arc fault circuit interrupters

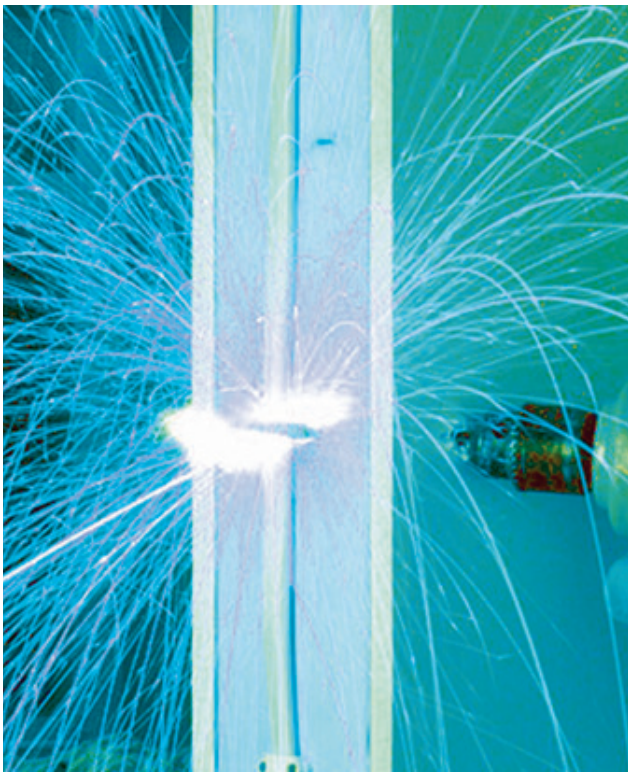
using advanced technology to reduce electrical fires

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
Low Voltage Distribution Equipment Section

INTRODUCTION

Arc Fault Circuit Interrupters (AFCIs) are required by the National Electrical Code for certain electrical circuits in the home. Questions have been raised regarding their application and even the need for them. Various technical "opinions," organizational "marketing pitches" and misinformation is being distributed about AFCIs that further mislead the public about the purpose of the device as a part of overall electrical safety for the public.



This brochure is intended to address the various aspects of AFCIs and clear up the misinformation circulating in the industry.

WHY DO WE REALLY NEED AFCIs?

Smoke alarms, fire extinguishers and escape ladders are all examples of emergency equipment used in homes to take action when a fire occurs. An AFCI is a product that is designed to detect a wide range of arcing electrical faults to help reduce the electrical system from being an ignition source of a fire.

Conventional overcurrent protective devices do not detect low-level hazardous arcing currents that have the potential to initiate electrical fires. It is well known that electrical fires do exist and take many lives and damage or destroy significant amounts of property. Electrical fires can be a silent killer occurring in areas of the home that are hidden from view and early detection. The objective is to protect the circuit in a manner that will reduce its chances of being a source of an electrical fire.

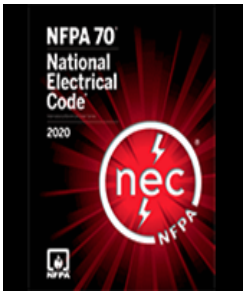
THE JOURNEY TO DEVELOP DETECTION TECHNOLOGY

Research in the arc fault area began in the late 1980s and early 1990s when the Consumer Product Safety Commission (CPSC) identified a concern with the residential fires of electrical origin. A large number of these fires were estimated to be in branch circuit wiring systems.

The concept of AFCIs gained more momentum when code proposals were made to the 1993 NEC® to change the instantaneous trip levels of 15A and 20A circuit breakers. The Electronic Industries Association (EIA) had studied the issue of electrical fires and determined that additional protection against arcing faults were an area that needed to be addressed by electrical protection. This proposal first attempted to do this by requiring that instantaneous trip levels of a circuit breaker be reduced from a range of 120- to 150-amperes down to 85-amperes. However, it became clear that the lowering of those levels below some of the minimums already available on the market would result in significant unwanted tripping due to normal inrush currents.

It was these early studies and code efforts that led to the first proposals requiring AFCIs, which were made during the development of the 1999 NEC. NEC Code-Making Panel 2 (CMP2) reviewed many proposals ranging from protecting the entire residence to the protection of living and sleeping areas. In addition, the panel heard numerous presentations on both sides of the issue. After much data analysis and discussion, the CMP2 concluded that AFCI protection should be required for branch circuits that supply receptacle outlets in bedrooms.

Subsequent editions of the NEC further upgraded the requirements to include protection on all outlets (lighting, receptacle, smoke alarm, etc.) in bedrooms along with other enhancements.



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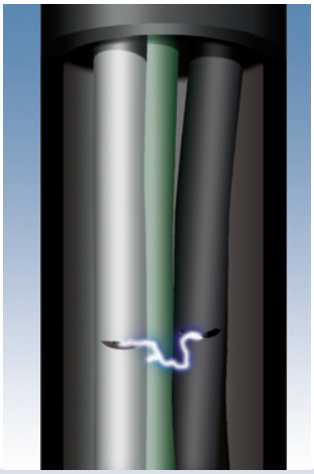
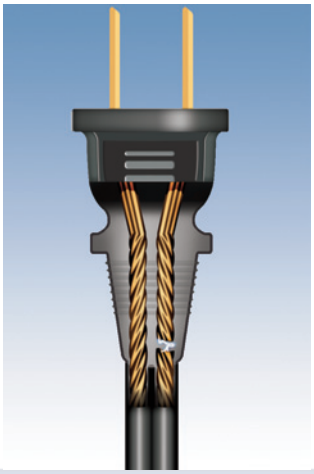


Parallel Arc



Series Arc

WHAT ARE ARC FAULTS?

The UL Standard for AFCIs (UL 1699) defines an arcing fault as an unintentional arcing condition in a circuit. Arcing creates high intensity heating at the point of the arc resulting in burning particles that may over time ignite surrounding material, such as wood framing or insulation.

The temperatures of these arcs can exceed 10,000 degrees Fahrenheit. Repeated arcing can create carbon paths that are the foundation for continued arcing, generating even higher temperatures.

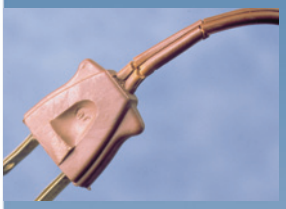
typical causes of arc faults

Example conditions where arc faults may start include:

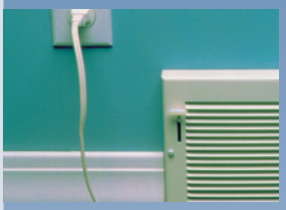
- Damaged wires
- Worn electrical insulation
- Wires or cords in contact with vibrating metal
- Overheated or stressed electrical cords and wires
- Misapplied or damaged electrical appliances

Furniture pushed against or resting on electrical cords can damage the wire insulation. Damaged cords can become a potential condition for arcing.

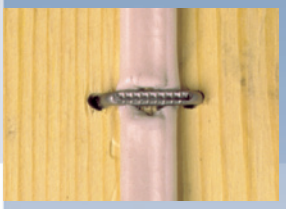
Extension or appliance cords that are damaged or have worn or cracked insulation can contribute to electrical arcing.



Cord insulation can be deteriorated by heat generated by hot air ducts or sunlight.

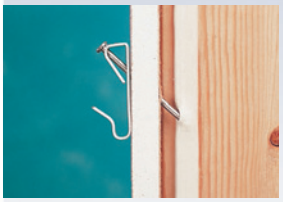


Cables that are improperly nailed or stapled too tightly against a wall stud can sever insulation and cause arcing.



Wires located behind walls can be accidentally punctured by a screw or drill bit damaging the insulation of the wiring.

Nails carelessly driven into walls can break wire insulation and cause arcing.



Cords caught in door jams can deteriorate the cable insulation through the action of opening and closing, allowing arcing to occur.

FIRE DATA ANALYSIS

The United States Fire Administration (USFA), the insurance industry and others track the incidence of electrical fires across the United States and categorize those fires based on their causes. Between 2014-2016, the USFA reports firefighters responded to 24,000 residential building electrical fires annually resulting in an estimated 310 deaths, 850 injuries and $871 million in property loss.*

According to research published in 2019 by the National Fire Protection Association (NFPA) and titled "Home Electrical Fires," electrical distribution, lighting, and power transfer equipment accounted for half of all home fires involving electrical failure or malfunction, followed by cooking equipment (15%), heating equipment (9%), fans (6%), air conditioners (3%) and clothes dryers (3%).**

The U.S. Department of Housing and Urban Development (HUD) – "Healthy Home Issues: Injury Hazards" – has stated that AFCIs are one of the many devices that can be used to prevent burns and fire related injuries. In addition, HUD cites a 1999 U.S. Consumer Product Safety Commission (CPSC) report recommending the use of AFCIs to "prohibit or reduce potential electrical fires from happening."***

As you can see from the data above, fires of electrical origin are a significant issue that must be addressed. Frequently, it is argued that fires only occur in older homes. However, it should be recognized that new homes become older homes. It is critical to install the AFCIs in the beginning so that they can perform their protection function from the start. Seldom are devices such as AFCIs added to homes after they are constructed and occupied.

***USFA/FEMA Data Statistics:**
https://www.usfa.fema.gov/data/statistics/reports/electrical_fires_v19i8.html

****NFPA Home Electrical Fires:**
https://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/Fire-causes/osHomeElectricalFires.pdf

*****HUD Healthy Homes Issues:**
Injury Hazards, U.S. Department of Housing and Urban Development, Version 3, March 2012

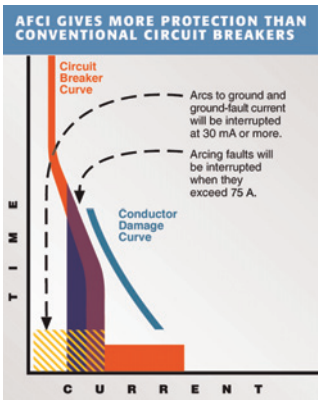
https://healthyhousingsolutions.com/wp-content/uploads/2014/12/HUD_Injury_Hazards_Paper_7-6-12.pdf

HOW IS AN ARC FAULT DETECTED?

Unlike a standard circuit breaker detecting overloads and short circuits, an AFCI utilizes advanced electronic technology to "sense" the different arcing conditions. While there are different technologies employed to measure arcs by the various AFCI manufacturers, the end result is the same, detecting parallel arcs (line-to-line, line-to-neutral and line-to-ground) and/or series arcs (arcing in series with one of the conductors).

How does arc fault detection work? In essence, the detection is accomplished by the use of advanced electronic technology to monitor the circuit for the presence of "normal" and "dangerous" arcing conditions. Some equipment in the home, such as a motor-driven vacuum cleaner or furnace motor, naturally create arcs. This is considered to be a normal arcing condition. Another normal arcing condition that can sometimes be seen is when a light switch is turned off and the opening of the contacts creates an arc.

A dangerous arc, as mentioned earlier, occurs for many reasons including damage of the electrical conductor insulation. When arcing occurs, the AFCI analyzes the characteristics of the event and determines if it is a hazardous event. AFCI manufacturers test for the hundreds of possible operating conditions and then program their devices to monitor constantly for the normal and dangerous arcing conditions.



THE NEC® AND UL® STANDARD

National Electrical Code®

The National Electrical Code® specifically defines and mandates the installation of AFCIs. In the 1999 edition of the NEC, Section 210.12 required that dwelling unit bedrooms have AFCIs installed to protect all branch circuits that supply 125-volt, single-phase, 15- and 20-ampere receptacle outlets installed in the dwelling unit bedrooms. This requirement became effective January 1, 2002.

In the 2002 NEC, section 210.2 expanded AFCI protection to all bedroom outlets (lighting, receptacle, smoke alarm, etc.).

The 2005 NEC 210.12 revised the AFCI requirement to provide for a technology upgrade. While previous generations of product detected parallel arcing, this new device – a combination AFCI – would also detect series arcing, and at lower current levels.

The 2020 NEC 210.12 now requires that for dwelling units, all 120-volt, single-phase, 15- and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, similar rooms or areas shall be protected by AFCIs.

UL® Standard

Product standards to cover AFCIs began to be developed in the mid-1990s. Underwriters Laboratories published UL 1699 – Standard for Safety for AFCIs - in 1996 to cover a wide variety of conditions to evaluate an AFCI. The standard includes requirements for the following conditions:

- Humidity Conditioning
- Leakage Current
- Voltage Surge
- Environmental Evaluation
- Dielectric Voltage
- Arc-Fault Detection
- Unwanted Tripping
- Operation Inhibition
- Resistance to Environmental Noise
- Abnormal Operation

One of the most frequent questions about AFCIs is related to resistance to unwanted tripping. There are four varieties of tests related to its ability to resist unwanted tripping:

- Inrush Current: High-current draw devices such as tungsten filament lamps and capacitor start motors.
- Normal Arcing: Brush motors, thermostatic contacts, wall switch and appliance plugs.
- Non-Sinusoidal Waveforms: Examples of devices creating these electrical waveforms include electronic lamp dimmers, computer switching-mode power supplies and fluorescent lamps.
- Cross Talk: This test measures trip avoidance for an AFCI when an arc is detected in an adjacent circuit. Only the circuit with the arc should cause the breaker to trip, not another circuit.

Through the use of the National Electrical Code requirement and extensive UL testing, manufacturers' AFCI products provide superior protection against arcing faults.

CONTRASTING AFCI AND GFCI

There is a major difference between the functioning of an AFCI as compared to a GFCI (Ground Fault Circuit Interrupter). The function of the GFCI is to protect people from the deadly effects of electric shock that could occur if parts of an electrical appliance or tool become energized due to a ground fault. The function of the AFCI is to protect the branch circuit wiring from dangerous arcing faults that could initiate an electrical fire.

AFCI and GFCI technologies can co-exist with each other and are a great complement for the most complete protection that can be provided on a circuit.

WHAT ARE THE VARIOUS SAFETY AND GOVERNMENTAL AGENCIES SAYING ABOUT AFCI?

"The National Association of State Fire Marshals (NASFM) strongly supports the broad adoption of AFCI technology through national, state and local building codes. AFCIs are the most welcome addition to fire prevention in decades. AFCIs promise to save hundreds of lives every year."
John C. Bean, President, NASFM

"The National Association of Home Inspectors (NAHI) strongly encourages its members to educate all of their clients about the life- and property-saving benefits of AFCI technology, especially those clients considering the purchase of a home more than 20 years old."
Mallory Anderson, Executive Director, NAHI

"The National Electrical Contractors Association (NECA) submitted comments to legislative committees in Michigan and South Carolina, urging them to retain requirements for AFCI protection of bedroom receptacles in their state electrical codes. Cost cutting pressure from homebuilders' associations in both states led to code proposals to delete AFCI protection required by the National Electrical Code, when constructing new homes."
NECA Contractor Code Letter

"CPSC has identified arc fault circuit interrupter (AFCI) technology as an effective means of preventing fires caused by electrical wiring faults in homes."
U.S. Fire Administration

"The Electrical Safety Foundation International (ESFI) urges that arc fault circuit interrupter (AFCI) technology be installed in all new and existing housing to protect homes and families from fires caused by electrical arcing."
Brett Brenner, President, ESFI

TYPES OF AFCI ARC FAULT CIRCUIT INTERRUPTER (AFCI)

AFCIs are intended to mitigate the effects of arcing faults by functioning to de-energize the circuit when an arc fault is detected. AFCIs are required by the NEC® to be a listed product. This means that they must be evaluated by a nationally recognized testing laboratory to the national standard for AFCIs (UL 1699). NEC 210.12 establishes the requirement to use AFCIs. Protection is required for branch circuits in locations as specified in this NEC rule.

Branch/Feeder AFCI

A device intended to be installed at the origin of a branch circuit or feeder, such as at a panelboard. The branch/feeder AFCI provides for detection of arcing faults that can occur line-to-line, line-to-neutral and line-to-ground.

To be able to handle shared neutral circuits (a common application in older homes), a two-pole AFCI can be used. This will accommodate the three-wire circuit arrangement used in shared neutral applications.

Combination AFCI

In addition to the protection provided by the Branch Feeder AFCI, the Combination AFCI provides for series arc detection down to 5-amperes. This series arc detection is beneficial to detect lower level arcing in both branch circuits and power supply cords. Combination AFCI protection became an NEC requirement in 2008*.

AFCI and GFCI Protection

An AFCI can be used in conjunction with GFCI protection to provide both arcing fault protection as well as 5mA ground fault (people) protection. A common way to provide both types of protection is to use an AFCI circuit breaker and a GFCI receptacle.

AFCIs can also incorporate 5mA GFCI protection into the same package. This solution for AFCI and GFCI on the same circuit can be useful where the circuit design requires both types of protection or where the installer (or user) wants to have both types of protection.

* The 2005 NEC added a requirement that went into effect in 2008 for combination AFCI protection.

WIRING AND INSTALLATION GUIDELINES

There are no special requirements of an AFCI circuit other than proper installation and wiring practices. There are various special considerations that must be given to certain circuits that vary from the norm, such as shared neutral applications, but in general the application of an AFCI is as simple as following the installation instructions that come from the manufacturer.

The basic difference between installing the AFCI versus a standard thermal magnetic circuit breaker is the requirement to connect both the hot and neutral conductor to the proper terminals of the AFCI. In a circuit wired with a conventional circuit breaker, the hot conductor is connected to the breaker and the neutral conductor is connected directly to the neutral bar of the load center.

defining the arc fault risk to people and property

As with any change in the required protection for the electrical system, there have been many discussions and deliberations both for and against arc fault protection being a part of the National Electrical Code. Some have argued that the cost of the AFCI is higher than a standard circuit breaker and, as such, it costs too much to provide the increased protection. Others have argued that since it is a relatively new type of protection, it does not have the history on which to base a decision as to whether to support or not.

These comments have been debated thoroughly and completely. It is important to keep a few critical facts in mind:

- According to Electrical Wholesaling Magazine (Sept. 2006), on an average size home of 2,500 square feet, the average total cost is $192,846. As per the Consumer Product Safety Commission,* the average professionally installed cost differential between an AFCI and a standard circuit breaker is between $15 and $20. With the average number of circuits requiring AFCIs being 12, this equates to an approximate cost increase of $180 to the homeowner, or .093% of the national average home cost.
- The Consumer Product Safety Commission staff report on *Estimated Residential Structure Fires on Selected Electrical Equipment* (October 2006) from 1999-2003 reported that 142,300 electrical distribution fires occurred on all distribution components. Installed wiring fires were estimated to have occurred in 50,200 instances. Taking these CPSC statistics into account, one has to ask that if a portion of the 50,200 fires could have been prevented, would the $180 have been worth the increased cost to the homeowner?

Using the same report, the CPSC projected that there were 910 deaths attributed to electrical distribution equipment during that five-year period. Installed wiring led to approximately 210 deaths as a part of that total. Applying technology to improve the electrical safety of the home is a wise investment for both the homeowner and the community at large. Reducing fires of electrical origin and saving lives is an important responsibility of the entire construction and regulatory community.

** CPSC Memorandum of March 10, 2003 titled: "Economic Considerations – AFCI Replacements" stated that "the average cost differential between AFCI Circuit Breakers compared to Residential Circuit Breakers without the AFCI feature is $15 - $20 per unit."*

what is the price of new safety technology worth?

When Ground Fault Circuit Interrupters (GFCIs) were introduced in the 1970s, similar discussions took place regarding the cost/benefit to the consumer, homebuilder and others. GFCIs have been a standard requirement in homes for nearly 50 years with additional locations and circuits being added over time as well. GFCI also has a statistical track record over time as to the reduction of electrocutions. On an annualized basis, in 1983, there were almost 900 electrocutions total per year with approximately 400 being consumer product related. Ten years later, the total was reduced to 650 annually and slightly over 200 consumer product electrocutions annually.

With around a half century of history, statistically based analysis of GFCIs was built on a solid foundation of data. After 20 years as an NEC requirement, AFCIs continue to offer homeowners an added layer of protection from potential electrical fires as the number of those fires has dropped. The smart technology of AFCIs, combined with improved construction materials, fire services education and more have helped bring down those incidents.

Some have argued that it should be shown how many times an AFCI has "prevented" a fire from occurring. Of course, this is not a feasible request. The AFCI disconnects the power when an arc fault occurs, so homeowners often don't know and don't report an incidence of fire or arcing to authorities. The same can be true when a smoke alarm alerts a homeowner and the small smoking event is extinguished without incident. Is that statistic reported to the government or local fire department? No. Safety prevention is just that ... prevention. The only statistics that are reported are those that have resulted in a fire or a response by a fire department. Many safety protection actions go unreported.

If we are to offer consumers a safer home, then the appropriate technology should be put into place. Removing AFCI requirements as a local or state code requirement will reduce and weaken safety requirements. These NEC requirements are established by a national body of experts that have heard testimony from many electrical and building experts as well as reviewed a significant amount of data to make their recommendations. They realize that a uniform electrical code recommendation must reflect the needs of all consumers and put safety first in new home building and renovation nationwide.

To learn more about the safety benefits of AFCIs, please visit our AFCI web site at www.afcisafety.org.

NEMA AND ELECTRICAL SAFETY

For more than 80 years, manufacturers of Low Voltage Distribution Equipment have been working to ensure public safety through standards writing efforts and the dissemination of important industry information through the National Electrical Manufacturers Association (NEMA), one of the most respected standards development organizations in the world.

Headquartered in Rosslyn, Virginia, NEMA has approximately 400 electroindustry companies, including large, medium and small businesses. To learn more about NEMA visit **www.nema.org.**

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