FEATURE

Service Tips - Ground fault circuit interrupters

by Chris Korinek

Chris Korinek is a project engineer with the swimming pool and spa group of the Water Equipment Division, Sta-Rite Industries, Inc., Delavan, Wisconsin. He is involved in the development and design of components, controls and systems for spa water conditioning, and holds a bachelor of science degree from Marquette University.

Have you ever been faced with a pump, light, or spa system that has been turned off by a ground fault circuit interrupter (GFCI)? It is well known throughout the pool/spa industry that a "Class A" GFCI's purpose is to protect personnel from shock injury by sensing a very low current leakage level and opening the supply circuit. This can still be a mysterious situation, however, as the cause may not be readily apparent. Also, the answer to the question "What can be done to remedy the problem that is quick and effective?" is often never found. Too frequently, a hit and miss procedure of replacement of GFCI's and components is used. This can be costly in terms of time, replacement parts, and frustration if the solution to the problem is found only after many service calls. There is, then, a need for a simple procedure that can be used to identify the problem area with a minimum of expense and indicate steps to be taken to remedy the problem. This article contains such a procedure, which is easy to understand and use by qualified service personnel.

One very important note about service personnel that work with a tripping GFCI or any electrical pool or spa work: Pools, spas, and hot tubs are no place for the untrained or unknowledgeable to begin experimenting with electrical circuitry. Swimming pool and spa water contains highly conductive electrolytes and, for this reason, a dangerous situation could be created if service is not done in a safe manner. Repeated tripping of a GFCI indicates problems which require investigation and correction by a competent, qualified person with adequate test equipment. Do not attempt service and consult a qualified electrician or service person if you are untrained.

The following procedure can be used for any circuit that is protected by a GFCI. Common applications include equipment close to swimming pools, pumps, lights, spa systems, and home wall outlets. Circuits with only one device are relatively simple to trouble-shoot, but multiple device systems are more difficult. Both cases are discussed in the article. A spa system is used as an example of a multiple device system, but the principles given can be used with other types of electrical systems.

During normal operation, a ground fault circuit interrupter (GFCI) will stay on except when a ground fault occurs or the "test" button is pushed (simulating a ground fault). The GFCI will then trip off. The GFCI may be checked by pressing the "test" button. Once the GFCI has tripped, pushing the "reset" button should turn the GFCI back on with the "reset" button staying depressed. If the GFCI trips off without pushing the "test" button, a potentially hazardous condition exists which requires proper identification and remedy.

In general, a GFCI will turn off itself for one of the three following reasons:

1. **Actual breakdown of insulation between conductors and ground.** This would mean that a ground fault in the system has been detected and stopped. A ground fault is leakage of current to ground and is illustrated in Figure 1. This is the proper operation of the GFCI. A ground fault condition is potentially dangerous and is what a GFCI is designed to protect against.
2. **Current leakage to ground is excessive because of location of GFCI.** This condition typically occurs when a GFCI circuit breaker is used in the home power panel. The GFCI may be located in a position too far away from the critical area to be protected, which in this case is the people immersed in a pool or spa. This situation can arise simply because there is a tiny leakage current present in any electrical wire or device. The more wire or devices present, the higher the leakage current. Moisture

Continued on next page

increases this current leakage substantially.

Because a GFCI needs to be very sensitive to protect against shock injury, this excessive leakage current can cause tripping. This condition of excessive leakage is not necessarily dangerous as the insulation between power conductors and ground may not have broken down to a level where an electric shock hazard is present. For this reason, this condition has been named nuisance tripping.

Nuisance tripping, however, is a common term that is erroneously used to describe all GFCI tripping. This can sometimes mask the significance of a GFCI trip caused by a potentially unsafe condition. For this reason, any tripping of a GFCI should be considered as proper operation unless otherwise proven. A GFCI should never be removed from an appliance, such as a spa system, because of tripping, except for replacement.

3. **Faulty GFCI.** Even though no dangerous condition exists, the GFCI turns the circuit off.

It needs to be stated that any of the conditions above can be present with any GFCI application (i.e. in a spa system control box, home power panel, wall outlet, etc.). However, a problem with a spa system GFCI located in the control box would most likely be an insulation breakdown or a faulty GFCI. Excessive length of conductors can usually be ruled out in this case, even though a very high moisture level around wiring could cause a spa system GFCI trip.

There are three tests that can differentiate between the various causes of GFCI tripping and suggest the appropriate steps to remedy the problem. These tests are detailed below. When doing these tests, disconnect electrical devices only after the power supply has been disconnected, and insulate any loose wire ends if they will become live during further testing. Also, refer to any manufacturer's instructions for checking of GFCI's.

A. **Test No. 1 is to disconnect the wires and devices from the "load" side of the GFCI.** The "load" side of the GFCI is the electrical output for operation of the devices. Conversely the input is called the "line" side and is the power coming from the source. If the GFCI does not trip by itself with the "load" disconnected, the GFCI should be tested and reset to confirm its proper operation. If this is the case, and only one device is drawing power through the GFCI, the wire or device protected by the GFCI has sufficient current leakage [5 mA (.005 amp) or more] to trip the GFCI. Replace the wire or device that, when disconnected, causes the GFCI not to trip off.

If the wiring is suspected to be causing the GFCI trip, the device can be disconnected with the wiring remaining intact. The wiring, by itself, can cause a GFCI trip if a ground fault is present. Actually, having the device connected or disconnected has no efect on the ground fault if the wiring is the problem. This can be a useful thing to know if the wiring and device are disconnected and the GFCI trip stops. Before both are replaced, the wiring can be tested by itself, to indicate whether it or the device has caused the trip. Again, when applying power to a circuit with a device disconnected, be sure to insulate all wire ends so as not to cause a shock hazard.

If multiple devices and wire circuits are used see test procedure No. 2.

A GFCI that trips with nothing wired on the "load" side is a faulty GFCI and should be replaced. A GFCI does not need to be operating a device to sense leakage current as long as 5 mA (.005 amp) goes from line to ground. A GFCI that trips without any device wired into the "load" side either has internal leakage or a faulty leakage current sensing circuit. Do not attempt to further use this GFCI as it will not stay "reset" when reset button is pushed.

B. **Test No. 2 is to disconnect the power to wiring or devices if more than one device or wiring circuit is used.** If a spa system GFCI exhibits tripping and does not trip when all the circuits and devices are disconnected from the "load" side of the GFCI, it can be concluded that the GFCI is functionable and there is leakage current somewhere in the system caused by an insulation breakdown. The leakage of current could be at any point in the system; control box wiring, logic board, heater, heater cord, pump, pump cord, blower, or blower cord. The identification of the problem then must be done via the process of elimination. A spa system is a good example of a multiple circuit and device system.

First, visually check the system wiring over completely to see if there are any bare power wires, terminals touching grounded metal, or excess moisture in wiring that could cause a short circuit. Also, check to see if wire insulation is cut or worn so that a short may occur. Next, power conductors should be disconnected from the devices one at a time in a definite order until the leakage current location is found, so that the wire or device can be replaced. The tripping will stop when the faulty wiring or device is disconnected from the power supply.

Do not disconnect any ground wires in the process or an unsafe condition may be created. The ground provides a return path for current that may be redirected to a person in contact with water or spa equipment. This leakage current will be used to isolate the problematic circuit or device.

For a spa system, here is the order in which the components should be disconnected from the power supply. First disconnect the power lines to the heater. This can be done at the heater or, with some systems, inside the control box. Operate the system so that the pump and blower run.

The time period of operation should be longer than the interval observed between previous trips. This could be anywhere between 1 second and several days as some trips happen less often than others. This longer time between trips happens sometimes if the heater is involved. Element operation can open tiny cracks in the heater elements. Water can seep into the element rods and eventually allow the leakage current

Ground fault circuit interrupter

Continued from previous page

to reach 5 mA. Most GFCI trips are immediate though, and the process can be completed in a short period of time.

If no trip occurs when the heater is disconnected, the heater or heater wiring has caused the GFCI trip and should be replaced or rewired such that no tripping occurs. Sometimes the cause of the tripping can be heater wiring terminals touching grounded metal. If the heater is reconnected properly, the above test can be repeated to confirm the diagnosis before the heater is replaced.

If the GFCI trip still occurs, disconnect the air blower. Leave the heater disconnected and simply run the pump in low speed and then in high speed. If no trip occurs, the blower or blower cord should be replaced.

If the trip persists, disconnect the pump. Leave the heater and the blower disconnected. As usual, if the trip stops, visually check the cord and replace the pump or cord as necessary.

If the trip still exists, the controls should be disconnected, one at a time. Leave the heater, blower and pump disconnected. Replace any controls that cause tripping to stop.

C. **Test No. 3 - If excessive length of conductors and/or moisture are present, the GFCI may exhibit nuisance tripping, even if the circuits have no insulation breakdown.** A starting point in talking about excessive length is approximately 100 feet or more, including the spa system conductors, but with moisture present, the distance can be much shorter. The common tip-off that excessive length or moisture is present is when the home panel GFCI breaker nuisance trips, but the GFCI on the spa system does not.

One note about home panel GFCI breakers: If this device trips, it is not always readily apparent if the GFCI is tripping out because of leakage current or if the breaker is tripping out because of overcurrent in the circuit. To verify that a leakage current problem is present, a measurement should be made to assure that the current drawn is not above the rating of the circuit breaker and causing the circuit breaker to trip.

Continued on page 14

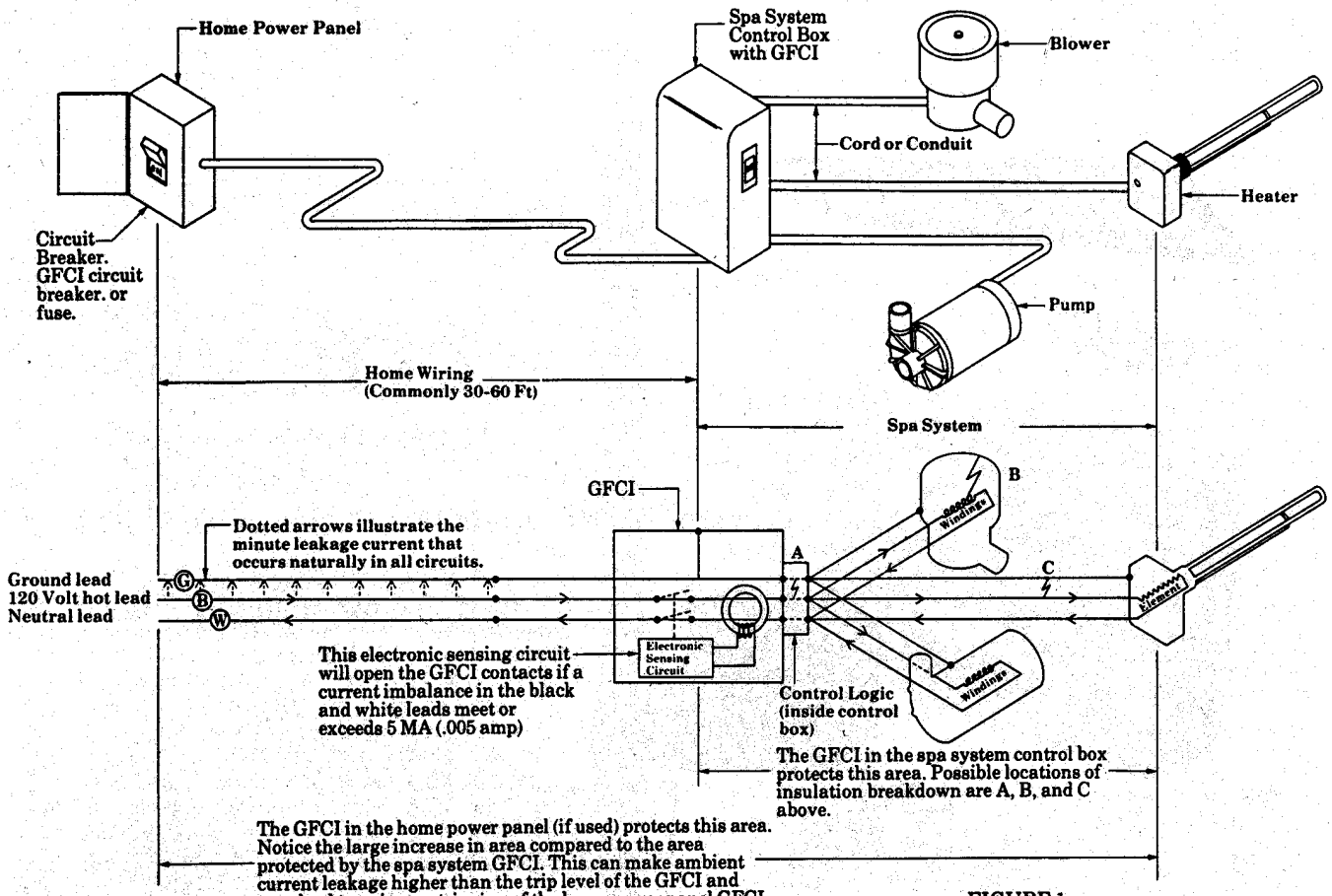

FIGURE 1
Typical spa system power circuit from the home power panel to the spa system components. The top view shows the approximate appearance of the equipment and the bottom view shows a simplified electrical schematic.

Ground fault circuit interrupter

Continued from page 12

It should be noted that circuits are supposed to be as moisture free as feasible, and possibly the circuit should be rewired to stay drier. Local codes must be consulted and, in the electricians best judgement, wiring should be done safely.

If this condition of excessive leakage current is suspected, the GFCI should be moved closer to the critical area of protection; this is test No. 3.

By following these rules, the problems of a tripping GFCI can be properly identified and solved. These tests have been set up to be very fast and effective to confirm any diagnosis before costly repairs are done. Of course, any problem not able to be solved by the spa serviceman should receive the attention of an electrician.

Below is a summary of the information outlined in the article.

Test	Test Outcome - Significance - Remedy
1. Disconnect "load" side wires from GFCI.	GFCI trips - Faulty GFCI - Replace GFCI No GFCI trip - GFCI OK - Replace defective device or wire with insulation breakdown.
2. Disconnect one device at a time if multiple devices are protected.	GFCI trips - Current leakage not found - Continue to disconnect devices until trip stops. No GFCI trip - Current leakage found - Inspect wiring and replace defective device.
3. Move GFCI closer to critical protection area.	GFCI trips - Current leakage not found - Continue to look for defective devices and wires or excessive moisture that causes leakage. No GFCI trip - Current leakage found - Continue circuit operation unless other problems occur.

NOTE: For safety, make sure the power is disconnected before attempting to disconnect any device. **The life you save may be your own.** ■