FEATURE

Shedding light on the purposes of the ground fault circuit interrupter

by Chris Korinek

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With the popularity of spas and underwater lights, many of us in the pool/spa trade have come in contact with a rather interesting device — the ground fault circuit interrupter (GFCI). Curiosity, however, remains high as to the actual purpose of the GFCI. People have asked whether it is a legitimate, justifiable device or a hoax. This article attempts to shed light on the GFCI's purpose in today' marketplace.

Electric shock hazards resulting from line to ground shorts have long been a concern to code-making agencies. These groups, over the years, have relied on insulation, grounding, and double insulation for protection. With any of these systems intact, there is no shock hazard. Each is sufficient to protect as long as the method is not rendered ineffective by broken connections or exposed live parts. However, insulation may break down, grounding networks may lose effectiveness if not maintained, and double insulation can be bypassed if equipment gets wet. There is, then, a definite need for a protective device that will limit the shock hazard, should one exist.[1]

The Canadian Electrical Code defines a GFCI as follows: "A device whose function is to interrupt, within a predetermined time, the electrical circuit to the load when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit."[2]

Shocks and the Human Body

Since protection of personnel is the prime purpose of a GFCI, a short discussion on the effects of electricity on the human body will be helpful. Our nervous system uses electrical current and voltage to function; without it, we would soon die. Also, our bodies can withstand a certain amount of externally induced current flow caused by contact with an outside voltage source.

As alternating current through a body increases, the following effects are seen; first, a tingling sensation, then muscular contractions and heat sensation increase until the point where voluntary control over muscles is lost. This is called the "let-go" current threshold, and the average levels of current to cause this condition have been measured for men to be 16 mA (.016 Amp), and for women to be 10.5 mA (.0105 Amp). These values were determined by tests conducted by Professor Charles F. Dalziel at the University of California at Berkeley. Prof. Dalziel concluded that, via probability calculations using the data found, it was acceptable to assume that the safe "let-go" currents are 9 mA (.009 Amp) and 6 mA (.006 Amp) for men and women, respectively. These test results were used as criteria in the design of GFCI's.[3]

As the current through a body increases above the "let-go" level, serious loss of muscle control, burns, respiratory and cardiac arrest and death may occur. Amperage as low as 18 mA (.018 Amp) has been known to be fatal, as even low levels of current can produce these adverse physiological effect.[4]

Studies of what happens when a person swims into an electrical field show that when the field becomes sufficiently intense, the victim loses control of the muscles in the limbs, stops breathing and sinks to the bottom. If he drifts sufficiently out of the electrical field, he may be able to use his legs, make an ascent and be rescued. If not, he remains motionless on the bottom and dies an asphyxial death called anoxia. If the victim receives a more severe electrical shock, such as by contacting an energized object (say the frame of an underwater lighting fixture), the shock may be sufficient to produce an effect on the heart known as ventricular fibrillation, when all pumping action stops. This condition rarely ceases spontaneously. The result is cardiac arrest and, if a rescue attempt is not successfully made, death most often ensues.[5]

A GFCI, if used in the above situation, would have sensed an electrical fault condition and de-energized the circuit. When a GFCI detects a dangerous ground fault, the hot and the neutral conductors to the equipment being protected are disconnected from the power supply so that no more shock potential exists at the equipment. The GFCI can interrupt a circuit in a sufficiently short period of time to virtually assure safety from electrocution.

One point needs to be made about electrical shock; a GFCI will not guarantee that a person will never receive a shock under fault conditions. On the contrary, the user probably will receive a shock, but it will be sufficiently small in magnitude and duration to prevent electrocution in a normal, healthy person. The fact remains that if a GFCI is installed correctly and properly grounded, there is no danger of injury to the equipment user. Normal grounding is designed to pick up and carry away any unintended electrical currents to ground, and this normal function of a ground will set off a GFCI if the current is large enough. Only if no grounding network exists, and a person contacts live and grounded parts, would the GFCI be put to the test. This consists of protecting people against physical harm, a test that a GFCI is designed to far surpass.

Senses Current to Ground

The key to understanding the operation of the GFCI is the ability of this device to sense "current to ground", which means that there is current leaking off through abnormal paths. These can be any one of a number of paths such as a properly connected grounding wire, a pipe, water, or a person with portions of his or her body acting as a bridge between electrically live and grounded parts. In any of these cases, current leaves the normal path of circuitry and travels to ground. This causes an imbalance in the current entering a circuit compared with the current

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leaving a circuit, with the imbalance being equal to the leakage current to ground.

A GFCI is essentially a current imbalance sensor that shuts off a circuit when unequal amperages are perceived in power lines. It can safely protect against injury by sensing very low current imbalances with the sophisticated electronics it utilizes. A "Class A" GFCI is so sensitive that a current imbalance as small as 5mA (0.005 Amp) can be detected and the circuit interrupted in time to preclude serious physical harm. In fact, when the "test" button on the GFCI is pushed, a tiny imbalance is created inside the GFCI, thereby testing the GFCI's ability to sense the imbalance. A GFCI that does not open the circuit when the "test" button is pushed is faulty and should be replaced.

As seen in Figure 1 below, the GFCI uses a differential transformer and an electronic sensing circuit to detect ground fault current. When an imbalance through the differential transformer exists, a current begins to flow in the electronic sensing circuit. As the current imbalance reaches 5 mA, the electronic sensing circuit current reaches a preset point and opens the contacts to de-energize the equipment.

A "Class A" GFCI is primarily used with pools and spas, to protect people from exposure to electric shock hazard while submersed in water. People immersed in water are subject to more harm from electrical shocks than those on a dry surface because a large proportion of surface area on their body is in contact with water, increasing the conductivity of the body. It is this increased risk of electrical shock that makes a GFCI ideal for use in the vicinity of water. The GFCI will also protect people from shock hazards between the GFCI and equipment that contact the pool/spa water, including pumps, heaters, thermostats, filters, various heater protection switches, control boxes and cords.

The application of GFCI's for personnel protection are limited, for the most part, to low amperage circuits. Class A GFCI's are readily available in 120 and 240 volt; 15, 20 and 30 amp devices. They come in many forms, such as GFCI receptacles, receptacles without plug slots, GFCI plugs, worker portable GFCI consoles, and GFCI breaker configurations. Swimming pool pumps, underwater lights and movable spa systems all fall within the amp range of these devices, and the use of GFCI's with these products is mandatory.

There are also GFCI's that can handle large current circuits for equipment such as spa systems with 11 kW heaters (60-70 amps at 240 volts). These GFCI's are fairly expensive but are required in many areas and

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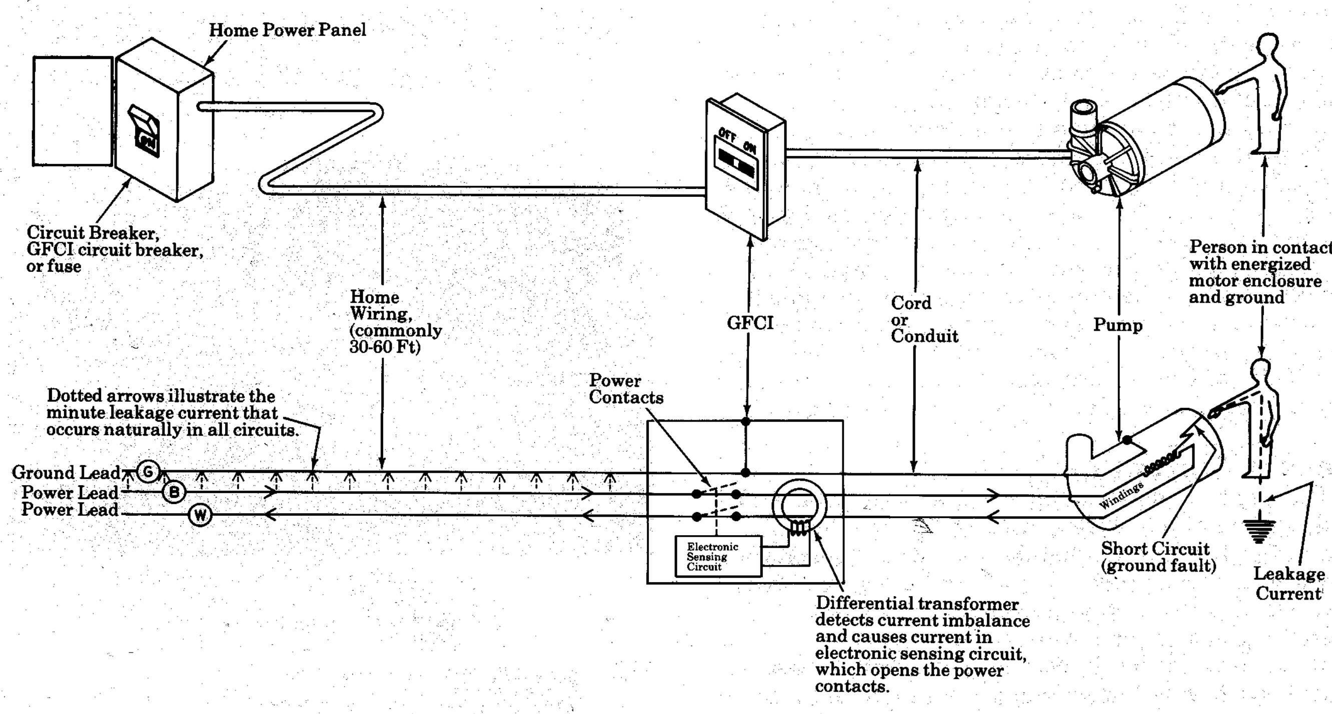

FIGURE 1
A ground fault circuit interrupter reacts to an imbalance created when small amounts of current seek ground without passing through the doughnut-shaped transformer. The imbalance is amplified by the electronic sensing circuit that opens the power contacts. All grounding conductors must be poor or broken for a hazard to exist.

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do give the same "Class A" personnel protection as the smaller devices.

Other Devices

As mentioned before, a GFCI senses current leakage "less than that required to operate the overcurrent device". It is not a circuit breaker. Circuit breakers are overcurrent detectors that trip only at a significant overload (in excess of 110% of rated load). In other words, a 20 amp breaker begins to trip at around 22 amps, basically to eliminate nuisance tripping at values close to 20 amps. Circuit breakers function to protect wires and electrical equipment. However, as we have seen, GFCI's are imbalance detectors exclusively designed for the protection of people from shock hazard. There are combination devices that include the independent functions of the GFCI and circuit breaker, along with the GFCIs and circuit breakers available separately. Typically only a GFCI is used on a movable spa system with the home power panel housing the circuit breaker. Underwater lights often are on separate circuits and use "GFCI type" circuit breakers.

Nuisance Tripping

Along with the advantages we already have discussed, there are other situations that must be guarded against. GFCI's, like any other device, are not without their limitations. They cannot protect against electrically energized grounding systems, open neutral power conductors, and line to line (line to neutral) contact by a person in which there would be shock hazard but no imbalance present. Also, GFCIs have been a source of frustration to builders unfamiliar with correct installation procedures when they have experienced a nuisance tripping problem, which can occur around wet or excessively long power lines. Closer detail to water and moisture proofing power lines can help eliminate this problem. There is also a natural current leakage whenever power is transmitted. Though it is normally negligible, very long power lines may cause this leakage to approach and even exceed the 5 mA trip level. The remedy, in this situation, is to place the GFCI closer to the equipment being protected.

In conclusion, the GFCI is a very effective and reliable safety device that seems to have an increasing market for personnel protection. Although the GFCI has only been in existence for approximately 12 years in the form that we now recognize (small and relatively inexpensive), its benefits are many. Developmental work is underway on new versions that will have features such as built-in open neutral protection and rain-proof operation.[7]

Consumers, pool/spa tradespeople and independent testing agencies have long acknowledged the need for a device to protect people from sustained electrical shock hazards. The GFCI, when properly installed with a grounding network, proper installation and prudent abuse protection, is the most cost effective way to achieve this protection today. ■

REFERENCES

[1]**Wells, J.** "A Guide to Personnel Ground Fault Protection", 1973.
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[3]**Dalziel, C.F.,** "Ground Fault Interrupter Increases Safety", 1969.
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[7]**Wells, J.,** interview, 1982.