Figure 2-15. Null-balance earth tester (or Megger ®). (Courtesy of James G. Biddle Company.)

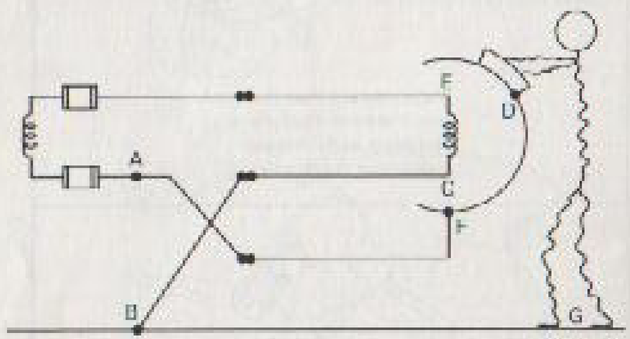


Figure 2-16. Wrong connections in receptacle, perfect insulation on tool and system; result: shock. (From Lt. R. L. Kline and Dr. J. B. Friauf, *Electric Shock—Its Causes and its Prevention*, U.S. Department of the Navy.)

erly. The danger is that you may have many more opportunities to touch ground if you are using an appliance or tool that is not properly grounded.

Remember: If it isn't grounded, it isn't dead.

Ground Fault Interrupters

Whenever insulation, double insulation, isolation, and grounding fail to do their job of keeping electricity in its place, an extremely dangerous situation may develop wherein the exposed parts (frame or shell) of an electrical device develop an unintended electrical potential. By touching such a device, you will establish an unintended path for electric current between the ungrounded conductor and ground. In this ground fault condition, electrocution is very likely to occur, unless your body resistance is high. Regardless of your resistance, no great harm will be done if the circuit is protected by a *ground fault interrupter* or *ground fault circuit interrupter* (Figure 2-17).

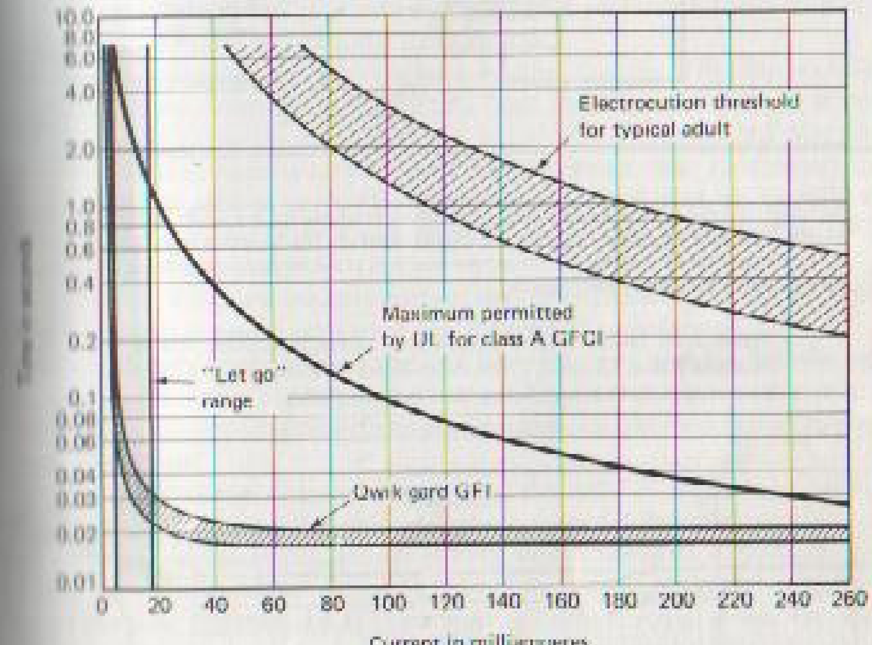


Figure 2-17. Action of ground fault interrupter. (Courtesy of Square D Company.)

The ground fault interrupter (hereafter called *GFI*) is a supersensitive, rapid-action power switch that does nothing until it detects the ominous fact that current is leaking to ground; whereupon, in a few milliseconds, it turns off the whole circuit (see Figures 2-18 and 2-19). With a GFI in the circuit, you may receive an uncomfortable shock from a ground fault, but the shock will not kill you, simply because you are not in the circuit long enough.

For the twenty years that GFIs have been in use in other countries, the National Safety Council reports that there has not been a single recorded electrocution from ground fault in any occupancy employing this type of protection. In 1971 A. W. Smoot of the Underwriters' Laboratories estimated that 81% of the electrocutions in the preceding forty-five months might not have happened if the circuits involved had been protected by GFIs.

volts) lamps and tools powered by an isolation transformer with a grounded static shield between the windings.

Personal Operating Safety Precautions

Proper insulation, grounding, isolation, and lockouts, plus the use of low voltage and ground fault interrupters can make your shop, laboratory, or transmitter room a much safer place in which to work. However, these precautions may be inadequate to keep you from being shocked, if you have poor or careless work procedures.

Here are some basic procedures to follow in the shop or lab:

1. Keep one hand in your pocket when working on energized circuits.
2. If you can't keep your hand in your pocket, do not touch any metal object with your free hand while holding an electrical tool in the other hand.
3. Don't depend on switches to kill a circuit; pull the plug from the outlet.
4. If you are working on high-voltage circuits, have a buddy standing by to help you in case of shock. Just anybody will not do; your observer must know how to kill the circuit to get you loose and how to give you mouth-to-mouth resuscitation and closed-chest heart massage.
5. Do not wear loose clothing, metallic frame eyeglasses, rings, watches, or other jewelry if you are near energized circuits.
6. Do not use an ordinary lamp as an extension trouble light.
7. If directions or instructions are available, follow them. The guy who wrote the book may know more about the hazards involved than you.
8. When you're mentally or physically fatigued, avoid work on energized circuits.
9. To measure high voltages, deenergize the equipment, discharge appropriate capacitors, attach the meter leads, step back, energize the equipment, and make your readings. Don't go probing with a test lead in your hand.
10. Try to make safety protection equipment fail-safe.
11. Never assume that a circuit is dead. Check it first.
12. Do not rely solely on interlocks unless you are certain that they have disconnected the circuit.

13. Have sufficient illumination to see the smallest parts of the equipment you're working on.
14. Discharge all items that can retain a charge.
15. Short out interlocks at your own risk!
16. Study equipment schematic and instruction manual before you start work.
17. If there is any possibility that the equipment chassis may be hot, connect it to an isolation transformer instead of the usual power outlet.
18. Do not draw arcs either intentionally or accidentally. Technicians on missile work have been nearly blinded by low voltage, high current arcs caused by accidental shorts. Such arcs can also be hazardous in flammable atmospheres.

Special Procedures

High Voltage Wire On Car[5]

Bear in mind if you touch the car or any of its occupants, you will suffer a serious accident or even death even though the occupants are safe in the car.

If an occupant of the car, in attempting to get out, should touch the ground and the car simultaneously, he will probably be killed.

Call the power company as soon as possible.

Remain calm and speak calmly.

Don't show excitement or undue concern. People in car may panic.

Stay at least 10 feet from car at all times.

Don't touch car in contact with a wire or the wire itself with anything held by you.

Tell occupants to stay in car.

Don't try to judge whether wire is live.

Tell occupants to drive car from contact with wire if it will operate.

Don't assume that covered wire is insulated. IT IS NOT. Assume any downed wire is dangerous and stay away.

If the car cannot move under its own power and if it is necessary that the occupants leave or be removed from the car, push it from contact with the wire with another car or truck.

If you use a car or truck to push car in contact with wire, remember the pushing vehicle will be energized upon contact with car with wire

[5] From booklet, "Partnership in Public Safety." Reprinted by permission of the Long Island Lighting Co., Mineola, N.Y.

on it. DON'T leave pushing car or let anyone touch either car until the wire has been cleared by both cars or contact between the two cars has been broken.

If the above suggestions are not feasible: Try wedging between the rear windows of another car a branch of a tree, a length of wood, or some other object so that in protruding from the second vehicle it may be used to snag and remove the wire from the first car, so that its occupants may be removed. If a truck is available, the same operation may be accomplished by wedging the protruding object in some section of the truck.

If you wedge a tree branch, section of wood, or some other object between the rear windows or other part of a second vehicle as a protrusion to snag wire from car, the second vehicle will become energized while the protruding object is contacting the wire or the first car.

DON'T leave or permit anyone to touch second vehicle until the protrusion has been cleared of both the wire and the first car.

DON'T permit anyone to touch any part of the object employed as a protrusion while it is in contact with the wire or the first car.

Only if the situation is critical and there is no alternative should the occupants be advised to jump "clear" while car is still in contact with wire.

Rescue From Contact With Fallen Wire[6]

Remember high voltages kill in seconds.

Don't permit a feeling of urgency to influence hasty action which might result in you, too, becoming a victim. Unless only seconds have elapsed since wire fell on victim, it is probably already too late to save his life.

Act with extreme caution.

Don't under any circumstances touch the victim while he is still in contact with wire or touch the wire itself.

Maneuver your car in such a manner as to snag the wire with branch of tree, length of wood, or some other object wedged and protruding from rear window or trunk or some other part of vehicle.

Don't leave your car or permit anyone to touch your car while it or the protruding object is in contact with wire.

Have assistant stand at safe distance until wire has been removed before approaching and removing victim to safe location to administer first aid.

[6]From booklet, "Partnership in Public Safety." Reprinted by permission of the Long Island Lighting Co., Mineola, N.Y.

Don't permit anyone to touch the protruding object while it is in contact with the wire.

FUNDAMENTAL FIRST AID

Fundamental first aid instruction and training are a necessity for technicians and engineers who work with potentially hazardous electrical equipment. It is especially important for such workers to be trained in mouth-to-mouth resuscitation and closed-chest heart massage. Through these first aid measures it is possible to revive many people from what would otherwise be a fatal shock.

The following paragraphs should not be considered an instruction course for cardiopulmonary resuscitation (the combination of mouth-to-mouth resuscitation and closed-chest heart massage). Classroom training using special manikins to practice on is essential for the prospective first-aider in electric shock cases. This is particularly true for closed chest massage, which may cause cracked ribs or a punctured lung if not done properly.

Classes on cardiopulmonary resuscitation (CPR) are given by several groups, including some YMCA's, electric utilties, and military groups. Look for them in your area.

The intent of the following paragraphs is not to show you how to do CPR but to show you how relatively simple CPR is. These paragraphs have been extracted from information supplied by the Edison Electric Institute, the American National Red Cross, and the American Heart Association.

In some cases the victim of a severe electric shock may be thrown from a hot line or equipment because of muscle spasms, while at other times the victim may remain frozen to the point of contact. To free such a victim without becoming a victim himself, a rescuer must be extremely careful. The safest way, of course, is to open the proper switch or to use well-insulated tools to cut the power line. If this is not possible, try to find several rubber mats or a *dry* rope to pull the victim loose. Freeing the victim this way can be a very tricky procedure and requires the utmost caution. Obviously the farther away you, as the rescuer, are from the victim the safer you will be.

Once the victim has been removed from the circuit and both you and the victim are at a safe distance from the hot line, you must start CPR immediately—seconds count. Within four to six minutes the brain will suffer irreparable damage unless CPR is started (see Figure 2-27). Therefore, there is no time to drag the victim to a more comfortable location or to call for help, or to even loosen his clothes.

Naturally, if the victim is conscious, there is no need for CPR. If he is unconscious, the first step is to observe his chest, listen at his nose and mouth, and feel for the movement of air. If none of these indications of breathing

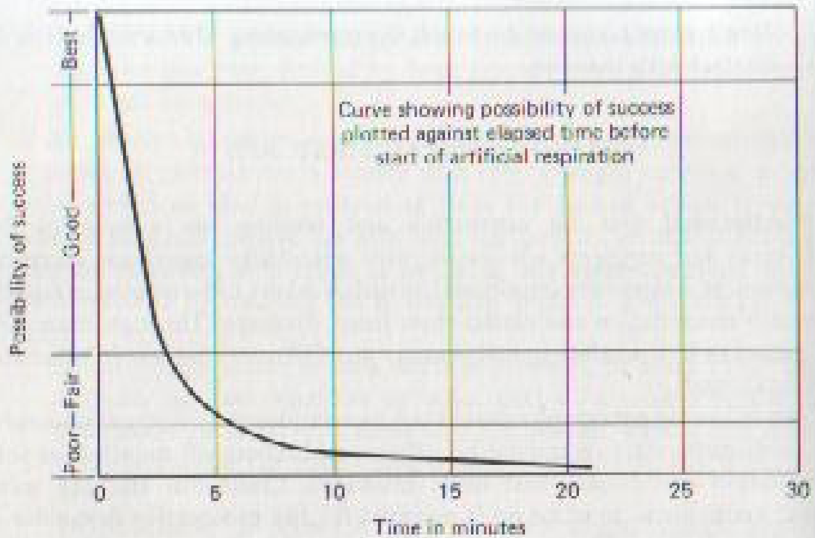


Figure 2-27. Possibility of success vs elapsed time before start of artificial respiration. (Courtesy of Edison Electric Institute.)

are present, give the victim six quick breaths using the following procedure (see Figure 2-28):

1. If foreign matter is visible in the mouth, wipe it out quickly with your fingers, wrapped in a cloth, if possible.
2. Tilt the victim's head backward so that his chin is pointing upward. This is accomplished by placing one hand under the victim's neck and lifting, while the other hand is placed on his forehead and pressing. This procedure should provide an open airway by moving the tongue away from the back of the throat.
3. Maintain the backward head-tilt position and, to prevent leakage of air, pinch the victim's nostrils with the fingers of the hand that is pressing on the forehead.

   Open your mouth wide; take a deep breath; and seal your mouth tightly around the victim's mouth with a wide-open circle and blow into his mouth. If the airway is clear, only moderate resistance to the blowing effort will be felt.

   If you are not getting air exchange, check to see if there is a foreign body in the back of the mouth obstructing the air passages. Reposition the head and resume the blowing effort.
4. Watch the victim's chest, and when you see it rise, stop inflation, raise your mouth, turn your head to the side, and listen for exhalation. Watch the chest to see that it falls.

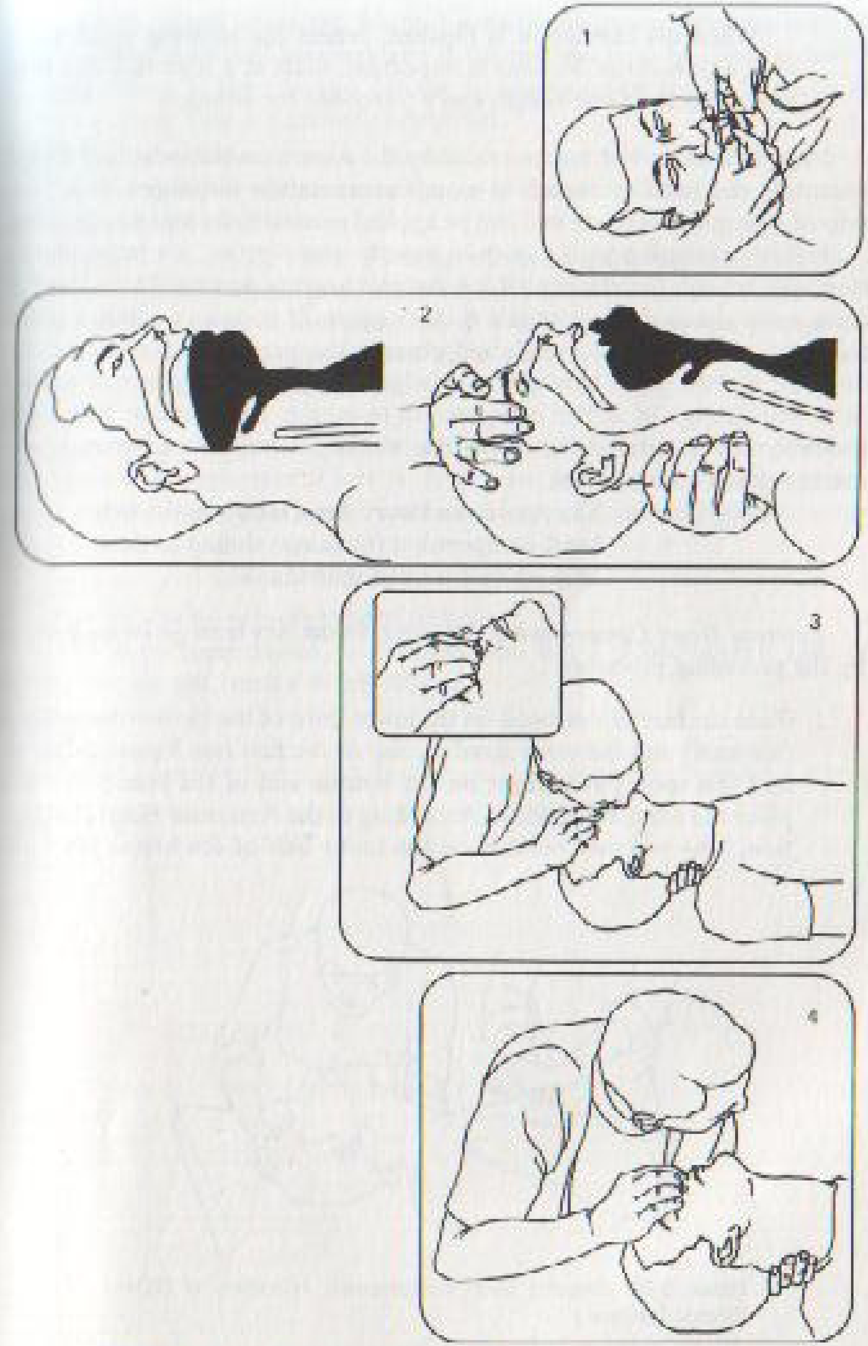


Figure 2-28. Mouth-to-mouth resuscitation. (Reprinted with permission of the American Red Cross.)

When his exhalation is finished, repeat the blowing cycle, for a total of 6 breaths. Volume is important. Start at a high rate and then provide at least one breath every 5 seconds for adults.

Steps 1 through 4 above, provided by the American National Red Cross, constitute the familiar mouth-to-mouth resuscitation technique. It is considered a simple procedure and can be applied even without manikin practice.

Before continuing with mouth-to-mouth resuscitation, it's important to stop long enough to determine if the victim's heart is beating. To do this feel for a pulse alongside the victim's Adam's apple. If you can't detect a pulse, raise one of the victim's eyelids and observe the pupil. If it is enlarged and does not narrow down in response to bright light, then the heart has stopped or is fibrillating. In either case, mouth-to-mouth resuscitation alone will probably not be enough to revive the victim; it must be combined with external heart compression.

CAUTION: The American Heart Association warns that heart compression (massage) should be done only by well-trained individuals.

External Heart Compression.[7] After the victim has been given six breaths by the preceding procedure:

1. Place the heel of one hand on the lower third of the victim's breastbone (sternum) and the other hand on top of the first (see Figure 2-29). To find this spot, put a finger on the bottom end of the breastbone and place the hand alongside it. According to the American Heart Association, "the pressure point is on the lower half of the breast plate just

Figure 2-29. External heart compression. (Courtesy of Edison Electric Institute.)

[7] *Resuscitation Manual*, Edison Electric Institute. Reprinted by permission of Edison Electric Institute.

above its soft lower end where it joins the abdomen. Pressure must be applied here and nowhere else if the method is to be effective and if breaking of the ribs and damage to organs inside the body are to be avoided. This is extremely important."

2. With the fingers extended so that no pressure is applied to the ribs, press down firmly and quickly, so that the breastbone is depressed about $1\frac{1}{2}$ to 2 inches.
3. If you're working alone, interrupt the heart compressions about every 15 or 20 strokes to give two or three breaths of air to the victim. If another rescuer is available, one of you should apply heart compressions at 60 cycles per minute while the other gives mouth-to-mouth resuscitation at 12 cycles per minute.

When to Stop. Continue resuscitation until the victim revives, medical help arrives, or rigor mortis sets in. If you are applying heart compression, do not use a "pressure-cycled" mechanical resuscitator for ventilating the lungs.

Do Not:

Give liquids to an unconscious person.

Give heart compression to a victim who has a pulse, broken ribs, or pupils that do not remain widely dilated.

hand, it is much less severe than if it flows from one hand through your heart and lungs to the other hand. For this reason, technicians working on hot circuits are always cautioned to put one hand behind the back or in the pocket.

RECOGNIZING SHOCK HAZARDS

Electrically unsafe equipment may continue to operate effectively without giving any warning to the user. However, in many situations electric shock hazards are quite obvious to the average technician or engineer. You don't have to be an expert to know that any kind of electrical equipment near swimming pools, marinas, bathrooms, basements, damp floors, or outdoors can be dangerous. It should be apparent too that any antenna you erect may fall, either during erection or later during use; if a power line is in the path of the fall, current may flow down the mast or guy wires to anyone unlucky enough to be holding on to either. It is likely that some of the victims of antenna shocks in recent years were aware of the potential danger. Possibly they misjudged the distance from the antenna to the power line, or, having recognized all the dangers they erected the antenna from the safe side of the line, only to have it fall in "the wrong direction," hitting the power line. Another situation may be seen in Figure 2-4.

Murphy's law—"if something *can* go wrong, it *will* go wrong"—should be kept in mind in any electrical or electronic installation, operation, test, or maintenance procedure. It is equally important never to assume anything about any electric circuit except perhaps that it can kill you if you don't take the proper precautions.

A few of the more obvious shock hazards are listed in Table 2-3. Table 2-4 lists some shock hazards that are not so obvious—in fact they may be

TABLE 2-3 *Obvious electric shock hazards*

Testing a circuit with a wet finger to see if it's "live"
Working on circuits assumed to be "dead" before checking that they *are* dead, and failing to prevent such circuits from being energized by others
Any electrical device that gives you a "tingle" when you touch it
Electrical equipment that does not have the Underwriters Laboratories (UL) label on both the cord and the equipment
Spliced, broken, frayed, and cracked cords and plugs
Ungrounded tools (drills, etc.), unless they are protected by double insulation
Transformer-less sets that may have hot chassis
Electric cords in floors where they may be worn or broken by people walking over them
Overloaded receptacles and circuits
Using metal ladders where they may brush or fall against power lines
Drilling into wall or floor without knowing what's on other side—it could be a hot electrical circuit

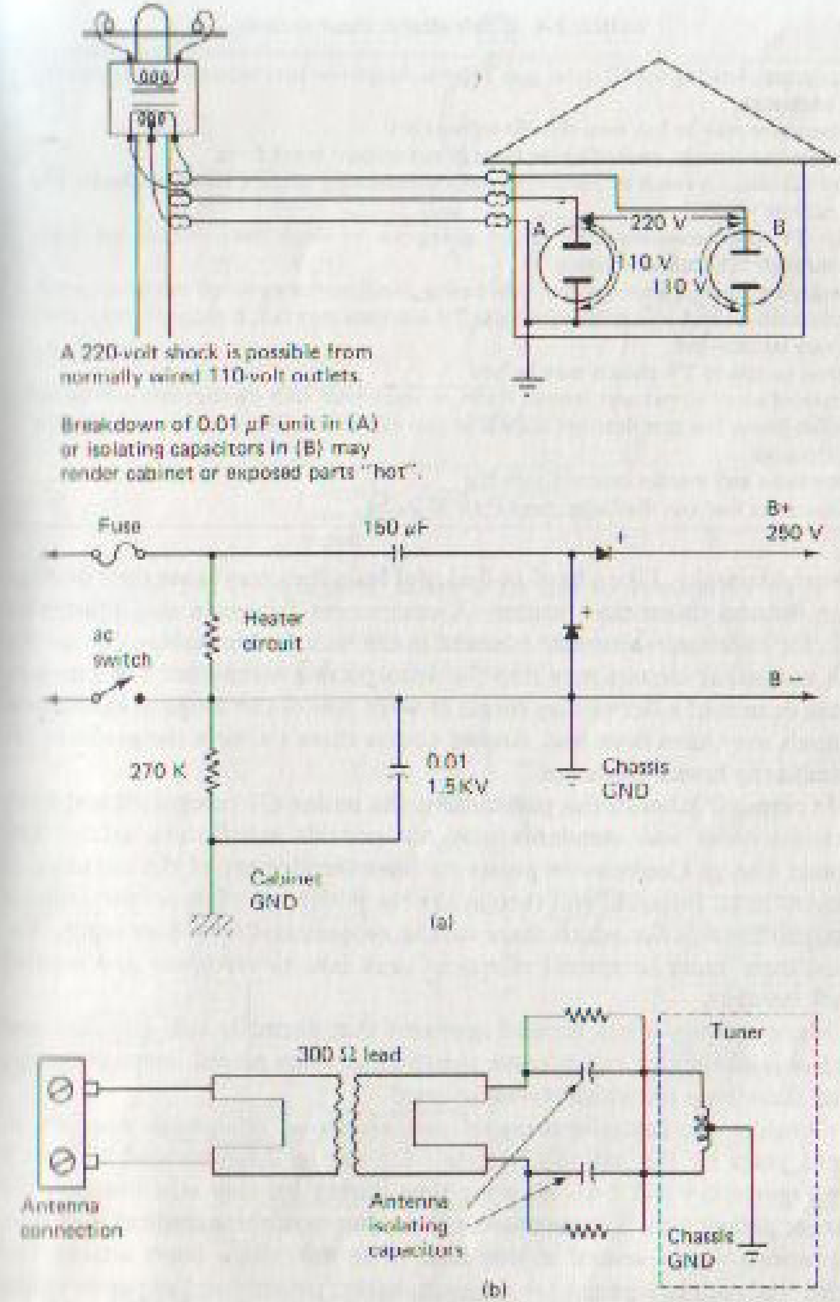


Figure 2-4. Possible shock hazards. (Courtesy of *Radio & TV News.* From Kenneth Braham, "Hot Chassis? Play It Safe," *Radio & TV News*, Dec. 1958, Copyright 1958 by Ziff-Davis Publishing Co.)

TABLE 2-4 *Subtle electric shock hazards*

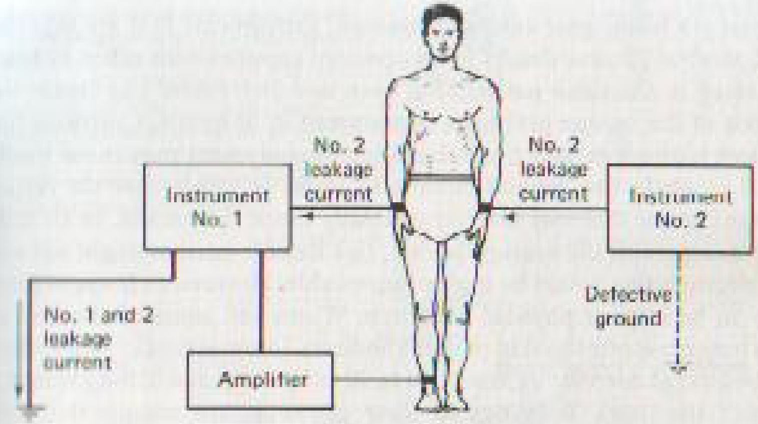
Equipment bearing the UL label may become dangerous later because of environment or misuse
Equipment may be hot even though turned OFF
Unfamiliar circuits, unpredictable types of component breakdown
Hot cabinets—a result of failure to replace insulating spacers between chassis and cabinet
Hot TV antenna—component failure giving rise to shock path through set balun through twinlead to antenna
Replacing push-on knobs with knobs having metal setscrews which can become hot
Insulation around collapsible rabbit-ear TV antennas may fail; if chassis is hot, rabbit ears become hot
Items on top of TV chassis may be hot
Exposed metal screws and control shafts on equipment with plastic cases may be hot
Fallen power line that does not crackle or pop can be harmless one minute and lethal the next
Interlocks and bleeder resistors may fail
Capacitors that can discharge more than 50 joules

downright sneaky. Like a hard-to-find roof leak, they may cause their damage some distance from their source. A component failure in one equipment rack, for instance, may create a hazard in the rack next to it. New equipment with unfamiliar circuits may trap the unsuspecting technician. The previous owner or user of a device may forget to warn you of the dangers. Instruction manuals may have been lost. And of course there's always the problem of: "Familiarity breeds contempt."

In research laboratories particularly, the nationally recognized and local electrical codes and standards may not provide satisfactory safety. The Atomic Energy Commission points out that the element of the unknown is inherent in all research, and therein lies the possibility of direct and indirect electrical hazards for which there can be no previous record or experience. Thus, there must be special efforts in such labs to recognize and control shock hazards.

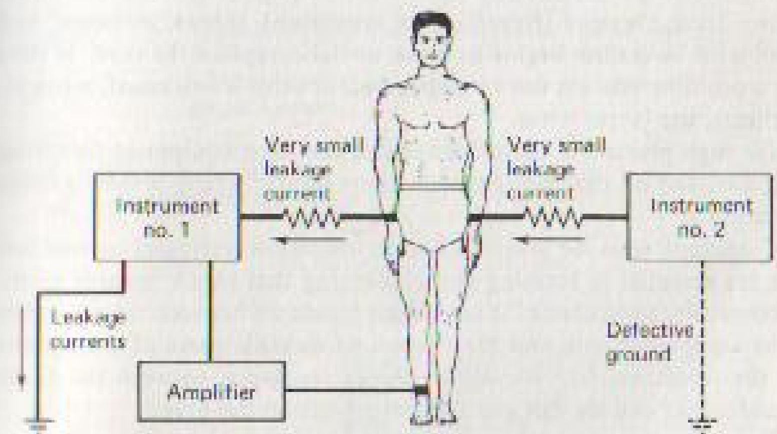
More recently it has become apparent that normally safe electrical and electronic equipment can become treacherous when placed in environments other than those for which it was designed.

Consider the fantastic array of new electronic equipment acquired in recent years by the nation's hospitals for use in diagnosis and treatment (see Figures 2-5 and 2-6). At some time during his stay at a hospital, the average patient may be connected to one or more of these medical electronic instruments—even several at one time if he has had a heart attack. The benefits of such equipment are unquestionable; patients and physicians alike profit from their use. Unfortunately, in some situations this equipment may deal the patient a fatal shock. Although the specific number of patients electrocuted each year in our hospitals is debatable, there is no denying that



Even with feedback amplifier, patient is in danger of shock when more than one instrument is used.

Figure 2-5. Potential shock hazard in the hospital. (Courtesy of *Popular Electronics*. From Hector French, "Medical Electronic Equipment and Hospital Safety," *Popular Electronics*, Jan. 1972, Copyright 1972 by Ziff-Davis Publishing Co.)



Safest hookup is shown here. In addition to amplifier, current-limiting high isolation inputs are used.

Figure 2-6. Safe hookup for the hospital patient. (Courtesy of *Popular Electronics*. From Hector French, "Medical Electronic Equipment and Hospital Safety," *Popular Electronics*, Jan. 1972, Copyright 1972 by Ziff-Davis Publishing Co.)