Safety
Electrical Hazards

Introduction

This article provides an overview of basic electrical safety for individuals with little or limited training or familiarity with electrical hazards.
Electrical standards address concerns that electricity has long been recognized as a serious workplace hazard, exposing employees to such dangers as electric shock, electrocution, burns, fires, and explosions.
Electrical standards help minimize these potential hazards by specifying safety aspects in the design and use of electrical equipment and systems. The standards cover only those parts of any electrical system that an employee would normally use or contact. For example, the exposed and/or operating elements of an electrical installation-lighting, equipment, motors, machines, appliances, switches, controls, and enclosures-must be constructed and installed so as to minimize workplace electrical dangers.

How Electricity Acts?

Electricity is essential to modem life, both at home and on the job. Some employees work with electricity directly, as is the case with engineers, electricians, electronic technicians, and power line workers. Others, such as office workers and sales-people, work with it indirectly. As a source of power, electricity is accepted without much thought to the hazards encountered. Perhaps because it has become such a familiar part of our surroundings, it often is not treated with the respect it deserves.
To handle electricity safely, it is necessary to understand how it acts, how it can be directed, what hazards it presents, and how these hazards can be controlled. Operating an electric switch may be considered analogous to turning on a water faucet. Behind the faucet or switch there must be a source of water or electricity, with something to transport it, and with pressure to make it flow. In the case of water, the source is a reservoir or pumping station; the transportation is through pipes; and the force to make it flow is pressure, provided by a pump. For electricity, the source is the power generating station; current travels through electric conductors in the form of wires; and pressure, measured in volts, is provided by a generator.
Resistance to the flow of electricity is measured in ohms and varies widely. It is determined by three factors: the nature of the substance itself, the length and cross-sectional area (size) of the substance, and the temperature of the substance.
Some substances, such as metals, offer very little resistance to the flow of electric current and are called conductors. Other substances, such as bakelite, porcelain, pottery, and dry wood, offer such a high resistance that they can be used to prevent the flow of electric current and are called insulators.
Dry wood has a high resistance, but when saturated with water its resistance drops to the point where it will readily conduct electricity. The same thing is true of human skin.
When it is dry, skin has a fairly high resistance to electric current; but when it is moist, there is a radical drop in resistance. Pure water is a poor conductor, but small amounts of impurities, such as salt and acid (both of which are contained in perspiration), make it a ready conductor. When water is present either in the environment or on the skin, anyone working with electricity should exercise even more caution than they normally would.

How Shocks Occur?

Electricity travels in closed circuits, and its normal route is through a conductor. Electric shock occurs when the body becomes a part of the electric circuit. The current must enter the body at one point and leave at another. Electric shock normally occurs in one of three ways. Individuals-while in contact with the ground- must come in contact with both wires of the electric circuit, one wire of an energized circuit and the ground, or a metallic part that has become "hot" by contact with an energized conductor.
The metal parts of electric tools and machines may become energized if there is a break in the insulation of the tool or machine wiring. The worker using these tools and machines is made less vulnerable to electric shock when there is a low-resistance path from the metallic case of the tool or machine to the ground. This is done through the use of an equipment grounding conductor- a low-resistance wire that causes the unwanted current to pass directly to the ground, thereby greatly reducing the amount of current passing through the body of the person in contact with the tool or machine. If the equipment grounding conductor has been properly installed, it has a low resistance to ground, and the worker is protected.

Severity of the Shock

The severity of the shock received when a person becomes a part of an electric circuit is affected by three primary factors: the amount of current flowing through the body (measured in amperes), the path of the current through the body, and the length of time the body is in the circuit. Other factors that may affect the severity of shock are the frequency of the current, the phase of the heart cycle when shock occurs, and the general health of the person.
The effects of electric shock depend upon the type of circuit, its voltage, resistance, current, pathway through the body, and duration of the contact. Effects can range from a barely perceptible tingle to immediate cardiac arrest. Although there are no absolute limits or even known values that show the exact injury from any given current, the table shows the general relationship between the degree of injury and amount of current for a 60-cycle hand-to-foot path of one second's duration of shock.
The table also illustrates that a difference of less than 100 milliamperes exists between a current that is barely perceptible and one that can kill. Muscular contraction caused by stimulation may not allow the victim to free himself or herself from the circuit, and the increased duration of exposure increases the dangers to the shock victim. For example, a current of 100 milliamperes for 3 seconds is equivalent to a current of 900 milliamperes applied for .03 seconds in causing ventricular fibrillation. The so-called low voltages can be extremely dangerous because, all other factors being equal, the degree of injury is proportional to the length of time the body is in the circuit. LOW VOLTAGE DOES NOT IMPLY LOW HAZARD!
A severe shock can cause considerably more damage to the body than is visible. For example, a person may suffer internal hemorrhages and destruction of tissues, nerves, and muscles. In addition, shock is often only the beginning in a chain of events. The final injury may well be from a fall, cuts, burns, or broken bones.

Effects of Electric Current in the Human Body

Current Reaction

1 Milliampere Perception level. Just a faint tingle.

5 Milliamperes Slight shock felt; not painful but disturbing.
Average individual can let go. However, strong involuntary reactions to shocks in this range can lead to injuries.

6-25 Milliamperes (women) Painful shock, muscular control is lost.

9-30 Milliamperes (men) This is called the freezing current or "let-go" range.

50-150 Milliamperes Extreme pain, respiratory arrest, severe muscular contractions.*
Individual cannot let go. Death is possible.

1,000-4,300 Milliamperes Ventricular fibrillation. (The rhythmic pumping action of the heart ceases.) Muscular contraction and nerve damage occur. Death is most likely.

10,000-Milliamperes Cardiac arrest, severe burns and probable death.

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*If the extensor muscles are excited by the electric shock, the person may be thrown away from the circuit.

Burns and Other Injuries

The most common shock-related injury is a burn. burns suffered in electrical accidents may be of three types: electrical burns, arc burns, and thermal contact burns.
Electrical burns are the result of the electric current flowing through tissues or bone. Tissue damage is caused by the heat generated by the current flow through the body. Electrical burns are one of the most serious injuries you can receive and should be given immediate attention.
Arc or flash burns, on the other hand, are the result of high temperatures near the body and are produced by an electric arc or explosion. They should also be attended to promptly.
Finally, thermal contact burns are those normally experienced when the skin comes in contact with hot surfaces of overheated electric conductors, conduits, or other energized equipment. Additionally, clothing may be ignited in an electrical accident and a thermal burn will result. All three types of burns may be produced simultaneously.
Electric shock can also cause injuries of an indirect or secondary nature in which involuntary muscle reaction from the electric shock can cause bruises, bone fractures, and even death resulting from collisions or falls. In some cases, injuries caused by electric shock can be a contributory cause of delayed fatalities.
In addition to shock and burn hazards, electricity poses other dangers. For example, when a short circuit occurs, hazards are created from the resulting arcs. If high current is involved, these arcs can cause injury or start a fire. Extremely high-energy arcs can damage equipment, causing fragmented metal to fly in all directions. Even low-energy arcs can cause violent explosions in atmospheres that contain flammable gases, vapors, or combustible dusts.

Preventing Electrical Hazards

Electrical accidents appear to be caused by a combination of three possible factors- unsafe equipment and/or installation, workplaces made unsafe by the environment, and unsafe work practices. There are various ways of protecting people from the hazards caused by electricity. These include: insulation, guarding, grounding, electrical protective devices, and safe work practices.

Insulation

One way to safeguard individuals from electrically energized wires and parts is through insulation. An insulator is any material with high resistance to electric current.
Insulators-such as glass, mica, rubber, and plastic-are put on conductors to prevent shock, fires, and short circuits. Before employees prepare to work with electric equipment, it is always a good idea for them to check the insulation before making a connection to a power source to be sure there are no exposed wires. The insulation of flexible cords, such as extension cords, is particularly vulnerable to damage.
The insulation that covers conductors is regulated by Subpart S of 29 Code of Federal Regulations (CFR) Part 1910.302, Design Safety Standards for Electrical Systems, as published in the Federal Register on January 16, 1981.
Subpart S generally requires that circuit conductors (the material through which current flows) be insulated to prevent people from coming into accidental contact with the current. Also, the insulation should be suitable for the voltage and existing conditions, such as temperature, moisture, oil, gasoline, or corrosive fumes. All these factors must be evaluated before the proper choice of insulation can be made.
Conductors and cables are marked by the manufacturer to show the maximum voltage and American Wire Gage size, the type letter of the insulation, and the manufacturer's name or trademark. Insulation is often color coded. In general, insulated wires used as equipment grounding conductors are either continuous green or green with yellow stripes. The grounded conductors that complete a circuit are generally covered with continuous white or natural gray-colored insulation. The ungrounded conductors, or "hot wires," may be any color other than green, white, or gray. They are often colored black, blue, brown or red.

Guarding

Live parts of electric equipment operating at 50 volts or more must be guarded against accidental contact. Guarding of live parts may be accomplished by:

location in a room, vault, or similar enclosure accessible only to qualified persons;
use of permanent, substantial partitions or screens to exclude unqualified persons;
location on a suitable balcony, gallery, or platform elevated and arranged to exclude unqualified persons; or
elevation of 8 feet (2.44 meters) or more above the floor.
Entrances to rooms and other guarded locations containing exposed live parts must be marked with conspicuous warning signs forbidding unqualified persons to enter.
Indoor electric wiring more than 600 volts and that is open to unqualified persons must be made with metal-enclosed equipment or enclosed in a vault or area controlled by a lock. In addition, equipment must be marked with appropriate caution signs.

Grounding

Grounding is another method of protecting employees from electric shock; however, it is normally a secondary protective measure. The "ground" refers to a conductive body, usually the earth, and means a conductive connection, whether intentional or accidental, by which an electric circuit or equipment is connected to earth or the ground plane. By "grounding" a tool or electrical system, a low-resistance path to the earth is intentionally created. When properly done, this path offers sufficiently low resistance and has sufficient current carrying capacity to prevent the buildup of voltages that may result in a personnel hazard. This does not guarantee that no one will receive a shock, be injured, or be killed.

Circuit Protection Devices

Circuit protection devices are designed to automatically limit or shut off the flow of electricity in the event of a ground-fault, overload, or short circuit in the wiring system. Fuses, circuit breakers, and ground-fault circuit interrupters are three well-known examples of such devices.

Fuses and circuit-breakers are over-current devices that are placed in circuits to monitor the amount of current that the circuit will carry. They automatically open or break the circuit when the amount of current flow becomes excessive and therefore unsafe. Fuses are designed to melt when too much current flows through them. Circuit breakers, on the other hand, are designed to trip open the circuit by electro-mechanical means.

Fuses and circuit breakers are intended primarily for the protection of conductors and equipment. They prevent over-heating of wires and components that might otherwise create hazards for operators. They also open the circuit under certain hazardous ground-fault conditions.

The residual current device, or RCD, is designed to shutoff electric power within as little as 1/40 of a second. It works by comparing the amount of current going to electric equipment against the amount of current returning from the equipment along the circuit conductors. If the current difference exceeds 6 milliamperes, the RCD interrupts the current quickly enough to prevent electrocution.

Safe Work Practices

Employees and others working with electric equipment need to use safe work practices. These include: deenergizing electric equipment before inspecting or making repairs, using electric tools that are in good repair, using good judgment when working near energized lines, and using appropriate protective equipment.

Training

To ensure that they use safe work practices, employees must be aware of the electrical hazards to which they will be exposed. Employees must be trained in safety-related work practices as well as any other procedures necessary for safety from electrical hazards.

Deenergizing Electrical Equipment. The accidental or unexpected sudden starting of electrical equipment can cause severe injury or death. Before ANY inspections or repairs are made -- even on the so-called low-voltage circuits-the current must be turned off at the switch box and the switch padlocked in the OFF position. At the same time, the switch or controls of the machine or other equipment being locked out of service must be securely tagged to show which equipment or circuits are being worked on.

Maintenance employees should be qualified electricians who have been well instructed in lockout procedures. No two locks should be alike; each key should fit only one lock, and only one key should be issued to each maintenance employee. If more than one employee is repairing a piece of equipment, each should lock out the switch with his or her own lock and never permit anyone else to remove it. The maintenance worker should at all times be certain that he or she is not exposing other employees to danger.

Protective Equipment. Employees whose occupations require them to work directly with electricity must use the personal protective equipment required for the jobs they perform. This equipment may consist of rubber insulating gloves, hoods, sleeves, matting, blankets, line hose, and industrial protective helmets.

Tools. To maximize his or her own safety, an employee should always use tools that work properly. Tools must be inspected before use, and those found questionable, removed from service and properly tagged. Tools and other equipment should be regularly maintained. Inadequate maintenance can cause equipment to deteriorate, resulting in an unsafe condition.

Tools that are used by employees to handle energized conductors must be designed and constructed to withstand the voltages and stresses to which they are exposed.

Good Judgment. Perhaps the single most successful defense against electrical accidents is the continuous exercising of good judgment or common sense. All employees should be thoroughly familiar with the safety procedures for their particular jobs. When work is performed on electrical equipment, for example, some basic procedures are:

Have the equipment deenergized.

Ensure that the equipment remains deenergized by using some type of lockout and tag procedure.

Use insulating protective equipment.

Keep a safe distance from energized parts.

Conclusion

The control of electrical hazards is an important part of every safety and health program. The measures suggested in this article should be of help in establishing such a program of control. The responsibility for this program should be delegated to individuals who have a complete knowledge of electricity, electrical work practices, and the appropriate standards for installation and performance.

Everyone has the right to work in a safe environment. Through cooperative efforts, employers and employees can learn to identify and eliminate or control electrical hazards.