

# ELECTRICAL WIRING RESIDENTIAL



Based on the 2014 National Electrical Code®

18<sup>TH</sup> EDITION



RAY C. MULLIN & PHIL SIMMONS

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Australia • Brazil • Mexico • Singapore • United Kingdom • United States

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# Foreword

## THE IMPORTANCE OF PROPER TRAINING

Now that I have retired after 48 years in the electrical industry, it has become even more evident that a good solid education about the world of electricity is of utmost importance.

Accurate materials and training are the two sides of the electrical safety coin. This coin is spent every day by various persons intrinsically involved in the electrical construction industry. Unfortunately, some spend it less wisely than others. Usually, the unwise spenders are those who rush to career, having neglected to acquire accurate materials and to focus on training themselves to a high level of proficiency.

Ray Mullin, coauthor of this book, *Electrical Wiring—Residential*, has often stated, “The cost of education is small when compared to the price paid for ignorance.” All too often, we, the citizens, pay the price for others’ ignorance—ignorance of the codes, ignorance of proper wiring methods, ignorance of proper installation procedures, ignorance of design requirements, ignorance of product evaluations. This price becomes dear when our friends and family lose health or life or when our homes are destroyed.

It is exciting to see that Phil Simmons has joined with Ray as coauthor of *Electrical Wiring—Residential*. Phil has served the electrical industry with distinction for many years. His ability to express complex electrical issues clearly and to illustrate them accurately is unparalleled among his peers.

Fortunately, accurate materials are so easy to obtain. Ray Mullin and Phil Simmons are both technical writers who have paid their dues in the electrical industry. Each has put in many years as an apprentice, a journeyman, and then as a master electrician before beginning to write about his trade. Phil was additionally a professional in the electrical inspection arena and managed the International Association of Electrical Inspectors (IAEI) for several years. Both have served or are serving on *NEC Code Making Panels*. *Electrical Wiring—Residential* contains accurate, up-to-date information about all aspects of residential wiring.

When installers and inspectors don’t keep abreast of installation procedures and code requirements, things like cables across scuttle access to attics; improper spacing of receptacle outlets; improper short-circuit and ground-fault protection; and improper grounding of electrical systems, phone system, and CATV systems can lead to hazardous situations causing electrical shocks and fire. Not just anybody can install or inspect safe electrical systems. Trained professionals can, but even they must be constantly improving their knowledge and skills.

Because Ray Mullin and Phil Simmons care about the electrical safety coin, they have striven to provide the most accurate information possible. It is up to each of us, however, to focus on the training. Some training can be acquired simply by reading the best books in our trade; some training can come through the online programs available; and other training, through participation in classes and seminars. In each instance, though, motivation and desire come from within—to know everything involved in our trade, to be totally proficient, to focus continually on improvement. As we seek both accurate information and training, we learn to

spend the coin of safety to benefit others as well as ourselves. I commend you for acquiring *Electrical Wiring—Residential*; now I challenge you to make it part of yourself. I challenge you to spend the electrical safety coin wisely.

**James W. Carpenter**

Former CEO and Executive  
Director,

International Association of  
Electrical Inspectors

Past Chair of the *NEC* Technical  
Correlating Committee



# Preface

## INTENDED USE AND LEVEL

STOP . . . Don't read any further . . . yet. Take a moment to familiarize yourself with how to use this text to get the most benefit from it. Think of it as a three-legged stool. One leg is this text, the second leg is the 2014 edition of the *National Electrical Code*<sup>®</sup>, and the third leg is the set of Plans that are in the packet in the inside back cover. If any one of the legs is missing, the stool will collapse. Stated another way, you will not get as much out of this course. When you have completed all of the chapters in *Electrical Wiring—Residential*, you will have virtually wired a typical house according to the requirements of the 2014 *National Electrical Code*, an accomplishment you can be proud of!

The *NEC*<sup>®</sup> defines a “qualified person” as **One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.\***

*Electrical Wiring—Residential* is intended for use in residential wiring courses at high schools, two-year and four-year colleges, and apprenticeship training programs. This comprehensive book guides readers, room by room, through the wiring of a typical residence and builds a foundation of knowledge by starting with the basic requirements of the *National Electrical Code (NEC)*, then continuing on to the more advanced wiring methods. Each *Code* rule is presented through text, illustrations, examples, and wiring diagrams. In addition, an accompanying set of Plans at the back of the book guides the reader through the wiring process by applying concepts learned in each chapter to an actual residential building in order to understand and meet the requirements set forth by the *NEC*.

### An Important Note about Safety

In the educational field, it is pretty much a given that “Society will pay for education . . . one way or another.” Proper training of a skilled trade is much better than hit-or-miss learning. Having to do the job over, having a house burn down, or having someone get electrocuted because of improper wiring is costly!

It really doesn't take any longer to do it right the first time than to have to do it over. You probably have heard the phrase “Measure twice . . . cut once. Measure once . . . cut twice.” How true!

Electrical wiring is a skilled trade. Wiring should not be done by anyone not familiar with the hazards involved. It is a highly technical skill that requires much training. This text

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provides all of the electrical codes and standards information needed to approach house wiring in a safe manner. In fact, *Electrical Wiring—Residential* has been adopted as the core text by the major electrical apprenticeship programs across the country. Their residential curriculum program directors and committee members made this text their top choice for their residential wiring training.

*Electrical Wiring—Residential* will provide you with the know-how so you can wire houses that “Meet Code.”

*Electrical Wiring—Residential* has become an integral part of approved (accredited) training programs by an increasing number of states that require residential electricians to have a residential license if they are going to wire homes and small apartments.

The *NEC* has one thing in mind—safety! There is too much at stake to do less than what the *NEC* requires. Anything less is unacceptable! The *NEC* in 90.1(A) makes it pretty clear. It states that *The purpose of this Code is The practical safeguarding of persons and property from hazards arising from the use of electricity.\**

**Do not work on live circuits!** Always de-energize the system before working on it! There is no compromise when it comes to safety! Many injuries and deaths have occurred when individuals worked on live equipment. The question is always: “Would the injury or death have occurred had the power been shut off?” The answer is “No!”

All mandatory safety-related work practices are found in the Federal Regulation Occupational Safety and Health Administration (OSHA), Title 29, Subpart S—Electrical, Sections 1910.331 through 1910.360.

## SUBJECT AND APPROACH

The 18th edition of *Electrical Wiring—Residential* is based on the 2014 *National Electrical Code (NEC)*. The *NEC* is used as the basic standard for the layout and construction of residential electrical systems. In this text, thorough explanations are provided of *Code* requirements as they relate to

residential wiring. To gain the greatest benefit from this edition, the student must use the *NEC* on a continuing basis.

It is extremely difficult to learn the *NEC* by merely reading it. This text brings together the rules of the *NEC* and the wiring of an actual house. You will study the rules from the *NEC* and apply those rules to a true-to-life house wiring installation.

Take a moment to look at the Table of Contents. It is immediately apparent that you will not learn such things as how to drill a hole, tape a splice, fish a cable through a wall, use tools, or repair broken plaster around a box. These things you already know or are learning on the job. The emphasis of this text is to teach you how to wire a house that “Meets Code.” Doing it right the first time is far better than having to do it over because the electrical inspector turned down your job.

The first seven chapters in this book concentrate on basic electrical code requirements that apply to house wiring. This includes safety when working with electricity; construction symbols, plans, and specifications; wiring methods; conductor sizing; circuit layout; wiring diagrams; numerous ways to connect switches and receptacles; how to wire recessed luminaires; ground-fault circuit interrupters (GFCIs); arc-fault circuit interrupters (AFCIs); and surge suppressors.

The remaining chapters are devoted to the wiring of an actual house—room by room, circuit by circuit. All of these circuits are taken into account when calculating the size of the main service. Because proper grounding is a key safety issue, the subject is covered in detail.

You will also learn about security systems, fire and smoke alarms, low-voltage remote-control wiring, swimming pools, and standby generators, and you will be introduced to structured wiring for home automation.

You will find this text unique in that you will use the text, an actual set of Plans and specifications, and the *NEC*—all at the same time. The text is perfect for learning house wiring and makes an excellent reference source for looking up specific topics relating to house wiring. The blueprints serve as the basis for the wiring schematics, cable layouts, and discussions provided in the text. Each chapter dealing with a specific type of wiring is referenced to

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the appropriate plan sheet. All wiring systems are described in detail—lighting, appliance, heating, service entrance, and so on.

The house selected for this edition is scaled for current construction practices and costs. Note, however, that the wiring, luminaires, appliances, number of outlets, number of circuits, and track lighting are not all commonly found in a home of this size. The wiring may incorporate more features than are absolutely necessary. This was done to present as many features and *Code* issues as possible, to give the student more experience in wiring a residence. Also included are many recommendations that are above and beyond the basic *NEC* requirements.

**Note:** The *NEC* (NFPA 70) becomes mandatory only after it has been adopted by a city, county, state, or other governing body. Until officially adopted, the *NEC* is merely advisory in nature. State and local electrical codes may contain modifications of the *NEC* to meet local requirements. In some cases, local codes will adopt certain more stringent regulations than those found in the *NEC*. For example, the *NEC* recognizes nonmetallic-sheathed cable as an acceptable wiring method for house wiring. Yet, the city of Chicago and surrounding counties do not permit nonmetallic-sheathed cable for house wiring. In these areas, all house wiring is done with electrical metallic tubing (thinwall).

There are also instances where a governing body has legislated action that waives specific *NEC* requirements, feeling that the *NEC* was too restrictive on that particular issue. Such instances are very rare. The instructor is encouraged to furnish students with any local variations from the *NEC* that would affect this residential installation in a specific locality.

## THE ELECTRICAL TRADE—TRAINING PROGRAMS

As you study *Electrical Wiring—Residential*, study with a purpose—to become the best residential wireman possible.

There will always be a need for skilled electricians! Qualified electricians almost always have work. It takes many hours of classroom and on-the-job training to become a skilled electrician. The best

way to learn the electrical trade is through a training program approved by the U.S. Department of Labor (<http://www.dol.gov>). Many times an apprenticeship program is called “Earn while You Learn.” These programs offer the related classroom training and the advantage of working on the job with skilled journeymen electricians. Completion of a registered apprenticeship program generally leads to higher pay, job security, higher quality of life, recognition across the country, and the opportunity for college credit and future degrees.

As a rule, these training programs require 144 to 180 hours of classroom-related technical training and 2000 hours of on-the-job training per year. Some programs have day classes and some have night classes. An electrical apprenticeship training program might run four to five years. The end result—becoming a full-fledged licensed journeyman electrician capable of doing residential, commercial, and industrial electrical work. A residential electrician training program might run two to three years, with the training limited to the wiring of single- and multifamily dwellings. The end result—receiving a license limited to residential wiring.

To get into an apprenticeship program, the individual usually must have a high school education, with at least 1 year of high school algebra; be at least 18 years old; must be physically in shape to perform the work electricians are called upon to do (e.g., climbing, lifting, work in inclement weather); and, most importantly, be drug free. There generally is a qualifying aptitude test to make sure the applicant has the ability to take on the responsibility of a rigid apprenticeship training program. In some areas, passing the high school equivalency General Education Development (GED) test is acceptable in place of a high school diploma.

What does it take to make a good apprentice and journeyman electrician? In no particular order: commitment to master the electrical field, willingness to study and understand the training material, strong math skills, ability to think clearly and logically to analyze and solve problems, ability to work indoors and outdoors, comfortable working with your head and hands, good mechanical skills, ability to communicate and work with others, good verbal skills, ability to follow directions, strong work and personal ethics, and being a self-starter.

Following completion of an apprenticeship program, continuing education courses are available to keep the journeyman up to date on codes and other related topics and skills.

Journeymen electricians who have an interest in teaching apprentices will usually have to take instructor training courses. In certain programs, satisfactory completion of the required courses can lead to an associate degree. Others will go on to become crew leaders, supervisors, and contractors.

There are some areas where a “pre-apprenticeship” program is offered. To learn more about the careers possible in the electrical field, chat with your instructor; your local high school’s guidance counselor; your vocational, technical, and adult education schools; and electricians and electrical contractors. Go online and search for electrical apprenticeship programs.

Your future is in your hands.

Some very important two-letter words that you should remember are

**IF IT IS TO BE, IT IS UP TO ME!**

## Job Titles

Most building codes and standards contain definitions for the various levels of competency of workers in the electrical industry. Here are some examples of typical definitions:

*Apprentice* shall mean a person who is required to be registered, who is in compliance with the provisions of this article, and who is working at the trade in the employment of a registered electrical contractor and is under the direct supervision of a licensed master electrician, journeyman electrician, or residential wireman.

*Residential Wireman* shall mean a person having the necessary qualifications, training, experience, and technical knowledge to wire for and install electrical apparatus and equipment for wiring one-, two-, three-, and four-family dwellings. A residential wireman is sometimes referred to as a *Class B Electrician*.

*Journeyman Electrician* shall mean a person having the necessary qualifications, training, experience, and technical knowledge to wire for, install, and repair electrical apparatus and equipment for light, heat, power, and other purposes, in accordance

with standard rules and regulations governing such work.

*Master Electrician* means a person having the necessary qualifications, training, experience, and technical knowledge to properly plan, lay out, and supervise the installation and repair of wiring apparatus and equipment for electric light, heat, power, and other purposes, in accordance with standard codes and regulations governing such work, such as the *NEC*.

*Electrical Contractor* means any person, firm, partnership, corporation, association, or combination thereof who undertakes or offers to undertake for another the planning, laying out, supervising and installing, or the making of additions, alterations, and repairs in the installation of wiring apparatus and equipment for electrical light, heat, and power.

Most electrical inspectors across the country are members of the International Association of Electrical Inspectors (IAEI). This organization publishes one of the finest technical bimonthly magazines devoted entirely to the *NEC* and related topics, and it is open to individuals who are not electrical inspectors. Electrical instructors, vo-tech students, apprentices, electricians, consulting engineers, contractors, and distributors are encouraged to join the IAEI so they can stay up to date on all *NEC* issues, changes, and interpretations. An application form that explains the benefits of membership in the IAEI can be found in the Appendix of this text.

## NEW TO THIS EDITION

Continuing in the tradition of previous editions, this edition thoroughly explains how *Code* changes affect house wiring installations. New and revised full-color illustrations supplement the explanations to ensure that electricians understand the new *Code* requirements. New photos reflect the latest wiring materials and components available on the market. Revised review questions test student understanding of the new content. New tables that summarize *Code* requirements offer a quick reference tool for students. Other reference aids are the tables reprinted directly from the 2014 edition of the *NEC*. The extensive revisions for the eighteenth edition make

*Electrical Wiring—Residential* the most up-to-date and well-organized guide to house wiring. Coverage of the *NEC* has been expanded to well over 1000 *Code* references.

This text focuses on the technical skills required to perform electrical installations. It covers such topics as calculating conductor sizes, calculating voltage drop, determining appliance circuit requirements, sizing service, connecting electric appliances, grounding service and equipment, installing recessed luminaires (fixtures), and much more. These are critical skills that can make the difference between an installation that “Meets *Code*” and one that does not. The electrician must understand the reasons for following *Code* regulations to achieve an installation that is essentially free from hazard to life and property.

**Note:** Symbols have been added to indicate changes in the 2014 *National Electrical Code* from the 2011 *National Electrical Code*. ▶◀

This text might be called “Work in Progress.” The authors stay in touch with the latest residential wiring trends and the *National Electrical Code*. Because the *NEC* is revised every three years, this text follows the same cycle. *Electrical Wiring—Residential* has been carefully reviewed to editorially simplify, streamline, and improve its readability. Many diagrams have been simplified. Some units were reorganized so the *Code* requirements for the various applications are more uniform.

Much rewriting was done. The 2014 *NEC* contains many editorial changes as well as renumbering and relocation of numerous *Code* references. All of these have been addressed in this edition of *Electrical Wiring—Residential*. Some text has been condensed and reformatted for ease in reading. Many diagrams have been simplified for clarity.

The Objectives have been fine-tuned for easier readability.

- Thousands of proposals are submitted each cycle 3-year to update the *NEC*. Additional comments are submitted to revise the action taken by the Code Panels on the proposals. The end result is the publishing of a new edition of the *National Electrical Code*.
- In *Electrical Wiring—Residential*, all *Code* requirements have been updated to the 2014

edition of the *NEC*. These have been revised throughout the text, wiring diagrams, and illustrations.

- Illustrations have been enhanced for improving clarity and ease in understanding.
- Emphasis was given to making the wiring of the residence conform to energy saving standards. In other words, the residence in *Electrical Wiring—Residential* is “green.”
- A most significant new rule in the 2011 *NEC* that a grounded conductor be taken to every switch location has been revised for the 2014 edition. This revision has been addressed in *Electrical Wiring—Residential*, with all wiring diagrams revised accordingly. In some locations 3-wire and 4-wire switch loops, and possibly larger boxes, will be required.
- The requirement for arc-fault circuit protection has been expanded to include kitchens and laundry areas. In addition, devices that are located in the rooms where AFCI protection is required now require that same AFCI protection. See *NEC 210.12(A)*.
- The outlets or devices in several rooms or areas now require both GFCI and AFCI protection. See *NEC 210.8(A)* and *210.12(A)*.
- Wiring for receptacle outlets in an attached garage or detached garage with electric power is not permitted to supply outlets outside the garage. See *NEC 210.52(G)(1)*.
- At least one receptacle outlet is required for each car space in the garage. The location relative to the car space is not specified. See *NEC 210.52(G)(1)*.
- All of the wiring diagrams have been updated to show the latest system of electrical symbols. This is based on the National Electrical Contractors Association’s *National Electrical Installation Standard*.
- Major revisions of many diagrams and figures have made to improve the clarity and ease of understanding the *Code* requirements.
- Many new full-color illustrations have been added.

## FEATURES OF THIS TEXT

This text may be used as a classroom text, as a learning resource for an individual student, or as a reference text for technicians on the job.

**Objectives** Objectives are listed at the beginning of each unit. The objective statements have been stated clearly and simply to give students direction.



### OBJECTIVES

After studying this chapter, you should be able to

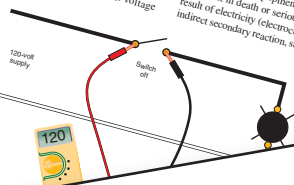
- understand the basic safety rules for working on electrical systems.
- access the Internet to obtain a virtual unlimited source of safety and technical related information.
- become familiar with important electrical codes, safety codes, and building codes such as NFPA 70, 70A, 70B, 70E, 73, OSHA, NIOSH, ADA, NRTL, and the ICC.
- learn about licensing, permits, plans, specifications, symbols, and notations.
- understand the role of the electrical inspector and the International Association of Electrical Inspectors.
- understand the metric system of measurement.
- understand the role of nationally recognized testing laboratories (NRTLs) and the necessity for listed equipment.

### SAFETY IN THE WORKPLACE

Electricity is great when it is doing what it is intended to do, and that is to stay in its intended path and do the work intended. But electricity out of its intended path can be dangerous, often resulting in fire, serious injury, or death.

Before getting into residential wiring and the National Electrical Code (NEC), we need to discuss on-the-job safety. Safety is not a joke! Electricians working on new construction, remodel work, maintenance, and repair work find that electricity is part of the work environment. Electricity is all around us. Just waiting for the opportunity to get out of control. Repeat these words: **Safety First** . . .

**Safety First** . . . The voltage level in a home is 120 volts between one "hot" conductor and the "neutral" conductor, or grounded surface. Between the two "hot" conductors (line-to-line), the voltage is 240 volts. An electrical shock is received when electrical current passes through the body. From basic electrical theory, you learned that line voltage appears across an open in a series circuit. Getting caught "in series" with a 120-volt circuit will give you a 120-volt shock. For example, open-circuit voltage



### SAFETY ALERT

Working on switches, receptacles, luminaires, or appliances with the power turned on is dangerous. Turn off the power! In addition, check with a voltmeter to be sure the power is off. Safety procedures require that you test the voltage tester on a known live source, then test for absence of voltage, and finally test the voltage tester again on a live source to make certain it is operational.

between the two terminals of a single-pole switch on a lighting circuit is 120 volts when the switch is in the OFF position and the lamp(s) are in place. See Figure 1-1. Likewise, getting caught "in series" with a 240-volt circuit will give you a 240-volt shock. Working on equipment with the power turned on can result in death or serious injury; either as a direct result of electricity (electrocution or burns) or from an indirect secondary reaction, such as falling off a ladder

### WHAT IS A LUMINAIRE?

The NEC® defines a luminaire as a complete lighting unit consisting of a light source such as lamp or lamps, together with the parts designed to position the light source and connect it to the power supply. Luminaire is the international term for "lighting fixture" and is used throughout the NEC.

### TYPES OF LUMINAIRES

There are literally thousands of different types of luminaires from which to choose to satisfy certain needs, wants, desires, space requirements, and, last but not least, price considerations. Note in Table 7-1 that whether the luminaire is incandescent or fluorescent, the basic categories are surface mounted, recessed mounted, and suspended ceiling mounted.

### The Code Requirements

Article 410 sets forth the requirements for installing luminaires. The electrician must "Meet Code" with regard to mounting, supporting, grounding, live-parts exposure, insulation clearances, supply conductor types, maximum lamp wattages, and so forth.

Probably the two biggest contributing factors to fires caused by luminaires are installing lamp wattages that exceed that for which the luminaire has been designed, and burying recessed luminaires under thermal insulation if the luminaire has not been designed for such an installation.

Nationally Recognized Testing Laboratories (NRTLs) test, list, and label luminaires that are in conformance with the applicable UL safety standards. Always install luminaires that bear the label from a qualified NRTL.

In addition to the NEC, the UL Guide for Information for Electrical Equipment (White Book), and manufacturers' catalogs and literature are excellent sources of information about luminaires.

### Read the Label

NEC 110.3(B) states that listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling.

It is important to carefully read the label and any instructions furnished with a luminaire. Most Code requirements can be met by simply following this information.

Here are a few examples of label and instruction information:

- Maximum lamp wattage
- Type of lamp
- For supply connections, use wire rated for at least \_\_\_\_\_ °C
- Type-IC
- Type Non-IC
- Suitable for damp, dry, or wet locations
- Thermally protected

### Installing and Connecting Luminaires

The circuit conductors in a wall or ceiling box where luminaires are to be installed are usually

- white—the "identified" grounded conductor.

**Safety Alert** Safety is emphasized throughout the book and is fully covered in the first chapter. Special considerations in working with electricity provide readers with an overview of what dangers are to be expected on the job.

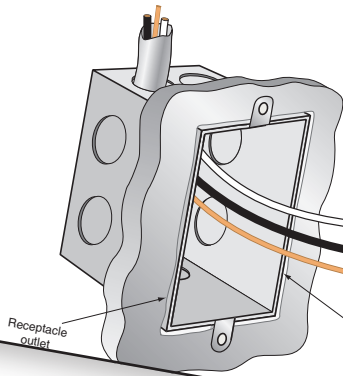
**Direct Quotes from the NEC** Direct quotes from the *National Electrical Code* are set in roman type with shaded background, enabling the reader to clearly distinguish direct *NEC* content.

## ELECTRICAL SYMBOLS

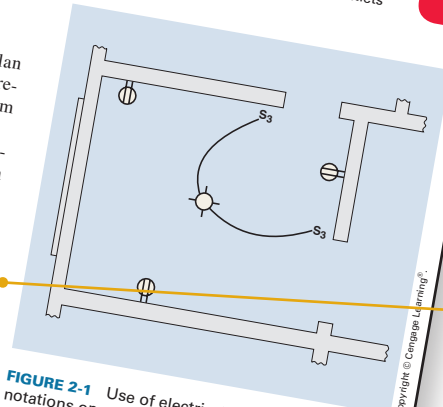
Electrical symbols used on an architectural plan show the location and type of electrical device required. A typical electrical installation as taken from a plan is shown in Figure 2-1.

The *NEC*® has many words unique to the electrical trade. Terms unique to the *NEC* are defined in either *Article 100* if the term is used in two or more articles or in the article itself if the term is used only in that article. For example:

- A **device** is **A unit of an electrical system, other than a conductor, that carries or controls electric energy as its principle function.\***
- An **outlet** is **A point on the wiring system at which current is taken to supply utilization equipment.\***
- A **receptacle** is **A contact device installed at the outlet for the connection of an attachment plug.\***
- A **receptacle outlet** is **An outlet where one or more receptacles are installed.\*** See Figure 2-2.



## CHAPTER 2 Electrical Symbols and Outlets



**FIGURE 2-1** Use of electrical symbols and notations on a floor plan.

- A **lighting outlet** is **An outlet intended for the direct connection of a lampholder or luminaire.\*** See Figure 2-3.

**Changes to the NEC** Sections that denote revisions to the *NEC* are set in roman type with opening and closing red triangles.

## CHAPTER 2 Electrical Symbols and Outlets

### REVIEW

**Note:** For assistance in finding the answers to these review problems, refer to the *NEC*, the plans in the back of this text, and the specifications found in the Appendix.

### PART 1—ELECTRICAL FEATURES

1. What does a plan show about electrical outlets? \_\_\_\_\_  
\_\_\_\_\_
2. What is an outlet? \_\_\_\_\_  
\_\_\_\_\_
3. Match the following switch types with the proper symbol. \_\_\_\_\_  

a. single-pole	$S_p$
b. three-way	$S_4$
c. four-way	$S$
d. single-pole with pilot light	$S_3$
4. The plans show curved lines running between switches and various outlets. What do these lines indicate? \_\_\_\_\_  
\_\_\_\_\_
5. Why are the lines referred to in problem 4 usually curved? \_\_\_\_\_
6. a. What are junction boxes used for? \_\_\_\_\_  
 b. Are junction boxes normally used in wiring the first floor? Explain. \_\_\_\_\_  
 \_\_\_\_\_
- c. Are junction boxes normally used to wire exposed portions of the basement? Explain. \_\_\_\_\_  
 \_\_\_\_\_
7. How are standard sectional switch (device) boxes mounted? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**Review Questions** Review questions at the end of each chapter can help to measure the student's knowledge of the chapter. There are a variety of question types including short answer, matching, true/false, and multiple choice.

## SUPPLEMENT PACKAGE

An *Instructor's Guide* contains answers to all Review questions included in the book and a blank service-entrance calculation form, which is also available in electronic format on the accompanying *Instructor Resources CD*.

(Order #: 978-1-285-17099-2)

An *Instructor Resources CD* provides instructors with valuable classroom materials on CD-ROM:

- **PowerPoint Presentations** outline the important concepts covered in each chapter. Extensively illustrated with photos, tables, and diagrams from the book, the presentations enhance classroom instruction. PowerPoint presentations also allow instructors to tailor the course to meet the needs of their individual class.
- An **Image Gallery** contains nearly all the images in the book and can be used to enhance the PowerPoint presentation or to create transparency masters and handouts.
- **Electronic Instructor's Guide** in Microsoft Word enables instructors to view and print answers to review questions contained in the book.
- **Electronic Blueprints** provide an online version of the drawings that are included at the back of the book, allowing instructors to project and reference in classroom presentations.
- **Video Clips** from the accompanying video series visually highlight important concepts presented in the book

(Order #: 978-1-285-17100-5)

A **Lab Manual** provides over twenty exercises to aid students in learning both basic and complex wiring circuits. Each lab consists of a hands-on wiring exercise as well as *NEC* drill problems. Students are also required to draw an electrical layout of wiring booths to familiarize themselves with electrical symbols. Allowing for instructor verification and student self-assessment, this manual is essential to applying important wiring concepts.

(Order #: 978-1-285-17112-8)

**Electrical Wiring Residential DVD Series:** *Electrical Wiring—Residential Video Series* correlates directly with the *Electrical Wiring—Residential* book. Shot on various construction sites and

enhanced with quality animations, each video is devoted to a specific, specialized topic. In addition to high-quality animations, questions have also been incorporated into each tape at strategic points to promote discussion aimed at enhancing viewers' understanding and preparing them for successful attainment of all learning objectives. Each video is approximately 20 minutes in length, making it easy to incorporate into a comprehensive electrician education and training program.

The complete set includes: Video #1: Introduction to Electrical Installation, Video #2: Planning for Circuit Installation, Video #3: Ground-Fault Circuit Interrupters, Video #4: Lighting by the Room, Video #5: Special Circuits, Video #6: Special-Purpose Outlets, Video #7: Miscellaneous and Custom Installations, Video #8: Service Entrances.

(DVD 1, Videos 1–4 Order #: 978-1-4354-9530-2)

DVD 2, Videos 5–8 Order #: 978-1-4354-9525-8)

## COURSEMATE

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1. Go to <http://login.cengage.com> and log in using the instructor e-mail address and password.
2. Enter author, title, or ISBN in the **Add a title to your bookshelf** search.
3. Click **Add to my bookshelf** to add instructor resources.
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The complete set includes the following: Video #1: Safety and Safe Practices, Video #2: Hardware, Video #3: Tools, Video #4: Initial Review of Plans, Video #5: Rough-In, Video #6: Service Entrance, Video #7: Trim-Out, Video #8: Testing & Troubleshooting.

For more information, visit <http://www.residentialconstructionacademy.com>. Visit us at [www.cengage.com/community/electrical](http://www.cengage.com/community/electrical), now LIVE for the 2014 Code cycle!

This newly designed website provides information on other learning materials offered by Cengage Learning, as well as industry links, career profiles, job opportunities, and more!

## ABOUT THE AUTHORS

This text was coauthored by Ray C. Mullin and Phil Simmons.



**Mr. Mullin** is a former electrical instructor for the Wisconsin Schools of Vocational, Technical, and Adult Education. He is a former member of the International Brotherhood of Electrical Workers. He is a member of the International Association of Electrical Inspectors, the Institute of Electrical and Electronic Engineers, and the National Fire Protection Association, Electrical Section, and has served on Code-Making Panel 4 of the *National Electrical Code*.

Mr. Mullin completed his apprenticeship training and worked as a journeyman and supervisor for residential, commercial, and industrial installations. He has taught both day and night electrical apprentice and journeyman courses, has conducted engineering seminars, and has conducted many technical *Code* workshops and seminars at International Association of Electrical Inspectors Chapter and Section meetings, and has served on their code panels.

He has written many technical articles that have appeared in electrical trade publications. He has served as a consultant to electrical equipment manufacturers regarding conformance of their products to industry standards, and on legal issues relative to personal injury lawsuits resulting from the misuse of electricity and electrical equipment. He has served as an expert witness.

Mr. Mullin presents his knowledge and experience in this text in a clear-cut manner that is easy to

understand. This presentation will help students to fully understand the essentials required to pass the residential licensing examinations and to perform residential wiring that “Meets Code.”

Mr. Mullin is the author of *House Wiring with the NEC*—a text that focuses entirely on the *National Electrical Code* requirements for house wiring. He is coauthor of *Electrical Wiring—Commercial, Illustrated Electrical Calculations*, and *The Smart House*. He contributed technical material for Cengage Learning’s *Electrical Grounding and Bonding* and to the International Association of Electrical Inspectors’ texts *Soares’ Book On Grounding* and *Ferm’s Fast Finder*.

He served on the Executive Board of the Western Section of the International Association of Electrical Inspectors and on their Code Clearing Committee, and, in the past, served as Secretary/Treasurer of the Indiana Chapter of the IAEI.

Mr. Mullin is past Chairman of the Electrical Commission in his hometown.

Mr. Mullin is past Director, Technical Liaison for a major electrical manufacturer. In this position, he was deeply involved in electrical codes and standards as well as contributing and developing technical training material for use by this company’s field engineering personnel.

Mr. Mullin attended the University of Wisconsin, Colorado State University, and the Milwaukee School of Engineering.



**Phil Simmons** is self-employed as Simmons Electrical Services. Services provided include consulting on the *National Electrical Code* and other codes;

writing, editing, illustrating, and producing technical publications; and inspection of complex electrical installations. He develops training programs related to electrical codes and safety and has been a presenter on these subjects at numerous seminars and conferences for universities, the NFPA, IAEI, Department of Defense, and private clients. Phil also provides plan review of electrical construction documents. He has consulted on several lawsuits concerning electrical shocks, burn injuries, and electrocutions.

Mr. Simmons is coauthor and illustrator of *Electrical Wiring—Residential* (17th and 18th editions), coauthor and illustrator of *Electrical Wiring—Commercial* (14th and 15th editions), and author and illustrator of *Electrical Grounding and Bonding*, all published by Cengage Learning. While at IAEI, Phil was author and illustrator of several books, including the *Soares’ Book on Grounding of Electrical Systems* (five editions), *Analysis of the NEC* (three editions), and *Electrical Systems in One- and Two-Family Dwellings* (three editions). Phil wrote and illustrated the National Electrical Installation Standard (NEIS) on *Types AC and MC Cables* for the National Electrical Contractors Association.

Phil presently serves NFPA on Code-Making Panel 5 of the *National Electrical Code* Committee (grounding and bonding). He previously served on the *NEC* CMP-1 (*Articles 90, 100, and 110*), as Chair of CMP-19 (articles on agricultural buildings and mobile and manufactured buildings), and member of CMP-17 (health care facilities). He served six years on the NFPA Standards Council, as NFPA Electrical Section President, and on the *NEC* Technical Correlating Committee.

Phil began his electrical career in a light-industrial plant. He is also a master electrician in the state of Washington and was owner and manager of Simmons Electric Inc., an electrical contracting company. He is also a licensed journeyman electrician in Montana. Phil passed the certification examinations for Electrical Inspector General, Electrical Plan Review, and Electrical Inspector One- and Two-Family.

He previously served as Chief Electrical Inspector for the State of Washington from 1984 to 1990 as well as an Electrical Inspector Supervisor, Electrical Plans Examiner, and field Electrical Inspector. While employed with the State, Phil performed plan



review and inspection of health care facilities, including hospitals, nursing homes, and boarding homes.

Phil served the International Association of Electrical Inspectors as Executive Director from 1990 to 1995 and as Education, Codes, and Standards Coordinator from 1995 through June 1999. He was International President in 1987 and has served on local and regional committees.

He served Underwriters Laboratories as a Corporate Member and on the Electrical Council from 1985 to 2000. He served on the UL Board of Directors from 1991 to 1995 and is a retired member of the International Brotherhood of Electrical Workers.

## IMPORTANT NOTE

Every effort has been made to be technically correct, but there is always the possibility of typographical errors. If changes in the *NEC* do occur after the printing of this text, these changes will be incorporated in the next printing.

The National Fire Protection Association has a standard procedure to introduce changes between *Code* cycles after the actual *NEC* is printed. These are called “Tentative Interim Amendments,” or TIAs. NFPA also publishes errata or changes of an editorial nature to each edition of the *NEC*. TIAs and errata documents can be downloaded from the NFPA website, <http://www.nfpa.org>, to make your copy of the *Code* current.





# Acknowledgments

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Phil Simmons once again wants to express his appreciation to his wife, Della, for her generosity in allowing him to devote so much time and effort to updating this book as well as *Electrical Wiring Commercial* and *Electrical Grounding and Bonding* to the new *NEC* during the year. Time after time she picked up the ball and ran with it on projects Phil would customarily attend to.

As always, the team at Cengage Learning has done an outstanding job in bringing this edition to press. Their drive, dedication, and attention to minute details ensure that this text, without question, is the country's leading text on house wiring. They sure know how to keep the pressure on!

Special thanks to our good friend Jimmy Carpenter, former Executive Director of the International Association of Electrical Inspectors, for his inspiring Foreword to this text regarding the "Importance of Proper Training."

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We wish we could name all our friends in the electrical industry, but there are so many, it would take many pages to include all of their names. Thanks to all of you for your input. We apologize if we missed anyone.

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## CHAPTER 1

# General Information for Electrical Installations

### OBJECTIVES

After studying this chapter, you should be able to

- understand the basic safety rules for working on electrical systems.
- access the Internet to obtain a virtual unlimited source of safety and technical related information.
- become familiar with important electrical codes, safety codes, and building codes such as NFPA 70, 70A, 70B, 70E, 73, OSHA, NIOSH, ADA, NRTL, and the ICC.
- learn about licensing, permits, plans, specifications, symbols, and notations.
- understand the role of the electrical inspector and the International Association of Electrical Inspectors.
- understand the metric system of measurement.
- understand the role of nationally recognized testing laboratories (NRTLs) and the necessity for listed equipment.

## SAFETY IN THE WORKPLACE

Electricity is great when it is doing what it is intended to do, and that is to stay in its intended path and do the work intended. But electricity out of its intended path can be dangerous, often resulting in fire, serious injury, or death.

Before getting into residential wiring and the *National Electrical Code (NEC®)*, we need to discuss on-the-job safety. Safety is not a joke! Electricians working on new construction, remodel work, maintenance, and repair work find that electricity is part of the work environment. Electricity is all around us, just waiting for the opportunity to get out of control. Repeat these words: **Safety First . . . Safety Last . . . Safety Always!**

The voltage level in a home is 120 volts between one “hot” conductor and the “neutral” conductor, or grounded surface. Between the two “hot” conductors (line-to-line), the voltage is 240 volts.

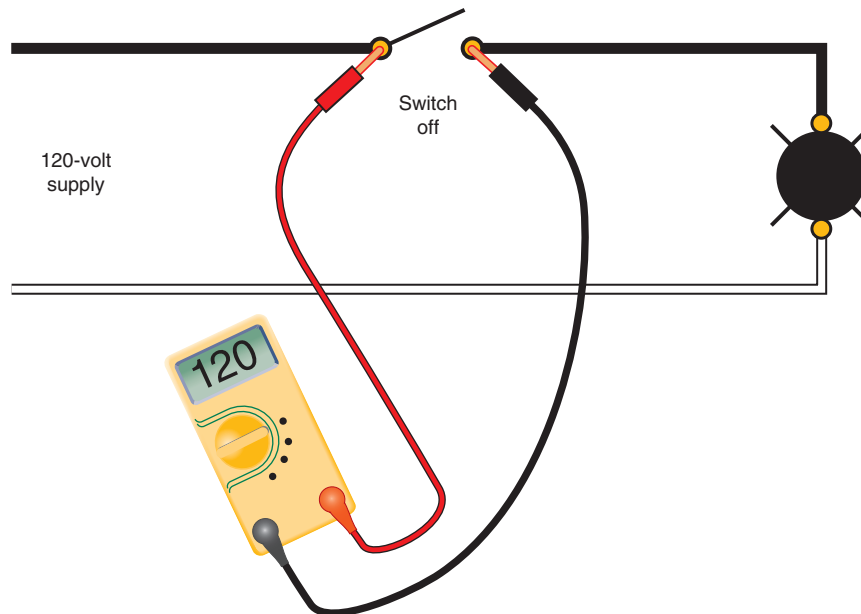
An electrical shock is received when electrical current passes through the body. From basic electrical theory, you learned that line voltage appears across an open in a series circuit. Getting caught “in series” with a 120-volt circuit will give you a 120-volt shock. For example, open-circuit voltage

## SAFETY ALERT

**Working on switches, receptacles, luminaires, or appliances with the power turned on is dangerous. Turn off the power! In addition, check with a voltmeter to be sure the power is off. Safety procedures require that you test the voltage tester on a known live source, then test for absence of voltage, and finally test the voltage tester again on a live source to make certain it is operational.**

between the two terminals of a single-pole switch on a lighting circuit is 120 volts when the switch is in the OFF position and the lamp(s) are in place. See Figure 1-1. Likewise, getting caught “in series” with a 240-volt circuit will give you a 240-volt shock.

Working on equipment with the power turned on can result in death or serious injury, either as a direct result of electricity (electrocution or burns) or from an indirect secondary reaction, such as falling off a ladder



**FIGURE 1-1** The voltage across the two terminals of the single-pole switch is 120 volts.

or jerking away from the “hot” conductor into moving parts of equipment such as the turning blades of a fan. For example: A workman was seriously injured while working a live circuit that supplied a piece of equipment. He accidentally came into contact with a “hot” terminal, and reflex action caused him to pull his hand back into a turning pulley. The pulley cut deeply into his wrist, resulting in a tremendous loss of blood.

Dropping a metal tool onto live parts, allowing metal shavings from a drilling operation to fall onto live parts of electrical equipment, cutting into a live conductor and a neutral conductor at the same time, or touching the live wire and the neutral conductor or a grounded surface at the same time can cause injury directly or indirectly.

## SAFETY ALERT

A short circuit or ground fault can result in a devastating arc flash that can cause serious injury or death. The heat of an electrical arc has been determined to be hotter than the sun. Tiny hot balls of copper can fly into your eye or onto your skin.

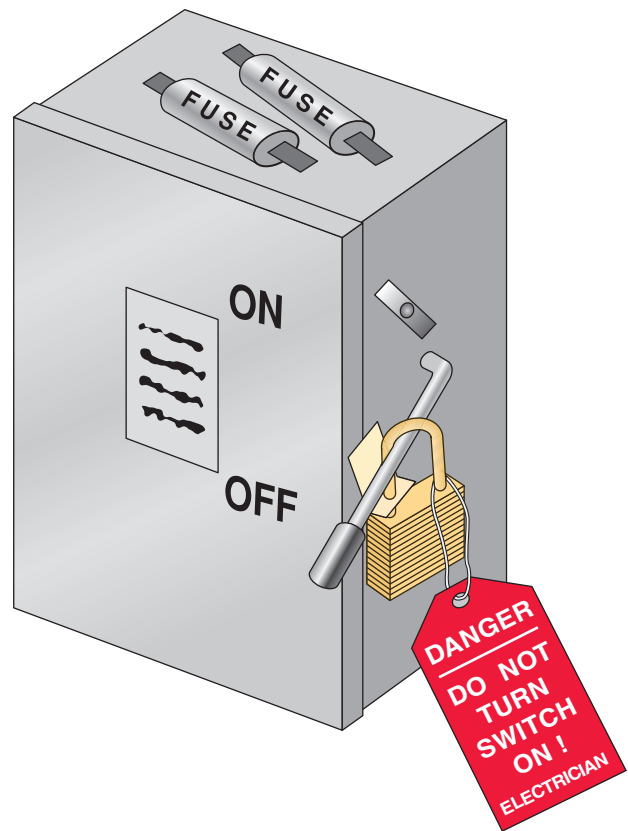
Figure 1-2 shows a disconnect switch that has been locked and tagged. Figure 1-3 shows a circuit-breaker panelboard with a lock-off accessory installed. After the circuit breaker handle is moved to the off position, a padlock can be easily added to prevent the breaker from being turned on.

Lockout/tagout (sometimes called LOTO) is the physical restraint of all hazardous energy sources that supply power to a piece of equipment. It simply means putting a padlock on the switch or circuit breaker and attaching a warning tag.

Dirt, debris, and moisture can also set the stage for equipment failure and personal injury. Neatness and cleanliness in the workplace are a must.

## What about Low-Voltage Systems?

Although circuits of less than 50 volts generally are considered harmless, don't get too smug when



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**FIGURE 1-2** A typical disconnect switch with a lock and a tag attached to it. In the OSHA, ANSI, and NFPA standards, this is referred to as the lockout/tagout procedure.



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**FIGURE 1-3** A lock-off accessory that can be added to circuit breakers allows for adding a padlock and tag to individual circuit breakers in a panelboard.

working on so-called low voltage. Low-voltage circuits are not necessarily low hazard. A slight tingle might cause a reflex. A capacitor that is discharging can give you quite a jolt, causing you to jump or pull back.

In commercial work, such as telephone systems with large battery banks, there is extreme danger even though the voltage is “low.” Think of a 12-volt car battery. If you drop a wrench across the battery terminals, you will immediately see a tremendous and dangerous arc flash.

It is the *current* that is the harmful component of an electrical circuit. *Voltage* pushes the current through the circuit. If you’re not careful, you might become part of the circuit.

Higher voltages can push greater currents through the body. Higher voltages like 240, 480, and 600 volts can cause severe skin burns and possibly out-of-sight injuries such as internal bleeding and/or destruction of tissues, nerves, and muscles.

## It’s the Law!

Not only is it a good idea to use proper safety measures as you work on and around electrical equipment, it is **required** by law. Electricians and electrical contractors need to be aware of these regulations. Practicing safety is a habit—like putting on your seat belt as soon as you get into your car.

The *NEC* is full of requirements that are safety related. For example, *430.102(B)* requires that a disconnecting means be located in sight from the motor location and the driven machinery location. This section also has in-sight and lock-off requirements, discussed in detail in Chapter 19.

The *NEC* in *Article 100* defines a qualified person as: **One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.\*** Merely telling someone or being told to be careful does not meet the definition of proper training and does not make the person qualified. An individual qualified in one skill might very well be unqualified in other skills.

According to NFPA 70E, *Electrical Safety in the Workplace*, circuits and conductors are not

considered to be in an electrically safe condition until all sources of energy are removed, the disconnecting means is under lockout/tagout, and the absence of voltage is verified by an approved voltage tester.

The US Department of Labor **Occupational Safety and Health Administration (OSHA)** regulations (Standards–29 CFR) is the law! This entire standard relates to safety in the workplace for general industry. Specifically, Part 1910, Subpart S, involves electrical safety requirements. The letters *CFR* stand for *Code of Federal Regulations*.

Key topics in the standard are electric utilization systems, wiring design and protection, wiring methods, components and equipment for general use, specific purpose equipment and installations, hazardous (classified) locations, special systems, training, selection and use of work practices, use of equipment, safeguards for personnel protection, and definitions (a mirror image of definitions found in the *NEC*).

A direct quote from 1910.333(a)(1) states that

“Live parts to which an employee may be exposed shall be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Live parts that operate at less than 50 volts to ground need not be de-energized if there will be no increased exposure to electrical burns or to explosion due to electric arcs.”

OSHA 1910.333(c)(2) states that:

“Only qualified persons may work on electric circuit parts or equipment that have not been de-energized under the procedures of paragraph (b) of this section. Such persons shall be capable of working safely on energized circuits and shall be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools.”

OSHA 1910.399 defines a *qualified person* as “One familiar with the construction and operation of the equipment and the hazards involved,” almost the same definition as that in the *NEC*.

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For the most part, turning the power off and then locking and tagging the disconnecting means is the safest practice. As the OSHA regulations state:

“A lock and a tag shall be placed on each disconnecting means used to de-energize circuits and equipment.”

Part 1926 in the OSHA regulation (Standards–29 CFR) deals with *Safety and Health Regulations for Construction*. Here we find the rules for anyone working in the construction industry, not just in the electrical field. A few of the topics are medical services and first aid, safety training and education, recording and reporting injuries, house-keeping, personal protective equipment, means of egress, head protection, hearing protection, eye and face protection, ladders, scaffolds, rigging, hand and power tools, electrical requirements (a repeat of Part 1910, Subpart S), fall protection, and required signs and tags.

## PERSONAL PROTECTIVE EQUIPMENT

Safety courses refer to personal protective equipment (PPE). These include such items as rubber gloves, insulating shoes and boots (footwear suitable for electrical work is marked with the letters “EH”), face shields, safety glasses, hard hats, ear protectors, Nomex™, and similar products. OSHA 1910.132(f)(1) requires that

“The employer shall provide training to each employee who is required by this section to use PPE.”

Working on electrical equipment while wearing rings and other jewelry is not acceptable. OSHA states that

“Conductive articles of jewelry and clothing (such as watch bands, bracelets, rings, key chains, necklaces, metalized aprons, cloth with conductive thread, or metal headgear) may not be worn if they might contact exposed energized parts. However, such articles may be worn if they are rendered nonconductive by covering, wrapping, or other insulating means.”

## ARC FLASH

Don’t get too complacent when working on electrical equipment.

A major short circuit or ground fault at the main service panel or at the meter cabinet or base can deliver a lot of energy. On large electrical installations, an arc flash (also referred to as an arc blast) can generate temperatures of 35,000°F (19,427°C). This is hotter than the surface on the sun. This amount of heat will instantly melt copper, aluminum, and steel. The blast will blow hot particles of metal and hot gases all over, resulting in personal injury, fatality, and/or fire. An arc flash also creates a tremendous air pressure wave that can cause serious hearing damage and/or memory loss due to the concussion. The blast might blow the victim away from the arc source.

*Don’t* be fooled by the size of the service. Typical residential services are 100, 150, and 200 amperes. Larger services are found on large homes. Electricians seem to feel out of harm’s way when working on residential electrical systems and seem to be more cautious when working on commercial and industrial electrical systems. A fault at a small main service panel can be just as dangerous as a fault on a large service. The available fault current at the main service disconnect for all practical purposes is determined by the kVA rating and impedance of the transformer. Other major limiting factors for fault current are the size, type, and length of the service-entrance conductors. Available fault current can easily reach 22,000 amperes, as is evident by panels that have a 22,000/10,000-ampere series rating.

Short-circuit calculations are discussed in Chapter 28 of this text.

*Don’t* be fooled into thinking that if you cause a fault on the load side of the main disconnect that that main breaker will trip off and protect you from an arc flash. An arc flash will release the energy that the system is capable of delivering for as long as it takes the main circuit breaker to open. How much current (energy) the main breaker will let through is dependent on the available fault current and the breaker’s opening time.

Although not required for house wiring, *NEC 110.16* requires that **Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket**

enclosures, and motor control centers, that are in other than dwelling units, and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field or factory marked to warn qualified persons of potential electric arc flash hazards. The marking shall meet the requirements in 110.21(B) and shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment. ◀\* More information on this subject is found in NFPA 70E and in the ANSI Standard Z535.4, *Product Safety Signs and Labels*.

## SAFETY ALERT

When turning a standard disconnect switch ON, don't stand in front of the switch. Instead, stand to one side. For example, if the handle of the switch is on the right, then stand to the right of the switch, using your left hand to operate the handle of the switch, and turn your head away from the switch. That way, if an arc flash occurred when you turned the disconnect switch ON, you would not be standing in front of the switch. You would not have the switch's door fly into your face, and the molten metal particles resulting from the arc flash would fly past you.

## Classifying Electrical Injuries

OSHA recognizes these as the four main types of electrical injuries:

- Electrical shock (touching live line-to-line or line-to-ground conductors) (ground-fault circuit interrupters are discussed in Chapter 6)
- Electrocutation (death due to severe electrical shock)

- Burns (from an arc flash)
- Falls (an electrical shock that might cause a person to lose balance, pull back, jump, or fall off a ladder)

## What to Do If You Are Involved with a Possible Electrocutation

The following is taken in part from the OSHA, NIOSH, NSC regulations, and the American Heart Association recommendations. These are steps that should be taken in the event of a possible electrocution (cardiac arrest). Refer to the actual cardiopulmonary resuscitation (CPR) instructions for complete and detailed requirements, and to take CPR training.

- First, you must recognize that an emergency exists. Timing is everything. The time between the accident and arrival of paramedics is crucial. Call 911 immediately. Don't delay.
- Don't touch the person if he or she is still in contact with the live circuit.
- Shut off the power.
- Stay with the person while someone else contacts the paramedics, who have training in the basics of life support. In most localities, telephoning 911 will get the paramedics.
- Have the caller verify that the call was made and that help is on the way.
- Don't move the person.
- Check for bleeding; stop the bleeding if it occurs.
- If the person is unconscious, check for breathing.
- The ABCs of CPR are: *airway* must be clear; *breathing* is a must, either by the victim or the rescuer; and *circulation* (check pulse).
- Perform CPR if the victim is not breathing—within 4 minutes is critical. If the brain is deprived of oxygen for more than 4 minutes, brain damage will occur. If it is deprived of oxygen for more than 10 minutes, the survival rate is 1 in 100. CPR keeps oxygenated blood flowing to the brain and heart.
- Defibrillation may be necessary to reestablish a normal heartbeat. Ventricular fibrillation is common with electric shock, which causes the

\*Reprinted with permission from NFPA 70-2014.

heartbeat to be uneven and unable to properly pump blood.

- By now, the trained paramedics should have arrived to apply advanced care.
- When it comes to an electrical shock, *timing is everything!*

## Who Is Responsible for Safety?

You are!

The electrical inspector inspects electrical installations for compliance to the *NEC*. He or she is not really involved with on-the-job safety.

For on-the-job safety, OSHA puts the burden of responsibility on the employer. OSHA can impose large fines for noncompliance with its safety rules. But because it's your own safety that we are discussing, you share the responsibility to apply safe work practices, use the proper tools and PPE equipment the contractor furnishes, and install listed electrical equipment. Be alert to what's going on around you! Do a good job of housekeeping!

## Tools

Using the proper tools for a job is vital to on-the-job safety.

OSHA Standard 1926.302 specifically covers the requirements for hand and power tools. The American National Standards Institute (ANSI) also has standards relating to tools.

If you want to learn more about tools, visit the website of the Hand Tools Institute at [www.hti.org](http://www.hti.org). The institute has a number of excellent safety education materials available. Of particular interest is its 90-plus-page publication *Guide to Hand Tools: Selection, Safety Tips, Proper Use and Care* that includes topics for selecting, proper use, maintaining, and avoiding hazards, as well as special emphasis on eye protection using all types of hand tools.

## Electrical Power Tools

You will be using portable electric power tools on the job. Electricity on construction sites is usually in the form of temporary power, covered by Article 590 of the *NEC*.



Courtesy Hubbell Lighting Outdoor & Industrial.

**FIGURE 1-4** Two types of portable plug-in cord sets that have built-in GFCI protection.

*NEC 590.6(A)(1)* requires that All 125-volt, single-phase, 15-, 20-, and 30-ampere receptacle outlets that are not a part of the permanent wiring of the building or structure and that are in use by personnel shall have ground-fault circuit interrupter protection for personnel.\*

Because this requirement is often ignored or defeated on job sites, you should carry and use as part of your tool collection a portable GFCI of the types shown in Figure 1-4—an inexpensive investment that will protect you against possible electrocution. Remember, “*The future is not in the hands of fate, but in ours.*”\*\*

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\*\*Jean Jules Jusserand, <http://www.inspirationalstories.com/quotes/t/on-future/page/48/>

## Digital Multimeters

Some statistics show that more injuries occur from using electrical meters than from electric shock.

For safety, electricians should use quality digital multimeters that are *category rated*. The International Electrotechnical Commission (IEC) Standard 1010 for *Low Voltage Test, Measurement, and Control Equipment* rates the ability of a meter to withstand voltage transients (surges or spikes). This standard is very similar to UL Standard 3111. When lightning strikes a high line; when utilities are performing switching operations; or when a capacitor is discharging, a circuit can “see” voltage transients that greatly exceed the withstand rating of the digital multimeter. The meter could explode, causing an arc flash (a fireball) that in all probability would result in personal injury. A properly selected category-rated digital multimeter is able to withstand the spike without creating an arc blast. The leads of the meter are also able to handle high transient voltages.

Digital multimeters also are category rated based on the location of the equipment to be tested, because the closer the equipment is to the power source, the greater the danger from transient voltages.

Cat IV multimeters are used where the available fault current is high, such as a service entrance, a service main panel, service drops, and the house meter.

Cat III multimeters are used for permanently installed loads such as in switchgear, distribution panels, motors, bus bars, feeders, short branch circuits, and appliance outlets where branch-circuit conductors are large and the distance is short.

Cat II multimeters are used on residential branch circuits for testing loads that are plugged into receptacles.

Cat I multimeters are used where the current levels are very low, such as electronic equipment. Note that the lower the category rating, the lower is the meter’s ability to withstand voltage transients. If you will be using the multimeter in all of the above situations, select the higher category rating.

Category-rated digital multimeters also contain fuses that protect against faults that happen when the meter is accidentally used to check voltage while it is inadvertently set in the current reading position.

To learn more about meters, visit the website of Fluke Corporation, <http://www.fluke.com>, for a wealth of technical information about the use of meters and other electrical and electronic measuring instruments.

## Ladders

To learn more about ladders, visit the website of Werner Ladder Company, <http://www.wernerco.com>. You can download their pamphlet entitled *Ladder Safety Tips*. You will learn about the right and wrong ways to use a ladder: Never work on a stepladder in which the spreaders are not fully locked into position; the 4:1 ratio, which means that the base of an extension ladder should be set back (S) one-fourth the length (L) of where the upper part of the ladder is supported ( $S = \frac{1}{4} L$ ); the duty ratings, such as do not stand higher than the second step from the top for stepladders, and do not stand higher than the fourth rung from the top for extension ladders; plus many more safety tips.

Ladders are labeled with their duty rating. Medium-duty commercial (Type II—225#), heavy-duty industrial (Type I—250#), and extra-heavy-duty (Type IA—300#) ladders bear an OSHA compliance label. Light-duty household (Type III—200#) ladders do not bear an OSHA logo.

## Hazardous Chemicals

Increasingly, hazardous chemicals are found on the job. What do you do if you get a spilled chemical on your skin or in your eyes, or if you breathe the fumes?

Every manufacturer of these products is required to publish and make available a comprehensive data sheet called the Material Safety Data Sheet (MSDS). There are supposedly over 1.5 million of these data sheets, containing product identification, ingredients, physical data, fire and explosion hazard data, health-hazard data, reactive data, spill or leak procedures, protection information, and special precautions.

The least you can do is to be aware that this information is available. Apprenticeship programs include some training about MSDSs.

You can learn more about MSDSs by checking any search engine for the letters MSDS.

## TRAINING

If you want to learn more, visit manufacturers' websites. For example, Bussmann's website is <http://www.bussmann.com>. It is easy to use and has an application for "smartphones" that can be downloaded for making arc-flash and fault-current calculations. This website also has a technical publication, *Selecting Protective Devices*, or bulletin SPD, a 268-plus-page publication about overcurrent protection selection, application, the *NEC*, and safety.

The OSHA Training Institute offers outreach training programs of interest to electricians, contractors, and instructors. The basic safety courses for general construction safety and health are the OSHA 10-hour and OSHA 30-hour courses. Instructors interested in becoming an outreach trainer for the 10- and 30-hour courses must complete the OSHA 500 course entitled "Trainer Course in Occupational Safety and Health Standards for the Construction Industry." To become an outreach trainer, you must pass a test. Before the end of 4 years, outreach trainers must take the OSHA 502 update course for the construction industry or the OSHA 502 update course "Update for Construction Industry Outreach Trainers." Completion cards are issued on completion of these courses.

Other courses, publications, "free loan" videos, schedules of upcoming safety training seminars, and other important information relating to safety on the job are available from OSHA for electricians, contractors, and trainers.

Visit the OSHA website at <http://www.OSHA.gov> for everything there is to know about OSHA safety requirements in the workplace. The OSHA website is a virtual gold mine of information relating to safety on the job.

Another valuable source of safety information is the National Institute for Occupational Safety and Health (NIOSH), a division of the Department of Health and Human Services Centers for Disease Control and Prevention (CDC). Check out its website at <http://www.cdc.gov/niosh>. NIOSH offers an excellent downloadable 80-plus-page manual on *Electrical Safety*.

The National Safety Council has a vast amount of information relative to all aspects of safety. Check out its website at <http://www.nsc.org>.

The Consumer Product Safety Commission offers many safety publications for downloading.

Visit its website at <http://www.cpsc.gov>, click on Library, click on CPSC Publications, click on By General Category, and then click on Electrical Safety. Here you will see a list of CPSC publications about GFCIs, AFCIs, metal ladder hazards, home wiring hazards, repairing aluminum wiring, and others.

The National Fire Protection Association offers many publications, videos, and a training course relating to safety. Browse its website at <http://www.nfpa.org>.

NFPA 70E, *Standard for Electrical Safety in the Workplace* and NFPA 70B, *Recommended Practices for Electrical Equipment Maintenance*, present much of the same text regarding electrical safety as does the OSHA regulation.

Accredited apprenticeship training programs incorporate safety training as an integral part of their curriculum.

## SAFETY CANNOT BE COMPROMISED!

It is impossible to put a dollar value on a life.

Don't take chances! Use the right tools! Turn off the power. Follow a lockout/tagout procedure. Mark the tag with a description of exactly what that particular disconnect controls.

How many times have we heard "The person would not have been injured (or electrocuted) had he turned the power OFF"? How many more times can we say it? **Turn OFF the power before working on the circuit!**

Visit the websites of the various organizations mentioned earlier. The website list can also be found in the back of this text. These organizations have a wealth of information about on-the-job safety educational material and safety training courses.

Check out the website of the Electrical Safety Foundation International (ESFI) at <http://www.electrical-safety.org>. This organization has a tremendous amount of down-to-earth, simple-to-understand electrical safety material. Some of their educational material is free; other items are priced. Certain items are downloadable. The bottom line is to reduce deaths and injuries from preventable electrical accidents.