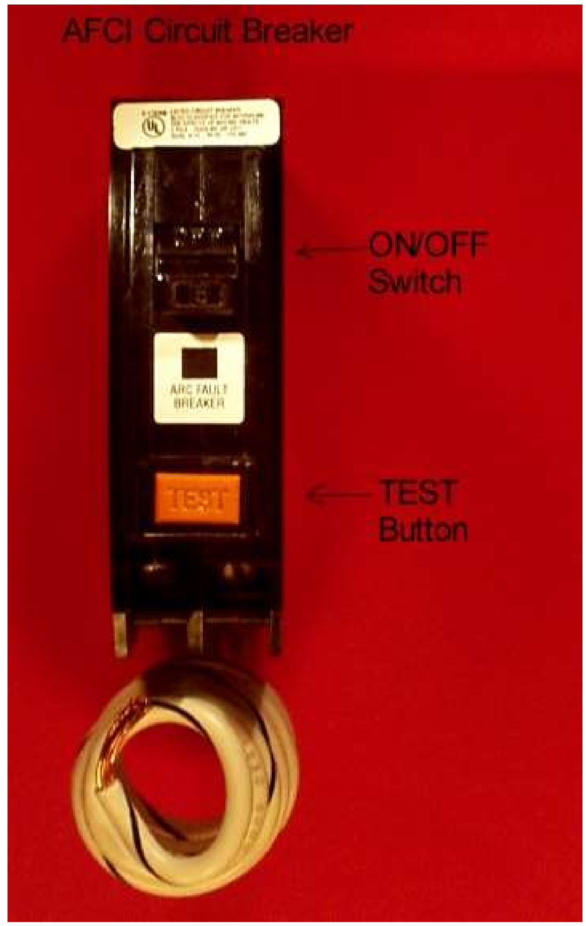
Arc Fault Circuit Interrupter
(AFCI)
FACT SHEET

THE AFCI

The "AFCI" is an arc fault circuit interrupter. AFCIs are newly-developed electrical devices designed to protect against fires caused by arcing faults in the home electrical wiring.



THE FIRE PROBLEM

Annually, over 40,000 fires are attributed to home electrical wiring. These fires result in over 350 deaths and over 1,400 injuries each year[1]. Arcing faults are one of the major causes of these fires. When unwanted arcing occurs, it generates high temperatures that can ignite nearby combustibles such as wood, paper, and carpets.

Arcing faults often occur in damaged or deteriorated wires and cords. Some causes of damaged and deteriorated wiring include puncturing of wire insulation from picture hanging or cable staples, poorly installed outlets or switches, cords caught in doors or under furniture, furniture pushed against plugs in an outlet, natural aging, and cord exposure to heat vents and sunlight.

HOW THE AFCI WORKS

Conventional circuit breakers only respond to overloads and short circuits; so they do not protect against arcing conditions that produce erratic current flow. An AFCI is selective so that normal arcs do not cause it to trip.

The AFCI circuitry continuously monitors current flow through the AFCI. AFCIs use unique current sensing circuitry to discriminate between normal and unwanted arcing conditions. Once an unwanted arcing condition is detected, the control circuitry in the

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[1] Ault, Singh, and Smith, "1996 Residential Fire Loss Estimates", October 1998, U.S. Consumer Product Safety Commission, Directorate for Epidemiology and Health Sciences.

AFCI trips the internal contacts, thus de-energizing the circuit and reducing the potential for a fire to occur. An AFCI should not trip during normal arcing conditions, which can occur when a switch is opened or a plug is pulled from a receptacle.

Presently, AFCIs are designed into conventional circuit breakers combining traditional overload and short-circuit protection with arc fault protection. AFCI circuit breakers (AFCIs) have a test button and look similar to ground fault circuit interrupter (GFCI) circuit breakers. Some designs combine GFCI and AFCI protection. Additional AFCI design configurations are anticipated in the near future.

It is important to note that AFCIs are designed to mitigate the effects of arcing faults but cannot eliminate them completely. In some cases, the initial arc may cause ignition prior to detection and circuit interruption by the AFCI.

The AFCI circuit breaker serves a dual purpose – not only will it shut off electricity in the event of an "arcing fault", but it will also trip when a short circuit or an overload occurs. The AFCI circuit breaker provides protection for the branch circuit wiring and limited protection for power cords and extension cords. Single-pole, 15- and 20- ampere AFCI circuit breakers are presently available.

WHERE AFCIs SHOULD BE USED

The 1999 edition of the National Electrical Code, the model code for electrical wiring adopted by many local jurisdictions, requires AFCIs for receptacle outlets in bedrooms, effective January 1, 2002. Although the requirement is limited to only certain circuits in new residential construction, AFCIs should be considered for added protection in other circuits and for existing homes as well. Older homes with aging and deteriorating wiring systems can especially benefit from the added protection of AFCIs. AFCIs should also be considered whenever adding or upgrading a panel box while using existing branch circuit conductors.

INSTALLING AFCIs

AFCI circuit breakers should be installed by a qualified electrician. The installer should follow the instructions accompanying the device and the panel box.

In homes equipped with conventional circuit breakers rather than fuses, an AFCI circuit breaker may be installed in the panel box in place of the conventional circuit breaker to add arc protection to a branch circuit. Homes with fuses are limited to receptacle or portable-type AFCIs, which are expected to be available in the near future, or AFCI circuit breakers can be added in separate panel boxes next to the fuse panel box.

TESTING AN AFCI

AFCIs should be tested after installation to make sure they are working properly and protecting the circuit. Subsequently, AFCIs should be tested once a month to make sure they are working properly and providing protection from fires initiated by arcing faults.

A test button is located on the front of the device. The user should follow the instructions accompanying the device. If the device does not trip when tested, the AFCI is defective and should be replaced.

AFCIs vs. GFCIs

The AFCI should not be confused with the GFCI or ground fault circuit interrupter. The GFCI is designed to protect people from severe or fatal electric shocks while the AFCI protects against fires caused by arcing faults. The GFCI also can protect against some electrical fires by detecting arcing and other faults to ground but cannot detect hazardous across-the-line arcing faults that can cause fires.

A ground fault is an unintentional electric path diverting current to ground. Ground faults occur when current leaks from a circuit. How the current leaks is very important. If a person's body provides a path to ground for this leakage, the person could be injured, burned, severely shocked, or electrocuted.

The National Electrical Code requires GFCI protection for receptacles located outdoors; in bathrooms, garages, kitchens, crawl spaces and unfinished basements; and at certain locations such as near swimming pools. A combination AFCI and GFCI can be used to satisfy the NEC requirement for GFCI protection only if specifically marked as a combination device.

Arc-Fault Circuit Interrupters (AFCIs) - Type and Performance Considerations

In February of 1999, UL published the First Edition of the Standard for Arc-Fault Circuit-Interrupters (AFCIs), UL1699. According to the National Electrical Code (NEC), an AFCI is defined as 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. The 2002 NEC will require all branch circuits that supply 125-volt, single-phase, 15- and 20-ampere outlets installed in dwelling unit bedrooms to be protected by an AFCI listed to provide protection to the entire branch circuit.

Branch Circuits

A branch circuit is defined in Article 100 of the NEC as the circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). The length of a branch circuit can vary from several feet to several hundred feet, and include from one to several outlets. Figure 1 shows a pictorial representation of a typical branch circuit that could be associated with a dwelling unit bedroom.

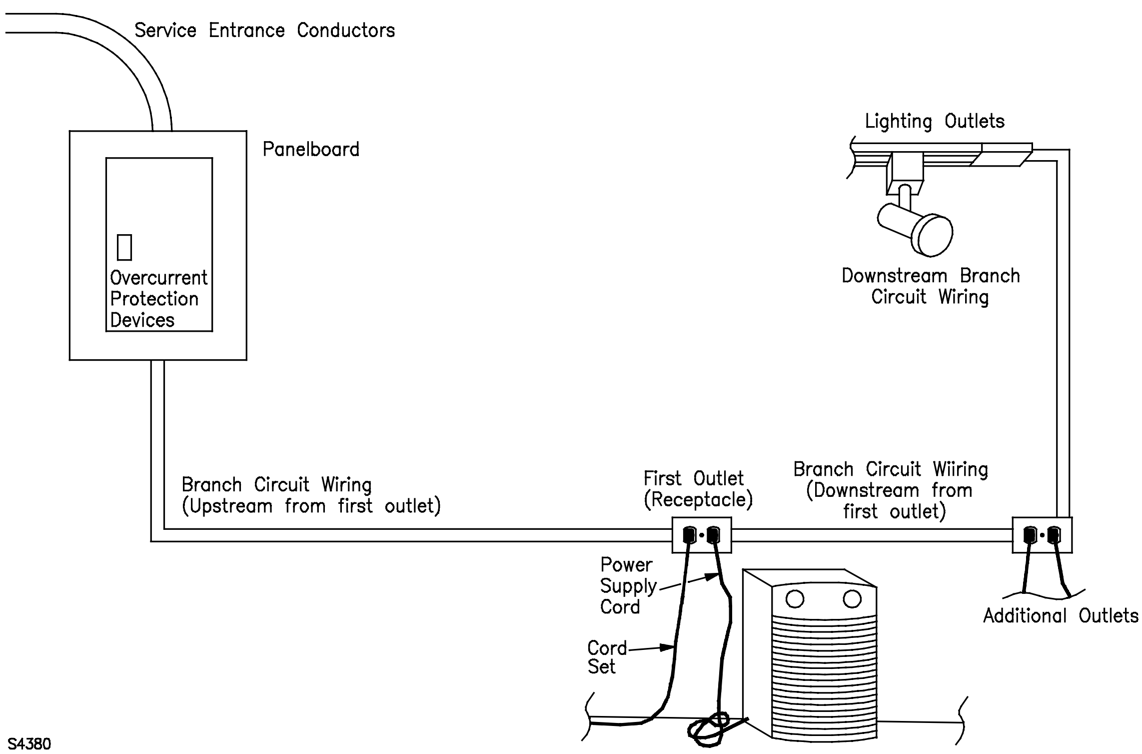

Figure 1 – Pictorial Representation of a Typical Branch Circuit (Not to Scale)

The branch circuit overcurrent protection is provided by a fuse or circuit breaker usually located in a centralized panelboard that is served with power by the local utility. As the name implies, overcurrent protection protects the branch circuit against any currents that are in excess of the rated current or ampacity of the branch circuit conductors. Overcurrents can be the result of overloads, short circuits, or ground faults. Overcurrent protection is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in the branch circuit conductors or conductor insulation.

The branch circuit conductors are normally contained within a non-metallic cable (NM-B), armored cable (AC), or a metal or non-metallic raceway such as conduit or tubing. Non-metallic cables and raceway systems contain a separate conductor for equipment grounding purposes. Metal armor cables and raceways may contain an equipment grounding conductor, but in most cases the metal itself is permitted to serve as the equipment grounding path.

The branch circuit conductors extend throughout the building to outlets, which may be a receptacle outlet for connecting to cord- and plug-connected appliances, or to fixed equipment, such as a lighting outlet for a wall or ceiling mounted lighting fixture (luminaire).

Receptacle outlets in the branch circuit provide for the connection of cord-connected appliances, which in a bedroom may include appliances such as portable lamps, clock-radios, and portable air heaters. The cords attached to these appliances are generally referred to as power supply cords, as they supply the power from the branch circuit to the cord-connected appliance. In some cases, a power supply cord is not long enough to reach from the intended location of the appliance to the nearest receptacle outlet. In these situations, a cord set, often referred to as an extension cord, is used to extend the length of the appliance power supply cord to the electrical outlet.

Cord sets and power supply cords are made from flexible cords that have designations such as SPT-2 which is often used on portable lamps and light duty extension cords. Although flexible cords are not a substitute for fixed branch circuit wiring, they are tested for mechanical impact and flexural strength properties that are suitable for their intended application. Flexible cords may or may not be provided with an equipment grounding conductor depending on the application or appliance involved. Cord sets and power supply cords are not part of the branch circuit wiring, but since they extend power beyond the branch circuit, they can be subjected to the same overloads, short circuits, and ground faults as would the branch circuit wiring.

Branch Circuit Protection

The branch circuit overcurrent protective device (OCPD), (i.e. a fuse or circuit breaker), is specifically designed to protect electrical circuits, including the branch circuit conductors and flexible cords, against the unwanted effects of overcurrents. For example, when too many products are plugged into the same electrical outlet, and the total load current exceeds the rating of the branch circuit (i.e. 15 or 20 amps), the OCPD will open the circuit before damage to equipment or a fire occurs. However, an OCPD is not designed to protect the circuit against arcing faults. Because of the time-current characteristics of the OCPD necessary to provide effective protection against overcurrents, some arcing faults, including damaging arcing faults, may have time and/or current characteristics below the threshold levels necessary to open the OCPD.

Arcing Faults

"Arcing" is defined as a luminous discharge of electricity across an insulating medium. The electrical discharge of an arc can involve temperatures on the order of several thousand degrees Celsius. In general, arcing can be divided into two categories: (1) non-contact arcing and (2) contact arcing.

"Non-contact arcing" is arcing that does not require direct physical contact between the conductors where the arcing is taking place. With arcing between conductors separated by insulation, the mechanism of initiating an arc between stationary conductors separated by insulation will depend on the type and geometry of the conductors and insulation between them. "Contact arcing" is arcing that involves direct or indirect physical contact between the conductors or "electrodes" where the arcing is taking place, such as arcing between closing or parting conductors making or breaking a circuit.

Arcing faults can occur in one of two ways, series arcing faults or parallel arcing faults. A series arcing fault can occur when one of the current-carrying paths (e.g. a single wire) in series with the load is unintentionally broken. For example, extreme flexing in an appliance power supply cord can cause one of the conductors to open and arc when flexed. Series arcing faults are limited in current to the load current of the connected appliance or appliances in that circuit. Parallel arcing faults occur when there is an unintentional conducting path between two conductors of opposite polarity, such as between a black and white conductor, or between a line conductor and ground. Parallel arcing faults generally involve high currents, as they are limited only by the available fault current of the circuit.

AFCI Types

The UL1699 Standard addresses several types of AFCIs. Each type of AFCI is intended for different applications and/or protection of different aspects of the branch circuit and extension wiring. Three types of AFCIs for permanent connection to the branch circuit are identified in UL1699 as follows:

- **Branch/Feeder AFCI** – This device is installed at the origin of a branch circuit or feeder, such as at a panelboard, 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 (e.g. cord sets and power supply cords). These may be a circuit-breaker type devices or a device in its own enclosure mounted at or near a panelboard.

- **Outlet Circuit AFCI** – This device is installed at a branch circuit outlet, such as at an outlet box, 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.

- **Combination AFCI** – This is an AFCI which complies with the requirements for both branch/feeder and outlet circuit AFCIs. It is intended to protect downstream branch circuit wiring, cord sets and power-supply cords.

The NEC and AFCIs

During the revision process for the 2002 NEC there were several proposals to revise Sec. 210-12 to require both a branch/feeder and outlet circuit AFCIs in branch circuits required to be protected (bedrooms). This would provide protection to both the branch circuit wiring, as well as cord sets and power supply cords that extend beyond the branch circuit. The Code Panel did not accept these proposals. There was also a proposal for the 2002 NEC to permit either a branch/feeder AFCI located at the origin of the branch circuit, or a new type of AFCI designated an "outlet branch circuit" type located at the first outlet receptacle. A proposed revision to UL1699 would include this new type of AFCI defined as follows:

- **Outlet Branch Circuit AFCI** – A device intended to be installed as the first outlet in a branch circuit. It is intended to provide protection to downstream branch circuit wiring, cord sets and power-supply cords against the unwanted effects of arcing. These devices also provide protection to upstream branch circuit wiring.

The final language agreed upon by the Code Panel for the 2002 NEC for Sec. 210.12 will indicate the following: "All branch circuits that supply 125-volt, single-phase, 15- and 20-ampere outlets installed in dwelling unit bedrooms shall be protected by an arc-fault circuit interrupter listed to provide protection to the entire branch circuit."

AFCI Tests

As the UL1699 Standard continues to develop and address different product types and technology enhancements, it is important to understand how each type of AFCI is suitable for protecting various regions of the entire circuit against arc faults, and the extent and conditions under which this protection will be provided. Four different arc-fault tests are identified in UL1699 as shown in Figure 2.

Tests	Branch/ feeder AFCI	Combination AFCI	Outlet branch circuit AFCI
Carbonized path arc ignition test <series>			
NM-B insulation cut	X	X	X(+)
<new> NM-B w/o gnd insulation cut			X(+)
Carbonized path arc interruption test <parallel>			
SPT-2 insulation cut	X	X	X
NM-B insulation cut	X	X	X
Carbonized path arc clearing time test <series>			
SPT-2 insulation cut		X	X
<new> NM-B insulation cut			X(+)
Point contact arc test <parallel>			
SPT-2 insulation cut	X	X	X
NM-B insulation cut	X	X	X

(+) – also includes an upstream insulation cut

Figure 2 – AFCI Arc-Fault Tests

The Carbonized Path Arc Ignition Test is a non-contact arcing test conducted with NM-B cable with a series insulation cut. Tests are conducted with arcing currents of 5 A, 10 A, rated current, and 150% rated current. The Branch/Feeder, Combination, and Outlet Branch Circuit AFCIs are subjected to the Carbonized Path Arc Ignition Test. The Outlet Branch Circuit AFCI is subjected to the Carbonized Path Arc Ignition Test with the arcing occurring upstream, to represent series arcing in the branch circuit wiring between the origin of the branch circuit and the first outlet receptacle. The Outlet Branch Circuit AFCI is also subjected to the Carbonized Path Arc Ignition Test using NM-B cable without a grounding conductor, as may be found in some older homes built over 40 years ago.

The Carbonized Path Arc Interruption Test is a non-contact arcing test conducted with NM-B cable and SPT-2 flexible cord with a parallel insulation cut. Tests are conducted with arcing currents of 75 A and 100 A. The Branch/Feeder, Combination, and Outlet Branch Circuit AFCIs are subjected to the Carbonized

Path Arc Interruption Test, however, the Outlet Branch Circuit AFCI is not tested with this parallel arcing occurring upstream from the device.

The Carbonized Path Arc Clearing Time Test is a non-contact arcing test conducted with SPT-2 flexible cord with a series insulation cut. Tests are conducted with arcing currents of 5 A, 10 A, rated current, and 150% rated current. The Outlet Branch Circuit and Combination AFCIs are subjected to the Carbonized Path Arc Clearing Time Test. The Branch/Feeder AFCI is not subjected to this series arcing test with flexible cord as found in many cord sets and power supply cords. The Outlet Branch Circuit AFCI is subjected to the Carbonized Path Arc Clearing Time Test with NM-B cable and the arcing occurring upstream, to represent series arcing in the branch circuit wiring between the origin of the branch circuit and the first outlet receptacle.

The Point Contact Arcing Test is a contact arcing test conducted with NM-B cable and SPT-2 flexible cord with a parallel insulation cut. Tests are conducted with arcing currents of 75 A through 500 A. The Branch/Feeder, Combination, and Outlet Branch Circuit AFCIs are subjected to the Point Contact Arcing Test, however, the Outlet Branch Circuit AFCI is not tested with this parallel arcing occurring upstream from the device.

Further Information

For more information on AFCIs, see the Regulators Page on the UL Web site at:

http://www.ul.com/regulators/afci/index.html