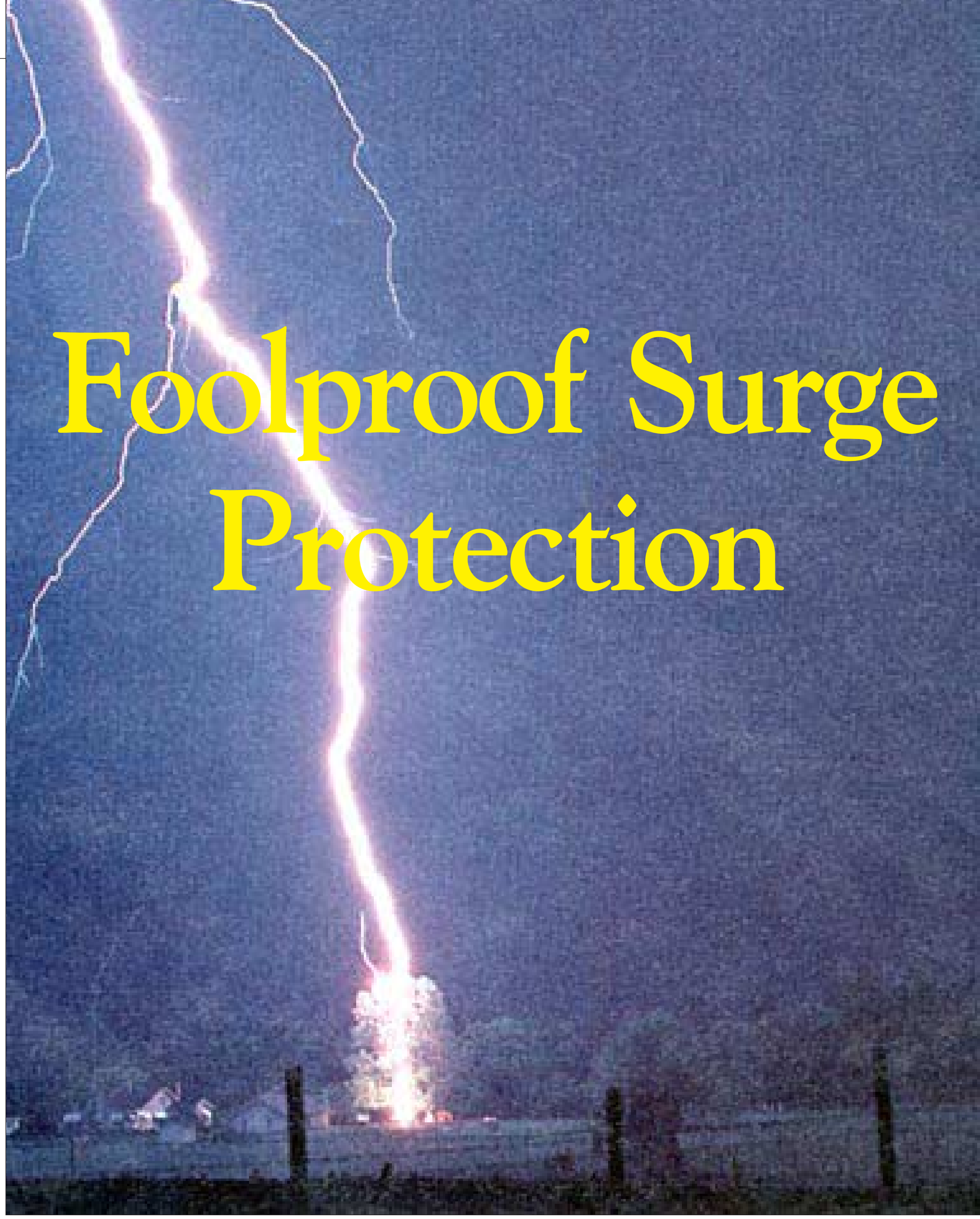
Foolproof Surge Protection



JOHNNY AUTEREY

With expensive televisions, stereos, and computers common in today's residences, I am frequently asked about surge protection to guard against equipment damage. This is especially important in the mountainous area where I live, as it is prone to heavy lightning storms. But although lightning produces the heaviest surges in an electrical system, it is not the only source. In some areas, power spikes are generated by the utility itself. And within a home, smaller but more frequent spikes and surges may be caused by switches, motors, or solenoids kicking in and out.

Over the years, I have developed a surge suppression system that can handle both the large power spikes induced by lightning and the smaller surges and interference generated from within a home. This system costs about $650 to $1,000 installed, which is less than it costs to replace many submersible pumps — common casualties of lightning (see "Protecting Submersible Pumps," page 30).

I take a three-tiered approach to surge protection: 1) I start with a good, low-resistance grounding system; 2) install a high-quality secondary lightning arrestor in the main panel; and 3) use high-quality plug-in transient voltage surge suppressors at the receptacles serving electronic appliances (see Figure 1, next page).

This approach takes care of the massive voltage first, then gets rid of noise and interference in the house lines with more sensitive devices that would be ruined by the larger initial surges.

> **From the grounding system to appliance receptacles, this layered system protects pumps and appliances even in lightning-prone areas**

The Grounding System

Lightning produces electromagnetic fields that can induce huge voltage surges in nearby power and telephone lines. These surges travel along the lines and either find a path to ground or enter buildings and cause damage.

by Rex Cauldwell

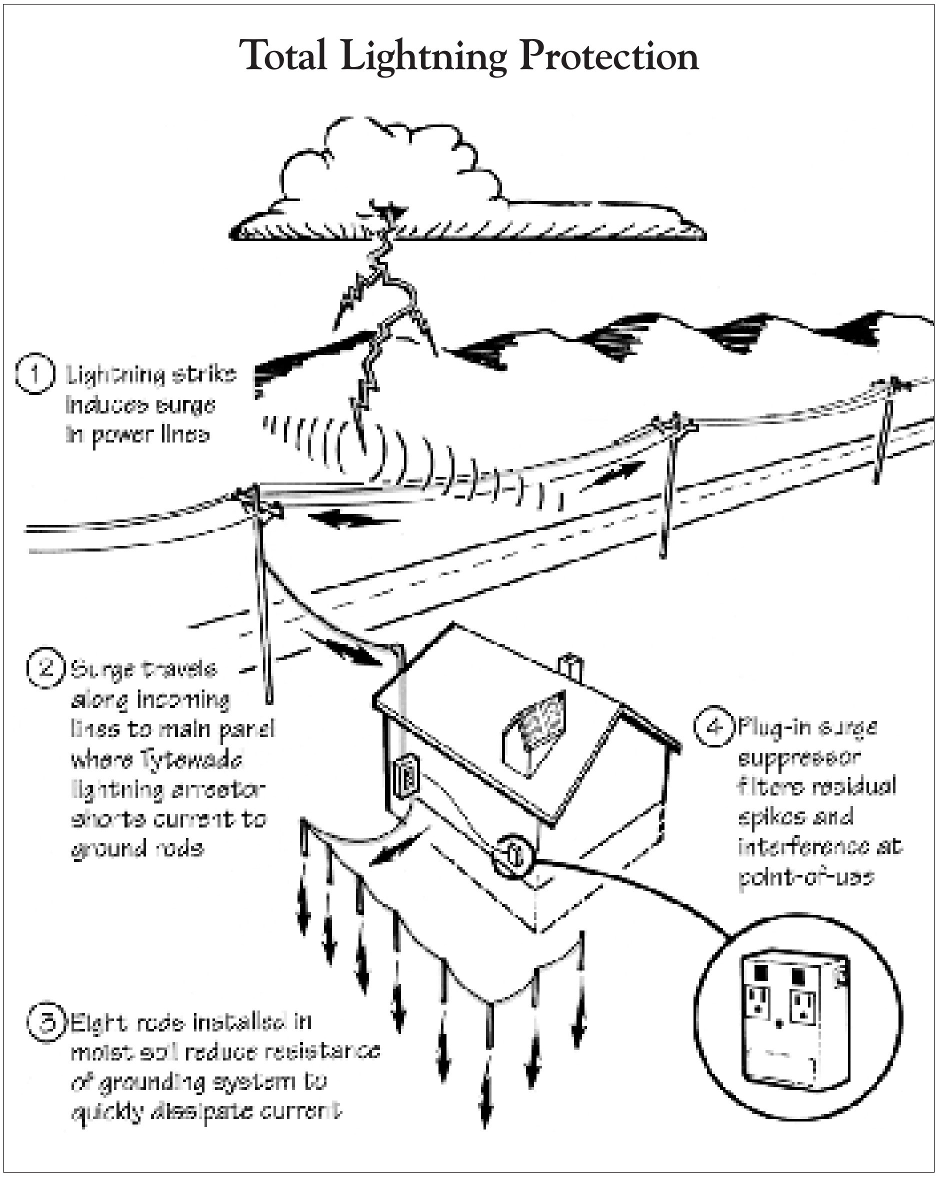


Figure 1. *The author provides lightning protection in three layers, beginning with a beefed-up, low-resistance grounding system with eight ground rods. A secondary lightning arrestor at the main panel gets rid of large spikes, while transient voltage surge suppressors at receptacles filter out smaller spikes and interference.*

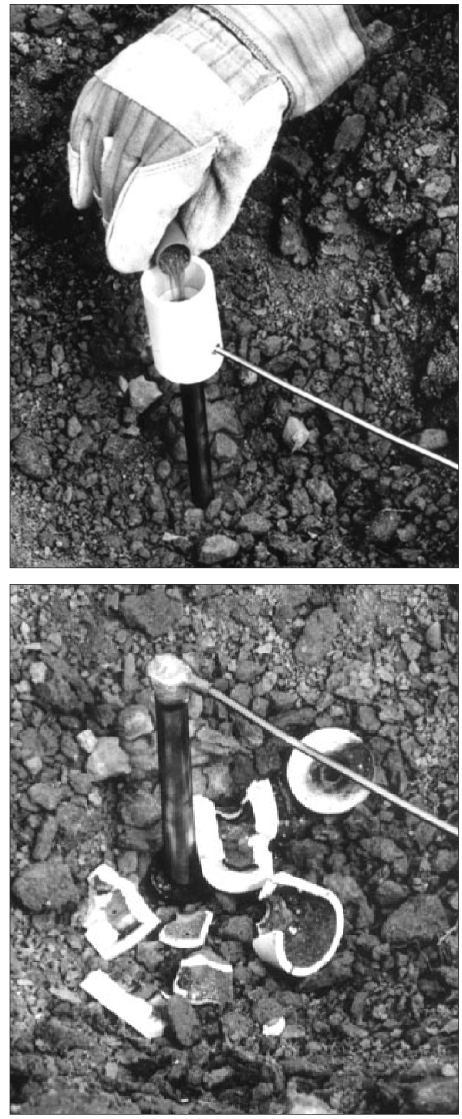


Figure 2. *The Cadweld One-Shot ensures a zero-resistance connection at ground rods. The copper grounding wire feeds through a small clay pot slipped over the top of the rod. Powdered chemicals (top), ignited with a spark, react to weld the wire to the rod (above).*

Though less susceptible than aerial lines, buried lines are also prone to develop lightning surges.

The first line of defense in surge protection is a good grounding system. Lightning's electromagnetic forces will not only cut across and induce voltage in power and telephone lines, but in *any* metal conductor — garage door tracks, the metal frame of a microwave or freezer, and the grounding system itself. The amount of voltage induced in the grounding system will be proportional to how effective the grounding system is when a lightning strike occurs: A good grounding system (one with minimum resistance) should develop only a small surge, which won't be large enough to cause any harm. A high-resistance grounding system, however, will develop a large voltage surge, which would be present in the main panel in the grounding circuit. Therefore, as its basis, a surge protection system must have a very good grounding system, and all metal parts and appliances that could be affected by lightning should be connected to it.

There is another important reason for having a good grounding system. You can't ground the two power conductors entering the house from the utility — if you did that you would probably blow the utility's transformer. The best you can do with voltage surges entering along the service entrance lines is to remove the power excesses, or spikes, and divert them to the grounding system. Where, for example, the incoming power lines normally carry 120 to 125 (average) volts, I use a secondary lightning arrestor at the panel that starts conducting at about 130 volts and sends large spikes above that voltage into the grounding system. A good grounding system can almost instantly remove the surge from the line. If the grounding system were not good — i.e., had too much resistance — then it would slow the response time of the secondary arrestor so that it couldn't get the surge off line in time to prevent damage. The bottom line is if you don't have a top-notch, low-resistance grounding system, even the most expensive arrestor may not work properly.

Ground rods. Ground rods are the most common grounding medium for residential construction, and are the basis for my lightning protection system. Never use the rebar in a foundation footing as the only grounding path, in lieu of ground rods. Lightning surges will vaporize the moisture in the concrete and crack it.

Ground rods should be copper-clad or galvanized steel, 8 to 10 feet long and a minimum $^5/_8$-inch diameter. The National Electrical Code requires two ground rods unless you can prove 25 ohms or less ground resistance. However, this part of the code is not usually enforced, so most homes have only one ground rod — meaning there is usually a high resistance to ground.

Doubling the number of ground rods cuts resistance almost in half. If one ground rod measures 50 ohms of ground resistance, two rods in parallel should measure close to 25 ohms. Four rods should lower the resistance to about 12.5 ohms. Going deeper doesn't seem to lower the resistance as fast as increasing the number of rods.

I normally use a minimum of eight ground rods spaced a minimum of 8 feet apart. Ground rods are not expensive — they cost about $10 apiece. It's driving them that's the problem. Driving them by hand can take all day, so instead I use a Makita hammer drill with a special attachment that Makita makes for driving ground rods. With this setup, I can drive a rod in one to two minutes in fairly rocky soil.

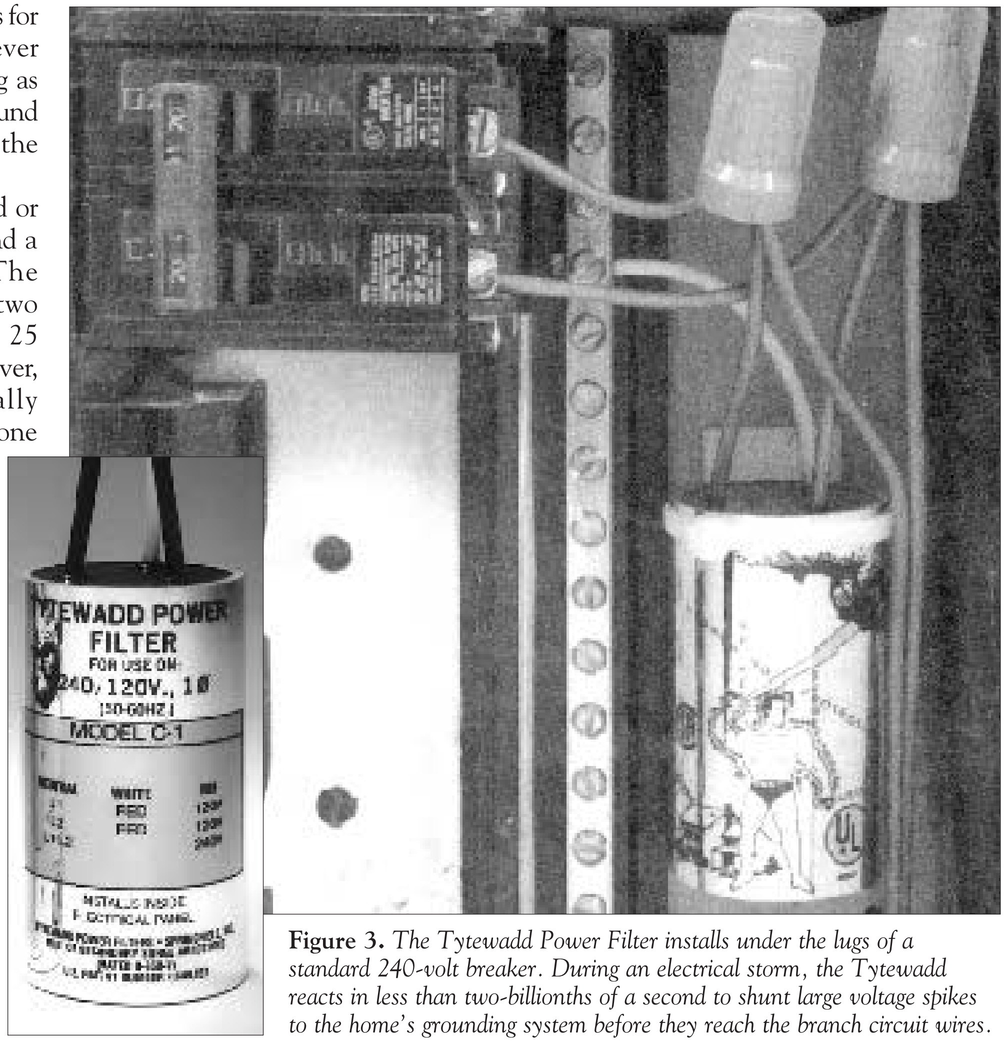


Figure 3. *The Tytewadd Power Filter installs under the lugs of a standard 240-volt breaker. During an electrical storm, the Tytewadd reacts in less than two-billionths of a second to shunt large voltage spikes to the home's grounding system before they reach the branch circuit wires.*

Rod location is very important. Ground rods must be driven in a moist location — at the drip line, by a gutter downspout, in a nearby ravine, or in an abandoned pond site. The top of the ground rod must be driven to at least 6 inches below grade. I dig the first 6 to 12 inches with a posthole digger, drive the rod, then backfill with gravel so that any rain will automatically fill and saturate the area around the rod to lower the resistance even further.

In areas with high-resistance soil (typically, where there is more rock than dirt), I pour a special material called GEM 25A (ERICO Electrical Products, 34600 Solon Rd., Solon, OH 44139; 800/248-9353) around the ground rod. This nontoxic, low-resistance material in effect increases the diameter of the ground rod, thus increasing its effectiveness.

Ground rod connection. A poor connection at the ground rod adds resistance (in addition to the resistance of the earth) to the grounding system. Most screw-type connections will eventually corrode or work loose. This is a common problem with residential grounding systems, and one I had to solve to prevent lightning damage. The best solution I've found is a connector called the Cadweld One-Shot (also available from ERICO Electrical Products, mentioned above). This innovative device actually creates a permanent, zero-resistance connection (Figure 2). The ground wire feeds through the clay pot of the Cadweld, which then slips down over the top of the ground rod. A mixture of powdered metals is poured in, and a chemical reaction, set off by a spark-type ignitor, welds the ground wire to the rod.

Grounding wire. The resistance of copper grounding wire (I never use aluminum wire for grounding) is insignificant compared with the resistance within the soil. Code dictates using a minimum No. 6 copper for 200-amp service, but experience has taught me to use No. 4 copper to prevent burned-out spots in the wire. Larger- diameter wire also has lower resistance because of a phenomenon known as the "skin effect": More electrical current travels along the surface of a wire than through the center, so the larger the circumference, the more surface area and the less resistance.

I never cut the grounding wire connecting the eight rods — it should always be one continuous piece. I buy the wire in long rolls. It must be kept flat and straight as it comes off the reel or it is hard to feed it through the first seven Cadweld connectors.

Secondary Protection

Even with a good grounding system, you must still have a secondary suppression system within the residence to handle the surges that come in along the ungrounded conductors (Figure 3). I have tried many different types, and so far the only one that has always worked to my satisfaction is the Tytewadd Power Filter (Tytewadd, 704 W. Battlefield Rd., Springfield, MO 65807; 417/887-3770).

Protecting Submersible Pumps

If you want to know where the "lightning belts" in the U.S. are, just call submersible pump makers — they can tell you where the hot spots are. A submersible pump is prone to lightning damage because it is located deep underground — making it a better grounding medium than the home's grounding system. Incoming surges will therefore follow the pump's equipment grounding wire or the hot wires (jumping through the motor's windings), looking for a ground path. Yet so far, I've never lost a pump at a home where my lightning protection system has been correctly installed. (Don't take this as a guarantee, however — yours could be the first!)

The Tytewadd in the panel and a good grounding system will protect a pump against pulses coming in along the utility lines. But the pump can still be damaged if an induced lightning pulse finds its way to the pump from another source. If, for example, lightning hits a tree and the power surge travels through the roots into the ground and finds a path to the well bottom, the pump motor may be damaged before the Tytewadd in the panel reacts.

Second Tytewadd. To prevent this from happening, I splice a second Tytewadd into the pump's power and grounding wires under the well cap (see illustration). Because it is closer to the pump, this Tytewadd can react faster.

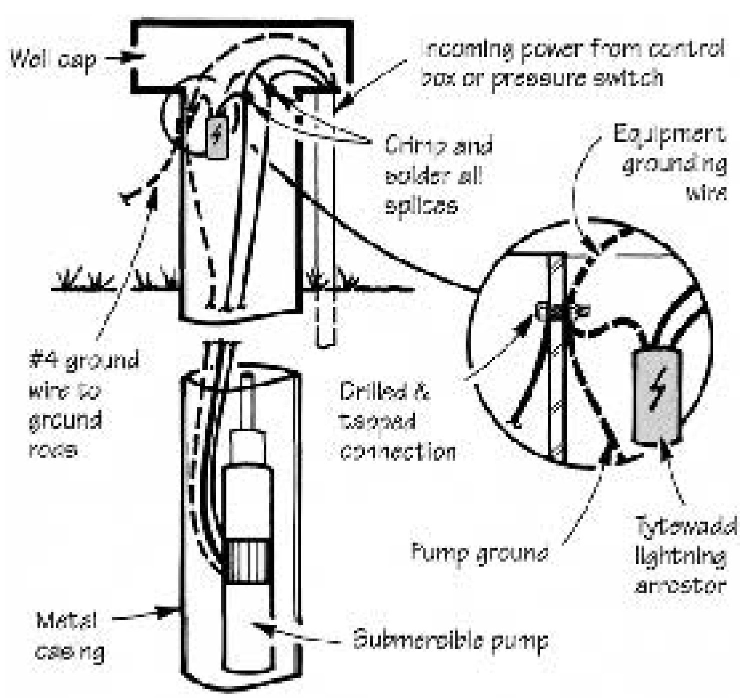
If the well casing is metal, I attach the pump's grounding wire directly to the well casing with a bolted connection through a tapped hole. I always grind the surface of the casing to bare metal to get good contact. Any incoming surges should then dissipate to ground through the metal casing.

In addition, I also run a No. 4 grounding wire from the well casing to the ground rods. This provides a ground path for surges that might come from the house seeking ground through the metal casing. Without this No. 4 copper wire, such surges would probably come along the equipment grounding conductor, which is only 12-gauge wire and which would be overstressed by large surges.

Plastic casings. Plastic well casings are obviously not a good grounding medium. So with plastic casings I also provide a No. 4 ground wire from the splice at the well cap directly to the eight ground rods at the house. This provides a "home run" ground path, avoiding all the splices at the pump's pressure switch, cutoff box, control box, and at the panel.

The pump's hot wires should also be home runs to the panel where the Tytewadd is. Never tap power from another circuit in between. There must also be no splices in the pump's equipment grounding wire between the panel and the pressure switch or pump control box. At the control box the grounding wire connections should be soldered, and you should use a third wire from the splice to the metal of the control box. Never depend on conduit to provide a low-resistance ground path — there are too many mechanical connections that can work loose.

Grounding a Well Pump



Because submersible pumps are prone to lightning damage, the author takes special care in grounding them. He uses only crimped and soldered splices, and installs a Tytewadd under the well cap. With metal casings, he also runs a separate No. 4 grounding wire from a tapped connection in the casing to the ground rods at the house.

Other Appliances

Pumps aren't the only common casualties of lightning. Automatic garage door openers and antennas should also be protected. If lighting strikes close enough to induce voltage in ungrounded metal garage door tracks, the surge may arc into the electronic door opener looking for a ground path. I always connect both metal railings to the ground rod system with No. 4 copper wire.

Avoid placing antenna masts right next to the electronic appliances they serve. If lightning strikes near an antenna, the area all around it may become saturated with an electrical charge. Any sensitive electronics nearby will be destroyed, regardless of other protective measures. Use protected, coax cable for the line into the house and a suppressor like the Leviton 5300PSC — one with a coax connector — at the point of use.

— R.C.

Figure 4. *This Leviton surge suppressor plugs into standard 120-volt receptacles. It filters small voltage surges and other noise that can damage or interfere with electronic appliances.*

This is *not* a transient voltage surge suppressor (which doesn't satisfy testing criteria for lightning), but a *secondary lightning arrestor*. It costs about $150 and meets ANSI/IEEE C62.1 standards for Secondary Surge Arrestors by withstanding 15,000-amp surge currents.

The Tytewadd installs inside the main service panel under the lugs of a standard double-pole breaker — preferably one that has some trickle current going through it, such as the breaker for an electric range with a clock. It works by quickly shunting surges from the panel's hot buses to the grounding system (see "The Electrical Panel," 10/93). The Tytewadd's leads should be cut as short as possible — I try to keep mine under 4 inches — since longer leads lengthen the response time.

I have a Tytewadd in my own house, and during a thunderstorm I can hear it crackling and arcing as it carries the surges to ground. I like the Tytewadd for three reasons: 1) It has a very fast reaction time — one- to two-billionths of a second; 2) if it goes bad, the breaker it is installed under will trip, letting you know; and 3) it is a passive unit — no transistors, resistors, or capacitors, which can't withstand heavy surges.

The Tytewadd will sacrifice itself rather than let a surge enter the residence. So far, I've only lost one Tytewadd — to a nearly direct lightning strike. But even in that case, the pump and other appliances were spared.

If you have multiple service panels, I recommend one Tytewadd in each panel. If the panels are next to each other, you might be able to get by with only one suppressor, but I don't recommend it. Subpanels will need to have a Tytewadd as well. If the subpanel is separate from the building, with its own grounding system, this grounding system should also be improved like the main grounding system.

Point-of-Use Protection

The Tytewadd handles the large current and voltage surges that make it to the main panel along the utility's ungrounded conductors. But it does not filter out the small spikes, or other unwanted interference and noise, that wreak havoc on high-tech electronic appliances. Nor does the Tytewadd suppress any spikes that might come in along the utility's neutral conductor. For these reasons, we need another line of defense — a transient voltage surge suppression device (Figure 4). I use the Levitan 5300PST (Leviton, 59-25 Little Neck Pkwy., Little Neck, NY 11362; 800/323-8920), which works for both power and telephone lines, and costs about $150.

The 5300PST has several advantages over other units. One big plus is that it provides sine wave tracking — which results in less noise on the line by quickly clamping any spikes that leave the sine wave. The 5300PST also handles any spikes coming along the neutral line, as well as getting rid of radio frequency noise, electrical motor noise, and static. I use the 5300PST for stereo systems, televisions, satellite equipment, electronic cash registers, computers, printers, and the like.

Telephone lines. The 5300PST also has phone jacks in and out, which makes it convenient for protecting modems and answering machines, which are very sensitive. Unfortunately, telephone lines often have poor grounding systems, so I usually have to upgrade a home's telephone ground in two additional ways. First, I run a grounding wire from the protector box outside the house (where the telephone line comes in) to the ground rod system. Second, inside the house I plug in a telephone lightning protector (available at any electronics store) at the receptacle closest to where the telephone line enters the house. If there is no receptacle available, I sometimes modify the protector and mount it in the box outside. These two measures will keep most surges from entering the house along the phone lines, and the Leviton 5300PST can handle any residual current.

The 5300PST has another nice feature: diagnostic lights that tell you whether a receptacle is wired and grounded properly. This is very important, although most manufacturers ignore it. But if the outlet is wired incorrectly, and many are, then no transient surge suppressor can do its job. In addition, an audible alarm on the 5300PST tells you if the device fails.

When shopping for a transient surge suppressor, make sure the device meets UL standard 1449. Also, be certain that the clamped voltage ratings are higher than those of the Tytewadd in the main panel. If the transient voltage suppressor had a lower rating, then it would start conducting sooner than the Tytewadd, and would probably be destroyed because it couldn't handle the massive surge from lightning.

No Lightning Rods

You've probably noticed that I haven't mentioned installing lightning rods on buildings. This is because I don't believe in them. No matter what the salesman says, they will not stop lightning surges from coming into the house, and they can't stop in-house surges from being created. Do they prevent the house from being prone to direct hits? Not in my opinion. Putting pointed objects high into the air *attracts* lightning, since lightning tends to strike the highest object around. Making your house seem even higher with a lightning rod hasn't yet made sense to me. ■

Rex Cauldwell owns Little Mountain Electric Co. in Copper Hill, Va.