Insurance Institute for Business & Home Safety®

Electrical Fires and Arc-Fault Circuit Interrupter Protection

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Protective devices such as circuit breakers (and fuses before them) have long been used in nearly all homes to reduce the risk of electric fires. These devices protect against excessive current, which can cause overheating and damage to the electrical circuit itself, potentially resulting in fire or explosion. Circuit breakers and fuses are designed to interrupt the current flow when it exceeds the limit the circuit was designed for. However, they do not address another common cause of electric circuit fires—those caused by arcing or leakage of electrical currents (i.e., exposure of electrical currents to air) in a circuit that is energized.[1] It is estimated that at least 65% of the almost 50,000 annual home fires result from these arc faults (Hall, 2013) that can reach temperatures of several thousand degrees Celsius and present a serious fire hazard.

What are Arc Faults?

Common causes of arc faults include:

- Loose connections in outlets, switches and wires in fixtures such as ceiling fans and lights
- Frayed or damaged electrical cords due to impacts, pressure from residing under furniture, or age and normal wear and tear
- Damage to wiring insulation—e.g., damage by nails or screws driven through walls
- Spillage of liquids

Protective Benefits of Arc-Fault Circuit Interrupters

Arc-fault circuit interrupters (AFCIs) are electronic devices designed to detect dangerous arc faults that occur at currents below levels that would trip an ordinary circuit breaker. The precise methods for detecting arc faults differ across manufacturers and devices, but generally speaking, AFCIs continually monitor the current and voltage wave forms in an electrical circuit and interrupt (cut off power to the circuit) if these wave forms have characteristics indicative of dangerous arcing. In addition to detecting problems in electrical wiring and connections, AFCIs can also detect and protect against arcing in connected cords and appliances.

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[1]Arcing conditions sometimes result in excessive current through the circuit, the type of condition standard circuit breakers are designed to respond to and protect against. However, in many situations, the high temperatures produced by arc faults can occur without drawing excessive current. In the absence of excess current, standard circuit breakers cannot protect against such arc faults, which they were not designed to detect.

Arc-Fault Circuit Interrupters and the National Electrical Code®(NEC)

The fire risk associated with arc faults has long been recognized. Research in the development of AFCIs took on greater urgency in the 1980s and 1990s in response to growing concern about electrical fires by the Consumer Product Safety Commission (CPSC). The goal was to develop a device that went beyond standard circuit breakers to detect and respond quickly to arc faults before they ignited, while at the same time minimizing nuisance tripping. In 1997, the first AFCIs that could detect and respond to different types of arcing conditions became commercially available. AFCIs were first included in the 1999 NEC[2] with a delayed adoption until 2002 in order to permit a transition period to accommodate the new requirement (Domitrovich & Lippert, 2013). In 1999, Underwriters Laboratories (UL) finalized UL 1699 Standard for Arc-Fault Circuit Interrupters which provides a standard for testing and listing approved AFCIs (Siemens Industry Inc., 2012).

The NEC requirements have evolved and expanded over time. Initially the NEC required protection of 120 volt, 15- and 20-ampere branch circuits that supplied outlets in bedrooms in new construction. Subsequent editions of the NEC have extended these requirements to include AFCI protection for branch circuits in kitchens, family rooms, dining rooms, living rooms, bedrooms, parlors, libraries, dens, sunrooms, recreation rooms, closets, hallways and laundry areas. (Outlets in bathrooms, garages, unfinished basements and outdoors are not required to be AFCI-protected.) Recognizing that electrical fires could also occur in existing dwellings, the NEC also requires AFCI protection where branch circuit wiring in an existing home is modified, replaced or extended (National Fire Protection Agency, 2014).

The NEC provides for multiple methods of protecting branch circuits for arc-fault conditions, but the simplest method of protection (particularly in new construction) can be achieved by installing listed combination-type AFCI devices at the panel box at the origin of the branch circuits. This method of protection may also be preferred when a branch circuit in an existing home is modified. However, an alternative method of providing protection in modifications to existing circuits is to install a listed branch circuit–type AFCI in the first outlet of the circuit, which will provide protection for the outlet and the remaining downstream branch circuit wiring and power supply cords.

Addressing Concerns about AFCIs

Most jurisdictions adopting the NEC do so without modifying the provisions related to arc-fault protection. However, some states have faced occasional efforts to remove or modify the arc-fault protection requirements during their code adoption process. Two of

[2]The NEC (also known as NFPA 70) published by the National Fire Protection Association (NFPA) is the most widely adopted standard for the safe installation of electrical wiring and equipment in the United States.

the most commonly cited arguments against mandating AFCIs are the issues of nuisance tripping and the increased cost of AFCIs over standard circuit breakers.

On occasion, normal operating conditions can mimic arcing conditions that cause AFCIs to interrupt the current (trip) when dangerous conditions do not actually exist. This is referred to as nuisance tripping. Since they became commercially available in 1997, AFCI technology has evolved and improved, resulting in fewer incidences of nuisance tripping while expanding the dangerous conditions they protect against. And it is important to remember that what may be perceived as nuisance tripping may actually be a properly functioning AFCI accurately detecting and responding to dangerous arcing conditions that are not readily apparent.

One source of nuisance tripping may be in the way circuits have been wired by electricians. For example, the practice of having more than one electrical circuit share a neutral line or having crossed neutral lines will cause the ground fault detection function in an AFCI to interrupt the circuit. In such cases, the AFCIs are performing as intended. But the practice of having multiple circuits share a neutral line has recently been prohibited in the 2011 edition of the NEC. Consequently, this should not be a source of nuisance tripping in new homes with AFCIs going forward.

The incompatibility of certain electrical devices has also been cited as a cause of nuisance tripping. A typical home will have multiple electronic devices with different loads on a common circuit and the combination of devices in use can result in a variety or current wave forms flowing through the circuit under normal operating conditions. Additionally, some electronic devices will have operational or “safe arcing” as part of their normal operating conditions. Treadmills, televisions and fluorescent lights have been known to create wave forms that mimic those of dangerous arcing. AFCIs are designed to analyze a range of current wave forms flowing through a circuit and distinguish between those that represent dangerous arcing versus those that are present under normal operating conditions and do not pose a risk. The technology for doing so is not perfect. However, before AFCIs are listed by UL (under standard UL 1699) and make it to market, they are tested not only to ensure they respond quickly to dangerous arcing conditions, but also to make sure they do not respond to a variety of safe conditions that resemble dangerous arcing conditions (Underwriters Laboratories, 2006).

The other cited issue is cost. Standard circuit breakers sold in big-box hardware retailers cost between $3.72 and $4.56, while circuit breakers with arc-fault protection cost between $37.97 and $42.97. In a typical 2,500-square-foot home requiring 12 breakers, the difference in the cost of the two types of breakers could be between $400 and $470. According to the U.S. census, the median price of a new home in 2015 was $271,300, so the cost of upgrading all of the circuit breakers to AFCIs represents a tiny fraction (about 0.15%) of the price of a typical new home. Safety advocates agree this is a small price to pay for the potential reduction in human and property losses that could be realized with the widespread use of AFCI protection.

Public and Private Organizations Endorse AFCI Technology

Laboratory-tested AFCI devices have proven to be effective in detecting and isolating wiring problems that could lead to electrical fires and fatalities (Domitrovich & Lippert, 2013). The same NFPA study that estimated an average of nearly 50,000 electrical fires between 2007 and 2011 also estimated that these fires resulted in an annual average of 455 civilian deaths, 1,518 civilian injuries, and $1.48 billion in direct property losses (Hall, 2013). The CPSC estimates 50% or more of these electrical fires could be prevented by the use of AFCI protection (Karels, 2003). Over their nearly 2 decades of commercial availability, AFCIs have gained the endorsement of many organizations.

- **Consumer Product Safety Commission (CPSC).** A letter to jurisdictions considering adopting the 2008 NEC stated, “The CPSC staff is a strong proponent of the implementation of AFCIs as a powerful tool in mitigating fires that originate in the electrical distribution system” (Trotta, 2008).
- **U.S. Fire Administration (USFA).** USFA literature highlights the value of AFCIs. “Arc fault circuit interrupters (AFCIs) shut off electricity when a dangerous situation occurs. Have a licensed electrician install them in your home” (U.S. Fire Administration, 2012).
- **National Association of State Fire Marshals (NASFM).** “The National Association 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,” says NASFM President John C. Dean (Siemens Industry Inc., 2012).
- **National Association of Home Inspectors (NAHI).** “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,” says Executive Director Mallory Anderson (Siemens Industry Inc., 2012).
- **Electrical Safety Foundation International (ESFI).** “ESFI urges that AFCI technology be installed in all new and existing housing to protect homes and families from fires caused by electrical arcing,” observes ESFI President Brett Brenner (Siemens Industry Inc., 2012).
- **The Federal Emergency Management Agency (FEMA).** FEMA recommends installation of AFCIs as a mean of preventing electrical fires (National Fire Data Center, 2014).

References

Babrauskas, D. V. (2001). How do Electrical Wiring Faults Lead to Structure Ignitions. *International Fire & Materials Conference.* Interscience Communications.

Domitrovich, T., & Lippert, K. (2013). AFCIs From a Standards Perspective. *Electrical Safety Workshop.* Dallas: Institute of Electrical and Electronics Engineers.

Hall, J. R. (2013). *Home Electrical Fires.* Fire Analysis and Research Division. Quincy, Massachusetts: National Fire Protection Association.

Karels, T. R. (2003). *Economic Considerations - AFCI Replacements.* Retrieved from Consumer Product Safety Commision: https://www.cpsc.gov/PageFiles/102325/ecafci.pdf

National Electrical Contractors Association. (2004). *Contractors Code Letter.* Retrieved from National Electrical Installation Standards: http://www.neca-neis.org/ccl/newsletter/report28a7.html?articleID=4180

National Fire Data Center. (2014). *Residential Building Electrical Fires.* Washington: Federal Emergency Management Agency.

National Fire Protection Agency. (2011). *NFPA 70 National Electrical Code 2011 Edition.* Quincy, Massachusetts: National Fire Protection Agency.

National Fire Protection Agency. (2014). *NFPA 70 National Electrical Code 2014 Edition.* Quincy, Massachusetts: National Fire Protection Agency.

Siemens Industry Inc. (2012). *History of the AFCI.* Retrieved from Siemens (Company Web Site): http://w3.usa.siemens.com/us/internet-dms/btlv/residential/residential/docs_AFIC%20Circuit%20Protection/SIE_WP_AFCI_History.pdf

Trotta, A. M. (2008). *2008 NEC PDF: To: Code Making Authorities Considering the Adoption of the 2008 National Electrical Code.* Retrieved from Consumer Product Safety Commission: http://www.cpsc.gov/PageFiles/107517/2008nec.pdf

Underwriters Laboratories. (2006). *Standard 1699 - Standard for Arc-Fault Circuit Interrupters*. Retrieved from Underwriters Laboratories: http://ulstandards.ul.com/standard/?id=1699

U.S. Fire Administration. (2012). *Fire Safety Checklist.* Retrieved from Federal Emergency Management Agency: https://www.usfa.fema.gov/downloads/pdf/publications/fa_221.pdf