CHAPTER I

RECOGNIZING AND AVOIDING THE HAZARDS OF ELECTRICAL EQUIPMENT

INTRODUCTION

Over the past years there have been many documented firefighter fatalities by electrocution. The purpose of this program is to:

- give you a basic knowledge of how electricity works,
- help you to understand basic construction,
- explain configurations of the electric utilities,
- make you aware of the hazards of electricity.

This chapter will help you better understand what precautions need to be taken when working around electrical equipment.

Electricity is invisible. When you look at an electric wire that could be energized from 120 volts all the way up to 500,000 volts, it seems harmless enough. That is why electrical energy is often referred to as the "**silent killer**" and remains a hazardous form of energy that has to be dealt with safely.

No matter what the voltage is in an electrical conductor, it is dangerous and can injure and/or kill emergency workers.

Some people believe that 120 volts (normal household current) is harmless. However, throughout the electrical industry there have been people killed when they have made contact with 120 volts. **Any voltage can kill!** It all depends on the situation, the amount of current involved, the part of the body affected, the duration of contact, and environmental conditions (wet or dry) at the time of contact.

Electricity is a blessing that is often taken for granted and must be treated with respect. *Electrocution is the fifth-leading cause of workplace death.* The majority of these fatalities are caused by the failure to recognize and avoid electrical hazards.

ELECTRICITY— THE BASICS

This section provides a general summary of electricity and electrical equipment. Key safety and tactical points are indicated.

Suppose nothing is coming out of a hose, but there is water under pressure inside it. If you open the valve, the force of that internal pressure releases a spray of water. An energized wire is similar. The force that causes electrons to flow is called voltage, and like water, the greater the pressure pushing electricity through a line, the higher the voltage. In water terms the pressure is measured in pounds per square inch. With electricity, pressure is measured in volts.

- *Voltage* is the electric force that causes the free electrons to move from one atom to another. Just as water needs pressure to force it through a hose, electrical current needs a force to make it flow. A *volt* is the measure of *electric pressure.* Voltage is usually supplied by a battery or a generator.
- Current is electricity in motion. It measures the amount of electrons that can flow through a material like a conductor. Electric current is measured in *amperes,* or "amps" for short. Amperes is like the amount of water flowing through a hose in a certain amount of time or the amount of electricity flowing through a wire.

Tactical Point If you discover someone who has made an electrical contact, do not attempt to pull the victim away from the source of contact with your hands. The power supply should be disconnected by the power company first. This may be done remotely by phoning the power company.

If someone is working from an elevated aerial apparatus and makes contact with an energized electrical conductor, *do not* climb onto the vehicle to lower the injured person by using the lower controls of the aerial apparatus until the power source has been de-energized or the aerial apparatus is clear of the electrical conductor.

The risk of electrical shock or contact can be reduced by:

- being able to identify electrical wires and equipment as you arrive at the incident.
- maintaining a safe working distance from any electrical wires or equipment.

- Resistance—The opposition to electrical current flow, measured in ohms.
- Conductors—These are made of materials that electricity can flow through easily.

These materials are made up of atoms whose electrons can move away freely.

Some Examples of Conductors Are

- Copper
- Aluminum
- Platinum
- Gold
- Silver
- Water
- People and Animals
- Trees

Electricity will always take the shortest path to the ground. Your body is 70 percent water, and that makes you a good conductor of electricity. If a power line has fallen on a tree and you touch the tree you become the path or "conductor" to the ground and could be *electrocuted.*

- Insulators are the opposite of conductors. The atoms in these materials are not easily freed and are stable, preventing or blocking the flow of electricity.

Some Examples of Good Insulators Are

- Glass
- Porcelain
- Plastic
- Rubber

The rubber or plastic on an electrical cord provides an *insulator* for the wires. By covering the wires, the electricity cannot go through the rubber and is forced to follow the path on the aluminum or copper wires.

As mentioned above, electricity flowing through a conductor is similar to water flowing through a pipe.

If you take a water pipe with the faucet shut off, there is water in the pipe putting pressure *(volts)* on the pipe. However, there is no flow of water *(amps)* since the faucet is turned off. This is the same situation found in a home when the electrical wiring is connected to a TV or other appliance and the switch is turned off.

When the faucet is opened, water starts to flow *(amps).* The rate at which the water flows depends on two things:

1. *The size of the pipe. (electrical comparison—resistance)*
2. *The pressure of the water. (electrical comparison—volts)*

Once you have *pressure (volts)* and *flow (amps)* you have accomplished *work (power, watts).* Just like the water that comes out of a faucet to fill a pot, water the lawn, and so on, the electricity is running the TV, VCR, lighting, and so on. Electric power is the term used for the product of the voltage and current in a circuit.

The length of time that you let the water flow will determine the gallons that are used; this is measured by the water meter. Likewise, the length of time the power is used is measured in watts by the electric meter and billed as a kilowatt-hour (1 kw = 1,000 watts).

Electricity is always trying to reach earth, which is ground, through the path of least resistance. In order to control electricity, insulators are used to isolate the energized conductors from all sources of ground potential. Air is a natural insulator; once an electrical arc has started the air becomes ionized which is now contaminated. The arc will continue until it is interrupted.

Caution Consider all downed wires as ENERGIZED until the utility representative confirms they are safe.

THE ELECTRIC SYSTEM

Generation

Electricity generating or power plants may be large or small, and generation is produced by several means: fossil, hydro, or nuclear. Generation is produced by several means: fossil, hydro, or nuclear. Appearances of the power plants differ, as does the equipment in the plant. However, there are certain conditions and equipment that are somewhat common to all power plants, such as the turbine, boiler, condenser, and electrical switch rooms.

The voltage that is produced by the generators is stepped or raised up through the use of power transformers to levels used to transmit the power by electrical transmission lines to locations miles from the generating stations. These transmission line voltages range from *115,000 to 500,000 volts. Transmission line towers* are usually 100 to 200 feet high and run in a straight line along utility right of ways. In most cases, the wires with the highest voltage are those at the tops of utility poles. Keep in mind that most poles also have other utility wires, such as telephone and cable.

The electrical power is carried great distances on these towers *to large substations.* An electric substation performs one or more of the following functions: (1) It transforms electric energy from one voltage to another, (2) it serves as a control center and switching facility, or (3) it serves as a center for distributing electric energy to end-use customers.

Substations can be classified into three categories: inside, outside, and a combination of both. Some are hidden from site by constructing a three-sided house around the station.

All substations contain electrical equipment, with some being insulating mineral oil filled, and/or pressurized insulating gas, such as sulfur hexafluoride (SF-6).

At these substations the voltage is stepped down, again by the use of power transformers, to *34,500 volts.* The 34,500-volt electrical conductors are carried to *smaller substations* on high utility poles ranging from 60 to 90 feet in height that run along power right of ways.

At these smaller substations, the voltage is once again reduced, this time to the *primary voltage level (2,400 to 19,900) volts.* These conductors are carried on smaller utility poles (40 to 50 feet in height) along residential streets.

The first objective of fire personnel is to size-up and communicate as much information to the utility as possible. Transmission substations, located with generating stations, are used to step-up the voltage from the generator; for example, 24,000 volts up to the transmission voltage of 115,000 volts or higher.

Distribution substations are located throughout communities; it steps the voltage down for distribution throughout neighborhoods. Distribution voltage may vary from 2,400 to 34,000 volts.

In order to reduce the voltage for residential use, there are *transformers* located on these poles that step the voltage down to *120 volts.* This is the voltage that is carried on the wire running from the utility pole to your home.

As you turn on a light switch in your home the electrical power is transmitted to the light bulb. Electric utility primary *(higher voltage)* lines contain *10 to 500 amps* and their *secondary (household current)* lines contain *60 to 400 amps.* Even though the voltage is lower in household currents the amperage is the same or higher than in higher voltage lines. There is enough amperage in secondary lines to cause serious injury or a fatality if contact is made.

At the top of a utility pole is the *power company's primary conductors.* These conductors may be covered with non-insulated weather jackets or bare. The voltage in these conductors could range from *2,400 volts to 19,900 volts.* There could be a single wire or as many as four at this location on the pole.

The next area down from the primary location is the power company's *secondary conductors.* The voltage in these conductors is usually *120 volts (residential areas).* However, in some situations the voltage may be as high as *480 volts (industrial areas).*

Voltage in the primary lines usually is 2,400 volts to 19,900 volts and secondary voltages range from 120 volts to 480 volts (Figure I-1).

Insulators are made from high di-electric or insulating materials, such as *glass, porcelain, polymer, plastic,* and so on. Insulators provide a mechanical means of clearance to prevent voltage from tracking to ground or another energized phase.

The *number of insulators ganged, or joined together* at any given point may give you a *general indication of the voltage level.* The more insulators on a single string, generally the higher the voltage.

In order to reduce the voltage for residential use, there are transformers located on poles that step the voltage (2,400 to 19,900) down to secondary voltage (120 to 480). Power transformers are located between the primary and secondary conductors. This is the voltage that is carried on the wire running from the utility pole to your home.

Safety Firefighters should never enter a substation property unless accompanied by a utility representative.

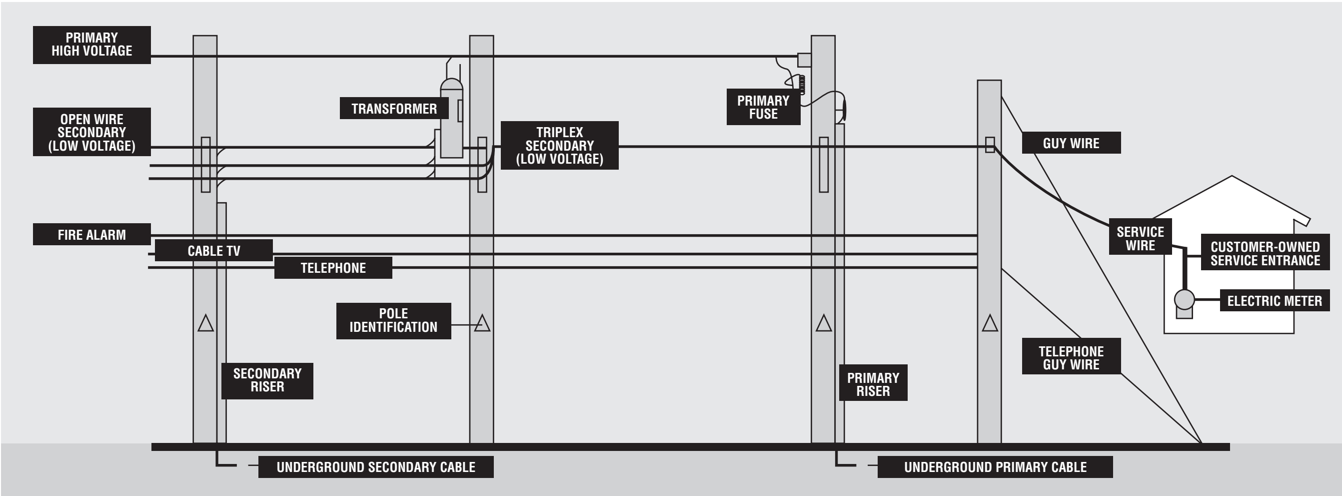

Figure I-1 Typical distribution system.

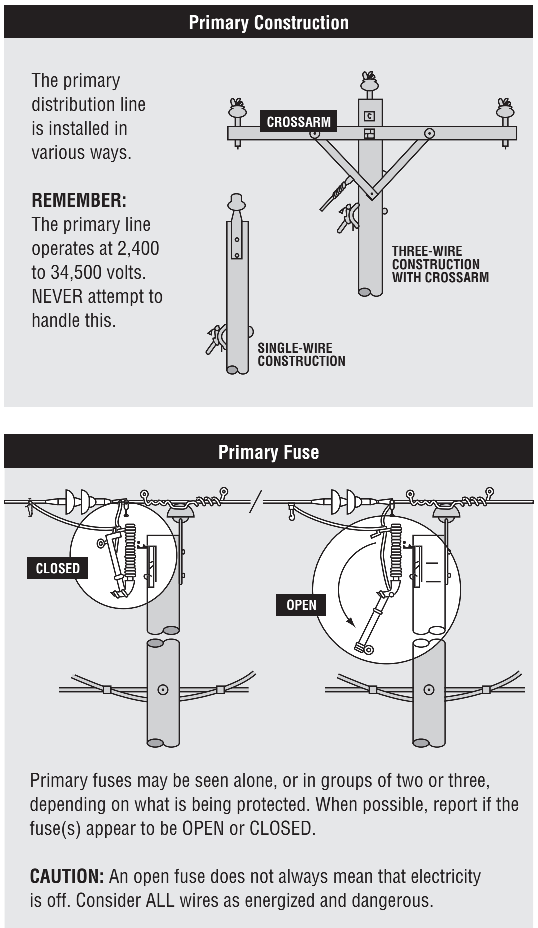

Figure I-2 Primary construction.

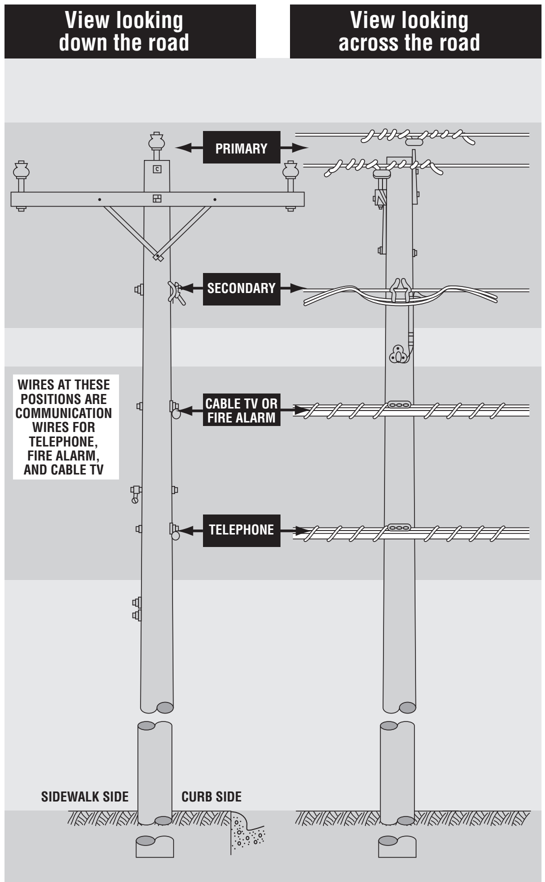

Figure I-3 Pole space construction.

Overhead electrical wires are all installed under strain. That is one of the reasons fire apparatus should be staged no closer than two pole lengths to either side of a pole that is involved in the incident.

Pole-mounted equipment can contain mineral insulating oil; if there is a spill, immediately notify the electric utility, Figure I-4.

Extreme caution should always be taken during storm conditions. Downed power lines may or may not be energized.

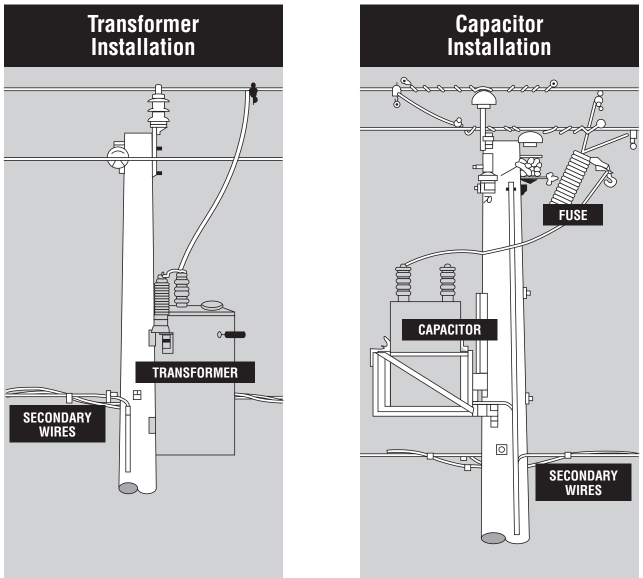

Figure I-4 Pole top utility facilities.

> **Safety** Protect with diking techniques any water runoff area that could be affected by the oil spill. Do not attempt to wash away the oil spill.
>
> Never position yourself or an apparatus directly under a pole involved in the incident.
>
> Positioning of aerial apparatus must be considered upon arrival: survey the area, locate overhead wires, and position the apparatus, maintaining a minimum of 10 feet from all overhead conductors.
>
> Consider all downed wires as ENERGIZED until the utility representative confirms they are safe.

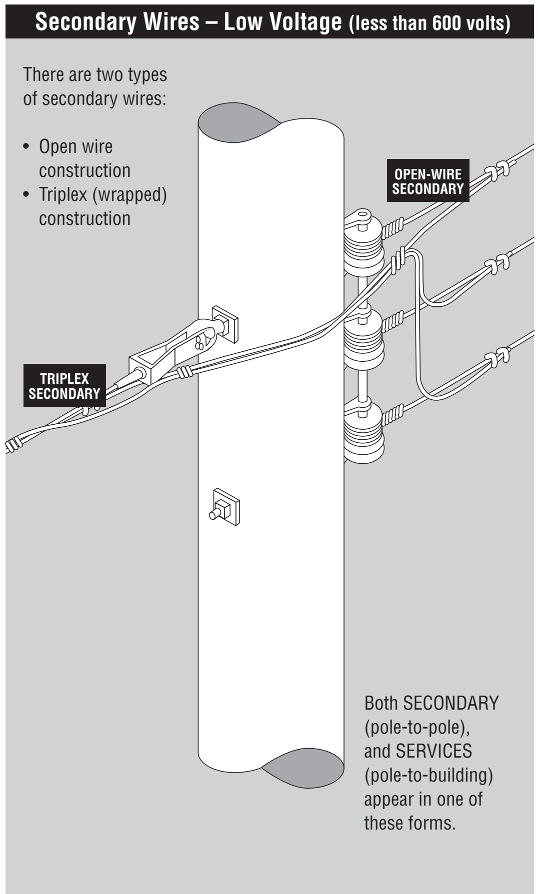

Figure I-5 Secondary wires.

> **Safety** Do not take chances: call the local power company for help. During a storm, stay away from any downed lines.

Identifying the type of a downed wire (power, phone, fire alarm, or cable TV) is difficult when the lines are covered with debris, ice, or snow. *Again, just stay away and call for help.*

Whenever there is a downed energized electrical line, a phenomenon known as "*step voltage*" may be present on the ground around the fallen power conductor. The downed conductor may energize the ground causing a rippling effect around the point where it is making contact with the ground and the voltage decreases as you go out from the center of this point.

In a *residential underground system,* the power, gas, phone, and cable television companies all have underground cables in certain areas to serve their customers. The first sign that you might be in an underground area is that there are no utility poles around.

The voltages in the power company's underground system are the same as their overhead systems.

Many times the power, phone, cable television, and even the gas company's lines and cables look alike and identification may not always be easy. Underground distribution lines are distribution lines that are directly buried underground to padmount transformer installations. The voltages can range from 2,400 volts to 34,500 volts. Pad mount transformers are locked and should only be handled or opened by a utility representative.

ELECTRICAL SHOCK

Electrical shock remains the greatest hazard in an electrical contact. Besides the pain that is suffered, there is often a loss of muscle control and continued contact could lead to a fatal injury.

Electric shock will occur when a person, by contacting an energized conductor or other energized objects, provides a path for the flow of electricity to a ground. Simultaneous contact with two energized conductors will also cause electric shock, which may result in serious injury or death.

When you unintentionally become part of an electrical circuit, current flows through your body, which could cause electrical burns and/or death.

The human body provides limited protection from electricity. The first line of defense is our skin, which has a high resistance to shock. Recall that resistance is measured in "ohms," and dry, unbroken skin can have up to 50,000 ohms in resistance. But inside the body, which is about 70 percent water, this resistance drops to only 300 to 500 ohms in resistance.

To measure the effect of electricity on the body, let's take common household voltage, 120 volts, and divide it by a resistance factor of 40,000 ohms, which is typical for human skin. The result of voltage divided by resistance is "amperes," the amount of current which flows through human skin. Only here, the amount is small, only 3/1000 of an ampere, or 3 milliamps of current.

Anatomy of an Electric Shock

- Resistance of the human body
- Voltage/Resistance = Amperes

Current (amps) plays a major part in the electrical shock killing factor. Voltage is important only because it determines how much current will flow through the resistance of the human body. The current necessary to operate a 10-watt light bulb is eight to ten times than the amount that would kill the average person.

- Effects of current on body
  - 1 milliamp or less—Causes no sensation and is not felt.
  - 1 to 8 milliamps—Sensation of shock, not painful. Individual can let go at will, as muscle control is not lost (5 ma is the acceptable maximum harmless current intensity).
  - 15 to 20 milliamps—Painful shock. Cannot let go. Muscle control is lost.
  - 20 to 50 milliamps—Painful. Severe muscular contractions. Breathing is difficult.
  - 100 to 200 milliamps—*Ventricular fibrillation.* A heart condition that could result in death.

The severity of a shock determines the severity of the injuries received. Three factors affect the severity of a shock:

1. The amount of current passing through a body. The higher the current, the more potential for injury. A current as little as 50 milliamps—50/1000 of an amp—can cause death.
2. The path of the current through the body. A shock that takes a path through one finger and out another finger on the same hand (such as when touching the prongs on a plug) might cause only a painful, temporary injury. However, the same current flowing through the chest can cause death through ventricular fibrillation.
3. The length of time that current flows through the body. Obviously, the longer the duration of a shock, the greater the potential for an injury.

Voltage in the primary lines usually is 2,400 to 19,900 volts and secondary voltages range from 120 to 480 volts.

Electric arcs or flashes are another form of an electrical hazard. Heat generated from an electrical flash could be as high as 43,000°F. This is equivalent to the temperature on the surface of the sun.

An electrical arc will occur when there is a fault on a line, usually caused by a tool or piece of metal equipment getting across the lines. The resulting electrical arc is similar to an arc weld.

Electrical arcs or flashes may also be the result of a failed or faulted piece of equipment.

Electrical burns are another form of an electrical hazard that results from contact with an energized conductor or from the heat generated from an electrical arc.

Firefighter Fact A 7-watt night light draws 60 milliamps of current, enough to cause ventricular fibrillation.

Electric utility primary *(higher voltage)* lines contain *10 to 500 amps* and their *secondary (household current)* lines contain *60 to 400 amps.* Even though the voltage is lower in household currents the amperage is the same or higher than in higher voltage lines. There is enough amperage in secondary lines to cause serious injury or a fatality if contact is made.

Firefighter Fact A small electric drill (¼ HP) draws 1,550 milliamps. This is seven times enough current to burn you and 31 times enough current to cause your heart to go into ventricular fibrillation.

Caution Rain gear (jackets, boots, gloves, and so on) and firemen's turnout gear provide virtually no protection against electricity.

Electricity, because it cannot be seen, must be approached with extreme care. To assume that the wire is not energized could be a deadly mistake. Always assume the wire is energized until it is tested by a qualified person.

RESPONDING TO INJURIES

Anytime someone has been shocked there are any number of possible injuries that you may need to address: first, second, and third degree burns; broken bones from a fall due to electrical contact; and most seriously cardiac arrest. Once you are certain the victim is not still in contact with any energized item (energized fence, ladder, car, etc.), you can then treat the victim accordingly.

When electrical shock traumatizes a nerve center in the brain, breathing often stops, and your response needs to be appropriate. Time is of the essence, but do not sacrifice yourself in the process.

It is essential to protect yourself from disease. The skin is a natural barrier protecting us from disease, but skin that's broken (cut, scrapes, etc.) will not protect you. Wearing rubber gloves, as well as a mask and eye protection, provides protection from disease.

When checking a victim for life signs remember not to move the victim unless he/she is in imminent danger. If no life signs are found (breathing or a pulse), treat the victim accordingly.

Current entering the body produces heat, which can cause damage at the entrance and exit points. Electrical burns are doubly dangerous, because tissues and organs beneath the skin may also be burned.

For any burn, the burning process must first be stopped. For a major burn where skin has been destroyed, apply dry sterile dressings.

When a powerful electrical current passes through the air or gas and reacts with particles in it, an intense arc can result, instantly emitting huge amounts of radiation and ultraviolet light. Exposed skin can be severely damaged, as if from an intense sunburn, as well as the eyes. By cooling the skin additional damage can be reduced. Superficial skin burns are treated like a sunburn, with cool compress.

Talk to the victim to assure him or her that you have things under control. Talking also helps to calm victims down and helps keep them from going into shock.

Safety Points to remember (electric contact):

- Cardiac arrest
- Electrical burns are another electrical hazard that results from contact with an energized conductor or from the heat generated from an electrical arc.
- Protect yourself from electric arcs or flashes, which are other forms of electrical hazard. Heat generated from an electrical flash could be as high as 43,000°F. This is equivalent to the temperature on the surface of the sun.
- An electrical arc will occur when there is a fault on a line, usually caused by a tool or piece of metal equipment getting across the lines. The resulting electrical arc is similar to an arc weld.
- Electrical arcs or flashes may also be the result of a failed or faulted piece of equipment.

Electrical shock remains the biggest hazard from electrical contact. Besides the pain that is suffered, there is often a loss of muscle control; continued contact could lead to a fatal injury. Electric shock will occur when a person, by contacting an energized conductor or other energized objects, provides a path for the flow of electricity to a ground. Simultaneous contact with two energized conductors will also cause electric shock that may result in serious injury or death.

Eye damage may not show up immediately, but symptoms to look for are burning and a sensation of sand irritation.

APPROACHING ENERGIZED AREAS

Overview

As a first responder, you are most likely to be on scene before the local electric company. Safety is extremely important.

Coordination between the first responders and the local electric company is extremely important. The safest way to make sure that a wire is de-energized is to have the on-scene representative from the electric company do the actual disconnection of the wire. The electric company will de-energize their facilities and

Caution All downed wires should be treated as if they were energized.

advise first responders that it is safe to proceed with their duties.

It is very important that the local electric utility be notified of any downed wires. Even if it is suspected that they are not electric lines (i.e., CATV or Telco), they could be energized due to a downed wire not in sight of your location. It is better to be safe than sorry by having the local electric company come out and secure it. Always consider all downed lines to be energized; contact the electric company and wait until they have given notice that it is safe to proceed.

Precautions When Approaching Downed Lines

A long-held misconception is that the rubber in the tires of vehicles will insulate you from electric contact. This is not true. Due to steel-belted radials, the tires can actually conduct electricity. The rubber protection that the utility uses is tested twice a year and is designed to protect against conductivity. The same goes with rubber fire boots or rubber rain boots. They are not designed to protect against electric shock.

Regardless of whether or not you know if the downed wire is CATV, telephone, or electric, you should always consider the wire to be live. You should never attempt to move it or handle it in any way. Let utility people do the work.

Circle of Safety

When approaching a downed wire, great care needs to be taken. A general rule of thumb is to maintain a minimum distance of 30 feet away. This is known as the "circle of safety." When in doubt, keep away and wait.

Storm Conditions

Extreme caution should always be taken during storm conditions. Downed power lines may or may not be energized. Do not take chances: *call the local power company for help.* During a storm, *stay away from any downed lines.*

Identifying the type of a downed wire (power, phone, fire alarm, or cable TV) is difficult when the lines are covered with debris, ice, or snow. *Again, just stay away and call for help.*

Whenever there is a downed energized electrical line, a phenomenon known as "*step & touch*" may be experienced while walking on the ground around the fallen power conductor. The energized conductor has a rippling effect around the point where it is making contact with the ground, and the voltage decreases as you go out from the center of this point.

VEHICLE RESCUE FROM DOWNED POWER LINES

Vehicle accidents involving utility poles are very common. In cases where energized lines land on the vehicle the best practice is to instruct the driver and occupants in the vehicle to remain in the vehicle. Instruct the occupants to remain in the vehicle and wait for the power company to arrive. Remember the circle of safety. Keep at least 30 feet away and try to keep the occupants calm.

If the vehicle is operational, instruct the driver to attempt to move the vehicle. There are a few safety points to remember. Keep all personnel far away until the car is at least 30 feet away from the downed line. One important factor to remember is wire coil memory. This means that the wire that may be pinned under a tire, when released, will recoil back to where it is connected. Be very aware of this. Keep all personnel far away until the wire comes to rest and stops moving.

A vehicle on fire with a wire downed and people trapped inside can be a very dangerous situation. The first responder's initial reaction may be to rush right in to get the fire out and help the people. This can be fatal. *DO NOT USE WATER!* If you do this the water, hose, engine, and all personnel making physical contact to it can become energized. If you have a situation where you have to suppress the fire, use dry chemical extinguishers. Don't forget to keep a safe distance away from the vehicle. A dry chemical usually has a stream of about 15 to 20 feet. Therefore, when you're approaching, be very aware of your surroundings. Use a spotter/safety officer to keep extra eyes on the situation. Remember that foam has water in it so it, too, can become energized. If there is no one in the vehicle and it is on fire, let it burn. Protect exposures and wait for the electric company.

Once the fire is out, wait. The lines still may be energized; forgetting this may result in you becoming a victim or fatality.

Safety Persons in vehicles that may be energized should be told to remain in the vehicle.

Step Potential

As you take each step the voltage between your feet and the ground will vary. This is known as step potential. The difference of voltage from one foot to another is enough to stop your heart. If you suspect that you are in an energized area there are two ways to exit the area. One is a shuffle step. Keep both feet on the ground and shuffle your feet while maintaining contact with the ground. Another way is to hop away. With both feet tighter, making contact at the same time, make very short hops. Remember, water is a conductor, so be very aware of puddles and streams of water. Avoid them at all costs, Figure I-6.

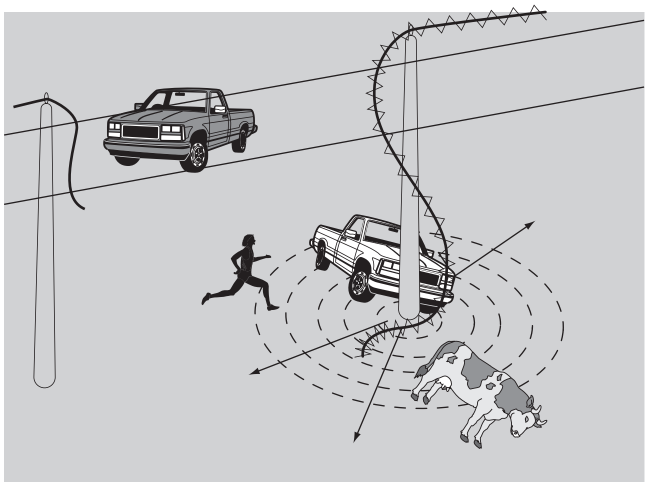

Figure I-6 Potential gradient/step potential.

Exiting the Vehicle

If trapped persons must exit the vehicle, there are a few safety tips to remember. It is critical that they do not make contact with the ground and the vehicle at the same time. Have them open the vehicle's door the widest they can. Have them stand on the doorsills of the car and jump clear away, landing with both feet together. Once they are clear have them hop or shuffle-step away. The best practice is to try and keep the people in the vehicle until the electric company representative on scene tells you that the electric has been de-energized.

EMERGENCIES INVOLVING ELECTRICAL FACILITIES

The common use of the term "electrical fire" (Class "C") refers to a fire involving electricity. Once the electricity is disconnected the fire becomes a Class "A" or "B" fire. Small Class "C" fires can be extinguished safely with carbon dioxide, dry chemical, or halon extinguishers. Water in the form of fog is also safe.

If utility company equipment is burning, allowing it to burn is the best course of action. Once damaged, it will be replaced, and no utility company wants responders to risk their lives to save a piece of equipment that won't be repaired.

Attempting to extinguish a burning pole-mounted transformer from the ground or a ladder is mostly futile, and extremely dangerous. Remember that since electricity seeks a path to the ground, the hose stream may provide that path through your body.

The utility company experts will advise you on what to do when they arrive. They may very well direct you to let it burn, or wait until power is shut off before trying to suppress the fire. This doesn't mean there are not actions that can be taken to provide a safer outcome. There are usually numerous exposures such as trees and buildings that need to be protected from fire.

Making the scene safe also includes keeping the public at a safe distance until the emergency is resolved. Dealing with burning transformers, the transformers on utility poles, high amounts of current move through this structure, and both contain oil for cooling which can present an additional hazard if released.

Considerations for Underground Chambers

This is a "Padmounted transformer." Similar to utility poles padmounted transformers are sometimes susceptible to vehicles accidentally smashing into them. As before, all safety precautions regarding distance, step potential, and the assumption that anything in contact (such as the vehicle) is energized needs to be followed.

If fire is involved, don't use water or foam to suppress it—only dry chemical. If a safe distance cannot be maintained, let the electrical fire burn and concentrate on protecting exposures while waiting for utility company assistance. As a rule, it is less expensive to replace damaged equipment than to repair it, so safety is the critical issue.

Much of the electrical distribution system, especially in urban areas, is underground. Any number of

Safety Securing the site: ONLOOKERS SHOULD BE KEPT BACK.

> **Caution** You should stay well clear of the opening, because underground gases and damaged cables are capable of exploding.

environmental changes can trigger fires in the passages and vaults housing electrical wires and equipment. If you detect signs of fire, but don't observe any workers, vehicles, or signs of work right here, most likely no one is in the underground vault or manhole. Don't make any attempt to investigate further, but report what you have seen to the utility company: "Those covers got blown off by exploding gases." Once on sight, the utility company, after de-energizing the area, may need some assistance from the fire department to clear the smoke out from the chamber so they can enter it to make repairs.

When work is being done, as a rule, someone from the crew will always be aboveground. Instinct may tell you to rush down into the chamber, but don't; you have no idea of what may be energized, and also suffer from poor visibility. Make sure the utility company has been notified, and wait for them to de-energize the area.

Once power has been shut off, with full protective equipment and breathable air supplied and monitored, the chamber can be entered. All the rules for confined space entry must be followed, and extra caution has to be taken to avoid any sparking, such as from flashlights being turned on, or metal scraped, because of the possible presence of combustible gases.

ELECTRICITY IN BUILDING FIRES

Most electrical fires are caused by excessive heat from wires, machines, and appliances, which have been overloaded or poorly insulated. When fires break out in buildings, you're almost always exposed to energized electrical wiring and power lines. Industrial facilities such as this have heavy-duty electrical systems with equipment operating at over 10,000 volts.

Residential systems mostly have 120- and 240-volt service. While much lower than industrial voltage, it is still very dangerous. Here are some guidelines that should be followed at all times:

1. When you enter a building, you may want to keep power on to aid you in investigating the fire.
2. However, because visibility is usually limited, keep your palms turned inward. Why? If you come into contact with any energized sources, and you experience muscle contractions, your arms and hands will be pulled toward your body, and away from the source of electricity.
3. Many firefighters believe that when responding to fire emergencies, the pulling of an electric meter is an acceptable procedure. It isn't. Meters can arc and explode.

What you want to do if possible is locate the main breaker box, or panel, and shut off the power from there. When doing so, turn away from the power source to avoid being burned if it arcs. All electrical wires should be approached as if they were energized. As shown earlier, while electrical wires are weather coated, don't make the mistake of thinking that means they are insulated. Firefighter gloves are not designed to handle energized electric lines. Don't be fooled into thinking it's safe to touch the lines—it's not. Nor is it safe to use any of your tools to cut power lines. This attempt to de-energize power to the burning structure is extremely dangerous.

Even after you have cut power, take care not to come in contact with machinery or appliances. Especially in commercial and industrial facilities, there may be alternate or emergency sources still supplying electricity. When you're fighting any kind of fire with overhead electric lines in the area, special precautions need to be taken.

Dense smoke often has carbon particles and moisture in it, which can become energized and produce a potentially lethal arc. This guideline also applies to any equipment and tools you are using. Make absolutely sure you're keeping that safe distance before jumping into action. Because of these dangers, only essential crew members should be anywhere near vehicles exposed to this risk.

Large scale fires involving multiple vehicles and possible different companies and agencies compound the complexities in responding.

> **Firefighter Fact** If a ladder or bucket extension needs to go over or near any power lines, a minimum safe distance of 10 feet from the energized line is required by OSHA regulations.

> **Caution** Anyone working on the vehicle must avoid any contact with the ground because of the possibility of electrical arcing.

Safety A "prefire plan" should be in place to ensure that everyone is aware of the location of power lines and other electrical sources, so coordination of all parties' actions creates a safe outcome.

When the utility company experts arrive, they will probably cut the service wire taps on the utility pole, or open a switch to cut power to the area. Only when they test to make sure all sources of electrical energy are removed will you get an all clear to move about safely.

SUBSTATION, PLANT, AND TRANSMISSION FIRES

An electric power substation has transmission and distribution lines coming in and out of it. Typically, some of the components include a control building, large transformers, structures to keep the lines elevated, and circuit breakers. Both transformers and circuit breakers are filled with oil, which insulates the internal electrical components. If a fire breaks out, the high voltage levels mandate special guidelines for responding safely.

Components of a Substation

The transmission and distribution substation consists of many components such as transformers, distribution breakers/reclosers, power circuit breakers, voltage regulators, reactors, capacitors, circuit switchers, switchgear, and switches that should be located and arranged in the substation yard in the most effective manner. One should take into account the physical aspects of the equipment as well as the operating, safety, and maintenance requirements when designing the electrical layout. The following subsections discuss the various aspects of the types of substation equipment used in the subtransmission and distribution substation.

Power Transformers

All substation-type power transformers are liquid-filled transformers for two or three winding oil insulated, three-phase outdoor power transformers. Most all transformers that are used are of the core form, circular coil winding construction. In the core form type of construction, the transformer windings are surrounded by the core steel. The liquid is generally an oil and may be flammable.

Power Circuit Breakers

A power circuit breaker is a device used to open or close an electric power circuit either during normal power system operation or during abnormal conditions. Circuit breakers used are vacuum, oil filled, or insulating gas filled.

Distribution Circuit Breakers/Reclosers

Interrupting devices used in the low voltage portion of a distribution substation consist of circuit breakers and/or circuit reclosers. These devices may use vacuum, insulating oil, or SF6 gas as the interrupting medium. Both devices are used to protect transformers, circuits, and other equipment in a distribution substation. Both have all relaying such as reclosing, phase, and neutral relaying included in their own control cabinet.

Control Buildings

Control buildings are generally deemed necessary when the installation of large batteries and relaying/control equipment on switchboard control panels is required for substation operation. Both transmission and distribution substations may have control buildings.

The overall size of the building is determined by the number of switchboard frames required plus the amount and size of additional equipment that must be housed within the building. Both initial and future requirements must be considered. The near future requirements are generally accommodated in the initial size of the building, while distant future requirements are accommodated by allowing ample space for additions to the building and laying out the building so that future expansion is practical.

The purpose of switchboard panels or frames is to provide a convenient and vertical surface for mounting and wiring control, as well as protective equipment for the various line exits, transformer circuits, transfer circuits, and so on located within a particular substation, Figures I-7 and I-8.

Under no circumstances should you attempt to enter the substation before the utility company experts are on the scene. Because of the high voltage and possibility of explosion, the danger zone is extended much further: a minimum of 300 feet.

Make sure your vehicles are parked at a safe distance, and be careful to avoid putting them under-

Figure I-7 Substation control room.

Figure I-8 Substation control room.

neath a power line. When utility company personnel arrive, they will provide guidance in approaching all the structures and equipment safely. They may decide to let the equipment burn itself out, while directing firefighters to protect exposures. Metal ladders should not be used, only ladders made of non-conducting materials. A good guideline to follow when inside the substation is to have no equipment extend beyond shoulder height, because any overhead equipment may be energized.

Upon entering an area involved in an event of this nature, the responder needs to be immediately aware of the condition and presence of overhead conductors. The overhead conductors should therefore be considered to be energized until proven otherwise by the owner or utility personnel. Isolation at the point of the emergency should not be considered as sole evidence of safety as the conductors may be fed in both directions and therefore may be energized at any time. The best advice is to ensure that they are isolated from both ends by competent and authorized personnel.

Most times the fire is coming from oil in the circuit breakers or transformers. Because large amounts are housed inside, it is a major concern, which requires special guidelines.

With equipment de-energized, the oil fires can be extinguished by using protein foam sprays and water fog streams. Never use a solid stream of water on oil or any pools of oil, which could actually spread the fire. However, the fire may continue burning inside the equipment. Reignition is not uncommon, and the oil may burn for an extended period of time. Continued burning on and off could go on for days. Be aware that the oil vapors are also capable of exploding, so full PPE and safe distances from equipment need to be maintained.

The high concentration of carbon particles that give the smoke its characteristic color will also conduct electricity from high-level energized equipment to the ground. Further, any firefighting operations will add to the conductivity by providing a steam component in the plume. Even dry chemical particles have been known to become conductive in high humidity environments by absorbing moisture and therefore acting like "airborne mud." Typically, this effect is seen between high-energy points such as exposed conductors or bushings on transformers.

The utility company may de-energize only the affected section within the substation, choosing to keep as many customers as possible in service. Therefore, they will work with you to set up a safe corridor of operations, which avoids areas that will remain energized. Following the advice of electric power experts produces the safest outcome.

The equipment, which has most likely been severely damaged by fire, will not be repaired, and the utility company doesn't want anyone being injured in trying to rescue it. Therefore, unless it poses a wider threat, it will be left to burn itself out. However, if the heat is intense enough, other structural systems may collapse, so these exposures need to be protected.

Safety Complete personal protective equipment for operating personnel should be mandatory including SCBA.

Caution Another danger: because glass and ceramics are excellent insulators, this equipment, under intense heat, can explode when water is applied.

There are other hazards to be aware of, such as toxic gases that can arise from insulation or batteries, so it is best to limit the number of people involved to only the most essential and to confine the fire within the substation fence line.

Transmission towers are constructed in "right of way" corridors that isolate them from traffic, construction, and trees. A large fire and smoke can extend upward far enough to present a different and dangerous scenario. Smoke contains carbon and carbon is a conductor of electricity. At a distance of approximately 6 feet, with enough heat, the particles of smoke can trigger arcing, with an intense burst of electrical energy flashing to the ground. Therefore, when you recognize these conditions forming, put at least a hundred feet of distance between you and the fire.

Generating stations such as these that burn fossil fuels to produce electricity rely on you to bring fire emergencies under control. If such a facility is in your coverage area, you need to be meeting with the utility company to discuss emergency preparedness to deal with possible dangers associated with the generation plant.

Safety Prefire plans include plant layout: know where chemical and oil tanks are located, as well as hydrant and fire pump locations.

Inside these generating stations you could encounter hazards from water, steam, natural gas, and toxic substances. If a fire starts at a generating plant, you will be met by a utility company specialist. This person will work with you to make sure that all of the contingencies you have discussed for this situation are addressed so that the safest course of action can be followed in a dangerous situation.

Power plants use some of the same equipment as found in a substation. The same guidelines apply in carrying tools and equipment: be sure to keep everything at shoulder height or below.

Electric Dos and Don'ts

DO

- Treat all utility lines as high voltage.
- Look for overhead lines when arriving at emergency scenes.
- Check for and avoid utility lines on the ground, in trees, or on vehicles.
- Notify the electric utility when there are downed lines or other electrical problems.
- Beware of step voltage and keep at least 30 feet away from downed lines.
- Have occupants remain in vehicles that are in contact with downed lines until the "all clear" is given by the electric utility.
- Instruct occupants of energized vehicles to jump clear and hop or shuffle away from their vehicles.
- When utility electrical equipment is on fire, let it burn, protect the exposures, and contact the utility company.

DON'T

- Park emergency vehicles under or near overhead lines.
- Touch downed lines, even with gloves, sticks, or tools.
- Assume the electric utility has already been notified when you encounter downed lines.
- Allow aerial device equipment such as ladder trucks to approach closer than 10 feet to an overhead utility line.
- Pull electric meters or cut service lines.
- Apply water or foam to burning electrical equipment.
- Enter electric utility substations without the OK from the electric company.
- Enter underground vaults or manholes until the "all clear" is given by the electric utility.

DEFINITIONS

AC Voltage: Alternating Current changes at a rate of 60 times a second, major source is generators.

Circuit: A conductor or system of conductors through which an electric current is intended to flow.

Communication Lines: The conductors and their supporting structures for telephone, telegraph, railroad signal, data, clock, fire, police alarm, community television antenna and other systems that are used for public or private signal or communication service.

Conductor: A material, usually in the form of a wire or cable suitable for carrying an electrical current.

Current: The flow of electricity through a conductor.

DC Voltage: Direct current steady consistent voltage, major source is batteries.

Direct Contact: When any part of the body touches or contacts an energized conductor or an energized piece of electrical equipment.

Ground (noun): A conductive connection by which an electric circuit or equipment is connected to ground.

Ground (verb): The connecting of an electric circuit or equipment to ground.

High Voltage: Greater than 600 volts.

Indirect Contact: When any part of the body touches any object that is in contact with an energized electric conductor or an energized piece of electrical equipment (EXAMPLES: Tree limbs, tools, equipment, trucks, etc.)

Insulated: Separated from other conducting surfaces by a dielectric substance offering a high resistance to the passage of current.

Low Voltage: 600 volts or less

Manhole: A subsurface enclosure which personnel may enter and is used for the purpose of installing, operating and maintaining submersible equipment and or cables.

Step & Touch Potential: The area around an energized conductor that is in contact with the ground and how far the voltage field extends from the contact point.

Resistance: The opposition to the flow of electricity measure in ohms.

Voltage: The speed that electricity flows through power lines.

REVIEW QUESTIONS

1. What is the minimum electrical voltage that can kill a human being?
2. Electricity will always take the shortest path to ground; if you get between the electrical source and the ground you would become a conductor and be __________.
3. What is the classification for a fire in energized electrical equipment?
4. What is the OSHA Standard that ground ladders and aerial ladders should be kept from high-voltage lines or equipment.
5. What is the only way to make sure that a wire is de-energized?