NECA 169

Standard for Installing and Maintaining Arc-Fault Circuit Interrupters (AFCIs) and Ground-Fault Circuit Interrupters (GFCIs)

Industry Review Draft
(Date TBD)

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Foreword

National Electrical Installation Standards™ are designed to improve communication among specifiers, purchasers, and suppliers of electrical construction services. They define a minimum baseline of quality and workmanship for installing electrical products and systems. NEIS® are intended to be referenced in contract documents for electrical construction projects. The following language is recommended:

Arc-Fault Circuit Interrupters (AFCIs) and Ground-Fault Circuit Interrupters (GFCIs) should be installed and maintained in accordance with NECA 169-2xxx, Standard for Installing and Maintaining Arc-Fault Circuit Interrupters (AFCIs) and Ground-Fault Circuit Interrupters (GFCIs) (ANSI).

Use of NEIS is voluntary, and the National Electrical Contractors Association assumes no obligation or liability to users of this publication. Existence of a standard shall not preclude any member or non-member of NECA from specifying or using alternate construction methods permitted by applicable regulations.

This publication is intended to comply with the National Electrical Code (NEC). Because they are quality standards, NEIS may in some instances go beyond the minimum safety requirements of the NEC. It is the responsibility of users of this publication to comply with state and local electrical codes when installing electrical products and systems.

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1. **Scope**

This standard describes the installation and maintenance procedures for arc-fault circuit interrupters (AFCIs) and ground-fault circuit interrupters (GFCIs).

1.1 **Products and Applications Included**

This standard covers the installation and maintenance of Arc-Fault Circuit Interrupters, AFCIs, and Ground-Fault Circuit Interrupters, GFCIs, permanently installed on building premises wiring systems for residential, commercial, and industrial applications. It applies to:

a) Combination AFCIs and GFCIs for new installations  
b) Branch/Feeder AFCIs only for replacement purposes in existing installations  
c) Branch/Feeder GFCIs for new installations

1.2 **Products and Applications Excluded**

This standard does not cover older designs of AFCIs, or AFCIs designed to be temporarily connected to premise wiring systems. It does not apply to:

a) Temporary installations  
b) Portable or cord AFCIs and GFCIs  
c) AFCIs and GFCIs required in mobile homes, manufactured homes, or mobile home parks  
d) AFCIs required in cord-and-plug connected air conditioning units  
e) GFCIs required for:
   - Fixed outdoor electric deicing or snow-melting equipment  
   - Fixed electric heating equipment for pipelines or vessels  
   - Carnivals, circuses, fairs, or similar events  
   - Park trailers, recreational vehicles, or recreational vehicle parks  
   - Marinas or boatyards, natural or artificially-made bodies of water  
   - Portable or mobile signs  
   - Electrified truck parking spaces  
   - Sensitive electronic equipment  
   - Pools, fountains and similar installations

1.3 **Regulatory and Other Requirements**

a) All information in this publication is intended to conform to the National Electrical Code® (ANSI/NFPA Standard 70). Installers should always follow the NEC®, applicable state and local codes, and manufacturer's instructions when installing and maintaining AFCIs and GFCIs.

b) Only qualified persons familiar with the construction and operation of AFCIs and GFCIs should perform the work described in this publication. All work should be performed in accordance with NFPA 70E, *Standard for Electrical Safety in the Workplace.*
c) General requirements for installing electrical products and systems are described in NECA 1-2006, Standard Practices for Good workmanship in Electrical Construction (ANSI). Other National Electrical Installation Standards provide additional guidance for installing particular types of electrical products and systems. A complete list of NEIS is provided in Annex A.

2. Definitions

Arc. The discharge of electricity over an insulating medium, such as air.

Arc-Fault Circuit Interrupter (AFCI). A device intended to provide protection from the effects of arc-faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc-fault is detected. AFCIs are rated 15 A and 20 A, and 120 Volts.

Branch/Feeder AFCI. An AFCI that is intended to be installed at the origin of the feeder or branch circuit and provides protection of feeder and branch-circuit wiring. A branch/feeder AFCI can be a circuit breaker-type AFCI installed in the panelboard, or an AFCI device installed in its own enclosure mounted at or near the panelboard.

Circuit Breaker-Type AFCI. An AFCI that is integrated into a circuit breaker that is designed for installation in a panelboard. A circuit breaker-type AFCI protects the circuit by disconnecting the circuit for arc-faults, overloads, and short-circuits.

Circuit Breaker-Type GFCI. A GFCI that is integrated into a circuit breaker that is designed for installation in a panelboard. A circuit breaker-type GFCI protects the circuit by disconnecting the circuit for overloads, and short-circuits, and protects personnel by disconnecting the circuit for ground-faults occurring anywhere on the circuit downstream of the device.

Combination-Type AFCI. An AFCI intended to comply with the requirements for both branch/feeder AFCIs that protect downstream feeder and branch circuit wiring, and outlet circuit AFCIs that protect cord sets and power-supply cords.

Ground-Fault Circuit Interrupter (GFCI). Circuitry designed to protect personnel from electrocution when contact between a live part of the protected circuit and ground causes current to flow through the body. A GFCI continually monitors the flow of current on the phase and neutral conductors and instantaneously disconnects the circuit when a current imbalance between the phase and neutral conductors is equal to or higher than the calibration point (4 mA to 6 mA) flows from the protected circuit to ground.

Outlet Circuit AFCI. An AFCI that is integrated into a receptacle that is designed for installation at a branch-circuit outlet, such as at an outlet box, and is intended to provide protection of cord sets and power-supply cords connected to it against the effects of arc-faults. A
receptacle outlet AFCI may provide feed-through protection of the cord sets and power-supply cords connected to downstream receptacles. Receptacle outlet AFCIs do not protect the entire branch and do not satisfy NEC 210.12 requirements.

**Receptacle-Type GFCI.** A GFCI that is integrated into a receptacle that is designed for installation at a branch-circuit outlet, such as at an outlet box, and is intended to provide ground-fault protection of personnel in cord sets, power-supply cords, and branch circuit wiring connected downstream of the device.

### 3.  2008 NEC Requirements for AFCIs and GFCIs

#### 3.1 AFCI Requirements in the 2008 National Electrical Code

Many electrical appliances and devices create arcs during normal operation, such as snap switches, contactors, motors with brushes, etc. Unintentional arcs or arc-faults can lead to elevated temperatures and sparking that can ignite combustible materials in close proximity to the heating. Causes of arc-faults include:

- Cracked conductor insulation due to natural aging.
- Overheated conductors from exposure to sunlight or sources of heat.
- Overloaded conductors.
- Loose or improper connections and terminations.
- Damaged conductor insulation from fasteners such as staples, nails, and screws driven into the conductor.
- Damaged conductors at stress points such as cords caught under doors or furniture, or objects pushed against plugs in an outlet.
- Faulty electrical equipment.

Hidden electrical fires caused by arc-faults can spread rapidly, delaying detection by smoke alarms and reducing the chances of survival. AFCIs are intended to provide protection from early detection of arc-faults. AFCI circuitry differentiates between arcs from normal equipment operation and arc-faults.

The requirements to install AFCIs in newly-constructed dwelling units depend on which edition of the National Electrical Code has been adopted for regulatory use in that jurisdiction.

#### 3.1.1 AFCIs Required

A. Listed, combination-type AFCIs must be installed in dwelling units to protect each single-phase 120 Volt branch circuit rated 15 A and 20 A that supply outlets in the following rooms [NEC 210.12]:

1) Family rooms
2) Dining rooms
3) Living rooms
4) Parlors
5) Libraries
6) Dens
7) Bedrooms
8) Sunrooms
9) Recreation rooms
10) Closets
11) Hallways
12) Similar rooms or areas

To comply with NEC 210.12, outlets for receptacles, lights, fans, window or wall air conditioners, single and multiple station smoke alarms, space heaters, etc, must have AFCI protection.

B. Branch circuits in guest rooms/suites in hotels, motels, dormitories, etc., that are provided with permanent provisions for cooking must comply with the rules for dwelling units [NEC 210.18], meaning that AFCIs are required in similar rooms and areas of guest rooms/suites in hotels, motels, etc.

### 3.1.2 AFCIs Not Required

AFCI protection is not required for the following rooms or circuits in dwellings:

1) Single-phase and three-phase 208 and 240 Volt branch circuits
2) Small appliance branch circuits
3) Bathroom branch circuits
4) Kitchen branch circuits
5) Laundry branch circuits
6) Branch circuits that supply only outlets in unfinished areas of basements and attics.
7) Branch circuits that supply only outlets in attached structures such as garages.
8) Branch circuits that supply only outlets located outdoors.

### 3.1.3 AFCIs Not Permitted

AFCI protection is not permitted for branch circuits supplying power sources for non-power-limited fire alarm circuits or power-limited fire alarm circuits [NEC 760.41(B) and 760.121(B)].

### 3.1.4 AFCIs Recommended

A. AFCIs are recommended to protect two-wire branch circuits, including knob-and-tube wiring, in existing dwelling units.

B. AFCIs are suitable for use in commercial applications in accordance with their ratings.
C. In jurisdictions where older editions of the NEC are being enforced, or where the NEC is not adopted for regulatory use, it is recommended that AFCI protection be installed in all newly-constructed dwelling units, hotels, motels, and dormitories following the 2008 NEC requirements.

3.2 GFCI Requirements in the 2008 National Electrical Code

When operating properly, the sum of the current on the current-carrying phase and neutral conductors of any given branch circuit is zero. A ground-fault occurs when circuit current leaks to ground, finding an alternate return path to back to the source. GFCIs constantly monitor the leakage current from the current-carrying conductors and instantly disconnect the circuit if the leakage current equals or exceeds its trip rating.

GFCIs are required in all areas where known electrical shock hazards exist, such as where outlets are located in close proximity to moisture, water, or water pipes, such as outdoors, swimming pools, saunas and hot tubs, kitchens, basements, bathrooms, and garages.

3.2.1 GFCIs Required

A. Dwelling Units: GFCI protection for personnel is required for all 120 Volt, single-phase receptacles rated 15 A and 20 A located in the following locations [NEC 210.8]:

1) Bathrooms
2) Garages and accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use
3) Outdoors
4) Crawl spaces at or below grade level
5) Unfinished basements or unfinished rooms within basements
6) Kitchens where the receptacles are installed to serve the countertop surfaces
7) Laundry, utility, and wet bar sinks where the receptacles are installed within six feet of the outside edge of the sink
8) Boathouses and boat hoist outlets not exceeding 240 volts

The GFCI protection for 15 A and 20 A receptacle branch circuits required by NEC 208.8 is permitted to be provided by GFCI protection for personnel on the feeder that supplies those branch circuits [NEC 215.9].

Guest rooms and guest suites that are provided with permanent provisions for cooking must have branch circuits installed to meet the rules for dwelling units [NEC 210.18].

B. Other Than Dwelling Units: GFCI protection for personnel is required for all 120 Volt, single-phase receptacles rated 15 A and 20 A located in the following locations [NEC 210.8]:

1) Bathrooms
2) Kitchens
3) Rooftops
4) Outdoors
5) Sinks where receptacles are installed within six feet of the outside edge of the sink.

C. Replacement of Existing Receptacles

1) GFCI protected receptacles are required where replacements are made at receptacle outlets that are required to be GFCI protected [NEC 406.3(D)(2)].
2) Non-grounding-type receptacles are permitted to be replaced with GFCI protected receptacles. Such receptacles must be marked “No Equipment Ground.” Such GFCI protected receptacles are permitted to protect grounding-type receptacles. Such grounding-type receptacles must be marked “GFCI Protected” and “No Equipment Ground” [NEC 406.3(D)(3)(b) and (c)].

D. Commercial Repair and Storage Garages and Aircraft Hangers. All 120-volt, single-phase, 15- and 20-ampere receptacles installed in areas where electrical diagnostic equipment, electrical hand tools, or portable lighting equipment are to be used must have GFCI protection for personnel [NEC 511.12 and 513.12].

E. Healthcare Facilities. All receptacles and fixed equipment within the area of a wet procedure location of healthcare facilities, such as operating rooms, must have GFCI protection for personnel or be served by an isolated power system [NEC 517.20(A)].

F. Agricultural Buildings. All 120 Volt, single-phase, 15 A and 20 A general-purpose receptacles installed in the locations listed in (1) through (4) must have GFCI protection for personnel [NEC 547.5(G)]:

1) Areas having an equipotential plane
2) Outdoors
3) Damp or wet locations
4) Dirt confinement areas for livestock

G. Elevators, Dumbwaiters, Escalators, Moving Walks, Platform Lifts, and Stairway Chairlifts [NEC 620.85].

1) Each 120 Volt, single-phase, 15 A and 20 A receptacle installed in pits, in hoistways, on elevator car tops, and in escalator and moving walkways must be of GFCI-type.
2) All 120 Volt, single-phase, 15 A and 20 A receptacles installed in machine rooms and machinery spaces must have GFCI protection for personnel.

H. Appliances.
1. Cord-and-plug-connected vending machines manufactured or re-manufactured prior to January 1, 2005, must be connected to a GFCI-protected outlet [NEC 422.51].
2. Electric drinking fountains must be protected with GFCI protection for personnel [NEC 422.52].

3.2.2 **GFCIs Not Required.**

A. **Dwelling Units.** A receptacle supplying only a permanently installed fire alarm or burglar alarm system in an unfinished basement in a dwelling unit is not required to have GFCI protection [NEC 210.8(A)(5)].

B. **Other than Dwelling Units** [NEC 210.8(B)]

1. In industrial establishments only, where the conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in 590.6(B)(2) is permitted for only those outdoor receptacle outlets used to supply equipment that would create a greater hazard if power is interrupted or having a design that is not compatible with GFCI protection [Exception Number 2 to (4)].
2. In industrial laboratories, receptacles installed within 6 feet of the outside edge of a sink that are used to supply equipment where removal of power would introduce a greater hazard is permitted to be installed without GFCI protection [Exception Number 1 to (5)].
3. For receptacles installed within 6 feet of the outside edge of a sink located in patient care areas of health care facilities other than those sinks in bathrooms, GFCI protection is not required.

B. **Healthcare Facilities.** GFCI protection for personnel is not required for receptacles installed in critical care areas where the toilet and basin are installed within the patient room [517.21].

C. **Agricultural Buildings.** GFCI protection for personnel is not required for an accessible receptacle supplying a dedicated load where a GFCI protected receptacle is located within 3 feet of the non-GFCI-protected receptacle [NEC 547.5(G)].

D. **Elevators, Dumbwaiters, Escalators, Moving Walks, Platform Lifts, and Stairway Chairlifts.** A single receptacle supplying a permanently installed sump pump does not require GFCI protection for personnel [NEC 620.85].

3.2.3 **GFCIs Not Permitted.**

A. Required elevator car lighting must not be connected to the load side of a GFCI [NEC 620.22(A)].
B. Required elevator machine room, control room, machinery space or control space lighting must not be connected to the load side of a GFCI [NEC 620.23(A)].

C. Required elevator hoistway pit lighting must not be connected to the load side of a GFCI [NEC 620.24(A)].

D. Branch circuits supplying power sources for non-power-limited fire alarm circuits or power-limited fire alarm circuits must not be supplied from a GFCI [NEC 760.41(B) and 760.121(B)].

4. Installing AFCIs and GFCIs

4.1 General

Follow manufacturer recommendations and use approved, listed parts, components, equipment and accessories for compatibility and ratings.

A. AFCIs and GFCIs contain sensitive electronic components that are susceptible to damage and contamination. Protect from damage and contamination until the time of installation.

B. Verify that panels boxes, etc., are sufficiently installed to receive AFCIs and GFCIs prior to installation.

C. Phase-control dimmers protected by AFCIs may cause nuisance tripping when switched on. Ensure that the wattage of lamps connected to dimmers protected by AFCIs is 1000 watts or less, and that the total load does not exceed NEC permitted limits.

D. GFCI receptacles do not typically interfere with branch/feeder or combination AFCIs protecting the circuit.

E. AFCIs are also well-suited for retrofit applications in older dwellings, including those with 2-wire circuits without a grounding conductor.

F. Do not plug sensitive electronic equipment that requires an equipment grounding conductor into GFCIs installed on two-wire branch circuits.

G. Do not install GFCIs while circuit conductors are energized. Install GFCIs only on de-energized circuits.

H. Swab raceways dry prior to installing branch circuit conductors for GFCI-protected circuits. Install GFCI-protected circuits in dedicated conduits. Do not combine GFCI-protected circuits with other circuits in same raceway. Do not install more than one GFCI-protected circuit in any raceway.

I. Do not protect devices in other rooms from GFCIs located in restrooms.
4.1.1 **Multi-Wire Branch Circuits**

Single-pole AFCIs and GFCIs are not suitable for installation where loads are supplied from multi-wire branch circuits. Multi-wire branch circuits are circuits that share a common neutral conductor between two or more phase conductors that are supplied from different phases of the distribution system. Load currents are not balanced between individual phase conductors and the shared neutral conductor in multi-wire branch circuits. This steady-state imbalance causes nuisance tripping of AFCIs and GFCIs. Single-pole AFCIs and GFCIs must directly compare balanced loads between an individual phase conductor that has a dedicated neutral conductor.

Two-pole AFCI circuit breakers are available for multi-wire branch circuits. If the circuit breaker has a common trip, two circuits are de-energized when the AFCI detects and arc-fault. If the circuit breaker has independent tripping between the two phase conductors, the shared neutral continues to carry load currents even though the one phase conductor is de-energized.

4.2 **Electrical Safety**

A. Neglecting fundamental installation and maintenance requirements may lead to personal injury or death, as well as damage to electrical equipment or other property. All work and actions must conform to the requirements of NFPA 70E-2004, Electrical Safety in the Workplace.

B. Do not work on energized equipment. Do not enter equipment enclosures with components are energized. Electrically isolate conductors and equipment in accordance with established procedures and manufacturer’s instructions and recommendations. Guard energized conductors and equipment in close proximity to work.

C. Consider all ungrounded and grounded metal parts of equipment and devices to be energized at the highest voltage to which they are exposed unless they are de-energized and tested in accordance with OSHA requirements.

D. De-energize conductors and equipment by opening source switching devices to completely isolate equipment and circuits from all power sources before exposing any conductors. Test conductors and equipment at both sources and equipment terminals to confirm that they are de-energized.

E. Use appropriate Personal Protective Equipment (PPE) and established safety procedures when working on or near energized electrical equipment, or equipment that has not been de-energized in accordance with NFPA 70E-2004, Electrical Safety in the Workplace. Do not wear conductive articles such as watches, rings, etc.

F. Use insulated hand tools when working on or around energized equipment. Use only properly rated tools for the energy present. Maintain tool inventories to ensure that all tools are removed from equipment prior to energizing.
G. Use care in opening and closing doors to energized equipment. Conductors and terminations may be exposed and within reach of openings.

H. Carefully inspect work area and remove any tools and objects left inside equipment before energizing. Install all devices, doors, covers, barriers, etc., before energizing equipment.

4.3 Installing Circuit Breaker-Type AFCIs and GFCIs in a De-energized Panelboard

Follow the manufacturer’s recommendations when installing AFCI and GFCI circuit breakers. These instructions provide general guidance for installing AFCIs and GFCIs in new construction, before power to a panelboard has been initially energized.

A. Remove the panel cover, if installed. Test the panelboard to ensure that it is de-energized.

B. Remove the existing circuit breaker, if any, and install the AFCI or GFCI circuit breaker in the de-energized panelboard with its operating handle in the OFF position. Tighten and torque the bus-connecting bolt of bolt-on circuit breakers in accordance with manufacturer’s recommendations.

C. Connect the circuit breaker neutral conductor pigtail to the neutral bus bar of the panelboard in a dedicated terminal in the bus bar. Do not connect the circuit breaker neutral conductor pigtail to a terminal with another conductor, equipment grounding conductor or neutral conductor [NEC 110.14(A) and NEC 408.41].

D. Identify the phase, neutral, and equipment grounding conductors of the circuit requiring AFCI or GFCI protection. Connect the equipment grounding conductor of the branch circuit to the panelboard equipment grounding bus bar. Connect the circuit neutral conductor to the neutral connection lug of the circuit breaker. Connect the circuit phase conductor of the branch circuit to the phase connection lug of the AFCI or GFCI circuit breaker. Ensure that the circuit phase conductor is connected to the same circuit breaker as the circuit neutral conductor.

E. Tighten and torque all terminations in accordance with manufacturer’s recommendations.

F. Install the panelboard cover, removing knockouts as necessary for any additional circuit breakers, and energize the panelboard in accordance with NECA 409.

G. With no load connected to the circuit, turn the circuit breaker handle to the ON position.

H. Move the circuit breaker handle to the ON position.
I. Test the circuit breaker by pressing the TEST button. For an AFCI circuit breaker, the TEST button generates a signal that simulates an arcing fault to the AFCI sensor. For a GFCI circuit breaker, the TEST button creates a current imbalance between the phase and neutral conductors. If the unit is operating properly, the circuit breaker will trip, and the handle will move to the tripped, or center position.

J. Restore power by switching the circuit breaker to the fully OFF position, then switching the circuit breaker to the fully ON position.

K. If the circuit breaker does not trip when the TEST button is pushed, or if the circuit breaker handle cannot be restored to the fully ON position, the circuit breaker is malfunctioning. Remove the circuit breaker and replace it with a new unit.

L. Energize all of the loads supplied by the circuit breaker. If the circuit breaker trips when loads are energized, troubleshoot AFCIs, GFCIs, fixed wiring and appliances in accordance with Annex A.

4.4 Installing Circuit Breaker-Type AFCIs and GFCIs in an Energized Panelboard

Follow the manufacturer’s recommendations when installing AFCI and GFCI circuit breakers. These instructions provide general guidance for installing or replacing AFCIs and GFCIs in a panelboard after power has been turned on to a panelboard:

A. Identify the circuit breaker to be replaced, if any, and turn OFF all loads on the branch circuit protected by that circuit breaker.

B. De-energize the panelboard by turning OFF the panelboard main circuit breaker or other main disconnecting device.

C. Remove the panelboard cover and test to confirm that the panelboard is de-energized. Keep in mind that the supply conductors connected to the source terminals of the main disconnecting means in the panelboard remain energized. Guard energized components in close proximity to the work.

D. Remove the existing circuit breaker, if any, from the panelboard.

E. Install the new circuit breaker, energize the panelboard, and test the circuit breaker in accordance with Section 4.3.

4.5 Installing AFCI and GFCI Receptacles

AFCI receptacles are not permitted in new construction per the 2008 NEC. Follow the manufacturer’s recommendations when installing new GFCIs, and when replacing existing AFCI and GFCI receptacles with new ones. These instructions provide general guidance.
A. Turn OFF the overcurrent device, circuit breaker or fuse, protecting the branch circuit where the existing receptacle, if any, is installed. Test the branch circuit using a voltage meter to ensure that the branch circuit is de-energized.

B. *Existing Receptacle.* With the power off, remove the existing coverplate, and gently remove the receptacle. If the existing electrical box is too small to accommodate an AFCI or GFCI outlet and the necessary pigtails, conductors, and connections, install a larger outlet box before installing the receptacle. If the branch circuit wiring is aluminum, install copper pigtails to the aluminum conductors for final connections to the receptacle. Identify, remove and label the existing branch-circuit wiring, differentiating between the supply conductors and conductors that supply loads downstream of the receptacle location. Testing of the conductors while energized may be necessary to differentiate between supply and load conductors.

C. *New Receptacle.* Install a new outlet box, level and plumb. For existing walls, be sure not to remove the portion of wall necessary for the mounting ears of remodel or old-work boxes. Install source conductors to the new outlet box matching the existing wiring methods.

D. Cut off the stripped portion of the existing conductor, if any, and strip approximately ¾-inch of insulation from each conductor. If the existing conductors do not extend a minimum of six inches beyond the face of the outlet box, provide a minimum of six-inch lengths of color-coded conductors to use as pigtails for connecting receptacles to fixed branch circuit wiring. Strip away approximately about ¾-inch of the insulation from each end of each conductor. Bend one end of each conductor into a “U” shape for connection to the terminals of the receptacle. Ensure that the “U” shape wraps around each terminal screw in a clockwise direction. Connect the bare or green conductor to the grounding terminal of the receptacle. Connect supply conductors to the receptacle terminals labeled SUPPLY or LINE. Where the new receptacle is intended to protect downstream locations, connect the conductors to downstream devices to the receptacle terminals labeled LOAD. Connect the white conductor to the silver or neutral terminal. Connect the colored wire to the brass or phase terminal. Tighten and torque connections in accordance with manufacturer recommendations. Wrap a length of electrical tape around the terminals of the receptacle to protect the terminals from inadvertent contact. Connect the receptacle pigtails to the fixed branch circuit wiring using wirenuts.

E. Gently push the conductors into the outlet box, and install the new receptacle in the outlet box. Install the coverplate.

F. Energize the receptacle by turning the overcurrent device, circuit breaker or fuse, to the ON position. Verify that the receptacle and any protected downstream receptacles are energized. With no load on the receptacle or on any downstream devices, test the receptacle by pressing the TEST button. For an AFCI receptacle, the TEST button generates a signal that simulates an arcing fault to the AFCI sensor. For a GFCI receptacle, the TEST button creates a current imbalance between the phase and neutral...
conductors. If the unit is operating properly, power will be interrupted to the receptacle and to any protected downstream devices, and the RESET button will pop out. If the receptacle does not de-energize when the TEST button is pressed, the receptacle is malfunctioning and must be replaced.

G. Restore power by pressing the RESET button on the receptacle. If the RESET button does not depress and reset when the button is pushed, verify that the supply conductors to the receptacle are still energized. If the supply conductors are energized and the RESET button will not depress, the unit is malfunction and must be replaced. If the supply conductors are de-energized, check for overcurrent protective device, circuit breaker or fuse, operation, and retest.

M. Energize all of the loads supplied by the receptacle and any protected downstream receptacles. If the circuit breaker trips when loads are energized, troubleshoot AFCIs, GFCIs, fixed wiring and appliances in accordance with Annex A.

H. Label all GFCI protected receptacles, including the GFCI receptacle and all protected downstream receptacles, "GFCI Protected" in accordance with NEC requirements. Label all three-prong receptacles that are installed on existing two-wire circuits and are GFCI protected, "No Equipment Ground" in accordance with NEC requirements.

5. Testing AFCIs and GFCIs

5.1 General

A. AFCIs and GFCIs are susceptible to damage from voltage surges, and GFCIs are susceptible to damage from stress over time from high capacity and high inrush loads. Test AFCIs and GFCIs monthly, and test GFCIs after thunderstorms to ensure proper operation.

B. Test AFCIs and GFCIs by pressing the TEST button on the device.

C. The TEST button of AFCIs is designed to simulate an arc to test the arc-fault detection circuitry that triggers the mechanical operation of the device. A successful trip verifies that the device is monitoring the entire branch circuit for arcing conditions.

D. The TEST button of GFCIs is designed to create an imbalance between the phase and neutral conductors to test the ground-fault detection circuitry that triggers the mechanical operation of the device. A successful trip verifies that the device is monitoring the device and any protected downstream devices for ground-fault conditions.

E. Replace defective AFCIs and GFCIs immediately.

F. Troubleshoot AFCIs, GFCIs, fixed wiring and appliances in accordance with Annex A.
5.2 Testing AFCI and GFCI Circuit Breakers

A. Turn off all loads supplied by AFCI and GFCI circuit breakers prior to testing.

B. Ensure that power is turned on to circuit breakers prior to testing. Ensure that circuit breaker handle is fully in the ON position.

C. Test circuit breakers by pressing the TEST button. Circuit breakers should trip when the TEST button is pressed, and the handle should move to the center or TRIPPED position. Reset circuit breakers by moving the handle fully to the OFF position, then fully to the ON position.

D. If the circuit breaker opens when the TEST button is pressed and can be reset, the circuit breaker is functioning properly.

E. If the circuit breaker does not open when the test button is pressed or cannot be reset, the circuit breaker is defective and must be replaced immediately.

5.3 Testing AFCI and GFCI Receptacles

A. Plug an appliance, such as a radio, nightlight, or lamp, into the receptacle and all protected downstream receptacles prior to testing.

B. With the appliances on, press the TEST button on the receptacle. The appliances should be immediately de-energized, and the RESET button should pop out.

C. Reset the receptacle by pressing the RESET button. The RESET button should snap back into place, and the appliances should be re-energized.

D. If the appliances are de-energized and the RESET button on the receptacle pops out, the receptacle is functioning properly.

E. If the appliances are not de-energized and the RESET button pops out, the receptacle is improperly wired or is not working and must be replaced immediately.

F. If the RESET button does not pop out, the receptacle is defective and must be replaced immediately.

G. If the RESET button does not reset the receptacle, there may be a fault on the branch circuit wiring or from a defective appliance, or the receptacle may be defective. Replace the receptacle immediately. If the new receptacle will not reset, troubleshoot AFCIs, GFCIs, fixed wiring and appliances in accordance with Annex A.
(This annex is not part of the standard)

Annex A: Troubleshooting AFCIs, GFCIs, Fixed Wiring and Appliances

AFCIs trip upon sensing arc-faults, and GFCIs trip upon sensing ground-faults. The circuit breaker version of these devices also trip upon sensing overcurrent and short-circuits. In addition to arc-faults, AFCIs can trip from high-voltage surges caused by lightning or utility switching transients, voltage or frequency fluctuations form a poorly-regulated backup generator, mechanical shocks such as earthquake, inadvertent grounding of the neutral conductor, overcurrents, and short circuits.

When a protective device trips under load, the abnormal operating condition that caused the device to operate should be investigated before placing the device back into service. The following is a brief description of methods used to troubleshoot AFCIs, GFCIs, fixed wiring and appliances to determine the most likely causes of the protective device operation.

A1. Troubleshooting GFCIs

A defective GFCI may still provide power without providing ground-fault protection for personnel. When a GFCI trips with an appliance plugged into the circuit, press the RESET button once to reset the device. If the GFCI trips again, replace the GFCI. If the new GFCI trips under similar conditions, the most likely cause is a ground-fault in the fixed branch circuit wiring or in an appliance protected by the GFCI. Troubleshoot the fixed wiring and appliances protected by the GFCI in accordance with Section A3.

A2. Troubleshooting AFCIs

With the AFCI off, disconnect the branch circuit phase and neutral conductors from the AFCI. Reset the AFCI. If the AFCI trips with no load conductors connected, replace the AFCI immediately.

A2.1 New Installations

Tripping of a newly installed AFCI is most often the result of improper wiring, installation or application. Check for:

- Multi-wire branch circuits, or phase conductors that share a neutral conductor.
- Crossed or common neutral connections between branch circuits in a junction, outlet, or switch box, or at the panel.
- Neutral conductors inadvertently touching an exposed grounding conductor or terminal on the load side of the AFCI.
- Reversed neutral and grounding conductors.
• Components and devices with conductors damaged during installation.
• Loose terminations and connections.

Correct deficiencies and test AFCIs in accordance with Section 5.

A2.2 Existing Installations

For existing AFCIs that trip after devices and components are installed, check for improper wiring and installation in accordance with Section A2.1. Keep in mind that AFCIs that are not de-energized when devices and components are installed may trip during installation when conductors inadvertently contact conductors of other circuits. Reset the AFCI and check that the AFCI does not trip again. Always de-energize AFCIs when working on AFCI-protected circuits and conductors.

A2.2 Troubleshooting AFCIs Using GFCIs

Consider temporarily replacing the AFCI with a GFCI to determine whether an AFCI is tripping due to a ground-fault or arc-fault. If the GFCI does not trip, the AFCI was most likely tripping due to an arc-fault. If the GFCI trips, the AFCI was most likely tripping due to a ground-fault. Troubleshoot the fixed wiring and appliances in accordance with Section A3.

A3. Troubleshooting Fixed Wiring and Appliances

WARNING: AFCIs are designed to protect against arc-faults because of the likelihood that the arc-fault will ignite surrounding flammable materials. Immediately disconnect and discontinue use of suspect equipment and appliances, and de-energize suspect conductors. Repair or replace deficient appliance and conductors.

Troubleshooting fixed wiring and appliances after an AFCI or GFCI trips is a process of elimination. If an AFCI or GFCI trips instantaneously when an appliance is plugged in or turned on during troubleshooting, remove the appliance from the circuit and reset the device. If the device does not trip, there is either a short-circuit, arc-fault, or ground-fault in the appliance or the appliance cord. If the device trips, there may be a short-circuit, arc-fault, or ground-fault in the fixed wiring.

Interview personnel who were present at the time the device tripped for information regarding evidence of an arc-fault or ground-fault, such as arcing, sparking, odors, buzzing, hissing sounds, or other evidence of electrical or thermal damage. Investigate wiring, appliances and equipment, identify possible sources of arcing, and immediately disconnect suspect appliances and equipment.

Ensure that the affected circuit, fixed wiring, and connected appliances and equipment are de-energized. Unplug all cord-and-plug appliances, table lamps, and extension cords connected to
the affected circuit. Carefully examine cords and plugs, and accessible components of light fixtures, appliances and equipment, such as connections, terminations, wiring, lampholders and ballasts, for evidence of arcing, thermal damage, insulation damage, shorted or pinched wires, etc.

Turn off all fixed appliances, such as lights, ceiling fans, switched wall outlets, etc. Test the fixed wiring to ensure that the circuit is de-energized. Perform insulation resistance testing of the fixed wiring from phase to neutral, from phase to ground, and from neutral to ground. Correct any deficiencies.

Keep in mind that insulation resistance testing will not detect a series fault, such as from a broken conductor or a loose connection. A series arc-fault cannot be detected by an AFCI until a load is connected and energized, establishing the arc. Additionally, a branch/feeder AFCI may not detect a series arc-fault because the current level may be below the detection threshold of the device.

Alternatively to insulation resistance testing, reset AFCIs and GFCIs in accordance with Section 5, and re-energize the fixed wiring system with no cord-and-plug appliances and with no fixed appliances connected to the fixed wiring system. If the AFCI or GFCI trips with no load connected to the fixed wiring system, examine all connections and terminations on the fixed wiring system, including junction, outlet and switch boxes, for evidence of arcing, thermal damage, insulation damage, shorted or pinched wires, etc. Correct deficiencies and test AFCIs and GFCIs in accordance with Section 5.

If the AFCI or GFCI does not trip without load connected to the fixed wiring system, turn on fixed appliances, such as lights, ceiling fans, switched wall outlets, hard-wired equipment, etc., one at a time to identify suspect equipment and components.

If the AFCI or GFCI trips after switching on a fixed appliance, examine the appliance and the wiring, connections and terminations between the switch and the appliance for evidence of arcing, thermal damage, insulation damage, shorted or pinched wires, etc. Correct deficiencies and test AFCIs and GFCIs in accordance with Section 5.

If the AFCI or GFCI does not trip after turning on all fixed appliances, plug in and turn on all cord-and-plug appliances and equipment one at a time. If the AFCI or GFCI trips after plugging in and turning on a cord-and-plug appliance, discontinue using the appliance and examine the appliance and the appliance cord for evidence of arcing, thermal damage, insulation damage, shorted or pinched wires, etc. Correct deficiencies and test AFCIs and GFCIs in accordance with Section 5.

If the AFCI or GFCI does not trip after plugging in and turning on all cord-and-plug appliances and equipment, measure the load current on the circuit to determine whether the circuit is overloaded. To test for overloads, turn off all of the loads on the circuit and energizing the branch circuit wiring. Turn on all loads one at a time. Measure the time delay between turning on the last load and when the AFCI or GFCI trips. Any measurable time delay in the tripping of an AFCI or GFCI would indicate that the device is tripping due to overload. Calculate or
measure the total load connected to the circuit and compare to its ratings. Transfer any load in excess of the device ratings to another circuit.

Keep in mind that turning off the circuit and reconnecting appliances, equipment and components may temporarily clear an arc that may not reappear or may appear some time after the circuit and loads are re-energized.

If there is no clear indication of any problems with an AFCI, GFCI, fixed wiring or appliances, replace the AFCI or GFCI. If the new device does not trip, the previous device was damaged or deteriorated. If the new device trips, troubleshoot the fixed wiring and appliances, correct deficiencies, and test AFCIs and GFCIs in accordance with Section 5.
(This annex is not part of the standard)

Annex B: Reference Standards