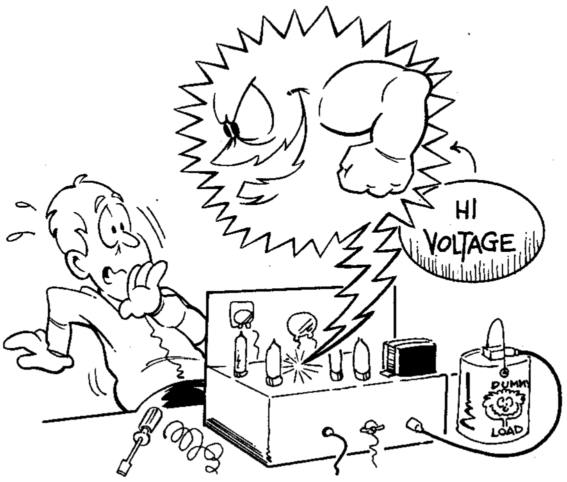
The Amateur and Electrical Safety



Part 12: Is your station as safe as it should be? If not, you may be endangering family members and neighbors as well as yourself.

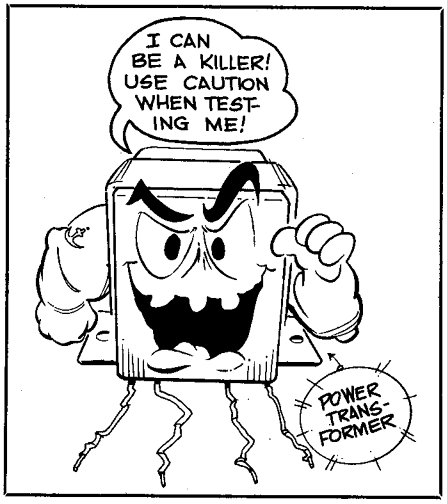
By Doug DeMaw,* W1FB

Safety First! may seem a trifle boring. After all, we have heard the expression all of our lives, and we see it in print almost everywhere. In fact, "safety first" is so commonplace that we tend to become oblivious to the warning. It is a sad fact that many of us do not become aware of the dangers of high voltage and lightning until we have had personal experience with it.

We may go on our happy way with hamming for years before having a bad experience, or we may never get hooked into a voltage line that jolts us. But we must always be aware that the danger lurks constantly when we operate an amateur station. Knowledge of some specific safety measures is necessary if we are to minimize the danger of a serious accident (and pass an amateur license examination!), so let's examine the fundamentals of station safety and learn preventive measures that might save our lives.

Where Are the Hazards?

Primary among the causes of danger, or even death, in the ham shack is momentary carelessness. To help illustrate this ever-lurking specter, I will relate a personal experience that nearly cost my life. A friend, W8JEK, came to my house some years ago with a high-voltage transformer that he wanted me to test for secondary voltage. He did not have an ac voltmeter that was capable of measuring more than 1000 volts. We placed the transformer on a wooden base (for insulation purposes), connected one lead of my voltmeter to one of the secondary-winding wires, then plugged the transformer primary into the 117-V ac outlet. All seemed normal, and no smoke or strange sounds came from the big transformer. My next step could have been my last, had fate not been favoring me. I placed one hand in my pants pocket (a good safety measure) and took the remaining voltmeter test lead in my free hand. I had an alligator clip on that test lead, so decided to attach it to the remaining secondary lead of the transformer, which I did. I woke up some three minutes later on the floor of the radio room, and my mouth had the taste of acid! The last thing I remembered was feeling as though some giant had hold of my arms and was shaking me violently.



Why did this happen? The answer is lack of attention to the conditions that prevailed. First, the insulation on the meter test lead was inadequate for the amount of voltage present. Second, I was wearing shoes with leather soles (rubber is better) and was standing on a concrete floor that was damp! This is a no-no of the first magnitude! Later, we learned that the transformer secondary was rated at 2500-V, and the current capability was ½ ampere!

Needless to say, that experience was a superb teacher, and had I not been young and in good health, I'd probably not be here to write this article today. This event clearly illustrates how important it is to plan ahead — consider every possibility and ensure that every safety measure is followed *before* exposing ourselves to lethal potentials. We should always have another person present when working around dangerous ac or dc potentials: Adopt the *buddy plan* without fail!

Other common hazards are transformers that develop short circuits internally between one of the windings and the metal core and frame of the transformer. When a breakdown of this type happens, it places dangerous potentials on the equipment chassis. For this reason it is vital for us to connect a quality earth ground to all of our station gear. The ground will cause a fuse or circuit breaker to open and eliminate the safety hazard. More on this later.

Proper fusing of power supplies is similarly important to protect people from shock hazards. A fuse with too high a rating may not blow before a person is exposed to dangerous voltages.

Lightning hazards should also be considered at all times. It is unfortunate that we can do little to protect ourselves and our equipment from the tremendous voltage potential of this natural phenomenon. The best safety plan is based on preventive techniques, which we will consider later in this article.

The remaining source of danger lies in RF energy. Severe burns to the flesh can result from accidental contact with anten-

*ARRL Contributing Editor, P.O. Box 250, Luther, MI 49656

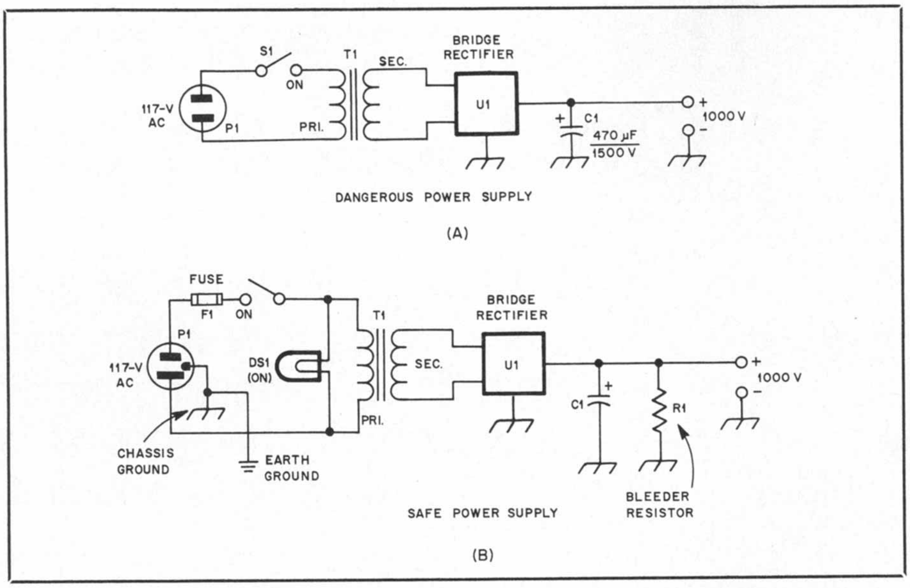


Fig. 1 — The circuit at A shows an unsafe ac power supply (see text). Example B illustrates some important safety features that should be applied to all power supplies.

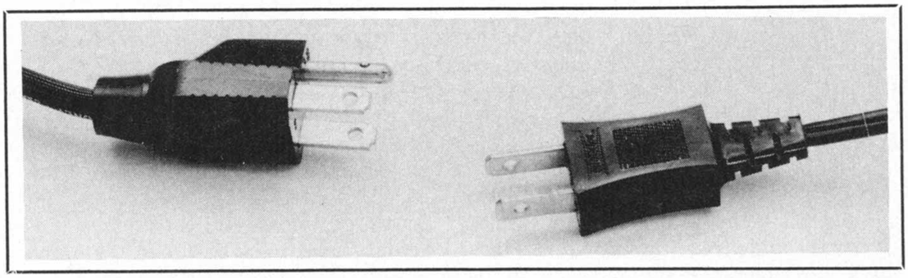


Fig. 2 — Photograph showing the difference between a three-conductor UL-approved ac line-cord plug and a two-conductor plug that is found on older equipment.

nas or transmitter components that carry high levels of RF (ac) voltage. There can even be a threat to animals with regard to RF voltage.

Power-Supply Safety

It matters not whether we use commercial ham gear or operate with homemade equipment. With the exception of mobile and certain types of portable operation, we will find ourselves relying on the ac mains for the primary power source. This dictates the need for some type of power transformer. Specific UL (Underwriters' Laboratory) safety codes should be followed. This includes a three-wire, polarized ac line cord and proper fusing of the primary side of the power supply. There is also a limitation for the distance a power supply can be from the wall outlet unless a specifically approved ac line is used.

Fig. 1 shows two simple power supplies. The first one (A) is typical of what we might find in some early-day ham shacks. Why is it dangerous? Well, first off, it does not have a safe line-cord plug (P1). The plug is not polarized (both pins are the same size and shape) and there is no third pin for automatically grounding the power-supply chassis to the ground lead in the power service.

The first circuit also lacks a fuse, which means that a breakdown in the transformer, as mentioned earlier, would permit high voltage to appear on the chassis of the equipment. Finally, there is no bleeder resistor between the output dc-voltage line and ground. A bleeder is vital for discharging or "bleeding" a power supply after it has been turned off. The filter capacitor (C1) or capacitors, depending on the design, are capable of storing a high-potential charge that could be lethal to human beings. The charge could last for hours or days, providing a significant shock hazard to persons working on the power supply or any piece of gear attached to it. The bleeder resistor drains off the stored energy within a few minutes, removing the shock probability. A bleeder resistor will, of course, dissipate some of the available power from the supply, but is a worthwhile trade-off in the interest of safety.

Fig. 1B illustrates a safe power supply. It has a three-wire power plug, a fuse, an on-off indicator lamp (DS1) and a bleeder resistor (R1). Also, as an additional safety measure, we have added a separate earth ground to the power-supply chassis. Note that P1 is polarized by virtue of one pin being larger that the others. This prevents us from plugging the line cord into the wall outlet in an improper manner. One pin goes to the neutral line and the other to the hot line. Make certain that all of your equipment contains all of these safety features. Fig. 2 shows a two-pin and a three-pin line-cord plug.

Developing a Station Ground System

A good earth ground is not a casual thing. Don't rely on a small metal rod driven into the soil. In many regions the conductivity of the soil is so poor (sand and loam) that a ground of this kind offers no effective safety measure. Furthermore, the quality of such a ground system can vary with the season, depending on the moisture content in the soil. In other words, the ground might be fairly effective during rainy seasons, but entirely ineffective in the hot, dry summer months.

How, then, might we develop a more effective earth ground? Step 1 is to connect a large-diameter conductor between the station and the nearest household cold-water line. Copper plumbing offers the best

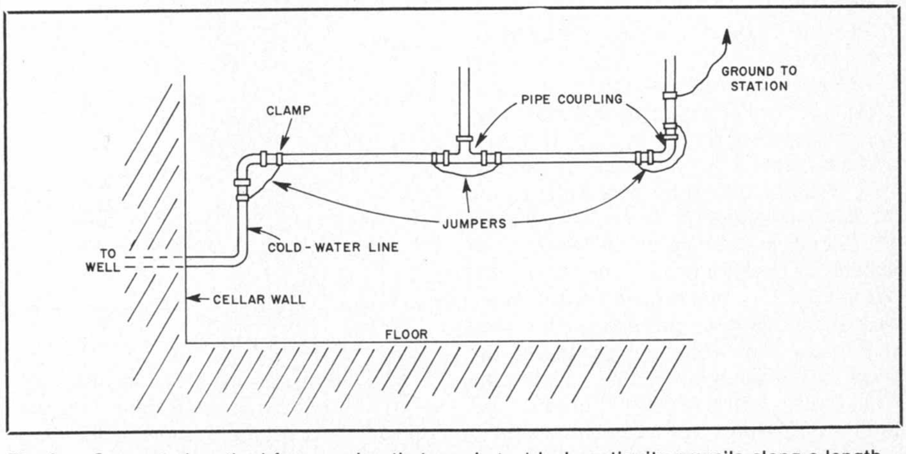


Fig. 3 — Suggested method for ensuring that good electrical continuity prevails along a length of cold-water pipe. Short conductive jumpers are bridged across each pipe joint where adaptors are present.

assurance of a quality ground, since the joints are soldered rather than being screwed together with joint compound. If iron pipes are used in your home, the problem can be solved by placing an electrical jumper wire across the pipe unions all of the way to the water source. The shield braid from RG-8/U coaxial cable is good for this purpose, as is flashing copper.

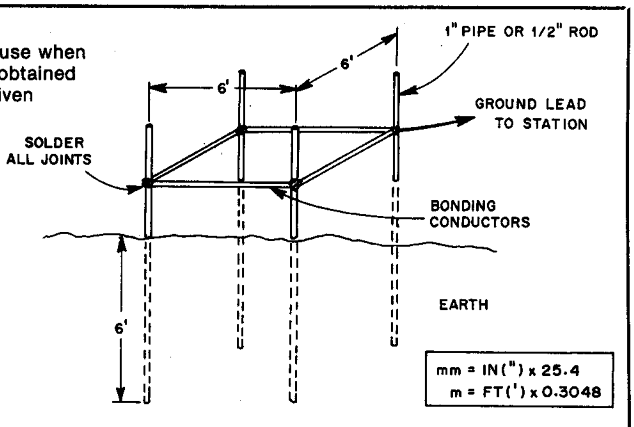
The connections can be made by means of steel cable clamps around the pipes. You can use an ohmmeter to learn if the joints are resistive (bad). A good electrical joint will show a dead short when using the ohmmeter on the low-ohms range. The conductor from the water pipe to the ham shack should be a heavy conductor, such as coaxial-cable braid or similar. See Fig. 3.

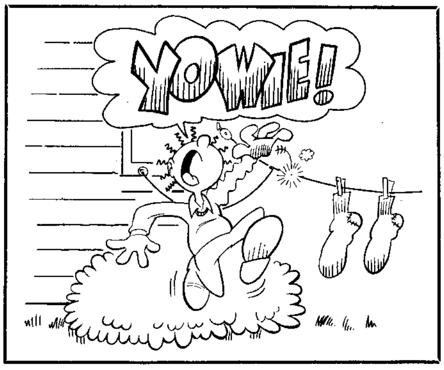
Rods driven into the soil can be effective if they are installed properly. They can be used to supplement the cold-water-pipe ground. Fig. 4 contains a sketch of the method I recommend for creating an earth ground with rods or pipes. Notice that the rods (four or more) are driven into the soil to a depth of approximately 6 feet. They are arranged in a square that is 6 feet per side.[1] Heavy conductor, such as RG-8/U cable shield braid, is used to join the pipes above ground. Ideally, it should be soldered to each pipe. A propane torch is handy for this job, since a soldering iron will not develop ample heat to make a solder connection to a rod or pipe. A heavy conductor is then routed from the ground-rod cluster to the radio room. This lead should be as short as possible. Hence, the ground posts need to be placed as close to the ham shack as practicable. Galvanized pipe or copper-plated rod is suggested for the ground stakes in order to retard rusting or corrosion. Copper pipes may be used as ground rods if you can justify the cost. It may not be possible to drive a copper pipe deeply into the soil, however, since copper is relatively soft. Pilot holes could be driven beforehand with iron pipes, though.

My system has a third ground element tied into the master ground network. I have two no. 12 bare copper wires (made from stripped vinyl-covered house wire) buried 6 inches in the soil. They are 60 feet in length. One of them is attached to the base of my 50-foot tower, which is also grounded by means of rods. It is correct to say that the more extensive your ground system, the better it will be for safety reasons.

[1]mm = in × 25.4; m = ft × 0.3048.

Fig. 4 — A technique for use when an earth ground must be obtained from metal conductors driven deep into the soil. Heavy-gauge bonding straps are soldered at each rod to join the four posts electrically. The station ground is routed by the shortest means possible from the group of ground rods.





There is an additional value for a good earth-ground system: It helps minimize unwanted RF energy on the chassis of station equipment. Too high a level of stray RF energy in the ham station can cause erratic operation of the equipment, and it can "sting" the operator when he or she touches the key, microphone or cabinets of the apparatus.

The Hazards of RF Voltage

Depending on the transmitter output power, thousands of volts of radio-frequency energy can develop in the transmitter amplifier section. The antenna can also carry this high potential. RF energy may cause severe burns to the flesh if someone comes in contact with a conductor that carries it. All of our antennas should, once they are erected, be out of reach to human beings and animals.

I learned this lesson when I lived in an apartment complex where exterior antennas of any description were prohibited for aesthetic reasons. It seemed crafty for me to use the metal clothesline in my back yard for a 10-meter antenna. Each yard had one. Things worked out rather well for a month or more, until my neighbor decided on a summer evening to use the end of my wash line to support himself while he was having a lazy conversation with his wife. He chose the wrong moment, for I was working 10-meter DX at the time with a 100-watt rig! He let out a yell, which brought me to my feet. Upon investigation of the problem I learned what he had done: His hand had a burn mark across all of the palm. Fortunately for me, he understood what had caused the burn, and created no fuss. I ceased using the clothesline for an antenna!

This illustrates what can happen when an amateur antenna is close to the ground. Insulated wire may or may not prevent such a hazard. It would depend on the quality of the insulating material and its characteristic breakdown voltage rating. RF energy will, indeed, get through some inferior grades of insulation unless it is very thick. From all of this emerges a strict rule: Never work on a transmitter or antenna when the transmitter is in the operating mode.

Damage from Lightning, and Protective Measures

Lightning is the most difficult of all danger sources to deal with. Here we are considering many thousands of high-current volts. The greater the power-source current the more devastating the damage will be. The human body, for instance, can endure only a few milliamperes of current before death occurs. When current is permitted to flow through flesh, it will heat the flesh to a point of no return. This may seem like a grim statement to make in an Amateur Radio article, but it can serve as a warning that is worth remembering.

There is no complete protective means against lightning damage to personnel or station equipment! You should disconnect all antennas and ground them when they're not in use. Similarly, all ac line cords should be removed from wall outlets, since energy from lightning can enter the house via the power mains. Whenever a severe storm is forecast, cease using your ham station and follow these procedures.

Lightning arrestors can be purchased for use in amateur antenna systems, but they are by no means a fail-safe solution. I have seen a number of blown-out arrestors that were used in systems where severe equipment damage resulted. The *ARRL Handbook* shows how to build a lightning arrestor for wire antennas. It is a good idea to add one, even though it may not offer complete protection.

What Have We Learned?

All of us want to protect ourselves, our families and our neighbors against shock hazards. This suggests that we should place considerable emphasis on electrical safety when using radio gear that is powered from the ac line. Slipshod methods of grounding the station may result in getting on the air quickly, but the byproduct may be irreparable. Short, large-area ground leads attached to an effective ground system will provide the margin of safety that all of us must rely on when operating a radio station. It is worth mentioning that the better the ground system the less chance there will be for interference to nearby TV and FM receivers.

If your ham station must be located in the basement or cellar for practical reasons, use a large rubber, plastic or rubber-backed carpet pad under the area where you sit or stand near the operating desk. This will ensure additional protection against electric shock. It is best to avoid measuring high voltage until you have the proper equipment and experience. Call in an experienced fellow ham for jobs of that type.