CENGAGE

ELECTRICAL WIRING

20TH EDITION

RESIDENTIAL

Based on the 2020 National Electrical Code®

Phil Simmons
Ray C. Mullin

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PHIL SIMMONS

Revised from the original text by Ray Mullin

CENGAGE

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

Electrical Wiring Residential, 20th Edition
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Contents

CHAPTER 23

CHAPTER 24

CHAPTER 25

CHAPTER 26

CHAPTER 27

CHAPTER 28

CHAPTER 29

CHAPTER 30

Plans for Single-Family Dwelling

Dedication

This 20th Edition of *Electrical Wiring Residential* is Dedicated to

Ray C. Mullin

Mr. Mullin was the original author of *Electrical Wiring Residential*. He saw the need for excellent training materials and devoted a good portion of his life to developing and enhancing several books including *Electrical Wiring Commercial* and *Electrical Wiring Industrial*. As a result of his vision and passion for excellence, these books have enjoyed wide acceptance and have positively impacted many readers over many years.

Mr. Mullin completed an apprenticeship training and worked as a journeyman electrician and supervisor for residential, commercial, and industrial installations. He recognized the importance of education and became an electrical instructor for the Wisconsin Schools of Vocational, Technical, and Adult Education. He taught both day and night electrical apprentice and journeyman courses, conducted engineering seminars, and conducted many technical *Code* workshops and seminars at International Association of Electrical Inspectors Chapter and Section meetings, and served on their code panels.

Mr. Mullin attended the University of Wisconsin, Colorado State University, and the Milwaukee School of Engineering. He was a member of the International Brotherhood of Electrical Workers, the International Association of Electrical Inspectors, the Institute of Electrical and Electronic Engineers, and the National Fire Protection Association. He served on Code-Making Panel 4 of the National Electrical Code Committee.

Mr. Mullin's contribution to the improvement of the electrical industry was outstanding and he will be sorely missed. Ray passed away in March, 2018.

Foreword

The Importance of Proper Training

I retired after 48 years in the electrical industry. It has become even more evident that a good solid education about the world of electricity and the National Electrical Code 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, who was the original author of this book, *Electrical Wiring—Residential*, 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, and ignorance of product evaluations. This price becomes dear when our friends and family lose health or life or when our homes are destroyed. I was saddened to learn that Ray passed away early in 2018.

It was exciting to see that Phil Simmons joined Ray as coauthor of recent editions of *Electrical Wiring—Residential* and continues as the author of this edition. 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 was and Phil Simmons continues to be an excellent technical writer. Both 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 Phil Simmons cares deeply about the electrical safety coin, he continues 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 2020 edition of the *National Electrical Code*®, and the third leg is the set of Plans that are shrink wrapped to this book. 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 2020 *National Electrical Code*, an accomplishment you can be proud of!

The *NEC*® 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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*Source: NFPA 70-2020

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 20th edition of *Electrical Wiring—Residential* is based on the 2020 *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 the appropriate plan sheet. All wiring systems are

*Source: NFPA 70-2020

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 (EMT).

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 able 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.

Many 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 2020 edition of the *NEC*. The extensive revisions for the twentieth 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 2020 *National Electrical Code* from the 2017 *National Electrical Code*.▶◀

This text might be called "Work in Progress." The author stays 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 2020 *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.

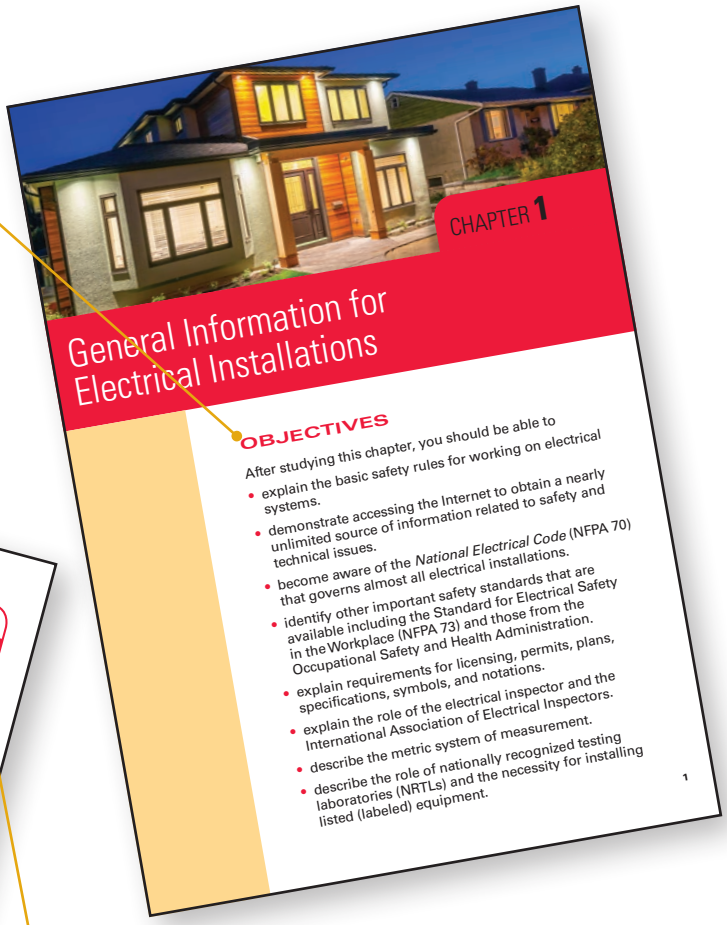
The Objectives have been fine-tuned for easier readability.

- Thousands of proposals or comments 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 2020 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 again for the 2020 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 manner in which the wiring is routed often determines the number of conductors required.
- The method of measuring for the distance from a sink has been specified, resulting in enhancing the requirement for GFCI protection in some instances.
- The requirements have been significantly revised for locating receptacles for peninsular and island cabinets in kitchens.
- Wiring for receptacle outlets in an attached garage or detached garage with electric power is now permitted to supply outlets outside the garage in a limited way. See *NEC 210.52(G)(1).*
- At least one receptacle outlet is required for each vehicle bay and not more than 5½ ft above the floor in the garage. See *NEC 210.52(G)(1).*
- All of the wiring diagrams have been updated to show the latest system of electrical symbols. The symbols are based on the National Electrical Contractors Association's *National Electrical Installation Standard.*
- Major revisions of many diagrams and figures have been made to improve the clarity and ease of understanding the *Code* requirements.
- Several new full-color illustrations and photographs 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.


CHAPTER 1

General Information for Electrical Installations

OBJECTIVES

After studying this chapter, you should be able to

- explain the basic safety rules for working on electrical systems.
- demonstrate accessing the Internet to obtain a nearly unlimited source of information related to safety and technical issues.
- become aware of the *National Electrical Code* (NFPA 70) that governs almost all electrical installations.
- identify other important safety standards that are available including the Standard for Electrical Safety in the Workplace (NFPA 73) and those from the Occupational Safety and Health Administration.
- explain requirements for licensing, permits, plans, specifications, symbols, and notations.
- explain the role of the electrical inspector and the International Association of Electrical Inspectors.
- describe the metric system of measurement.
- describe the role of nationally recognized testing laboratories (NRTLs) and the necessity for installing listed (labeled) equipment.

1


2

CHAPTER 1 General Information for Electrical Installations

Safety in the Workplace

Electricity is great when it stays in its intended path and does the work intended. But electricity out of its intended path can be dangerous, often resulting in fire, damage to equipment, 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, remodels, maintenance, and repair find that electricity is part of the work environment. Electricity is all around us, just waiting for the opportunity to do the task intended or get out of control. Repeat these words: **Safety First . . . Safety Last . . . Safety Always!**

The voltage level in a home is usually 120 volts between one ungrounded or "hot" conductor and the "neutral" or grounded conductor, or a grounded surface. Between the two ungrounded or "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 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 the circuit. 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

SAFETY ALERT

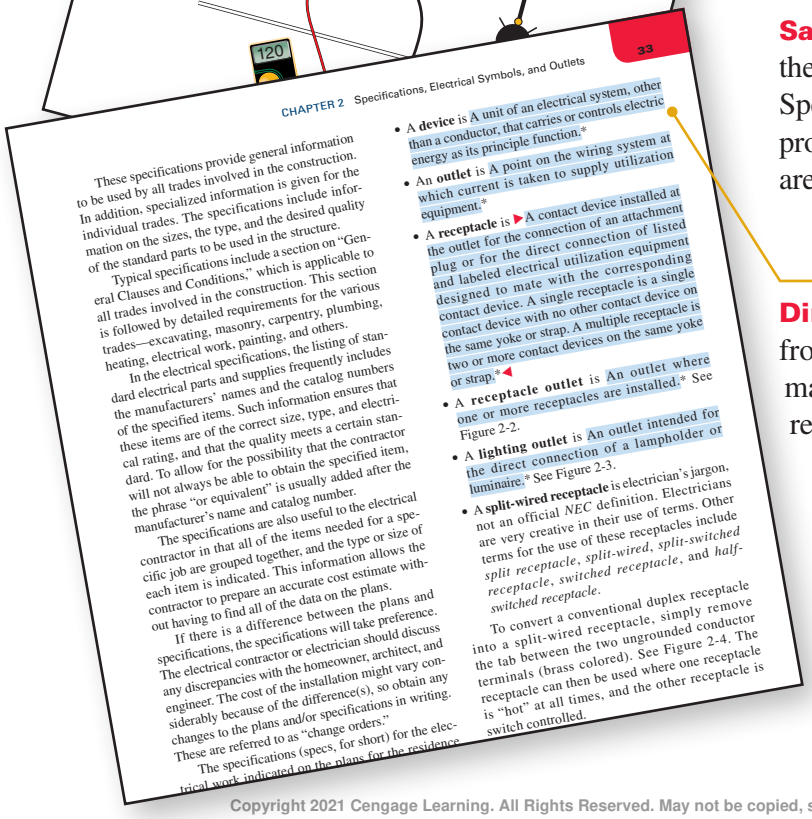
Working on switches, receptacles, luminaires, or appliances with the power turned on is dangerous. Turn off the power! In addition, check with a voltmeter to be sure the power is off. Safety procedures require that you test the voltage tester on a known live source, then test for absence of voltage,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

120-volt supply

Switch off

120

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.


CHAPTER 2 Specifications, Electrical Symbols, and Outlets 33

These specifications provide general information to be used by all trades involved in the construction. In addition, specialized information is given for the individual trades. The specifications include information on the sizes, the type, and the desired quality of the standard parts to be used in the structure.

Typical specifications include a section on "General Clauses and Conditions," which is applicable to all trades involved in the construction. This section is followed by detailed requirements for the various trades—excavating, masonry, carpentry, plumbing, heating, electrical work, painting, and others.

In the electrical specifications, the listing of standard electrical parts and supplies frequently includes the manufacturers' names and the catalog numbers of the specified items. Such information ensures that these items are of the correct size, type, and electrical rating, and that the quality meets a certain standard. To allow for the possibility that the contractor will not always be able to obtain the specified item, the phrase "or equivalent" is usually added after the manufacturer's name and catalog number.

The specifications are also useful to the electrical contractor in that all of the items needed for a specific job are grouped together, and the type or size of each item is indicated. This information allows the contractor to prepare an accurate cost estimate without having to find all of the data on the plans.

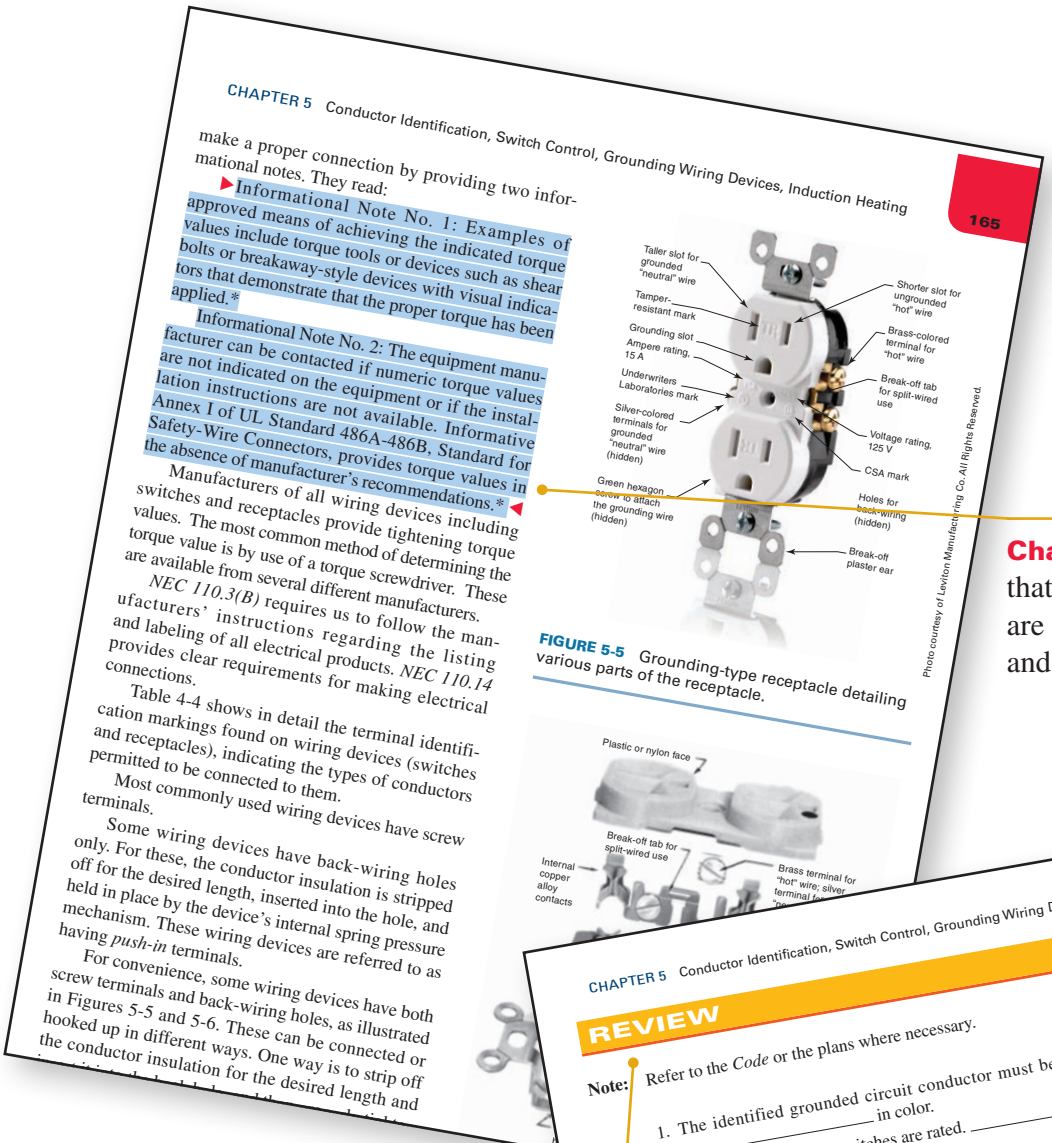
If there is a difference between the plans and specifications, the specifications will take preference. The electrical contractor or electrician should discuss any discrepancies with the homeowner, architect, and engineer. The cost of the installation might vary considerably because of the difference(s), so obtain any changes to the plans and/or specifications in writing. These are referred to as "change orders."

The specifications (specs, for short) for the electrical work indicated on the plans for the residence

- 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 or for the direct connection of listed and labeled electrical utilization equipment designed to mate with the corresponding contact device. A single receptacle is a single contact device with no other contact device on the same yoke or strap. A multiple receptacle is two or more contact devices on the same yoke or strap.*◀
- A **receptacle outlet** is An outlet where one or more receptacles are installed.* See Figure 2-2.
- A **lighting outlet** is An outlet intended for the direct connection of a lampholder or luminaire.* See Figure 2-3.
- A **split-wired receptacle** is electrician's jargon, not an official *NEC* definition. Electricians are very creative in their use of terms. Other terms for the use of these receptacles include *split receptacle, split-wired, split-switched receptacle, switched receptacle,* and *half-switched receptacle.*

To convert a conventional duplex receptacle into a split-wired receptacle, simply remove the tab between the two ungrounded conductor terminals (brass colored). See Figure 2-4. The receptacle can then be used where one receptacle is "hot" at all times, and the other receptacle is switch controlled.

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.



CHAPTER 5 Conductor Identification, Switch Control, Grounding Wiring Devices, Induction Heating 165

make a proper connection by providing two informational notes. They read:

Informational Note No. 1: Examples of approved means of achieving the indicated torque values include torque tools or devices such as shear bolts or breakaway-style devices with visual indicators that demonstrate that the proper torque has been applied.*

Informational Note No. 2: The equipment manufacturer can be contacted if numeric torque values are not indicated on the equipment or if the installation instructions are not available. Informative Annex I of UL Standard 486A-486B, Standard for Safety-Wire Connectors, provides torque values in the absence of manufacturer's recommendations.*

Manufacturers of all wiring devices including switches and receptacles provide tightening torque values. The most common method of determining the torque value is by use of a torque screwdriver. These are available from several different manufacturers.

NEC 110.3(B) requires us to follow the manufacturers' instructions regarding the listing and labeling of all electrical products. *NEC 110.14* provides clear requirements for making electrical connections.

Table 4-4 shows in detail the terminal identification markings found on wiring devices (switches and receptacles), indicating the types of conductors permitted to be connected to them.

Most commonly used wiring devices have screw terminals.

Some wiring devices have back-wiring holes only. For these, the conductor insulation is stripped off for the desired length, inserted into the hole, and held in place by the device's internal spring pressure mechanism. These wiring devices are referred to as having *push-in* terminals.

For convenience, some wiring devices have both screw terminals and back-wiring holes, as illustrated in Figures 5-5 and 5-6. These can be connected or hooked up in different ways. One way is to strip off the conductor insulation for the desired length and

FIGURE 5-5 Grounding-type receptacle detailing various parts of the receptacle.

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

CHAPTER 5 Conductor Identification, Switch Control, Grounding Wiring Devices, Induction Heating 189

REVIEW

Note: Refer to the *Code* or the plans where necessary.

1. The identified grounded circuit conductor must be _____ or _____ in color.
2. Explain how lighting switches are rated. _____
3. A T-rated switch may be used to its _____ current capacity when controlling an incandescent lighting load.
4. What switch type and rating is required to control five 300-watt tungsten filament lamps on a 120-volt circuit? Show calculations. _____
5. List four types of lighting switches.
   a. _____
   b. _____
   c. _____
   d. _____
6. To control a lighting load from one control point, what type of switch would be used? _____
7. Single-pole switches are always connected to the _____ wire.
8. Complete the connections in the following arrangement so that both ceiling light outlets are controlled from the single-pole switch. Assume the installation is in cable.

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

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About the Author

This text was authored by Phil Simmons.

Phil Simmons is self-employed as Simmons Electrical Services. Services have included 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 was coauthor and illustrator of *Electrical Wiring—Residential* (17th through this 20th edition), coauthor and illustrator of *Electrical Wiring—Commercial* (14th through this 17th edition), and author and illustrator of *Electrical Grounding and Bonding*, all published by Cengage Learning. Phil continues as the author of these three titles. While at the International Association of Electrical Inspectors, 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. 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 as well as educational and institutional facilities.

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

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!

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We want to express our appreciation to **Paul W Abernathy**. Paul served as lead reviewer and editor for two of the chapters of this edition. He currently serves on the National Fire Protection Association's (NFPA) *NEC*® Code Making Panel 5 and 17. He has held ICC Certifications as an electrical inspector, electrical plans examiner, commercial electrical inspector, building inspector, plumbing inspector and mechanical inspector.

Paul has served as electrical engineer II for the City of Richmond, Virginia and as code supervisor for the City of Alexandria, Virginia. He also served as the southern region Field Representative for the National Electrical Manufacturers Association (NEMA). He holds a BS and MS in Engineering as well being a licensed Master Electrician in Texas and Virginia.

Paul also serves as the CEO & President of Electrical Code Academy, Inc. a corporation dedicated to providing electrical seminars and educational training for electricians and electrical engineers on the National Electrical Code. He also is the head of the Codes and Standards Division for Encore Wire Corporation in McKinney, TX.

We are so appreciative of our friends and colleagues in the electrical industry who have provided assistance and information. Several are respected as *Code* experts. These include Madeline Borthick, David Dini, Joe Ellwanger, David Hittinger, Mike Johnston, Robert Kosky, Richard Loyd, Bill Neitzel, Cliff Rediger, Gordon Stewart, Clarence Tibbs, Charlie Trout, and David Williams. Over the years, technical reviewers have provided invaluable suggestions to make *Electrical Wiring Residential* the best it can be! Special thanks again to Robert Boiko for his technical input on water heaters and their safety related controls.

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

- explain the basic safety rules for working on electrical systems.
- demonstrate accessing the Internet to obtain a nearly unlimited source of information related to safety and technical issues.
- become aware of the *National Electrical Code* (NFPA 70) that governs almost all electrical installations.
- identify other important safety standards that are available including the Standard for Electrical Safety in the Workplace (NFPA 73) and those from the Occupational Safety and Health Administration.
- explain requirements for licensing, permits, plans, specifications, symbols, and notations.
- explain the role of the electrical inspector and the International Association of Electrical Inspectors.
- describe the metric system of measurement.
- describe the role of nationally recognized testing laboratories (NRTLs) and the necessity for installing listed (labeled) equipment.

Safety in the Workplace

Electricity is great when it stays in its intended path and does the work intended. But electricity out of its intended path can be dangerous, often resulting in fire, damage to equipment, 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, remodels, maintenance, and repair find that electricity is part of the work environment. Electricity is all around us, just waiting for the opportunity to do the task intended or get out of control. Repeat these words: **Safety First . . . Safety Last . . . Safety Always!**

The voltage level in a home is usually 120 volts between one ungrounded or "hot" conductor and the "neutral" or grounded conductor, or a grounded surface. Between the two ungrounded or "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 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 the circuit. See Figure 1-1. Likewise, getting caught "in series" with a 240-volt circuit will give you a 240-volt shock.

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.

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

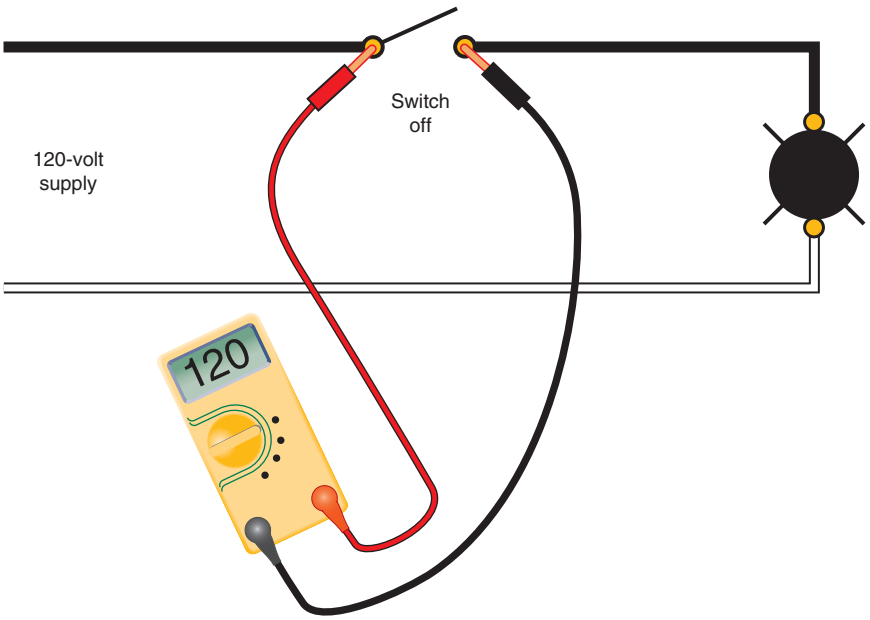

FIGURE 1-1 The voltage across the two terminals of the single-pole switch is 120 volts.

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 is performed by

- verifying the rating of PPE (personal protective equipment) required and putting it on,
- removing covers of equipment, if necessary,
- opening the circuit breaker or fused switch ahead of the equipment to be serviced,
- testing the operation of the voltmeter on a known live circuit (such as a receptacle),
- testing the equipment to be serviced for the absence of voltage,
- testing the voltmeter again on a known live source to be certain the voltmeter is operating correctly,
- putting a padlock on the switch or circuit breaker, and
- attaching a warning tag.

Only after following each step in this procedure is the equipment considered safe to work on.

Equipment that is cord-and-plug connected can be worked on safely after removing the plug from the receptacle.

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

It is the *current* that is the harmful component of an electrical circuit. *Voltage* pushes the current through the circuit. In this example, you or another person represent the resister in the circuit. The circuit voltage pushes current through the person. If you're not careful, you might become part of the circuit.

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.

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.

Higher voltages can push greater currents through the body. 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 locationw and the driven machinery location. This section also has in-sight and lock-off requirements, discussed in detail in Chapters 19 and 23 of this book.

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 U.S. 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

*Source: NFPA 70-2020
**Source: U.S. Department of Labor Occupational Safety and Health Administration (OSHA).

equipment, insulating and shielding materials, and insulated tools."**

OSHA 1910.399 defines a *qualified person* as "One who has received training in and has demonstrated skills and knowledge in the construction and operation of electric equipment and installations and the hazards involved," almost the same definition as that in the *NEC*.

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 at 1910.333(b)(2)(iii)(A):

> "A lock and a tag shall be placed on each disconnecting means used to deenergize circuits and equipment on which work is to be performed … . The lock shall be attached so as to prevent persons from operating the disconnecting means unless they resort to undue force or the use of tools."

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, housekeeping, 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 in 1910.333(c)(8) of their regulations 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 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

**Source: U.S. Department of Labor Occupational Safety and Health Administration (OSHA).

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.

*Source: NFPA 70-2020

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)
- Electrocution (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 about Low-Voltage Systems?

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

What to Do If You Are Involved with a Possible Electrocution

The following is taken in part from the OSHA, 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), National Safety Council (NSC) regulations, and the American Heart Association recommendations. These are steps that should be taken in the event of 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: *a*irway must be clear; *b*reathing is a must, either by the victim or the rescuer; and *c*irculation (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 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. 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*.

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 Ground-Fault Circuit-Interrupter (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.*"***

*Source: NFPA 70-2020

**Source: U.S. Department of Labor Occupational Safety and Health Administration (OSHA).

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

Courtesy Hubbell Lighting Outdoor & Industrial.

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

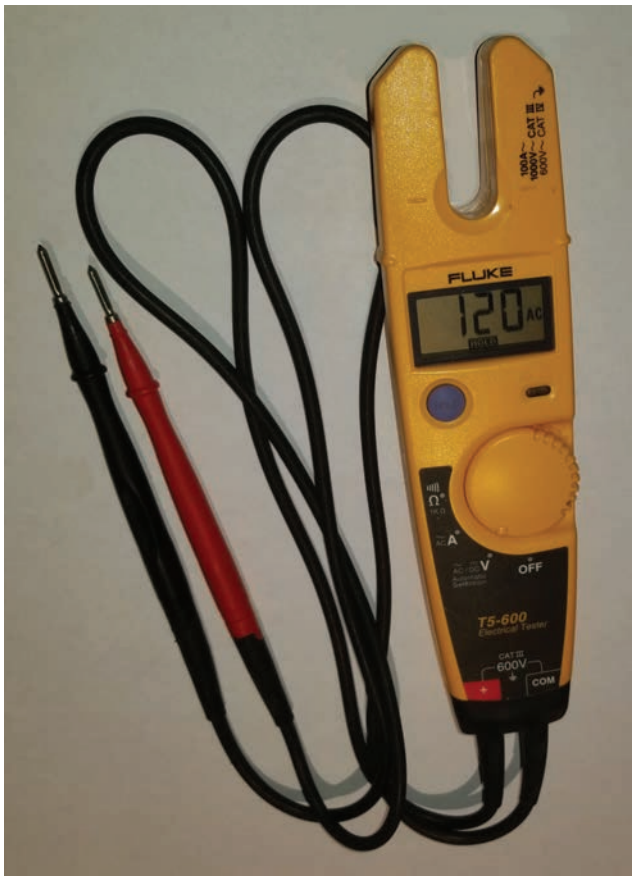

FIGURE 1-5 This digital volt-meter and amp-meter is rated Category III for voltage readings (contact through test leads) and Category IV for current readings (non-contact through open jaws).

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 an improperly rated 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 intoreceptacles.

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. See Figure 1-5 for an example of a digital multimeter that is category rated.

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 including:

- Never work on a stepladder in which the spreaders are not fully locked into position.
- The 4:1 ratio must be established, 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 = ¼ L).
- The duty rating must not be exceeded.
- Do not stand higher than the second step from the top for stepladders.
- 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 lbs), heavy-duty industrial (Type I—250 lbs), and extra-heavy-duty (Type IA—300 lbs) ladders bear an OSHA compliance label. Light-duty household (Type III—200 lbs) 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.

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.

Training

Many organizations offer training on the *NEC* and electrical safety. The International Electrical Inspectors Association is one such organization that has sections, chapters, and divisions throughout the United States and Canada. Local meetings are held where electrical training is offered. Times and locations can be found by doing a search of the Internet.

Trade organizations, such as the International Brotherhood of Electrical Workers and the Independent Electrical Contractors, offer apprenticeship and continuing education training.

Many manufacturers of electrical equipment offer training as well. If you want to learn more, visit manufacturers' websites. You can search for panelboards, wiring devices, outlet boxes, fuses, and so forth. The list is almost endless.

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 NIOSH. 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 (NFPA) 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.

Licensing and Permits

Several communities, counties, and/or states require electricians and electrical contractors to be licensed. This usually means they have completed education, training, and work experience requirements as well as having taken and passed a test. Often, these regulatory agencies have minimum qualifications that must be met before the applicant is permitted to take an examination. To maintain a valid license, many licensing agencies require electricians and electrical contractors to attend and satisfactorily complete approved continuing education courses consisting of a specified number of classroom hours over a given period of time. Quite often, a community will have a "Residential Only" license for electricians and contractors that limits their activity to house wiring.

Permits are a means for a community to permanently record electrical work to be done and who is doing the work, and to schedule inspections during and after the rough-in stage and in the final stages

of construction. Usually, permits must be issued prior to starting an electrical project. In most cases, homeowners are allowed to do electrical work in their own home where they live, but not in other properties they might own.

Figure 1-6 is a simple application for an electrical permit form. Some permit application forms are much more detailed.

If you are not familiar with licensing and permit requirements in your area, it makes sense to check this out with your local electrical inspector or building department before starting an electrical project. Not to do so could prove to be very costly. Many questions can be answered: you will find out what tests, if any, must be taken; which permits are needed; which electrical code is enforced in your community; minimum size electrical service; and so on. Generally, the electrical permit is taken out by an electrical contractor who is licensed and registered as an electrical contractor in the jurisdictional area.

For new construction or for a main electrical service change, you will also need to contact the electric utility.

APPLICATION FOR ELECTRICAL PERMIT

VILLAGE OF ANYWHERE, USA 1-234-567-8900, EXT. 1234

Date _____ Permit No. _____
Owner _____ Job Address _____
Telephone No. _____ Job Start Date _____

CONTRACTOR INFORMATION AND SIGNATURE

Electrical Contractor _____ Tel. No. _____
Address _____ City _____ State _____ Zip _____
Registration No. _____ City of Registration _____
Supervising Electrician (Please Print Name) _____
Supervising Electrician's Signature _____
Insurance Bond _____ Village Business License _____

SERVICE INSPECTIONS OR REVISIONS

Existing Service Size: Amps _____ Volts _____ No. of Circuits _____ No. Added _____
New Service Size: Amps _____ Volts _____ No. of Circuits _____
Type: Overhead _____ Underground _____
Service Installation Fees: 100–200 amps $50 _____ over 200 amps $75 _____

MOTORS AND AIR-CONDITIONING EQUIPMENT

No. of Motors: up to 1 HP @ $50 _____ Over 1–10 HP @ $50 _____
11–25 HP @ $25 _____ Over 25 HP @ $25 _____
Air Conditioner/Heat Pump:
No. of Tons _____ ($20 for first ton, $5 for each additional ton) _____
Furnace (electric): kW _____ Amps _____ ($25) _____
Dryer (electric): kW _____ Amps _____ ($10) _____
Range, oven, cooktop (electric): Total kW _____ Amps _____ ($10 each) _____
Water Heater (electric): kW _____ Amps _____ ($10) _____

TYPE OF MISCELLANEOUS ELECTRIC WORK

_____
_____

Minimum Inspection Fee: $40.00 _____
Escrow Deposit, if applicable _____
TOTAL DUE _____

FIGURE 1-6 A typical Application for Electrical Permit.

Temporary Wiring

There is an ever-present electrical shock hazard on construction sites. The *NEC* addresses this in *Article 590*. This is covered in Chapter 6 of this text.

Construction Terms

Electrical Wiring—Residential covers all aspects of typical residential wiring, with focus on the *NEC*. Electricians work with others on construction sites. An extensive Glossary of the *NEC* and related terms is located in the Appendix of this book. Time is well spent in becoming familiar with these terms. Knowing construction terms and symbols is therefore a key element to getting along with the other workers. A rather complete dictionary of construction terms can be found on http://www.constructionplace.com/glossary.asp. Architectural symbols are found in this book in Chapter 2 and in the Appendix.

National Electrical Code® (NEC®)

The *NEC* is the electrical *Code* standard recognized by everyone in the electrical industry.

The first sentence in the *NEC* is found in *90.1*. This sentence lays the foundation for all electrical installations. It states, **(A) Practical Safeguarding**. The purpose of this *Code* is the practical safeguarding of persons and property from hazards arising from the use of electricity. This *Code* is not intended as a design specification or an instruction manual for untrained persons.*

It goes on to state, **(B) Adequacy**. This *Code* contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance will result in an installation that is essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.*

*Source: NFPA 70-2020

As you study this text, you will learn how to "Meet *Code*" for wiring a typical house, not "Beat *Code*." This means that your installation will be in full compliance with the *NEC* as well as all wiring regulations from the local electrical inspection jurisdiction, if any. In addition, it will comply with all local electric utility regulations.

As *NEC* requirements are discussed throughout this text, the sheer number of *Code* references can become mind-boggling. To simplify using this text as a reference, in addition to the conventional subject index at the back of the text, there is a Cross Index, making it easy for you to pinpoint specific *Code* sections and articles found in this text.

The *NEC* is published by the National Fire Protection Association and is referred to formally as NFPA 70. Varied users, inspectors, and insurance groups recognized the need for uniform standards related to the safe installation of electric wiring. This resulted in the publication of the first *NEC* in 1897. It is revised every 3 years so as to be as up to date as possible. The *NEC* does not become law until adopted by official action of the legislative body of a city, municipality, county, or state. Because of the ever-present danger of fire or shock hazard through some failure of the electrical system, the electrician and the electrical contractor will want to use listed materials and must perform all work in accordance with recognized standards.

Other Electrical Codes

As mentioned earlier, in addition to the *NEC*, you must also consider local and state electrical regulations and codes. Many inspection agencies create local amendments or additional regulations when they adopt the *NEC*. These local regulations supercede the requirements of the *NEC* and become the minimum level of installation of electrical equipment. Don't even think about planning the electrical installation project without learning the local regulations!

This text, *Electrical Wiring—Residential*, is based on the *NEC* and does not include local amendments to the *NEC*.

Because local electrical codes may differ from the *NEC*, you should check with the local inspection authority to determine which edition of the *NEC* is enforced, and what, if any, local requirements or amendments take precedence over the *NEC*.

Electric Utility Requirements

In addition, most every electrical serving utility has requirements for the electrical supply to the service equipment. These requirements must be complied with as a condition for receiving electrical energy from the power company. Many electric utilities have a booklet that can be downloaded from their Internet site. These booklets usually include drawings that illustrate their requirements.

Code Arrangement

It is important to understand the arrangement of the *NEC*, which is laid out in a very efficient and precise manner, as stated in *90.3* and illustrated in Figure 1-7.

Wiring of dwellings is covered mostly in *Chapters 1* through *4* of the *NEC*. The requirements for grounding and bonding of spas, hot tubs, and swimming pools in *Article 680* is an example of how the rules in *Chapter 6* modify the rules for grounding and bonding that are located in *Article 250*, which is in *Chapter 2*.

Table 1-1 provides additional information on the content of the chapters and *Informative Annexes* of the *NEC*.

NEC 90.3 covers the arrangement of the *NEC* and reads, This *Code* is divided into the introduction and nine chapters, as shown in Figure 90.3. Chapters 1, 2, 3, and 4 apply generally. Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions and may supplement or modify the requirements in Chapters 1 through 7.

Chapter 8 covers communications systems and is not subject to the requirements of Chapters 1 through 7 except where the requirements are specifically referenced in Chapter 8.

Chapter 9 consists of tables that are applicable as referenced.

Informative annexes are not part of the requirements of this *Code* but are included for informational purposes only.*

*Source: NFPA 70-2020

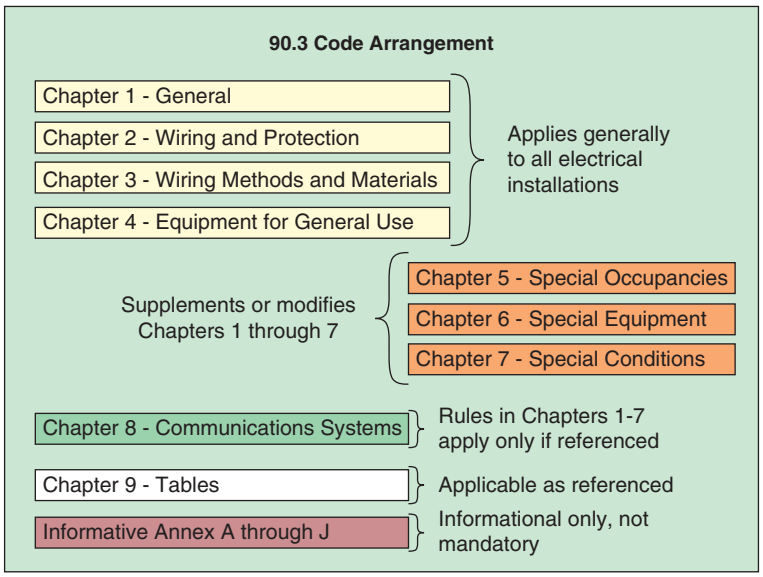

FIGURE 1-7 *NEC* Figure 90.3 illustrates the arrangement of the *NEC*.

TABLE 1-1

Arrangement of the *NEC*.

Article 90	An introduction to the *NEC*. Explains what is and what is not covered in the *NEC*, the arrangement of the *NEC*, and who has the authority to enforce the *Code*. This article also explains the meaning of some of the language used in the *NEC* including what mandatory rules are, what permissive rules are, and the basics of metric vs. inch-pound measurements found throughout the *NEC*.
Chapter 1	General *Article 100: Definitions* (Contains definition of terms that are used in two or more Articles of the *NEC*.) *Article 110: Requirements for Electrical Installations* Applies to all electrical installations.
Chapter 2	*Wiring and Protection* *Articles 200–250* Applies to all electrical installations.
Chapter 3	*Wiring Methods* *Articles 300–399* Applies to all electrical installations.
Chapter 4	*Equipment for General Use* *Articles 400–490* Applies to all electrical installations.
Chapter 5	*Special Occupancies* *Articles 500–590*
Chapter 6	*Special Equipment* *Articles 600–695*
Chapter 7	*Special Conditions* *Articles 700–770*
Chapter 8	*Communications Systems* *Articles 800–840* The articles in *Chapter 8* are not subject to the requirements of *Articles 1* through *7* unless specifically referenced in *Chapter 8*.
Chapter 9	Tables showing the permitted fill for raceways, dimensional data for raceways and conductors, resistance and reactance values of conductors, Class 2 and Class 3 circuit power limitations.
Informative Annex A	Provides a comprehensive list of product safety standards from Underwriters Laboratories (UL) for electrical products or equipment that is included in the *NEC*.
Informative Annex B	Provides data for determining conductor ampacity under engineering supervision.
Informative Annex C	Has tables showing the maximum number of conductors that have a specific type of insulation that are permitted in various types of raceways. These tables can be used only if all conductors in a raceway are the same size and have the same type insulation.
Informative Annex D	Examples of load calculations.
Informative Annex E	Types of building construction.
Informative Annex F	*Availability and Reliability of Critical Operations Power Systems*
Informative Annex G	*Supervisory Control and Data Acquisitions (SCADA)*
Informative Annex H	*Administration and Enforcement.* A comprehensive suggested typical electrical ordinance that could be adopted on a local level.
Informative Annex I	*Recommended Tightening Torque Tables from UL Standard 486A-B*
Informative Annex J	*ADA Standards for Accessible Design*
Index	The alphabetical index for the *NEC*.

Note: *Annexes* and *Informational Notes* are informational only. They are not mandatory.

Language Conventions

The *National Electrical Code* is intended for mandatory adoption by authorities having jurisdiction. As such, it is very important that the language used in the *Code* be suitable for mandatory enforcement. *NEC 90.5* provides an explanation of mandatory rules, permissive rules, and explanatory material. Other requirements for writing the *National Electrical Code* are contained in the *NEC Style Manual*. These rules help ensure uniformity throughout the *NEC*.

- Mandatory rules identify what is required or prohibited, and use the term *shall* or *shall not*.
- Permissive rules are actions that are allowed, but not required. Permissive rules use the term *shall be permitted* or *shall not be required*.
- Explanatory material is identified as an *Informational Note*. *Informational Notes* may make reference to other important rules or provide helpful information related to the *Code* itself. These *Informational Notes* are not intended to be enforceable. If more than one *Informational Note* is applicable to a *Code* rule, they are numbered sequentially.
- The Annexes near the back of the *NEC* are also considered informational as identified in their titles such as "*Informational Annex* A, B, and so forth."

Exceptions

The *NEC Manual of Style* gives instructions on how Exceptions are to be used in the *NEC*. Although there has been an effort in recent years to reduce the number of exceptions used in the *NEC*, in some cases they remain the best method of rule construction. When exceptions are used, the general requirement is stated first, followed by one or more modifications of the general requirement. Often the exception contains a condition that must be met for the exception to apply. Exceptions are often similar to "If-Then" statements in computer spreadsheets. These statements usually mean, if this condition is true or false, then the operation is to be performed.

- Exceptions are required to immediately follow the main rule to which they apply. If exceptions are made to items within a numbered list, the exception must clearly indicate the items within the list to which it applies. Exceptions containing the mandatory terms *shall* or *shall not* are to be listed first in the sequence. Permissive exceptions containing *shall be permitted* are to follow any mandatory exceptions and should be listed in their order of importance as determined by the Code-Making Panel.
- If used, exceptions are to convey alternatives or differences to a basic *Code* rule. The terms *shall* and *shall not* are used to specify a mandatory requirement that is either different from the rule or diametrically opposite to the rule. The term *shall be permitted* designates a variance from the main rule that is permitted but not required.
- See *250.110* for an example of three exceptions to the general rule. The exceptions present a different set of conditions for providing relief from the general rule.

Citing *Code* References

Every time an electrician makes a decision concerning the electrical wiring, the decision should be checked by reference to the *Code*. Depending on how familiar the person is with the rule, this may be done from memory, without actually using the *Code* book. Since requirements in the *Code* change from time to time, the *Code* should be referenced directly—just to make sure. When the *Code* is referenced, it is a good idea to record the location of the information in the *Code* book—this is referred to as "citing the *Code* reference." Electrical inspectors should always give a reference, preferably in writing, for any correction they ask be made. If they cannot cite the site of the rule, they should not cite the installation!

There is a very exact way that the location of a *Code* item is to be cited. The various levels of *Code* referencing are shown in Table 1-2. Starting at the top of the table, each step becomes a more specific reference. If a person references *Chapter 1*, this reference includes all the information and requirements that are set forth in several pages. When citing a specific *Section* or an *Exception*, only a few words

TABLE 1-2

Citing the *NEC*.

DIVISION	DESIGNATION	EXAMPLE
Chapter	1–9	*Chapter 1*
Article	90 through 840	*Article 250*
Part	Roman numeral	*Article 250, Part II*
Section	Article number, a dot (period), plus one, two, or three digits	*250.20*
Paragraph	Section designation, plus uppercase letter in ( ), followed by digit in ( ), followed by a lowercase letter in ( ) as is required	*250.119(A)(1)*
List	Usually follows an opening paragraph or section	*250.110 (1) through (8)*
Exception to	Follows a rule that applies generally and applies under the conditions included in the Exception	*250.142(B) Exception No. 2*
Informational Note	Explanatory material, such as references to other standards, references to related sections, or information related to a *Code* rule. Such notes are informational only and are not enforceable.	*Informational Note*
Informative Annex	A, B, C, D, E, F, G, H, I, and J (are not part of the *NEC* and are not enforceable)	*Informative Annex A*

may be included in the citation. The electrician and inspector should be as specific as possible when citing the *Code*. For the most part, the word *section* does not precede the section numbers in the *Code*.

Common Numbering

Finding similar requirements in different *Articles* in the current edition of the *NEC* is much easier than in past editions. All articles in *Chapter 3* of the *NEC* cover wiring methods. In each article, the same section number has been assigned for a particular requirement. Here are a few examples:

- *Scope* is found in *XXX.1 such as 320.1, 330.1 and 344.1*
- *Definitions* (if present in the *Article*) are found in *XXX.2* such as *240.2, 517.2* and *680.2*.
- *Permitted Uses* are found in *XXX.10*.
- *Uses Not Permitted* are found in *XXX.12*.
- *Securing and Supporting* is found in *XXX.30*.

This is referred to as "the parallel numbering system."

How to Spot Changes in the 2020 *NEC*

Each new edition of the *NEC* includes the following usability features as aids to the user. Changes that are made to text, other than those that are editorial, are highlighted with gray shading within sections. An "N" is located at the margin to indicate new sections or for large blocks of changed or new text and for new tables and changed or new figures. If one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain. The previous edition of the *NEC* must be consulted to determine what text was deleted. New articles are identified by an "N" at the margin.

Individual pages have dictionary-style headers that indicate the beginning section number at the top left corner of the left page and the ending section number at the top right corner of the right page.

Who Writes the *Code*?

For each *Code* cycle, the NFPA solicits public input from anyone interested in electrical safety. Anyone may submit public input to change the *NEC* using the online submission software on the NFPA website. Public inputs received are then assigned to a specific Code-Making Panel (CMP) to process. These actions are published in the First Draft Report and may be viewed at www.nfpa.org. Individuals may send in their comments on these actions using the online software system at

www.nfpa.org. The CMPs meet again to review and take action on the comments received. These actions can be viewed in the Second Draft Report and may be viewed at www.nfpa.org. Final action (voting) on public input and comments is taken at the NFPA annual meeting.

However, before the *NEC* is published, if there is disagreement on any specific *Code* requirement adopted through the above process, the NFPA will consider an *Appeal* that is reviewed and acted upon by the NFPA Standards Council several weeks after the annual meeting. After an *Appeal* is acted upon by the Standards Council, should there still be controversy, another step not often used in the *Code* adoption process is a petition that is reviewed and acted upon by the NFPA Board of Directors.

Individuals who serve on CMPs are electrical inspectors, electrical contractors, electricians, electrical engineers, individuals from utilities, manufacturers, testing laboratories, the Consumer Product Safety Commission, insurance companies, and similar organizations. CMP members are appointed by the NFPA. The CMPs have 10 to 20 principal members, plus a similar number of alternate members. All of the CMPs have a good balance of representation so no one membership interest group can control the result of the voting.

Which Edition of the *NEC* to Use

This text is based on the 2020 edition of the *NEC*. Some municipalities, cities, counties, and states have not yet adopted this edition and may continue using older editions. Check with your local electrical inspector to find out which edition of the *Code* is in force at the location where your electrical wiring is being performed. NFPA has added a free and handy tool that is useful to determine which edition of the *NEC* is adopted at the state or local level. The location on the Internet is https://codefinder.nfpa.org/.

Copies of the latest edition of the *NEC* NFPA 70 may be ordered from several bookstores, including Amazon.com, as well as the following:

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101
Phone: 617-770-3000
http://www.nfpa.org

International Association of Electrical Inspectors
901 Waterfall Way, Suite 602
Richardson, TX 75080-7702
Phone: 800-786-4234
http://www.iaei.org

Electrical Inspection Code for Existing Dwellings

This code is published by the NFPA and is referred to as *NFPA 73*. It is a brief standard that provides requirements for evaluating installed electrical systems within and associated with existing dwellings to identify safety, fire, and shock hazards. These include improper installations, overheating, physical deterioration, and abuse. This code lists most of the electrical things to inspect in an existing dwelling that could result in a fire or shock hazard if not corrected. It only points out things to look for that are visible. It does not get into examining concealed wiring that would require removal of permanent parts of the structure. It also does not get into calculations, location requirements, and complex topics, as does the *NEC* NFPA 70.

This code can be an extremely useful guide for electricians doing remodel work and for electrical inspectors wanting to bring an existing dwelling to a reasonably safe condition. Many localities require that when a home changes ownership, the wiring must be brought up to some minimum standard, but not necessarily as extensively as would be the case for new construction.

Homes for the Physically Challenged

The *NEC* now covers the wiring of homes for the physically or mentally challenged and disabilities associated with the elderly in Informative Annex J. Because this information is in an Informative Annex, it is not a requirement.

The preface to *Informative Annex J* reads, The provisions cited in Informative Annex J are intended to assist the users of the *Code* in properly considering the various electrical design constraints of other building systems and are part of the 2010 ADA Standards for Accessible Design. They are the same

provisions as those found in ANSI/ICC A117.1-2009, *Accessible and Usable Buildings and Facilities.**

Each installation for the physically challenged must be based on the specific need(s) of the individual(s) who will occupy the home. Some physically challenged people are bedridden, require the mobility of a wheelchair, have trouble reaching or bending, and so forth. There are no hard and fast rules that *must* be followed—only many suggestions to consider.

Some of these follow:

- Install more ceiling luminaires instead of switching receptacles. Cords and lamps are obstacles.
- Install luminaires having more than one bulb.
- Go "overboard" in the amount of lighting for all rooms, entrances, stairways, stairwells, closets, pantries, bathrooms, and so on.
- Use higher wattage bulbs—not to exceed the wattage permitted in the specific fixture.
- Consider installing luminaires in certain areas (such as bathrooms and hallways) to be controlled by motion detectors.
- Consider installing exhaust fans in certain areas (such as laundries, showers, and bathrooms) that turn on automatically when the humidity reaches a predetermined value.
- Consider the height of switches and thermostats, usually 42 in. (1.0 m) or lower, instead of the standard 46–52 in. (1.15–1.3 m).
- Consider rocker-type switches instead of toggle type.
- Install pilot light switches.
- Consider "jumbo" switches.
- Be sure stairways and stairwells are well lit.
- Consider stair tread lighting.
- Position lighting switches so as not to be over stairways or ramps.
- Locate switches and receptacles to be readily and easily accessible—not behind doors or other hard-to-reach places.
- Consider installing wall receptacle outlets at a height of 24–27 in. (600–675 mm) above the finished floor rather than the normal 12 in. (300 mm) height.
- Install lighted doorbell buttons.
- Chimes: Consider adding a strategically located "dedicated" lamp(s) that turn on when doorbell buttons are pushed. The wiring diagram for this is found in Figure 25-25.
- Telephones: Consider adding visible light(s) strategically located that flash at the same time the telephone is ringing.
- Consider installing receptacle outlets and switches on the face of kitchen cabinets. Wall outlets and switches can be impossible for the physically challenged person to reach.
- Consider fire, smoke, and security systems, directly connected to a central office for fast response to emergencies, that do not depend on the disabled to initiate the call.
- Consider installing the fuse box or breaker panel on the first floor instead of in the basement.
- Consider the advanced home systems concept of remotely controlling lighting, receptacles, appliances, television, telephones, and so on. The control features can make life much easier for a disabled person.

When involved with multifamily dwellings, check with your local building authority. They have copies of the Americans with Disabilities Act (ADA) from the U.S. Department of Justice and the Fair Housing Act from the U.S. Department of Housing and Urban Development (HUD); these basically require that all units must have accessible light switches, electrical outlets, thermostats, and other environmental controls.

The ANSI publication *ANSI A117.1–2009, Standard for Accessible and Useable Buildings and Facilities*, contains many suggestions and considerations for buildings and facilities for the physically challenged. This and other standards can be ordered from

American National Standards Institute
25 West 43rd Street
New York, NY 10036
Tel: 212-642-4900
Fax: 212-398-0023

*Source: NFPA 70-2020

The same standard is available from the International Code Council (ICC) under the publication number *ICC/ANSI A117.1–2009*.

Another virtually unlimited source of standards is

Global Engineering Documents
15 Inverness Way East
Englewood, CO 80112
Phone: 800-854-7179
303-397-7956
Fax: 303-397-2740
http://www.global.ihs.com
e-mail: globalcustomerservice@ihs.com

Building Codes

The majority of the building departments across the country have for the most part adopted the *NEC* rather than attempting to develop their own electrical codes. As you study this text, you will note numerous references to the *NEC*, the electrical inspector, or the authority having jurisdiction.

An authority's level of knowledge varies. The electrical inspector may be full-time or part-time and may also have responsibility for other trades, such as plumbing or heating. The heads of the building departments in many communities are typically called the Building Commissioners or Directors of Development. Regardless of title, they are responsible for ensuring that the building codes in their communities are followed.

International Code Council (ICC)

Rather than writing their own codes, most communities adopt the codes of the International Code Council (ICC). Over the years, the ICC has developed comprehensive and coordinated model construction codes. These include building, mechanical, plumbing, fire, energy conservation, existing building, fuel gas, sewage disposal, property maintenance, zoning, and residential, codes. The ICC provides technical, educational, and informational products. Its address is

ICC Headquarters
500 New Jersey Avenue, NW, 6th Floor
Washington, DC 20001
Phone: 888-422-7233
http://www.iccsafe.org

The *ICC International Residential Code* includes several chapters that contain electrical provisions that were written and produced under the guidance of the NFPA. The material in these chapters is copyrighted by the NFPA. These provisions are similar to the *NEC* other than the layout and numbering system. Due to publishing cycles, the IRC is usually one cycle behind the *NEC*.

American National Standards Institute

The **American National Standards Institute (ANSI)** is an organization that coordinates the efforts and results of the various standards-developing organizations, such as those mentioned in previous paragraphs. Through this process, ANSI approves standards that then become recognized as American National Standards. There is a lot of similarity among the technical information found in ANSI standards, the UL standards, the International Electronic and Electrical Engineers standards, and the *NEC*.

International Association of Electrical Inspectors

The International Association of Electrical Inspectors (IAEI) is a nonprofit organization. The IAEI membership consists of electrical inspectors, building officials, electricians, engineers, contractors, and manufacturers throughout the United States and Canada. The major goal of the IAEI is to improve the understanding of the *NEC*. Representatives of this organization serve as members of the various Code Making Panels (CMP) of the *NEC* and share equally with other members in the task of reviewing and revising the *NEC*.

The IAEI publishes a bimonthly magazine—*The IAEI News*. It is devoted entirely to electrical code topics. Anyone in the electrical industry is welcome to join the IAEI. An application form is found after the Appendix of this text. Its address is

International Association of Electrical Inspectors
901 Waterfall Way, Suite 602
Richardson, TX 75080-7702
Phone: 800-786-IAEI
http://www.iaei.org

NEC Definitions

The electrical industry uses many words (terms) that are unique to the electrical trade. These terms need clear definitions to enable the electrician to understand completely the meaning intended by the *Code*.

Article 100 of the *NEC* is a "dictionary" of these terms. *Article 90* also provides further clarification of terms used in the *NEC*. Here are a few examples:

Ampacity: The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.*

Approved: Acceptable to the authority having jurisdiction.*

Authority Having Jurisdiction (AHJ): An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure. See *NEC 90.4*.* An extensive Informational Note follows the definition of Authority Having Jurisdiction and gives several examples of AHJs.

Dwelling Unit: A single unit, providing complete and independent living facilities for one or more persons, including permanent provisions for living, sleeping, cooking, and sanitation.*

Listed: Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or services meets appropriate designated standards or has been tested and found suitable for a specified purpose.*

Refer to Key Terms in the Glossary of this text for the definition of additional terms that are important to residential wiring.

Read and Follow *110.3(B)* Carefully!

One of the most far-reaching *NEC* rules is *110.3(B)*. This section states that Equipment that is listed, labeled, or both shall be installed and used in accordance with any instructions included in the listing or labeling.* This means that all *listed* components of the electrical system must be *installed* and *used* in accordance with the *NEC* and any installation instructions provided by the manufacturer.

The phrase In accordance with any instructions included in the listing or labeling* is commonly interpreted to include the Guide Card information included in the UL *White Book* and the successor UL Product iQ™ database. The Guide Card information contains hundreds, if not thousands, of installation instructions that must be carefully followed to achieve a safe and *NEC*-compliant installation. Here are a few examples of installation requirements contained in the previous UL *White Book*, and UL Product iQ™ database followed by the UL four alpha character key (the four-letter alpha key is used by UL to alphabetize the entries in the database):

- "Enclosure Type 1 is suitable for only indoor locations (AALZ)"**
- "Enclosure Type 3 is suitable for outdoor use, and will be undamaged by the formation of ice on the enclosure (AALZ)"**
- "Except as noted in the general Guide Information for some product categories, most terminals, unless marked otherwise, are for use only with copper wire. If aluminum or copper-clad aluminum wire can be used, marking to indicate this fact is provided. Such marking is required to be independent of any marking on terminal connectors, such as on a wiring diagram or other visible location. The

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marking may be in an abbreviated form, such as "AL-CU." (AALZ)"**

- "Except as noted in the following paragraphs or in the general Guide Information for some product categories, the termination provisions are based on the use of 60°C ampacities for wire size Nos. 14-1 AWG, and 75°C ampacities for wire size Nos. 1/0 AWG and larger, as specified in Table 310.16 of the NEC. (AALZ)"**

Manufacturers of equipment may include specific instructions such as these:

- Supply conductors must have an insulation rated not less than 90°C.
- Do not locate this baseboard heater below a receptacle outlet.
- This appliance must be supplied from a receptacle connected to an equipment grounding conductor.

The previous UL *White Book* and UL Product iQ™ database are sometimes referred to as "the other Code book." Some have emphasized the importance of these documents by stating, "Don't leave home without it!"

Metrics (SI) and the *NEC*

The United States is the last major developed country in the world not using the metric system of weights and measures as the primary system. For most of our lifetime, we have used the English system of weights and measures, also referred to as inch-pound and U.S. Customary. But this is changing!

Some manufacturers are now showing both inch-pound and metric units in their catalogs. By law, plans and specifications for new governmental construction and renovation projects have used the metric system since January 1, 1994. However, later legislation softened this position so U.S. manufacturers are not required to produce nearly identical products or to maintain two different inventories.

You may not feel comfortable with metric measurements, but metric measurements are here to stay. You might just as well become familiar with the metric system.

All measurements in the *NEC* are shown in both inch-pound and metric values. Because the *NEC* is adopted in many countries that use the metric system of measurement, the measurements in the *NEC* show the metric value first followed by the U.S. inch-pound equivalency in parentheses.

For more information about metrics, refer to the "Metric System of Measurement" section found in the Appendix of this text.

Trade Sizes

A unique situation exists. Strange as it may seem, what electricians have been referring to for years has not been correct!

Raceway sizes have always been an approximation and are trade sizes. For example, there has never been a ½ in. raceway. Measurements taken from the *NEC* for a few types of raceways are shown in Table 1-3.

You can readily see that the cross-sectional areas of raceways, critical when determining conductor fill, are different. Generally, the different thicknesses of the wall of the conduit change the internal area. The internal area of Electrical Metallic Tubing (referred to as EMT or thinwall) differs from conduit and must be used to determine the square-inch area that is permitted for conductors. It makes sense to refer to conduit, raceway, and tubing sizes as *trade sizes*. The *NEC* in *90.9(C)(1)* states that Where the actual measured size of a product is not the same as the nominal size, trade size designators shall be used rather than dimensions*. This edition of *Electrical Wiring—Residential*

TABLE 1-3

Comparison of trade size vs. actual inside diameters.

TRADE SIZE	INSIDE DIAMETER (I.D.)
½ Electrical Metallic Tubing	0.622 in.
½ Electrical Nonmetallic Tubing	0.560 in.
½ Flexible Metal Conduit	0.635 in.
½ Rigid Metal Conduit	0.632 in.
½ Intermediate Metal Conduit	0.660 in.

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uses the term *trade size* when referring to conduits, raceways, and tubing. For example, a ½ in. EMT is referred to as trade size ½ EMT.

The *NEC* also uses the term *metric designator*. A trade size ½ EMT is shown as *metric designator 16 (½)*. A trade size 1 EMT is shown as *metric designator 27 (1)*. The numbers 16 and 27 are the metric designator values; the (½) and (1) are the trade sizes. The metric designator is the raceway's inside diameter—in rounded-off millimeters (mm). Table 1-4 shows some of the more common sizes of conduits, raceways, and tubing. A complete listing is found in *NEC Table 300.1(C)*.

For ease in understanding, this text uses only the term *trade size* when referring to conduit and raceway sizes.

TABLE 1-4

Trade sizes of raceways and their metric designator identification.

METRIC DESIGNATOR AND TRADE SIZE	
Metric Designator	**Trade Size**
12	⅜
16	½
21	¾
27	1
35	1¼
41	1½
53	2
63	2½
78	3

TABLE 1-5

Comparison of knockout trade size vs. actual measurement.

TRADE SIZE KNOCKOUT	ACTUAL MEASUREMENT
½	⅞ in.
¾	1 3⁄32 in.
1	1⅜ in.

Conduit knockouts in boxes do not measure up to what we call them. Table 1-5 shows some examples.

Outlet boxes and device boxes use their nominal measurement as their *trade size*. For example, a 4 in. × 4 in. × 1½ in. box does not have an internal cubic-inch volume of 4 in. × 4 in. × 1½ in. = 24 in^3. *Table 314.16(A)* shows this size box as having a 21-cubic in. volume. This table shows *trade sizes* in two columns—millimeters and inches.

In this text, a square outlet box is referred to as trade size 4 × 4 × 1½. Similarly, a single-gang device box would be referred to as a trade size 3 × 2 × 3 box.

Trade sizes for construction material will not change. A 2 × 4 is really a *name*, not an actual dimension. A 2 × 4 will keep its name forever. This is its *trade size*.

In this text, most measurements directly related to the *NEC* are given in both inch-pound and metric units. In many instances, only the inch-pound units are shown. This is particularly true for the examples of raceway and box fill calculations, load calculations for square foot areas, and on the plans (drawings).

Because the *NEC* rounded off most metric conversion values, a calculation using metrics results in a different answer when compared to the same calculation done using inch-pounds. For example, load calculations for a residence are based on 3 volt-amperes per square foot, or 33 volt-amperes per square meter.

For a 40 ft × 50 ft dwelling: 3 VA × 40 ft × 50 ft = 6000 volt-amperes.

In metrics, using the rounded-off values in the *NEC*: 33 VA × 12 m × 15 m = 5940 volt-amperes.

The difference is small; nevertheless, there is a difference.

To show calculations in both units throughout this text would be very difficult to understand and would take up too much space. Calculations in either metrics or inch-pounds are in compliance with the *NEC, 90.9(D)*. In *90.9(C)(3)* we find that metric units are not required if the industry practice is to use inch-pound units.

It is interesting to note that the examples in Informative Annex D of the *NEC* use inch-pound units, not metrics. Rather, conversion formulas are given for m^2 and m.

TABLE 1-6

Metric prefixes, symbols, multipliers, powers, and values.

PREFIX	SYMBOL	MULTIPLIER	SCIENTIFIC NOTATION (POWERS OF TEN)	VALUE
tera	T	1 000 000 000 000	10^{12}	one trillion (1 000 000 000 000/1)
giga	G	1 000 000 000	10^{9}	one billion (1 000 000 000/1)
mega	M	1 000 000	10^{6}	one million (1 000 000/1)
kilo	k	1 000	10^{3}	one thousand (1 000/1)
hecto	h	100	10^{2}	one hundred (100/1)
deka	da	10	10^{1}	ten (10/1)
unit		1	—	one (1)
deci	d	0.1	10^{-1}	one-tenth (1/10)
centi	c	0.01	10^{-2}	one-hundredth (1/100)
milli	m	0.001	10^{-3}	one-thousandth (1/1 000)
micro	m	0.000 001	10^{-6}	one-millionth (1/1 000 000)
nano	n	0.000 000 001	10^{-9}	one-billionth (1/1 000 000 000)
pico	p	0.000 000 000 001	10^{-12}	one-trillionth (1/1 000 000 000 000)

Guide to Metric Usage

The metric system is a base-10, or decimal system in that values can be easily multiplied or divided by 10 or powers of 10. The metric system as we know it today is known as the International System of Units (SI), derived from the French term "le Système International d'Unités."

In the metric system, the units increase or decrease in multiples of 10, 100, 1000, and so on. For instance, one megawatt (1,000,000 watts) is 1000 times greater than one kilowatt (1000 watts).

By assigning a name to a measurement, such as a *watt*, the name becomes the unit. Adding a prefix to the unit, such as *kilo*, forms the new name *kilowatt*, meaning 1000 watts. Refer to Table 1-6 for prefixes used in the metric system.

The prefixes used most commonly are *centi*, *kilo*, and *milli*. Consider that the basic unit is a meter (one). Therefore, a centimeter is 0.01 meter, a kilometer is 1000 meters, and a millimeter is 0.001 meter.

Some common measurements of length and equivalents are shown in Table 1-7.

Electricians will find it useful to refer to the conversion factors and their abbreviations shown in Table 1-8.

TABLE 1-7

Some common measurements of length and their equivalents.

one inch	=	2.54	centimeters
	=	25.4	millimeters
	=	0.025 4	meter
one foot	=	12	inches
	=	0.304 8	meter
	=	30.48	centimeters
	=	304.8	millimeters
one yard	=	3	feet
	=	36	inches
	=	0.914 4	meter
	=	914.4	millimeters
one meter	=	100	centimeters
	=	1000	millimeters
	=	1.093	yards
	=	3.281	feet
	=	39.370	inches