The Word: Grounding and Bonding

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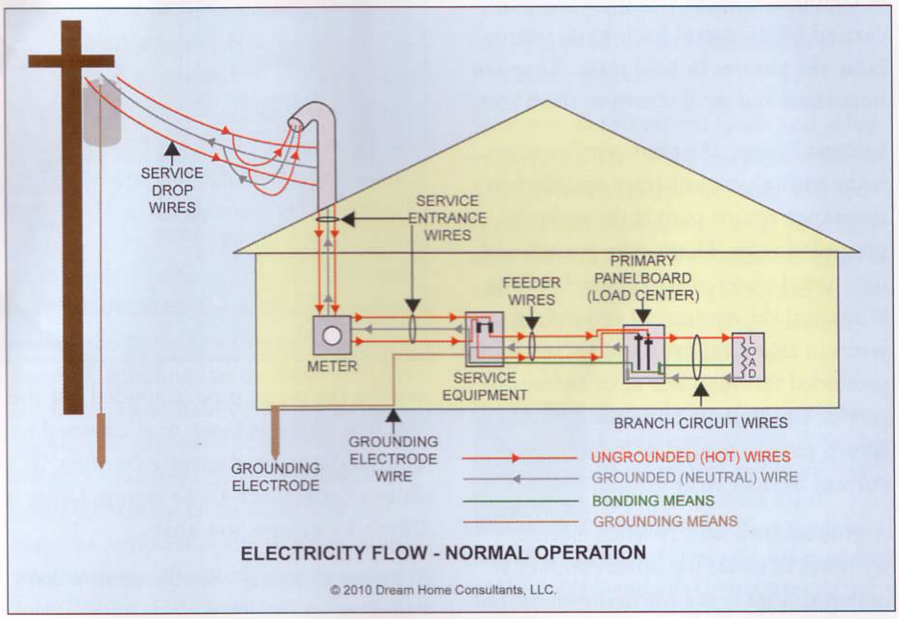
Once again, The Word invites you to travel into the dark realm of terms that are often misused or misunderstood in home inspection reports. The Word hopes you will find this trip informative and maybe a little entertaining.

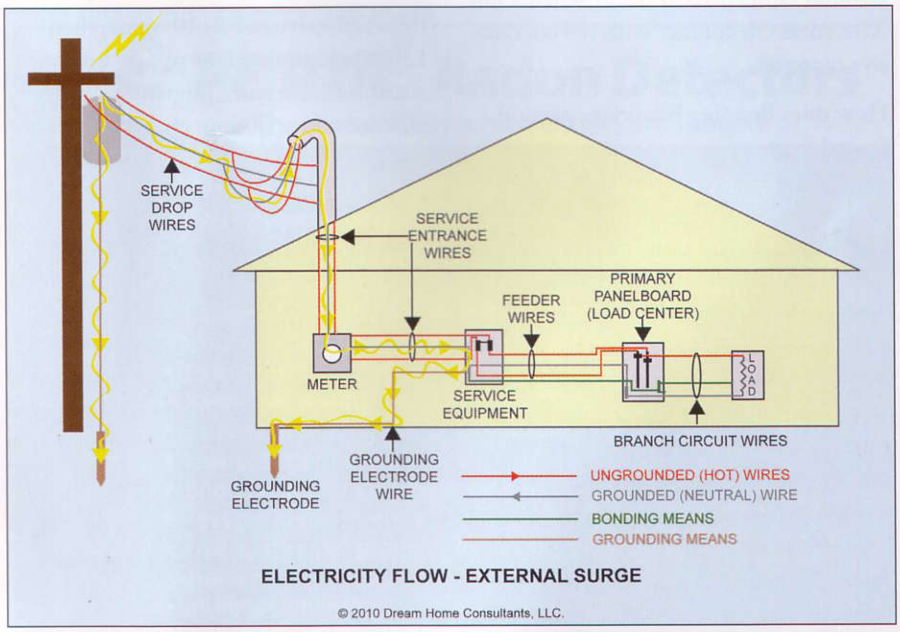
The Word's terms today are **grounding** and its cousin, **bonding**. The Word finds these terms interesting because so much confusion surrounds them. Books have been written about these terms, so The Word may live to regret tackling them in a short article.

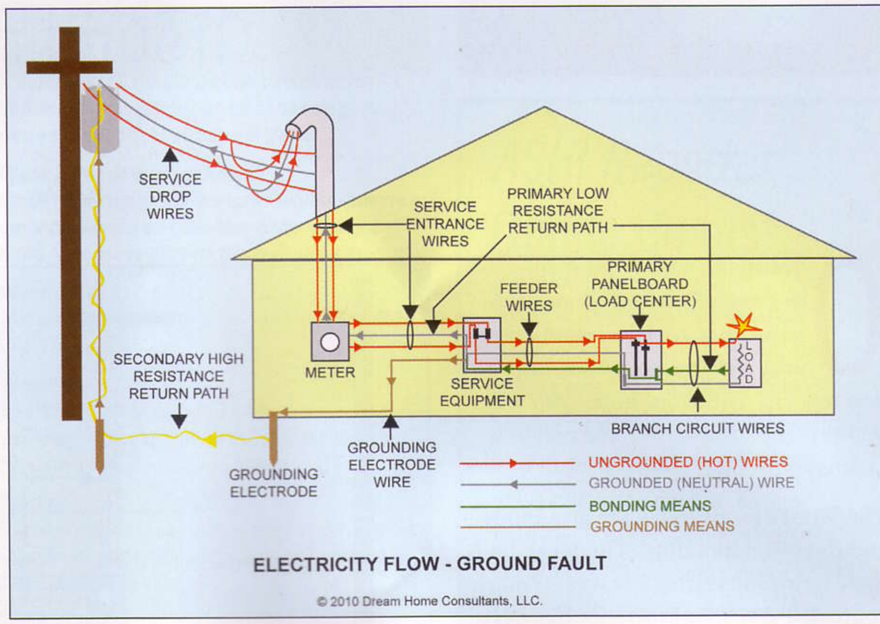
Let's begin by remembering how electricity flows in many homes. Electricity begins its journey into the home through the utility's ungrounded (hot) wires. It flows through the service entrance wires and into the service equipment (main disconnect). From there, it flows through feeder wires into panelboards (load centers), through overcurrent protection devices (circuit breakers or fuses) and into branch circuit wires. The electricity does its work and returns to its source through the home's grounded (neutral) wires and the utility's grounded wire.

Note that we did not mention the home's grounding system. Electricity flows just fine, thank you, without the home's grounding system because it is not required for normal daily operation of the home's electrical system.

One of the reasons for the home's grounding system is to help deal safely with voltage surges. What if lightning strikes near the utility's transformer, or what if a higher voltage wire falls on the service drop, or what if there is a switching surge? Some of that energy may wind up in the home's electrical system. Without the home's grounding system, the energy has no safe path to ground. It may find an unsafe path, perhaps arcing through branch circuit wire insulation to metal water or gas pipes, or welding the wires in a motor or transformer, or frying your new plasma TV. Damaged equipment, electrocution and fires all are possible when voltage surges have no safe path to ground. If the voltage surge is large enough, for example from a lightning strike, even the home's grounding system may not prevent equipment damage and fires. While it serves other functions, the home's grounding system acts like a surge suppressor. It limits voltage surges in the home's electrical distribution system and shunts them safely to ground. And while grounding gets more attention, bonding is at least as important for electrical safety. ▶▶▶







Bonding occurs when: (1) metal that could carry electricity (but is not supposed to), (2) is intentionally connected together to provide a permanent **low-resistance return path,** (3) that is capable of conducting all electricity accidentally carried by the metal back **to its source**. Note the phrases in bold print. They are important and we'll return to them later.

In most homes, the electricity's source is the utility's transformer and the low-resistance return path is the utility's grounded wire. That's why you should find metal water and gas pipe bonding wires and the equipment grounding wires in electrical cable connected to the grounded terminal bar at or before the service equipment. This low-resistance return path is critical to helping overcurrent devices clear ground faults.

A ground fault occurs when electricity flows in metal (or other conductive material) that is not normally energized. Ground faults usually occur when a hot wire comes in contact with the conductive material.

How does bonding help clear ground faults? Suppose a rat sits on a copper water pipe and chews through insulation on an electrical cable. If the pipe is bonded, as it should be, the pipe and the rat become the conductive material that returns the electricity to its source. The unfortunate rat is fried and the current in the pipe should quickly increase past the circuit breaker's limit. The circuit breaker trips and clears the fault. But what if the pipe were not bonded? Well, the rat lives to chew another day because without a return path, no current flows. The pipe is still energized even when no current flows. That is, until someone touches a metal water supply fixture. If the person is grounded, the person becomes the conductive material and the return path. Current flows and the results may be unfortunate.

A **low-resistance return path** is critical for proper bonding because a high-resistance return path may not trip the circuit breaker and clear the ground fault. Returning to the rat example, assume the water pipe is bonded but the bonding clamp is loose or is clamped to a painted or rusted surface creating 10 ohms of resistance at the clamp. Using Ohm's Law, we know that:

I(current in amps) = E(voltage in volts) / R(resistance in ohms).

If E=120 volts and R=10 ohms, then 120/10=12 amps. This poorly bonded circuit will carry 12 amps. Twelve amps will not trip a 15-amp circuit breaker, but it's more than enough to kill the rat or anyone else.

Note we did not mention the home's grounding system during our discussion of bonding and ground faults. That's because the home's grounding system has a minimal impact on clearing ground faults. Two reasons exist for this minimal impact and they deal with two common electrical myths.

Myth one is that electricity wants to return to ground. It really wants to return **to its source**, which, in the case of most home electrical systems, is the utility's transformer. If all bonded metal is connected by a low-resistance path to the utility's grounded wire, that's the lowest resistance return path to the electricity's source. The home's grounding system is usually a higher-resistance return path and thus has less impact on returning electricity to its source.

Myth two is that electricity takes the path of least resistance back to its source. It really takes all available paths. The current carried by each path is determined by the resistance in each path. Assume that the resistance in an effectively bonded water supply pipe is 0.5 ohms and the resistance through a person touching a metal water supply fixture connected to the pipe is 10 ohms. The current in the bonded water supply pipe is 120/0.5=240 amps and the current through the person is 120/10=12 amps. The person will certainly get lit up, but only for a fraction of a second because the current flowing through the bonded path will quickly trip the circuit breaker.

There's much more to grounding and bonding. Otherwise, how could people fill entire books on the subjects? For our purposes as home inspectors, this is the easiest way to think about them. The home's grounding system acts like a voltage surge suppressor that helps safely shunt voltage surges to ground. Bonding is a safety system that helps clear ground faults in normally non-current carrying materials.

By the way, a home's grounding system is not a surge suppressor; it just acts like one in some cases. A real surge suppressor is a good idea if you have expensive and sensitive computers and other equipment.

Before we move on to consider some grounding and bonding components and their installation requirements, let's distinguish between the home's grounding system and the equipment grounding wires contained in modern electrical cable. Both use the term grounding, but the equipment grounding wires are really bonding wires. They are not part of the home's grounding system. Their function is to provide a low-resistance return path for components like metal switch plates and metal equipment cabinets that may become energized. The Word does not suggest renaming equipment grounding wires. Once before, the Word suggested renaming components and that didn't work well.

A home's grounding system consists of grounding electrode(s) and a grounding electrode wire. Common grounding electrodes include: (1) at least 20 feet of #4 rebar or #4 AWG bare copper wire encased in concrete (a ufer ground), (2) a galvanized iron or steel rod or pipe or a copper rod or pipe driven at least eight feet into the ground, or (3) metal water pipe (including metal well casings) in contact with the ground for at least ten feet. Only one grounding electrode is usually required, however all accessible grounding electrodes around a home must be bonded together using the same size wire as the grounding electrode wire. In newer homes, metal water pipe can't be the only grounding electrode, but if it is present, it must be bonded to all other grounding electrodes.

The grounding electrode wire is at least #6 AWG copper for 150-amp and greater service. Number 4 AWG copper wire is required for ufer grounding electrodes with 200-amp and greater service. A number 8 AWG copper wire may be used for 125-amp and smaller services. An aluminum wire may be used, but restrictions make it impractical in most cases. In newer homes, the connection to a water pipe grounding electrode may not occur more than five feet from where the pipe enters the home.

The grounding electrode wire must be connected to the utility's grounded wire at an accessible location between the load side of the service drop or lateral and the service equipment. No other grounding connections are permitted downstream from this connection except for detached buildings supplied from service at another building. This is because additional grounding connections could create unintentional return paths to the electricity's source.

The best way to remember bonding requirements is like this: If it's metal and it is or could be near electrical wires, then it probably needs to be bonded to the utility's grounded wire. Components that may require bonding include metal: (1) water and gas distribution pipes, (2) electrical conduit, (3) electrical equipment cabinets and cases, (4) framing and sheathing, (5) HVAC ducts, and (6) all metal parts of the electrical service and distribution systems. Satellite and cable TV coax cable must also be bonded. Bonding connections at electrical fittings and boxes must be physically secure and provide a low-resistance electrical connection. Any non-conductive contaminants such as paint and rust must be removed at the bonding connection point. Bonding jumpers must be installed around interruptions such as plastic boxes, water meters and sometimes components such as water softeners and filters. Bonding wires must usually be the same size as the grounding electrode wire.

That was longer and more complicated than the usual column. The Word hopes you now have a little better understanding of grounding and bonding in the homes we inspect.

Memo to the electrical Gods and other authorities: The Word does not reside on Mt. Olympus (just at its base) and welcomes other viewpoints. Send your lightning bolts or e-mails to inspectorbruce@cox.net. The thoughts contained herein are those of The Word. They are not ASHI standards or policies. ■

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