Section 2
Dangers of Electrical Shock

The severity of injury from electrical shock depends on the amount of electrical current and the length of time the current passes through the body. For example, 1/10 of an ampere (amp) of electricity going through the body for just 2 seconds is enough to cause death. The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 milliamperes (milliamps or mA). Currents above 10 mA can paralyze or “freeze” muscles. When this “freezing” happens, a person is no longer able to release a tool, wire, or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current. For this reason, hand-held tools that give a shock can be very dangerous. If you can’t let go of the tool, current continues through your body for a longer time, which can lead to respiratory paralysis (the muscles that control breathing cannot move). You stop breathing for a period of time. People have stopped breathing when shocked with currents from voltages as low as 49 volts. Usually, it takes about 30 mA of current to cause respiratory paralysis.

Currents greater than 75 mA cause ventricular fibrillation (very rapid, ineffective heartbeat). This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim. Heart paralysis occurs at 4 amps, which means the heart does not pump at all. Tissue is burned with currents greater than 5 amps.²

The table shows what usually happens for a range of currents (lasting one second) at typical household voltages. Longer exposure times increase the danger to the shock victim. For example, a current of 100 mA applied for 3 seconds is as dangerous as a current of 900 mA applied for a fraction of a second (0.03 seconds). The muscle structure of the person also makes a difference. People with less muscle tissue are typically affected at lower current levels. Even low voltages can be extremely dangerous because the degree of injury depends not only on the amount of current but also on the length of time the body is in contact with the circuit.

LOW VOLTAGE DOES NOT MEAN LOW HAZARD!

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1. **ampere (amp)**—the unit used to measure current
2. **milliampere (milliamp or mA)**—1/1,000 of an ampere
3. **shocking current**—electrical current that passes through a part of the body
4. **You will be hurt more if you can’t let go of a tool giving a shock.**
5. **The longer the shock, the greater the injury.**

Defibrillator in use.
Sometimes high voltages lead to additional injuries. High voltages can cause violent muscular contractions. You may lose your balance and fall, which can cause injury or even death if you fall into machinery that can crush you. High voltages can also cause severe burns (as seen on pages 9 and 10).

At 600 volts, the current through the body may be as great as 4 amps, causing damage to internal organs such as the heart. High voltages also produce burns. In addition, internal blood vessels may clot. Nerves in the area of the contact point may be damaged. Muscle contractions may cause bone fractures from either the contractions themselves or from falls.

A severe shock can cause much more damage to the body than is visible. A person may suffer internal bleeding and destruction of tissues, nerves, and muscles. Sometimes the hidden injuries caused by electrical shock result in a delayed death. Shock is often only the beginning of a chain of events. Even if the electrical current is too small to cause injury, your reaction to the shock may cause you to fall, resulting in bruises, broken bones, or even death.

The length of time of the shock greatly affects the amount of injury. If the shock is short in duration, it may only be painful. A longer

<table>
<thead>
<tr>
<th>Current</th>
<th>Reaction</th>
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</thead>
<tbody>
<tr>
<td>1 milliamp</td>
<td>Just a faint tingle.</td>
</tr>
<tr>
<td>5 milliamps</td>
<td>Slight shock felt. Disturbing, but not painful. Most people can “let go.”</td>
</tr>
<tr>
<td>6–25 milliamps (women)†</td>
<td>Painful shock. Muscular control is lost. This is the range where “freezing currents” start. It may not be possible to “let go.”</td>
</tr>
<tr>
<td>9–30 milliamps (men)</td>
<td>Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.</td>
</tr>
<tr>
<td>50–150 milliamps</td>
<td>Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.</td>
</tr>
<tr>
<td>1,000–4,300 milliamps (1–4.3 amps)</td>
<td>Cardiac arrest and severe burns occur. Death is probable.</td>
</tr>
<tr>
<td>15,000 milliamps (15 amps)</td>
<td>Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!</td>
</tr>
</tbody>
</table>

*Effects are for voltages less than about 600 volts. Higher voltages also cause severe burns. †Differences in muscle and fat content affect the severity of shock.
shock (lasting a few seconds) could be fatal if the level of current is high enough to cause the heart to go into ventricular fibrillation. This is not much current when you realize that a small power drill uses 30 times as much current as what will kill. At relatively high currents, death is certain if the shock is long enough. However, if the shock is short and the heart has not been damaged, a normal heartbeat may resume if contact with the electrical current is eliminated. (This type of recovery is rare.)

The amount of current passing through the body also affects the severity of an electrical shock. Greater voltages produce greater currents. So, there is greater danger from higher voltages. Resistance hinders current. The lower the resistance (or impedance in AC circuits), the greater the current will be. Dry skin may have a resistance of 100,000 ohms or more. Wet skin may have a resistance of only 1,000 ohms. Wet working conditions or broken skin will drastically reduce resistance. The low resistance of wet skin allows current to pass into the body more easily and give a greater shock. When more force is applied to the contact point or when the contact area is larger, the resistance is lower, causing stronger shocks.

The path of the electrical current through the body affects the severity of the shock. Currents through the heart or nervous system are most dangerous. If you contact a live wire with your head, your nervous system will be damaged. Contacting a live electrical part with one hand—while you are grounded at the other side of your body—will cause electrical current to pass across your chest, possibly injuring your heart and lungs.

- **The greater the current, the greater the shock!**
- **Severity of shock depends on voltage, amperage, and resistance.**
- **Resistance**—a material's ability to decrease or stop electrical current
- **Ohm**—unit of measurement for electrical resistance
- **Lower resistance causes greater currents.**
- **Currents across the chest are very dangerous.**

Power drills use 30 times as much current as what will kill.
A male service technician arrived at a customer's house to perform pre-winter maintenance on an oil furnace. The customer then left the house and returned 90 minutes later. She noticed the service truck was still in the driveway. After 2 more hours, the customer entered the crawl space with a flashlight to look for the technician but could not see him. She then called the owner of the company, who came to the house. He searched the crawl space and found the technician on his stomach, leaning on his elbows in front of the furnace. The assistant county coroner was called and pronounced the technician dead at the scene. The victim had electrical burns on his scalp and right elbow.

After the incident, an electrician inspected the site. A toggle switch that supposedly controlled electrical power to the furnace was in the “off” position. The electrician described the wiring as “haphazard and confusing.”

Two weeks later, the county electrical inspector performed another inspection. He discovered that incorrect wiring of the toggle switch allowed power to flow to the furnace even when the switch was in the “off” position. The owner of the company stated that the victim was a very thorough worker. Perhaps the victim performed more maintenance on the furnace than previous technicians, exposing himself to the electrical hazard.

This death could have been prevented!

- The victim should have tested the circuit to make sure it was de-energized.
- Employers should provide workers with appropriate equipment and training. Using safety equipment should be a requirement of the job. In this case, a simple circuit tester may have saved the victim’s life.
- Residential wiring should satisfy the National Electrical Code (NEC). Although the NEC is not retroactive, all homeowners should make sure their systems are safe.

**NEC—National Electrical Code**
a comprehensive listing of practices to protect workers and equipment from electrical hazards such as fire and electrocution.

Electrical burn on hand and arm.
There have been cases where an arm or leg is severely burned by high-voltage electrical current to the point of coming off, and the victim is not electrocuted. In these cases, the current passes through only a part of the limb before it goes out of the body and into another conductor. Therefore, the current does not go through the chest area and may not cause death, even though the victim is severely disfigured. If the current does go through the chest, the person will almost surely be electrocuted. A large number of serious electrical injuries involve current passing from the hands to the feet. Such a path involves both the heart and lungs. This type of shock is often fatal.

Arm with third degree burn from high-voltage line.
Summary of Section 2

The danger from electrical shock depends on . . .

the amount of the shocking current through the body,

the duration of the shocking current through the body, and

the path of the shocking current through the body.