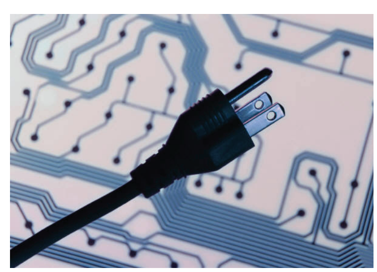
MODULE 1
INTRODUCTION TO ELECTRICAL SAFETY

At the end of this module, you will be able to…

- Recognize key statistics relating to electrical injuries.
- Recognize OSHA regulations and other standards relating to electrical safety.
- Understand basic electrical terminology.
- Identify the four types of injury relating to electrical incidents.
- Understand key facts relating to electric shock.
- Understand the basic facts of electricity.
- Understand Ohm's Law and describe how the terms current, voltage and resistance relate to Ohm's Law.
- Recognize the effects of electricity on the human body.



Electrical Injury Facts

Question: Why should you be concerned about electrical safety?

Answer:

The Statistics Tell the Story

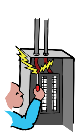
In a 2006 publication, the National Institute for Occupational Safety and Health (NIOSH) reported that from 1992 through 2002, there were 3,378 workers who died from on-the-job electrical injuries.

- That number reflects 4.7% of all occupational deaths.
- That's almost one death per day.
- The number makes electricity the fourth leading cause of injury-related occupational death.
- Contact with overhead power lines was the most common cause of electrocutions, resulting in 42% of all on-the-job electrical deaths.
- The second most common cause of electrocutions was failure to properly de-energize electrical equipment prior to commencing work.
- The third most common cause was contact with electrical components mistakenly thought to be de-energized due to a mistake in wiring or re-wiring, or misidentified wiring.
- Contact with buried, underground power lines caused 1% of the fatalities.

Also from 1992 through 2002, 46,598 workers were non-fatally injured by electricity. Of these non-fatal injuries:

- 36% were caused by contact with the electric current of a machine, tool, appliance or light fixture.
- 34% of the non-fatal injuries were caused by contact with wiring, transformers or other electrical components.
- 2% of non-fatal injuries were caused by contact with buried, underground power lines.

Note that all of the above statistics are related to contact with a source.



Sources for statistics:

NIOSH Publication No. 20031087, **Trends in Electrical Injury,** 1992-2002.

http://www.cdc.gov/Niosh/noirs/abstractsc6.html

Regulations and Standards Relating to Electricity

There are many regulations and standards that address working safely around electricity. The information in this course is based on key OSHA regulations and the National Fire Protection Association's (NFPA) 70E, ***Standard for Electrical Safety in the Workplace***. Below are some of the most important regulations.

Regulation	What it Addresses
OSHA 29 CFR 1910, Subpart I	Personal Protective Equipment. Section 1910.137 specifically addresses electrical protective devices.
OSHA 29 CFR 1910, Subpart P	Safe operation of hand and portable powered tools and other hand-held equipment.
OSHA 29 CFR 1910, Subpart S	Electrical safety requirements necessary for the practical safeguarding of employees in the workplace.
OSHA 29 CFR 1910.147	Lockout/tagout procedures. Describes how to service or maintain equipment that might unexpectedly energize.
OSHA 29 CFR 1910.333	Lockout/tagout procedures. Describes how to service or maintain energized circuits.

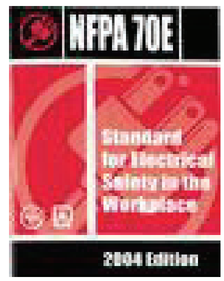
Regulations and Standards Relating to Electricity—continued

National Fire Protection Association (NFPA) 70E

This standard addresses electrical safety in the workplace. It applies to all employees who work on or near exposed energized electrical conductors or circuit parts. It also applies to employees who face a risk from electrical shock, thermal heat, or arc flash or blast.

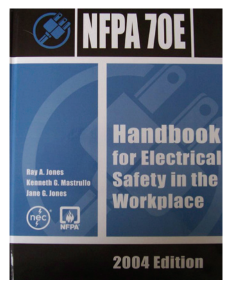
It addresses the following:

- Safety related work practices
- Safety related maintenance requirements
- Safety requirements for special equipment
- Installation safety requirements



In addition to the above publication, NFPA publishes a handbook that:

- Gives step-by-step instructions for how to implement the standard.
- Provides the thought process and rationale for the standards.



How to Obtain OSHA and NFPA Resources

1. You can access the entire OSHA Code of Federal Regulations (CFR) at: http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=0&p_keyvalue=&p_status=CURRENT.

2. The NFPA 70E ***Standard for Electrical Safety in the Workplace*** can be purchased from the National Fire Protection Association's website: http://www.nfpa.org.

3. For your convenience, the entire OSHA 29 CFR 1910, Subpart S is available on your *Tools and Resources* CD-ROM.

Qualified/Unqualified Person

Qualified Person

According to OSHA 29 CFR 1910.399, a qualified person is "one who has received training in and has demonstrated skills and knowledge in the construction and operation of electric equipment and installations and the hazards involved."

Whether an employee is considered to be a "qualified person" will depend upon various circumstances in the workplace. For example, it is possible and, in fact, likely for an individual to be considered "qualified" with regard to certain equipment in the workplace, but "unqualified" as to other equipment. (See 1910.332(b)(3) for training requirements that specifically apply to qualified persons.)

An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person is considered to be a qualified person for the performance of those duties.

Note that this program does **NOT** meet the requirements for becoming a Qualified Person. For more information, see NFPA 70E Article 110.6 and OSHA 29 CFR 1910.332 "Training."

Requirements of a Qualified Person

- Completion of required training on the hazards of electrical equipment and operations.
- Training and experience in working with electricity.
- Knowledge of electrical hazards (such as shock and flash) and how to avoid them.
- Ability to distinguish exposed energized parts from other parts of electrical equipment.
- Ability to read and interpret a facility's electrical one-line diagram.
- Ability to determine nominal voltage of exposed live parts.
- Ability to determine approach distances when working on electricity.
- Knowledge of proper Personal Protective Equipment (PPE).
- Knowledge of lockout/tagout procedures.
- Knowledge of a facility's electrical safety plan.

Only a Qualified Person can Perform the Following

- Work on energized parts over 50V
- Test exposed circuits

Unqualified Person

- Has some electrical knowledge/experience, but must limit work to de-energized parts.
- Has little or no training on identifying and preventing the electrical hazards associated with working on or near exposed energized parts.

Basic Terminology

People who work with electricity need to have a grasp of the basic terminology. Following are the most important terms you should know.

Term	Definition
Amp/Amperage (I)	Strength of an electrical current. Measure of electron flow past a certain point in a given period of time.
Alternating Current (AC)	Current produced by constantly changing the voltage from positive to negative to positive, etc.
Arc Blast	An explosive release of molten material.
Arc Flash	Luminous electrical discharge (bright, electrical sparking) through the air that occurs when high voltages exist across a gap between conductors.
Circuit	Complete path for the flow of current.
Current	The movement of an electrical charge. Current is measured in amps.
Direct Current	Current in which the electrons flow from the negative to the positive terminal.
Energize	A term meaning that a voltage is present that can cause a current. Also can be referred to as “live” or “hot”.
Fault	Any current that is not in its intended path.
Ground	A conductive connection to the earth.
Lockout/Tagout	The process of applying a physical lock to an energy source and applying a tag that alerts workers that circuits and equipment have been shut off and locked out.
Ohm (Ω)	A unit of measurement for electrical resistance.
Resistance (R)	The ability of a material to decrease or stop electrical current. All materials exhibit some resistance. Resistance is measured in ohms.
Voltage (V) or (E)	A measure of electrical force.
Watts or Power (W or P)	Quantity of electricity being consumed.

Types of Electrical Injury

There are four types of injury relating to electrical incidents.

Electric Shock

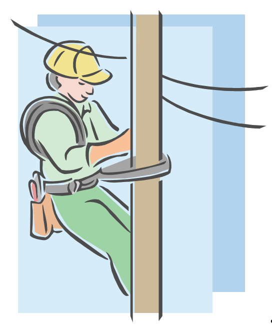
Electric shock is a reflex response possibly involving trauma which occurs when electrical current passes over or through a worker's body. It usually involves burns and abnormal heart rhythm and unconsciousness.

Electrocution

Electrocution occurs when electrical current passes over or through a worker's body resulting in a fatality.

Falls

Electric shock may cause muscles to contract causing a worker to lose his or her balance and fall. An explosion from an electrical incident can also cause a fall.



Burns

Electrical burns are the most common shock-related, nonfatal injury. They occur when a worker contacts energized electrical wiring or equipment. Although electrical burns can occur anywhere on the body, they most often occur on the hands and feet.

Facts About Electric Shock

Basic Rules of Electrical Action

In order to understand how electric shock works, it's important first to understand the basic rules of electricity, which include the following.

1. Electric current won't flow until there is a complete loop.
2. Electric current always tries to return to its source, that is, the transformer or other sources that supplied it.
3. When current flows, work (measured in watts) can be accomplished.

How Shock Occurs

Now let's take a look at how shock occurs. We've learned that electricity travels in closed circuits through a conductor. Electric shock occurs when the body becomes part of the electrical circuit. This can happen when any of the following occurs.

1. The body comes into contact with wires in an energized circuit.
2. The body comes into contact with one wire of an energized circuit and a path to the ground.
3. The body comes into contact with a metallic part that has become "hot" by contact with an energized conductor.

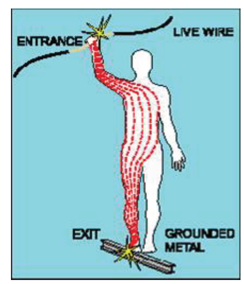


Diagram courtesy of Electrical Safety Foundation International

Severity of Shock

The severity of the shock depends on three factors.

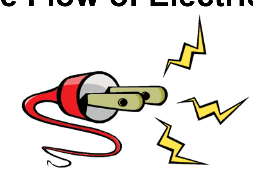
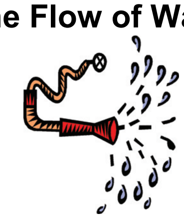
1. The <u>path</u> of the current through the body.
2. The <u>amount of current</u> flowing through the body.
3. The <u>length of time</u> the body is in the circuit.

Basic Facts of Electricity

Electricity is the most versatile form of energy when used properly. Before dealing with electrical equipment, workers should know basic electrical facts and the importance of learning and following safe work practices.

ELECTRICITY = ELECTRONS IN MOTION

These electrons can be measured in current, force and resistance. To understand these terms, let's compare electricity flowing through a circuit to water flowing through a garden hose.

Term	The Flow of Electricity 	The Flow of Water 
Current	- Flow of electrons - Measured in amps - I = amps	- Flow of liquid - Measured in gallons per minute (gpm)
Force	- Measured in voltage - V or E = volts	- Measured in pounds per square inch (psi)
Resistance	- Electrical resistance to flow is measured in ohms - R or Ω = ohms	- Water resistance to flow is measured as friction or baffles

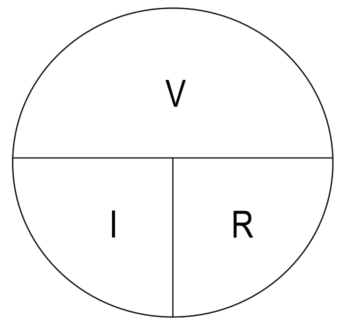
Ohm's Law

Ohm's Law states that one volt will cause a current of one ampere to flow through a conductor having the resistance of one ohm. As a formula, Ohm's law is represented by:

V (volts) = I (amps) X R (resistance)*

An easy way to remember this formula is to use the symbols in a circle like the one to the right.

- To determine amps (I = V/R), put your finger on the "I" in the figure to the right.
- To determine resistance (R = V/I), put your finger on the "R."
- To determine volts (V = I x R), put your finger on the V.



Using this formula, you can understand and explain the amount of electric current moving through a conductive body.

*Remember that resistance (R) is measured in ohms (Ω).

Practice: A worker is using an electric drill and perspiring. He has hand-to-hand resistance of 1,000 ohms. The worker contacts 120 volts with one hand and touches a ground surface with the other. This completes the loop to the voltage sources. Using Ohm's Law and the values stated in this problem, calculate the flow of current.

Answer:

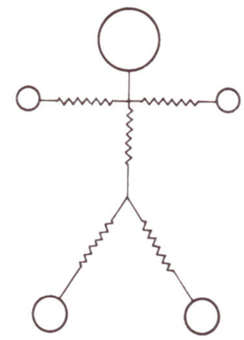
Note: Electrical current is often expressed in terms of milliamps. Just as we can divide one meter into one thousand millimeters, one amp can be divided into one thousand milliamps.

1 amp = 1,000 milliamps

The Human Body Resistance Model

It is important to understand the resistance of parts of the human body to electric current. The following chart shows the resistance of various parts of the human body.

Body Part	Resistance
Dry, intact (no cuts or scabs) skin	100,000 – 600,000 ohms
Wet skin	1,000 ohms
Within the body	400 ohms
Ear to ear	100 ohms



Why would resistance of wet skin be so much lower than the resistance of dry skin?

What practical implication does an understanding of the low resistance within a human body have to a safety professional?

Current and Its Effect on the Human Body

The effects of electricity on the human body depend on many variables.

- The strength of the current
- Duration of contact
- Body mass (small frames provide less resistance, large frames provide more)
- Gender of the person
- Moisture of the body
- The path of the current

Current	Reaction
1 Milliampere	Perception level, a faint tingle
5 Milliamperes	Slight shock felt, not painful, but disturbing Average individual can let go 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)	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 Death is most likely
10,000+ Milliamperes	Cardiac arrest Severe burns Probable death

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

Source: W.B. Kouwenhoven, "Human Safety and Electric Shock," Electrical Safety Practices, Monograph 112, Instrument Society of America, p. 93. (Papers delivered at the third presentation of the Electrical Safety Course in Wilmington, DE in November 1968.)

Note: To help you remember the effects of current on the body, the above chart is available on your *Tools and Resources* CD-ROM.

Case Study

One hot summer morning, a 23 year old apprentice construction worker had just started his shift when he felt a tingling sensation in his hand while using an electric power drill. The young man took the drill to the air conditioned construction trailer where the 59-year old project manager worked. The project manager plugged the drill into a wall socket, but did not feel any tingling. Assuming the young man was trying to get out of his assigned tasks, he told the young worker either to use the drill to complete his job assignments or to punch out and go home. The young man was angry and returned to his work area. The apprentice spent the next ninety minutes working on various tasks. He then returned to the assignment requiring the use of the drill. He plugged in the drill, knelt down on one knee and began to drive a screw into a board. Coworkers saw the employee on the floor convulsing. A coworker was able to knock the extension cord from the source and power to the drill was cut. The apprentice suffered a cardiac episode before an emergency crew arrived. Efforts to revive the young man were unsuccessful.

What were the volts present in the drill?

What are some potential differences between the work environment of the apprentice and that of the project manager?

What is the likely resistance of the project manager's skin?

What is the likely resistance of the apprentice's skin?

Using Ohm's Law, calculate the flow of current experienced by both the project manager and the apprentice.

<u>Project Manager</u> <u>Apprentice</u>

Case Study Lessons

Directions: Based on the case study we have just completed, answer the following questions.

1. Are lower amperage/voltage circuits a threat to humans?

   Notes:

2. Does your organization have emergency response procedures for electrical incidents? If so, how often do you provide training on them and review them with your employees? If you do not have emergency procedures, consider developing them to be in compliance with NFPA 70E 110.6, paragraph C.

   Notes:

Planning for Your Small Business

Directions: Based on what you've learned in this module, what will you do back on the job?

1. Identify two or three actions you will take when you return to your worksite.
2. In addition, identify the potential barriers you might encounter in taking these actions.
3. Next, list ideas for overcoming the barriers identified.

Action Plan

Action	Potential Barriers	Overcoming the Barriers