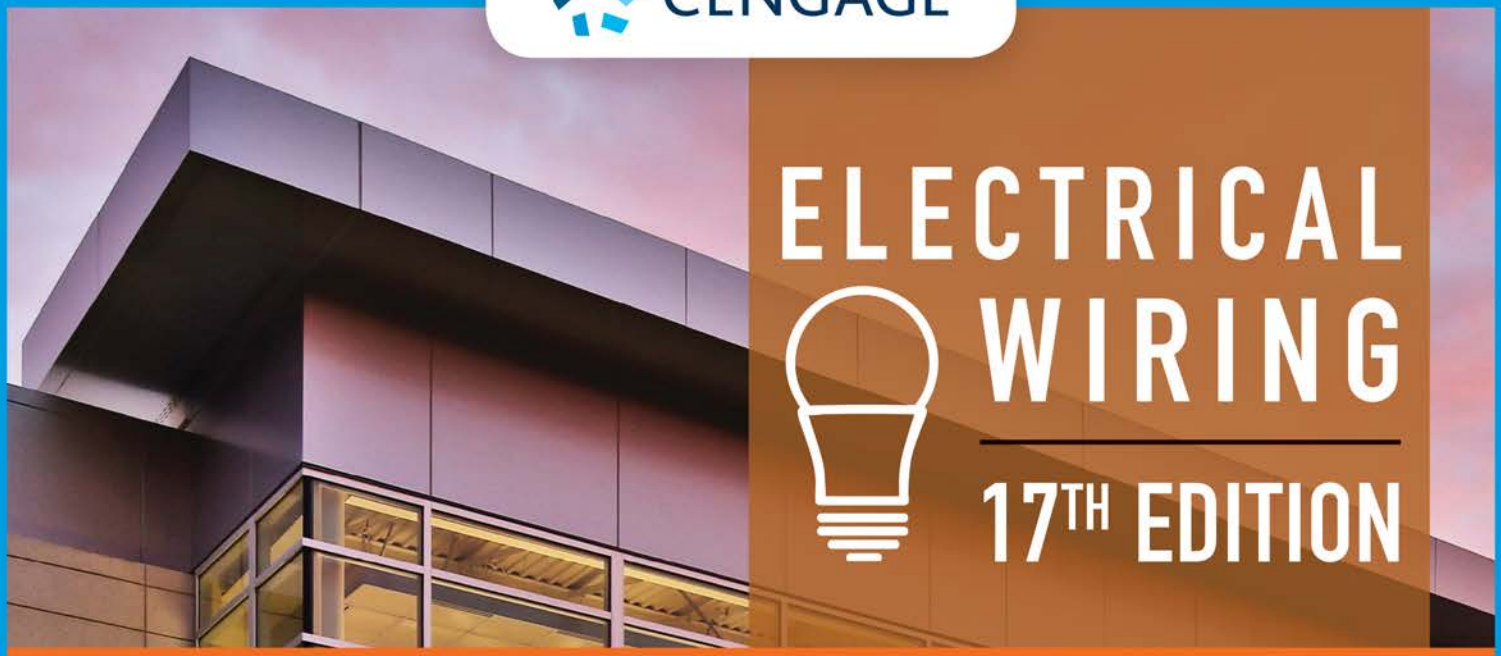
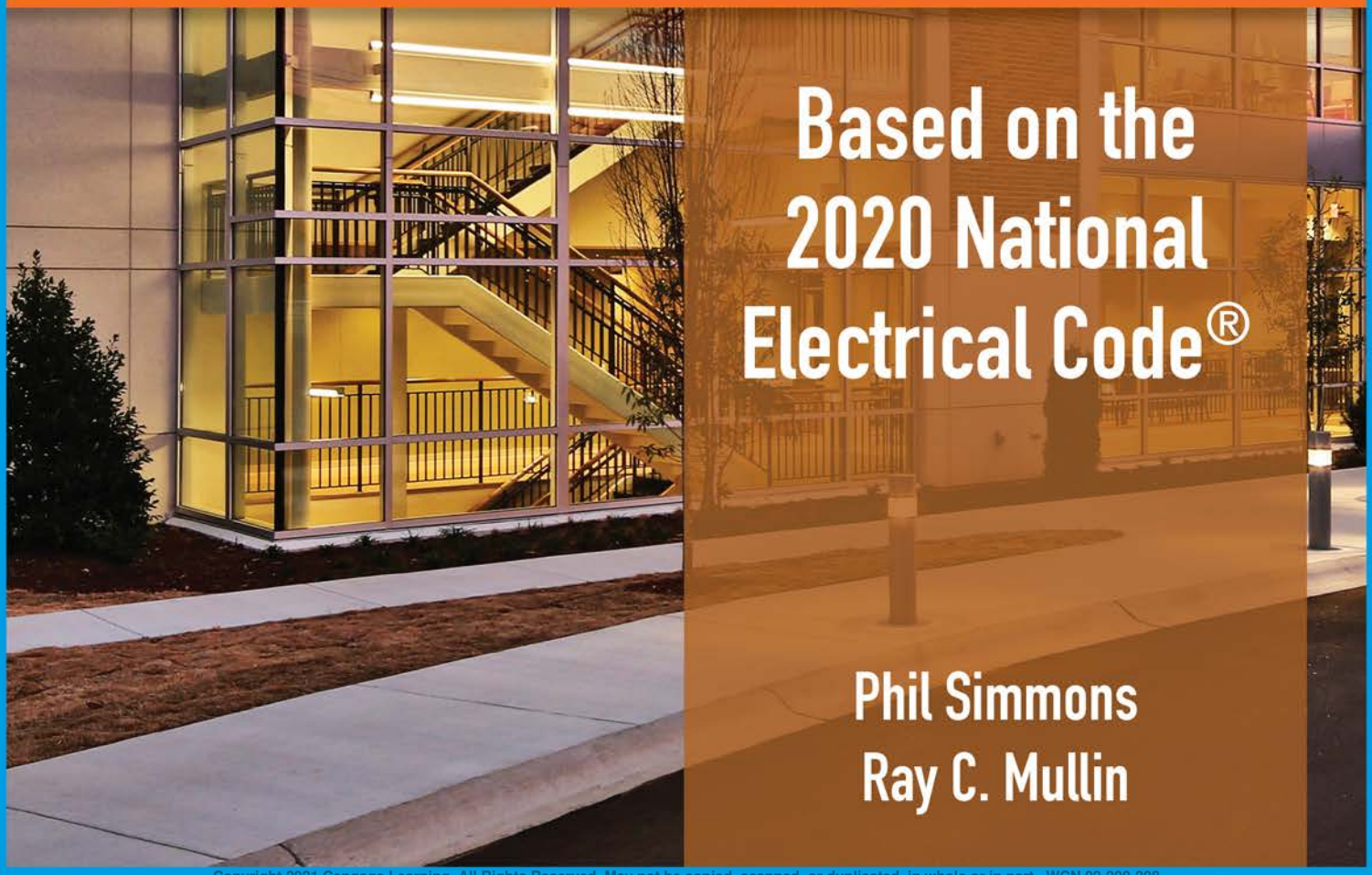
CENGAGE



ELECTRICAL WIRING

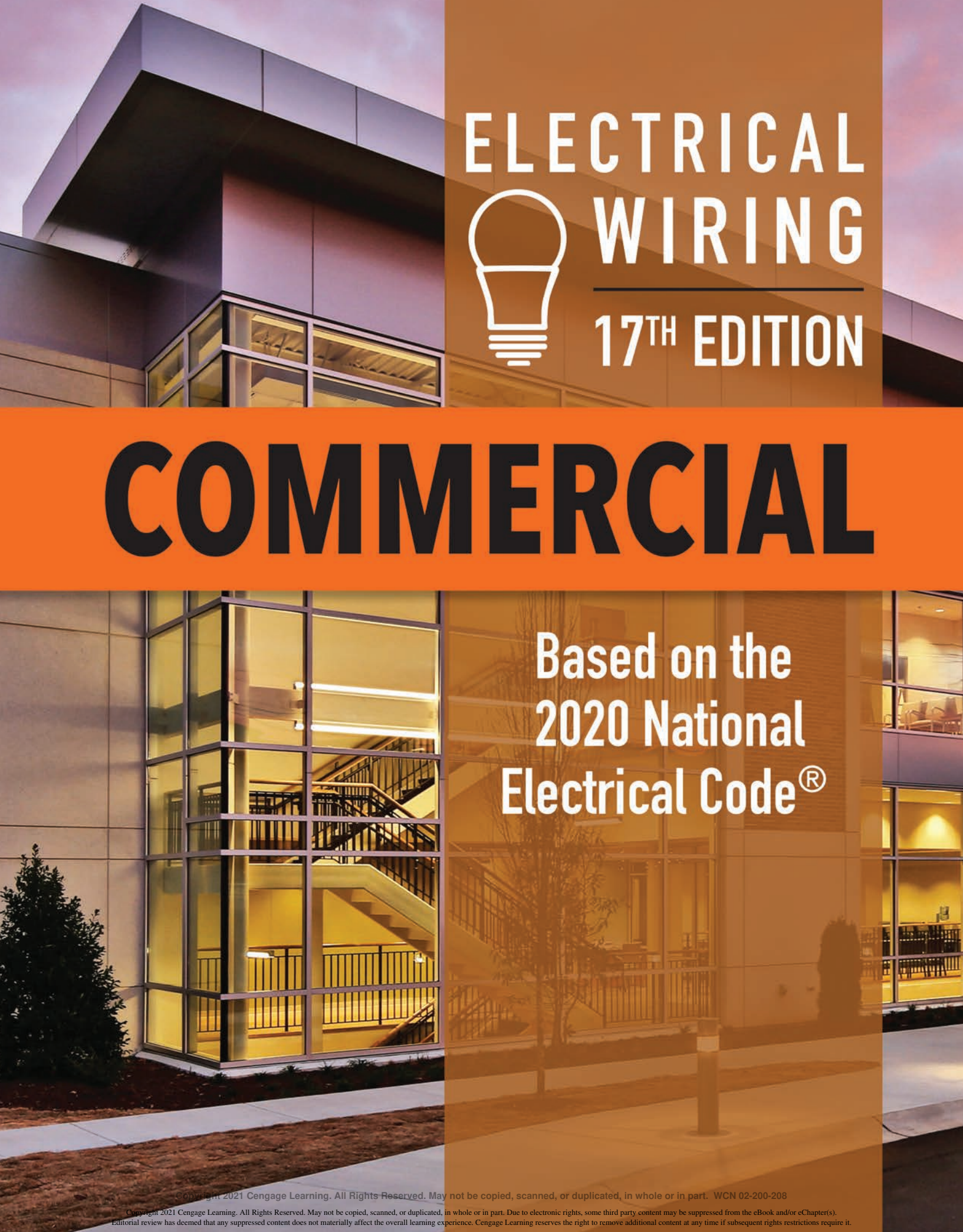
17TH EDITION

COMMERCIAL



Based on the 2020 National Electrical Code®

Phil Simmons
Ray C. Mullin

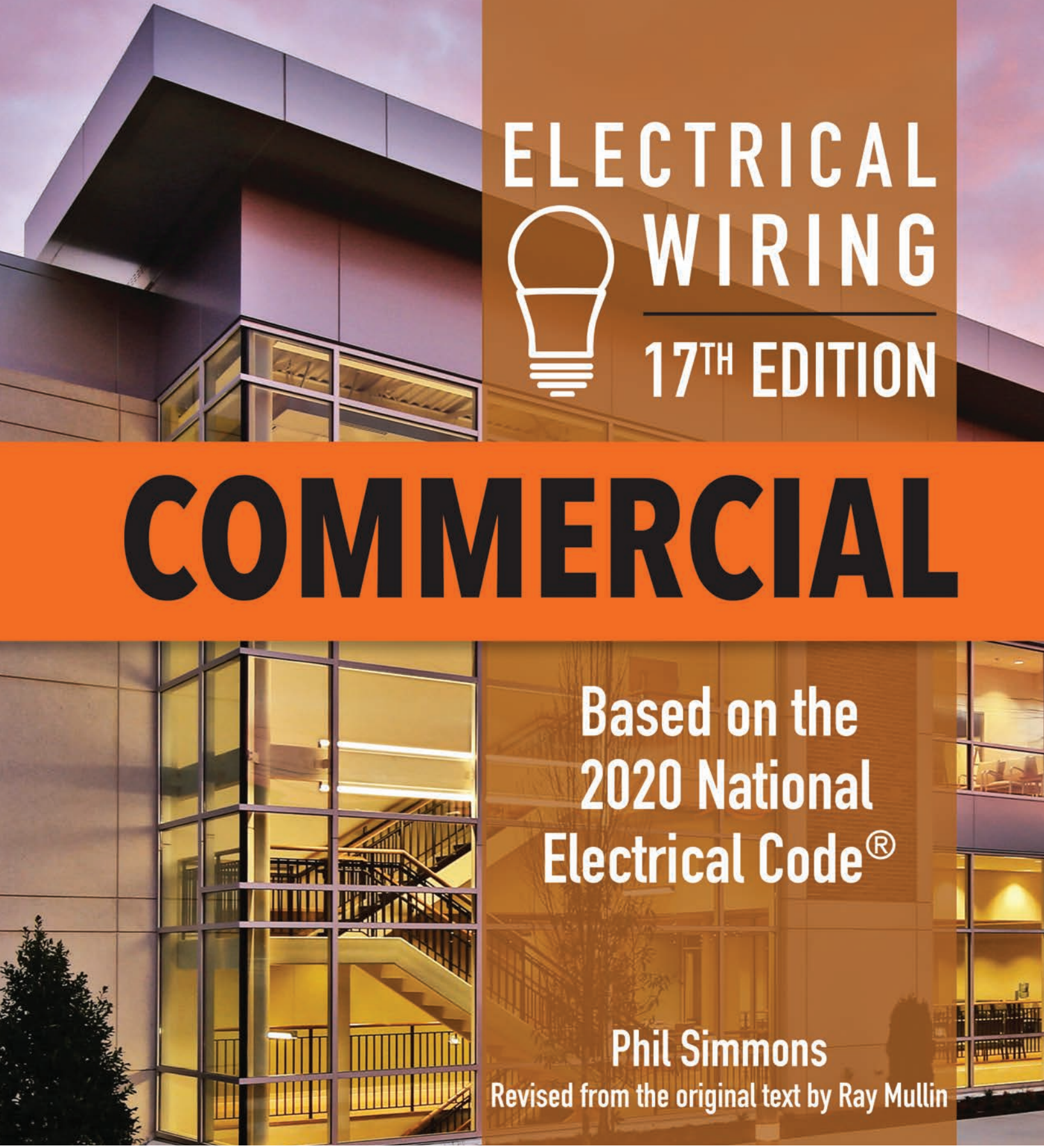


ELECTRICAL WIRING

17TH EDITION

COMMERCIAL

Based on the 2020 National Electrical Code®



ELECTRICAL WIRING

17TH EDITION

COMMERCIAL

Based on the 2020 National Electrical Code®

Phil Simmons
Revised from the original text by Ray Mullin

CENGAGE

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

Electrical Wiring Commercial, 17th Edition
Phil Simmons, Ray C. Mullin

SVP, Higher Education & Skills Product: Erin Joyner

Product Director: Matthew Seeley

Senior Product Manager: Vanessa Meyers

Product Assistant: Kimberly Klotz

Director, Learning Design: Rebecca von Gillern

Senior Manager, Learning Design: Leigh Hefferon

Learning Designer: Elizabeth Berry

Marketing Director: Sean Chamberland

Marketing Manager: Scott Chrysler

Director, Content Creation: Juliet Steiner

Content Creation Manager: Alexis Ferraro

Senior Content Manager: Cheri Plasse

Digital Delivery Lead: Elizabeth Cranston

Art Director: Jack Pendleton

Designer: Erin Griffin

Cover image(s): House—Reel Video and Stills/ShutterStock.com, Lightbulb—TheFarAwayKingdom/ShutterStock.com

Library of Congress Control Number: 2019953513

Softcover with blueprints
ISBN: 978-0-357-13769-7

Softcover book only
ISBN: 978-0-357-36062-0

Cengage
200 Pier 4 Boulevard
Boston, MA 02210
USA

Cengage is a leading provider of customized learning solutions with employees residing in nearly 40 different countries and sales in more than 125 countries around the world. Find your local representative at **www.cengage.com.**

Cengage products are represented in Canada by Nelson Education, Ltd.

To learn more about Cengage platforms and services, register or access your online learning solution, or purchase materials for your course, visit **www.cengage.com.**

Notice to the Reader

Publisher does not warrant or guarantee any of the products described herein or perform any independent analysis in connection with any of the product information contained herein. Publisher does not assume, and expressly disclaims, any obligation to obtain and include information other than that provided to it by the manufacturer. The reader is expressly warned to consider and adopt all safety precautions that might be indicated by the activities described herein and to avoid all potential hazards. By following the instructions contained herein, the reader willingly assumes all risks in connection with such instructions. The publisher makes no representations or warranties of any kind, including but not limited to, the warranties of fitness for particular purpose or merchantability, nor are any such representations implied with respect to the material set forth herein, and the publisher takes no responsibility with respect to such material. The publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or part, from the readers' use of, or reliance upon, this material.

Printed in the United States of America
Print Number: 01 Print Year: 2019

Contents

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 9

CHAPTER 17

CHAPTER 18

CHAPTER 19

Dedication

This 17th Edition of *Electrical Wiring Commercial* 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, has conducted engineering seminars, and has conducted many technical *Code* workshops and seminars at International Association of Electrical Inspectors Chapter and Section meetings, and has served on their code panels.

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 will be sorely missed. Ray passed away in March, 2018.

Preface

INTENDED USE AND LEVEL

Electrical Wiring—Commercial is intended for use in commercial wiring courses at two-year and four-year colleges, as well as in apprenticeship training programs. The text provides the basics of commercial wiring by offering insight into the planning of a typical commercial installation, carefully demonstrating how the load requirements are converted into branch circuits, then to feeders, and finally into the building's main electrical service. An accompanying set of plans at the back of the book allows the reader to step through the wiring process by applying concepts learned in each chapter to an actual commercial building, in order to understand and meet *Code* requirements set forth by the *National Electrical Code*®.

SUBJECT AND APPROACH

The seventeenth edition of *Electrical Wiring—Commercial* is based on the 2020 *National Electrical Code*. This new edition thoroughly and clearly explains the *NEC*® changes that relate to typical commercial wiring.

The *National Electrical Code* is used as the basic standard for the layout and construction of electrical systems. To gain the greatest benefit from this text, the learner must use the *National Electrical Code* on a continuing basis.

State and local codes may contain modifications of the *National Electrical Code* to meet local requirements. The instructor is encouraged to furnish students with any variations from the *NEC* as they affect this commercial installation in a specific area.

This book takes the learner through the essential minimum requirements as set forth in the *National Electrical Code* for commercial installations. In addition to *Code* minimums, the reader will find such information above and beyond the minimum requirements.

The commercial electrician is required to work in three common situations: where the work is planned in advance, where there is no advance planning, and where repairs are needed. The first situation exists when the work is designed by a consulting engineer or by the electrical contractor as part of a design/build project. In this case, the electrician must know the installation procedures, be able to read and follow the plans for the project, be able to understand and interpret specifications, and must know the applicable *Code* requirements. The second situation occurs either during or after construction when changes or remodeling are required. The third situation arises any time after a system is installed. Whenever a problem occurs with an installation, the electrician must understand the operation of all equipment included in the installation in order to solve the problem. And as previously stated, all electrical work must be done in accordance with the *National Electrical Code* and any local electrical codes.

The electrician must understand that he or she is a part of a construction team with the goal of getting the project completed on time and within the budget. Cooperation and "pulling your load" are the keys to success. The general contractor and owner count on every trade and specialist to get the components on the job when they are needed and install them so as to keep the project moving ahead smoothly.

When the electrician is working on the initial installation or is modifying an existing installation, the circuit loads must be determined. Thorough explanations and numerous examples of calculating these loads help prepare the reader for similar problems on the job. The text and assignments make frequent reference to the Commercial Building drawings at the back of the book.

The electrical loads (lighting, outlets, equipment, appliances, etc.) were selected to provide the reader with experiences that he or she would encounter when wiring a typical commercial building. The authors also carry many calculations to a higher level of accuracy as compared to the accuracy required in many actual job situations. This is done to demonstrate the correct method according to the *National Electrical Code*. Then, if the reader and/or the instructor wish to back off from this level, based upon installation requirements, it can be done intelligently.

FEATURES

- **Safety** is emphasized throughout the book and fully covered in the first chapter. Special considerations in working with electricity, such as how to avoid arc flash, as well as guidelines for safe practices, provide readers with an overview of what dangers are to be expected on the job.
- **Commercial Building Drawings** are included with the book, offering readers the opportunity to apply the concepts that they have learned in each chapter as they step through the wiring process. A description of working drawings and an explanation of symbols can be found in the first chapter.
- ***National Electrical Code*** references are integrated throughout the chapters, familiarizing readers with the requirements of the *Code* and including explanations of the wiring applications. Revisions to the *NEC* between the 2017 and 2020 editions are carefully identified.
- **Review Questions** at the end of each chapter allow readers to test what they have learned in each chapter and to target any sections that require further review.

NEW TO THIS EDITION

Every *Code* reference in the seventeenth edition of *Electrical Wiring—Commercial* is the result of comparing each and every past *Code* reference with the 2020 *NEC*. As always, the author reviews all comments submitted by instructors from across the country, making corrections and additions to the text as suggested. The input from current users of the text ensures that what is covered is what electricians need to know.

- Emphasis is given to making the wiring of the Commercial Building conform to energy saving Standards. In other words, the wiring and connected loads in *Electrical Wiring—Commercial* are "Green."
- Text and a figure were added about the requirement that the short-circuit current be marked at the service equipment, the calculation documented and distributed. The value in the marking must be updated if this value changes due to modifications.
- *Article 100*: Definitions of "Accessible (as applied to equipment" and "Service" were revised. Definitions of "Dormitory Unit," Habitable Room," and "Reconditioned" were added.
- Requirements on Reconditioned Equipment as well as which equipment can and cannot be reconditioned have been added throughout the Code.
- *110.26(C)*: Requirements on Entrance to and Egress from Working Space have been expanded and clarified.
- *210.8*: Clarification is provided for measuring the distance from a sink for GFCI protection.

- *210.8(B)*: GFCI protection required is required for all 125-volt through 250-volt receptacles supplied by single-phase branch circuits rated 150-volts to ground, 50-amps or less and all receptacles supplied by 3-phase branch circuits rated 150-volts or less to ground, 100-amperes or less that are installed in the locations specified in *210.8(B)(1)* through *(B)(12)*.
- *210.12(C)*: AFCI protection required for Guest Rooms, Guest Suites, and Patient Sleeping Rooms in Nursing Homes and Limited Care Facilities.
- *210.65*: Receptacle requirements for meeting rooms moved and revised.
- *220.12*: Unit loads for nondwelling occupancy load calculations significantly revised. Loads now include a 125% factor.
- *230.46*: Requirements added for power distribution blocks at services.
- *230.71(B)*: Rules for from 2 to 6 service disconnecting means are revised again.
- *Article 242*: Former *Article 280* on *Surge Arresters* and *Article 285* on *Surge-Protective Devices* combined in new article.
- *250.122(F)*: Rules for equipment grounding conductors in parallel are revised again.
- *Article 310*: The article is reorganized, requirements revised, and rules for *Medium Voltage Conductors and Cable* are moved to a new *Article 311*.
- *338.10(4)*: Installation requirements for service-entrance cable revised.
- *422.5(A)*: GFCI protection requirements for appliances are expanded.
- *422.16*: Requirements for flexible-cord supply to appliances are revised.
- *Article 500* through *516*: Definitions for these articles have been moved to a new *Part III* of *Article 100*.
- *Article 555*: The article has been reorganized and former *Article 553* on *Floating Buildings* has been incorporated.
- Extensive changes were made to *Article 690* for photovoltaic systems. The chapter in this text was revised to update these requirements.
- Major revisions of many diagrams and figures have been made to improve the clarity and ease of understanding the *Code* requirements.
- All *National Electrical Code* references have been updated to the 2020 *NEC*. Changes between the 2017 and 2020 editions of the *NEC* are marked with these symbols: ▶◀

SUPPLEMENT PACKAGE

Instructor Companion Website

The *Instructor Companion Website*, found on cengagebrain.com, offers the following components to help minimize instructor preparation time and engage students:

- **PowerPoint®** lecture slides outline the important concepts covered in each chapter. Extensively illustrated with photos, tables, and diagrams from the book, the presentations enhance classroom instruction. The slides allow instructors to tailor the course to meet the needs of the individual class.
- An **Image Gallery** that offers a database of hundreds of images in the text. These can easily be imported into the PowerPoint® presentation.
- **Instructor's Guide** in Microsoft Word enables instructors to view and print answers to review questions contained in the book.
- **Blueprints** from the back of the book are available in PDF format.

Cengage Learning Testing Powered by Cognero is a flexible, online system that allows you to:

- Author, edit, and manage test bank content.
- Create multiple test versions in an instant.
- Deliver tests from your LMS, your classroom, or wherever you want.

Mindtap for Electrical Wiring Commercial

MindTap is a personalized teaching experience with relevant assignments that guide students to analyze, apply, and improve thinking, allowing you to measure skills and outcomes with ease.

- *Personalized Teaching*: Becomes your own with a Learning Path that is built with key student objectives. Control what students see and when they see it; match your syllabus exactly by hiding, rearranging, or adding your own content.
- *Guide Students*: Goes beyond the traditional "lift and shift" model by creating a unique learning path of relevant readings, multimedia, and activities that move students up the learning taxonomy from basic knowledge and comprehension to analysis and application.
- *Measure Skills and Outcomes*: Analytics and reports provide a snapshot of class progress, time on task, engagement, and completion rates.

ABOUT THE AUTHOR

This text was prepared by Phil Simmons.

Phil Simmons is self-employed as Simmons Electrical Services. Services provided 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 has provided plan review of electrical construction documents. He has consulted on several lawsuits concerning electrical shocks, burn injuries, and electrocutions.

Mr. Simmons is the author and illustrator of *Electrical Wiring Commercial, Electrical Wiring Residential* and *Electrical Grounding and Bonding*. He was co-author with Ray Mullin and illustrator of the previous three editions of *Electrical Wiring Commercial* and *Electrical Wiring Residential*. Mr. Simmons is the original author and illustrator of *Electrical Grounding and Bonding*. These titles are published by Cengage Learning.

While at the International Association of Electrical Inspectors (IAEI), Phil was author and illustrator of several books, including the *Soares Book on Grounding of Electrical Systems* (five editions), *Analysis of the NEC* (three editions), and *Electrical Systems in One- and Two-Family Dwellings* (three editions). Phil wrote and illustrated the National Electrical Installation Standard (NEIS) *Standard 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 a master electrician 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.

Phil served the IAEI 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 several local and regional committees.

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

IMPORTANT NOTE

Every effort has been made to be certain that this book is 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 *NEC Code* cycles after the actual *NEC* is printed. These are called "Tentative Interim Amendments," or TIAs. TIAs and a list of errata items 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 Residential* 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 support, dedication, and attention to minute details ensure that this text, without question, is the country's leading text on commercial wiring. They sure know how to keep the pressure on!

The author and publisher 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.

The author and Publisher wish to thank the following reviewers of this and past editions for their contributions:

Kris Asper
Houston Community College
Houston, Texas

Warren DeJardin
Northeast Wisconsin Technical College
Green Bay, Wisconsin

Charlie Eldridge
Indianapolis Power and Light, Retired
Indianapolis, Indiana

Greg Fletcher
Kennebec Valley Technical College
Fairfield, Maine

David Gehlauf
Tri-County Vocational School
Glouster, Ohio

Wesley Gubitz
Cape Fear Community College
Castle Hayne, North Carolina

Fred Johnson
Champlain Valley Tech
Plattsburgh, New York

Thomas Lockett
Vatterott College
Quincy, Illinois

Gary Reiman
Dunwoody Institute
Minneapolis, Minnesota

Barrett Stapleton
IBEW 1186
Honolulu, Hawaii

Lester Wiggins
Savannah Technical College
Savannah, Georgia

The author extends his heartfelt appreciation to his friends and colleagues who over the years have provided us with many helpful comments and suggestions. These individuals are in the electrical industry, members of Code Making Panels, electrical inspectors, instructors, training directors, electricians, and electrical contractors. To name but a few . . . Madeline Borthick, David Dini, John Dyer, Paul Dobrowsky, Joe Ellwanger, Ken Haden, David Hittinger, Michael Johnston, Robert Kosky, Richard Loyd, Neil Matthes, Bill Neitzel, Don Offerdahl, Cliff Redinger, Jeff Sargent, Gordon Stewart, Clarence Tibbs, Charlie Trout, Ray Weber, J. D. White, Lester Wiggins, David Williams, and the electrical staff at NFPA headquarters. We apologize for any names we might have missed.

The authors gratefully acknowledge the contribution of the chapter on Commercial Utility Interactive Photovoltaic Systems by Pete Jackson, electrical inspector for the City of Bakersfield, CA.

Applicable tables and section references are reprinted with permission from NFPA 70-2020, *National Electrical Code*, copyright © 2019, National Fire Protection Association, Quincy, MA 02169. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

- *National Electrical Code* and *NEC* are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA 02269. Applicable tables and section references are reprinted with permission from NFPA 70-2020, the *National Electrical Code*, Copyright © 2019, National Fire Protection Association, Quincy, Massachusetts 02169.

CHAPTER 1

Commercial Building Plans and Specifications

OBJECTIVES

After studying this chapter, you should be able to

- explain how the *NEC*® is organized and how the articles relate.
- explain the process for updating the *NEC*.
- explain the basic safety rules for working on electrical systems.
- define the project requirements from the contract documents.
- demonstrate the application of building plans and specifications.
- locate specific information on the building plans.
- obtain information from industry-related organizations.
- apply and interchange International System of Units (SI) and English measurements.

INTRODUCTION TO *Electrical Wiring—Commercial*

You are about to explore the electrical systems of a typical small commercial building along with other related electrical systems. You may find this text to be challenging depending on your experience and understanding in installing electrical equipment and wiring, along with the many requirements in the *National Electrical Code*® (*NEC*®). This book and the *NEC* may seem easy at times and difficult at other times. As you study, you may want to have both this text and the *NEC* open, as well as to spread out the drawings located in the back of this book.

As you study this book, you will learn about safety, wiring methods, electrical equipment, luminaires, and *NEC* requirements. You will be using the text, the set of Plans, and the *NEC*.

The set of Plans and Specifications in the back of this text will be used and referred to continually. The objective is to correlate what you are learning to a typical commercial installation. Tying the text, the Plans, and the *NEC* together is much preferred over merely presenting a stand-alone *NEC* rule without associating the rule to a real situation. The Plans are those of an actual building, not just a convenient drawing to illustrate a specific *Code* rule. For all intents and purposes, upon completing this text you will have wired a commercial building.

Throughout this text, red triangles ▶◀ indicate a change in the 2020 edition of the *NEC* from the previous 2017 edition.

Let us begin with probably the most important part of learning the electrical trade: *safety*.

SAFETY IN THE WORKPLACE

Before we get started on our venture into the wiring of a typical commercial building, let us talk about safety.

Electricity can be dangerous! The Occupational Safety and Health Act (OSHA) regulations and *National Fire Protection Association (NFPA) 70E, Standard for Electrical Safety in the Workplace*, consider working on energized equipment over 50 volts to represent a shock hazard. Working on electrical equipment with the power turned on can result in death or serious injury, either as a direct result of electricity flowing through a person, from electrical arc-flash or blast, or from an indirect secondary reaction such as falling off a ladder or falling into the moving parts of equipment. Dropping a metal tool onto live parts or allowing metal shavings from a drilling operation to fall onto live parts of electrical equipment generally results in an arc flash and arc blast, which can cause deadly burns and other physical trauma. The heat of an electrical arc flash has been determined to be as much as 35,000°F (19,427°C), or about four times hotter than the sun. Pressures developed during an arc blast can blow a person across the room and inflict serious injuries. Dirt, debris, and moisture can also set the stage for catastrophic equipment failures and personal injury. Neatness and cleanliness as well as wearing appropriate personal protective equipment and following all safety procedures in the workplace are a must.

The *OSHA Code of Federal Regulations (CFR) Number 29, Subpart S,* in paragraph *1910.332,* discusses the training needed for those who face the risk of electrical injury. Proper training means "*trained in and familiar with the safety-related work practices required by paragraphs 1910.331 through 1910.335.*" Numerous texts are available that cover the OSHA requirements in great detail.

NFPA 70E, the *Standard for Electrical Safety in the Workplace*, should be used in conjunction with the OSHA regulations to develop and implement an effective electrical safety program for the workplace. The OSHA rules state what is required. *NFPA 70E* provides information on how to comply with the OSHA rules and achieve a safe workplace. 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.* Merely telling someone or being told to be careful does not meet the definition of proper training and does not make the person qualified. This definition emphasizes not only recognizing hazards but also avoiding them. Avoiding an electrical accident is usually worth much more than "an ounce of prevention" and certainly much more than "a pound of cure." Shock and burn injuries usually happen

*Source: NFPA 70-2020

so fast that it is difficult to react quickly enough to get out of harm's way. Yet these injuries can almost instantly change your life in a very negative manner. Most often, victims are never the same as before the incident.

Important requirements for training are found in *NFPA 70E Article 110*. The training required is specifically related to the tasks to be performed. The rule includes a statement: A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others.** If you have not been trained to do a specific task, you are considered unqualified in that area. The training given and received is required to be documented. If you are ever in an electrical accident that is reportable to OSHA, one of the first things they will ask for is a copy of your personnel record to prove you were trained for the task you were performing. Employers are required to provide appropriate training and safety procedures. Employees are required to comply with the safety training they have received.

Only qualified persons are permitted to work on or near exposed energized equipment. To become qualified, a person must

- have the skill and training necessary to distinguish exposed live parts from other parts of electrical equipment;
- be able to determine the voltage of exposed live parts; and
- be trained in the use of special precautionary techniques, such as personal protective equipment, insulations, shielding material, and insulated tools.

An unqualified person is defined in *Article 100* of *NFPA 70E* as *A person who is not a qualified person.** Although this seems simplistic, a person can be considered *qualified* for performing some tasks and yet be *unqualified* for other tasks. Training and experience make the difference.

Subpart S, paragraph 1910.333, of the OSHA regulations, requires that safety-related work practices be employed to prevent electrical shock or other injuries resulting from either direct or indirect electrical contact. Live parts to which an employee may be exposed are required to be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards.

Working on "live" equipment is acceptable only if there would be a greater hazard if the system were de-energized. Examples of this would be life-support systems, some alarm systems, certain ventilation systems in hazardous locations, and the power for critical illumination circuits. Working on energized equipment requires properly insulated tools, proper flame-resistant clothing, rubber gloves, protective shields and goggles, and in some cases insulating blankets. As previously stated, OSHA regulations allow only qualified personnel to work on or near electrical circuits or equipment that has not been de-energized. The OSHA regulations provide rules regarding lockout and tagout (LOTO) to make sure that the electrical equipment being worked on will not inadvertently be turned on while someone is working on the supposedly dead equipment. As the OSHA regulations state, "*A lock and a tag shall be placed on each disconnecting means used to de-energize circuits and equipment.*"

Some electricians' contractual agreements require that, as a safety measure, two or more qualified electricians must work together when working on energized circuits. They do not allow untrained apprentices to work on live equipment but do allow apprentices to stand back and observe.

According to *NFPA 70E, Standard for Electrical Safety in the Workplace*, circuits and conductors are not considered to be in an electrically safe work 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. Proper personal protective equipment (PPE) is required to be worn while testing equipment for absence of voltage during the lockout/tagout procedure. Equipment is considered to be energized until proven otherwise.

Safety cannot be compromised. Accidents do not always happen to the other person.

Follow this rule: *Turn off* and *lock off* the power, and then properly tag the disconnect with a description as to exactly what that particular disconnect serves.

**Reprinted with permission from NFPA 70E-2018
*Source: NFPA 70-2020

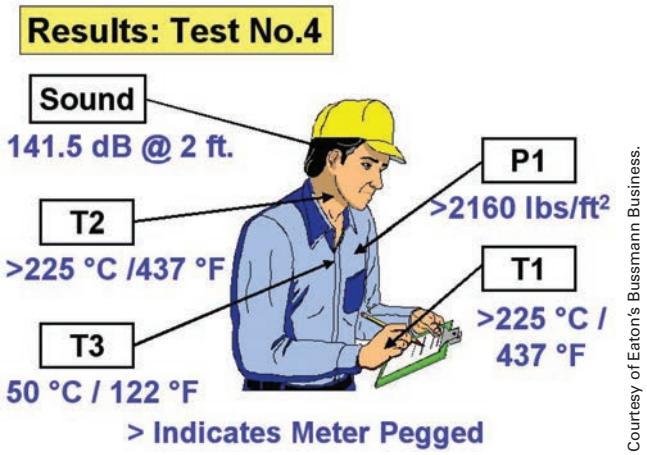
Arc Flash and Arc Blast

An electrician should not get too complacent when working on electrical equipment. A major short circuit or ground fault at the main service panel, or at the meter cabinet or base, can deliver a lot of energy. On large electrical installations, an arc flash can generate temperatures of 35,000°F (19,427°C). This is hotter than the surface of the sun. This amount of heat will instantly melt copper, aluminum, and steel. For example, copper expands 64,000 times its original volume when it changes state from a solid to a vapor. The resulting violent blast will blow hot particles of metal and hot gases all over, often resulting in personal injury, fatality, or fire. An arc blast, Figure 1-1, also creates a tremendous air-pressure wave that can cause serious ear damage or memory loss due to the concussion. Damage to internal organs such as collapsed lungs is common in these events, Figure 1-2. The blast might blow the victim away from the arc source, causing additional injuries from falls.

A series of tests were performed to determine the temperatures and pressures an arc flash and blast event would produce. The results of test No. 4 are shown in Figure 1-2. For this test, the voltage was 480, with approximately 22,600 amperes short-circuit current available. The overcurrent device on the supply side of the fault was an electronic power circuit breaker set to open in 12 cycles.

Courtesy of Eaton's Bussmann Business.

FIGURE 1-1 Arc-flash and arc-blast event.



Courtesy of Eaton's Bussmann Business.

FIGURE 1-2 Results of arc-flash and arc-blast event.

The significance of the test results are as follows:

- Sound: hearing protection is required for sound levels above 85 db.
- T1: the temperature on exposed skin exceeded 437°F (225°C). No doubt third- or fourth-degree burns will occur almost instantly at that temperature.
- T2: Same comment as for T1.
- T3: The temperature probe was on the skin under the clothing. A significant reduction in temperature resulted in no injury to the skin.
- P1: The pressure on the chest exceeded 2160 lbs per square ft. At these pressures, damage to internal organs is very likely.

An electrician should not be fooled by the size of the service. Commercial installations often have very large services, providing a potential for a significant arc-flash and arc-blast hazard. The Commercial Building discussed in this text is served by three 350 kcmil (thousand circular mils) copper Type XHHW-2 conductors that total 930 amperes in the 75°C column of *NEC Table 310.16*.

It is important that an arc-flash hazard analysis is performed to determine the arc-flash protection boundary as well as the level of personal protective equipment that people are required to wear within the arc-flash boundary. New requirements are contained within *NFPA 70E* for posting the level of

incident energy that is available or the rating of flame-resistant personal protective equipment that must be worn. This posting is so important because the incident energy can vary from one piece of equipment to another. With this information, electricians can select the personal protective equipment that is needed so they are protected in the hazardous area. In some cases, the arc-flash study may dictate that an arc-flash suit with a beekeeper-type hood be used. The best approach continues to be that work on the equipment only be done while it is de-energized.

Electricians seem to feel out of harm's way when working on small electrical systems and seem to be more cautious when working on commercial and industrial electrical systems. Do not allow yourself to get complacent. Nearly half of the electrocutions each year are from 120-volt systems. A very small current is all that is needed when flowing through our nervous system to cause paralysis so the electrician is "hung up." This occurs when the external voltage flowing through the electrician's nervous system prevents him or her from releasing contact with the energized part.

A fault at a small main service panel, however, 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 kilovolt-ampere (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. If you want to learn more, we suggest that you search for "fault current calculations" on the Internet, where you will find a lot of information on the topic, including tutorials. An Excel spreadsheet designed to simplify fault-current calculations is available for free download from several sources including at http://www.mikeholt.com/technical-calculations-formulas.php. Applications for smart phones are readily available; most can be downloaded for free.

Short-circuit calculations are discussed in detail in Chapter 18 of this text.

Electricians should not be fooled into thinking that if they cause a fault on the load side of the main disconnect, the main breaker will trip off and protect them 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 or fuse to open. How much current (energy) the main breaker will let through depends on the available fault current and the breaker or fuse opening time. A joke in the electrical trade is that a power company will sell power to you a little at a time—or all in one huge arc blast.

NEC 110.16 specifies that, Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that is in other than dwelling units, and is 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.*

Section 110.21(B) provides requirements for warning or hazard labels that are applied in the field. It includes requirements to adequately warn of the hazard using effective words, colors, or symbols.

See Figure 1-3 for an example of the warning, danger, and caution labels *in standard colors specified by ANSI Z535.4 Product Safety Signs and Labels*.

The warning label must also be permanently affixed to the equipment and is not permitted to be hand written except for filling in a blank for variable information. The label must be of sufficient durability to withstand the environment where located.

Figure 1-4 is an example of a commercially available label.

Electrical Power Tools on the Job

On the job, you will be using portable electric power tools. Although many of these tools are battery powered, several larger tools like threaders, benders, bandsaws, and pullers are powered by 120 or 240 volts. The electrical supply on construction sites is often in the form of temporary power, covered by *Article 590* of the *NEC*.

*Source: NFPA 70-2020

DANGER indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.

WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.

CAUTION or NOTICE without the safety alert symbol is appropriate for property-damage-only hazards.

FIGURE 1-3 Danger, Warning, Caution, and Notice signs as indicated in ANSI Z535.4.

FIGURE 1-4 Typical pressure-sensitive arc flash and shock-hazard label to be affixed to electrical equipment as required by *NEC 110.16*.

NEC 590.6(A) and *(B)* require that ground-fault circuit-interrupter protection for personnel be provided for all 125-volt, single-phase, 15-, 20-, and 30-ampere receptacle outlets irrespective of whether they are a part of the permanent wiring of the building or structure, or are supplied from a portable generator that is rated 15 kW or less. The issue is whether these power sources supply receptacle outlets that are in use by the worker. An exception is provided for receptacle outlets of other ratings that have protection by the testing protocols of an assured equipment grounding conductor–testing program.

Because the GFCI requirement is sometimes ignored or defeated on job sites, as part of your tool

Courtesy of Hubbell Lighting Outdoor & Industrial

FIGURE 1-5 Two types of portable plug-in cord sets that have built-in GFCI protection.

collection you should carry and use a portable ground-fault circuit interrupter (GFCI) of the type shown in Figure 1-5—an inexpensive investment that will protect you against possible electrocution. Remember, "The future is not in the hands of fate, but in ourselves."

Now consider the effects of 60-hertz (60-cycle) ac currents on humans in the study by Charles F. Dalziel ("Dangerous Electric Currents," reported in *AIEE Transactions*, vol. 65 [1946], p. 579; discussion, p. 1123), presented in Table 1-1. (The effects vary depending on whether the current is dc or ac and on the frequency if it is ac.)

Mr. Dalziel is credited with inventing the ground-fault circuit interrupter (GFCI), which, for the Class A personnel protection version, is required to open between 4 and 6 mA of current flow. This device has saved countless lives and reduced the electric shock injuries.

Refer to Chapter 5 of this text for details on how GFCIs operate and where they must be installed.

Stand to One Side!

A good suggestion is that when turning a standard disconnect switch on, *do not* 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 occurs when you turn the disconnect switch on, you will not be standing in front of the switch. You will

TABLE 1-1

Current in milliampere (mA), 60 Hz.

EFFECT(S)	MEN	WOMEN
Slight sensation on hand	0.4	0.3
Perception of "let go" threshold, median	1.1	0.7
Shock, not painful, and no loss of muscular control	1.8	1.2
Painful shock—muscular control lost by half of participants	9	6
Painful shock—"let go" threshold, median	16	10.5
Painful and severe shock—breathing difficult, muscular control lost	23	15

not have the switch's door fly into your face. There is a good chance that the molten metal particles resulting from an arc flash will fly past you.

More Information

You will find more information about the hazards of an arc flash and when conditions call for personal protective equipment (PPE) in *Electrical Safety in the Workplace NFPA 70E* and in Chapter 13 of this text.

Information on the content of warning signs can be found in the ANSI Standard Z535.4, *Product Safety Signs and Labels.*

Just about every major manufacturer of electrical equipment has arc-flash information on its website.

Where Do We Go Now?

With safety the utmost concern in our minds, let us begin our venture on the wiring of a typical commercial building.

COMMERCIAL BUILDING SPECIFICATIONS

When a building project contract is awarded, the electrical contractor is given the plans and specifications for the building. These two contract documents govern the construction of the building. It is very important that the electrical contractor and the electricians employed by the contractor to perform the electrical construction follow the specifications exactly. The electrical contractor will be held responsible for any deviations from the specifications and may be required to correct such deviations or variations at personal expense. Thus, it is important that any changes or deviations be verified—in writing. Avoid verbal change orders.

It is suggested that the electrician assigned to a new project first read the specifications carefully. These documents provide the detailed information that will simplify the task of studying the plans. The specifications are usually prepared in book form and may consist of a few pages to as many as several hundred pages covering all phases of the construction. This text presents in detail only that portion of the specifications that directly involves the electrician; however, summaries of the other specification sections are presented to acquaint the electrician with the full scope of the document.

The specification is a book of rules governing all of the material to be used and the work to be performed on a construction project. The specification is usually divided into several sections.

General Clauses and Conditions

The first section of the specification, *General Clauses and Conditions*, deals with the legal requirements of the project. The index to this section may include the following headings:

Notice to Bidders
Schedule of Drawings
Instructions to Bidders
Proposal
Agreement
General Conditions

Some of these items will impact the electrician on the job, and others will be of primary concern to the electrical contractor. The following paragraphs give a brief, general description of each item.

Notice to Bidders. This item is of value to the contractor and their estimator only. The notice describes the project, its location, the time and place of the bid opening, and where and how the plans and specifications can be obtained.

Schedule of Drawings. The schedule is a list, by number and title, of all of the drawings related to the project. The contractor, estimator, and electrician will each use this schedule prior to preparing the bid for the job: the contractor, to determine whether all the drawings required are at hand; the estimator, to do a takeoff and to formulate a bid; and the electrician, to determine whether all of the drawings necessary to do the installation are available.

Instructions to Bidders. This section provides the contractor with a brief description of the project, its location, and how the job is to be bid (lump sum, one contract, or separate contracts for the various construction trades, such as plumbing, heating, electrical, and general). In addition, bidders are told where and how the plans and specifications can be obtained prior to the preparation of the bid, how to make out the proposal form, where and when to deliver the proposal, the amount of any bid deposits

required, any performance bonds required, and bidders' qualifications. Other specific instructions may be given, depending on the particular job.

Proposal. The proposal is a form that is filled out by the contractor and submitted at the proper time and place. The proposal is the contractor's bid on a project. The form is the legal instrument that binds the contractor to the owner if (1) the contractor completes the proposal properly, (2) the contractor does not forfeit the bid bond, (3) the owner accepts the proposal, and (4) the owner signs the agreement. Generally, only the contractor will be using this section.

The proposal may show that alternate bids were requested by the owner. In this case, the electrician on the job should study the proposal and consult with the contractor to learn which of the alternate bids has been accepted in order to determine the extent of the work to be completed.

On occasion, the proposal may include a specified time for the completion of the project. This information is important to the electrician on the job because the work must be scheduled to meet the completion date.

Agreement. The agreement is the legal binding portion of the proposal. The contractor and the owner sign the agreement, and the result is a legal contract. After the agreement is signed, both parties are bound by the terms and conditions given in the specification.

General Conditions. The following items are normally included under the *General Conditions* heading of the *General Clauses and Conditions*. A brief description is presented for each item:

- General Note: Includes the general conditions as part of the contract documents.
- Definition: As used in the contract documents, defines the owner, contractor, architect, engineer, and other people and objects involved in the project.
- Contract Documents: Lists the documents involved in the contract, including plans, specifications, and agreement.
- Insurance: Specifies the insurance a contractor must carry on all employees and on the materials involved in the project.
- Workmanship and Materials: Specifies that the work must be done by skilled workers and that the materials must be new and of good quality.
- Substitutions: Specifies that materials used must be as indicated or that equivalent materials must be shown to have the required properties.
- Shop Drawings: Identifies the drawings that must be submitted by the contractor to show how the specific pieces of equipment are to be installed.
- Payments: Specifies the method of paying the contractor during the construction.
- Coordination of Work: Specifies that each contractor on the job must cooperate with every other contractor to ensure that the final product is complete and functional.
- Correction Work: Describes how work must be corrected, at no cost to the owner, if any part of the job is installed improperly by the contractor.
- Guarantee: Guarantees the work for a certain length of time, usually one year.
- Compliance with All Laws and Regulations: Specifies that the contractor will perform all work in accordance with all required laws, ordinances, and codes, such as the *NEC* and city codes.
- Others: Sections added as necessary by the owner, architect, and engineer when the complexity of the job and other circumstances require them. None of the items listed in the General Conditions has precedence over another item in terms of its effect on the contractor or the electrician on the job. The electrician must study each of the items before taking a position and assuming responsibilities with respect to the job.

Supplementary General Conditions

The second main section of the specifications is titled *Supplementary General Conditions*. These conditions usually are more specific than the *General Conditions*. Although the *General Conditions* can be applied to any job or project in almost any location with little change, the *Supplementary General Conditions* are rewritten for each project.

The following list covers the items normally specified by the *Supplementary General Conditions*:

- The contractor must instruct all crews to exercise caution while digging, as any utilities damaged during the digging must be replaced or repaired by the contractor responsible. Most communities have a Call Before You Dig program. Services are available to locate and mark all underground utilities in the area such as power, water, sewer, telephone, and cable systems.
- The contractor must verify the existing conditions and measurements.
- The contractor must employ qualified individuals to lay out the work site accurately. A registered land surveyor or engineer may be part of the crew responsible for the layout work.
- Job offices are to be maintained as specified on the site by the contractor; this office space may include space for owner representatives.
- The contractor may be required to provide telephones at the project site for use by the architect, engineer, subcontractor, or owner.
- Temporary toilet facilities and water are to be provided by the contractor for the construction personnel.
- The contractor must supply an electrical service of a specified capacity to provide temporary light and power at the site.
- The contractor may have to supply a specified type of temporary heating to keep the temperature at the level specified for the structure.
- According to the terms of the guarantee, the contractor agrees to replace faulty equipment and correct construction errors for a period of one year.
- The previous listing is by no means a complete catalog of all of the items that can be included in the section *Supplementary General Conditions*.

Other names may be applied to the *Supplementary General Conditions* section, including *Special Conditions* and *Special Requirements*. Regardless of the name used, these sections contain the same types of information. All sections of the specifications must be read and studied by all of the construction trades involved. In other words, the electrician must study the heating, plumbing, ventilating, air-conditioning, and general construction specifications to determine whether there is any equipment furnished by the other trades and where the contract specifies that such equipment is to be installed and wired by the electrical contractor. The electrician must also study the general construction specifications because the roughing in of the electrical system will depend on the types of construction that will be encountered in the building.

This overview of the *General Conditions* and *Supplementary General Conditions* of a specification is intended to show the student that construction workers on the job are affected by parts of the specification other than the part designated for their particular trade.

Contractor Specification

In addition to the sections of the specification that apply to all contractors, separate sections exist for each of the contractors, such as the general contractor who constructs the building proper, the plumbing contractor who installs the water and sewage systems, the heating and air-conditioning contractor, and the electrical contractor. The contract documents usually do not make one contractor responsible for work specified in another section of the specifications. However, it is always considered good practice for each contractor to be aware of how he or she is involved in each of the other contracts in the total job.

WORKING DRAWINGS

The construction plans for a building are often called *blueprints*. This term is a carryover from the days when the plans were blue with white lines. Today, a majority of the plans used have black lines on white paper because this combination is considered easier to read and more economical to produce. The terms *plans* and *working drawings* will be commonly used in this text.

A set of 10 plan sheets is included at the back of the text, showing the general and electrical portions of the work specified:

- *Sheet A1—Architectural Floor Plan; Basement*
- *Sheet A2—Architectural Floor Plan; First Floor*

- *Sheet A3—Architectural Floor Plan; Second Floor:* The architectural floor plans give the wall and partition details for the building. These sheets are drawn to scale (dimensioned); the electrician can find exact locations by referring to these sheets. The electrician should also check the plans for the materials used in the general construction, as these will affect when and how the system will be installed.
- *Sheet A4—Site Plan, East and West Elevations:* The plot plan shows the location of the commercial building and gives needed elevations. The east elevation is the street view of the building, and the west elevation is the back of the building. The index lists the content of all the plan sheets.
- *Sheet A5—Elevations; North and South:* The electrician must study the elevation dimensions, which are given in feet and hundredths of a foot above sea level. For example, the finished second floor, which is shown at 218.33 ft, is 218 ft 4 in. above sea level.
- *Sheet A6—Building Cross Sections*
- *Sheet E1—Basement Electrical Plan*
- *Sheet E2—First Floor Electrical Plan*
- *Sheet E3—Second Floor Electrical Plan*
- *Sheet E4—Panelboard & Service Schedules, One-Line Diagram of Service and Feeders*

These sheets show the detailed electrical work on an outline of the building. Because dimensions usually are not shown on the electrical plans, the electrician must consult the other sheets for this information. It is recommended that the electrician refer frequently to the other plan sheets to ensure that the electrical installation does not conflict with the work of the other construction trades.

To assist the electrician in recognizing components used by other construction trades, the following illustrations are included: Figure 1-6A and Figure 1-6B, Architectural drafting symbols; Figure 1-7, Standard symbols for plumbing, piping, and valves; and Figure 1-8, Sheet metal ductwork symbols. A comprehensive list of electrical symbols typically used for commercial building wiring is included in Chapter 2 of this text. Electrical symbols that are important for reference are included in Appendix H of this text. However, the electrician should be aware that variations of these symbols may be used, and the specification and/or plans for a specific project must always be consulted.

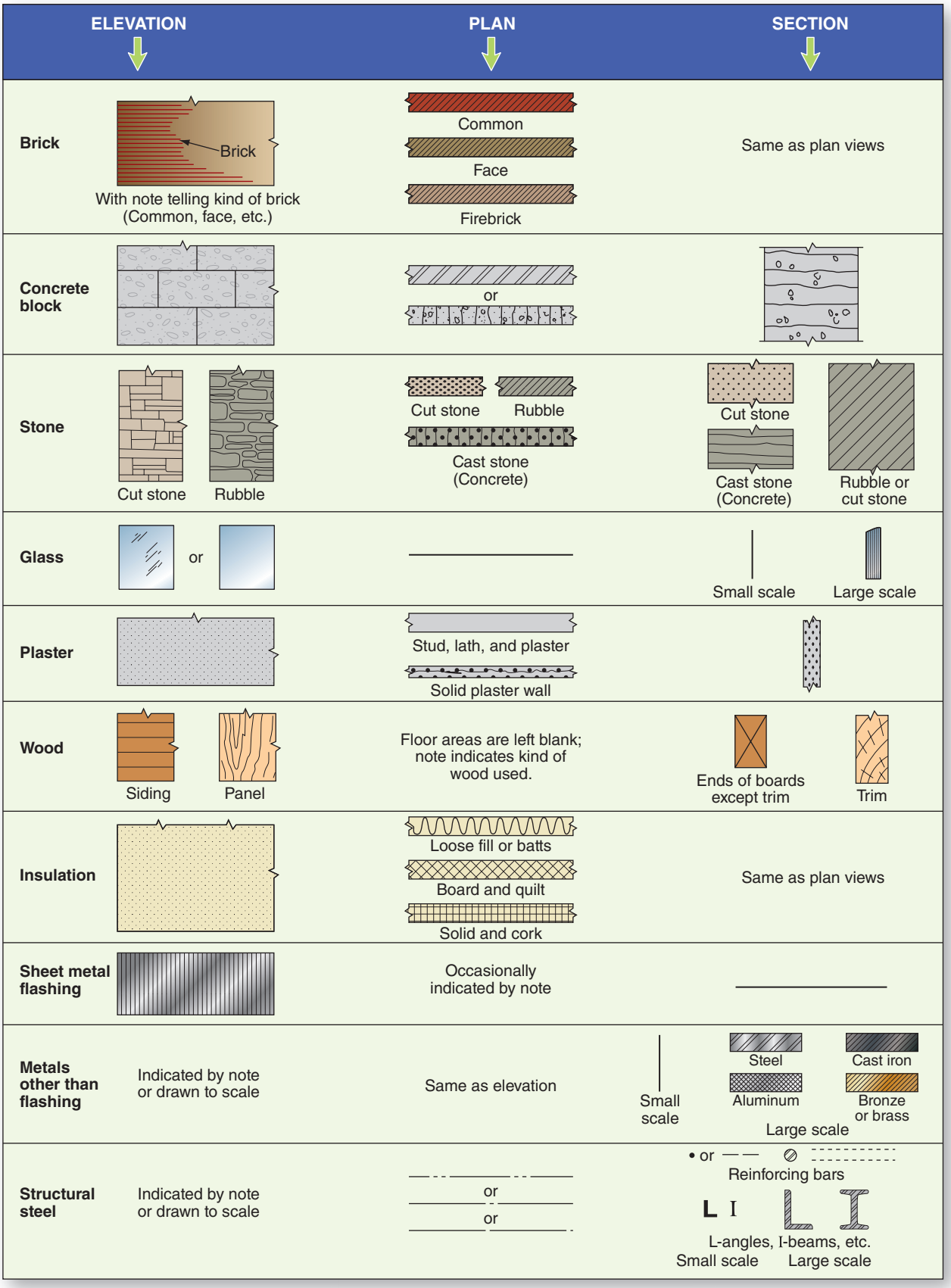
Building Information Modeling (BIM)

Preparing working drawings has evolved over the years, from draftsmen laboring over a drafting table using T-squares, triangles, compasses, architectural scales, and pen and ink, to computer aided design and drafting software (CADD) programs. The architectural firm prepared the master drawings and furnished these to other disciplines such as mechanical, electrical, plumbing, and structural engineers, who added design features of their disciplines to the master drawings. A tremendous amount of coordination was necessary to prevent conflicts from developing where piping, equipment, and ductwork, for example, were competing for the same space. Often, these conflicts were not discovered until the building or structure was in some stage of construction. Correcting these conflicts, which almost always required one or more designs to be changed, was time-consuming and expensive. It seemed the larger the project, the more change orders were issued to compensate for conflicts in design.

Traditionally, working drawings were and are two-dimensional. This relates to length and width or height of floor plans or cross-sectional drawings. All these drawings were (are) drawn to scale.

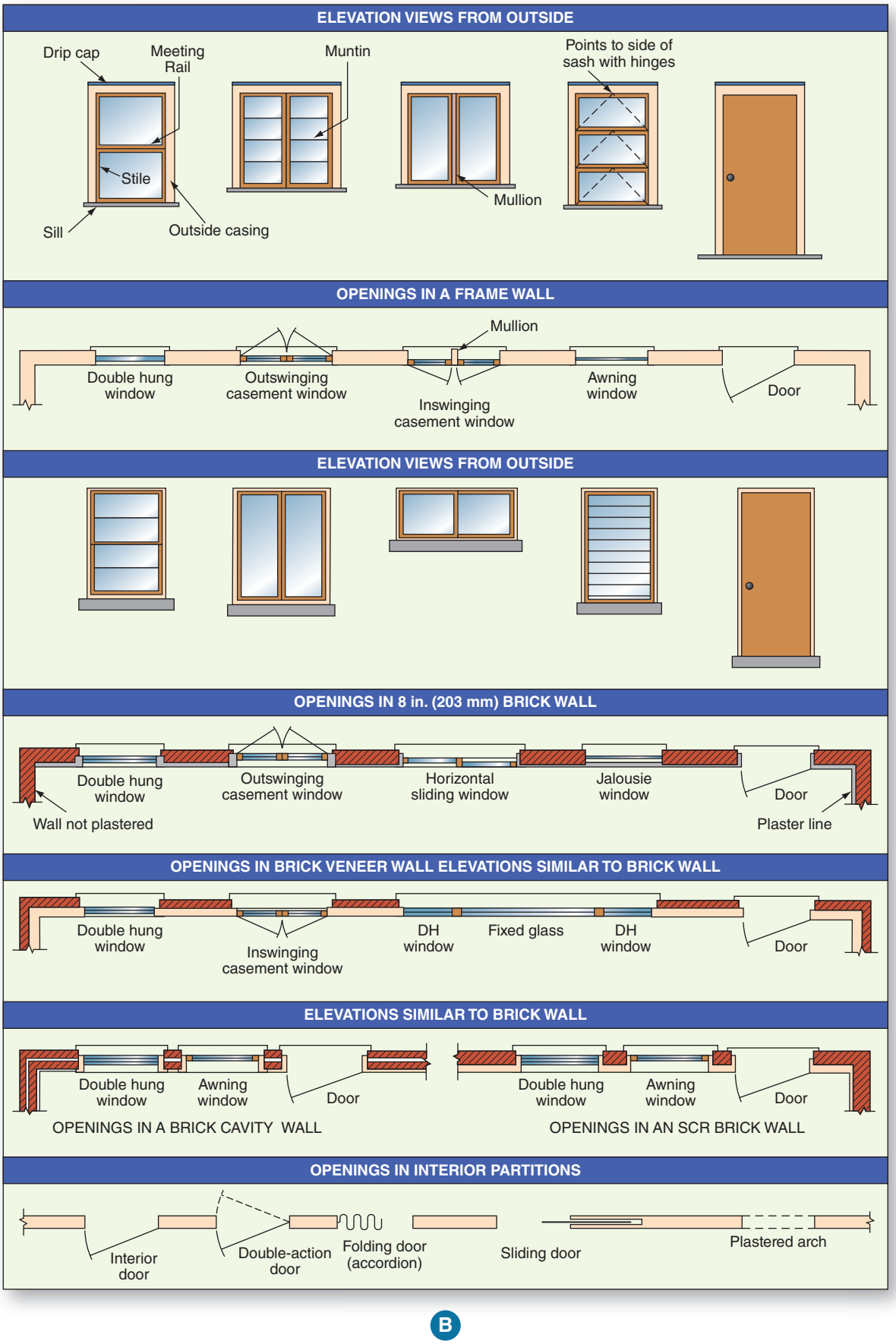
Building Information Modeling (BIM) is a significant enhancement to CADD programs. It adds the third dimension of height to the drafting software. This allows a more real-world visualization to take place. Actual dimensions of equipment to be installed, such as panelboards, switchboards, cable tray, conduit and hanger systems are loaded into the software so it can be used effectively in the design process as well as to avoid conflict in design. The dimensions of equipment products or components for all trades or crafts, including mechanical, electrical, plumbing, and structural system components, are entered in a similar way.

The BIM software analyzes design or construction features based on all of the information that has been entered and then produces conflict reports. Typically, a meeting is held weekly, early in the design process, among representatives of the



A

FIGURE 1-6 Architectural drafting symbols.



B

FIGURE 1-6 (continued)

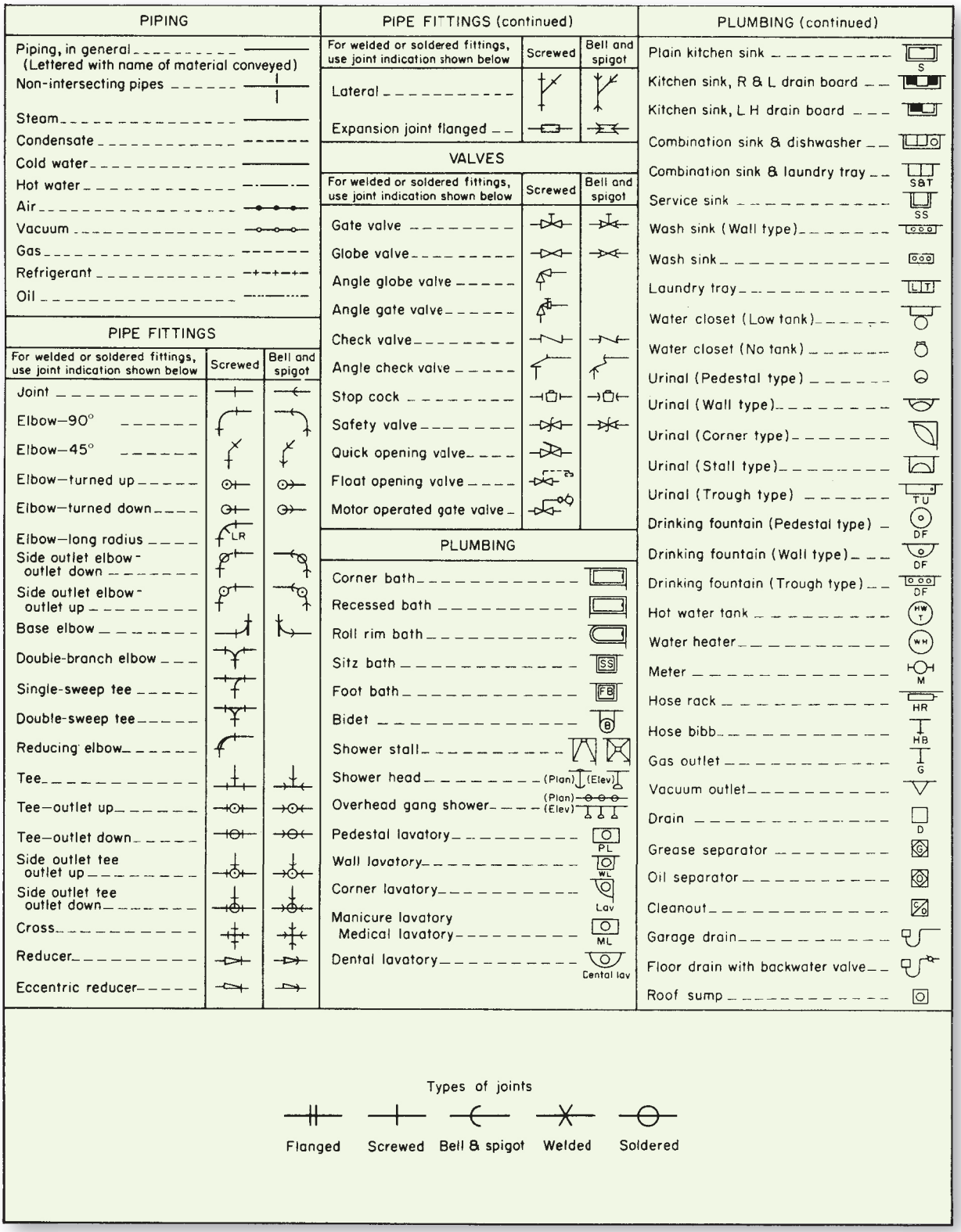


FIGURE 1-7 Standard symbols for plumbing, piping, and valves.

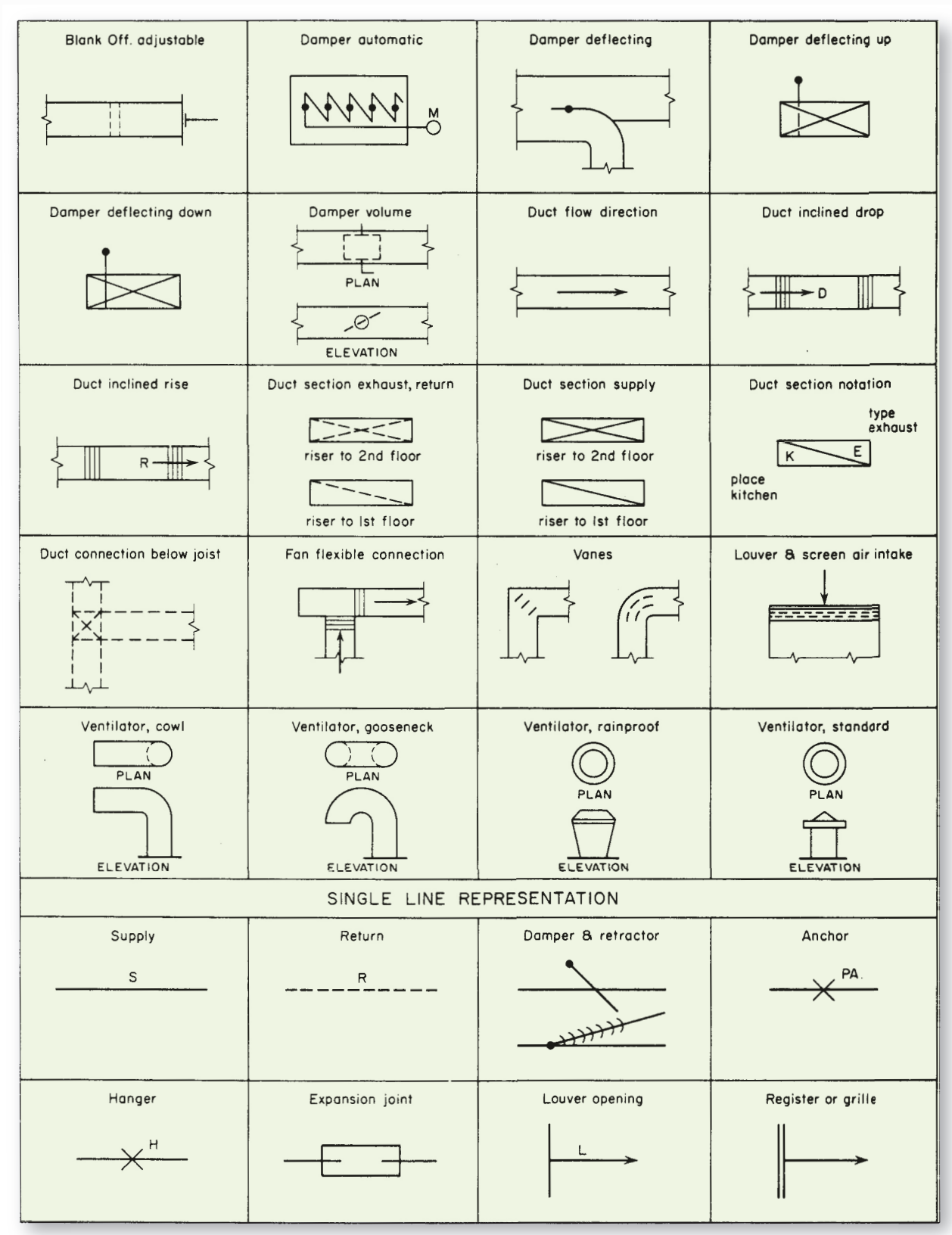


FIGURE 1-8 Sheet metal ductwork symbols.

design team, to analyze the conflicts and determine the most appropriate corrective action needed to eliminate them.

The 3-dimensional aspects of the design significantly facilitate estimating quantities of cable tray, cables, conduit, and wire that will be needed for the project. With this accurate information at hand, it is much easier for estimators to prepare accurate bids and to order proper quantities of the many products that are needed in a construction project.

The benefit to the electrician and other tradesmen is significant. For example, the design software can be loaded into devices that can be used to accurately position anchors for conduit and cable tray support systems, as well as to position cutouts that can be safely made without degrading the structural integrity of the building. The information can be loaded into sophisticated conduit-bending machines, so proper offsets and bends can be effectively produced. The usefulness of the BIM software facilitates the off-site production of components or assemblies that can be brought to the construction site when needed.

Submitting Plans

In most communities, building plans and specifications must be submitted to a building department for review prior to the issuance of a construction permit. *NEC 215.5* states, If required by the authority having jurisdiction, a diagram showing feeder details shall be provided prior to the installation of the feeders. Such a diagram shall show the area in square feet of the building or other structure supplied by each feeder, the total calculated load before applying demand factors, the demand factors used, the calculated load after applying demand factors, and the size and type of conductors to be used.*

Construction Terms

As you will learn, *Electrical Wiring—Commercial* covers all aspects of typical commercial wiring. On construction sites, electricians work with other trades and crafts. Knowing construction terms and symbols is a key element to getting along with the other workers. A rather complete dictionary of construction terms can be found at http://www.constructionplace.com.

CODES AND ORGANIZATIONS

Many organizations such as cities and power companies develop electrical codes that they enforce within their areas of influence. These codes generally are concerned with the design and installation of electrical systems. It is important to verify which edition of the *NEC* has been adopted and is to be used as the basis for the local code. Some jurisdictions routinely adopt the latest edition of the *NEC* soon after it is published. Other jurisdictions may be operating on an edition of the *NEC* that is several years out of date. Consult these organizations before starting work on any project. The local codes may contain special requirements that apply to specific and particular installations. Additionally, the contractor may be required to obtain special permits and/or licenses before construction work can begin.

National Fire Protection Association

Organized in 1896, the National Fire Protection Association (NFPA) is an international, nonprofit organization dedicated to the twin goals of promoting the science of fire protection and improving fire protection methods. The NFPA publishes 300 or more safety standards. Some are available in print, on CD, and by Internet download.

Although the NFPA is an advisory organization, the codes, standards, and recommended practices contained in its published codes are widely used as a basis for local codes. Additional information concerning the publications of the NFPA and membership in the organization can be obtained by writing to

National Fire Protection Association
1 Batterymarch Park
PO Box 9101
Quincy, Massachusetts 02169-7471
617-770-3000
Fax: 617-770-0700
www.nfpa.org

*Source: NFPA 70-2020

National Electrical Code

The *NEC* as we know it today began in 1897 when several regional electrical codes were amalgamated. Sponsorship of the *Code* was assumed by the NFPA in 1911.

The *National Electrical Code* generally is the bible for the electrician. However, the *NEC* does not have a legal status until the appropriate authorities adopt it as a legal standard. In May 1971, the Department of Labor through OSHA adopted the *NEC* as a national consensus standard. Therefore, in the areas where OSHA safety requirements are enforced, the *NEC* is the law.

Throughout this text, references are made to chapters, articles, sections, and tables of the *National Electrical Code*. The use of the term *Section* has been removed from the *Code* for the most part. It is used extensively in this text to ensure proper identification of the *Code* references.

The student, and any other person interested in electrical construction, should obtain and use a copy of the latest edition of the *NEC*. Keep in mind the importance of determining which edition of the *NEC* is being enforced by the authority having jurisdiction (AHJ) where the work is being performed. To help the user of this text, relevant *Code* sections are paraphrased where appropriate. However, the *NEC* must be consulted before any decision related to electrical installation is made.

The *NEC* is revised and updated every three years through an open, participative, and consensus process.

Who Writes the *Code*?

The process for revising the *NEC* is very comprehensive. The process begins, continues, and ends with involvement from the public, particularly from those who use or enforce the *NEC*.

For each *Code* cycle, the NFPA solicits input from the public to make a change in the current *NEC* from anyone interested in electrical safety. Beginning with the cycle for the 2017 *NEC*, the NFPA process has gone high-tech. The public is encouraged to submit input electronically. The Code Panels work in an online-type process.

Anyone may submit a public input online by electronic means. Public inputs received are then assigned to a specific Code-Making Panel (CMP) for action. The Code-Making Panel can take one of several actions to accept or reject the public input. Often, several public inputs on the same section are combined into a single revision that then is processed under the name of the committee. Following review by the Correlating Committee, NFPA publishes a first draft of the next edition of the *NEC*. It can be viewed online at www.nfpa.org/70 under the Next Edition tab.

The next phase in the process is the comment or second revision meeting. After review of the Code-Making Panel's actions at the Public Input or First Revision meeting, individuals may send in their comments on the committees' actions using the NFPA online submission process. The CMP meets again to review and take action on the comments received. These actions are reviewed by the Correlating Committee and published online by NFPA as a second draft.

The next step in the process is the final action (voting) on first (public input) and second (public comment) revisions at the NFPA Annual Meeting.

After the Annual Meeting voting, should there be disagreement on the actions, there still is an opportunity for *Appeals* that are considered by the NFPA Standards Council, and/or *Petitions* that are considered by the NFPA Board of Directors.

After all of the final decisions are made, the *National Electrical Code* is published.

NEC ARRANGEMENT

NEC 90.3 contains important rules on the arrangement of the *NEC*. The *NEC* is divided into the introduction and nine chapters. The introduction is included in *Article 90*. This organization of the *NEC* is shown in Figure 1-9. *Chapters 1*, *2*, *3*, and *4* apply generally. These chapters include the general requirements for all installations, wiring, and protection in *Chapter 2*; wiring methods and materials in *Chapter 3*; and equipment for general use in *Chapter 4*.

Chapters 5, *6*, and *7* apply to special occupancies, special equipment, or other special conditions. These three chapters supplement or modify the general rules in *Chapters 1–7*. *Chapters 1–4* apply to

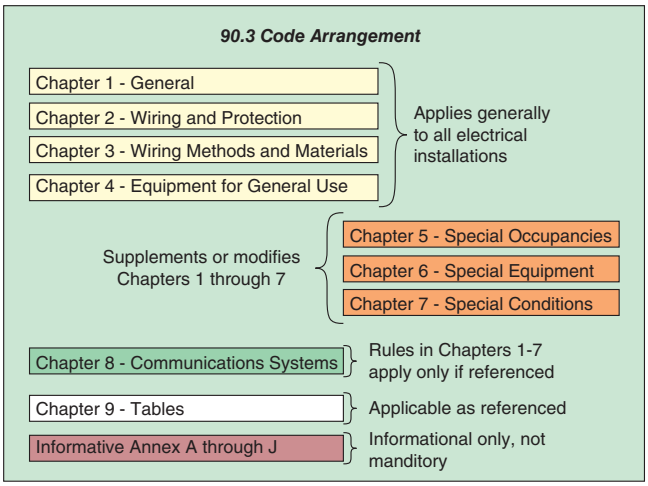


FIGURE 1-9 Organization of the *NEC*.

all of the requirements in the *NEC* unless they are amended by the rules in *Chapters 5*, *6*, or *7*.

Examples of this organization can be found in *Article 250* and *Article 680*. *Article 250* contains the general requirements for grounding and bonding of electrical systems and equipment. *Article 680* includes requirements for swimming pools, spas, and hot tubs. Many grounding and bonding rules are contained in *Article 680* and amend the rules found in *Article 250*.

The requirements in *Chapter 8* cover *Communications Systems* and are not subject to the requirements of *Chapters 1–7* unless a rule in *Chapter 8* specifically refers to a rule in *Chapters 1–7*.

Chapter 9 consists of tables that are very helpful and important in the proper application of the *NEC*.

Informative Annexes are included in the back of the *NEC* and provide valuable information but are not enforceable unless adopted by an Authority Having Jurisdiction.

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 or Informational Annex*. *Informational Notes* may make reference to other important rules or provide helpful information related to the *Code* itself. These *Informational Notes* and *Informational Annexes* are not intended to be enforceable. If more than one *Informational Note* is applicable to a *Code* rule, they are numbered sequentially.

Some articles or sections in the *NEC* include brackets at the end of the rule or figure. The information in these brackets, such as [33:6.5.1], identifies the source of the rule that is imported into the *NEC*. This is done under the NFPA extract policy. As identified in this example, the rule is extracted from *NFPA 33*, the *Standard for Spray Application Using Flammable and Combustible Materials*. This is an efficient manner in developing and maintaining electrical code requirements, as the expertise for flammable and combustible materials resides in another NFPA committee and can be imported into the *NEC*.

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 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

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	*285.23(B), (1), (2), (3), and (4)*
Exception to	Follows a rule that applies generally and applies under the conditions included in the Exception. Set in italics font.	*250.30(C) Exception or 250.86 Exception No. 3*
Informative Annex	A, B, C, D, E, F, G, H, I, J (are not part of the enforceable requirements of the *NEC* and are included for information.)	*Informative Annex A*

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.

Copies of the *NEC* are available from the NFPA, the International Association of Electrical Inspectors, and from many bookstores.

Citing *Code* References

Every time an electrician makes a decision concerning the electrical wiring, the decision should be checked by reference to the *Code*. Usually this is done from memory, without actually using the *Code* book. If there is any doubt in the electrician's mind, then 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 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*.

DEFINED TERMS

Many terms used in the *NEC* have a meaning that is particular or unique and must be carefully followed and understood for proper application of the rules. Standard dictionary terms do not apply to a term that is defined in the *NEC*. Although an exhaustive study of the rules often seems boring, the importance of understanding the meaning of the terms used in the *NEC* cannot be overstated. Terms that are used in more than one *NEC* article are included in

Article 100. As you will find, *Article 100* is divided into several parts. *Part I* includes terms used throughout the *Code*, and *Part II* includes terms that apply to installations of equipment operating at over 1000 volts. *Part III* includes terms related to Hazardous (Classified) Locations that were previously located in the related articles in *Chapter 5*.

Many articles in the *Code* have terms that are used in only that article and have a definition that is important to the proper application of requirements in the article. These terms are most often included near the beginning of the article in the XXX.2 location. For example, see *240.2*, *250.2*, *330.2*, *517.2*, and *680.2*.

We will not review all the definitions at this point but suggest that you do that on your own. The following terms are defined in *NEC Article 100* and are used throughout the *Code* as well as in this text. We will review other definitions at the location where the term is used in this text. It is important to understand the meanings of these terms.

- **Approved:** Acceptable to the authority having jurisdiction* *(AHJ)*. Note that *90.4* of the *NEC* outlines several of the duties of the AHJ. Other duties, responsibilities, and authority of the AHJ are included in *Annex H* of the *NEC*. The local law or ordinance enacting an electrical installation and inspection program states the exact applicable requirements. These laws or ordinances often include requirements for licensing of contractors, electricians, and apprentices, as well as for permits and inspections.
- **Authority Having Jurisdiction:** The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.* An extensive list of examples is included in an *Informational Note* that follows this definition in *Article 100*.
- **Equipment:** A general term including fittings, devices, appliances, luminaires, apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation.*
- **Identified (as applied to equipment):** Recognizable as suitable for the specific purpose, functions, use, environment, application, and so forth, where described in a particular *Code* requirement.*
- **Labeled:** Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.*
- **Listed:** Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with the evaluation of products or services, that maintains periodic inspection of the production of listed equipment or materials or periodic inspection 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.*

Qualified Electrical Testing Laboratories

A new *Section 110.3(C)* was added to the 2017 *NEC* that deals with electrical product testing, evaluation, and listing (product certification). The section reads:

▶ (C) Listing. Product testing, evaluation, and listing (product certification) shall be performed by recognized qualified electrical testing laboratories and shall be in accordance with applicable product standards recognized as achieving equivalent and effective safety for equipment installed to comply with this Code.

Informational Note: The Occupational Safety and Health Administration (OSHA) recognizes qualified electrical testing laboratories that perform evaluations, testing, and certification of certain products to ensure that they meet the requirements of both the construction and general industry OSHA electrical standards. If the listing (product certification) is done under a qualified electrical testing laboratory program, this listing mark signifies that the tested and certified product complies with the requirements of one or more appropriate product safety test standards.*◀

*Source: NFPA 70-2020

This section indicates that to be acceptable, electrical testing laboratories have to be both recognized and qualified. The authority having jurisdiction has the responsibility and authority to determine which testing laboratory they will accept and for which product category. Some electrical testing laboratories have very broad and comprehensive testing capabilities while others are extremely limited in capability, sometimes to a single product category.

When legal issues arise regarding electrical equipment, the courts must rely on the testing, evaluation, and product certification by qualified testing organizations. OSHA has recognized a number of organizations that meet the legal requirements found in OSHA 29 CFR 1910.7. Such an organization is referred to in the industry as a "NRTL" (pronounced "nurtle," as in *turtle*). The letters stand for *Nationally Recognized Testing Laboratory*. Visit the OSHA website at http://www.osha.gov/dts/otpca/nrtl/nrtllist.html for more details.

Many electrical inspection authorities accept the listing marks on equipment under the conditions stated in the OSHA recognition. Keep in mind that all electrical product testing laboratories are not created equal. Some can test any and all products. Others are limited by their testing equipment, facilities, or personnel. Some electrical inspection authorities have created and enforce their own electrical testing laboratory certification program.

Although there is no blanket requirement in the *NEC* that all electrical equipment used in installations must be listed and labeled to indicate conformity with a product safety standard, many electrical inspectors in fact require just that. Some inspection jurisdictions require blanket listing and labeling under authority of a local law, rule, or ordinance. Other inspectors require listing and labeling of electrical equipment as a condition of their acceptance of the installation. This authority is endorsed in *NEC 110.2*, which states, Approval. The conductors and equipment required or permitted by this Code shall be acceptable only if approved.* The word *approved* is defined in *Article 100* as Acceptable to the authority having jurisdiction.* So, the rule in *110.2* can be read with substitution of the definition of *approved* as, "The conductors and equipment required or permitted by this *Code* shall be acceptable only if acceptable to the authority having jurisdiction."

Other important terms or rules that are related are *90.4*, *90.7*, *110.3*: *Identified*, *Labeled*, and *Listed*.

Most electrical testing laboratories provide field evaluations and labeling for products that have been installed without a listing mark on the product. Some of these products have been produced in a foreign country without testing laboratory evaluation at the factory. Others are one-of-a-kind products, are unique in one or more features, or are complex and were produced at the factory without evaluation by a third-party testing laboratory. A definition of *Field Evaluation Body* and *Field Labeled (as applied to evaluated products)* have been added to *Article 100* of the *NEC*.

UL (Underwriters Laboratories)

UL (Underwriters Laboratories), founded in 1894, is a highly qualified, nationally recognized testing laboratory with numerous testing laboratories in the United States and service locations in numerous other countries. UL develops product safety standards and performs tests to these standards. Most reputable manufacturers of electrical equipment submit representative samples of their products to UL, where the equipment is subjected to numerous tests. These tests determine whether the product can perform safely under normal and abnormal conditions to meet published standards. After UL tests and evaluates product samples, and determines that the product samples comply with the specific standard, the manufacturer is then permitted to *label* its product with the *UL Mark* (Figure 1-10). The products are then *listed* in UL's Online Certifications Directory.

The UL Mark. The UL Mark is required to be on the product! The UL Listing Mark almost always consists of four elements—UL in a circle, the word "LISTED" in capital letters, the product identity, and a unique alphanumeric control, issue or file number. If the product is too small, or has a shape or is made of a material that will not accept the UL Mark on the product itself, the marking is permitted on the smallest

*Source: NFPA 70-2020

FIGURE 1-10 UL Listing mark indicates product compliance with Canadian and USA product standards.

UL® Listed is a registered trademark of UL LLC. Reprinted with permission.

unit carton or container that the product comes in. Marking on the carton or box is nice but does not ensure that the product is UL listed! For additional information on the listing marks of Underwriters Laboratories, see the information at www.ul.com.

The listing mark shown in Figure 1-10 indicates the product is in compliance with the applicable product safety standards in the United States and in Canada. A listing mark with only UL in a circle indicates the product has been evaluated only to US standards.

When UL tests and certifies products that comply only to the requirements of a particular Canadian standard, the UL mark shown in Figure 1-10 appears with a "C" outside of and to the left of the circle. This means the product has been tested and certified for compliance *only* with Canadian requirements. Product standards are being harmonized in North America as a result of the North American Free Trade Act (NAFTA). Discussions are also going on with Mexico. When all of this is finalized, electrical equipment standards may be the same in the United States, Canada, and Mexico.

Additional efforts are being made to harmonize North American standards with those of Europe.

The Enhanced UL Certification Mark

UL has begun a transition to an enhanced product certification mark, as illustrated by the example in Figure 1-11.

The basic enhanced UL Certification Mark consists of the familiar UL in a circle and the word "Certified." A module directly adjacent to the basic enhanced certification mark will include an attribute describing the scope of certification, such as

FIGURE 1-11 Example of new UL Enhanced Product Certification Mark.

UL® Certified is a registered trademark of UL LLC. Reprinted with permission.

"Safety." Additionally, country codes such as "US" for the United States or "CA" for Canada may also appear in the mark to identify the geographic scope of a certification. The last element of the enhanced mark is a unique identifier, which is often a UL file number. This unique identifier can be used to access more information on UL's Online Certifications Directory at www.ul.com/database. An optional QR code can also be used with the enhanced Certification Mark.

The UL Enhanced Certification Mark may be used in lieu of the UL Listing or Classification Mark on products. For more information on UL's enhanced Certification Mark, go to www.ul.com/markshub.

SAFETY ALERT

Counterfeit electrical products may present a significant safety hazard as there is no assurance the construction complies with a safety standard.

Counterfeit Products. Be on the lookout for counterfeit electrical products. These products have not been tested and certified by a recognized testing laboratory. They can present a real hazard to life and property. Counterfeit products continue to come from China as well as many other countries. Counterfeit electrical products might also be referred to as "black market products."

Look for unusual logos or wording. For example, the UL mark might be illustrated in an oval instead of a circle, or the UL mark might not be encircled with anything, or the wording might say *approved* instead of LISTED. UL doesn't approve anything! It tests representative samples of the product. If samples of the product meet UL standards, the manufacturer is then permitted to apply the appropriate product listing or certified mark (label).

Federal legislation was passed by Congress and is now law that makes it a criminal offense to traffic in counterfeit products and counterfeit trademarks. The law makes it mandatory that the counterfeit products and any tools that make the products or markings be seized and destroyed.

To learn more about counterfeits, check out http://www.ul.com, then search on (type in) the word "counterfeit." Also, check out http://www.nema.org, then type in the word "counterfeit."

Recognized Components. Do not confuse a UL marking in a circle with the markings found on *recognized components*. Recognized components that have passed certain tests are marked with the letters "RU" printed in mirror image (Figure 1-12). By themselves, recognized components are not to be field-installed. They are intended for use in end-use products or systems that would ultimately be tested and certified, with the final assembly becoming a UL-listed product. Some examples of recognized components are relays, ballasts, insulating materials, special switches, and so on.

UL previously produced several directories including: *Electrical Construction Equipment Directory (Green Book)* and the *Electrical Appliance and Utilization Equipment Directory (Orange Book)*. The information previously provided in these directories is now in UL's Online Certifications Directory located at www.ul.com/database as well as UL Product iQ www.ul.com/apps/product-iq.

FIGURE 1-12 The *recognized components* mark.

RU® is a registered trademark of UL LLC. Reprinted with permission.

Many times the answer to a product-related question that cannot be found in the *NEC* can be found in the UL Online *Product iQ* database.

UL provides several electric equipment or product marking guides. These marking guides provide very valuable information in an easy-to-read format. Several tables are provided. The marking guides include:

- Dead-Front Switchboards
- Electrical Heating and Cooling Equipment
- Luminaires
- Molded Case Circuit Breakers
- Panelboards
- Swimming Pool Equipment, Spas, Fountains, and Hydromassage Bathtubs
- Wire and Cable
- Alternative Energy Power Equipment and Systems Application Guide
- Lightning Protection Application Guide
- Green Construction Application Guide

Canadian Standards Association (CSA Group)

In ways, the CSA Group is the Canadian counterpart of Underwriters Laboratories, Inc., in the United States. CSA Group develops the *Canadian Electrical Code (CEC)* and of the Canadian Standards for the testing, evaluation, and listing of electrical equipment in Canada. The *Canadian Electrical Code* is quite different from the *NEC*. A Canadian version of *Electrical Wiring—Residential* is available in Canada.

The *Canadian Electrical Code* is significantly different from the *National Electrical Code*. It is considered *Part I* of the *Canadian Electrical Code*. *Part II* of the *Canadian Electrical Code* consists of electrical product safety standards similar to the standards produced in the United States by Underwriters Laboratories. Canadian product safety standards are produced by the Canadian Standards Association (CSA Group). In fact, many of the Canadian and U.S. standards have been harmonized. This allows a product to be evaluated and listed to the same requirements in both countries. Efforts are continuing to harmonize U.S. and Canadian standards with those from Mexico.

CSA Group also serves as a third-party independent electrical product testing laboratory. Manufacturers are permitted to use a listing mark to identify products that have been found by examination and testing to comply with the *Canadian Electrical Code*, *Part II*.

Those using this text in Canada must follow the *Canadian Electrical Code*. *Electrical Wiring—Commercial* (© Thomas Nelson Holdings) is available based on the *Canadian Electrical Code*.

The *Canadian Electrical Code* is a voluntary code suitable for adoption and enforcement by electrical inspection authorities. *The Canadian Electrical Code* is published by and available from

CSA Group
178 Rexdale Boulevard
Toronto, Ontario, Canada
M9W 1R3
416-747-4000
Fax: 416-747-4149
http://www.csagroup.org

Intertek

Intertek is a nationally recognized testing laboratory. Its Product division provides testing, evaluation, labeling, listing, and follow-up service for the safety testing of electrical products. This is done in conformance to nationally recognized safety standards.

The Intertek ETL listing mark, like the UL and CSA Group listing marks, indicates which nation's product safety standards the equipment has been found to be in compliance with. See Figure 1-13.

FIGURE 1-13 Listing mark for Intertek for electrical products.

Courtesy Intertek.

Intertek
3933 US Route 11
Cortland, NY 13045
Phone: 800-345-3851
http://www.intertek.com

National Electrical Manufacturers Association (NEMA)

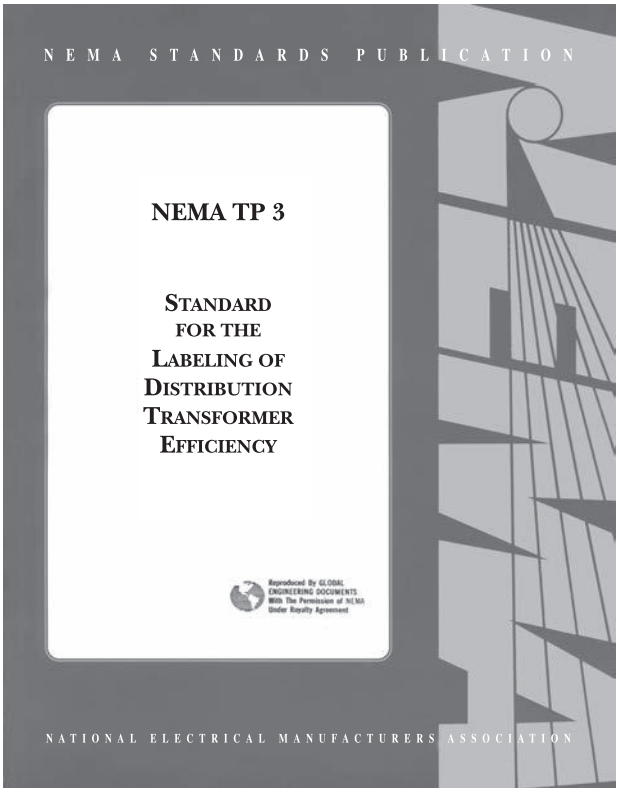
NEMA is a nonprofit organization supported by the manufacturers of electrical equipment and supplies. NEMA develops standards that are designed to assist the purchaser in selecting and obtaining the correct product for specific applications. A typical standard is illustrated in Figure 1-14. Information concerning NEMA standards may be obtained by writing to

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1752
Rosslyn, VA 22209
703-841-3200
Fax: 703-841-5900
http://www.nema.org

Free Standards: NEMA offers a number of its standards at no cost. These free standards are available for downloading. Check out the website.

American National Standards Institute (ANSI)

Various working groups in the organization study the numerous codes and standards. An American National Standard implies "a consensus of those concerned with its scope and provisions."



Courtesy of National Electrical Manufacturers Association.

FIGURE 1-14 A typical NEMA standard.

The *National Electrical Code* is approved by ANSI and is numbered ANSI/NFPA 70-1999.

ANSI (Operations)
25 West 43rd Street, 4th Floor
New York, NY 10036
212-642-4900
Fax: 212-398-0023
http://www.ansi.org

International Association of Electrical Inspectors (IAEI)

IAEI is a nonprofit organization whose membership consists of electrical inspectors, electricians, contractors, testing laboratories, electric utilities, and manufacturers throughout the United States and Canada. One goal of the IAEI is to improve the understanding of the *NEC*. Representatives of this organization serve as members of the various panels of the *NEC* Committee and share equally with other members in the task of reviewing and revising the *NEC*. The IAEI publishes a bimonthly magazine, the *IAEI News*. Additional information concerning the organization may be obtained by writing to

International Association of Electrical Inspectors
901 Waterfall Way, Suite 602
Richardson, TX 75080-7702
800-786-4234, 972-235-1455
Fax: 972-235-6858
http://www.iaei.org

Illuminating Engineering Society of North America (IESNA)

IESNA was formed in 1906. The objective of this group is to communicate information about all facets of good lighting practice to its members and to consumers. The IESNA produces numerous publications that are concerned with illumination.

The *IESNA Lighting Handbooks* are regarded as the standard for the illumination industry and contain essential information about light, lighting, and luminaires. Information about publications or membership may be obtained by writing to

Illuminating Engineering Society of North America
120 Wall St., 17th Floor
New York, NY 10005-4001
212-248-5000
Fax: 212-248-5000
http://www.iesna.org

American Society of Heating, Refrigerating, and Air-Conditioning (ASHRAE)

ASHRAE was formed in 1894. ASHRAE states it is an international organization of some 51,000 persons and fulfills its mission of advancing heating, ventilation, air conditioning, and refrigeration to serve humanity and promote a sustainable world through research, standards writing, publishing, and continued education.

What has become increasingly important to ASHRAE and every other organization is energy conservation—all are concerned about "Green" technology. ASHRAE has a number of publications relating to energy conservation, for example, their *Standard 189.1* and *Standard 189.1P* with emphasis on the design of high performance "Green" buildings. ASHRAE standards even cover illuminance (lighting) calculations, which are identical to the illuminance calculations recommended by the Illuminating Engineers Society of North America (IESNA).

The *ASHRAE Handbook* is considered the bible of the industry, as the *National Electrical Code* is to the electrical industry.

Those of us in the electrical arena are aware of the importance of promoting energy conservation through the use of energy efficient ballasts, low-wattage fluorescent lamps (T8 instead of T12), less use of conventional incandescent lamps, increased use of compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs), along with lower current ratings for air-conditioning equipment.

Visiting their website, www.ashrae.org, will reveal a tremendous amount of technical information available to members of their organization. They have many publications, standards, and conduct on-line courses relating to energy conservation and sustainability.

Information may be obtained by contacting

ASHRAE
1791 Tullie Circle, N.E.
Atlanta, GA 30329
(404) 636-8400
Fax: (404) 321-5478

National Electrical Installation Standards (NEIS)

The *NEC* in *110.12* states that Electrical equipment shall be installed in a neat and workmanlike manner.* Just what does that mean?

It means that unused openings shall be closed and that Internal parts of electrical equipment, including busbars, wiring terminals, insulators, and other surfaces, shall not be damaged or contaminated by foreign materials such as paint, plaster, cleaners, abrasives, or corrosive residues. There shall be no damaged parts that may adversely affect safe operation or mechanical strength of the equipment such as parts that are broken; bent; cut; or deteriorated by corrosion, chemical action, or overheating.*

To help the electrical industry understand what is required by *110.12*, the National Electrical Contractors Association (NECA) has been developing installation standards.

NEIS, an ongoing project of NECA, covers installation standards for the electrical trade. These installation standards are not about the *NEC*, but rather cover those issues not covered in the *NEC*, such as housekeeping; how to properly handle, receive, and store electrical equipment; checking

*Source: NFPA 70-2020

out the equipment before energizing; and so on. These are actual on-the-job issues that are not necessarily *Code*-related, but issues electricians need to know. In the past, this was hands-on, on-the-job training. Now, there are installation standards that can be followed by everyone in the electrical industry. These installation standards are also recognized by ANSI.

Installation Standards. At the moment, installation standards are available on the following subjects:

- *NECA 1, Good Workmanship in Electrical Contracting*
- *NECA 90, Commissioning Electrical Systems*
- *NECA 100, Symbols for Electrical Construction Drawings*
- *NECA 101, Steel Conduits*
- *NECA 102, Aluminum Rigid Metal Conduit*
- *NECA 104, Aluminum Wire and Cable*
- *NECA 105, Metal Cable Tray Systems*
- *NECA 111, Nonmetallic Raceways*
- *NECA 120, Armored Cable (AC) and Metal Clad Cable (MC)*
- *NECA 121, Installing Type NM and Type UF Cables*
- *NECA 130, Installing and Maintaining Wiring Devices*
- *NECA 169, Installing and Maintaining Arc-Fault Circuit Interrupters*
- *NECA 200, Temporary Power at Construction Sites*
- *NECA 202, Industrial Heat Tracing Systems*
- *NECA 230, Electric Motors and Controllers*
- *NECA 301, Installing and Testing Fiber Optic Cables*
- *NECA 303, Closed-Circuit Television (CCTV) Systems*
- *NECA 305, Fire Alarm System Job Practices*
- *NECA 331, Building and Service Entrance Grounding and Bonding*
- *NECA 400, Installing and Maintaining Switchboards*
- *NECA 402, Installing and Maintaining Motor Control Centers*
- *NECA 404, Installing Generator Sets*
- *NECA 405, Installing and Commissioning Interconnected Generation Systems*
- *NECA 406, Residential Generator Sets*
- *NECA 407, Installing and Maintaining Panelboards*
- *NECA 408, Installing and Maintaining Busways*
- *NECA 409, Installing and Maintaining Dry-Type Transformers*
- *NECA 410, Installing & Maintaining Liquid-Filled Transformers*
- *NECA 411, Installing and Maintaining Uninterruptible Power Supplies (UPS)*
- *NECA 413, Installing and Maintaining Electric Vehicle Supply Equipment*
- *NECA 420, Standard for Fuse Applications*
- *NECA 430, Installing Medium-Voltage Metal-Clad Switchgear*
- *NECA 500, Installing Indoor Lighting Systems*
- *NECA 501, Installing Exterior Lighting Systems*
- *NECA 502, Installing Industrial Lighting Systems*
- *NECA 503, Installing Fiber Optic Lighting Systems*
- *NECA 505, Installing and Maintaining High Mast, Roadway and Area Lighting*
- *NECA 568, Installing Building Telecommunications Cabling*
- *NECA 600, Installing Medium-Voltage Cable*
- *NECA 605, Installing Underground Nonmetallic Utility Duct*
- *NECA 607, Telecommunications Bonding and Grounding Planning and Installation for Commercial Buildings*
- *NECA 700, Installing Overcurrent Protection for Selective Coordination*

- *NECA 701, Energy Management, Demand Response and Energy Solutions*

Check price and availability by contacting

National Electrical Contractors Association
3 Bethesda Metro Center, Suite 1100
Bethesda, MD 20814
301-657-3110
Fax: 301-215-4500
http://www.necanet.org

Registered Professional Engineer (PE)

Although the requirements may vary slightly from state to state, the general statement can be made that a registered professional engineer has demonstrated his or her competence by graduating from college and passing a difficult licensing examination. Following the successful completion of the examination, the engineer is authorized to practice engineering under the laws of the state. A requirement is usually made that a registered professional engineer must supervise the design of any building that is to be used by the public. The engineer must indicate approval of the design by affixing a seal to the plans.

Information concerning the procedure for becoming a registered professional engineer and a definition of the duties of the professional engineer can be obtained by writing the state government department that supervises licensing and registration.

ABANDONED CABLES

Abandoned cables might not be the cause of starting a fire, but they certainly are fuel for a fire.

Often overlooked when bidding and working on commercial and industrial installations is being confronted with a lot of existing unused conductors and cables. The specifications may not be clear on this issue. The electrical inspector will probably take a strong position on abandoned wiring. There are many places in the *NEC* that require the removal of abandoned conductors and cables. Here is the list:

- *372.58*: Cellular concrete floor raceways
- *374.58*: Cellular metal floor raceways
- *390. 57*: Underfloor raceways
- *640.6(B)*: Audio signal processing, amplification, and reproduction equipment
- *645.5(G)*: Information technology cables
- *650.7*: Pipe organs
- *725.25*: Class 1, 2, and 3 remote-control, signaling, and power-limited circuits
- *760.25*: Fire alarm cables
- *770.25*: Optical fiber cables
- *800.25*: Communications cables
- *840.25*: Premises-powered broadband communications systems

METRICS (SI) AND THE *NEC*

The United States is the last major country in the world not using the metric system as the primary system for weights and measurements. We have been very comfortable using English (United States Customary) values, but this is changing. Manufacturers are now showing both inch-pound and metric dimensions in their catalogs. Plans and specifications for governmental new construction and renovation projects started after January 1, 1994, have been using the metric system. You may not feel comfortable with metrics, but metrics are here to stay. You might just as well get familiar with the metric system.

Some common measurements of length in the English (Customary) system are shown with their metric (SI) equivalents in Table 1-3.

The *NEC* and other *NFPA Standards* are becoming international standards. All measurements beginning with the 2011 *NEC* are shown with metrics first, followed by the inch-pound value in parentheses. For example, 600 mm (24 in.).

In *Electrical Wiring—Commercial*, ease in understanding is of utmost importance. Therefore, inch-pound values are shown first, followed by metric values in parentheses. For example, 24 in. (600 mm).

Units of measurement are covered in *90.9* of the *NEC*. It permits both soft and hard conversion from the inch-pound system to or from the SI units of measurement. The accuracy of the conversion is just the opposite from what it might appear. Soft

TABLE 1-3

Customary and metric comparisons.

CUSTOMARY	HARD CONVERSION	SOFT CONVERSION
0.25 in.	6 mm	6.35 mm
0.5 in.	12.7 mm	12.7 mm
0.62 in.	15.87 mm	15.875 mm
1.0 in.	25 mm	25.4 mm
1.25 in.	32 mm	31.75 mm
2 in.	50 mm	50.8 mm
3 in.	75 mm	76.2 mm
4 in.	100 mm	101.6 mm
6 in.	150 mm	152.4 mm
8 in.	200 mm	203.2 mm
9 in.	225 mm	228.6 mm
1 ft	300 mm	304.8 mm
1.5 ft	450 mm	457.2 mm
2 ft	600 mm	609.6 mm
2.5 ft	750 mm	762 mm
3 ft	900 mm	914.4 mm
4 ft	1.2 m	1.2192 m
5 ft	1.5 m	1.524 m
6 ft	1.8 m	1.8288 m
6.5 ft	2.0 m	1.9182 m
8 ft	2.5 m	2.4384 m
9 ft	2.7 m	2.7432 m
10 ft	3.0 m	3.048 m
12 ft	3.7 m	3.6576 m
15 ft	4.5 m	4.572 m
18 ft	5.5 m	5.4864 m
20 ft	6.0 m	6.096 m
22 ft	6.7 m	6.7056 m
25 ft	7.5 m	7.62 m
30 ft	9.0 m	9.144 m
35 ft	11.0 m	10.668 m
40 ft	12.0 m	12.192 m
50 ft	15.0 m	15.24 m
75 ft	23.0 m	22.86 m
100 ft	30.0 m	30.48 m

conversion is more precise than hard conversion; it is fairly easy to determine which dimension is a soft conversion and which has a hard conversion. Typically, soft conversion will result in two or more digits to the right of the decimal point.

A *soft metric conversion* is when the dimensions of a product already designed and manufactured to the inch-pound system have their dimensions converted to metric dimensions. The product does not change in size. Soft conversions are more precise than hard conversions.

A *hard metric measurement* is where a product has been designed to SI metric dimensions. No conversion from inch-pound measurement units is involved. A *hard conversion* is where an existing product is redesigned into a new size.

In the 2020 edition of the *NEC*, existing inch-pound dimensions did not change. Metric conversions were made, then rounded off. Please note that when comparing calculations made by both English and metric systems, slight differences will occur due to the conversion method used. These differences are not significant, and calculations for both systems are therefore valid. Where rounding off would create a safety hazard, the metric conversions are mathematically identical (a soft conversion).

For example, if a dimension is required to be 6 ft, it is shown in the *NEC* as 6 ft (1.8 m). Note that the 6 ft remains the same, and the metric value of 1.83 m has been rounded off to 1.8 m. This edition of *Electrical Wiring—Commercial* reflects these rounded-off changes. In this text, the inch-pound measurement is shown first, in other words, 6 ft (1.8 m).

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. 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 1-4.

You can readily see that the cross-sectional areas, critical when determining conductor fill, are different. 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. Trade practices shall be followed in all cases.* This edition of *Electrical*

*Source: NFPA 70-2020

TABLE 1-4

Trade sizes of raceways versus 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.

Wiring—Commercial uses the term *trade size* when referring to conduits, raceways, and tubing. For example, instead of referring to a ½ in. electrical metallic tubing (EMT), it is referred to as trade size ½ EMT. EMT is also referred to in the trade as "thinwall."

The *NEC* also uses the term *metric designator.* A ½ in. EMT is shown as *metric designator 16 (trade size ½)*. A 1 in. EMT is shown as *metric designator 27 (trade size 1)*. The numbers 16 and 27 are the *metric designator* values. The (½) and (1) are the *trade sizes*. The metric designator is based on the inside diameter of Rigid Metal Conduit—in rounded-off millimeters (mm). Table 1-5 shows some of the more common sizes of conduit, raceways, and tubing. A complete table is found in the *NEC, Table 300.1(C)*. Because of possible confusion, this text uses only the term *trade size* when referring to conduit and raceway sizes.

TABLE 1-5

Metric designators for raceways through trade size 3.

METRIC DESIGNATOR	TRADE SIZE
12	⅜
16	½
21	¾
27	1
35	1¼
41	1½
53	2
63	2½
78	3

TABLE 1-6

Trade size of a knockout compared to the actual measurement of the knockout.

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 1-6 shows trade size knockouts and their actual measurements.

A word unique to the electrical industry is *device*. The *NEC* defines a device as A unit of an electrical system, other than a conductor, that carries or controls electric energy as its principal function.* You will see this word often throughout this text.

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

Table 1-7 provides the detailed dimensions of some typical sizes of outlet and device boxes in both metric and English units.

In this text, a square outlet box is referred to as 4 × 4 × 1½ inch square box, 4" × 4" × 1½" square box, or trade size 4 × 4 × 1½ inch square box. Similarly, a single-gang device box might be referred to as a 3 × 2 × 3-inch device box, a 3" × 2" × 3"-deep device box, or a trade size 3 × 2 × 3 device box. The box type should always follow the trade size numbers.

Trade sizes for construction material will not change. A 2 × 4 is really a *name*, not an actual dimension. A 2 × 4 stud will still be referred to as a 2 × 4 stud though its actual dimension is approximately 1½ × 3½ in. This is its *trade size*.

In this text, 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.

*Source: NFPA 70-2020

TABLE 1-7

Box dimensions.

BOX DIMENSIONS		BOX TYPE	MINIMUM CAPACITY	
mm	in.		cm^3	$in.^3$
100 × 32	4 × 1¼	round/octagonal	205	12.5
100 × 38	4 × 1½	round/octagonal	254	15.5
100 × 54	4 × 2⅛	round/octagonal	353	21.5
100 × 32	4 × 1¼	square	295	18.0
100 × 38	4 × 1½	square	344	21.0
100 × 54	4 × 2⅛	square	497	30.3
75 × 50 × 38	3 × 2 × 1½	device	123	7.5
75 × 50 × 50	3 × 2 × 2	device	164	10.0
75 × 50 × 57	3 × 2 × 2¼	device	172	10.5

See *NEC Table 314.16(A)* for complete listing.

This is particularly true for the examples of raceway calculations, box fill calculations, and load calculations for square foot areas, and on the plans (drawings). To show both English and metric measurements on a plan would certainly be confusing and would really clutter up the plans, making them difficult to read.

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, but 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 *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 *Annex D* of the *NEC* use inch-pound units, not metrics.

Guide to Metric Usage

The metric system is a base-10, or decimal, system in that values can be easily multiplied or divided by ten or powers of ten. 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 United States, it is the practice to use a period as the decimal marker and a comma to separate a string of numbers into groups of three for easier reading. In many countries, the comma has been used in lieu of the decimal marker and spaces are left to separate a string of numbers into groups of three. The SI system, taking something from both, uses the period as the decimal marker and the space to separate a string of numbers into groups of three, starting from the decimal point and counting in either direction. For example, 12 345.789 99. An exception to this is when there are four numbers on either side of the decimal point. In this case, the third and fourth numbers from the decimal point are not separated. For example, *2015.1415*.

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