Arc-Fault Circuit Interrupters

What they are, why you should care, and how to install them

BY REX CAULDWELL

AFCIs are the law of the land

AFCIs are part of the 2002 National Electrical Code. All new 120v single-pole 15- and 20-amp circuits serving bedrooms must originate from an AFCI breaker at the service panel. AFCIs offer fire protection that GFCIs and common breakers don't.

I could hear my garage light from across the room: a loud snap followed by a long frying sound. I removed the fixture to look at the wiring. It was a problem I'd seen before: another bad light fixture in which an arc had jumped through a loose, press-fitted rivet joint.

The danger is fire

Arcing is a luminous discharge of electrical current crossing a gap between two electrodes. According to Underwriters Laboratories (UL), arcing can involve temperatures of several thousand degrees Celsius. An unintentional discharge is called an arc fault, which can cause a fire in your home.

Arc-fault circuit interrupters (AFCIs), a part of the 2002 National Electrical Code, use available technology to help deter fires caused by arc faults. Currently, they're required in all new 120v bedroom branch circuits—anywhere a cable enters the bedroom through the walls, floor or ceiling. This requirement affects receptacles, lights, fans and smoke alarms, and eventually may be expanded to the rest of the house. Because they're so new, prices for AFCIs vary a lot; they can be found at electrical-supply houses starting at $40 and going up from there.

Three kinds of arc faults

There are three types of arc faults: hot to neutral, hot to ground and a series arc. The hot-to-neutral and hot-to-ground arcs—the two-wire direct shorts seen all the time—are called parallel arcs because they're parallel with the electrical load. They generally involve higher current because they're limited only by the available fault current of the circuit. (For a description of series and parallel arcs, see the bottom drawing on the facing page.)

A series arc can occur when a loose or frayed wire makes intermittent contact with itself during use (for more on causes of arc faults, see top drawing, facing page).

What is an AFCI?

Common fuses and breakers aren't designed to prevent arcing unless the arc is of enough amperage or duration for the breaker to sense it. An arc at low current levels still can cause a fire. I've actually arc-welded with hot conductors without tripping the breaker. The current version of AFCIs works like a regular breaker in the service panel (sidebar pp. 102-103), but it also shuts off the circuit if it detects a hazardous arc. The sensitive internal electronics of an AFCI can distinguish the difference in wave form between a hazardous arc and the kind of ordinary arcing that occurs when, for example, you plug in a vacuum with its switch in the on position.

AFCIs not only are sensitive to parallel arcs of 75 amps or more, but they're also sensitive to series arcs of 5 amps or more.

AFCIs detect series arcs indirectly. To trip the breaker, an AFCI depends on 30 milliamps to 50 milliamps (ma) of current leaking to ground. Indirect series-arc detection works only if a ground wire is present. It

Photo this page: Scott Phillips

WHAT CAUSES ARC FAULTS?

Residential fires caused by arc faults can start in many places. Poorly wired fixtures and appliances, loose or corroded connections, pierced wiring insulation and overheated or frayed extension cords can result in arc faults and fires.

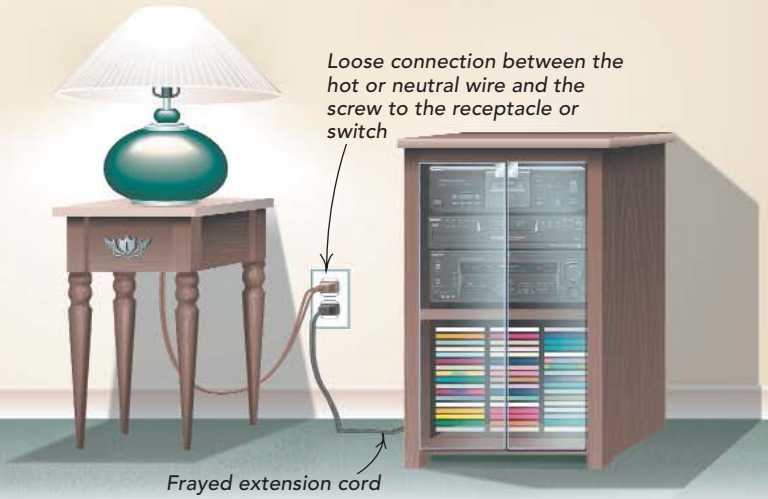
Do your wiring connections look like this? The photo above (left) shows a loose, arcing connection. On the right, the blackened area and melted metal on the screw head are evidence of arcing.

Additional trouble spots

- Extension cords draped over a heat source.
- Extension cords mashed beneath a door or window.
- Torn insulation on NM cable.
- Too many electrical cables bundled together.

Pierced insulation on NM cable (driving a nail through the wall to hold a picture)

Poorly made light fixture with a loose connection



won't work with old ungrounded wiring such as ungrounded NM (nonmetallic) cable or knob-and-tube wiring.

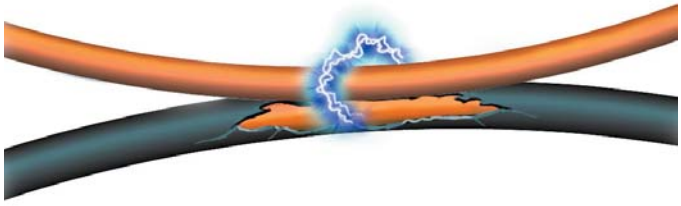
Would an AFCI have tripped the breaker on my arcing garage-light circuit? The answer is no: There's no adjacent ground wire, and the 100w light doesn't draw enough current to meet the 5-amp series arc requirement (sidebar p. 103). Although AFCIs aren't a panacea, they are able to detect certain kinds of arc faults and shut down the circuit before arcing has a chance to ignite a fire. □

Rex Cauldwell, a frequent contributor to *Fine Homebuilding*, is the author of *Wiring a House* (The Taunton Press, 2002). Photos by Chris Green, except where noted.

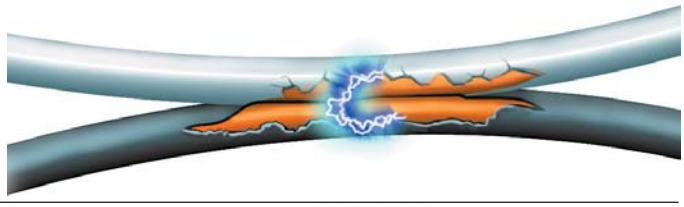
Types of arc faults

Parallel arcs

The hot wire arcs against the ground wire.



The hot wire arcs against the neutral wire through worn insulation.



Series arc

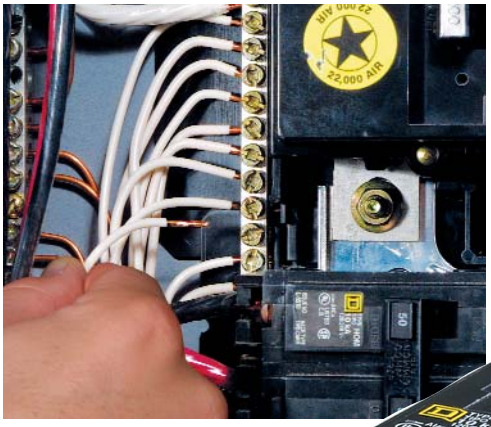
A broken wire makes intermittent contact with itself during use.

Drawings, except where noted: Paul Perreault

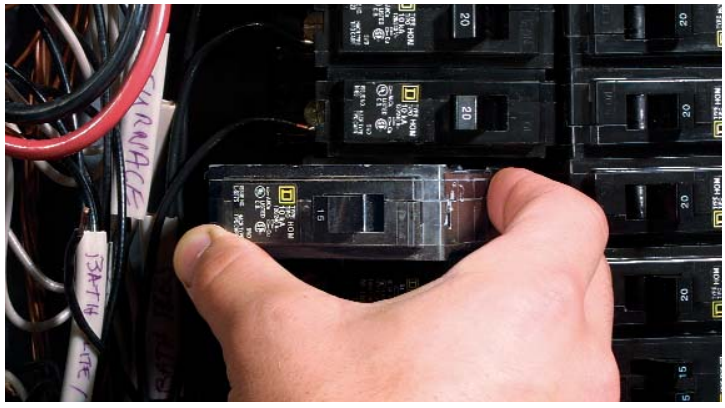
Installing an AFCI in an existing service panel

Although the 2002 National Electrical Code doesn't require AFCIs in existing houses, they are required in new bedroom circuits. And if you choose to upgrade, bedroom circuits are a good place to start. Before beginning, locate the correct circuits. With a partner using a tester on the bedroom receptacles, switch successive circuit breakers off, then back on until the correct circuit is identified. Mark the circuit breaker in the service panel. Do the same for any additional bedroom circuits serving lights, fans and smoke alarms, and replace them with AFCI breakers of equal amperage.

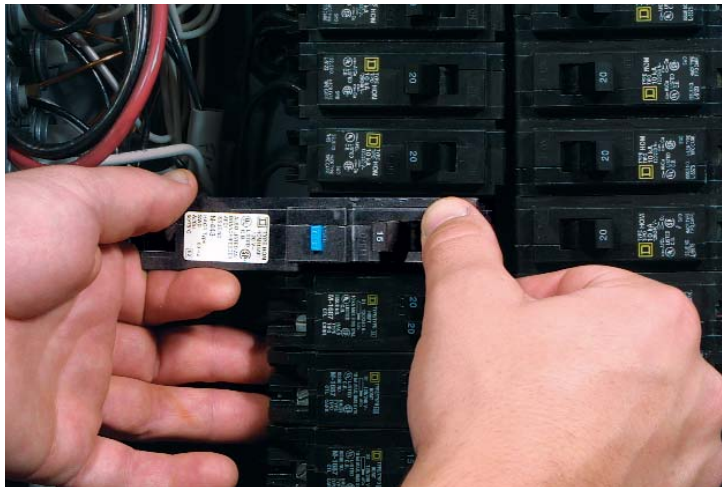
1 and *2*. *After locating the correct circuit, turn off power to the main breaker, then remove the service-panel cover.*



3. ***Remove the hot wire (usually black) to the existing breaker. Locate its corresponding neutral (white) wire, and remove it from the neutral bar.***



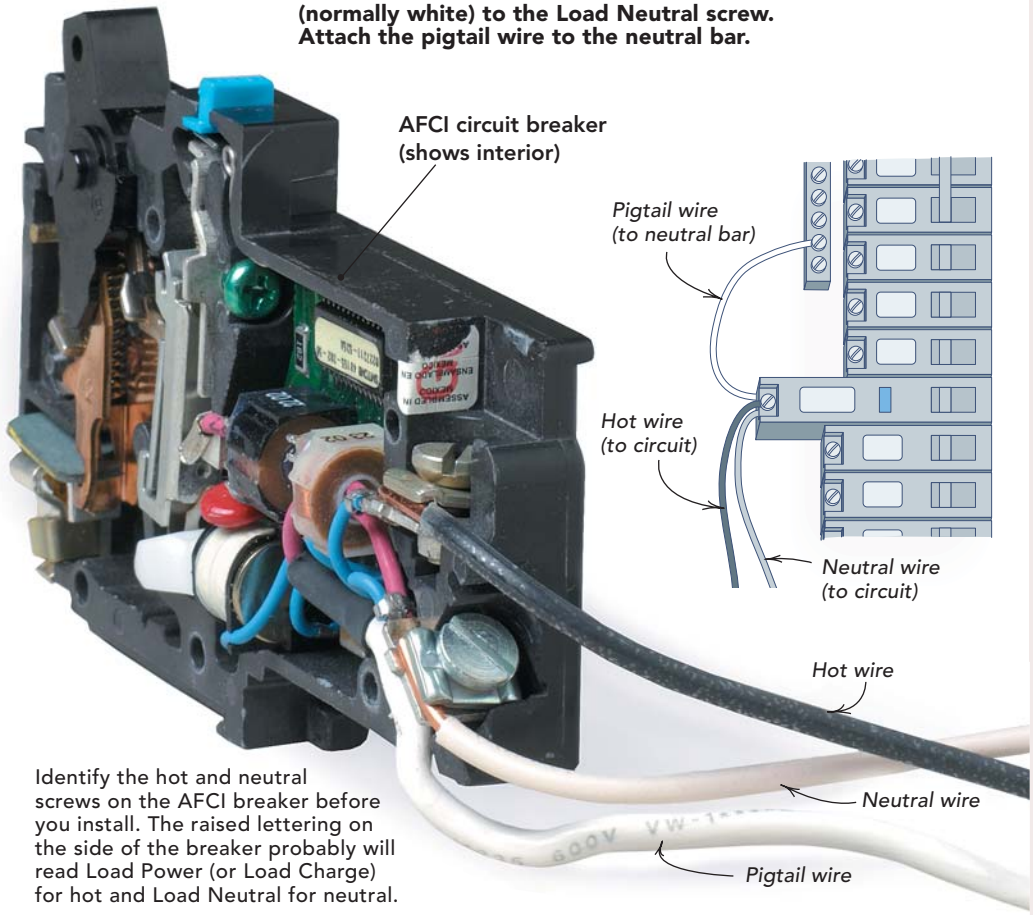
4. ***Remove the existing breaker from the service panel.***



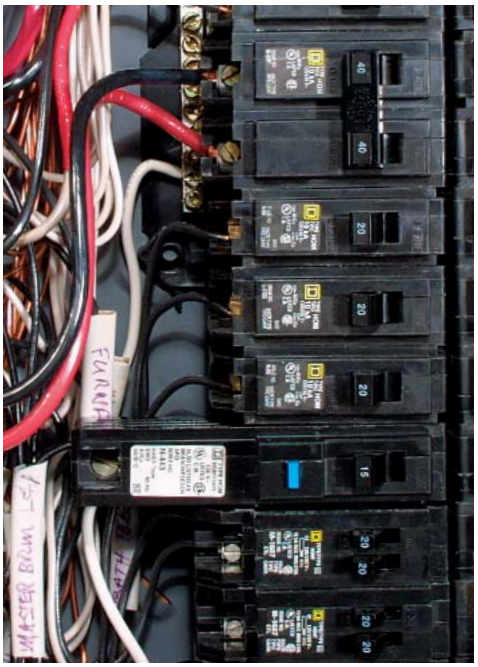
5. ***Install a new AFCI breaker of equal amperage in the old breaker's location.***

Photo bottom left this page: Scott Phillips

6. Attach the hot wire (normally black) to the Load Power screw and attach the neutral wire (normally white) to the Load Neutral screw. Attach the pigtail wire to the neutral bar.



Identify the hot and neutral screws on the AFCI breaker before you install. The raised lettering on the side of the breaker probably will read Load Power (or Load Charge) for hot and Load Neutral for neutral.



7. Replace the service-panel cover. *Once the cover is in place, all breakers look very much alike. Several manufacturers (including Siemens, Murray and Square D) use blue test buttons to distinguish AFCIs from other breakers.*

Top photo this page: Scott Phillips. Drawing this page: Dan Thornton

Are we better off with AFCIs?

AN ELECTRICIAN WEIGHS IN

It would be irresponsible to talk about the benefits of AFCIs without also mentioning the current controversy surrounding their cost compared with their value. We are paying significantly more for AFCIs compared with common breakers. Are we getting our money's worth? The AFCI manufacturers say yes; many electricians disagree.

I'm convinced that the parallel system works well—hot to ground and hot to neutral. When a significant parallel arc occurs (75 amps or more), the breaker trips. But we have that feature in effect in a common breaker. An AFCI capable of detecting an arc fault of 15 amps or less would be more useful. So only the series-arc detection is new. But even this method doesn't detect true series arcs: It detects them indirectly as they occur. When the hot or neutral leaks 30 ma to 50 ma of current over to the integral ground wire, the breaker trips.

What's needed is true series-arc detection independent of an integral ground wire. There's no series-arc detection for the older houses using knob-and-tube wiring and ungrounded NM wiring; this is where arc-fault detection is needed most.

So are arc-fault circuit interrupters worth their cost? As I see it, we haven't gained much for a cost that has increased 8 to 10 times per breaker.

—R. C.

continued

Reader Response

Don't use AFCIs on three-wire circuits

Your article about arc-fault circuit interrupters (*FHB* #152, pp. 100-103) omitted an important warning: AFCIs cannot be used on three-wire circuits (where a single three-wire cable is run to feed two circuits in lieu of two two-wire cables). And those who don't understand three-wire circuits should not even open the panel cover. Pulling the wrong neutral or adding an AFCI to a three-wire circuit can cause an interesting problem: 220v. Very bright lights and a smoking computer. And in my opinion, a neutral shock is more painful than a hot shock. Warn your readers: If you don't know, call a pro.

—Mark Heller, San Francisco, CA