CHAPTER 13

Lightning and Surge Protection

I LOVE LIGHTNING. I've always been fascinated by the way the bolts crisscross the sky. Something so powerful and uncontrollable can play wonders with a child's imagination. And I've never grown up.

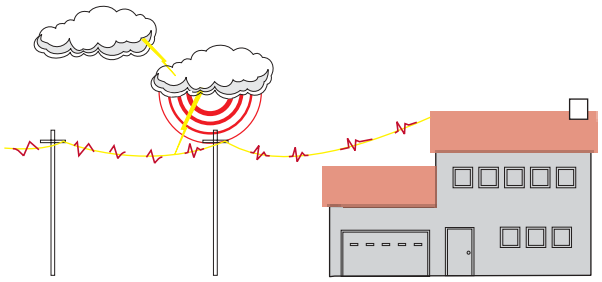
Although I've never lost my awe of lighting, I've had to deal with some of its—pardon the pun—negative effects. Protecting yourself and your home from the effects of lightning is not a big deal. If you understand how the surges get into the house, it's an easy jump to adding equipment to keep them out. The trick here is choosing the right equipment (I've installed a lot that didn't work). You can learn from my mistakes. In this chapter, I'll tell you what has been field-tested and actually does what it claims.

Induced Voltage

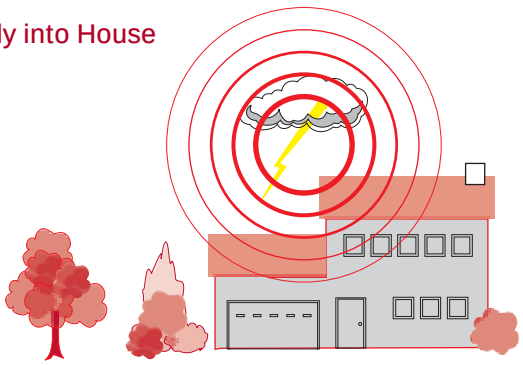
We all know that lightning is dangerous up close, but I had no idea that its magnetic lines of force were powerful even at a long distance. I was first introduced to lightning's far-reaching effects in the

Induced Voltage

Cloud-to-Cloud or Direct Hit through Utility Lines



Directly into House



TAKE NOTE

A high-quality, low-resistance grounding system is an essential part of any lightning protection system (you may want to reread chapter 5). A million-dollar lighting suppressor won't work without a low-resistance ground.

mountains of Virginia. I was checking newly buried telephone cable to make sure the plastic jacket hadn't been ripped during installation. Thus, the cable ends were just sticking straight up out of the ground. Thunder rolled far off in the distance but I thought it was too far away to affect me—I thought wrong. As I touched the ungrounded cable shield, it zapped me hard. Lesson number one: The magnetic lines of force from distant lighting can build a charge onto the cable's metal shield (about a mile of it in this one section) and it can discharge through a person to ground.

Since it had already discharged once, I thought it would be safe to touch it again—and it zapped me again. Lesson number two: Drain the shield with a jumper and give it a longer time to discharge the static voltage buildup.

I then ran a jumper from the shield to earth, waited a couple of minutes for the charge on the shield to completely drain away, and then removed the jumper. As I touched the shield a third time, it bit me again . . . hard. Third lesson: Lightning can instantly rebuild a charge on a long, continuous conductor from very far away.

Lightning three, Rex zero. I went home.

TAKE NOTE

I know of no codes that require grounding a metal roof or metal siding, but I think it's a good idea.

The invisible lines of force that I encountered on that cable are the same ones that can wreak havoc on the conductors and appliances in your home. This is why it is imperative to install surge protection on the current-carrying conductors and ground all noncurrent-carrying conductors. A noncurrent-carrying conductor is any metal that isn't used as part of the wiring system but can conduct electricity, such as an appliance frame, steel beams, furnace duct work, metal water or drain line, and metal flues. Connect a #4 copper wire from what needs to be grounded to the grounding electrode (normally a ground rod), to the grounding electrode conductor (the big copper wire going from the service panel to the ground rod), or to the service panel grounding bus.

Direct Strikes

No matter how "biting" the long distance effects of lightning may feel, it cannot compare to close strikes. Massive amounts of induced voltage from lightning can build up on every wire, metal appliance frame, and metal water pipe in your house just as it did on that telephone cable shield. That's one of many reasons, as we will find out later, that all such items in your house need to be connected to a low-resistance grounding system. Picture the grounding system as a drain—one that takes away current rather than water. If the drain isn't working properly, the electricity can arc over and cause electrical damage as it finds another path.

In addition to lightning-induced voltage saturating your house, which can create voltage spikes everywhere, surges can enter via the utility expressways: the power, coaxial cable, and telephone lines. Massive spikes can run into your house, look around, and find all kinds of damage to do . . . and then zap! Fortunately, it is possible to limit the zaps that come in on the utility lines by clipping off their highest peaks and sending them to earth.

The neutral, being grounded at various poles and at the utility transformer, is thought by many to have no pulse coming into the house. In my opinion, this is not true. The theory that the neutral pulse voltage is zero stems from the assumption that the ground resistance provided by the utility to drain away all

neutral surges is 0 ohms. But those who have ever measured ground resistance know this is not true (5 ohms is considered very low, less than 50 is considered adequate by some, and 100 ohms or more is considered high). In truth, there is no such thing as a perfect ground. We drive one or more ground rods, tie into whatever else is considered grounded, and live with what we get.

Utility and In-House Surge Creators

Power utilities have to work on their lines. They are always adding this, fixing that, installing new poles, replacing broken ones, tapping into lines for new service, and so on. Each time they come on-line (and sometimes off-line as well) a surge is placed on the utility conductors. For example, a capacitor bank (installed to reduce voltage fluctuations) produces a significant pulse and initially charges as it is brought up on-line. Trees falling on the lines also create voltage and current surges that can be as damaging as lightning.

The equipment we try to protect also produces surges that can hurt other equipment. For example, a washing machine solenoid snapping in and out sends pulses on the in-house electrical wiring. These pulses may not be as massive as a lightning surge, but they are a lot more numerous. Sometimes the problem is so simple that we overlook it (such as a common snap switch). If you can help it, never put a snap switch on the same circuit as an electronic device.

Here is a simple test: Plug a radio in to the outlet and turn the room lights on and off. The crack you hear coming from the radio is the pulse created by the switch. If you have a computer on that circuit, you are sending a pulse to it as well.

In the past, the only way to ensure that appliances were safe from damaging surges was to unplug them. Back then, most people had only two major appliances: a stove and a washing machine. Not too long after came electric dryers and television sets. Today, unplugging appliances is no longer practical. Our appliances are integral with the house, but they are also very fragile. Operating at only a few volts, they can't survive a battle with lighting or any other surge source. This cause and effect brings on the newest step in home evolution—surge protection.

Adding Surge Protection

A house needs surge protection in two locations: at the point-of-entry (the main panel or subpanel) and at the point-of-use (where the equipment is used). Point-of-entry devices will have a longer life if you use a heavy-duty protector with a high clamping level that affects only large pulses. If a super-sensitive system is installed at the point-of-entry (say, one that cuts and filters every surge down to just above a nominal 120 volts), the protective device will degrade and die an early death from the excessive number of times it must divert surges. Let the point-of-use devices deal with the smaller pulses.

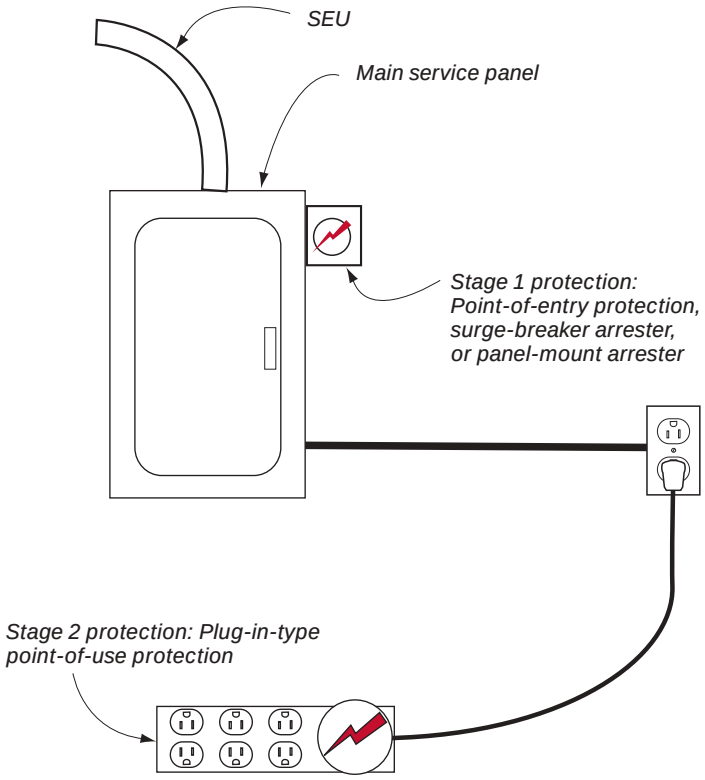
Point-of-entry protection

This is the first line of defense against surges. Without a point-of-entry protection system, one voltage spike can affect the entire house. This happens through the service panel. The service panel is the central hub, and every wire, receptacle, switch, and load is connected to this

WORK SAFE
WORK SMART
THINKING AHEAD

Sometimes the problem of incoming surges lies with the utility. Have the utility verify that it has properly installed a surge arrester on the pole and a multiple ground-rod system. You may have to get an electrician to make the official complaints, following the age-old adage of "It's not what's said but who's saying it."

Surge Protection

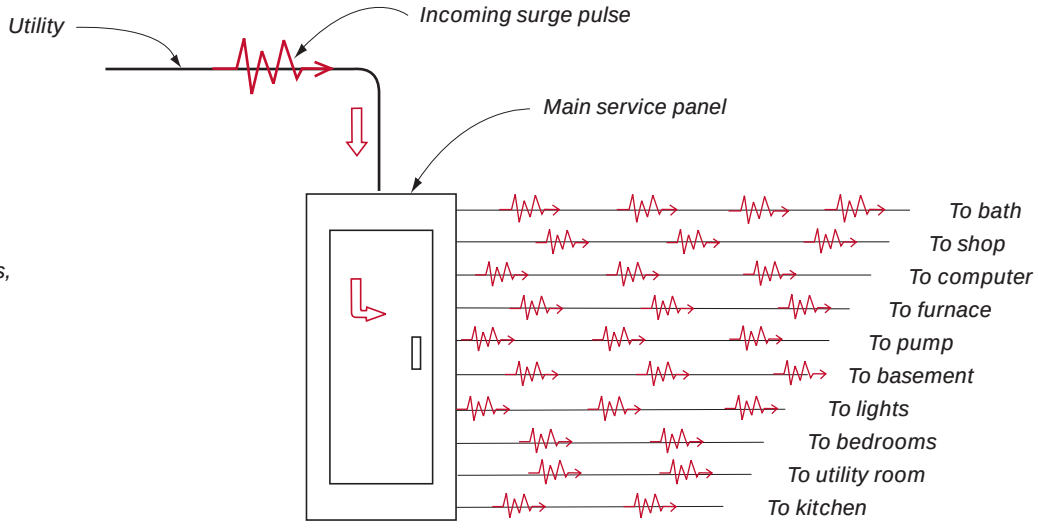


panel. Although this may be an efficient system for wire distribution, it also allows any incoming surge to branch out and run on every circuit throughout the house.

A surge can come into the panel from the utility (as in a lightning strike) or from in-house equipment, such as a washing machine solenoid or switching appliance. But no matter where it comes from, once a surge hits the main panel it will go through the house like a virus, infecting all the circuits. The only thing that can stop it is an effective point-of-entry protection device. There are two basic types of point-of-entry protection: plug-in and hardwired protection.

PLUG-IN SURGE PROTECTION Plug-in surge protection is the easiest type of protection to install—and, perhaps, the best.

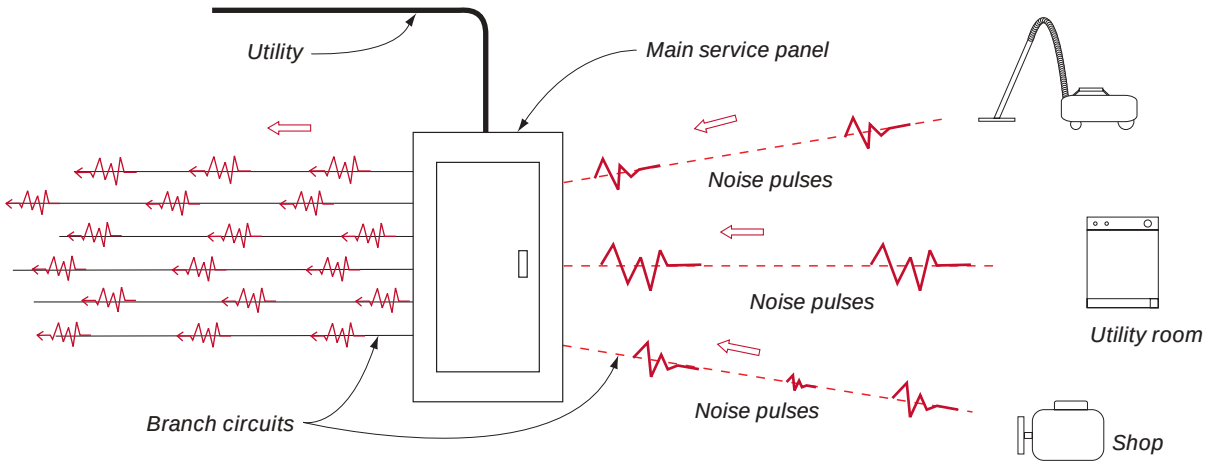
No Entry Protection



Without point-of-entry protection, every surge that comes in on the utility goes through the service panel, out to all the branch circuits, and to the loads.

Noise Pulses

Surges and noise pulses can flow from the load to the service panel. Without point-of-entry protection, pulses and electrical noise generated in-house, such as those from a vacuum cleaner, washing machine solenoid, or shop motor, flow from the branch circuit on which they originate to the main service panel. From there, they flow onto every branch circuit in the house.



ABOVE CODE The surge breaker, officially called a Circuit Breaker and Secondary Surge Arrester, made by Siemens, is what I use in my Above Code system. It consists of two single-pole breakers (to protect each phase) and installs just like a common circuit breaker. A red light indicates whether the protection system is working. The nice thing about this system is that it protects the entire panel.

A surge breaker has a tremendous advantage over a hardwired arrester because it snaps right onto the tabs of the service panel and has no long leads that may develop excessive voltages caused by massive surge currents (see Hardwired surge protection below) taken off the line. It has just one wire connecting the breaker to the ground bus. This wire must be as short as possible.

If there is more than one breaker box (say, two 200-amp boxes), you need a surge breaker in each box. If there is a subpanel downstream from the main panel (in a different room), you should put one in there as well.

This two single-pole breaker module, made by Siemens, mounts in the main service panel like a standard breaker, but it also works as a surge arrester to protect the entire house. The lights indicate that the surge-protection system is working.

HARDWIRED SURGE PROTECTION

Hardwired protection is exactly what it sounds like—the wires are stripped and connected into some type of device. These are further broken down into two subcategories: those that are encased

Although this Primax mounts outside the panel, it is encased in a metal box. The hardwired surge protector mounts on the side of the breaker panel and clips off surges coming in from the utility line. It receives power from a 30-amp double-pole breaker. Do not hide these within the walls.

within metal boxes (either one of its own or the service panel itself) and those that are not. You want the former, not the latter. Any point-of-entry surge protection device that takes massive surges through its body has the potential to explode. (I have seen the damage caused by the resulting shrapnel.) For that reason, hardwired, point-of-entry protection must be mounted either within a metal service panel or within its own metal box adjoining the panel.

When mounted on the outside frame of the panel, make sure that the surge protector is not hidden within a wall, which makes it inaccessible for inspection. (I don't like the idea of having the device explode inside a wall where it could start a fire.) An example of a well-designed, hardwired system is the Primax™ unit made by Panamax. It is encased in a steel box, mounts immediately next to the service panel, and is ideal for surface-mounted panels. For flush-mounted panels, mount the unit on the wall immediately adjacent to the panel and run the wiring into the panel via a nipple on the Primax's side. This particular unit also has an audible alarm to indicate loss of protection.

Point-of-use protection

Point-of-use protection is the second stage of surge protection. Once the massive surges have been taken off the line at the service panel, the more sensitive components of point-of-use protection can come into play.

Point-of-use protection normally comes on a receptacle strip with a long, plug-in cord. The specific type of point-of-use protection you need depends on the equipment you want to protect (AC, telephone, cable, satellite, and so on). You need point-of-use protection for each appliance or group of equipment you want to protect. For example, I have two in my office behind the computer to protect it and all the equipment around it. Then I have another at the portable phone in the kitchen, one for each of the two TV sets, one for the copying machine, one for the stereo system, and so on.

Not installing point-of-use protection shortens the life of all your expensive electronic equipment and entertainment playthings. It is folly to go out and buy a $2,500 top-of-the-line

Keep the Wires Short

The length of the wires on an arrester may dictate whether the unit will work or not. Massive surge currents flowing through these wires develop a voltage proportional to their length. A wire with the resistance of only 1 ohm is still subject to Ohm's Law: Voltage = Current × Resistance. For example, 10,000 amps flowing through a 1-ohm-resistance wire develop a whopping 10,000 volts . . . and that's enough to blow anything apart.

The rule to remember here is the shorter the wire, the smaller the voltage. Always mount a hardwired device as close as you can to the main service panel. Once the leads enter the panel, keep the leads as short as possible, with no extra slack wound in the panel.

digital-ready TV set and not spend a few more dollars to protect it against surges that will either burn it up or hasten its demise.

AC protection comes in various-size outlet strips, including two, four, six, and eight plug-ins. My experience is that you need at least six; eight is better. Make sure the strip is designed to allow room for transformers to be mounted side by side or back to back.

PICKING THE RIGHT PROTECTION

The biggest challenge in selecting a point-of-use protection device is choosing from such a large assortment of products. Unfortunately, some of the devices on the marketplace are just junk and others are a fire hazard. Here is a list of prerequisites to help you separate the wheat from the chaff:

- UL approval.
- Automatic power disconnect. If the unit fails, which can happen when a massive surge or electrical fault occurs on the line, the unit will disconnect all power to the load.
- A self-diagnostic system. Look for units that indicate whether the receptacle is properly grounded and the protection system is operating.
- An abundance of receptacle slots for all the AC, phone, and coaxial cable lines you want to protect. Make sure it can house several transformers at once.
- A good warranty and guarantee. In addition to insuring itself, look for a unit that insures the objects it's protecting. Some come with a $100,000 insurance policy.

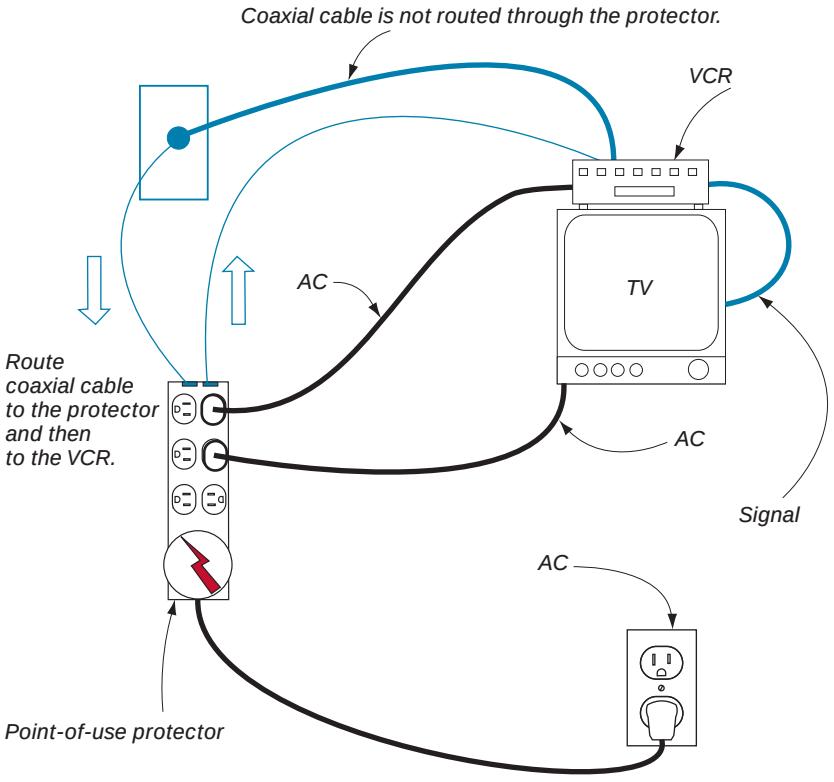
PROBLEMS WITH POINT-OF-USE PROTECTION

Nothing is without problems, and Murphy's Law seems to work overtime with anything electrical. Here are the most common problems I see in installing point-of-use protection:

- Poor or nonexistent grounding. No low-resistance grounding means no protection.
- Wrong surge device used. Having an unprotected appliance, such as a telephone line or a coaxial cable to the TV or VCR, endangers the entire system.
- Ground skew. This situation is also caused by using two or more different circuits for interconnected equipment. In the drawing on p. 234, there are two ground references. This could cause a difference in ground potential and even a ground loop (current flowing on the ground wires between circuits).

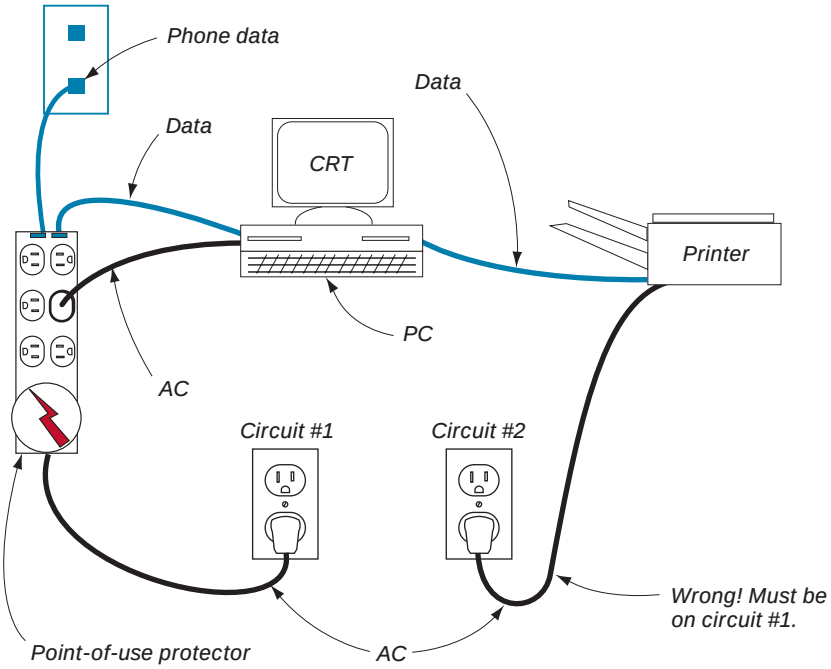
Missing Protection

The AC is protected but the coaxial cable is not. You can have the same problem at a computer by not protecting the phone line.



Ground Skew

Here, interconnected appliances—the computer and the printer—are plugged into two different circuits. The printer is not protected and it has a different ground reference from the computer. This is known as ground skew. As a result, the equipment may not work correctly at times.



- Used outside, around water, or in high heat. Keep any point-of-use device (or anything electrical, for that matter) away from water and high humidity. Also, don't put the unit next to a wood burning stove, which you might do to protect the blower.
- Connected to a two-prong receptacle through a cheater plug or by cutting off the ground lug. Again, no ground means no protection.
- Connected to an outlet that uses cheap push-in connections. This type of receptacle overheats easily and can produce intermittent connections. Rewire the receptacle by putting the wires under the screws, or even better, replace the receptacle with a good-quality one.

Phone and Coaxial Cable Protection

Surges coming into the house via the phone and cable lines are quite common and problematic. They destroy computers, TVs, VCRs, modems, answering systems, telephones, and just about anything to which these lines are connected. Although both aerial and buried cables are shielded to protect the wires inside them from lightning-induced surges, the system obviously is not without problems and can pick up major surges. One problem is that many utility systems do not have enough ground rods at their poles and pedestals.

For the phone system, another problem lies with the network interface device (also called NID, or a network interface unit). The NID is mounted on the house siding and is where the telephone cable comes in and the house telephone wire goes out. It provides catastrophic surge protection and an interface point between the house telephone wiring and the utility cable. Back in the old days, an NID was just a tall metal can, and lightning protection was provided via carbon blocks or fuses. Except for providing protection from massive strikes, they did not work well. But then they didn't have to—our telephones were not as sensitive as they are now.

As the electronic era emerged, better methods of telephone surge control were needed. The carbon blocks were replaced with gas tubes, but the first models were a bit too sensitive and put a lot of noise on the line. Today's NIDs work best for long-duration massive surges (I've seen many a protector box literally blown off the house), but they aren't designed to protect your in-house equipment from quick, small surges. It's up to you to provide your own protec-

tion. And, as with AC protection, phone surge protectors start with low-resistance grounding.

Telephone protection

You can protect your own phone and cable system by simply adding point-of-use protection (always needed) and point-of-entry protection (optional; you'll have to use a commercial unit). Most residential and small- or home-business installations don't have thousands of feet of telephone lines running throughout the building and can normally get by with point-of-use protection for each piece of equipment or line. For extremely large homes and businesses, I recommend commercial point-of-entry protection in addition to point-of-use protection.

Coaxial cable protection

Most houses have some type of coaxial cable, either from their own antenna or satellite or from the utility. Residential cable point-of-entry protection doesn't exist unless you use a commercial product. The blocks that the cable connects to on your house are grounding blocks, not surge-protection blocks. Their purpose is to send to ground any noise or surges that their shields pick up.

In some areas, installers have stopped putting in grounding blocks and simply use them as a coupling. There are two reasons for this: First, installers don't want to go to the trouble and expense of running the ground wire from the block to the other side of the house where the grounding system is located. Second, the runs from the dish to the house equipment are sometimes very short and don't have the potential to pick up surges as longer runs do. But this logic is thrown out the window as soon as a lightning strike hits a nearby tree and all your equipment goes up in smoke.

Don't assume that the equipment the coaxial cable connects to after it enters the house will ground the cable's shield and thus take the surges to ground. Most electronic equipment is two-wire AC (no ground). The bottom line is that without point-of-use protection to provide both protection and grounding, the coax shield will remain ungrounded, waiting for a surge to burn up the electronic gear.

Point-of-use protection for both phone and cable is quite easy to obtain. Many multioutlet point-of-use AC line protection systems safeguard these circuits as well. The most unique and versatile concept in protection design that I've seen is called the MAX 6 (made by Panamax). This plug-in protector has a base module providing AC protection and removable modular ends for different types of wiring protection, such as coaxial, telephone, and data lines.

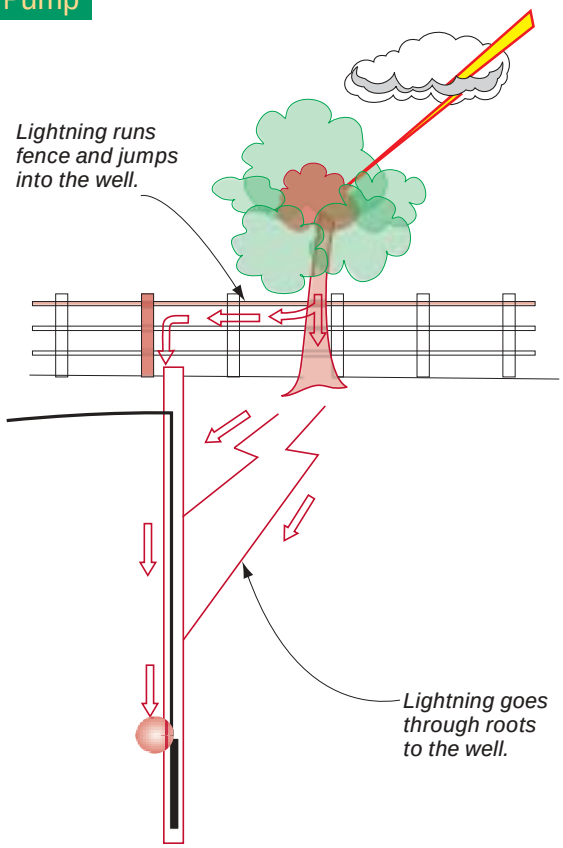
Protecting Pumps

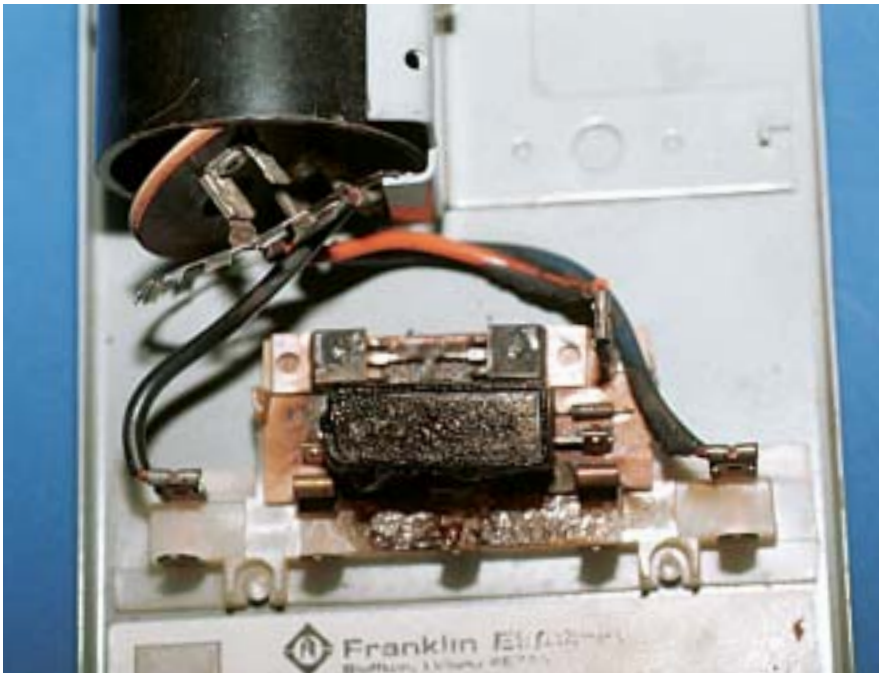
In high-lightning areas, submersible pumps can easily burn up even if they are under water. Protecting pumps from lightning is a little different from protecting appliances within the house. In addition to surges coming down the utility lines, pumps are bombarded with heavy surges from a variety of directions.

After years of experimenting with brands and designs, I finally came up with a system that worked. (My apologies to those who received the systems that didn't.) The first part of my system is a Siemens surge breaker or a hardwired Primax unit in the main service panel to stop massive surges from coming in on the utility line. In high-lightning areas, not having one of these means certain death for a submersible pump.

How Lightning Finds a Pump

Lightning can destroy a submersible pump by entering in the opposite direction. For instance, lightning hits a tree and finds its way through the ground to the pump—sometimes through the earth, sometimes by running a fence. By the time the surge gets to the protector in the panel, the pump is toast.





This burned hulk is what's left after a surge came in backward from a well. The surge-protection system within the pump protected the motor but not the control box (the surge also burned out the pressure switch). I've seen the lids of these boxes explode across a room.

Pumps can get major hits from other sources as well, especially when the pump system is a long distance from the service panel. Typical problems include induced surges into the pump wire from overhead lightning, strikes hitting a metal vent line and jumping to the pump wire, strikes running along metal water lines, lightning running along fence lines and jumping to the pump wire, and lightning hitting a tree and running into the ground to the well. Thus, a surge comes into the house backward and blows apart the first thing it sees—namely, the pump control box and pressure switch. (Both of these units are located at the water pressure tank.)

The control box starts the motor in three-wire pumps (two-wire pumps have this circuitry in the motor) and the pressure switch turns the system on and off as water is needed. I've actually seen control boxes that have blown across a room and punched holes in the drywall. This is another reason why I started wiring in the Primax unit at the cutoff switch, control box, or pressure switch.

For wells nowhere near the house, pumps need protection at the wellhead. Here I use a hardwired arrester cut right into the wires and placed under the well cap. I use a Tytewadd suppressor unit because these wells are normally in some type of building housing the electrical gear.

My last piece of magic is an Above Code grounding system to make sure surges always have a low-resistance ground. Be sure to include the metal well casing in the grounding system. If the well is close to the house, run a #4 copper wire from the last ground rod to the casing.

A submersible pump deep in a well has its own protection in the motor, but it still can be damaged. When the surge comes in to the pump's motor, the pulse races to the end of the winding and

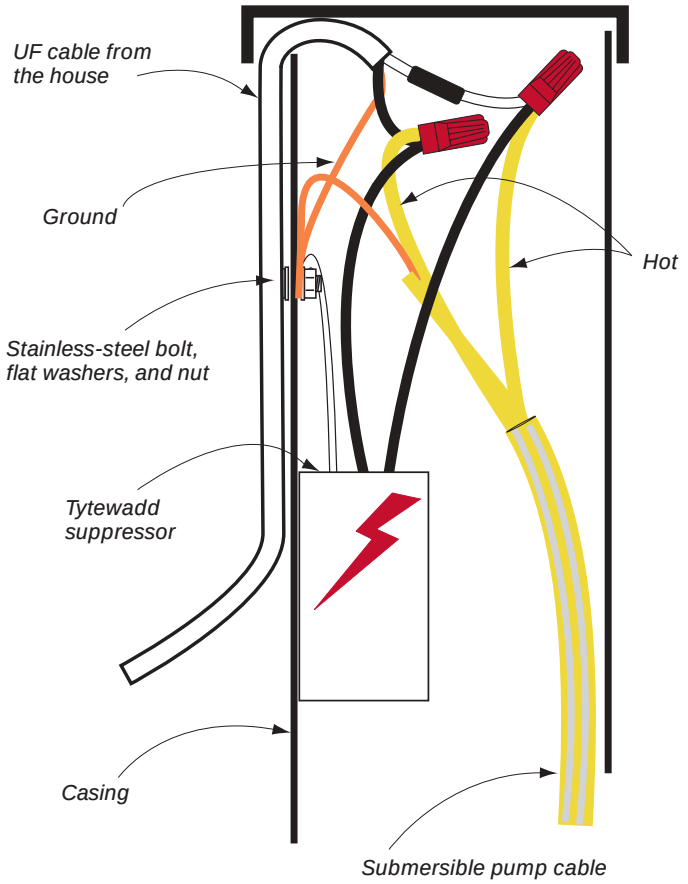
doubles in value each time it bounces back to the opposite end of the winding—10,000 volts, 20,000 volts, 40,000 volts—until the windings fail.

Many pump motors don't fail because of just one thunderstorm. The damage is cumulative, with the windings becoming more susceptible to catastrophic damage with each surge until the unit just dies one day. Without a breaker surge arrester mounted in the cutoff switch to limit the surges before they reach the pump motor, lightning surges stream down into the motor time and time again and overstress the motor windings. The motor may continue to work, but the day will come when it takes one surge too many—or just gives up the ghost during Thanksgiving or Christmas.

Well Casings

If you are having a well drilled, the installer will give you a choice of casings: galvanized steel, nongalvanized steel, and plastic (PVC). Always choose galvanized steel. Nongalvanized steel can rust and contaminate the well. PVC is less expensive and doesn't rust, but it has two big disadvantages. First, you lose the ability to include the casing in the grounding system, which makes the absolute best ground possible. Second, PVC doesn't seal well in bedrock. If you use steel casing, the driller can pound it hard into the rock for a good, watertight seal. You cannot do that with plastic, because it will shear off and block the casing hole.

Protecting a Pump



Lightning Protection for Pumps

One of my customers went through three submersible pumps in three days—all in the same storm.

As I was replacing the original pump (between rain showers), I told the customer of my multistage system of lightning protection for pumps. He thought it sounded great, but he didn't want to buy it right then and there. The next day he called me and said he had lost the new pump I had just installed—again to lightning.

As I was replacing the pump for the second time, I again suggested my special system. This time he agreed, but said that he would install it himself in order to save on labor. I sold him the material, told him what to do, and went on my way.

The very next day, just like clockwork, he called again (by now we were becoming close friends). He had lost the second pump to lightning. I asked him if he had installed my special system because I had never lost anything with it installed properly. He said he hadn't gotten around to it yet, but he would now. After I installed the third pump and he installed my multistage pump protection system, I never heard from him again (so much for good friends). Bottom line: Put the system in before you lose your pump, not after.

Pump Protection System

A pump lightning-protection system is done in layers just like all other protection systems. The first layer is at the service panel and the second is at the pump controls. The third (optional) layer is at the wellhead.

Use a Siemens surge breaker or a Primax hardwired system in the main service panel.

Wire in a Primax unit at the cutoff switch adjacent to the pressure switch or pump control box.

Install an Above Code grounding system by including a ground to the metal well casing.

Optional: If a well casing is farther away than 100 ft. and there is a danger of lightning directly hitting the well from a tall, deep-rooted tree or a fence line, install a heavy-duty, hardwired suppresser (such as a Tytewadd) under the wellhead.