

SIEMENS

History of the AFCI

AFCIs: Big fire prevention in a small package

Arc-Fault Circuit Interrupters (AFCIs) could save hundreds of lives, reduce thousands of injuries and save nearly $1 billion in property damage annually[1], according to the Electrical Safety Foundation International (ESFI). The United States Fire Administration (USFA) has partnered with the National Association of State Fire Marshals (NASFM) to urge homeowners to install these devices. And the Consumer Product Safety Commission (CPSC) for years has sought to educate the public about the benefits of AFCIs as it estimates that more than 50 percent of electrical fires yearly are preventable by AFCIs.

Underwriters Laboratories (UL) has listed products from several manufacturers after extensive testing for reliability and effectiveness. The Executive Director of Standards and Safety for the National Electrical Contractors Association (NECA) further says the devices are "on the front line of home electrical safety."[2]

AFCI devices are specialized circuit breakers that detect the hidden problems that spark 82 percent of all electrical fires, according to an estimate by NASFM.[3] From 2013 to 2017, electrical distribution and lighting equipment were the leading cause of property damage from home fires, racking up a yearly $1.4 billion in direct property damage. Even worse, an average of 35,000 fires caused 500 deaths and 1,130 injuries each year.[4] AFCIs help prevent such fires, but unfortunately most houses do not have them.

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1 Electrical Safety Foundation International, news release, November 7, 2005.

2 "NECA Stands Up for Arc-fault Circuit Interrupters," National Electrical Contractors Association website, www.necanet.org, February 10, 2004.

3 National Association of State Fire Marshals, Consumer Product Safety Task Force report, https://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/oshomes.pdf2002.

4 "Home Structure Fires" National Fire Protection Association, October 2019.



Combination Type Arc Fault Circuit Interrupters (AFCI) detect arcing faults (an unintentional arcing condition in a circuit) that standard circuit breakers are unable to detect.

Why not? After two decades of commercial availability, AFCIs have been introduced to homebuilding, but not fast enough to become an industry standard. Slow building code updates, special-interest opposition to AFCIs, and lack of awareness among homebuyers all contribute to the problem. The result is the changeover simply is taking too long, even though adding the extra protection delivered by AFCIs incurs minimal costs.

The evolution of AFCIs into an established technology

The problem of arcing faults has been recognized for almost as long as the time that electricity has been in widespread use. In fact, patent applications related to arcing fault protection date back to the 1930s. Applications peaked between 1990 and 2005.

Although arcing faults were recognized long before, the hunt for a commercially viable technology gained significant momentum only a few decades ago. In 1980, the USFA commissioned a fire loss comparison study that showed the U.S. suffered one of the world's highest death rates from fire – two to four times higher than in European countries.

About three-fourths of those deaths occurred in residential fires. Furthermore, the study found that "fires in residential electrical distribution systems are an important contributor to this problem."[5]

The USFA report helped prompt the U.S. Consumer Product Safety Commission to delve deeper into the cause of electrical fires. But most of the existing electrical fire data available to the CPSC from local fire departments blamed "failure of electrical wiring," a generic description that did little to help pinpoint the real cause of electrical fires.[6]

5 "On the Safety Circuit: A Fact Sheet on Home Electrical Fire Prevention," U.S. Fire Administration, March 2006.

6 "CPSC Staff Activities on Electrical Fires," by Douglas Lee, U.S. Consumer Product Safety Commission, undated (circa 2001).

Figure 1: National Electrical Code® Progression

The need for AFCIs has been established by various respected organizations. Requirements are already in place to mandate the use of the Combination Type AFCI. These Combination Type AFCIs provide the maximum protection available today for reducing the possibly catastrophic effects of arcing faults.

1999 NEC®

- Listed AFCI future requirement in Code
  - Allows Branch/Feeder AFCI
- January 1, 2002: bedroom receptacles

2002 NEC®

- Listed AFCI in ALL bedroom circuits
  - Allows Branch/Feeder AFCI

2005 NEC®

- Combination Type AFCI in bedroom circuits
- Branch/Feeder AFCI permitted until January 1, 2008

2008 NEC®

- Combination Type AFCI
- Expand to 1 pole, 15-20A circuits installed in bedrooms, family rooms, living rooms, parlors, libraries, dens, sunrooms, recreation rooms, closets or similar rooms.

2011 NEC®

- Combination Type AFCI
- 15-20A circuits installed in family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, or similar rooms or areas.

2014 NEC®

- Combination Type AFCI
- All 120-volt, single-phase, 15-20A 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 or similar rooms or areas.

2017 NEC®

- Combination Type AFCI
- Same as 2014, and expanded to guest rooms and guest suites in hotels and motels as well as dormitory units.

2020 NEC®

- Combination Type AFCI
- Same as 2017, and expanded to patient sleeping rooms in nursing homes and limited-care facilities.

To get better data, the CPSC paid the USFA to train fire investigators in select cities to analyze electrical fires for the root cause.[7] The inspectors gathered detailed data on 149 fires in 16 cities between 1980 and 1981, and 1984 to 1985. A final report completed in December 1987 found that electrical fires occurred most often in branch circuit wiring, followed by receptacle outlets and extension cords.

In 1993, the Electronic Industries Alliance (EIA) and UL attempted to identify a solution for the specific problem of arcing faults in appliance and extension cords. Since arcing faults often lead to short circuits, they sought to define an appropriate decrease in the short-circuit trip level of circuit breakers. This was determined by an analysis of the available current at receptacle outlets. The report found a tradeoff between increased protection and unwanted tripping due to high initial currents associated with certain electrical appliances at turn-on. A proposal to the 1996 National Electric Code (NEC) was rejected unanimously, with the NEC Code Making Panel recommending "a more complete analysis of actual cord problems and alternate solutions such as other cord constructions, supplemental overcurrent protection, and electronic sensing is needed."

AFCIs could save hundreds of lives and nearly $1 billion in property damage annually.



Around this time, the CPSC began work on a more comprehensive study to identify a technical solution to mitigate the risk of electrical fires. In December 1994, the CPSC issued a call to 800 domestic and foreign manufacturers, asking them to submit any promising new technology for evaluation. The request was republished in the January 2005 edition of UL Trends. Nineteen inventors and manufacturers responded, and 11 products were submitted for testing. The CPSC retained UL to evaluate five technologies: arcing fault detection, modified-trip circuit breakers (similar to those in the EIA/ UL study), ground-fault circuit interrupters, supplementary protection, and surge protection.

After months of testing, UL concluded in September 1995 that "from the technologies analyzed, arcing fault detection appeared to be very promising, especially when added to residential branch-circuit breakers and combined with other proven technologies such as ground-fault protection." [8]

7 Ibid.

8 "Technology for Detecting and Monitoring Conditions that Could Cause Electrical Wiring Fires," Underwriters Laboratories Inc., UL Project Number: NC233, 94ME78760, CPSC Contract Number CPSC-C-94-1112, September 1995.

AFCIs enter the commercial mainstream

UL and the National Electrical Manufacturer Association (NEMA) collaborated on the creation of a draft standard defining a set of operational requirements for AFCIs in December 1996.[9] AFCIs began appearing commercially in 1997, and the CPSC tested the devices from multiple manufacturers to determine if they could reliably detect arcing faults without tripping in the presence of operational arcing, which occurs in motors, switches, etc. The tests generally followed the requirements in the draft UL standard, although the CPSC included several tests for unwanted tripping that were not included in the standard. In spite of this, all the AFCIs detected the presence of arcing fault conditions while avoiding nuisance tripping.[10]

In the fall of 1997, UL began work on conversion of the draft standard into UL 1699, Standard for Arcing fault Circuit Interrupters, which was published in February 1999. UL announced the standard in an article headlined: "AFCIs show promise to save lives by preventing electrical fires."[11]

During this time, the NEC Code Making Panel began to consider proposals to require AFCIs as part of the NEC. In 1997, three separate proposals were made to require AFCIs in the 1999 NEC. This resulted in a 1999 NEC requirement of AFCI protection for 15-amp and 20-amp bedroom receptacles beginning January 1, 2002. The 2002 NEC expanded the requirement for AFCI protection to include not only bedroom receptacles, but also all 15A and 20A bedroom circuits.

Reacting to the development of new technology, the 2005 NEC required Combination Type AFCIs, which detect more types of arcing faults, beginning January 1, 2008. Branch/ Feeder AFCIs are permitted until that date. The 2008 NEC expanded Combination Type AFCI protection beyond bedrooms to also include family rooms, living rooms, parlors, libraries, dens, sunrooms, and recreation rooms. This provided even more electrical safety protection in the home.

A timeline of the history of AFCI development is shown in Figure 1 of this paper.

Widely endorsed technology

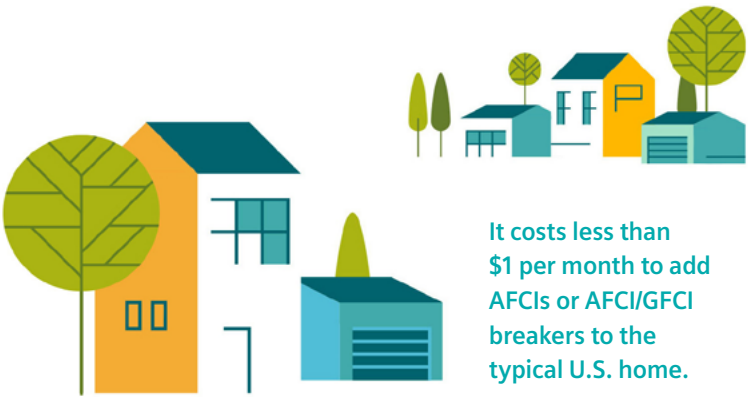
In 2007, AFCIs marked a decade of commercial availability. The technology has been endorsed by a wide range of public and private organizations:

- **Consumer Product Safety Commission.** This U.S. government agency's electrical engineers "have tested the new AFCIs on the market and found these products to be effective." In addition, the Consumer Product Safety Commission (CPSC) has helped educate the public about the benefits of AFCIs.

9 "New Technology for Preventing Residential Electrical Fires: Arc-fault Circuit Interrupters (AFCIs)," by Douglas A. Lee et al, undated (circa 1999).

10 Ibid.

11 "AFCIs Show Promise to Save Lives by Preventing Electrical Fires," by Dave Dini and Rich Wagner, Underwriters Laboratories newsletter, 1999.



It costs less than $1 per month to add AFCIs or AFCI/GFCI breakers to the typical U.S. home.

- **U.S. Fire Administration.** Also a U.S. government agency, USFA advocates AFCIs, noting in its literature that "CPSC has identified AFCI technology as an effective means of preventing fires caused by electrical wiring faults in the home."

- **National Association of State Fire Marshals.** This group, which represents state-level fire officials, "strongly supports the broad adoption of AFCI technology through national, state, and local building codes," according to its president, John C. Dean. "AFCIs are the most welcome addition to fire prevention in decades. AFCIs promise to save hundreds of lives every year."

- **National Electrical Contractors Association.** NECA has fought to keep AFCIs in state and local building codes, urging state legislatures to stand up to those who would put profit ahead of consumer safety. "AFCIs are right there on the front line of home electrical safety," says Brooke Stauffer, executive director for standards and safety at NECA. "They add very little to the cost of wiring a new house but a large measure of extra protection for the occupants. Opposing AFCIs in new residential construction is incredibly short-sighted."

- **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," says Executive Director Mallory Anderson.

- **Electrical Safety Foundation International.** "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.

Small Investment with Big Return

Considering AFCI's potential for saving lives and property, the actual cost of installing the technology is minimal. The price of an AFCI unit is roughly around $40, according to listed prices at a major home improvement retailer. A dual-function AFCI/GFCI breaker, which combines AFCI and GFCI technology in one device, adds only another $7 to the price. Based on averages, a house may require six units, which means the added cost of construction would be only between $240 and $282 per home for the peace of mind of protecting a home from fires caused by electrical arcing.

Calculated into most monthly mortgage payments, this amounts to an increase of less than $1. For instance, the homeowner of a house costing $229,000 with a 30-year mortgage at 3.5 percent interest rate would see a monthly payment increase of 76 cents for the AFCI units or 92 cents for AFCI/GFCI units.

Even with such a negligible increase, homebuilders typically resist adding costs to construction, especially if the cost involves electrical equipment. Homeowners generally are more disposed to spend extra on other items such as countertop upgrades or light fixtures, and this makes it difficult for builders to realize additional profit from a few AFCI devices.

It would, therefore for the sake of safety, make sense to take the decision out of the hands of homebuilders by requiring AFCIs in building codes set by municipalities, counties and states. When the benefits of AFCIs are weighed against the costs, it is hard to argue against a small cost that helps prevent electrical fires in homes.

Proven technology for a proven need

As noted, AFCIs can prevent many of the deaths and injuries caused by home fires, as well as substantially reduce property damage. AFCIs work, and their effectiveness has been proven in hundreds of laboratory tests and years of commercial use. However, AFCIs cannot do their work unless they are installed, and at this point most homes still do not have them.

The solution for this is simple, though it will take time. State and local building code committees should follow the example of the NEC and require AFCIs in all new homes. Meanwhile, owners of existing homes should hire licensed electricians to install the technology. In the hands of a skilled technician, the job typically does not require rewiring -- and costs only a few hundred dollars per home, a small price to pay for a family's safety.

With a concerted effort, arcing fault-induced fires, deaths, and injuries could be virtually eliminated over time. The need is clear and the technology has proven itself. But for the technology to produce the desired outcomes, it has to be mandated. Only then will it be possible to make arcing fault fires a thing of the past.

Brief description	Timeframe	Source
Documented damages on 277/480V systems due to arcing GFCI requirement followed — results indicated that GFCI did not properly address issue	1960s	Arcing faults and their effect on the settings of ground fault relays in solidly grounded low voltage systems
CPSC identified concern with residential fires of electrical origin	late 1980s, early 1990s	IAEI News, Apr. 1, 1988
CPSC fact finding efforts to determine root cause of electrical fires	1980s	NEC Digest, Fall 2003
Arc fault detection technology concepts demonstrated to UL	early 1990s	CPSC, Sept. 1995
NEC proposal to reduce instantaneous trip levels of breakers to address issues with arcing (EIA) Proposal rejected due to nuisance concerns; not supported by NEMA	1993	CPSC, Sept. 1995
Arc fault detection technology appears in circuit breakers	1993	NFPA Journal, Oct. 25, 1993
CPSC reviews technologies to reduce electrical fires, including arc fault detection	1994	NFPA Journal, Sept. 1995
CPSC investigation finds that arc fault detection is a very promising technology	Dec-1994 through Sept-1995	NFPA Journal, Sept. 23, 2003
First commercial AFCIs available	1997	NFPA Journal, 1997
First proposal to NEC requiring AFCI protection	1997	IAEI News, 1999
UL forms Industry Advisory Group to create a Standard for Safety for AFCI products	1998	UL, Sept. 1995
1999 NEC requires AFCI for bedroom receptacle circuits	Sept-1998	NFPA, Sept. 1998
UL released “Standard for Safety for Arc-Fault Circuit Interrupters”, UL 1699	Feb-1999	NFPA Journal, Feb. 1999
2002 NEC requires AFCI for all bedroom circuits	Sept-2001	NFPA, Sept. 2001
CPSC determines AFCI proves cost effective	Mar-2003	CPSC, Summer 1999, Vol. 4 No. 1
2005 NEC requires AFCI for all bedroom circuits	Sept-2004	NFPA, Sept. 2004
U.S. Fire Administration advocates AFCI technology	Dec-2006	USFA, Dec. 28, 2006

Figure 2: AFCI timeline

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