Arc-Fault Circuit Interrupters:
National Electrical Code Inclusion Was Based on Faulty Reasoning

What Are AFCIs?

Arc-fault circuit interrupters (AFCIs) are devices "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." (National Fire Protection Association, Inc., 2016) Specifically, AFCIs are meant to protect against a sustained arc at a loose connection or between conductors that have damaged insulation. (Lee, Trotta, & King, 2000)

Limitations of AFCIs

These unwanted arcs can sometimes reach conditions that will ignite adjacent combustible material, and while AFCIs can mitigate the arc's potential effects, it cannot prevent them. (Hansen, 2012) Also, while AFCI devices detect some ground faults, they do not protect against as many as a ground-fault circuit interrupter (GFCI). This is by design, since each device is made for a different purpose.

AFCIs and the National Electrical Code

AFCIs were first introduced in the 1999 edition of the National Electrical Code (NEC) with an effective date of Jan. 1, 2002. Code Making Panel 2, which had responsibility over branch circuits where AFCIs are addressed, largely based its approval of the code change on several U.S. Consumer Product Safety Commission (CPSC) reports. **However, the number of incidents cited at the time were several times higher than in later reports, and where the data showed that AFCIs would have a minimal benefit, the results were ignored.** The resulting expected benefits led to AFCI requirements being included in the NEC, but were overblown.

The problems with the rationale were so evident that even electrical manufacturers spoke against the proposal. During the 1998 code development cycle comment period, manufacturers' representatives stated that a large body of information was available to support rejecting an AFCI mandate. (National Fire Protection Association, 1998) The main issue: the electrical problems AFCIs are designed to prevent occur overwhelmingly in older dwellings.

A CPSC epidemiological study, "Residential Electrical Distribution System Fires," showed that 85% of fires of electrical origin occur in homes that are more than 20 years old. (Linda & Dennis, Residential Electrical Distribution System Fires, 1987) This means that the bulk of these homes were wired in accordance with the 1965 or earlier editions of the NEC. Further, they were wired with products manufactured to product safety standards of a similar vintage. In the years since, numerous changes have been made in both the NEC and product safety standards which mitigate against similar fires in newer homes—even as they age.

The strongest association with electrical distribution fires was observed in dwellings over 40 years old, and with more than half of the housing stock older than 35 years, electrical issues have become an increasingly larger player in residential fires. (U.S. Fire Administration, 2016)

Differences between Older and Newer Homes

The 1987 CPSC study confirmed the logical assumption that older homes with smaller services, few GFCIs, overloaded circuits and many extension cords have a greater risk of electrical fires than a new home built to a recent edition of the NEC. Homes built before 1965 may still have fuses instead of circuit breakers, and those built before 1945 may still have knob and tube wiring. As of 2011, roughly 41% of the nation's occupied detached single-family homes had been built before 1965, which suggests fuses are still present in about 20% of all homes. (John R. Hall, 2013)

Many older homes were wired with a very limited number of receptacle outlets, necessitating extensive use of extension cords or improper alterations and additions to the original electrical system, both recognized fire hazards. However, in the intervening years, the NEC has required significant increases in the number of required receptacle and lighting outlets, significantly reducing the need for extension cords in newer homes.

Grounding provisions in the NEC have expanded to require electrical enclosures and boxes to be grounded and an equipment grounding conductor in the wiring. In technical language, these grounding methods increase the likelihood of low-level arcing faults progressing rapidly to arcing ground faults of a magnitude sufficient to activate conventional circuit breakers. As non-metallic sheathed cable (Romex) with its bare ground wire has become the norm, the likelihood of an arcing fault being the hot-to-ground type, which is detectable by a conventional circuit breaker, has increased significantly. (National Fire Protection Association, 1998) And conversely, there has been an equally significant decrease in the probability of arc faults occurring that an AFCI device can detect, namely line-to-line and line-to-neutral faults.

Ever since the 1978 edition of the NEC, electrical wires must be run not less than 1 ¼ inches from the front edge of the framing members or be protected with a steel plate or other means. This almost eliminates the chance of wires getting hit by nails or screws because it offers a margin of safety against such damage. Standard nails and screws for ½-inch drywall are 1 ¼ inches long, leaving ½ inch of space between the fastener and where a wire might run.

Further code provisions that protect wiring from damage include requiring a maximum support spacing of 4 ½ feet, a maximum support distance from an electrical box of 12 inches to reduce vibrations that might cause the wire to rub where it enters the box, and requiring bushings where wiring runs through openings in metal framing members and where entering an electrical box or fitting. (National Fire Protection Association, Inc., 2016)

Even advocates for AFCI requirements have stated, "The preponderance of fires is clearly in dwellings over 10 years old. With improvements in the NEC over the past decade, a dwelling

constructed with proper wiring methods and equipment by present standards should not be prone to fire." But they then argue that "all new dwellings eventually get old" and so AFCIs are necessary. **These two rationales are contradictory, and the improvements in the NEC as cited above remain as the home ages.**

The Data Used to Support AFCIs

In 1998, when AFCI requirements were added to the NEC, data from the CPSC report "Revised Residential Fire Loss Estimates 1980-1998" was integral to that decision. The report stated that approximately 41,000 fires per year could be attributed to electrical distribution equipment (e.g. installed wiring, lighting). (Linda & Jean, Revised Residential Fire Loss Estimates 1980-1998, 1998) This was equal to about 10% of all residential fires. The report claimed that these fires also accounted for about 350 deaths and 1,400 injuries each year. The CPSC's later report, "Residential Fire Loss Estimates 2010-2012," showed a much different picture. There were an estimated 9,600 fires annually which could be attributed to electrical distribution equipment, or 2.7% of all residential fires. (David, 2012) For this time period, these fires accounted for an estimated 130 deaths and 470 injuries annually.

There is a reason for the discrepancy: These fire loss estimates are based on the National Fire Protection Association's national fire loss estimates and the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS) data. Beginning with 1999 data, a major revision to the NFIRS data coding system considerably affected the estimates of residential fires and related deaths, injuries, and property losses. Because of these changes, the pre-1999 numbers should not be compared with estimates from subsequent years. That being said, if the inclusion of AFCIs in the NEC were being debated after the later report had been published, proponents of the change would have had a much weaker case.

Data in the reports also included fires that occurred in mobile homes and motor homes. Both are outside the scope of the NEC and, therefore, inflated the occurrences of fires. The 1998 report only referred to "residential" fires, but did not define which specific types of residences were included. The 2012 report clarified that the data included not only single-family and multifamily dwellings, but also mobile and motor homes while used as a structure and not in transit.

Conclusions

AFCI requirements in the NEC apply predominantly to new construction, whereas it is in older homes, built to outdated electrical code requirements and using outdated technology, where they would be most effective. An electrical manufacturer representative during the 1998 committee meetings stated it best: "The question of whether this [AFCI] mandate will have a meaningful impact in reducing the number of dwelling fires of electrical origin in new homes as they age (beyond the reduction already resulting from previous code-mandated improvements) is speculative at best."

References

Bremer, D. (2006, September). Evolution of AFCIs and the NEC. *Electrical Contractor*. Retrieved from www.ecmag.com/section/codes-standards/evolution-afcis-and-nec

David, M. (2012). *2010-2012 Residential Fire Loss Estimates.* Bethesda, MD: U.S. Consumer Product Safety Commission. Retrieved from www.cpsc.gov/s3fs-public/20102012ResidentialFireLossEstimates.pdf

Hansen, D. (2012). *AFCIs Come of Age.* Newtown, CT: Code Check LLC. Retrieved from Code Check: www.codecheck.com/cc/ccimages/PDFs/AFCIsComeOfAge.pdf

John R. Hall, J. (2013). *Home Electrical Fires.* Quincy, MA: National Fire Protection Association. Retrieved from www.nfpa.org/~/media/files/news-and-research/fire-statistics/major-causes/oshomeelectricalfires.pdf

Lee, D., Trotta, A., & King, J. W. (2000). *New Technology for Preventing Residential Electrical Fires: Arc-Fault Circuit Interrupters (AFCIs).* Bethesda, MD: U.S. Consumer Product Safety Commission. Retrieved from www.cpsc.gov/s3fs-public/AFCIFireTechnology.pdf

Linda, S., & Dennis, M. (1987). *Residential Electrical Distribution System Fires.* Washington, DC: U.S. Consumer Product Safety Commission. Retrieved from www.cpsc.gov/s3fs-public/reselecfire.pdf

Linda, S., & Jean, M. (1998). *Revised Residential Fire Loss Estimates 1980-1998.* Washington, DC: U.S. Consumer Product Safety Commission. Retrieved from www.cpsc.gov/s3fs-public/pdfs/fire8098.pdf

National Fire Protection Association. (1998). NFPA 70 - 1998 Report on Comments., (pp. 93-99). Retrieved from www.nfpa.org/Assets/files/AboutTheCodes/70/NEC-ROCA-1998-Articles%2090%20to%20310.pdf

National Fire Protection Association, Inc. (2016). *NFPA 70, National Electrical Code 2017 Edition.* Quincy, MA. Retrieved from www.nfpa.org/70

U.S. Fire Administration. (2016). *One- and Two-Family Residential Buildings Fires (2012-2014).* Emmitsburg, MD: U.S. Fire Administration. Retrieved from www.usfa.fema.gov/downloads/pdf/statistics/v17i2.pdf