12th Edition

Modern Residential Wiring

Harvey N. Holzman
Master Electrician

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Preface

Modern Residential Wiring provides you with a solid background of electrical principles and practices, as well as a thorough understanding of *National Electrical Code*®* requirements. Once having mastered the information provided here, you will be well equipped to design and install modern and safe residential wiring systems that meet the electrical power demands of today's world.

Modern Residential Wiring covers not only the "how" but also the "why" of safe electrical wiring practice. Although the content is concerned primarily with residential installations, many of the same concepts and principles may be applied to commercial and industrial electrical construction.

The chapters are arranged in a logical sequence. The order of instruction follows the normal order in which an installation is made. However, each chapter is designed to stand alone and may be studied independently to suit a specific need.

Modern Residential Wiring makes the study of electrical wiring easy. Even the most complicated procedures are explained in a clear, simple, easy-to-understand manner. Procedures are presented "step-by-step," while the many illustrations are fully integrated into the easy-to-read text. The illustrations should be carefully examined as they will often clarify and explain the more difficult principles of electricity and the requirements of the *National Electrical Code*.

The principles of electricity remain fixed. However, the methods, materials, and tools of the trade are continuously evolving. *Modern Residential Wiring* presents both the fundamentals of electrical wiring and the latest practices used in the trade. This new edition of *Modern Residential Wiring* is revised to be consistent with changes in the trade practices, materials, and the requirements of the 2020 *National Electrical Code*.

The author wishes to express his sincere appreciation to each of the individuals, organizations, and associations that provided input, assistance, and illustrative materials for this new edition. A special thanks to my wife, Linda, for her active assistance in the creation of this edition.

Harvey N. Holzman

About the Author

Harvey N. Holzman is a licensed Master Electrician with 45 years of hands-on experience in several states, including New York, Florida, Kansas, North Carolina, Pennsylvania, and Texas. Besides owning his own electrical contracting services company, Mr. Holzman has worked for several major constructors at both refineries and power generating stations, providing consulting, supervision, and field engineering. He has been a member of many electrical trade organizations and has trained dozens of individuals, many of whom have gone on to become master electricians.

Reviewers

The author and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of *Modern Residential Wiring*, with special thanks to Robert W. Baird of R. W. Baird & Associates and Philip Schmidt for their in-depth reviews.

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EduHub provides a solid base of knowledge and instruction for digital and blended classrooms. This easy-to-use learning hub delivers the foundation and tools that improve student retention and facilitate instructor efficiency. For the student, EduHub offers an online collection of eBook content, interactive practice, and test preparation. Additionally, students have the ability to view and submit assessments, track personal performance, and view feedback via the Student Report option. For instructors, EduHub provides a turnkey, fully integrated solution with course management tools to deliver content, assessments, and feedback to students quickly and efficiently. The integrated approach results in improved student outcomes and instructor flexibility.

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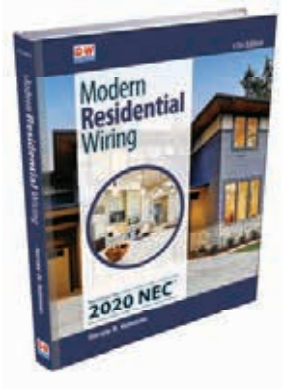

Student Text

Modern Residential Wiring includes information on safety, electrical theory, tools, and electrical systems, as well as specialized installations, such as swimming pools and emergency standby systems. It features content covering career/workplace skills, electrical measurement and testing equipment, and lighting systems. *Modern Residential Wiring* is consistent with changes in the trade practices, materials, and the requirements of the 2020 *National Electrical Code*®.

Student Workbook

The student workbook provides minds-on practice with questions and activities. Each chapter corresponds to the text and reinforces key concepts and applied knowledge.

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Instructor Resources One resource provides instructors with time-saving preparation tools such as answer keys, editable lesson plans, and other teaching aids.

Instructor's Presentations for PowerPoint® These fully customizable, richly illustrated slides help teach and visually reinforce the key concepts from each chapter.

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- A Respondus 4.0 license can be purchased directly from Respondus, which enables you to easily create tests that can be printed on paper or published directly to a variety of Learning Management Systems. Once the question files are published to an LMS, exams can be distributed to students with results reported directly to the LMS gradebook.
- Respondus LE is a limited version of Respondus 4.0 and is free with purchase of the Instructor Resources. It allows you to download question banks and create assessments that can be printed or saved as a paper test.

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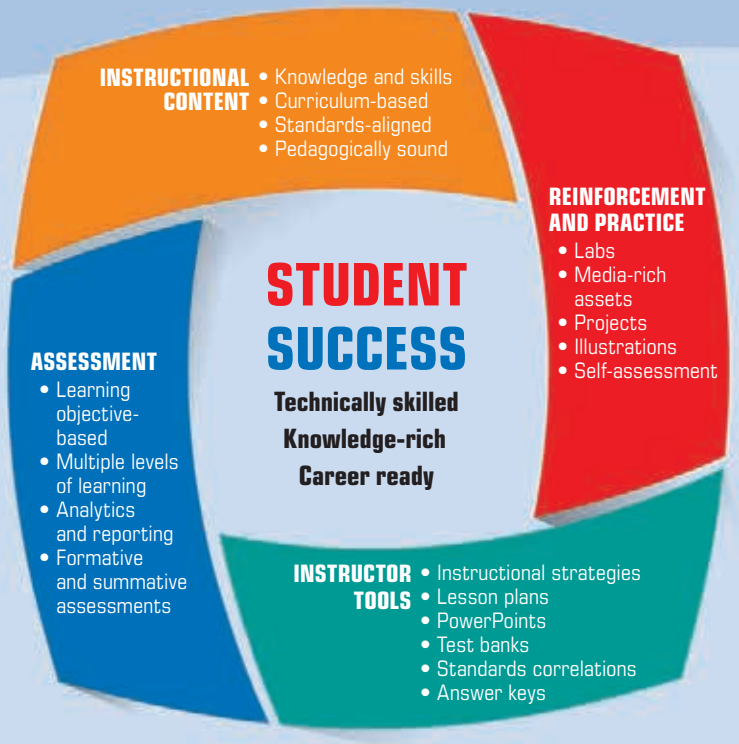

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EMPLOYABILITY SKILLS · TECHNICAL SKILLS · ACADEMIC KNOWLEDGE · INDUSTRY RECOGNIZED STANDARDS

Features of the Textbook

The instructional design of *Modern Residential Wiring* includes student-focused learning tools to help you succeed. In the textbook you will find the following features that will guide you through your learning experience.

Chapter Opening Materials

Each chapter opening contains an outline and a list of learning objectives and technical terms. The **Chapter Outline** previews the topics that will be covered. **Objectives** clearly identify the knowledge and skills to guide your learning as you progress through the chapter. **Technical Terms** list key vocabulary you will encounter as you read the content.

Special Features

Special features are used throughout the body of each chapter to extend learning and knowledge. **Code Alerts** highlight specific items from the *National Electrical Code* and from typical building codes. **Pro Tips** provide advice and guidance that is especially applicable for on-the-job situations. **Safety Notes** alert you to potentially dangerous materials and practices. **Thinking Green** features highlight key items related to sustainability, energy efficiency, and environmental issues.

CHAPTER 12
Device Wiring

Chapter Outline
12.1 Wiring Methods and Materials
12.1.1 Mechanical Considerations
12.1.2 Electrical Connections
12.1.3 Working Clearances
12.1.4 Identification for Safety
12.2 Preparation of Conductors
12.2.1 Stripping Wire
12.2.2 Splicing Conductors
12.3 Wiring Switches and Receptacles
12.3.1 Switch Wiring
12.3.2 Receptacle Wiring
12.4 Wiring Circuits

Objectives
Information in this chapter will enable you to:
- Discuss the significance of listing or labeling electrical devices and materials.
- Properly prepare conductors for connection to devices and equipment.
- Make safe, secure conductor splices.
- Demonstrate the proper method for attaching conductors to switches and receptacles.
- Ground a receptacle.
- Split-wire a receptacle.

Technical Terms
break-off fin
duplex receptacle
grounding-type receptacle
pigtail
receptacle
splicing
split-wired receptacle
wire connector

In the finishing stages of a wiring project, the electrician makes the final connection between conductors and switches and receptacles as well as fixtures, motors, and other devices. *NEC Article 110* specifies requirements for the installation of such materials and equipment. This chapter focuses on wiring switches and receptacles. Lighting is covered in Chapter 13, **Lighting Systems**, and motors are covered in Chapter 22, **Motors**.

12.1 Wiring Methods and Materials

Details on various wiring methods and materials are presented in the articles of *Chapter 3* of the *NEC*. These articles describe, define, limit, and specify the methods and materials of wiring used in the electrical industry today.

CODE ALERT
Avoiding Violations
Common code violations can be avoided with a thorough knowledge of Articles 110 and 300, which specify requirements for electrical installations and wiring methods and materials. If you become knowledgeable in these areas of the *NEC*, your installations will be less likely to suffer the time-consuming, embarrassing, and costly "red-flagging" during an inspection.

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177

200 Section 3 Installation

bayonet, and prong-style. Every light fixture is labeled with the code of the lamp base it accepts.

PRO TIP
Different Base Types
Always check the label of a lamp base to ensure the proper one is selected. Not only are there several different sizes of Edison bases, there are also over 75 varieties of pin-style bases.

13.4.2 Light Sources

Electric lamps use a variety of technologies to produce visible light. The three primary types of lamps are:
- Incandescent
- Fluorescent
- LED

Incandescent lighting has been the predominant type used in household lamps since the late 1800s, but it is steadily being replaced by more energy-efficient light sources, primarily fluorescent and LED. In addition to energy use, different light sources offer different lighting characteristics, including the quality, or "temperature," and the brightness of the light produced.

Incandescent Lamps

Incandescent lamps are still the standard for many household lighting applications. They produce light by running electricity through a thin metal filament, causing it to heat and emit

Halogen lighting is a form of incandescent lighting that includes a metal filament inside a bulb that is filled with pressurized halogen gas. The gas increases the brightness of the light and the life of the filament. Halogen lamps operate very hot and must be handled carefully. Never change a halogen lamp with bare hands. The oil from your skin can cause the lamp to heat up too quickly, shortening the life of the lamp and possibly causing it to explode. Because halogen lighting can produce a lot of light in a small lamp size, it is often used in small accent fixtures and in low-voltage systems.

SAFETY NOTE
Maximum Wattage Ratings
Most people ignore the little labels on light fixtures that specify a maximum lamp wattage rating, but the labels are there for a very good reason. Wattage relates to how hot the lamp gets when it is illuminated. A fixture rated for 60 watts is designed to withstand the heat generated by a 60-watt incandescent lamp. Using a higher-wattage lamp with this fixture can melt the insulation on the fixture wiring, possibly leading to fixture failure, a dangerous short circuit, or a house fire.

Fluorescent Lamps

Fluorescent lamps produce light by conducting an electric current through an inert gas. [illegible] results in an ultraviolet light that [illegible] phosphor coating of the lamp to [illegible] light into bright, white light. [illegible] lamps are widely available as fluo- [illegible] lamps and compact fluorescent [illegible]

[illegible] tubes come in the standard [illegible] used in utility fixtures as well as [illegible]-shaped tubes used in more com- [illegible]. Most fluorescent tubes do not [illegible] so they must be used in fixtures [illegible] a ballast.

[illegible]eter of a fluorescent tube is mea- [illegible]ths of an inch and is referenced in [illegible]me. A T12 lamp is a tube that mea- [illegible]ths of an inch (1 1/2") in diameter.

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224 Section 3 Installation

Baseboard

Wall-Mount

Exploded View

Cadet

Figure 14-10. Electric heating units are available in a variety of sizes, shapes, styles, and power ratings. Units typically include a mounting box that is installed in the wall, a heating unit, and a cover plate.

Baseboard Units

Perhaps the most common residential and small commercial-type heaters are baseboard units. These operate at 120, 208, or 240 volts, and have a load rating ranging from 35 W to about 4.5 kW (4.5 kVA), depending on their size and construction. Control is possible from either a wall-mounted or integrated thermostat.

THINKING GREEN
Energy-Efficient Heating and Cooling
Water heating and space heating and cooling together use about two-thirds of the energy in the average home. Energy-efficient heating and cooling appliances can lower a home's energy use and reduce energy costs significantly. In most cases, efficient appliances cost more to purchase than conventional models, but due to lower operating costs, efficient appliances can save money over their lifetimes.

Consider the purchase price and lifetime operating cost of an electric appliance to determine its cost efficiency in addition to energy savings. Sometimes, more efficient technologies are less expensive to use *and* to purchase and install. For example, evaporative coolers (suitable in dry climates only) cost about half as much as conventional central air conditioners to purchase and install and use about one-quarter as much electricity to operate.

Other Units

Although only a few specific types of heater units are discussed here, there are many other types available. The choice depends on many factors:
- Size of area to be heated
- Heat loss factors
- Amount of insulation present
- Climatic conditions
- Desired temperature of area to be heated
- Style preference.

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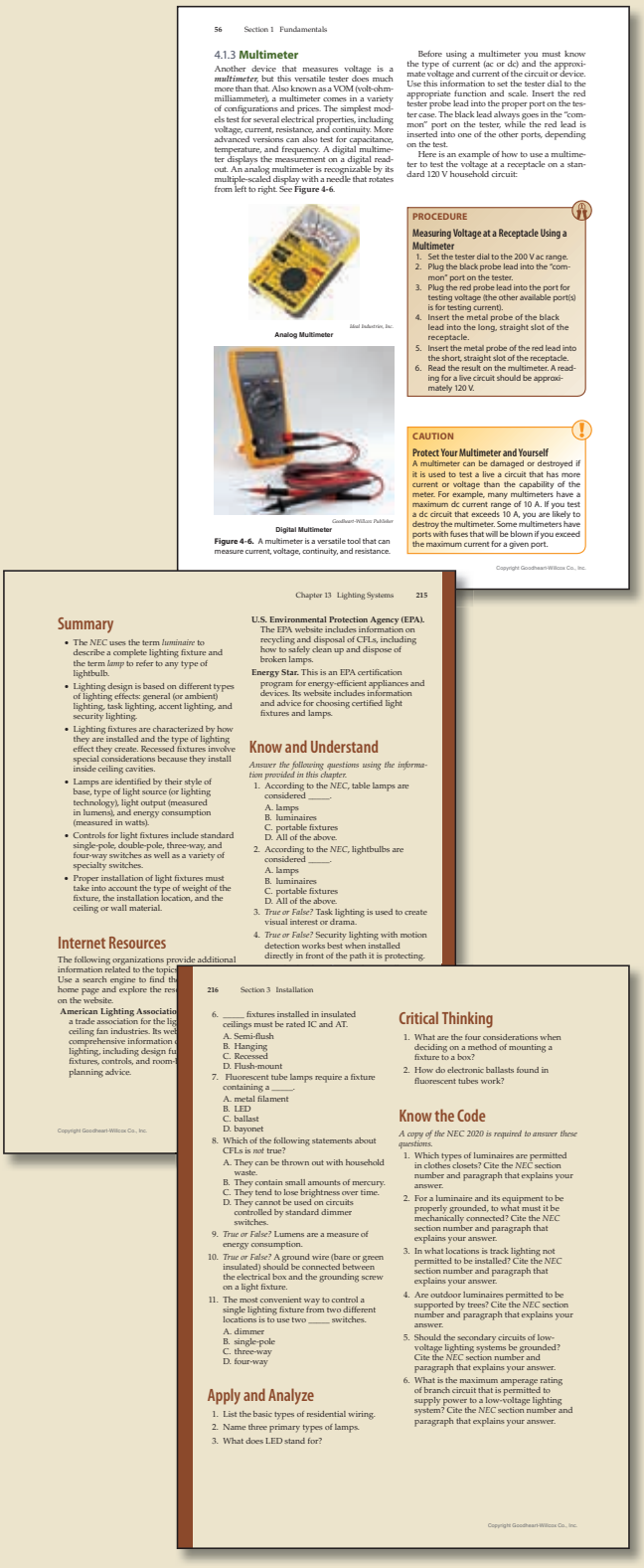


56 Section 1 Fundamentals

4.1.3 Multimeter

Another device that measures voltage is a ***multimeter***, but this versatile tester does much more than that. Also known as a VOM (volt-ohm-milliammeter), a multimeter comes in a variety of configurations and prices. The simplest models test for several electrical properties, including voltage, current, resistance, and continuity. More advanced versions can also test for capacitance, temperature, and frequency. A digital multimeter displays the measurement on a digital readout. An analog multimeter is recognizable by its multiple-scaled display with a needle that rotates from left to right. See **Figure 4-6**.

Before using a multimeter you must know the type of current (ac or dc) and the approximate voltage and current of the circuit or device. Use this information to set the tester dial to the appropriate function and scale. Insert the red tester probe lead into the proper port on the tester case. The black lead always goes in the "common" port on the tester, while the red lead is inserted into one of the other ports, depending on the test.

Here is an example of how to use a multimeter to test the voltage at a receptacle on a standard 120 V household circuit:

Ideal Industries, Inc.

Analog Multimeter

Goodheart-Willcox Publisher

Digital Multimeter

Figure 4-6. A multimeter is a versatile tool that can measure current, voltage, continuity, and resistance.

PROCEDURE

Measuring Voltage at a Receptacle Using a Multimeter

1. Set the tester dial to the 200 V ac range.
2. Plug the black probe lead into the "common" port on the tester.
3. Plug the red probe lead into the port for testing voltage (the other available port(s) is for testing current).
4. Insert the metal probe of the black lead into the long, straight slot of the receptacle.
5. Insert the metal probe of the red lead into the short, straight slot of the receptacle.
6. Read the result on the multimeter. A reading for a live circuit should be approximately 120 V.

CAUTION

Protect Your Multimeter and Yourself

A multimeter can be damaged or destroyed if it is used to test a live a circuit that has more current or voltage than the capability of the meter. For example, many multimeters have a maximum dc current range of 10 A. If you test a dc circuit that exceeds 10 A, you are likely to destroy the multimeter. Some multimeters have ports with fuses that will be blown if you exceed the maximum current for a given port.

Chapter 13 Lighting Systems 215

Summary

- The *NEC* uses the term *luminaire* to describe a complete lighting fixture and the term *lamp* to refer to any type of lightbulb.
- Lighting design is based on different types of lighting effects: general (or ambient) lighting, task lighting, accent lighting, and security lighting.
- Lighting fixtures are characterized by how they are installed and the type of lighting effect they create. Recessed fixtures involve special considerations because they install inside ceiling cavities.
- Lamps are identified by their style of base, type of light source (or lighting technology), light output (measured in lumens), and energy consumption (measured in watts).
- Controls for light fixtures include standard single-pole, double-pole, three-way, and four-way switches as well as a variety of specialty switches.
- Proper installation of light fixtures must take into account the type of weight of the fixture, the installation location, and the ceiling or wall material.

Internet Resources

The following organizations provide additional information related to the topics
Use a search engine to find th
home page and explore the res
on the website.

American Lighting Associatio
a trade association for the lig
ceiling fan industries. Its web
comprehensive information
lighting, including design fu
fixtures, controls, and room-
planning advice.

U.S. Environmental Protection Agency (EPA). The EPA website includes information on recycling and disposal of CFLs, including how to safely clean up and dispose of broken lamps.

Energy Star. This is an EPA certification program for energy-efficient appliances and devices. Its website includes information and advice for choosing certified light fixtures and lamps.

Know and Understand

Answer the following questions using the information provided in this chapter.

1. According to the *NEC*, table lamps are considered _____.
   A. lamps
   B. luminaires
   C. portable fixtures
   D. All of the above.
2. According to the *NEC*, lightbulbs are considered _____.
   A. lamps
   B. luminaires
   C. portable fixtures
   D. All of the above.
3. *True or False?* Task lighting is used to create visual interest or drama.
4. *True or False?* Security lighting with motion detection works best when installed directly in front of the path it is protecting.

216 Section 3 Installation

6. _____ fixtures installed in insulated ceilings must be rated IC and AT.
   A. Semi-flush
   B. Hanging
   C. Recessed
   D. Flush-mount
7. Fluorescent tube lamps require a fixture containing a _____.
   A. metal filament
   B. LED
   C. ballast
   D. bayonet
8. Which of the following statements about CFLs is *not* true?
   A. They can be thrown out with household waste.
   B. They contain small amounts of mercury.
   C. They tend to lose brightness over time.
   D. They cannot be used on circuits controlled by standard dimmer switches.
9. *True or False?* Lumens are a measure of energy consumption.
10. *True or False?* A ground wire (bare or green insulated) should be connected between the electrical box and the grounding screw on a light fixture.
11. The most convenient way to control a single lighting fixture from two different locations is to use two _____ switches.
    A. dimmer
    B. single-pole
    C. three-way
    D. four-way

Apply and Analyze

1. List the basic types of residential wiring.
2. Name three primary types of lamps.
3. What does LED stand for?

Critical Thinking

1. What are the four considerations when deciding on a method of mounting a fixture to a box?
2. How do electronic ballasts found in fluorescent tubes work?

Know the Code

A copy of the NEC 2020 is required to answer these questions.

1. Which types of luminaires are permitted in clothes closets? Cite the *NEC* section number and paragraph that explains your answer.
2. For a luminaire and its equipment to be properly grounded, to what must it be mechanically connected? Cite the *NEC* section number and paragraph that explains your answer.
3. In what locations is track lighting not permitted to be installed? Cite the *NEC* section number and paragraph that explains your answer.
4. Are outdoor luminaires permitted to be supported by trees? Cite the *NEC* section number and paragraph that explains your answer.
5. Should the secondary circuits of low-voltage lighting systems be grounded? Cite the *NEC* section number and paragraph that explains your answer.
6. What is the maximum amperage rating of branch circuit that is permitted to supply power to a low-voltage lighting system? Cite the *NEC* section number and paragraph that explains your answer.

Procedures are highlighted throughout the textbook to provide clear instructions for hands-on service activities. You can easily refer back to these procedures for review and mastery. **Cautions** alert you to practices to avoid that could potentially damage equipment or instruments.

End-of-Chapter Content

End-of-chapter material provides an opportunity for review and application of concepts. A concise **Summary** provides an additional review tool that reinforces key learning objectives. This helps you focus on important concepts presented in the text. **Internet Resources** list websites that provide content related to the electrical wiring profession. **Know and Understand** questions enable you to demonstrate knowledge, identification, and comprehension of chapter material. **Apply and Analyze** questions extend learning and help you analyze and apply knowledge. **Critical Thinking** questions develop higher-order thinking and problem solving, personal, and workplace skills. **Know the Code** questions help you gain knowledge of and become comfortable with the *NEC*.

The *National Electrical Code*®

The most informative and authoritative body of information concerning electrical wiring installation in the United States, and perhaps the world, is the *National Electrical Code*® (*NEC*). This code establishes a set of rules, regulations, and criteria for the installation of electrical equipment. Compliance with these methods will result in a safe installation.

The *NEC* is drafted by a team of experts assembled for this purpose by the National Fire Protection Association (NFPA). This team is formally called the *National Electrical Code* committee. They revise and update the *NEC* every three years. It is imperative that anyone installing electrical wiring obtains and studies the *NEC*. Articles and sections of the *NEC* are referred to throughout this text. Although certain portions, tables, and examples are directly quoted from its text, there is enough useful information in the *NEC* that not having it available would be a tremendous hindrance. The latest edition of the *National Electrical Code* can be purchased from the National Fire Protection Association by visiting their website.

New to This Edition

The following changes were made to the 12th edition of *Modern Residential Wiring* to strengthen the integrated learning solution and to remain current with professional codes:

- Content and tables have been updated to correspond with the 2020 version of the *National Electrical Code®* (*NEC®*).
- Chapter 8 has been updated to address code and table revisions as they apply to conductors.
- Additional updates have been made in other chapters, where appropriate, to address code revisions to topics such as service equipment and motors.
- Up-to-date pedagogical features give instructors and students a learning edge, including questions at the end of each chapter. For this edition, new types of questions include:
  - Know and Understand questions. These autogradable questions provide an opportunity for students to demonstrate knowledge, identification, and comprehension of chapter material.
  - Apply and Analyze questions. These questions, also based on chapter content, extend learning by helping students analyze questions and apply knowledge.
  - Critical Thinking questions require students to make connections beyond the text. These questions extend student learning and develop higher-order thinking skills.
- The addition of EduHub, an easy-to-use learning hub, provides the foundation and tools that improve student retention and facilitate instructor efficiency. For the student, EduHub provides an eBook with text-to-speech capabilities, highlighting, and bookmarking.

Brief Contents

Contents

Section 3
Installation

Section 4
Specialized Installations

Features

Procedures

Thinking Green

Code Alerts

CHAPTER 2

Safety

Chapter Outline

Objectives

Information in this chapter will enable you to:

- Understand the effects of electrical shock.
- Describe conditions likely to affect the severity of an electrical shock.
- List basic workplace safety rules.
- Explain a lockout/tagout/blockout program.
- Describe steps for helping a shock victim.
- Identify common workplace hazards.

Technical Terms

arc flash
blockout device
electrical burn
electrocution
insulated tool
lockout device
personal protective equipment (PPE)
tagout

This chapter teaches you the basics of working safely in a residential wiring environment. Knowledge of safety will boost your confidence so that you may do your job well without fear or apprehension. However, be very careful about letting this confidence turn into complacency. Shortcuts around safe practices quickly become shortcuts to disaster.

2.1 Workplace Injuries

There are many types of injuries that may occur on the work site, the most obvious one being electrical shock. Other possible injuries include burns, eye wounds, punctures, cuts, and back injuries.

The effects of these injuries range from stopping an installation because a cut needs to be bandaged to inflicting grief onto family and friends because carelessness caused a death. These are situations that you can avoid if you learn about safe methods, practice those methods, and repeat the practice until safety becomes a habit.

2.1.1 Electrical Shock

Electricity passing through the human body causes an electrical shock. The severity of a shock

does not have as much to do with the voltage as with the amount of current. A shock of 10,000 V is no more deadly than that of 120 V. A shock approaching 10 milliamperes (0.01 A) is painful and could cause severe injury. See **Figure 2-1**. The values and the bodily effects listed in the table are only an average. Conditions of body size, skin moisture, amount of food and liquids in the body, surrounding humidity, and clothing all can affect the severity of the shock. You will learn more about volts and amperes later in the text. For now, know that the electricity in most homes is far more than required to electrocute a person. ***Electrocution*** is not just any electric shock; it is death caused by electric shock.

2.1.2 Burns

There are two types of electricity-related burns that can occur. Both are life threatening. The first is called an ***electrical burn***, which occurs when electricity passes through the body. Just as wires heat up when too much electricity passes through them, so will the human body. Often, the victim has extensive internal damage with very little external indication of any injury.

The second type of electricity-related burn is the result of arc flash. ***Arc flash*** is an explosion that takes place when electricity short-circuits through the air or across inadequate insulation.

Average Effects of Electric Current on the Body

Amount of Current	Effects on the Body
0.001 A (1 mA)	Felt slightly as a tingle
0.001 A to 0.01 A (1 mA to 10 mA)	Would probably cause muscles to contract and prevent victim from releasing the object
0.01 A to 0.1 A (10 mA to 100 mA)	Fatal after several seconds duration
0.1 A or more (100 mA or more)	Almost always fatal

Goodheart-Willcox Publisher

Figure 2-1. Even very small amounts of current passing through the body can be lethal.

CAUTION

Calling for Emergency Help

Always know where you are working and be able to describe the location of the work site if you have to call 911 for emergency help. Some work sites may not have a street address yet. If you call 911 from a cellular phone, the dispatch center may be able to trace your call to determine your general location. However, this information may not be specific enough to locate you quickly. Always learn the street address of the work site, if available. If not, know the nearest existing address or cross streets and be prepared to describe your exact location.

The temperatures during an arc flash are high enough to melt metal. An arc flash projects melted metal outward, injuring any unprotected workers in the area. The best way to prevent an arc flash is to de-energize equipment before working on it. If this is not possible, be sure to wear the appropriate clothing and eye protection.

Immediate treatment for a burn involves removing the source of the heat and calling for medical help. Burns caused by electric shock or arc flash are usually too severe to be treated by anyone other than a doctor or paramedic. While waiting for help to arrive, cool the burn with sterile gauze soaked in cool (not cold) water. Do not apply ice to a burn, and never put butter, grease, or medical ointments on the burn. Be prepared to treat the person for shock.

2.1.3 Eye Injury

An eye injury can be one of the most devastating wounds a person can receive, but is also one of the easiest to prevent. Always wear your safety glasses whenever there is the slightest chance of an object being projected. You should also wear safety glasses when working in a position that causes you to look overhead. Dust and debris often fall from upper areas during construction. If any of this material falls into your eye, you may suffer an injury ranging from eye irritation

to a scratched eye. Wear a face shield instead of glasses when a task calls for full face protection. See **Figure 2-2**.

2.1.4 Puncture Wound

Puncture wounds typically result from carelessness or sloppy housekeeping. Using a file without a handle, pushing a tool toward your body, or working around wood scraps with nails are common hazards that lead to puncture wounds. If you or a coworker receives a puncture wound, the first step is to call for help. If the object is embedded in the victim, do not try to remove it. Instead, lay the victim down and stabilize the object. Removing it may cause further harm. If the victim remains standing or sitting, there is a chance of falling or fainting, which may result in additional injury.

Safety Glasses

Face Shield

National Safety Apparel

Figure 2-2. Safety glasses are available in a wide variety of styles. Face shields conveniently clip onto hard hats and can be flipped up when not needed.

2.1.5 Cuts

Most cuts occur on the hands and arms. Sharp edges of electrical components and carelessness with cutting tools are just two of the many causes of cuts. When a cut occurs, you will need to clean and dress the wound quickly to prevent infection. Wash the cut by running cool water over it. If the cut appears deep, you should see a doctor in case stitches are needed. Use an adhesive bandage to keep the cut clean and closed.

2.2 Working Safely

Being aware of the types of injuries that can occur on the work site is important, but more important is practicing safe work habits to prevent injuries from occurring. The following are some key safety goals to keep in mind:

- Dress appropriately
- Use ladders and scaffolds correctly
- Operate tools safely
- Practice safe work habits.

2.2.1 Personal Protective Equipment (PPE)

Personal protective equipment (PPE) is the clothing and equipment you wear to protect yourself from known hazards. This equipment may be the only barrier between you and high voltage. There are basic pieces of PPE that you should always have available. These include gloves, safety glasses, flame-resistant clothing, and a hard hat. Some electrical work requires arc flash protective gear, which offers a higher level of flame-resistance and burn protection than most standard PPE. See **Figure 2-3**. There may also be situations that require earplugs and a face shield. The proper items and ratings of PPE are determined by the specific tasks of a given project as well as the general work environment. When shopping for PPE, purchase items that are certified by a nationally recognized testing laboratory (NRTL).

National Safety Apparel

Figure 2-3. A basic set of PPE for electrical work may include a flame-resistant or arc-rated coverall or other clothing, insulated rubber gloves, and a hard hat with face shield.

2.2.2 Ladders and Scaffolding

Electrical work often requires a ladder, and sometimes a scaffold or other elevated platform. Improper setup or use of ladders and scaffolding is a common cause of injury and property damage. Falls from ladders and scaffolds account for a high percentage of work-related deaths. When setting up or moving ladders and scaffolding, be particularly careful not to contact overhead wires or exposed wires.

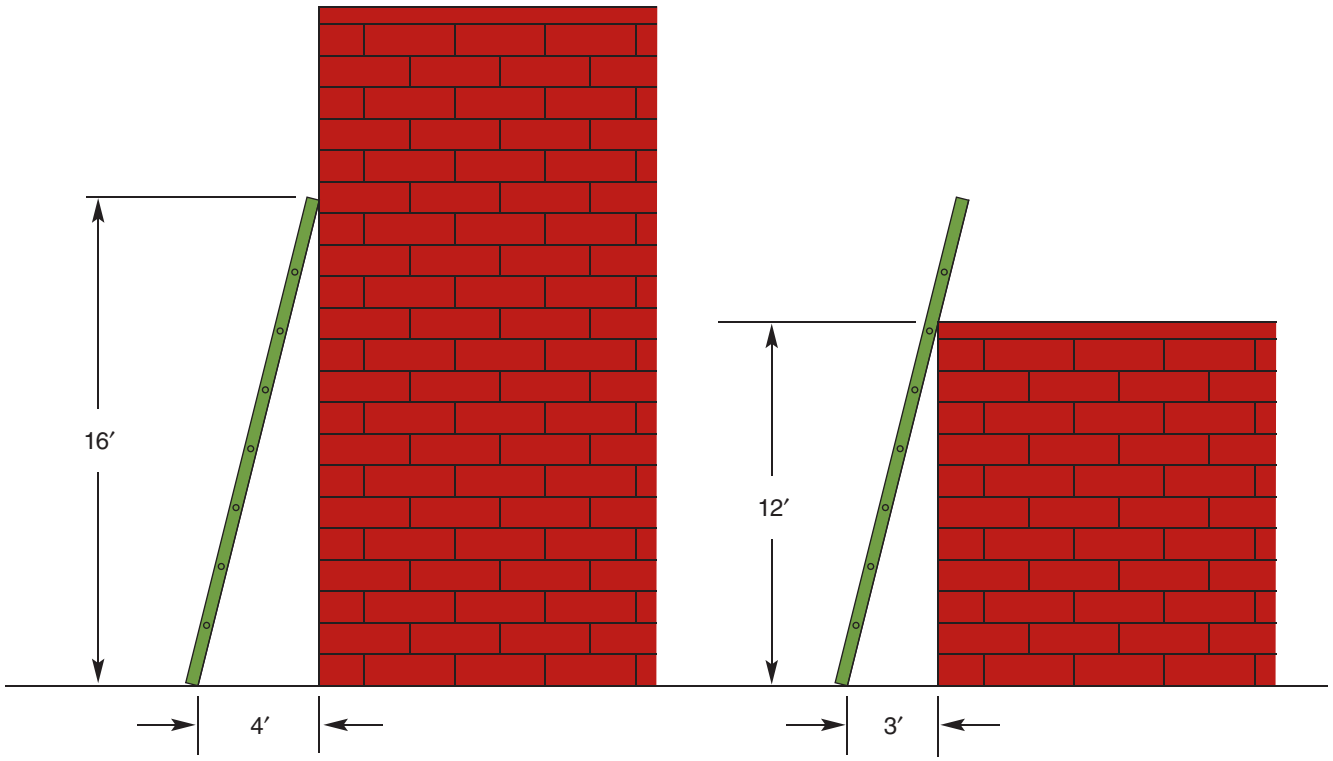
Ladders

Ladders used by electricians should be nonconductive and made of wood or fiberglass. See **Figure 2-4**. When working with an extension ladder, always set it at a safe angle and tie it off to prevent a slip or fall. As a rule of thumb, the horizontal distance from the base of the ladder to the structure should be one-quarter of the height where the ladder touches the structure, **Figure 2-5**. Make sure the base of the ladder has firm support. The ground or floor should be level. If it is not, use a ladder leveler to position the ladder safely. See **Figure 2-6**. Use extreme care if the surface is wet or icy. Special blocking may be needed to prevent slipping.

Stepladders must be set on a level surface and must be fully opened so the hinges are locked. Never use a stepladder while it is leaning against a structure. Always open the ladder.

Werner Co.

Figure 2-4. Use only nonmetallic ladders when working around electricity.



Goodheart-Willcox Publisher

Figure 2-5. The base of an extension ladder should be set away from the structure a distance equal to one-quarter of the height where the ladder rests on the structure.

Werner Co.

Figure 2-6. Use a ladder leveler when positioning a ladder on an uneven surface.

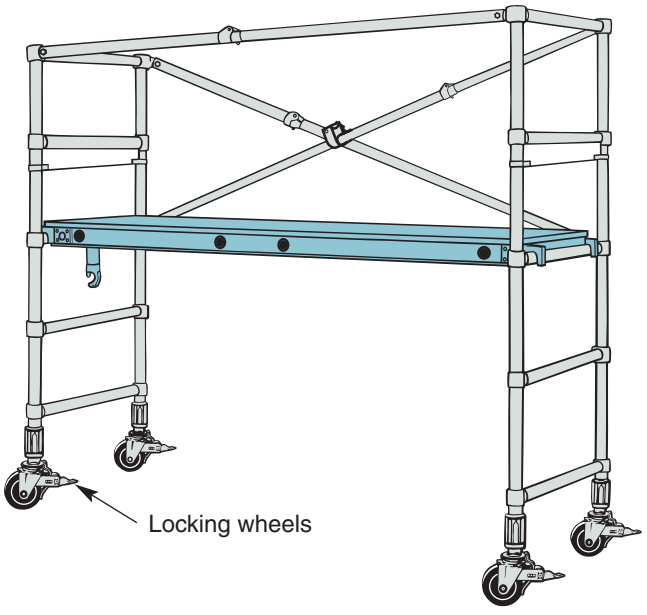
When working on any type of ladder, always face the ladder. See **Figure 2-7**. Never use the top rung or step of a ladder for support. Check ladders often for step rot or other structural damage. Tighten any connecting hardware as needed to ensure joints are tight so the ladder does not wobble or lean. Discard ladders in poor condition.

Scaffolds

Wooden scaffolds are preferred to metal scaffolds for electrical work. If a metal scaffold must be used, it should be grounded. Scaffolds higher than 10′ must have a guardrail. Lock all wheels, if equipped, to prevent unwanted movement. See **Figure 2-8**. Tie off the scaffold when its height exceeds four times the width of the scaffold base. For example, if the base is 3′ wide, the scaffold must be tied off if it is any taller than 12′. Always climb a scaffold using the integrated ladder rungs on the scaffold sections. Never climb on the braces.

Werner Co.

Figure 2-7. Always face the ladder and never stand on the top rung.



Werner Co.

Figure 2-8. Always lock the wheels on a scaffold before climbing.

SAFETY NOTE

Grounding a Scaffold

Metal scaffolds must be grounded by connecting a 2 AWG copper conductor between the scaffold and a ground-connecting fixture (such as a ground plate or a ground rod).

2.2.3 Proper Tool Use

Tool safety involves both proper tool use and using the right tool for the job. This is particularly important for electrical work, which often calls for insulated tools to protect against shock hazards. The specific types of tools electricians are most likely to use are covered in Chapter 3, *Hand and Power Tools*. Always follow general guidelines for safe tool use and refer to manufacturer's instructions for complete, safe operating procedures. See **Figure 2-9**.

Isantilli/Shutterstock.com

Figure 2-9. When using power tools, be sure to wear appropriate protective gear, such as gloves, safety glasses, and hearing protection.

Power Tools

Power tools are designed to make your job easier, but they also introduce additional safety risks. Power cords and moving parts are two potential hazards. Be sure that the tool is switched to the off position before plugging it in. Inspect the cords for damage regularly. If the insulation becomes damaged or the cord cut, do not splice or wrap it with electrical tape. This is not a proper repair. Install a new cord to maintain the original safety of the tool.

Hand Tools

Injuries commonly caused by hand tools include cuts and puncture wounds. The primary risk of hand tools often is related to the force you apply to them. If you are bearing down on a screwdriver or pushing hard on a cutting tool, and the tool slips, where will it land? Always ask yourself this question to make sure that if the tool slips it will not injure you or a coworker.

Insulated Tools

You should always turn the power off before working on electrical equipment. This is the simplest preventive measure you can take to guard against electrical shock. There may be times when you need to work on equipment with the power on. In these rare instances, you should use insulated tools and the proper PPE (personal protective equipment). ***Insulated tools*** have a nonconductive covering that prevents the transfer of electricity from the tool to the user. Just because a tool has a nonmetallic coating or plastic handles does not mean that the tool will protect you from electrical shock. The tool must be identified as an insulated tool that is capable of resisting a specific amount of electricity. See **Figure 2-10**.

Insulated Pliers

Standard Pliers

Klein Tools, Inc.

Figure 2-10. A tool is considered insulated only if the manufacturer has certified it at a specific level of electricity.

2.2.4 Safe Work Methods

There are many tasks that you will perform repeatedly throughout your electrical training and career. Adopting safe work habits with these tasks will greatly reduce the chance of injury. Keep in mind that staying safe not only allows you to be a productive worker, it also helps ensure you can enjoy life outside of work.

Lifting and Carrying

Improper lifting is a major cause of back injuries in the workplace. Bending over to pick up something and twisting your back while lifting are sure ways to invite back pain. This pain can quickly escalate to the point where you may not be able to get out of bed, and that means a day of lost wages. To reduce the risk of back injury, always follow the basic rules of lifting shown in **Figure 2-11**.

Good Housekeeping

Often, it may seem logical to clean your work site only at the end of the day or even the end of the week. After all, it is during this cleanup time that you tend to think about everything you accomplished that day and all of the tasks you need to do tomorrow. However, it is just as important to maintain a clean site throughout the day. Working in an untidy area leads to tripping hazards, lost tools and materials, and general disorganization, all of which waste time and increase the chance of accidents.

Proper Lifting Technique

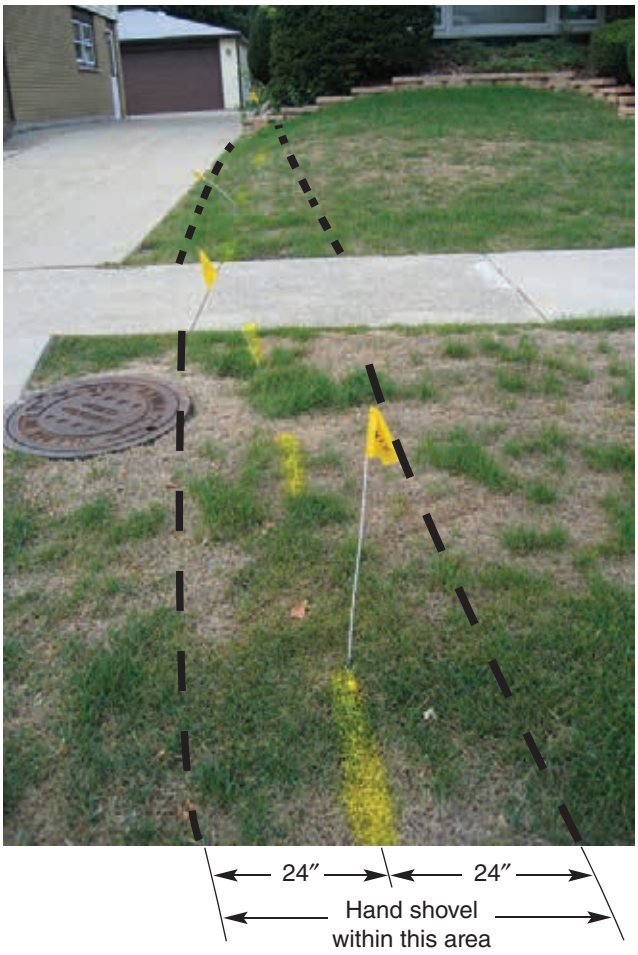
- Position feet shoulder-width apart.
- Bend at your knees.
- Lift the load smoothly, without any sudden movements.
- Keep the load close to your body while lifting—do not extend your arms away from your body.
- Keep your body straight while lifting and holding the load—do not twist your back or turn to the side.
- Lift heavy loads with a partner—do not try to lift a heavy load by yourself.

Goodheart-Willcox Publisher

Figure 2-11. Always follow proper lifting procedures to reduce strain on your back.

Excavating

Digging in the earth poses special hazards. Namely, the risk of contacting an underground utility line and the risk of a large trench caving in. To prevent accidental contact with any type of buried service line, call the national Call Before You Dig hotline (dial 811) to have the lines marked before you begin digging. Do not use any powered excavating equipment within 24″ of the utility markings. See **Figure 2-12**.



Goodheart-Willcox Publisher

Figure 2-12. The local utilities mark the position of underground service lines. You may use powered equipment to excavate no closer than 24″ to the markings. Any digging within the 24″ zone must be done with a hand shovel.

SAFETY NOTE

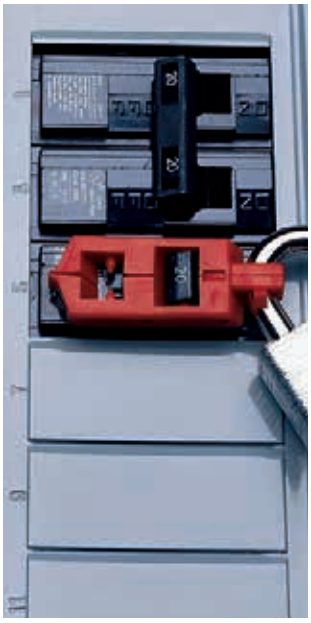
Call 811 Before You Dig

Prevent hitting underground electrical, water, gas, and other utility lines by having the lines marked in the work area. All it takes is one phone call. Dial 811 to reach the national Call Before You Dig operator. They will connect you to a local call center who will in turn contact all local utilities with lines in your area. Each utility will send out a representative to mark the lines on your site, for free and usually within three days. Be sure to call at least three days prior to digging to prevent work delays.

To reduce the possibility of a trench collapse, reinforce any trench over 5′ deep to prevent the walls from caving in. There are various types of shoring designed for this purpose. Also, install barricades and warning signs around the trench. Without these warnings, other workers or passersby may fall into the trench.

Lockout/Tagout/Blockout

One of the most important procedures designed to protect electricians is the lockout/tagout/blockout procedure. This is a combination of rules and devices that prevent the energizing of a circuit that could injure a worker. If an



Ideal Industries, Inc.

Circuit Breaker Lockout **Wall Switch Lockout**

Figure 2-13. Lockout devices prevent other workers from energizing a circuit that is being worked on.

electrician flips a breaker to open a circuit and starts to work on that circuit, what prevents another worker from resetting the breaker? Placing a strip of tape across the breaker or attaching a tag to it does not prevent the closing of the circuit. Tape falls off, tags are ignored, and as a result workers get hurt or killed. Always follow proper lockout/tagout/blockout procedures whether working on residential, commercial, or industrial projects.

A ***lockout device*** prevents the release of energy by attaching one or more locks to switches, breakers, valves (gas and liquid), and enclosures. See **Figure 2-13**. The person working on the circuit is the only one with a key for that lock. If more than one person is working on the circuit, each is able to attach a lock to the device.

Tagout is the identification procedure that lets other workers know who applied the lockout. A lockout/tagout kit is shown in **Figure 2-14**. Your name should be on the tag

Ideal Industries, Inc.

Figure 2-14. Lockout/tagout kits contain various types of lockout devices and tagout devices. Some lockout devices can accommodate multiple locks. This type of device is used when more than one electrician is working on a circuit.

so other workers know that you are working on the circuit. You may also include the date and time of lockout, your phone number, when you expect to be done, and your company's name. All of this information is intended to improve communication among workers. Write your name on a handful of tags and keep them in your toolbox. A tagout should never be used without a lockout or blockout. Always follow the correct lockout/tagout procedures. See **Figure 2-15**.

A ***blockout device*** is used to stop dangerous machinery if energy is accidentally applied. Opening a circuit does not mean all energy has been controlled. The power to a fan may be turned off and locked out, but if the fan blades have not been blocked, there is still the possibility of injury. Air movement from another fan can cause the blades to move with enough force to cause injury. Also, switches have been known to fail and close a circuit. In this situation, a lockout device will not prevent the machinery on this circuit from running, but a blockout device will. There are devices that are designed as blockouts for specific equipment, but a board or pipe can be used if it is properly secured.

PRO TIP

Turn the Power Off!

These four words will be repeated to you throughout this book and throughout your apprenticeship. **Turn the power off!** See **Figure 2-16**. Never work on energized equipment unless it is absolutely necessary and you have the proper training, equipment, and PPE (personal protective equipment). At times, turning the power off may take more time than performing the actual work, but this is never a good reason to work on energized equipment. Replacing damaged equipment or making a trip to the hospital takes far more time than turning the power off. Using insulated tools can help prevent shock in some situations but should never be used as a substitute for turning off the power.

Lockout/Tagout Procedure

- ☑ Identify all sources of energy for the equipment being serviced.
- ☑ Disable any backup energy sources, such as batteries and generators.
- ☑ Identify shut-offs for each energy source.
- ☑ Notify all other workers of the lockout.
- ☑ Shut off energy sources and lock switches in the Off position. If multiple workers are working on the equipment, each should place a lock on each energy source.
- ☑ Place a tag with the lockout device.
- ☑ Deplete any stored energy sources, such as capacitors.
- ☑ Test the equipment and circuit to make sure the energy has been disconnected.

Goodheart-Willcox Publisher

Figure 2-15. A sample lockout/tagout checklist. Always refer to the appropriate lockout/tagout procedure to ensure that no steps are forgotten.

Lisa F. Young/Shutterstock.com

Figure 2-16. Turn off the power to an individual household circuit by shutting off the circuit's breaker in the home's main service panel.

2.3 Responding to an Accident

Since you may be the first person to respond to an accident, knowing a few basic emergency procedures may help you save someone's life. This book is not intended to give you all of the information for aiding a victim. Instead, it offers a brief overview of some of the techniques that can be applied in an emergency. As a start, it is highly recommended that you receive certification in cardiopulmonary resuscitation (CPR) and first aid.

If a coworker is a victim of electric shock, tell someone to call for help while you start to assist the victim. Immediate action must be taken. This is particularly true if the victim is still in contact with the source of electrical current. If you cannot shut off the power immediately, remove the source of electric shock without touching the conductor or the victim. Use great care that you do not receive a shock yourself. After all, you will not be able to help the victim if you become one yourself. Use a wood stick or other nonconductive or insulated material to separate the conductor from the victim.

After the electricity source has been removed and safely controlled, talk to the victim in a loud and clear voice to see if he or she is conscious. If there is no response, try to keep the victim still while checking for signs of breathing. If the victim is not breathing, initiate CPR (cardiopulmonary resuscitation) yourself, or find someone who is trained in CPR. Try to stay with the victim throughout the entire rescue. Let the medical team take over when they arrive.

2.4 Hazardous Environments

All construction sites are, to some degree, hazardous environments. It is very easy to look around these sites and see dangerous situations and be aware of them. As an electrical worker, you must also be aware of the invisible—the electricity within wires and electrical panels. When you step into this environment, you must be able to focus on the job at hand and be aware of the activity around you.

2.4.1 Recognize the Hazard

You cannot actively avoid or control a hazard if you do not know that it exists. Through training and experience you will be able to recognize a hazard and take action. If you see a situation that you believe may be a hazard, but you are not sure, let your supervisor or instructor know. The following are just a few of the common types of hazards found on construction sites.

Overhead

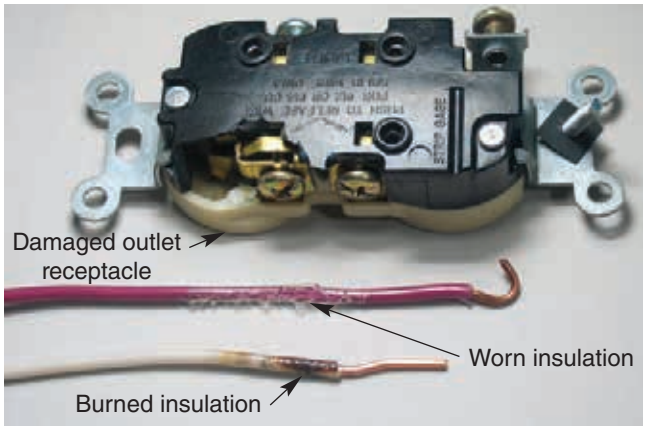
Overhead power lines can create one of the most hazardous situations. These lines are high-voltage conductors that are often uninsulated and can be low to the ground. Use extreme caution when carrying a metal ladder or conduit near these conductors. If the equipment contacts the power lines, the electricity will flow through the equipment, through your body, and into the ground. Even if the equipment does not touch the power lines, it can come close enough to draw an arc. To reduce this risk, carry the equipment horizontally or avoid walking under the power lines.

Improper Installation

Whether working in new or existing construction, you may come across an installation that is not safe or is not allowed by local code rules. The worst reaction to this situation is to ignore it. Doing so could put you, your coworkers, and future homeowners at risk. Warn those in the area of the danger and immediately notify your supervisor or instructor. If the installer made a mistake without knowing, an important lesson will be learned. If the improper installation was due to carelessness or laziness, the supervisor or instructor will know to pay close attention to that person's work.

Worn Components

When working in older construction, you may come across outlets, light fixtures, switches, or wires that are worn to the point of being unsafe. Broken plastic, stripped screws, and brittle wire insulation are indications that these items need to be replaced. Do not try to reuse any components that are not in good mechanical or electrical condition. The cost of a new part is very small when compared to the possible costs of not replacing it. See **Figure 2-17**.



Goodheart-Willcox Publisher

Figure 2-17. Common examples of damaged household equipment include cracked or broken receptacle housings and faces and worn or burned wiring insulation. Never use damaged components or wiring.

Wet Conditions

Utility workers often must repair power lines in the rain. Water is an excellent conductor of electricity. Special equipment and training are necessary to prepare the workers for these high-risk situations. Although you may not find yourself in a rainstorm, the rules of working in any wet conditions are the same. The first rule is to avoid it. If you are working on an entire house, work on the interior wiring on rainy days and install the service on a dry day. If you must work in wet conditions, make sure that you have the proper equipment and training to complete the job safely and TURN THE POWER OFF. The proper equipment includes ground-fault circuit interrupter (GFCI) protection, insulated tools, and PPE (personal protective equipment) that is designed for these situations. See **Figure 2-18**.

Hubbell, Inc.

Figure 2-18. This temporary power distribution box contains ground-fault circuit interrupters to protect workers in wet working conditions.

Fumes

This may not seem to be a concern of electrical workers, but flammable fumes affect everybody on the work site. Always keep flammable fumes well away from any electrical equipment. A simple light switch can create a spark large enough to ignite fumes.

Nonflammable fumes, although not a fire hazard, can be just as dangerous. Fuel-powered tools emit carbon monoxide, a colorless and odorless gas that can be deadly. This applies to any equipment or appliances that burn fossil fuels, including gasoline, diesel, propane, natural gas, kerosene, and others. Always provide adequate ventilation and fresh-air intake when using this equipment. If you experience dizziness, headache, or any other symptoms, exit the building immediately and inform someone about your condition and the safety issue.

2.4.2 Report the Hazard

As stated earlier, you must report any hazardous situations. There are different methods of reporting a hazard, depending on the severity and risk involved. You already know what to do if you come across an improper installation: notify your supervisor or instructor. Other situations may require notifying your coworkers through lockout and tagout procedures. Barricades and warning tape are effective tools to alert others of hazardous areas. The main purpose of all of these methods is to let others know about the environment they are working in. Another procedure is holding morning meetings to alert all crews of an unusual hazard, such as an overhead crane lift that is scheduled for that day. Communication among all involved is the most effective tool for preventing accidents.

2.4.3 Remove the Hazard

Correcting hazardous situations may be as simple as practicing good housekeeping or as involved as reworking an improper installation. You may not be able to address some hazards, such as a problem with overhead power lines. Removing this type of hazard involves notifying others or erecting barricades.

2.4.4 Review the Hazard

Once a hazardous situation has been recognized, reported, and removed, you should take time to review the preceding events, on your own or with your instructor or supervisor. Address the following questions:

- Why did this happen?
- What are the chances that it will happen again?
- How can this be prevented from happening again?
- Was the appropriate action taken?
- Is this situation covered by a *National Electrical Code* specification or recommendation?

2.4.5 OSHA's Construction Focus Four

OSHA (Occupational Safety and Health Administration) is part of the United States Department of Labor and was created in 1970 to help ensure safe work environments for American employees. Electricians and other tradespeople are required to comply with OSHA standards on many projects. These standards often include basic safety protections, such as wearing a hard hat and other personal protective equipment, using GFCI-protected extension cords, tying off ladders, and using scaffolds with guardrails.

OSHA's Construction Focus Four is an employee training program based on the four most common types of injuries in the construction environment:

- Falls
- Caught-in or caught-between
- Struck by
- Electrocution.

All of the training materials for this program are available for viewing and downloading on OSHA's website. Simply reading through these materials provides an excellent introduction to the real hazards of construction sites and how to prevent injuries of all kinds, including many fatal injuries.

2.5 Reference

The following organizations are involved in researching, developing, and maintaining rules, codes, and laws designed to promote safety. Some of the groups, such as OSHA and NIOSH, focus on workplace safety. Others, including the NFPA and ICC, publish widely adopted codes that promote safe electrical installations. All of these organizations are commonly known and referred to in the electrical field. It is recommended that you become familiar with each of them by visiting their websites. You will also find more discussion on some of these organizations in later chapters.

- **OSHA.** Occupational Safety and Health Administration
- **NFPA.** National Fire Protection Association (Publisher of the *National Electrical Code®*)
- **NIOSH.** The National Institute for Occupational Safety and Health
- **ICC.** International Code Council
- **IBEW.** International Brotherhood of Electrical Workers®
- **NECA.** National Electrical Contractors Association

Summary

- Electrical shock and related injuries are caused by electricity passing through the body.
- Small increases in the amount of current (amperage) passing through the body significantly increase the severity of electrical shock.
- Safe work habits for electricians include proper use of tools, ladders, and personal protective equipment, in addition to following electrical safety rules.
- Lockout/tagout/blockout procedures prevent injury caused by accidental energizing of electrical equipment that is being worked on.
- Electricians and apprentices must know how to safely respond to help a victim of electric shock.
- Identifying and addressing electrical hazards in the workplace is everyone's responsibility.

Internet Resources

The following resources provide additional information related to the topics in this chapter. Use a search engine to find the company or organization home page and explore the resources available on the website.

Electrical Contractor. Magazine and website published by the National Electrical Contractors Association (NECA). Content includes up-to-date information on industry standards, safety, tools and techniques, and other topics for professionals in the electrical field.

American Red Cross. Sponsors CPR and first aid certification programs held nationwide.

American Ladder Institute. Professional association that promotes ladder safety and develops standards for the American National Standards Institute (ANSI). A source for tips on ladder safety and a handy ladder safety checklist as well as additional resources for related information.

MedlinePlus. Website of National Institutes of Health (NIH), containing information on causes, symptoms, and treatment of electrical injuries as well as additional resources.

Hand Tool Institute. Information on the safe and appropriate use of specific hand tools. Many of the press releases available on this site contain useful information.

Power Tool Institute. Information on general power tool safety and tips specific to many different power tools.

Know and Understand

Answer the following questions using the information provided in this chapter.

1. The amount of current passing through the body is an important factor relating to the effect of an electrical shock. A current approaching _____ is painful and can lead to severe injury.
   A. 1 mA
   B. 5 mA
   C. 10 mA
   D. 13 mA
2. A(n) _____ flash is an explosion that takes place when electricity short-circuits through the air or across inadequate insulation.
   A. lockout
   B. arc
   C. blockout
   D. insulated

3. Which of the following statements about personal protective equipment (PPE) is *false*?
   A. Wearing PPE during an arc can help prevent burns to the skin and eyes.
   B. PPE includes clothing and equipment.
   C. Earplugs are not considered PPE and are unnecessary.
   D. PPE ratings are determined by the specific tasks of a given project and the general work environment.
4. *True or False?* An aluminum ladder should *not* be used when working around electrical wiring.
5. *True or False? Blockout procedure* is another name for *lockout procedure*.
6. To aid a victim of electrical shock, which of the following should you *not* do?
   A. Quickly grasp and drag the victim away from the current-carrying material.
   B. Shut off the power.
   C. Call for help.
   D. If the shutoff switch is too far away, use a wooden stick to remove victim from current-carrying equipment.
7. The worst reaction to an improper installation is to _____.
   A. warn others in the area of the danger
   B. notify your supervisor
   C. ignore it
   D. notify your instructor

Apply and Analyze

1. List eight safety rules an electrician should observe when working with electrical equipment and tools.
2. What is PPE?
3. What does CPR stand for?
4. What types of fumes are hazardous on a job site?
5. When is it acceptable to ignore a hazard?

Critical Thinking

1. According to OSHA, what are the most frequent causes of electrical injuries?
2. Create a list of safety precautions you would take when working with electricity while on a ladder.