

# What is an Arc Fault Circuit Interrupter?

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An **Arc Fault Circuit Interrupter (AFCI)** is a circuit breaker designed to prevent fires by detecting a non-working (i.e., non-intended/non-useful) electrical arc and disconnect power before the arc starts a fire. An AFCI should, but does not always, distinguish between a working arc that may occur in the brushes of a vacuum cleaner, light switch, or other household devices and a non-working arc that can occur, for instance, in a lamp cord that has a broken conductor in the cord from overuse. Arc faults in a home are one of the leading causes for household fires.<sup>[1]</sup>

AFCI's resemble a GFCI/RCD (Ground- Fault Circuit Interrupt/Residual-Current Device) in that they both have a test button, although it is important to distinguish between the two. GFCIs are designed to protect against electrical shock, while AFCIs are primarily designed to protect against arcing and/or fire.

## Electrical Code Requirements

Starting with the 1999 version of the National Electrical Code (NEC, also called NFPA 70) in the United States and the 2002 version of the Canadian Electrical Code in Canada (CSA Standard C22.1), the national codes require AFCIs in all circuits that feed receptacles in bedrooms of dwelling units. This requirement is typically accomplished by using a kind of circuit-breaker (defined by UL 1699) in the breaker panel that provides combined arc-fault and over current protection. Not all U.S.A. jurisdictions have adopted the AFCI requirements of the NEC as written.

The AFCI is intended to prevent fire from arcs. AFCI circuit breakers are designed to meet one of two standards as specified by UL 1699: "branch" type or "combination" type (note: the Canadian Electrical Code uses different terminology but similar technical requirements). A branch type AFCI trips on 75 amperes of arcing current from the line wire to either the neutral or ground wire. A combination type adds series arcing detection to branch type performance. Combination type AFCIs trip on 5 amperes of series arcing. Advanced electronics inside an AFCI breaker detect sudden bursts of electric current in milliseconds, long before a standard circuit breaker or fuse would trip. A "combination AFCI breaker" will provide protection against

1. Parallel arcing (line to neutral).
2. Series arcing (a loose, broken, or otherwise high resistance segment in a single line)
3. Ground arcing (from line, or neutral, to ground)
4. Overload protection (for resistance loads such as heaters. inductive loads such as motors may require additional overload protection)
5. Short circuit protection

In 2002, the NEC removed the word "receptacle" leaving "outlets", in effect adding lights within dwelling bedrooms to the requirement [debated interpretation]. The 2005 code made it more clear that all outlets must be protected, despite code making panel discussion about excluding bedroom smoke detectors from the requirement. "Outlets" is defined in "Article 100 Definitions" of the NEC as "A point on the wiring system where current is taken to supply utilization equipment" and this includes receptacles, light fixtures, and smoke alarms, among other things.

As of January 2008, only "combination type" AFCIs will meet the NEC requirement. **The 2008 NEC requires installation of combination-type AFCIs in all 15 and 20 ampere residential circuits with the exception of laundries, kitchens, bathrooms, garages, and unfinished basements.**

## Limitations

AFCIs are designed to protect against fires caused by electrical arcing faults. However, they provide no specific protection against "glowing" connections, excess current, high line voltages, or low line voltages. For descriptions of electrical fire causes, see "How Electricity Starts Fires", John S Robison, P.E., Electrical Line magazine, November / December 2007 issue, pages 60–70 (<http://www.electricaline.com/>); NFPA 921 "Guide for Fire and Explosion Investigations", 2004 edition; and "Ignition Handbook", Dr. Vytenis Babrauskas, Fire Science Publishers, 2003.

Glowing connections occur when relatively high electric current exists in a relatively large resistance. Heat comes from power dissipation. Power (in watts, symbol W) equals the current (in amperes, symbol A) squared, multiplied by the resistance (in ohms, symbol  $\Omega$ ). For example, a 60 watt lamp operating on a 120 V circuit draws 1/2 ampere of current. An 1800 watt space heater on a 120 V circuit draws up to 15 amperes. If a bad wiring junction in a circuit has a resistance of 1 ohm, then a 60 W lamp will cause it to dissipate 0.25 watt of power ( $0.5 \text{ A} * 0.5 \text{ A} * 1 \Omega$ ). In contrast, an 1800 W heater could theoretically cause the bad wiring junction to dissipate 178 watts ( $13 \text{ A} * 13 \text{ A} * 1 \Omega$ ). Note that the current is less than 15 A because of the combined resistance of the heater plus the bad wiring junction. This energy, dissipated in a small junction area, can generate temperatures above 1000 degrees Celsius. Those temperatures can ignite most flammable materials. Bad wiring junctions can occur in utilization equipment, cords, or premise wiring (especially in defective switch, socket, plug, or wire connection, even at circuit breaker or fuse panels). High resistance junctions are commonly observed in improperly terminated aluminum wire junctions. No technology located in a circuit breaker or fuse panel could detect a high-resistance wiring fault, as no measurable characteristic exists that differentiates a glow fault from normal branch circuit operation. Power Fault Circuit Interrupters (PFCI) located in receptacles are designed to prevent fires caused by glowing connections in premise wiring or panels. From the receptacle, a PFCI can detect the voltage drop when high current exists in a high resistance junction. In a properly designed circuit, substantial voltage drops should never occur. Proper wire terminations inside utilization equipment (e.g. appliances, lamps, heaters) and cords prevent high-resistance connections that can lead to fires.

Excess current can heat entire lengths of wire. Thermal circuit breakers are designed to protect against excess current through the permanent circuit wiring. However, excess current through the smaller wires in utilization equipment can exist, at levels below the trip thresholds of a circuit

breaker. Overload fault circuit interrupters (OFCI) are designed to protect against excess current drawn by utilization equipment. OFCIs must be located within receptacles. Both thermal circuit breakers and OFCIs are required to prevent fire ignition from excess current.

High line-voltage creates excess power and heat in utilization devices such as heaters, light bulbs, appliances, motors, and electronics. In extreme cases, this heat can ignite fires. One extreme source of high line voltage occurs from a neutral path opening within a two-leg 120 V residential electrical system. When a neutral wire breaks or opens, the utilization voltage can almost double to over 200 V with large leg-to-leg load imbalances. This extreme situation can result in almost four times the power and heat in loads. With such overheating, some loads can reach self-ignition temperature in less than 10 minutes. Power fault circuit interrupters (PFCIs) are designed to prevent fires caused by excess voltage across loads. Voltage-trip circuit breakers detect excess line voltages, but are unable to detect sub-circuit open neutral conditions.

Low line voltage can cause electro-mechanical relays (on-off switches) to repeatedly turn off (relay opens) and on (relay closes again). If current is flowing through the load contacts, it will cause arcing across the contacts when they open. The arcing can oxidize, pit and melt the contacts. This process can increase the contact resistance, superheat the relay and lead to fires. Power fault circuit interrupters are designed to prevent fires from low voltage across loads.

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