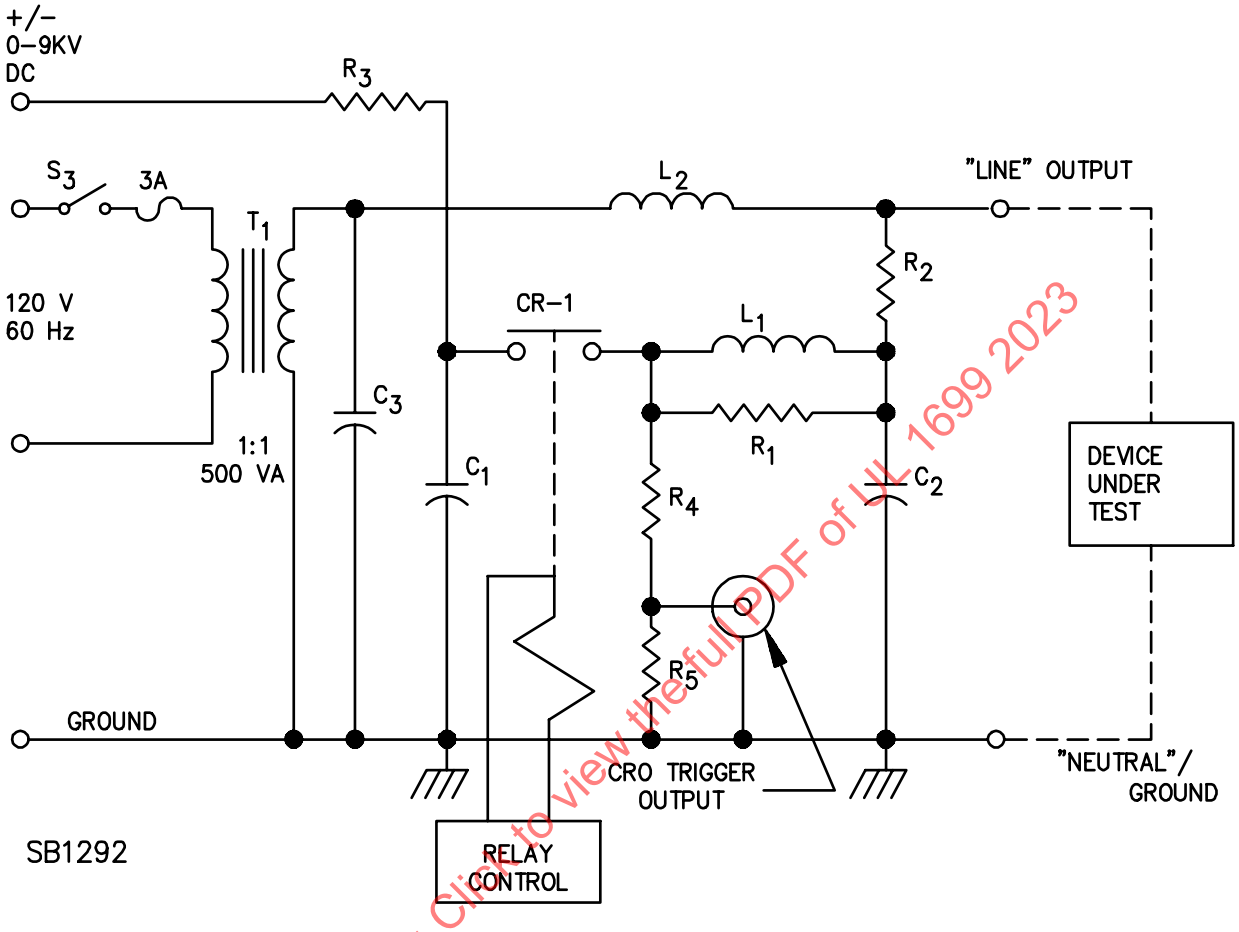
b) The period of the following oscillatory wave, 10 microseconds; and

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.

Figure 38.1

Typical surge generator circuit



C_1 = 0.025 µF, 10 Kv

C_2 = 0.01 µF, 10 Kv

C_3 = 4 µF, 400 v

L_1 = 15 µH [23 turns, 23 AWG wire, 0.7 inch (18 mm) diameter air core]

L_2 = 70 µH [28 turns, 23 AWG wire, 2.6 inch (66 mm) diameter air core]

R_1 = 22 Ohms, 1 W, composition

R_2 = 12 Ohms, 1 W, composition

R_3 = 1.3M Ohms (12 x 110X Ohms, 1/2 W)

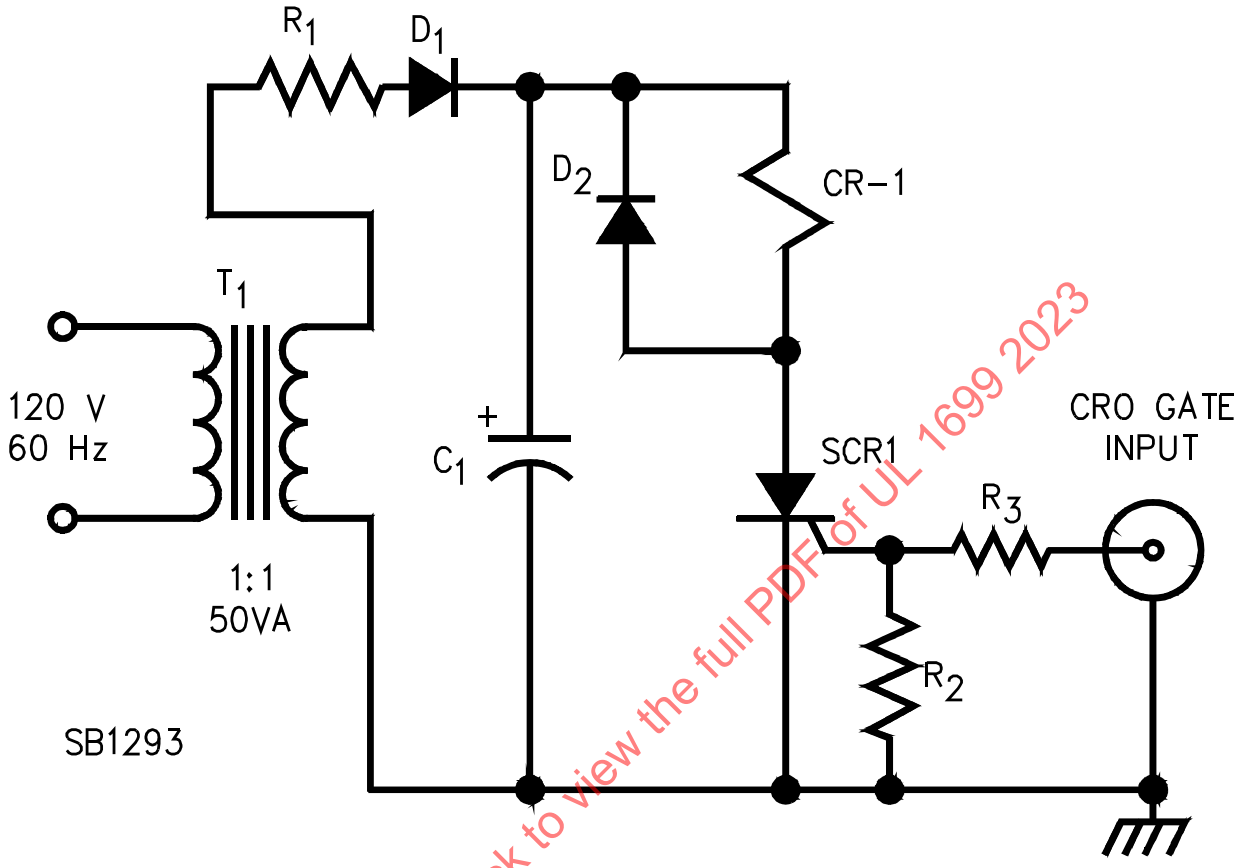
R_4 = 47K Ohms (10 x 4.7 Ohms, 1/2 W)

R_5 = 200 Ohms, 1/2 W

CR-1 = Relay

Figure 38.2

Typical relay control circuit for surge generator



R_1 = 10K Ohms, 1 W

R_2 = 1K Ohms, 1/2 W

R_3 = 1K Ohms, 1/2 W

C_1 = 32 µF, 250 V

D_1 = IN5060 or equivalent

D_2 = IN5060 or equivalent

SCR1 = GE C122B or equivalent

CR-1 = Relay GE CR 2790 E 100 A2 or equivalent

T_1 = Triad N4S X or equivalent

38.3 Surge immunity test (Combination wave)

38.3.1 The AFCI subjected to the Unwanted Tripping Test shall be subjected to the Surge Immunity Test without demonstrating, either during or after testing:

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

b) Ignition of the enclosure; or

c) Creation of any opening in the enclosure that results in accessibility of energized parts, when judged in accordance with Accessibility of Energized Parts, Section 7.

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

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

38.3.4 The surge impulse test levels in Table 38.1 shall be used.

Table 38.1
Surge impulse test levels

Impulse[a]	
Peak voltage (KV p)	**Peak current (KA p)**
4	2

[a] Combination 1.2/50 µs, 8/20 µs Voltage/Current surge waveform. For specifications and tolerances, refer to the IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits (ANSI/IEEE), IEEE C62.41.

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

38.3.6 Following exposure to the voltage surges the AFCI shall be in a condition to continue the test sequence in Table 34.1.

39 Environmental Test Sequence

39.1 A device that has been conditioned by drop or impact (when required and as appropriate), humidity, leakage current, and voltage surge, shall comply with the tests in Arc Fault Detection Tests, Section 40, while operating in ambient air at 25°C. The same representative device shall respond to the presence of an arcing fault by being subjected to a repeated Point contact arc test, while in ambient air at 66, -35, and 25°C by following the sequence shown in Table 39.1.

39.2 Before starting the test sequence in Table 39.1, the mounting position of the device under test shall be studied to determine whether there is one position that is more adverse to correct operation than another position. This study is to be made by introducing faults or by injecting signals that simulate faults while the device is placed in different positions. The mounting position of a device that is marked to specify a mounting position is to be varied from the marked mounting position by not more than 10 degrees in any direction. A representative AFCI that has not been conditioned or subjected to other tests is to be used for this study. The device that has been conditioned is to be subjected to the tests in Table 39.1 while mounted in the position determined to be most adverse. When no position is found to be most adverse, the test sequence is to be performed with the device mounted in any convenient position.

Table 39.1
Test sequence for arc fault detection tests

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)	Rated voltage	Test per Section 40 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)	Rated voltage	Test per Section 40.5.
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)	Rated voltage	Test per Section 40.5.
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)	Rated voltage	Tests per Section 40.5 as soon as possible to minimize self-heating.
10. 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.
11. 25.0 ±5.0°C (77.0 ±9.0°F)	Rated voltage	Test per Section 40.5.

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

[b] In the event that an AFCI 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.

40 Arc Fault Detection Tests

40.1 General

40.1.1 In order to demonstrate that the AFCI can detect and protect against arcing, a representative AFCI of each rating shall be tested for each test within the appropriate test series as defined in Table 34.2 and described in this Section. Unless otherwise indicated, tests with nonmetallic sheathed cable (Type NM-B) shall utilize cable specimens which include a bare equipment grounding conductor.

40.2 Carbonized path arc ignition test

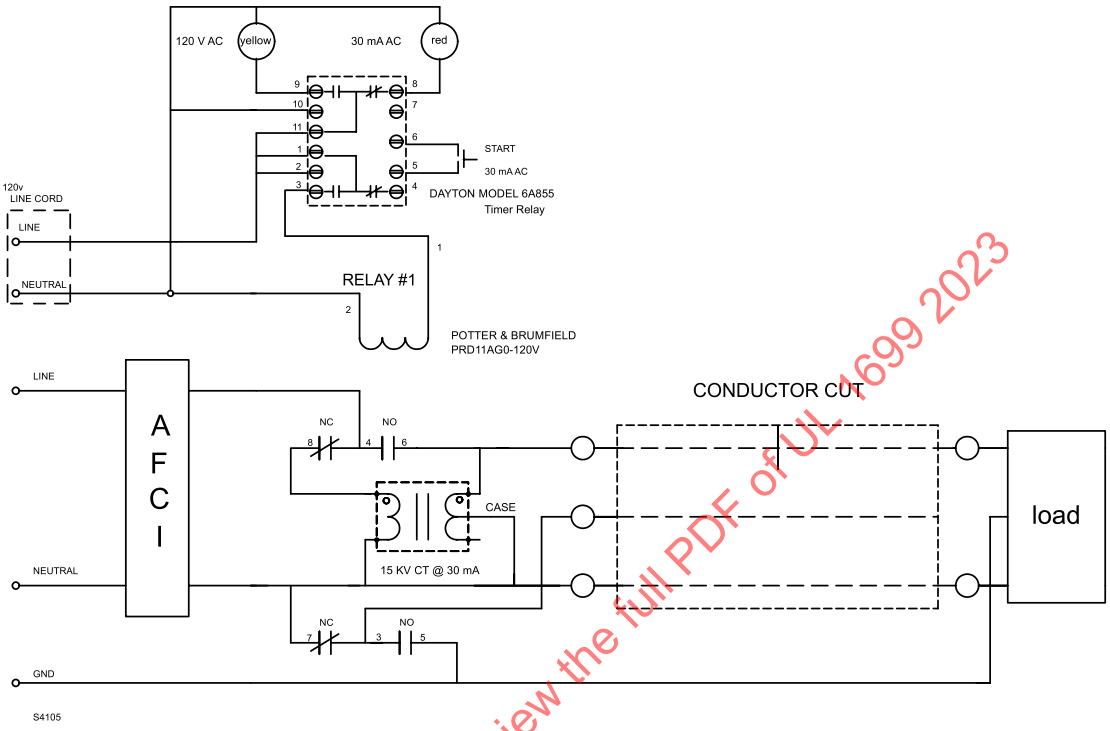
40.2.1 After being tested as described in this Subsection, the representative AFCI shall interrupt the electric circuit to the load prior to ignition of a cotton fire indicator.

40.2.2 A Carbonized Path Arc-Fault Tester as shown in Figure 40.1 and described in 40.2.3 and 40.2.4 is used to condition the conductors and test the AFCI.

40.2.3 The schematic for the Carbonized Path Arc-Fault Tester is shown in Figure 40.1. A 10 seconds ON and 10 seconds OFF timer is used to control a contactor. Two form A contacts are wired in series as shown. A 15 kV ±10 percent center tapped gas tube sign transformer is used to provide a 30 mA current source for creating a carbonized conductive path across the insulation of the cable specimens.

Figure 40.1

Carbonized path tester – arc ignition test (load deenergized)



40.2.4 The test is initiated by energizing the transformer through the normally closed relay contacts. The transformer's 30 mA secondary current flows through the gap in the cable specimens (caused by the cut wire) and load. The cable specimen's input terminal voltage becomes impressed across the gap in the cable plus the voltage across the load with 30 mA flowing in the test circuit. After 10 seconds the relay is energized, de-energizing the transformer, allowing the 120 VAC input voltage to be applied to the cable specimen's line-to-neutral terminals through the relay's normally opened contacts. After another 10 seconds the relay is opened and the 30 mA high voltage cycle is repeated. These 10 second cycles of high voltage and rated voltage are to be repeated until the device opens. Interruption of the electric circuit during the high voltage cycle does not count as meeting the intent of the test. An oscilloscope is to be utilized to determine the moment of interruption. It shall be permissible to modify the test circuit such that current does not flow through the device under test during the high voltage conditioning cycle.

40.2.5 The AFCI shall be tested with three samples of nonmetallic sheathed cable (Type NM-B copper), of rated ampacity for the device being tested, at each current level.

40.2.6 The test apparatus is to be located between the AFCI and a resistive load. The taped area of the prepared conductor specimen is to be loosely wrapped with surgical cotton. The load resistance is to be adjusted for 5 A. The test is to be conducted until the AFCI trips or the cotton ignites, except that a test need not be continued if either result is not achieved within a period of 5 minutes. In this case the test is considered to be indeterminate and is to be repeated with a new conductor specimen prepared in accordance with 40.2.7. The test is to be repeated with the load adjusted for 10 A, rated current, and 150 percent of rated current RMS without the presence of a series arc. For each test a new conductor specimen is to be used.

40.2.7 The conductor specimens are to be prepared as follows:

a) A minimum 8-inch (203-mm) length of cable is to be stripped of insulation 1 inch (25.4 mm) from each end.

b) The ungrounded circuit conductor is to be cut as indicated in Figure 40.1 without damaging insulation on the other conductor.

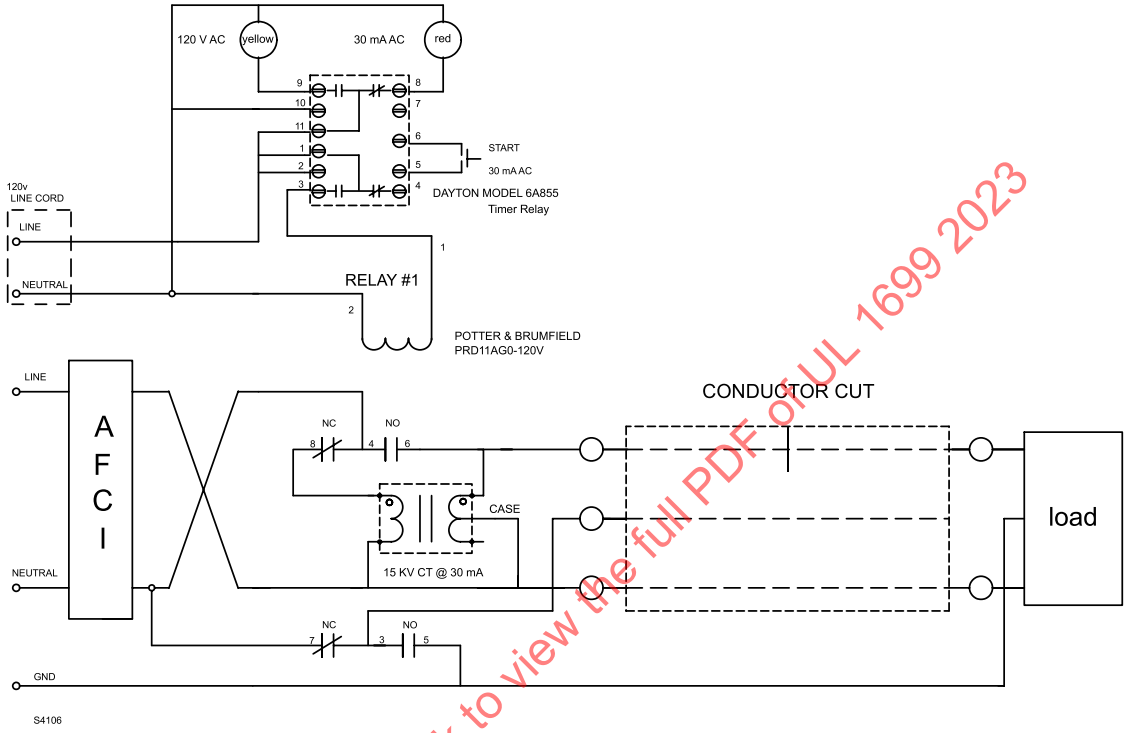
c) The cut is to be wrapped with two layers of electrical grade black PVC tape and overwrapped with two layers of fiberglass tape. The tape is to be centered on the cut and wrapped completely around the cable specimen.

40.2.8 The test in 40.2.6 is to be repeated with the cut in the grounded circuit conductor (neutral) using the tester in Figure 40.2.

Figure 40.2

Carbonized path tester – arc ignition test

(load deenergized – cut grounded circuit conductor)



40.3 Carbonized path arc interruption test

40.3.1 As a result of being tested as described in this Subsection, an AFCI shall clear the arcing fault if 8 half-cycles of arcing occur within a period of 0.5 seconds. For the purposes of these requirements, an arcing half-cycle is considered to be all of the current traces occurring within a period of 8.3 ms (for a device rated 60 Hz). Within that time period there may be current flow for some but not all of the time. Prior to and following each period of current flow, there may be a period of no current or very reduced current. Very reduced current is considered to be current with an amplitude less than 5 percent of the available current or current that continues for not more than 0.42 ms. This may last for either a portion of a half cycle or for several half cycles. A complete sinusoidal half cycle of current flow is not considered to be an arcing half cycle. When counting arcing half-cycles, the first half cycle corresponding to the initiation of the current shall not be included in the count.

40.3.2 The cord and cable specimens shall be 16 AWG (1.3 mm^2) two-conductor Type SPT-2 flexible cord and nonmetallic sheathed cable (Type NM-B copper) of rated ampacity for the AFCI being tested.

40.3.3 The tests shall be performed at fault current levels of 75 A and 100 A. The schematic for the carbonized path arc interruption tester is shown in Figure 40.3.

40.3.4 The cord or cable specimen is to be prepared as follows:

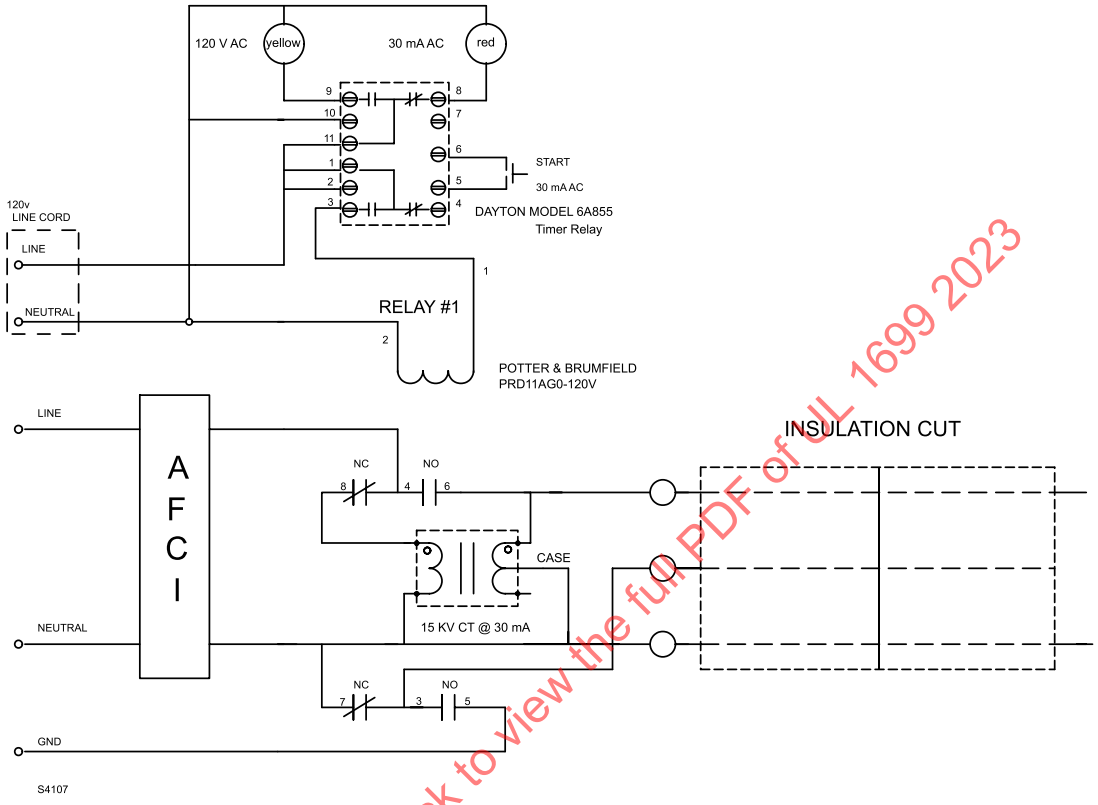
a) A minimum 8-inch (203-mm) length of cord or cable is to be stripped of insulation 1 inch (25.4 mm) from one end of the specimen.

b) A transverse cut is to be made across the midpoint of the specimen. This cut is to penetrate the insulation to all of the conductors. The cut is to be wrapped with two layers of electrical grade black PVC tape and overwrapped with two layers of fiberglass tape.

40.3.5 The prepared specimen is to be installed in the tester in Figure 40.3.

Figure 40.3

Carbonized path tester – arc interruption test, insulation only cut



NOTE:

The grounding conductor is not present when testing the 2-conductor specimen.

40.3.6 The test is initiated by energizing the transformer through the normally closed relay contacts. The transformer's secondary current flows from one conductor of the specimen to the adjacent conductor or conductors (through the cut in the insulation). The cable specimen's input terminal voltage becomes impressed across the space between conductors. After 10 seconds the relay is energized, de-energizing the transformer, allowing the 120 VAC input voltage to be applied to the cable specimen's line-to-neutral terminals through the relay's normally opened contacts. After another 10 seconds the relay is opened and the high voltage cycle is repeated. These 10 second cycles of high voltage and rated voltage are to be repeated until the device opens. Interruption of the electric circuit during the high voltage cycle does not count as meeting the intent of the test. It shall be permissible to modify the test circuit such that current does not flow through the device under test during the high voltage conditioning cycle.

40.3.7 If the AFCI opens, the test is to be repeated at the next fault current level. If the arcing fault self extinguishes with less than 8 arcing half cycles within a period of 0.5 seconds, the test sequence is to be repeated. The 0.5 s period is considered to begin with the first arcing half cycle.

40.4 Carbonized path arc clearing time test

40.4.1 After being tested as described in this Section a representative AFCI shall clear the arcing fault in the time specified in Table 40.1 for the current level being tested.

Table 40.1
Arc test clearing times

Test current, Amperes[c]	15 Amp AFCI	20 Amp AFCI	30 Amp AFCI
5	1 sec	1 sec	1 sec
10	0.4 sec	0.4 sec	0.4 sec
Rated current	0.28 sec	0.20 sec	0.14 sec
150 percent rated current	0.16 sec[a]	0.11 sec[a]	0.1 sec
	0.19 sec[b]	0.14 sec[b]	

[a] Required clearing time when the switch is closed on the load side of the AFCI. See 40.4.6.

[b] Required clearing time when the AFCI is closed on the fault. See 40.4.6.

[c] Tests at 120 V are also applicable to cord AFCIs rated 120 V/240 V.

40.4.2 Specimens of Type SPT-2 16 AWG (1.3 mm^2) cord are to be prepared as follows:

a) The cord specimens are to be cut to a minimum length of 8 inches (203 mm) and the individual wires separated at each end of the cord specimen for 1 inch (25.4 mm).

b) The insulation across both wires is to be slit 2 inches (50.8 mm) from one end to a depth to expose the conductors without severing any strands.

c) The slit in the insulation is to be wrapped with a double layer of electrical grade black PVC tape and overwrapped with a double layer of fiberglass tape.

d) The conductors are to be stripped at the end farthest from the slit approximately 1/2 inch (12.7 mm) for connection to the test circuits.

40.4.3 The cord specimens shall be conditioned using a supply of sufficient voltage(s) and current(s) to rapidly pyrolyze the insulation at the slit in the cord and create a carbonized conductive path across the insulation between the cord conductors. The carbonized path shall be considered complete if a 100 W incandescent lamp in series with the path draws 0.3 A or can start to glow at 120 V. The following steps are one method that is known to produce such a carbonized path:

a) The cord specimen is to be connected to a circuit providing 30 mA short circuit current and an open circuit voltage of at least 7 kV. The circuit is to be energized for approximately 10 seconds or until the smoking stops.

b) The cord specimen is to be connected to a circuit providing 300 mA short circuit at a voltage of at least 2 kV or sufficient to cause the current to flow. The circuit is to be energized for approximately one minute or until the smoking stops.

It shall be permissible to modify the test circuit such that current does not flow through the device under test during the high voltage conditioning cycle.

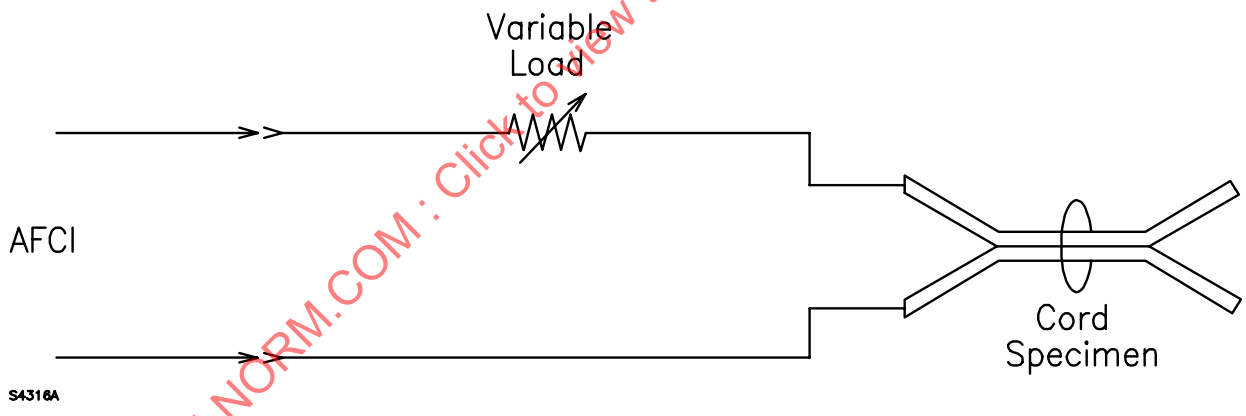
40.4.4 The tests shall be conducted at the rated voltage of the AFCI and at the current level specified in Table 40.1 Each AFCI shall be tested with three cord specimens at each current level and the AFCI shall meet the test criteria with each specimen. Each cord specimen shall only be used for one test.

40.4.5 The current shall be limited by a purely resistive load ahead of and in series with the cord specimen in the test circuit.

40.4.6 The test shall be conducted by connecting the cord specimen in series with the AFCI. The AFCI is to be closed on the fault and allowed to open the circuit. The test is to be repeated by closing a switch on the load side of the AFCI. See Figure 40.4.

Figure 40.4

Carbonized path arc clearing time test



40.5 Point contact arc test

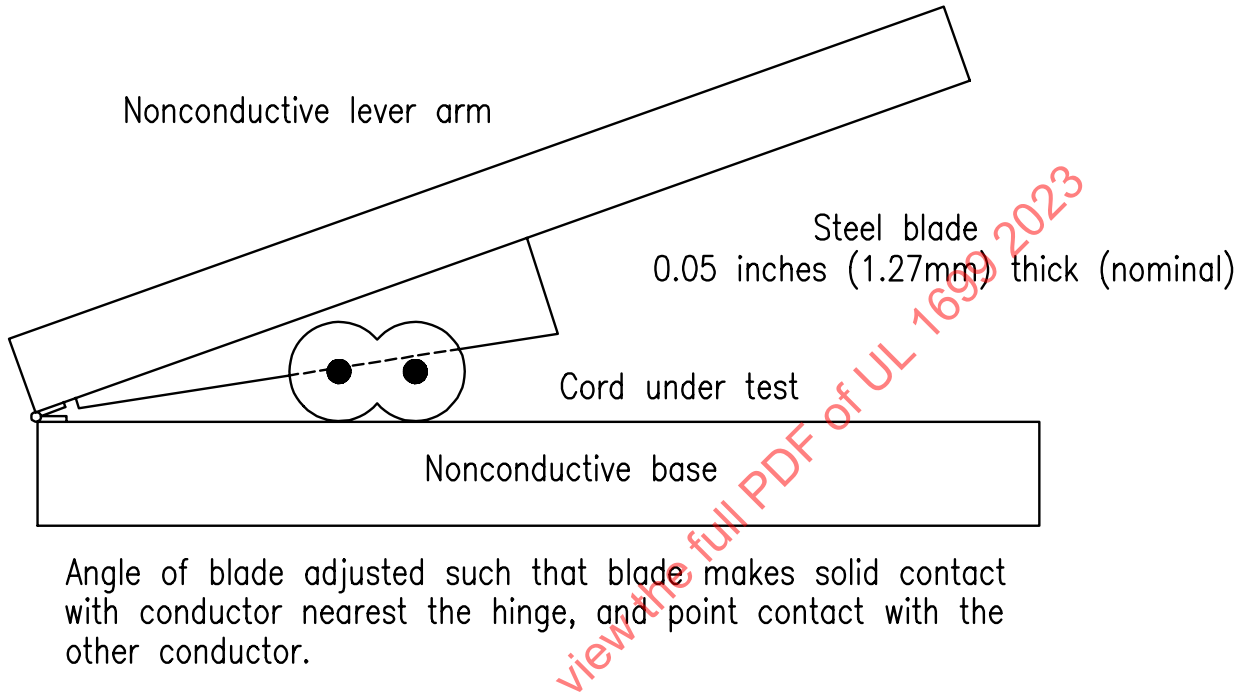
40.5.1 The test apparatus for the point contact arc test shall be as shown in Figure 40.5, or equivalent. The steel blade shall be 0.05 inches (1.27 mm) thick (nominal), with approximate dimensions of 1-1/4 inches (32 mm) by 5-1/2 inches (140 mm). The blade may be replaced as necessary. The blade may be sharpened if agreeable to all concerned. This shall be attached to a lever arm to maintain a cutting angle to produce the effect described in 40.5.5. Using the test apparatus shown in Figure 40.5, or equivalent, the blade is to be positioned so that solid contact is made with one conductor and arcing contact is made with the second conductor.

40.5.2 The conductor samples to be tested shall be two conductor 16 AWG (1.3 mm^2) Type SPT-2 flexible cord and nonmetallic sheathed cable (Type NM-B copper) of rated ampacity for the AFCI being

tested. The samples shall be a maximum of 4 feet (1.22 m) long and shall be positioned below the blade as shown in Figure 40.5.

Figure 40.5

Point contact arc test apparatus



40.5.3 The tests shall be conducted at rated voltage of the AFCI and at 75, 100, 150, 200, 300, and 500 A. The ampere levels are limited by lengths of cable. The AFCI shall be tested with three samples of each wire type at each current level. Each wire sample shall only be used for one test.

40.5.4 The circuit shall be connected to a supply that meets the requirements of PERFORMANCE, General, Section 34.

40.5.5 The test shall be conducted by connecting the cord or cable specimen in series with the AFCI. The cutting edge of the lever arm (the length of the blade edge to be in contact with the representative conductors) is to be anywhere along the length of the cutting edge of the blade. The circuit shall be closed and a slow steady vertically direct force shall be applied to the lever arm so as to allow the blade to cut through the insulation of the conductor specimen under test. The blade is to make solid contact with one conductor and then point contact with the other conductor.

40.5.6 The AFCI shall clear the arcing fault if 8 half-cycles of arcing occur within a period of 0.5 seconds. The test is to be repeated with a new cord or cable specimen if the arcing is of a shorter duration than 8 half-cycles and the AFCI does not trip. An arcing half-cycle is as defined in 40.3.1.

41 Unwanted Tripping Tests

41.1 General

41.1.1 A representative AFCI of each rating shall not trip after being tested under each of the 120-V loading conditions as described in this Section. When tripping occurs, an additional five representative AFCIs of the rating under test shall be tested and shall not trip.

41.2 Loading condition I – inrush current

41.2.1 Loading condition I is as follows:

a) A 1000-W tungsten load consisting of four 150-W bulbs and four 100-W bulbs. With the AFCI closed, the load shall be energized by using a controlled switch closing the circuit at 30, 60 and 90 degrees on the voltage waveform or 60 times with random closing. The switch is to be on the load side of the AFCI. The maximum peak inrush shall not be less than 100 A when measured at a 90 degree closing angle. The lamps are to cool for one minute between each energization.

b) A capacitor start (air compressor type) motor with a peak inrush current of 130 A ±10 percent is to be started under load (compressor operating without any air pressure in the air tank) and operated for one minute then switched off. The test shall be repeated five times. The motor is allowed to come to rest after each "off" operation. The air tank is to be empty at the start of each test.

41.3 Loading condition II – normal operation arcing

41.3.1 Loading condition II is as follows:

a) A vacuum cleaner rated at 10.8 – 12 A full load having a universal motor shall be started and run for one minute and then switched off using the switch on the appliance. This test is to be repeated 5 times. The vacuum cleaner shall then be started by plugging the vacuum into a wall receptacle to start the motor and run for one minute then unplugging the motor from the wall receptacle. This test is to be repeated five times. The motor is allowed to come to rest after each off operation.

b) A bi-metallic appliance (such as flat iron, skillet, or similar appliance) rated 1200 W ±10 percent and having slow-make slow-break thermostatically controlled contacts for temperature regulation as follows:

1) The appliance shall be operated for 4 hours continuously during which the thermostat contacts are to open and close at least 25 times.

2) During a 1-minute period the appliance shall be rapidly moved and jolted and then placed into the normal rest position 10 times.

c) A 1000-W tungsten load consisting of four 150-W bulbs and four 100-W bulbs shall be controlled by a general-use snap switch. The load shall be energized "on" and "off" for 10 cycles using normal force and care. The test is to be performed at a rate of 6 – 10 operations per minute. The bulbs need not be allowed to cool.

d) The test in 41.3.1(c) is to be repeated with a general-use snap switch that complies with the Standard for General-Use Snap Switches, UL 20, and has been conditioned by cycling for 30,000 operations under rated load conditions of 15 A, 120 V, with 10,000 operations of resistive load, 10,000 operations with a load power factor of 75 – 80 percent, and 10,000 operations with a tungsten lamp load.

e) An electronic variable-speed electric hand-held shop tool rated 5 – 7 A that has been conditioned by undergoing 24 hours of continuous operation under a no-load condition at maximum speed. The speed shall be evenly varied from minimum to maximum and again to minimum every 10 seconds for one minute under a no-load condition.

f) A ceiling fan speed control (capacitive type with a rotary switch) rated 1.5 A controlling a ceiling fan. The speed shall be varied from the "off" position to maximum and again to the "off" position every 10 seconds for one minute.

g) An air purifier (a model employing electrostatic forces to move air and containing UV lamp to provide germicidal protection) shall be started by plugging the purifier into a wall receptacle to start the air moving and run for one minute, then unplugging the device from the wall receptacle. The device should have the following settings:

1) Power control switch – in the highest air movement position.

2) Mode control switch – in “ON/GP” position (power + UV light).The test is to be repeated 20 times.

The test also should be conducted 20 times with the mode control switch in “OFF” position (no power and no UV light).

41.4 Loading condition III – non-sinusoidal waveform

41.4.1 Loading condition III is as follows:

a) A 1000-W electronic lamp dimmer (thyristor type) with a filtering coil controlling a 1000-W tungsten load consisting of four 150-W bulbs and four 100-W bulbs. The dimmer is to be turned on for 1 minute each with the dimmer preset at full on, conduction angles of 60, 90, and 120 degrees, and at the minimum setting that causes the lamps to ignite. The lamps are to cool for one minute between each energization. The test is to be repeated with a 600-W dimmer without a filtering coil controlling a 600-W tungsten load consisting of two 150-W bulbs and three 100-W bulbs.

b) A previously unconditioned electronic variable-speed electric hand-held shop tool rated 5 – 7 A. The speed shall be evenly varied from minimum to maximum and again to minimum every 10 seconds for one minute under a no-load condition. A tool that has been used for a previous test, but not conditioned for 24 hours, is capable of being used as an unconditioned tool.

c) An electronic switching mode power supply (or power supplies), having a total load current at 120 V of at least 5 A with a minimum Total Harmonic Distortion (THD) of 100 percent, and individual minimum current harmonics of 75 percent at the 3rd, 50 percent at the 5th, and 25 percent at the 7th. The power supply (or power supplies) shall be turned on for one minute and then turned off.

d) Two 40-W fluorescent lamps plus an additional 5-A resistive load. The lamps are to be initiated from a cold start and operate for at least 10 seconds.

e) At the manufacturer’s option, a high wattage electronic lamp dimmer (thyristor type) with a filtering coil controlling a tungsten load as specified in Table 41.1. The dimmer is to be turned on for 1 minute each with the dimmer preset at full ON, conduction angles of 60, 90, and 120 degrees, and at the minimum setting that causes the lamps to ignite. The lamps shall cool for one minute between each energization.

Table 41.1
Optional high wattage dimmer lamp loads

AFCI amp rating	Tungsten lamp load (W)	Lamps
15	1400	6 – 150 W
		5 – 100 W
20	1900	8 – 150 W
		7 – 100 W

41.5 Loading condition IV – cross talk

41.5.1 Loading condition IV is as follows:

a) Two branch circuits connected to the same ungrounded conductor of the source circuit, one with AFCI protection and one without AFCI protection (but with conventional overcurrent protection) shall be installed using 14 AWG (2.1 mm^2) copper Type THHN conductors in the same EMT 1/2 inch trade size metal raceway. The conduit shall be 25 ft. (7.62 m) long and grounded, and serves to maintain the conductors in close proximity. With arcing produced using the method in 40.5, except only at 150 A, in the circuit without the AFCI, the AFCI protected circuit shall not trip.

b) Two branch circuits connected to the same ungrounded conductor of the source circuit, one with AFCI protection and one without AFCI protection (but with conventional overcurrent protection) shall be installed using 14 AWG (2.1 mm^2) copper Type NM-B cables. Each cable shall be 25 ft. (7.62 m) long, with the cables secured under a common staple every 4 ft. (1.22 m). With arcing produced using the method in 40.5 except only at 150 A, in the circuit without the AFCI, the AFCI protected circuit shall not trip.

41.6 Loading condition V – multiple load

41.6.1 The tests in 41.4.1 (b) and (d) are to be repeated with the total AFCI load current equal to the AFCI rating. The additional load necessary to reach rated current shall be resistive.

41.7 Loading condition VI – lamp burnout

41.7.1 As a result of being tested as described in this Section, the AFCI shall not trip.

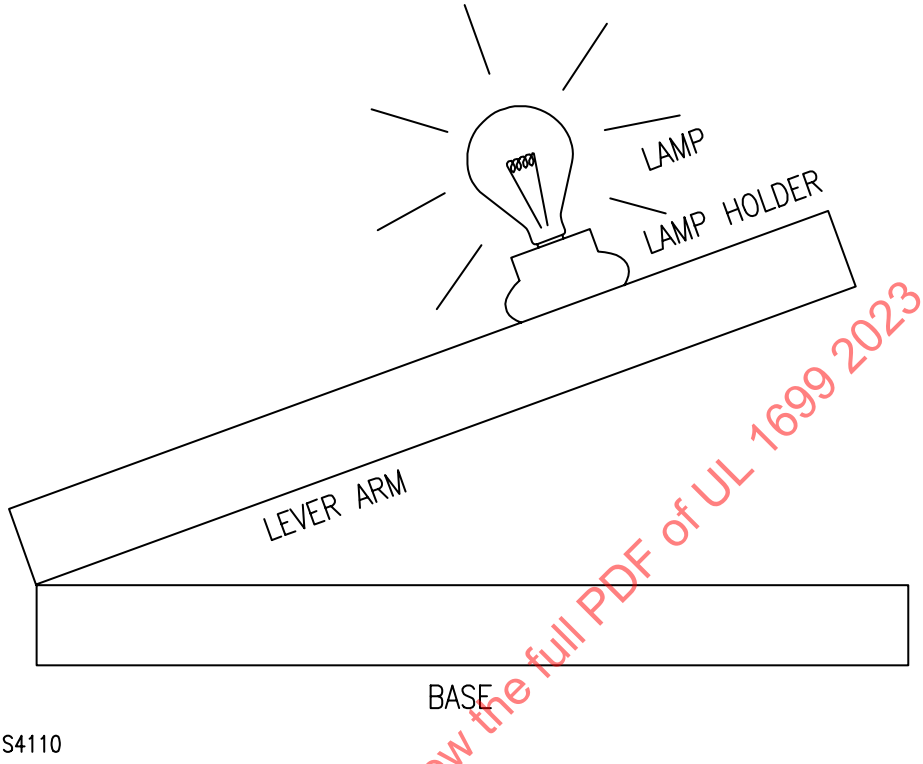
41.7.2 A Type A incandescent, 100-W lamp is to be installed in the lampholder as shown in Figure 41.1 and energized in a circuit as described in PERFORMANCE, General, Section 34 that is protected by the AFCI. The lever arm is to be raised to approximately a 20 degree angle and allowed to drop. This is to be repeated until the lamp burns out. Preconditioning of the lamp for a few minutes at greater than rated voltage is permitted to help promote lamp burnout at rated voltage.

41.7.3 The test apparatus is shown in Figure 41.1. The base and lever arm are to be approximately 48 inches (1.22 m) in length and constructed of wood or similar material. The lampholder is to be secured to the lever arm approximately 30 inches (762 mm) from the hinged end of the apparatus.

41.7.4 The test is to be repeated three times.

Figure 41.1

Lamp burnout test apparatus



42 Operation Inhibition Tests

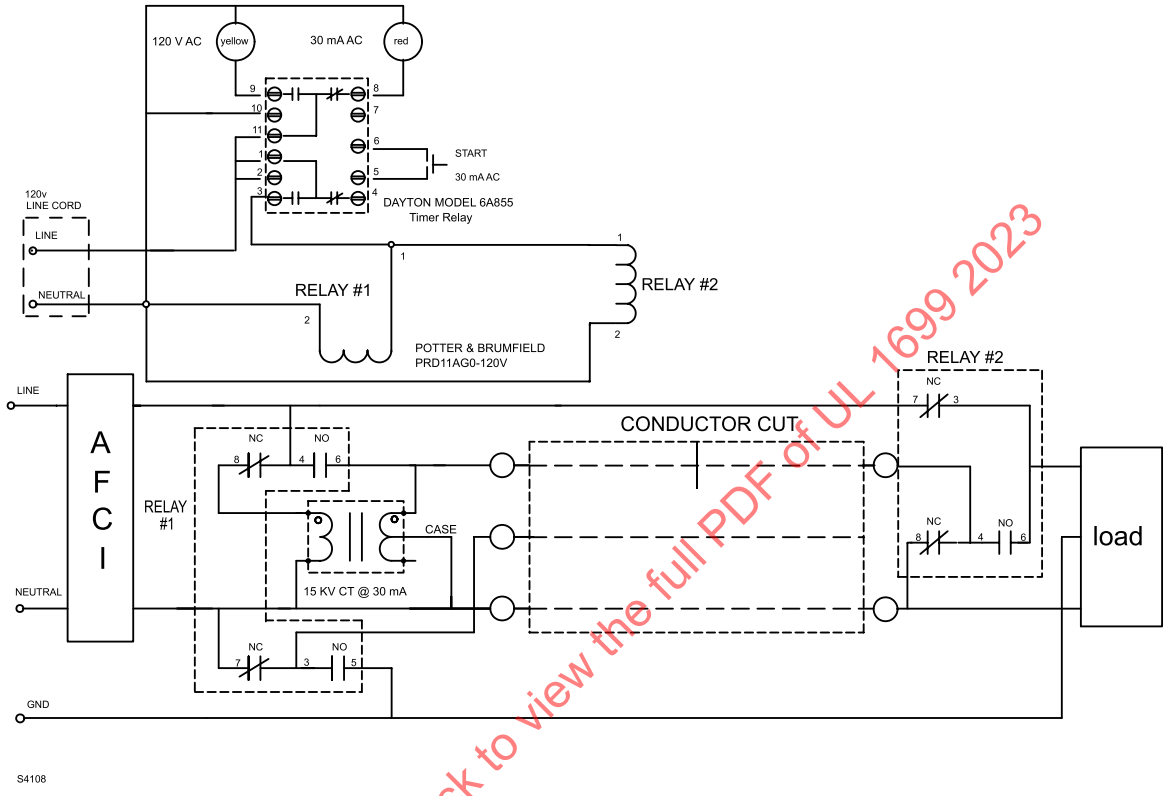
42.1 General

42.1.1 The masking the signal to operate and EMI filter tests in Subsections 42.2 and 42.3, respectively, are to be conducted using the apparatus described in 42.1.2 for a branch/feeder AFCI and for a combination AFCI, and in 42.1.3 or 40.4 for an outlet circuit, portable, or cord AFCI. The test methods of 42.1.3 or 40.4 shall also be applied to combination AFCIs. When the test in 40.4 is used, a shorting switch is to be used so as to not introduce the fault during the start up conditions of the load. The tests shall be initially conducted with no inhibition load.

42.1.2 When conducting the carbonized path arc ignition test in 40.2, it is to be performed with the load energized using the apparatus in Figure 42.1.

Figure 42.1

Carbonized path tester, arc ignition test (load energized)



42.1.3 The arc generator test shall be conducted as follows:

a) An arc generator test apparatus shall be used for this test.

b) The arc generator consists of a stationary electrode and a moving electrode as shown in Figure 42.2.

c) One electrode shall consist of a 0.25-inch (6.4-mm) diameter carbon-graphite rod and the other electrode shall be a copper rod. The arcing end of one or both electrodes may be pointed as shown in Figure 42.2.

d) For the initial tests with no inhibition load, the AFCI and arc generator are connected in the circuit of Figure 42.3 with current limited by a resistive load on the neutral side of the arc generator. Test voltage shall be the rated voltage of the AFCI. Each AFCI shall be tested three times at each current level specified in Table 40.1.

e) For the tests with inhibition loads, the AFCI and arc generator are connected in the circuit of Figure 42.3 with current limited by the loads specified in 42.2.1 and 42.3.1. Test voltage shall be the rated voltage of the AFCI. Each AFCI shall be tested three times for each load configuration.

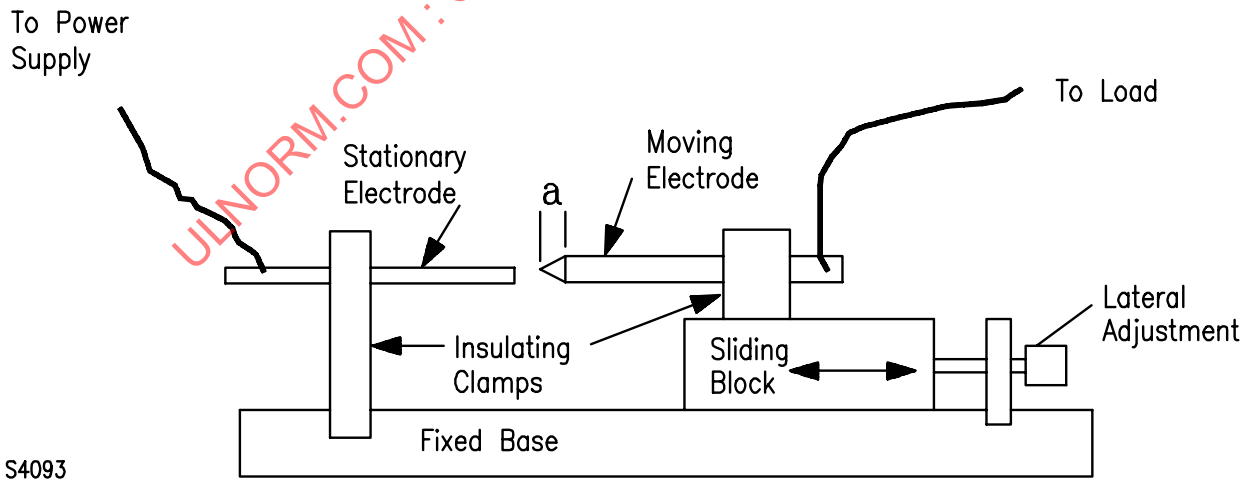
f) With the electrodes touching each other, the circuit shall be closed. The electrodes then shall be separated slowly using the lateral adjustment until arcing occurs.

g) The total arcing time before the AFCI trips shall not exceed the values in Table 40.1.

Exception: When the test current to which the Arc Fault Tester is exposed is not one of the values in Table 40.1, the allowable arc clearing time shall be determined by either using the value associated with the next higher test current, or by interpolating between the clearing time values above and below the actual test current.

Figure 42.2

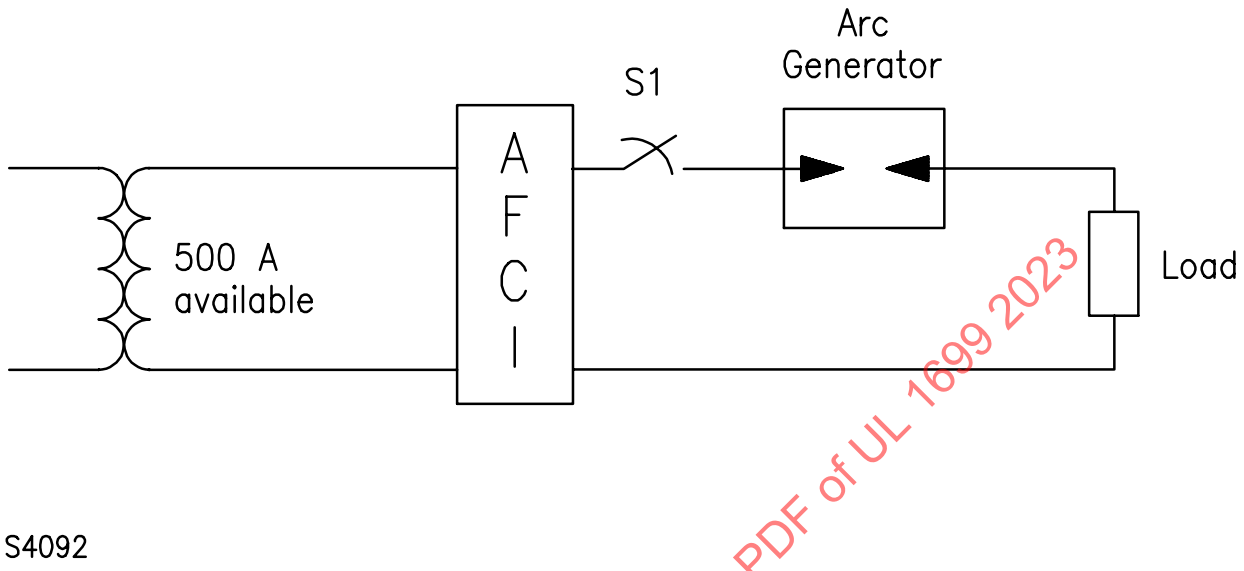
Arc generator



a = 0.7 ±0.3 inches

Figure 42.3

Arc generator test circuit



42.2 Masking the signal to operate

42.2.1 The AFCI shall be tested with each of the following masking loads using the arc tests in accordance with 42.1.1. The AFCI shall clear the arcing fault as specified in the description for the test in 40.2.6 or in Table 40.1, depending on the AFCI type. For combination AFCIs, both 40.2.6 and Table 40.1 apply. The resistive load in Figure 42.4 is to be 5 A. See Figure 42.4 for the circuit diagrams of the test setup to be used. When applying Configuration A or C of Figure 42.4, this test is not required for conditions in which the masking load current, when measured before the arc is placed in the circuit, is lower than 5 A rms.

a) A vacuum cleaner described in 41.3.1(a).

b) An electronic switching mode power supply (or power supplies) described in 41.4.1(c).

c) A capacitor start (air compressor type) motor described in 41.2.1(b).

d) A 1000-W and 600-W electronic lamp dimmer described in 41.4.1(a).

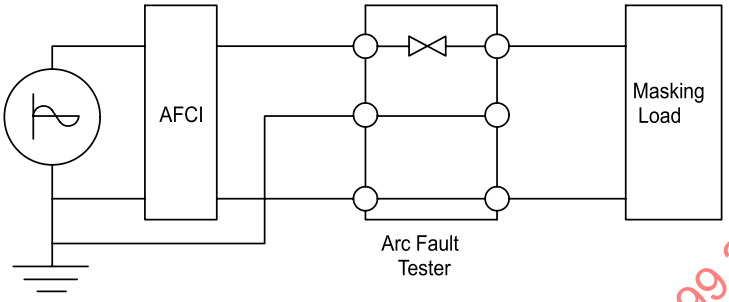
e) Two 40-W fluorescent lamps plus an additional 5-A resistive load.

Exception: When the test current to which the Arc Fault Tester is exposed is not one of the values in Table 40.1, the allowable arc clearing time shall be determined by either using the value associated with the next higher test current, or, by interpolating between the clearing time values above and below the actual test current.

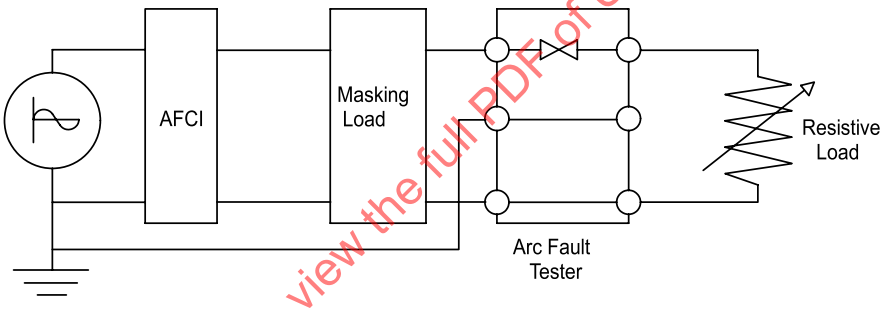
Figure 42.4

Test configurations for operation inhibition tests

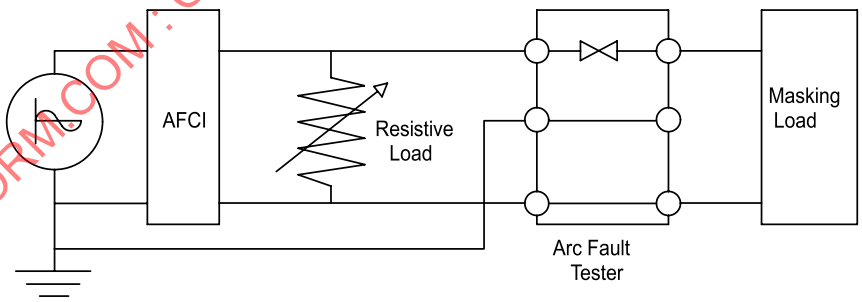
Configuration A



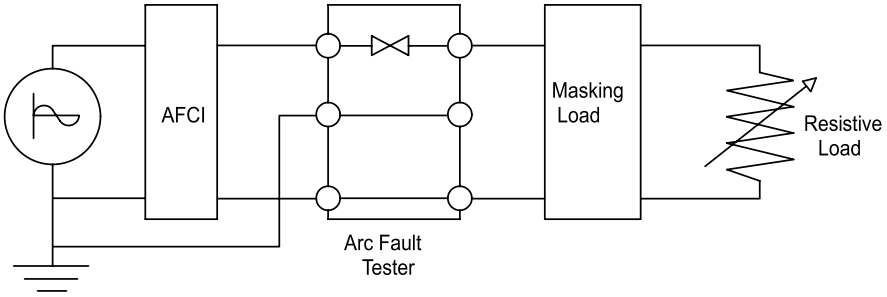
Configuration B



Configuration C



Configuration D



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42.3 EMI filter

42.3.1 The AFCI shall be installed in the following circuits. An arc test as described in Subsection 42.1 shall be introduced with a 5-A load. The AFCI shall clear the arcing fault as specified in the description for the test in 40.2.6, or in Table 40.1, or in 40.2.6 and Table 40.1, depending on the AFCI type.

a) Two EMI filters of 0.22 µF shall be installed. One filter shall be installed at one end of two resistive loads of 50 ft. (15.2 m) lengths of 12 AWG (3.3 mm^2) Type NM-B cable. Each filter shall be on the end of approximately 6 ft. (1.8 m) of 16 AWG (1.3 mm^2)Type SJT flexible cord. The arcing shall be initiated as shown in Figure 42.5.

b) An EMI filter as described in Figure 42.7 shall be installed at the end of 50 ft. (15.2 m) of 12 AWG (3.3 mm^2) Type NM-B cable. The filter shall be on the end of 6 ft. (1.8 m) of 16 AWG (1.3 mm^2) Type SJT flexible cord. The AFCI and the arcing shall be located as shown in Figure 42.6.

When testing an outlet circuit AFCI without feed through or a portable AFCI, 20 ft. (6.1 m) of 16 AWG (1.3 mm^2) Type SPT-2 flexible cord is to be substituted for the 50 ft. (15.2 m) lengths of Type NM-B cable.

Figure 42.5

EMI filter test #1

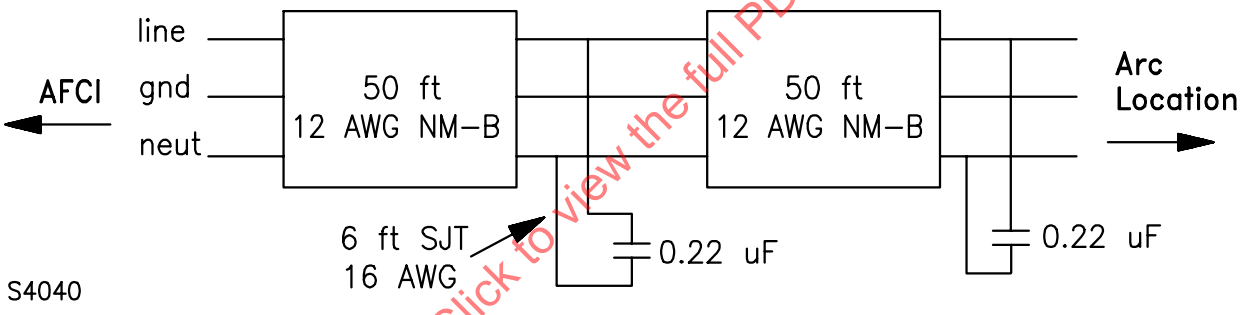


Figure 42.6

EMI filter test #2

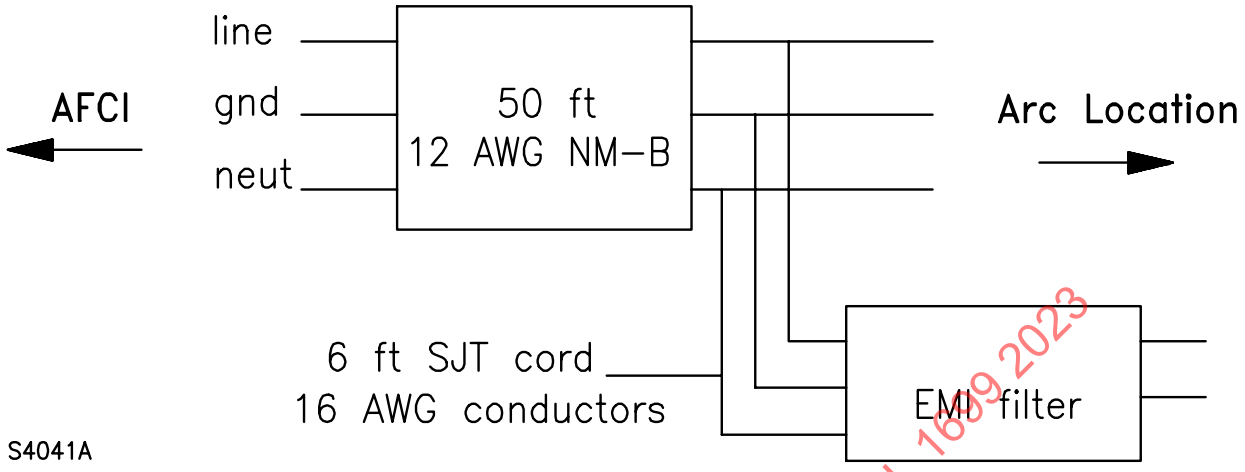
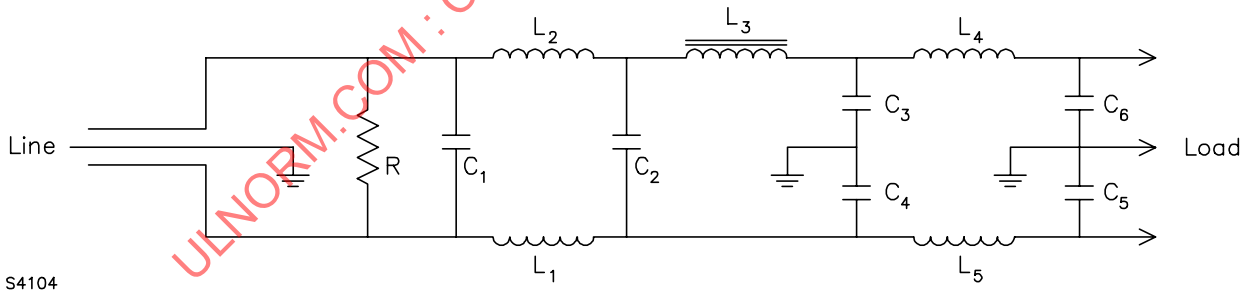


Figure 42.7

EMI filter



$L_1 = L_2 = 6.36mH$

$L_3 = 0.036mH$

$L_4 = L_5 = 1.47mH$

$C_1 = 0.47\mu F$

$C_2 = 0.27\mu F$

$C_3 = C_4 = C_5 = C_6 = 0.002\mu F$

$R = 330\ K\Omega$

42.4 Line impedance

42.4.1 The AFCI shall be installed as intended on a branch circuit, and under each of the following conditions of line impedance, the AFCI shall operate in accordance with the Point contact arcing test in 40.5, with 500 A available at the AFCI when arcing is produced at the end of the branch circuit, as modified below.

a) A branch circuit consisting of 100 ft. (30.5 m) of 14 AWG (2.1 mm^2) armored cable, 2-conductor with steel armor. The arcing shall occur from line to the grounded metal armor. See Figure 42.8; and

b) A circuit consisting of 50 ft. (15.2 m) of 14 AWG (2.1 mm^2) copper wire (single conductor) with four 90 degree bends, and 25 ft. (7.62 m) of 1/2 inch grounded steel pipe, with two 90 degree bends. The location of the arcing shall be between the wire and the steel pipe. See Figure 42.9.

c) For outlet circuit AFCIs, tests (a) and (b) shall be repeated with the power supply line source connected to the input neutral terminal and with the power-supply neutral source connected to the input line terminal. See Figure 42.10.

Figure 42.8

Line impedance test with armored cable

Figure 42.9

Line impedance test with steel pipe

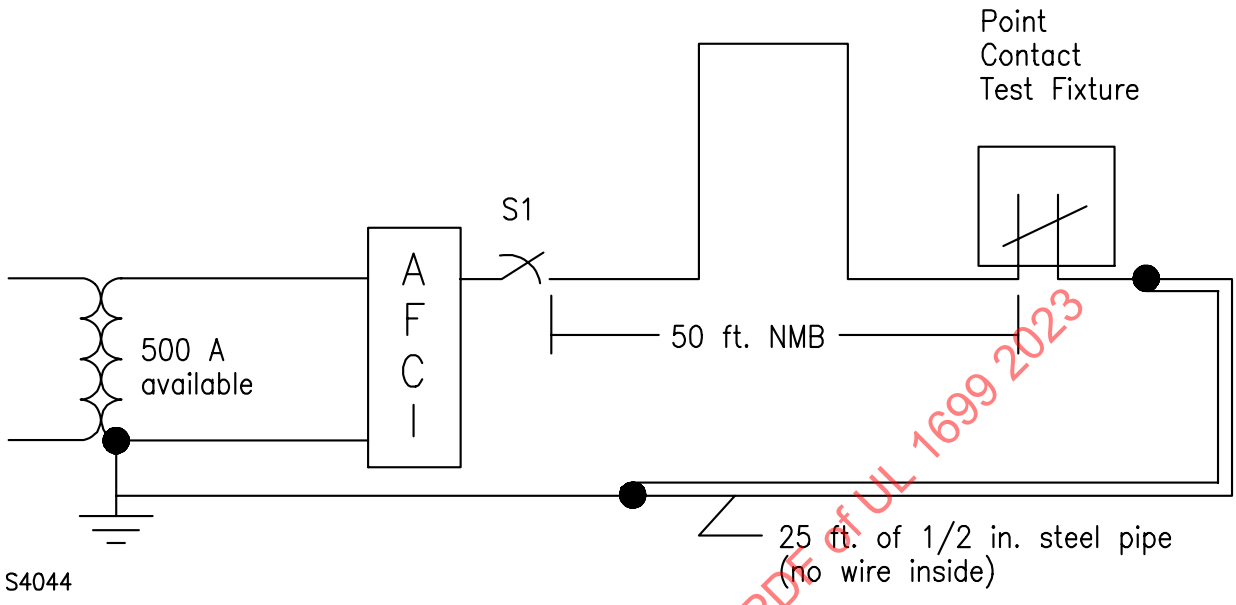
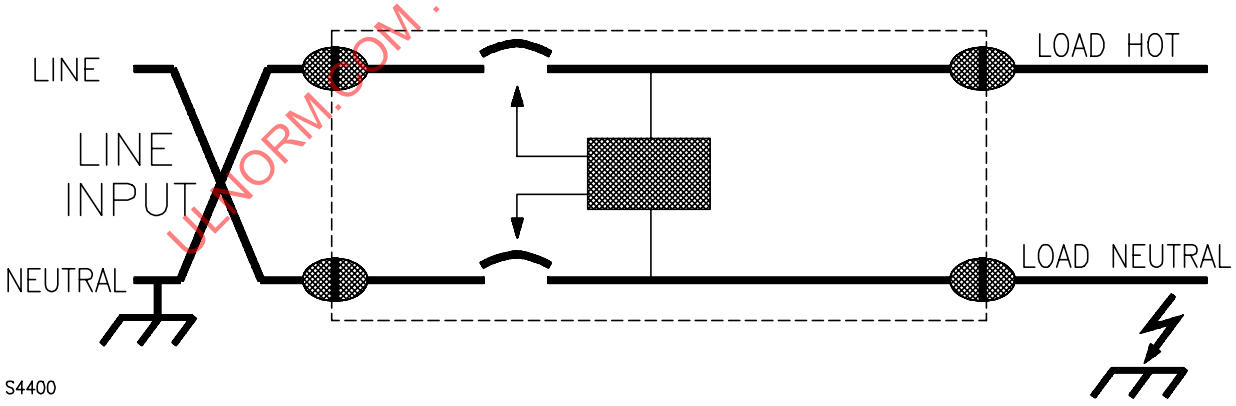


Figure 42.10

Test for line-side miswiring



43 Dielectric Voltage-Withstand Test

43.1 In a device, except as described in 43.2, the insulation and spacings between:

a) Line and load; and

b) Line and parts that are grounded

shall withstand without breakdown the following test potentials. The functional insulation and spacings of other circuits too shall withstand without breakdown the application of 1000 V + twice rated voltage, except that where the potential does not exceed 70 V peak in normal service, the test potential is to be 500 V.

43.2 The test voltage across the dielectric of a capacitor shall be 900 volts.

43.3 Basic insulation and spacings inherent in a component need not withstand the test potentials mentioned in 43.1 if the component in question complies with the requirements applicable to the component.

43.4 In order to determine compliance with the provisions of 43.1, 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.

43.5 Where the construction of the device is such as to deny access to the insulation to be tested, suitable subassemblies may be employed.

43.6 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.

44 Resistance to Environmental Noise Test

44.1 General

44.1.1 A device shall demonstrate immunity from false operation when exposed to the conditions described in this Section. The levels for immunity specified in this Section represent those that could be expected in a typical domestic/commercial electromagnetic environment. The intent of this Section is to configure the device under test as shown in Section 40.5 using the point contact arc test apparatus to induce the arc fault and determine that the device functions as intended after exposure to the electromagnetic environment specified herein.

44.1.2 The same representative device shall be tested for all of the tests described in 44.2, 44.3, 44.4, 44.5, 44.6, and 44.7.

44.1.3 The device is to be tested as described in each section, and shall not trip as a result of the electromagnetic event.

44.1.4 After all of the tests involving the electromagnetic events, the representative device shall be tested in accordance with 40.5 using wire Type SPT-2 and any two of the currents specified in 40.5.3, and shall trip as required.

44.2 Electrostatic discharge immunity

44.2.1 The Standard for Electromagnetic compatibility (EMC) Part 4; Testing and measurement techniques – Section 2: Electrostatic discharge immunity test – Basic EMC publication, IEC 61000-4-2, is to be used as the reference for testing and measuring techniques. The test limits are:

a) 4kV, positive and negative polarity, for direct contact discharge; and

b) 8kV, positive and negative polarity, for air discharge.

44.3 Radiated electromagnetic field immunity

44.3.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 3: Radiated, radio frequency, electromagnetic field immunity test, IEC 61000-4-3, is to be the test measurement reference. The frequency range to be investigated is to be from 80 MHz to 1 GHz. The exposure is to be level 2, 3 V/m modulated with 80 percent AM modulation at 1 kHz. The protective device shall not false trip when exposed to these fields. The frequencies to be used encompass the standard broadcast frequency ranges for commercial and amateur ("ham") radio and television. The step size for the test frequency ranges is to be 1 percent of fundamental. In addition the device should be exposed to radiated electromagnetic fields that simulate those generated by digital radio telephones (commonly known as "cell phones"). This test consists of exposure to 3 V/m field using a 200 Hz digital modulation technique with a 50 percent duty cycle on one frequency between 895 MHz and 905 MHz. Other frequency ranges that are used in the United States are to be considered.

44.4 Electrical fast transient immunity

44.4.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test – Basic EMC publication, IEC 61000-4-4, is to be the standard for testing methods and to specify multiple levels of limits based on installation environment. Level 2 is to be the test limit.

44.5 Voltage surge

44.5.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 5: Surge immunity test – Basic EMC publication, IEC 61000-4-5, is to be the standard for testing methods and to specify multiple levels of limits based on installation environment. The test limit is to be level 3 at 2 kV line-to-ground and level 2 at 1kV line-to-line and line-to-neutral.

44.6 Immunity to conducted disturbances, induced by RF fields

44.6.1 The test method described in the Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 6, Immunity to conducted disturbances, induced by radio-frequency fields, IEC 61000-4-6, are to be followed. The representative product is to be subjected to a conducted disturbance at 3 V over a frequency range of 150 kHZ to 80 MHz.

44.7 Voltage dips, short interruptions and voltage variations immunity

44.7.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measuring techniques – Section 11: Voltage dips, short interruptions and voltage variations immunity tests, IEC 61000-4-11, is to be the standard for testing methods. The protective aspects of the device are not to be compromised under the following power line conditions:

a) 100 percent voltage dip for 10 mS;

b) 60 percent voltage dip for 200 mS; or

c) 30 percent voltage dip for 1 S.

44.7.2 A protective device turning OFF during the disturbances specified in 44.7.1 meets the intent of the requirement provided:

a) The power to the protected unit is removed, and

b) Operation is automatically restored when input power is restored to at least 85 percent of rated voltage.

45 Normal Temperature Test

45.1 When carrying rated current and with rated voltage applied, a device shall not attain a temperature at any point that is sufficiently high to:

a) Constitute an increased risk of fire;

b) Affect injuriously any materials used in the device; or

c) Exhibit greater rises in temperature at specific points than indicated in Table 45.1, based on an assumed average ambient temperature in normal service of 25°C (77°F).

45.2 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 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 45.1.

Table 45.1
Maximum acceptable temperature rises

Material and components	°C	°F
Wire insulation or insulating tubing	35	63
Electrical tape	55	99
Varnish-cloth insulation	60	108
Fiber employed as electrical insulation	65	117
Phenolic composition or melamine[a]	125	198
Urea composition[a]	75	108
Other insulating materials[a]	–	–

[a] The acceptability of insulating materials shall be determined with respect to properties – such as flammability, arc resistance, relative or generic temperature indices, and the like – based on the temperature rise plus 25°C (45°F).

45.3 Except at coils, temperature readings are to be obtained by means of thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2), 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 30 AWG (0.05 mm^2) 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.

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

45.5 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 Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

46 Overvoltage Test

46.1 A device shall operate continuously while connected to a supply set at 110 percent of rated voltage. The test shall continue for 4 hours or until thermal equilibrium is reached. During the 4 hours, the device shall not trip or become inoperative, and shall be in condition to continue the sequence at the end of the 4 hours.

47 Overload

47.1 A device shall have necessary interrupting capacity.

47.2 In order to determine compliance with the provisions of 47.1, a device that may be required to open a load circuit 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.

47.3 Reactive components of the impedance in the AC test circuit mentioned in 47.2 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.

47.4 The value of paralleled resistance R in ohms mentioned in 47.3 may be obtained by calculation from the following equation:

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

in which:

E is the closed-circuit voltage at the load, and

I is the load current in amperes, without resistance R.

47.5 The supply circuit for the test mentioned in 47.2 is to have the capacity to provide a closed-circuit voltage not less than 85 percent of the rated voltage of the device. 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 device. A 1-A fuse is to be connected between the grounded conductor of a grounded supply circuit and accessible conductive parts of the device. This fuse shall not operate to open the circuit.

47.6 In performing the test mentioned in 47.2 the device is to be switched "on" and, after not less than one period duration of a 60 Hz line voltage waveform, switched "off". Each cycle of on/off operation is to be repeated for a total of 50 cycles of operation, at the rate of six cycles of operation per minute.

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

48 Endurance Test

48.1 A device shall have the necessary capacity for normal operation.

48.2 In order to determine compliance with 48.1, a device 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.

48.3 In performing the test described in 48.2, 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 and switched "on" and, after one second "tripped" off by using the test switch for 3000 cycles. Ten percent of the latter 3000 operations shall be performed with the supply voltage reduced to 85 percent of rated voltage.

Exception: When the device under test has no ON/OFF switch, the initial 3000 cycles are not required.

48.4 Reactive components of the load mentioned in 48.2 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.

48.5 The value of paralleled resistance R in ohms mentioned in 48.4 may be obtained by calculation from the following equation:

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

in which:

E is the closed-circuit voltage at the load, and

I is the load current in amperes, without resistance R.

48.6 In performing the test described in 48.2, 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 device. 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 AFCI. A 1-A fuse is to be connected between the grounded conductor of a grounded supply circuit and accessible conductive parts of the device. This fuse shall not operate to open the circuit.

49 Abnormal Operations Test

49.1 A device shall not become a risk of fire or shock when operating while in an abnormal condition, such as with a short-circuited or open-circuited component.

49.2 A single layer of cheesecloth is to be loosely draped over the device. In addition, a portable or cord AFCI 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.

49.3 The cheesecloth mentioned in 49.2 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).

49.4 A device operating under abnormal conditions will be considered to have become a risk of injury if:

a) There is glowing or flaming of the cheesecloth or tissue paper mentioned in 49.2;

b) There is emission of molten metal;

c) The fuse mentioned in 49.2 operates to open the circuit;

d) Except if the device is likely to be removed from service, there is dielectric failure (see 49.5 and 49.6);

e) It is possible to touch a part with the articulated probe shown in Figure 7.1 while there is a risk of shock at that part; or

f) There is any other evidence of a risk of injury.

49.5 Failure to comply with the provisions of 43.1 will be considered to be dielectric failure.

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

50 Surge Current Test

50.1 General

50.1.1 All AFCIs when subjected to the Surge Current test in 50.3.1 – 50.4.1, shall comply with the requirements in 50.1.2.

50.1.2 During and following the Surge Current Test the following conditions shall not result:

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

b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.

c) Ignition of the enclosure.

d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Energized Parts, Section 13.

50.1.3 Three previously untested representative devices of the AFCI are to be subjected to the test.

50.2 Mounting and installation

50.2.1 A AFCI shall be placed on a softwood surface covered with a double layer of white tissue paper. Each AFCI is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

50.3 Surge parameters

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

50.4 Surge polarity

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

51 Abnormal Overvoltage Tests

51.1 General

51.1.1 The test described in Full Phase Voltage-High Current Abnormal Overvoltage Test, 51.2, and Limited Current Abnormal Overvoltage Test, 51.3, shall not result in any of the following conditions:

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

b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth;

c) Ignition of the enclosure; and

d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Energized Parts, Section 7.

51.1.2 The representative devices used for each of the tests described in 51.2.1 – 51.3.2 are to be previously untested.

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

51.1.4 Portable and cord arc-fault circuit-interrupter types intended for connection to common outlet boxes shall be tested in accordance with Limited Current Abnormal Overvoltage Test, 51.3, in both normal and reversed polarity.

51.1.5 When agreed upon by all concerned parties, fewer representative arc-fault circuit-interrupters than those specified in 51.2.1 – 51.3.2 shall be used for testing.

51.1.6 Following the tests described in the Full Phase Voltage – High Current Abnormal Overvoltage Test, 51.2, and the Limited Current Abnormal Overvoltage Test, 51.3, the same representative devices are to be subjected to and comply with the Leakage Current Measurement, Section 37, for cord-connected and direct plug-in AFCIs, and comply with requirements for Grounding, Sections 19, 23, 28, and 32 for branch/feeder, outlet circuit, portable, and cord AFCIs, respectively, as appropriate. The leakage current test shall be conducted within five minutes of the end of the abnormal overvoltage tests.

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

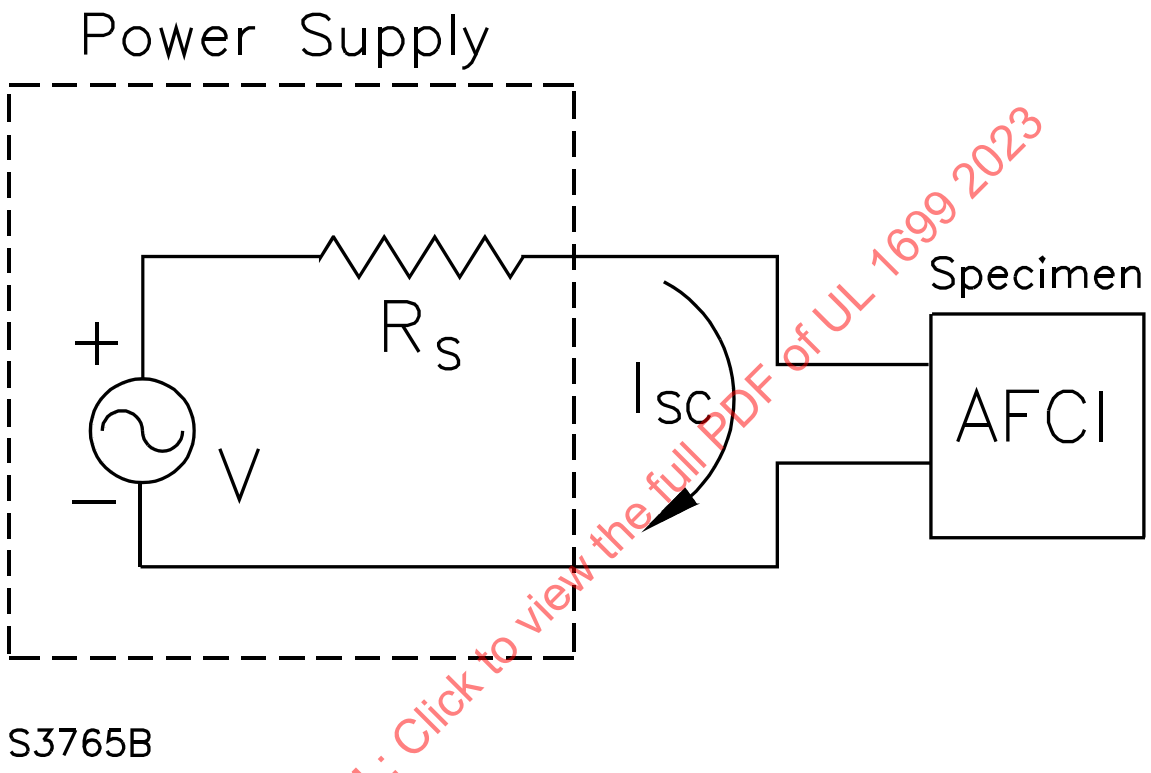
51.2 Full phase voltage – high current abnormal overvoltage test

51.2.1 The test described in this section shall not result in any of the conditions described in 51.1.1. One previously untested arc-fault circuit-interrupter, for each combination of conductor pairs that were tested in accordance with the Voltage Surge Test, Section 38, is to be subjected to the application of the test voltage as specified in Table 51.1 with a power factor as specified in Table 51.3. The ac power source shall have an available short-circuit (fault) current (I_{sc}) as specified in Table 51.2. For each representative device, the overvoltage is to be applied for 7 hours, or until current to, or temperatures within the AFCI attain equilibrium, or until the AFCI becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device). See Figure 51.1.

Exception: This testing is not required for an end-product employing a component or components that have been previously tested and shown not to conduct current nor to exhibit any condition in 51.1.6 when subjected to the maximum phase voltage or twice the conductor pair voltage rating as specified in Table 51.1 for the end-product.

Figure 51.1

High current abnormal overvoltage



51.2.2 Permanently-connected AFCIs intended for mounting in an outlet box shall be tested in the smallest standard metal box in accordance with the National Electrical Code, ANSI/NFPA 70.

Table 51.1
Test voltage selection table

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

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

Table 51.2
Available fault current from source of supply

Permanently connected devices		Cord connected or direct plug-in devices		
Rating A	**Available fault current, amperes**	**Rating volts**	**Rating, volts times amperes**	**Available fault current, amperes**
100 A or less	5,000	250 ac or less	1175 or less	200
			1176 to 1920	1000
			1921 to 4080	2000
			4081 to 9600	3500
			More than 9600	5000

Table 51.3
Power factor

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

51.2.3 Connection of the test circuit in series with a circuit breaker or time delay non-current limiting fuse rated for the maximum ampacity of the circuit in which the AFCI is to be installed, as specified in the National Electrical Code, ANSI/NFPA 70, is not prohibited.

51.3 Limited current abnormal overvoltage test

51.3.1 The test described in this section shall not result in any of the conditions described in 51.1.1. Each of four previously untested representative AFCIs is to be connected to an ac power supply having an open circuit voltage equal to the test voltage specified in Table 51.1. The power supply is to incorporate a series variable resistor that can be adjusted to obtain the short-circuit current (I_{sc}) specified below. See Figure 51.2. No load is to be connected. The variable resistor is to be adjusted such that Isc equals 5 A for the first representative device, 2.5 A for the second, 0.5 A for the third, and 0.125 A for the fourth. The four representative devices are to be energized for 7 hours, or until current to, or temperatures within the AFCI attain equilibrium, or until the AFCI becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device). See Figure 51.2.

Exception No. 1: This test is not required for an end-product employing a component or components that have been previously tested and shown not to conduct current nor to exhibit any condition in 51.1.6 when subjected to the maximum phase voltage or twice the conductor pair voltage rating as specified in Table 51.1 for the end-product.

Exception No. 2: When this test is performed at a current level specified above and results in neither:

a) Any condition specified in 51.1.6; nor

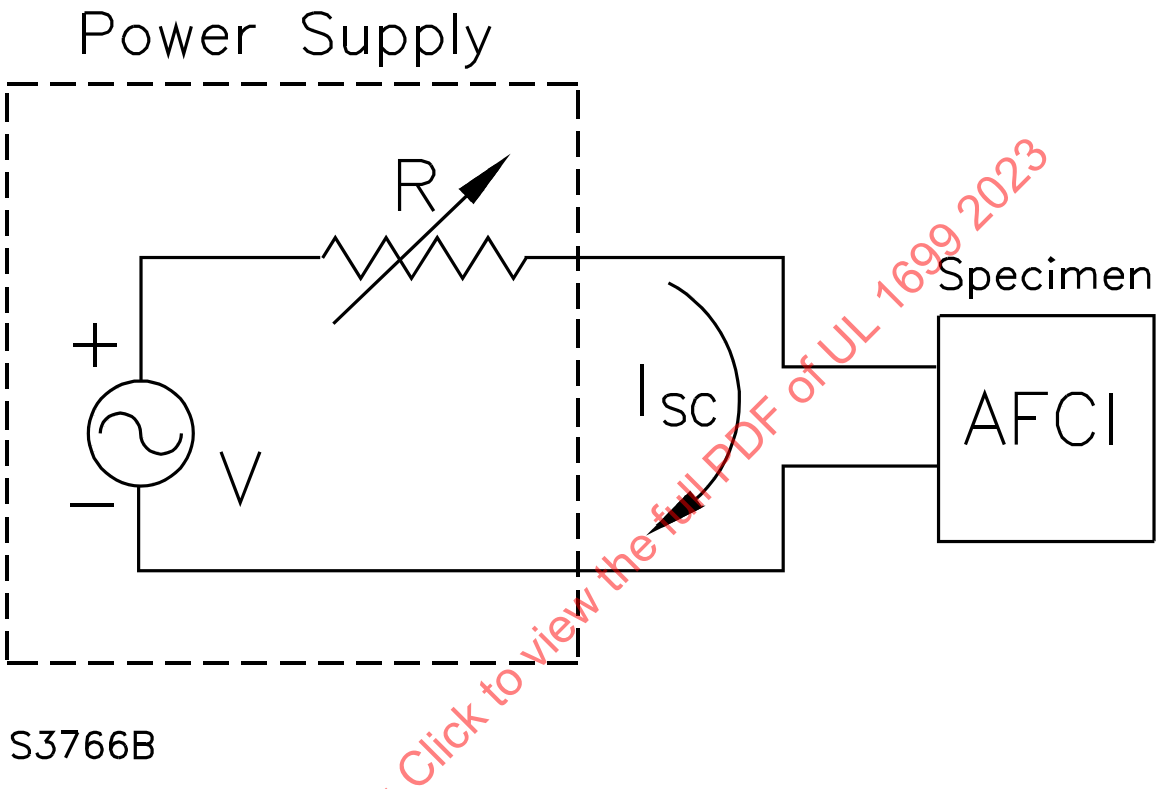
b) Operation of any overcurrent or thermal device

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

51.3.2 Permanently-connected AFCIs intended for mounting in outlet boxes are to be mounted in the smallest standard non-metallic box with faceplate in accordance with the National Electrical Code, ANSI/NFPA 70.

Figure 51.2

Limited current abnormal overvoltage test circuit



52 Short Circuit Current Test

52.1 A device intended for use on circuits where such faults can occur shall withstand short-circuit currents.

52.2 In order to determine compliance with the provisions of 52.1, the supply circuit is to have an open-circuit voltage in the range of 100 – 105 percent of the rating of the device. The impedance of the supply is to be such as to provide a prospective current as shown in Table 52.1 as a minimum.

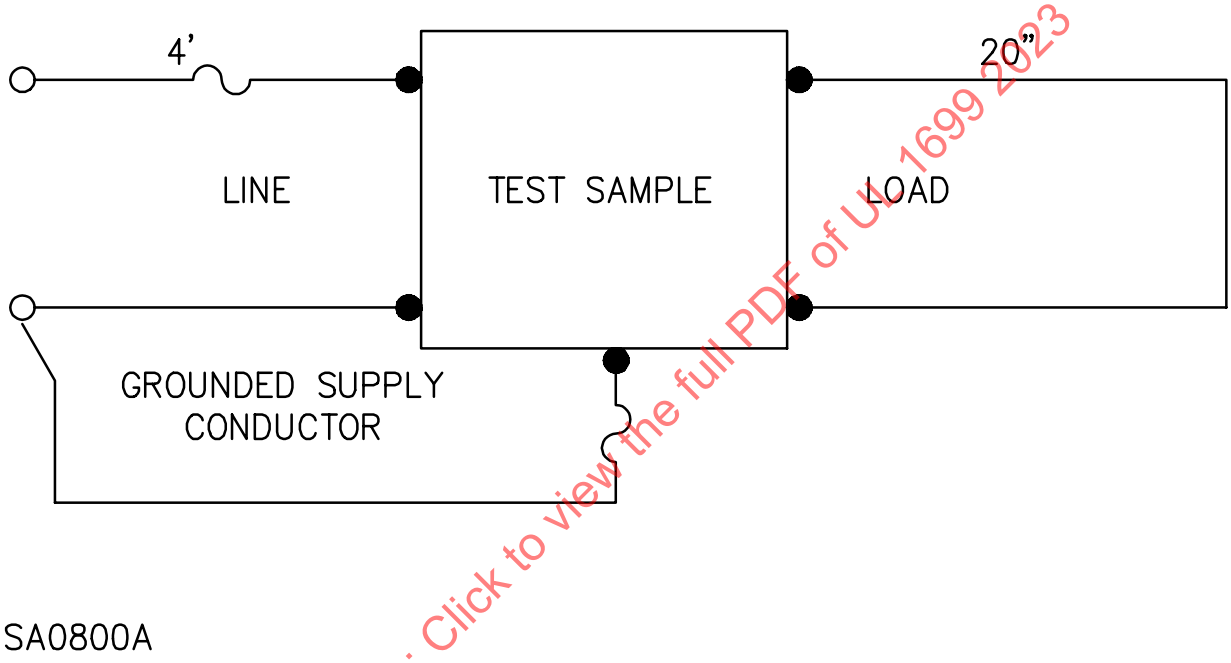
Table 52.1
Test circuit parameters

AFCI type	Current (A)	Power factor (%)
Branch/feeder AFCI	5000	45 - 50
Combination Type AFCI	5000	45 - 50
Outlet circuit AFCI	2000	90 - 100
Portable and cord AFCI	2000	90 - 100

52.3 Each line terminal of a device is to be connected to the supply mentioned in 52.2 using 4 ft (1.2 m) of insulated wire, sized for the rating of the device. A circuit breaker or time delay non-current limiting fuse rated for the maximum ampacity of the circuit in which the AFCI is to be installed is to be connected in series with the ungrounded line conductor or conductors. A 20-inch (508-mm) conductor is to be connected between the load terminals. 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 device. Surgical cotton is to cover openings of the device where flame may be emitted. See Figure 52.1.

Figure 52.1

Short circuit test circuit



52.4 For a portable or cord AFCI, the conductors may be attached to the attachment plug blades of the device so as not to be dislodged during the test.

52.5 The prospective current is to be initiated once by means of a switch in the supply circuit. The test is to be repeated with the prospective current initiated once by means of any control of the device. A single representative device is not required to experience more than one current initiation. The 1-A fuse shall not open, and there shall not be any flaming of the cotton, both mentioned in 52.3.

52.6 After the short circuit current tests, each representative device shall be tested in accordance with 40.5 using wire Type SPT-2 and the two lowest currents of the currents specified in 40.5.3, and shall trip as required.

53 Terminal Lead Strain-Relief Test

53.1 A device that is provided with terminal leads intended to be connected in the field shall be subjected to the test described in 53.2. Following the test there shall be no indication that either the device or the

lead has sustained damage as a result of the test, or that the force would have been transmitted to the terminations.

53.2 The leads are to be disconnected from the internal point of termination. Each terminal lead shall be subjected to a tensile force increased gradually to 20 lbf (89 N), and maintained at that value for five minutes.

54 Power-Supply Cord Strain-Relief Test

54.1 A device that is provided with a power-supply cord shall be subjected to the test described in 54.2. Following the test there shall not be any indication that the force was transmitted to the cord-conductor terminations.

54.2 The leads are to be disconnected from the internal point of termination. The cord shall be subjected to a tensile force increased gradually to 35 lbf (156 N) and maintained at that value for one minute.

55 Mechanical Tests

55.1 An interrupting device that is provided with pressure wire connectors or wire binding screw terminals intended for field wiring shall be subjected to the tests described in 55.2 or 55.3.

55.2 There shall be no breakage or damage of any part of the device when 110 percent of the marked terminal tightening torque is applied to the wire securing means of a pressure wire connector.

55.3 A wire binding screw or nut is to be tightened on a conductor selected in accordance with the ampere rating of the device, but no less than 14 AWG (2.1 mm^2), 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, 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.

56 Crushing Test

56.1 The polymeric enclosure of a portable AFCI that is of the direct plug-in type shall be capable of withstanding for 1 minute a crushing force of 75 lbf (334 N) applied in any direction perpendicular to its major axis.

56.2 Any testing equipment that can apply a steady force of 75 lbf (334 N) to the plug may be employed. The plug is to be tested between two 1/2-inch (13-mm) or thicker parallel flat maple blocks. The crushing force is to be applied gradually.

57 Dust Test

57.1 To determine compliance with 12.6(b)(2), each of six devices, each mounted in a different mounting orientation, is to be placed, deenergized, in an air tight chamber having an internal volume of at least 0.09 m^3 (3 cubic feet).

57.2 A 0.06-kg (2-oz.) quantity of cement dust, maintained at a relative humidity of 20 – 50 percent, and capable of passing through a 200 mesh screen, is to be circulated for 15 minutes by means of compressed air or a blower so as to completely envelop the device in the chamber. The air flow is to be maintained at an air velocity of approximately 0.25 m/s (50 fpm).

57.3 Following the exposure to dust, the exterior of the device is to be cleaned carefully. The device is to be opened and examined for the presence of dust. To be considered as meeting Pollution Degree 2, there shall not be any evidence of dust in the interior of the device.

58 Permanence of Markings

58.1 An adhesive backed label shall comply with the Standard for Marking and Labeling Systems, UL 969.

58.2 Labels that come in contact with uninsulated live parts shall be of a nonconductive material that complies with the Dielectric Breakdown Test, the Moisture Absorption Test and the Test for Indirect Measurement of Conductor Corrosion, of the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510.

59 Reverse Line – Load Miswire Test

59.1 A previously untested arc-fault circuit-interrupter intended for mounting in an outlet box shall interrupt the electric circuit to the line terminals when a supply circuit is wired to the load terminals of the device.

59.2 Under the conditions described in 59.3 and 59.4 the arc-fault circuit-interrupter shall interrupt the electric circuit to the line terminals or not permit power to be applied to the line terminals when the power is first applied to the load terminals, and each time the reset is operated.

59.3 For this test:

a) The supply line voltage is to be set at 85 percent of the rated voltage.

b) The arc-fault circuit-interrupter is to be switched on unless it is shipped from the manufacturer in the tripped condition and cannot be reset until properly installed. If shipped in the tripped condition, to verify the arc-fault circuit-interrupter cannot be reset until properly installed, attempt to engage reset by first pressing the reset button and then by pressing the test and reset buttons simultaneously. This is to be performed before and after load terminals are connected to supply voltage.

c) Power is to be applied to the load terminals, and the reset shall be operated ten times in rapid succession.

59.4 The test described in 59.2 is to be repeated on the same device, with the supply line voltage set at 110 percent of the rated voltage.

60 Supplemental Voltage Surge Immunity Test

60.1 General

60.1.1 The line side terminals of the arc-fault circuit-interrupter shall be subjected to this test.

60.1.2 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 (if provided) 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. AFCIs that are intended only for use in enclosures shall be tested in their intended enclosure for the tests referenced in 60.1.1. The enclosure shall be representative of the worst case situation for the tests.

60.2 Surge immunity test (combination wave)

60.2.1 The AFCI shall be subjected to the Surge Immunity Test without demonstrating, either during or after testing:

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

b) Ignition of the enclosure; or

c) Creation of any opening in the enclosure that results in accessibility of energized parts, when judged in accordance with Accessibility of Energized Parts, Section 7.

60.2.2 The test method is to be conducted in accordance with the testing methods described in the Standard for Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test, IEC 61000-4-5.

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

60.2.4 Only the surge impulse test levels in Table 60.1 shall be used. Using a separate representative AFCI for each surge impulse test level meets the intent of the requirement.

Table 60.1
Surge impulse test levels[a]

Peak voltage (kV p)	Peak current (kA p)
2	1
6	3

[a] Combination 1.2/50 µs, 8/20 µs Voltage/Current surge waveform. For specifications and tolerances, refer to the Standard for Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test, IEC 61000-4-5.

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

60.2.6 After the 2 kV test the same AFCI shall be in condition to comply with the Point Contact Arc Test of 40.5 and the Dielectric Voltage Withstand Test, Section 43.

60.2.7 After the 6 kV test, the same AFCI shall comply with either (a) or (b):

a) The AFCI shall be in condition to comply with the Point Contact Arc Test of 40.5, see 60.2.8, and the Dielectric Voltage-Withstand Test, Section 43; or

b) The AFCI shall trip as a result of the surge test and render itself incapable of delivering power after attempting reset. Reset shall be attempted 5 times as fast as possible with rated voltage applied.

60.2.8 Continued ability to provide protection shall be demonstrated by subjecting the representative device to the Point Contact Arc Test of 40.5, using a fault current of 100 A.

RATINGS

61 General

61.1 An AFCI shall be rated 120 V and 60 Hz. A branch/feeder, combination, or outlet circuit AFCI shall be rated 15 or 20 A. A portable AFCI shall be rated 20 A maximum. A cord AFCI shall be rated 30 A maximum.

61.2 The load capacity of a portable or cord AFCI shall also be rated in watts.

MARKINGS

62 General

62.1 An arc-fault circuit-interrupter shall be marked with the manufacturer's name, trademark, or other suitable means of identification, a type or catalog designation, and the electrical ratings in voltage, frequency, and load capacity in amperes.

62.2 An arc-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.

62.3 If the arc-fault circuit-interrupter is manufactured in more than one location, the finished device shall have a distinctive marking, which may be in code, to identify the product of a particular factory.

62.4 An arc-fault circuit-interrupter shall be marked "Arc-Fault Circuit-Interrupter" or "AFCI", and with the specific device name or respective abbreviation noted in Sections 64 – 67.

62.5 A device that is required to be mounted in a specific orientation shall be marked to identify that orientation.

62.6 Controls on an arc-fault circuit-interrupter such as those provided for Test and Reset of the device shall be identified.

62.7 A device that complies with 41.4.1 (e) shall be marked "Suitable for ____ Watt tungsten lamp dimmer load" on the packaging material or the instructional material. The wattage to be included in the marking is that specified by Table 41.1.

63 Terminations

63.1 The abbreviation "CU" for the word "copper" and "AL" for the word "aluminum" shall be permitted in any required marking.

63.2 An arc-fault circuit-interrupter with wiring terminals intended and found acceptable for use with copper and aluminum conductors shall be marked "Use copper or aluminum wire" or with the abbreviations "CU", and "AL", "CU/AL", or the equivalent.

63.3 An arc-fault circuit-interrupter with terminals intended and found acceptable for copper wire only shall be marked "USE COPPER WIRE ONLY" or with the abbreviation "CU ONLY". If the terminals are intended and found acceptable for aluminum wire only, the marking shall be "USE ALUMINUM WIRE ONLY" or "AL ONLY".

63.4 An arc-fault circuit-interrupter shall be marked with the proper wire range of the wiring terminals. If the terminals are intended for solid wire only, or stranded wire only, the device shall be marked "(wire range) AWG SOLID" or "(wire range) AWG SOL.", or with equivalent wording. The marking shall be located adjacent to the terminal and shall be visible after installation.

63.5 A permanently installed arc-fault circuit-interrupter shall be marked with a range of values or a nominal value of tightening torque to be applied to the clamping screws of all terminal connectors for field wiring.

Exception: An Outlet Circuit AFCI is not prohibited from having the torque information on the smallest unit container or on an information sheet that is shipped in the smallest unit container.

63.6 If a terminal is acceptable for the connection of more than one conductor in the same opening and is intended for such use, the marking shall indicate the proper connection.

63.7 Terminals or leads of an arc-fault circuit-interrupter intended to be connected to the grounded conductor shall be identified by the color white or gray. Terminals or leads intended to be connected to ungrounded conductors shall be identified by a contrasting color. The color green shall not be used.

64 Branch/Feeder Arc-Fault Circuit-Interrupter

64.1 In reference to 62.4 above, a branch/feeder arc-fault circuit-interrupter shall be marked "Branch/Feeder Arc-Fault Circuit-Interrupter" or "Branch/Feeder AFCI" where visible, with a dead-front or faceplate removed, while the device is installed.

65 Combination Arc-Fault Circuit-Interrupter

65.1 In reference to 62.4 above, a combination arc-fault circuit-interrupter shall be marked "Combination Type Arc-Fault Circuit-Interrupter" or "Combination Type AFCI" where visible, with a dead-front or faceplate removed, while the device is installed.

66 Outlet Circuit Arc-Fault Circuit-Interrupter

66.1 In reference to 62.4 above, an outlet circuit arc-fault circuit-interrupter shall be marked "Outlet Circuit Arc-Fault Circuit-Interrupter" or "Outlet Circuit AFCI" where visible, with a dead-front or faceplate removed, while the device is installed.

67 Portable and Cord Arc-Fault Circuit-Interrupters

67.1 In reference to 62.4 above, a portable arc-fault circuit-interrupter shall be marked "Portable Arc-Fault Circuit-Interrupter" or "Portable AFCI". A cord arc-fault circuit-interrupter shall be marked "Cord Arc-Fault Circuit-Interrupter" or "Cord AFCI".

67.2 Unless a portable or cord arc-fault circuit-interrupter has been found suitable for use in wet locations, it shall be marked "Indoor use only".

67.3 A portable or cord arc-fault circuit-interrupter not provided with a permanently attached cord shall be marked with the following or equivalent wording "This product should be used only with a (two or three)-

conductor, 120 volt, (15 or 20) ampere supply cord set employing Type (cord specified by the manufacturer) cord. In event of cord set damage, it should be replaced only with an equivalent cord set." where the information in parentheses is to be selected or filled in as appropriate.

67.4 A portable or cord arc-fault circuit-interrupter shall be clearly marked in upper or lower case letters at least 1/16 inch (1.6 mm) high with the following, or equivalent, statement: "In the event this device trips, the cause is to be corrected before further use. See owners manual."

67.5 The rated load-capacity marking of a cord-connected arc-fault circuit-interrupter shall include watts.

INSTRUCTIONS

68 Installation Instructions/Owner's Manual

68.1 The installation instructions of an arc-fault circuit-interrupter shall contain the following:

a) Manufacturer's name and complete address.

b) Type designation (such as Branch/Feeder AFCI) and catalog number or other specific identification.

c) Intended conductor material, wire type, and wire size.

d) Electrical ratings in amperes, volts, and frequency. The load capacity as required by 61.2 shall be in watts.

e) Cable preparation (strip length, required slack, tools, and the like).

f) Torque rating.

g) Wiring instructions.

h) Correct operation and test instructions.

68.2 The owner's manual shall contain plain, legible, and durable instructions for effective use of an arc-fault circuit-interrupter. Whenever possible, such instructions are to appear on the device or the enclosure of the device, and be so located that they may be readily viewed without the use of tools, after the device has been installed in normal operation. The required instructions may be supplied by an electronic labeling method on the product, product package, and/or "stuffer sheets" included with the arc-fault circuit-interrupter.

68.3 When any instructions are included on an adhesive-backed label, the label shall comply with the requirements of Permanence of Markings, Section 58.

68.4 Text of the owner's manual/instructions shall be verbatim to, or in equally definitive terminology except where specific conflict of the application to a product exists. The items may be numbered, and the phrases "IMPORTANT SAFETY INSTRUCTIONS – READ ALL INSTRUCTIONS BEFORE USING," and "SAVE THESE INSTRUCTIONS" shall be first and last, respectively, in a list of items. Other important safety instructions considered appropriate by the manufacturer may be included.

68.5 A branch/feeder or combination AFCI not intended for installation in a panelboard, and an outlet circuit AFCI with feed through provisions 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 arcing fault protection. Read instructions prior to wiring."

68.6 Each outlet-circuit AFCI with feed-through provisions and receptacle outlets shall be provided with the installation instructions shown in Figure 68.1 – Figure 68.6. The installation instruction sheet, containing the detail of all six figures, shall not be smaller than 8-1/2 inches (215.9 mm) high x 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 x 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 Figure 68.1 – Figure 68.3. The back of the installation instruction sheet shall contain steps 7 and 8 as shown in Figure 68.4 – Figure 68.6. 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.

68.7 The installation instruction sheet shall be provided in the form of actual printed material, Quick Response (QR) code, or the address on the internet where users can download the required instructions. When a manufacturer’s website is used to identify information, the web address shall be marked on the AFCI, packaging, and/or information sheet. The web address may be in the form of a Uniform Resource Locator (URL – http://www.____.com/___/), or as a Quick Response (QR) Code. The web address link shall take the installer/operator to an internet page containing a link to the installation instruction/Owner’s manual. The file shall be unrestricted and in a file format that is commonly used and downloadable.

Figure 68.1

Installation instructions

Manufacturer's Name

Installing and Testing an Outlet Circuit AFCI

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 Outlet Circuit AFCI with copper or copper-clad wire. Do not use it with aluminum wire.
- Do not install this Outlet Circuit AFCI on a circuit that powers life support equipment because if the AFCI trips it will shut down the equipment.
- To be installed only in branch circuits provided with an equipment grounding conductor or other acceptable equipment grounding method.
- For installation in wet locations, protect the Outlet Circuit AFCI 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?

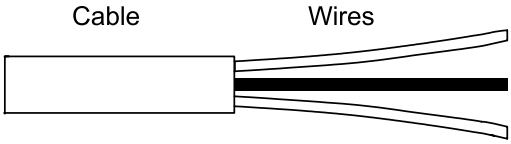
Installing an Outlet Circuit AFCI can be more complicated than installing a conventional receptacle.

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 Outlet Circuit AFCI 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 AFCI. If there is only one cable entering the electrical box, it is the LINE cable. This cable should be connected to the AFCI's LINE terminals only.

LOAD cable:

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

Figure 68.2

Installation instructions

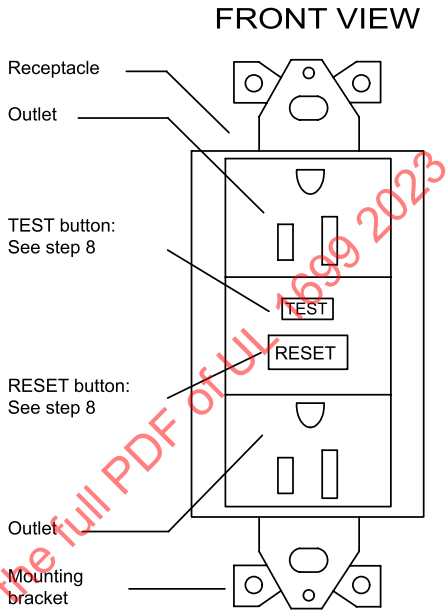
1. What is an Outlet Circuit AFCI?

An Outlet Circuit AFCI is different from conventional receptacles. It is intended to provide protection of cord sets and power-supply cords connected to it against the unwanted affects of arcing. In the event of an arcing fault, an AFCI will trip and stop the flow of electricity to mitigate the effects of the arcing that may have posed a risk of fire ignition if the arcing persisted.

Definition of an arcing fault:
An arcing fault is an unintentional arcing condition in a circuit. Arcing occurs as a normal condition in some motors or when a switch opens. An example of unintentional arcing would be arcing that occurs due to severed power-supply cord conductors.

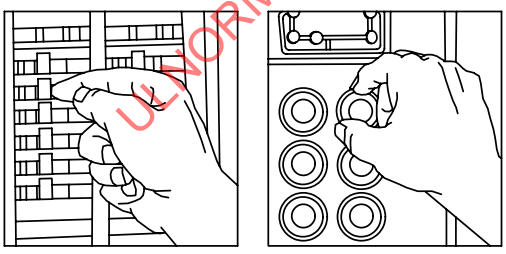
An Outlet Circuit AFCI does not protect against circuit overloads or short-circuits or against shock hazards.

2. The AFCI's features —



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 Outlet Circuit AFCI 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.

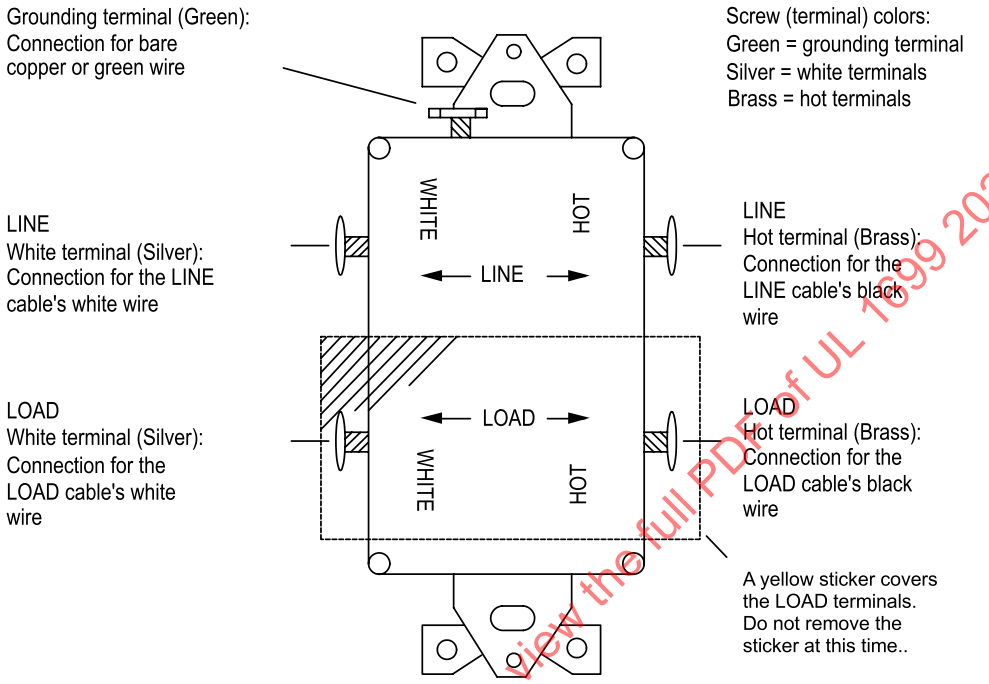
- If you see two cables (4-6 wires), the receptacle is probably in position A or B (see diagram to the right). Follow steps a-e of the procedure to the right.

afci2

Figure 68.3

Installation instructions

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.

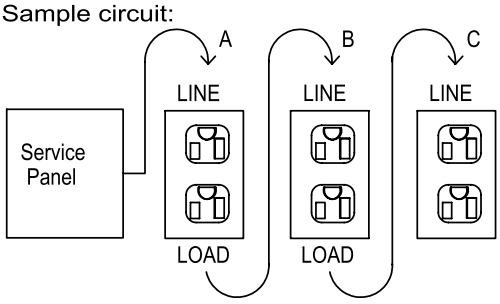
(d) Turn the power OFF at the service panel, label the LINE and LOAD wires, then remove the receptacle.

(e) Go to step 7B.

Placement in circuit:

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

Sample circuit:



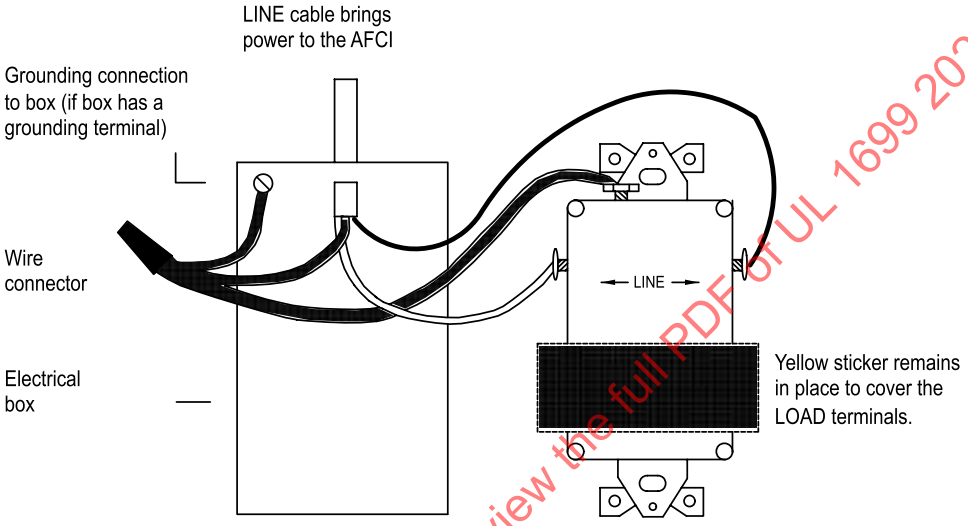
Placing the AFCI in position A will also provide protection to "load side" receptacles B and C. On the other hand, placing the AFCI in position C will not provide protection to receptacles A or B. Remember that receptacles A, B and C can be in different rooms.

Figure 68.4

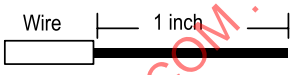
Installation instructions

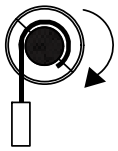
7. Connect the wires (choose A or B) ... only after

A: One cable (2 or 3 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 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 Outlet Circuit AFCI.
- 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 AFCI. 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.

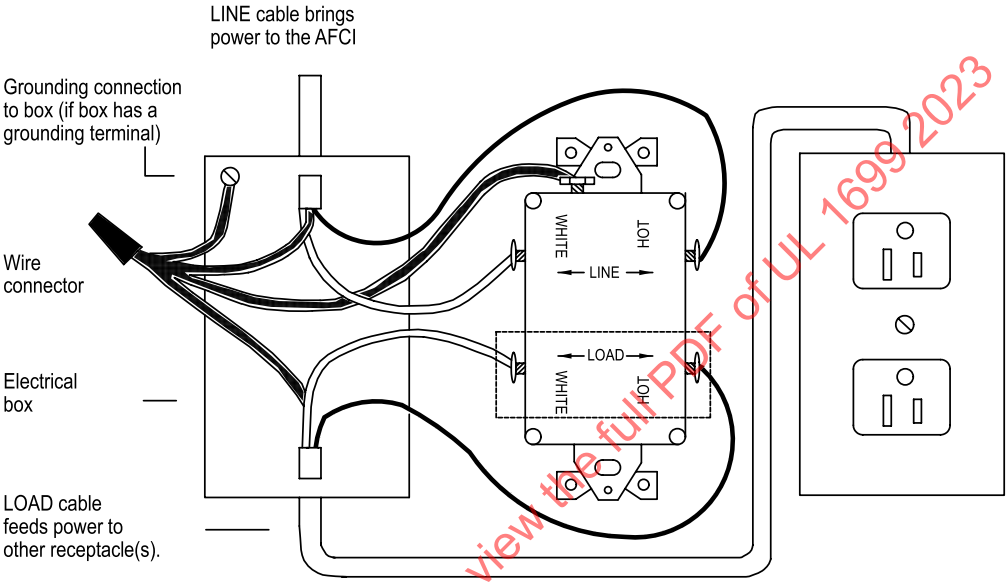
afci4

Figure 68.5

Installation instructions

reading other side completely

R B: Two cables (4 or 6 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 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 AFCI. 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.

afci5

Figure 68.6

Installation instructions

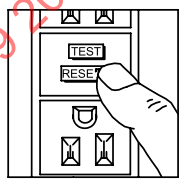
8. Test your work

Why perform this test?

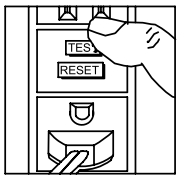
- If you miswire the AFCI it may not mitigate the effects of arcing faults due to unintentional arcing in a circuit.
- If you mistakenly connect the LINE wires to the LOAD terminals, the AFCI will still operate like an ordinary receptacle, but it will not interrupt an unintentional arcing fault.

Procedure:

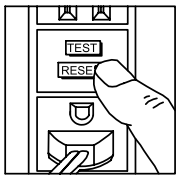
(a) Turn the power ON at the service panel. Press the RESET button fully. Plug a lamp or radio into the AFCI (and leave it plugged-in) to verify that the power is ON. If there is no power, go to Trouble-shooting.



(b) Press the 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 RESET button will pop-out. If the power stays ON, go to Troubleshooting. If the power goes OFF, you have installed the outlet circuit AFCI correctly. To restore power, press the RESET button.



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

General Information

Outlet Circuit AFCI rating:
The receptacle's ratings go here.

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

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

SUPPLEMENT SA – AFCIs RATED 120/240 V

INTRODUCTION

SA1 Scope

SA1.1 These requirements cover arc-fault circuit-interrupters rated 120/240 V that are intended to be installed on circuits with two ungrounded conductors and a grounded conductor.

SA1.2 An arc-fault circuit-interrupter rated 120/240 V shall comply with the requirements of the preceding sections of this Standard as modified or supplemented by the following requirements.

SA1.3 Arc-fault circuit-interrupters meeting the requirements of this Supplement shall be suitable for use on only 120/240 V single-phase systems unless they also meet the additional requirements of SA4.4.

CONSTRUCTION

SA2 Spacings

SA2.1 Spacings at field wiring terminals where the potential is 201 to 400 V peak between terminals shall not be less than 3/8 inch.

SA3 Operation

SA3.1 Except as indicated in SA3.2, an arc-fault circuit-interrupter rated 120/240 V shall operate to open the circuit in the event of a fault, with the supply to each of the ungrounded line terminals disconnected, one at a time.

SA3.2 A cord AFCI rated 120/240 V constructed with arc fault protection circuitry integral to the attachment plug and intended for a dedicated load need not comply with the requirements of SA3.1.

SA3.3 An arc-fault circuit-interrupter rated 120/240 V shall operate to open both ungrounded conductors in the event of a fault.

PERFORMANCE

SA4 General

SA4.1 The available short-circuit current for the tests where the supply is 120/240 V shall be 1,000 A RMS ±10 percent line-to-line.

SA4.2 When test currents of less than 1,000 A are required, the current is to be limited by adding lengths of wire for currents of 75 A and higher, and by adding resistances for currents less than 75 A.

SA4.3 An arc-fault circuit-interrupter rated 120/240 V is to be subjected to tests in accordance with Sections 34 – 42 on test circuits rated 120 V where faults are applied on each ungrounded conductor, in turn, and in accordance with Sections SA4 – SA12 on test circuits rated 120/240 V, where 240 V is available between the two ungrounded conductors.

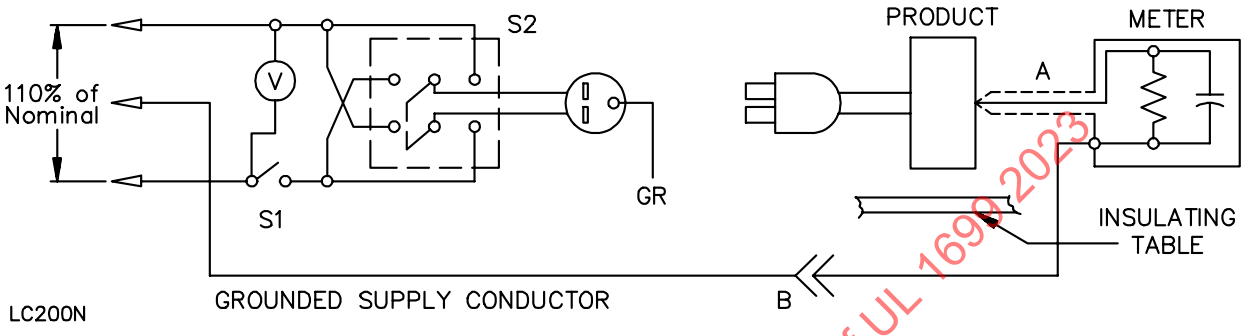
SA4.4 An AFCI intended for use on 208Y/120 V three-phase systems shall also meet the performance requirements of this Supplement when connected to a 208Y/120 V power supply.

SA5 Leakage Current Measurement

SA5.1 The two-pole AFCI is to be subject to the Leakage Current Measurement Test of Section 37, except that the supply voltage is to be 110 percent of nominal instead of 120 V, as shown in Figure SA5.1.

Figure SA5.1

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.

SA6 Voltage Surge Test

SA6.1 The representative AFCI is to be subject to the Voltage Surge Test of Section 38, except that the surge voltage impulses are to be applied on each ungrounded conductor, in turn, rather than on one ungrounded conductor.

SA7 Carbonized Path Arc Ignition Test

SA7.1 The two-pole AFCI is to be subject to the Carbonized Path Arc Ignition Test of 40.2, except that the supply voltage is to be 120/240 V instead of 120 V and the AFCI is to be connected line-to-line instead of line-to-neutral, as shown in the circuit in Figure SA7.1, which shows a typical way of performing the test.

Figure SA7.1

Carbonized path tester – arc ignition test (load deenergized)