

# Causes of electrical fires

## The hidden danger of arc faults

### White Paper

Two recent reports – one from the National Fire Protection Agency (NFPA)<sup>®</sup> and one from the National Association of State Fire Marshals (NASFM)<sup>®</sup> – estimate that 50 to 75 percent of all electrical home fires in the United States are caused by arc fault conditions. Data from the National Fire Incident Reporting System and the NFPA, meanwhile, indicate that between 1994 and 1998, electrical arcing caused approximately 48,800 fires annually in one- and two-family dwellings. If these statistics surprise you, you are not alone. Even many electrical professionals do

not realize the true extent of arcing-related fires because the real culprit can be hidden by the reporting categories used to classify fires. These classifications, which include categories such as heating, cooking, electrical distribution, appliances, light fixtures, electronic/office, and “other equipment,” tend to point to the places where the fires originate rather than to what caused them. Increasingly, however, experts are realizing that many of these categories trace back to a single source: arc faults.



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### How arc-fault conditions can develop

Arcing refers to a "luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization (burning) of the electrodes."<sup>3</sup> The insulating medium can be an air gap, insulation worn thin by aging, abuse, or a number of other factors. The conditions for arcing may form over a wide range of time intervals, from milliseconds to decades, before an arcing fault develops. Both current level and duration are factors that allow arcs to generate the heat needed to cause a fire. Arcing faults can readily produce temperatures in excess of 1,000 degrees Celsius (1,832°F) with as little as an ampere of current flowing. Arcing also gradually breaks down organic insulating materials. As these materials carbonize, they release hydrocarbon vapors that allow the conduction of electricity more readily than the air/metal interface. This further supports the process of arcing. For example, the ignition point of various types of PVC wire insulation is between 240° C and 422° C, much lower than the temperatures produced during arcing faults. So how do arcing faults occur? And why does the time for them to develop vary so widely? These questions can be answered by examining the three basic types of arcing: line-to-neutral, line-to-ground, and series arcing. Although many examples may be found for each of these types of arcing, an explanation of a few specific examples is provided here to better describe the various hazardous conditions that can exist.

### Line-to-neutral arc faults

A damaged power supply cord can be an example of a line-to-neutral arc fault. Power supply cords can experience repetitive flexing that, over time, may damage the insulation and/or conductors inside. This flexing may be caused by repetitive use – plugging and unplugging a hair dryer day after day or wrapping a cord around a toaster for storage, for example – or from a door or other weighty obstruction that continually pinches the cord.



Photo 1: Example of line-to-neutral arc fault (door pinching power cord).

This process may cause the cord to be worn to the point that the insulation between the line and neutral conductors is no longer sufficient to prevent an arc from forming. The insulating material will carbonize quickly, causing an arc fault and further degradation of the insulation.

### Line-to-ground arc faults

A line-to-ground arc can occur from an event as simple as hanging a picture. Very few people know what is behind the drywall when they drive a nail. The wiring in most homes, typically NM-B wire, runs behind this drywall. The nail driven to hang a picture can easily penetrate the insulation of NM-B wire. NM-B wire typically includes a bare ground wire positioned between individually insulated hot and neutral conductors.



Photo 2: Example of line-to-ground arc fault (nail puncturing NM-B wire).

If the hot wire insulation is damaged by a nail, a line-to ground arc can easily occur. The danger may not be revealed quickly. Sufficient air may separate the nail from the ground wire to prevent immediate arcing. However, surges along the wire, such as those generated by vacuum cleaners or lightning, can cause a carbon path to form between the energized nail and the ground wire, starting the process of a line-to-ground arc fault.

### Series arc faults

A series arc fault can occur anywhere in the line or neutral wire of a circuit. By definition, the current flowing in a series arc fault is limited by the load on the circuit. The connection at a receptacle outlet is an example of a place where a series arc fault may occur. Even when thought to be properly installed, the screw terminal that connects a wire to a receptacle may become loose as the receptacle is pushed back into the work box. The photo below shows a receptacle that has been wired but not yet pushed back into the work box. Photo 4 illustrates the movement of the neutral wire after force has been applied to insert the receptacle into the work box.



Photo 3: Wired receptacle not yet pushed back into box.



Photo 4: Example of series arc fault (pushing receptacle into work box).

In the example above, pushing the receptacle into the work box created a counterclockwise torque on the screw terminal. This torque could loosen the connection if it were not tightened sufficiently. This loose connection may carry current without arcing after installation. However, intermittent current flow is part of the design of every electrical system and appliance. With very few exceptions, electrical circuits do not run continuously. Loads cycle on and off, either manually or automatically. This intermittent current flow creates heating and cooling cycles at the screw terminal electrical connection. This cycling can cause a thin oxidation layer to form on the connection surfaces. This oxidation layer acts as an insulator. However, the typical 120VAC line voltage is enough to exceed the insulating capacity of the oxide layer. When the voltage exceeds the insulating value of the oxidation layer, electrons jump the insulating gap, allowing current flow in the form of an arc fault. The increased heat from arc formation further accelerates the formation of a carbonized path.

#### Arc faults: A potentially silent and invisible fire hazard

In each case outlined above, the result is an arcing fault that can reach several thousand degrees centigrade, enough to ignite many materials. One of the greatest dangers is that the entire process may occur silently and invisibly. Examples of this dangerous condition have been reproduced repeatedly in laboratory experiments, allowing researchers to document the process that leads to arc faults. In everyday life, the receptacle, power supply cord, wall switch, heater, or hair dryer that work perfectly one day seem to “inexplicably” create a fire the next. But anyone familiar with the process of arc faults understands exactly what occurred and that it was, in fact, inevitable given the right conditions. It’s important to note that while arc faults occur often in older electrical systems, new electrical systems also can be just as susceptible to certain types of arc faults. Arc fault scenarios initiated by a nail driven into the wall that accidentally nicks an electrical wire, wire damage during

installation or due to abuse, defective or misapplied equipment, moisture or contaminants introduced between conductors of different voltages, loose or improper connections, even connecting an aging appliance with a concealed internal arc fault to a new electrical system – any of these situations and many more can cause arc fault induced fires in new construction. As much as we might like to think of new construction as safe, the simple fact is that arc faults do not discriminate between new and existing construction. Most of the reasons commonly provided for electrical fires – overloading of circuits, frayed or worn wiring, dust-covered televisions, and the like – are contributors, not causes. These conditions do not themselves produce enough heat to spark a fire, but they can certainly contribute to arcing. When added to these common conditions, arcing creates spectacular amounts of heat – enough heat to spark a fire many times over.



Photo 5: Example of potential line-to-ground arc fault (wire stapled too tight).

## An AFCI detects silent, invisible arc faults before a fire starts

Once you recognize that arc faults are inevitable and threaten both new and existing construction, the need for a way to detect arc faults and shut them down before an arc persists long enough to start a fire becomes obvious. Arc Fault Circuit Interrupters (AFCIs) continuously monitor the electrical current in a circuit and are designed to detect the characteristics uniquely associated with arcing faults. When those specific characteristics are detected, AFCIs de-energize the circuit in fractions of a second. The AFCI can be reset manually, but until the suspect condition is eliminated, the AFCI will continue to trip, preventing an arc from being sustained long enough to create a fire.

AFCI technology has been tested extensively in laboratories for more than a decade. Use in actual field applications is widespread and continually increasing. Thanks to the 1999-2008 versions of the National Electric Code (NEC), consumers and electrical professionals are becoming increasingly aware of the need for and the benefits of AFCIs.

In view of the dangers that lurk in electrical systems, it's clear that this is a technology whose time has come.

For more about Siemens Combination Type Arc Fault Circuit Interrupters for residential applications, log on to [www.usa.siemens.com/afci](http://www.usa.siemens.com/afci)

For AFCI installation and troubleshooting information, consult Siemens "Arc Fault Circuit Interrupter Troubleshooting Guide," available on [www.usa.siemens.com/afci](http://www.usa.siemens.com/afci).



- ① On the Safety Circuit: A Fact Sheet on Home Electrical Fire Prevention  
United States Fire Administration (2006).
- ② Oct. 1, 2002 CPSC-NFPA Technical Committee Document Proposal Form.
- ③ UL 1699 Standard for Arc Fault Circuit Interrupters.

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