GFCI Circuits

Whenever a customer asks me to defend the need for GFCI's (ground-fault circuit interrupters), I recount the old movie scene where the radio falls — or is thrown — into a water-filled bathtub, swiftly electrocuting the unfortunate bather. I then explain that if the radio had been plugged into a GFCI receptacle, the bather would still be alive. This leads us to the ultimate purpose of GFCI's — the protection of life.

Do GFCI's work? Absolutely. These devices have saved countless lives and provide much needed protection for both the tradesman and homeowner. If you are ever unlucky enough to receive an electrical shock, but lucky enough to have a GFCI in the line, it will feel like you're being stuck with a needle, then the GFCI will trip and open the circuit, stopping the current.

How GFCI's Work

In ordinary 125-volt residential circuits using NM (non-metallic sheath) wire, the amperage leaving the panel, usually through a black wire, must equal the amperage returning to the panel through a neutral, or white, wire.

A GFCI continually monitors the amount of current going to the load and compares it to that coming back. As long as the two are equal, the electricity is doing its work properly. However, if some of the electrons are missing and the current coming back from the load is less than that going to it, the GFCI will trip the circuit. The logic of GFCI design is that if the current is not coming back via the wiring, it must be going somewhere else. Often this "somewhere else" is to earth (ground) through a person holding a tool or appliance.

Here's an example from my own experience. I was using a drill that was plugged into an extension cord that, in turn, was plugged into a GFCI receptacle in my garage. The drill was old and the shell made out of solid metal. While I was using it, one of the wires inside the drill shorted to the metal case, which made it electrically hot. Since electricity can cause muscles to contract, my hand tightened around the metal handle so that I could not release it. The current was now leaving the service panel, traveling through the black wire of the house wiring to the GFCI, then through the extension cord into the drill. From the drill, the current was flowing through me to ground. This was a classic ground fault: The electrical short within the drill caused the current to pass through me to ground, rather than flowing back to the service panel via the white wire. The GFCI detected this imbalance and opened the circuit immediately, saving my life. My only discomfort was the pin prick feeling.

Split-second response. The time it takes for a GFCI to open a circuit will vary from manufacturer to manufacturer, but it should be no more than V30 of a second to comply with UL standards. The actual amount of current imbalance that the GFCI must detect before it trips is four to six milliamps (thousandths of an amp), also a UL standard. Theoretically, the average person can tolerate four to six milliamps of current for 1/30 of a second before his or her heart goes into fibrillation. (Fibrillation means that the heart goes out of sync; the result can be death.) With GFCI protection, you may still get a shock, but its duration will be limited to V30 of a second.

Why doesn't the circuit breaker trip? Most circuit breakers controlling general purpose receptacles will not trip until at least 15 or 20 amps of current flow has been exceeded. This amount of current is normally fatal. In order to protect against fatal shocks, you need a device on line, like the GFCI, that will trip before the circuit breaker can trip.

Common sense. Just because you are plugged into a GFCI doesn't mean that you can cast all common sense to the wind. You can still die if your body — your heart in particular — is placed between the incoming black wire and the outgoing white wire. In this case, your body is in series with the electrical current, just like a light bulb. As long as your body isn't grounded, you are no different to the GFCI than a normal working load. If you get caught in this situation, the GFCI will not trip because there is no current leakage to ground to create an imbalance...and you could be killed.

CFCI Types

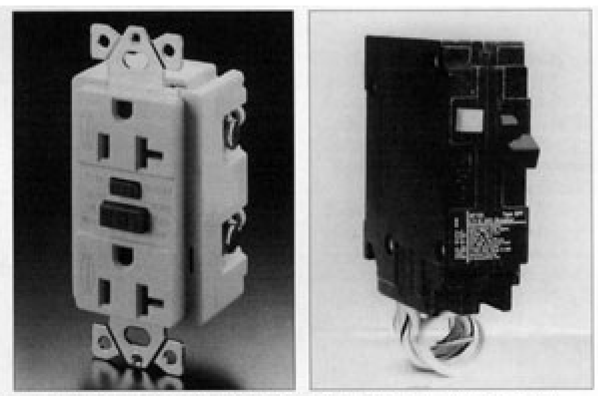

Figure 16. Residential ground-fault circuit interrupters are available in two types. Use receptacle-style GFCIs where possible for convenient resetting at the point of use (left). GFCI circuit breakers (right) protect an entire circuit but must be reset at the panel.

For residences, GFCI's come in two types (Figure 16). One type looks like a receptacle. It has a test button on it and sometimes a light. The second type looks like a 15- or 20-amp circuit breaker with a test button on it. In both designs, the purpose of the test button is, when pressed, to place a current imbalance on the circuit. The GFCI should then trip if it is working properly.

Circuit breaker GFCI's. Use a GFCI circuit breaker only if all receptacles on the circuit require ground-fault protection. It fits into the service panel like a standard breaker but wires a little differently. Circuit breaker GFCI's have two main disadvantages: They cost more than receptacle GFCI's and are somewhat inconvenient. Because they're located in the service panel, the homeowner has to walk to the panel each time the GFCI trips the circuit.

Receptacle GFCI's are fed from the service panel through a standard circuit breaker. The GFCI receptacle is then placed at the point of use so that when it trips, the homeowner can immediately reset it without leaving the room.

I recommend using GFCI receptacles wherever possible inside the house, both for cost and convenience. However, the cost can escalate far above the cost of a circuit breaker GFCI if you install them at several locations on a single circuit.

To power outdoor receptacles, however, I definitely recommend using a GFCI circuit breaker. Experience has shown that GFCI receptacles can have a short life span when located outside, even in watertight boxes. The boxes and lids may be watertight but they are not vapor tight. The water vapor seems to shorten the life of the electronics within.

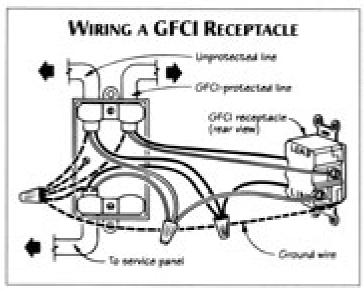

Figure 17. To give ground-fault protection to downstream receptacles, you must wire them off the load side of the GFCI.

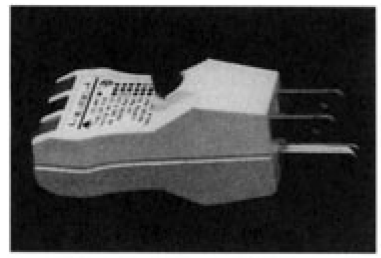

Figure 18. This plug-in tester can test a GFCI receptacle and any downstream receptacles it protects, but only in a grounded circuit.

Incorrect Wiring of GFCI's

A GFCI receptacle may be wired incorrectly by a homeowner or novice electrician. GFCI receptacles have a "line," or input, side and a "load," or output, side. The line side must be connected to the wiring that originates at the service panel. The load side must be connected to any downside receptacles that are to be protected (Figure 17).

Often a receptacle GFCI is wired incorrectly by pig tailing the downstream receptacles off the line side. These receptacles are now in parallel with the GFCI and are not ground-fault protected. Only those receptacles feeding out of the load side will be protected.

Remember to label any downstream receptacles as ground-fault protected. Use the stickers supplied with the receptacle expressly for this purpose. Inspectors often overlook this, but be sure to do it anyway. Without the label, the homeowner has no way of knowing that a particular outlet is protected.

It is also possible to wire a circuit-breaker GFCI incorrectly. However, the incorrect hookup would be immediately apparent if the "test" button doesn't trip the device. Under test, this type of device typically places an eight milliamp ground-fault on the circuit.

Testing

Always test GFCI's (using the test button located on the GFCI) immediately after installation. If you are at a site where you will be using a preexisting GFCI to power your tools, always test it first to verify that the ground-fault protection is still working. It's possible to obtain 125 volts from a GFCI receptacle without its ground-fault protection working. Manufacturers normally request monthly testing of GFCI's.

Plug-in tester. Do not test a GFCI by shorting across the hot-to-neutral slots in the receptacle. This will not test the GFCI and may cause damage. Three-prong plug-in

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testers with a push button are specifically designed for the testing of GFCI's and are commonly available at most electrical supply houses. This type of tester typically places a .0068-amp current imbalance on the line to trip the GFCI. All electricians, contractors, and inspectors should carry and use these little testers (Figure 18).

You can also use a plug-in tester to test a GFCI that has several receptacles on its load side. First test the actual GFCI receptacle or GFCI circuit breaker. Then test the most distant receptacle working off its load side. The GFCI should trip when you push the button on the tester.

Testing GFCI's in an ungrounded circuit. Plug-in testers create an actual fault to the ground wire in a three-wire circuit, causing the GFCI to trip if it is working properly. However, this can lead to uncertain test results for a GFCI installed in an ungrounded (two-wire) circuit. The GFCI may actually work fine, but it will not respond to the tester since there is no ground wire to short to.

However, for UL-approved receptacle GFCI's, the test button on the device itself will still yield an accurate test. This is because the built-in test device works by taking some of the current from the black wire on the load side of the GFCI and shunting it back to the white wire on the line side to unbalance the circuit. This is, in effect, a ground-fault simulation rather than a true ground fault, but the imbalance effect is the same.

Code Requirements

The National Electric Code (NEC) defines where and how GFCI's should be used. Here are some of the more common regulations affecting residences. (Unless otherwise stated, "receptacle" refers to a 125-volt, single-phase, 15-amp or 20-amp standard residential receptacle.)

Kitchen. All countertop receptacles within a 6-foot straight-line distance from the kitchen sink must have GFCI protection. Since, according to code, two separate circuits must feed the countertop receptacles, I normally wire my kitchens with one GFCI circuit to the left of the sink and one GFCI circuit to the right (assuming the sink is in the center of the countertop). This normally separates the load evenly and, if I come back ten years later to troubleshoot a problem, I know exactly how the circuits are wired. I use GFCI receptacles, as opposed to circuit breaker GFCI's, since the former can be reset at the point-of-use in the kitchen. Countertop receptacles beyond the 6-foot limit, as well as other general use kitchen, dining, and pantry receptacles, can be wired into the line, or unprotected, side of the GFCI.

Bathroom. All receptacles installed in bathrooms must have GFCI protection. I always use receptacle GFCI's for reset convenience.

Garage. Every receptacle in a garage must have GFCI protection unless it is not readily accessible, such as a receptacle located on the ceiling for a garage door opener, or one serving a plug-in appliance occupying dedicated space, such as a freezer. Any 230-volt outlet is exempt, as is the laundry circuit.

Outdoors. All receptacles installed outdoors that are readily accessible and within 6 feet 6 inches of grade level must have ground-fault protection. Unfinished basements and crawl-spaces at or below grade level. All receptacles installed in these locations must have ground-fault protection, except for:

- A single (not duplex or triplex) receptacle supplied by a dedicated branch circuit for a plug-in appliance such as a freezer or refrigerator
- A laundry circuit
- A single receptacle supplying a permanently installed sump pump

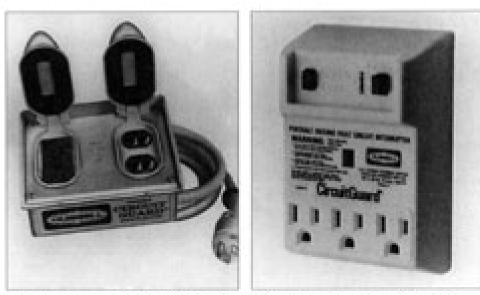

Figure 19. GFCI-protected extension cords are recommended by OSHA for power tool use in outdoor or damp locations (at left). Another option is a portable plug-in GFCI (at right).

Job-site protection. In most areas of the country, builders are required to use a GFCI-protected temporary panel. This type of panel normally protects single-phase, 125-volt, 15-amp and 20-amp receptacle outlets. If you use a generator of five kilowatts or less, you may be exempt. Extension cords with built-in GFCI protection are also available for job-site use and are recommended by OSHA (Figure 19).

Where Not to Use GFCI's

Even though it isn't against code, room lights should not be placed on a GFCI unless there is a specific need for doing so. The reason is simple: If the GFCI trips, you don't want to be left in the dark trying to find your way out of the room — especially in the bathroom, where the floor might be wet and slippery, with many objects to bump against or trip over.

Avoid this by wiring only the receptacles in the room, if you want them protected, off the load side of the GFCI, but put the lights on the line side. Also, unless there is a specific reason, don't use a GFCI for equipment and appliances that cannot go without power for an extended time, such as a freezer or sump pump, since GFCI's are sensitive and are subject to nuisance tripping.