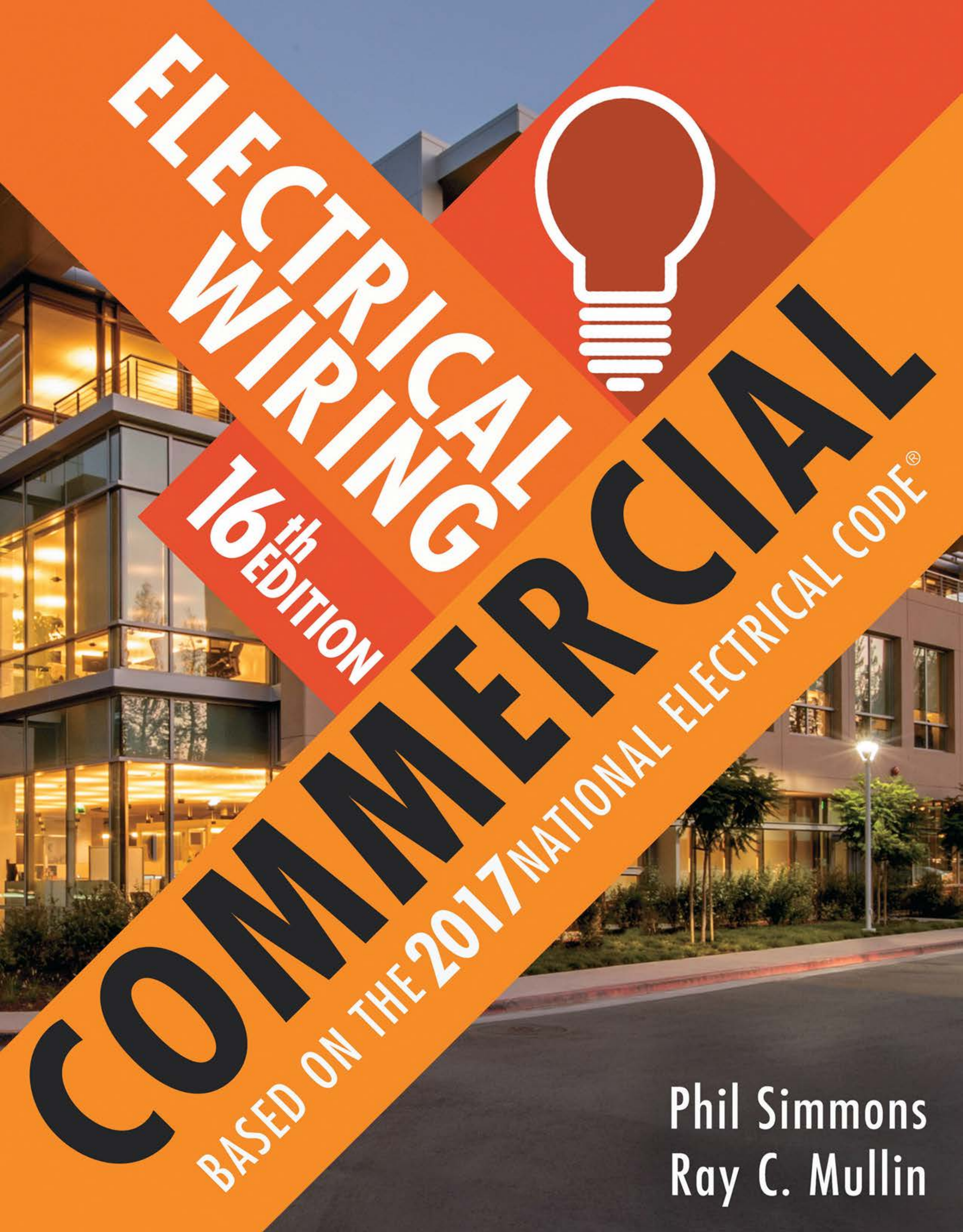

ELECTRICAL WIRING

COMMERCIAL

16th EDITION

BASED ON THE 2017 NATIONAL ELECTRICAL CODE®

Phil Simmons
Ray C. Mullin

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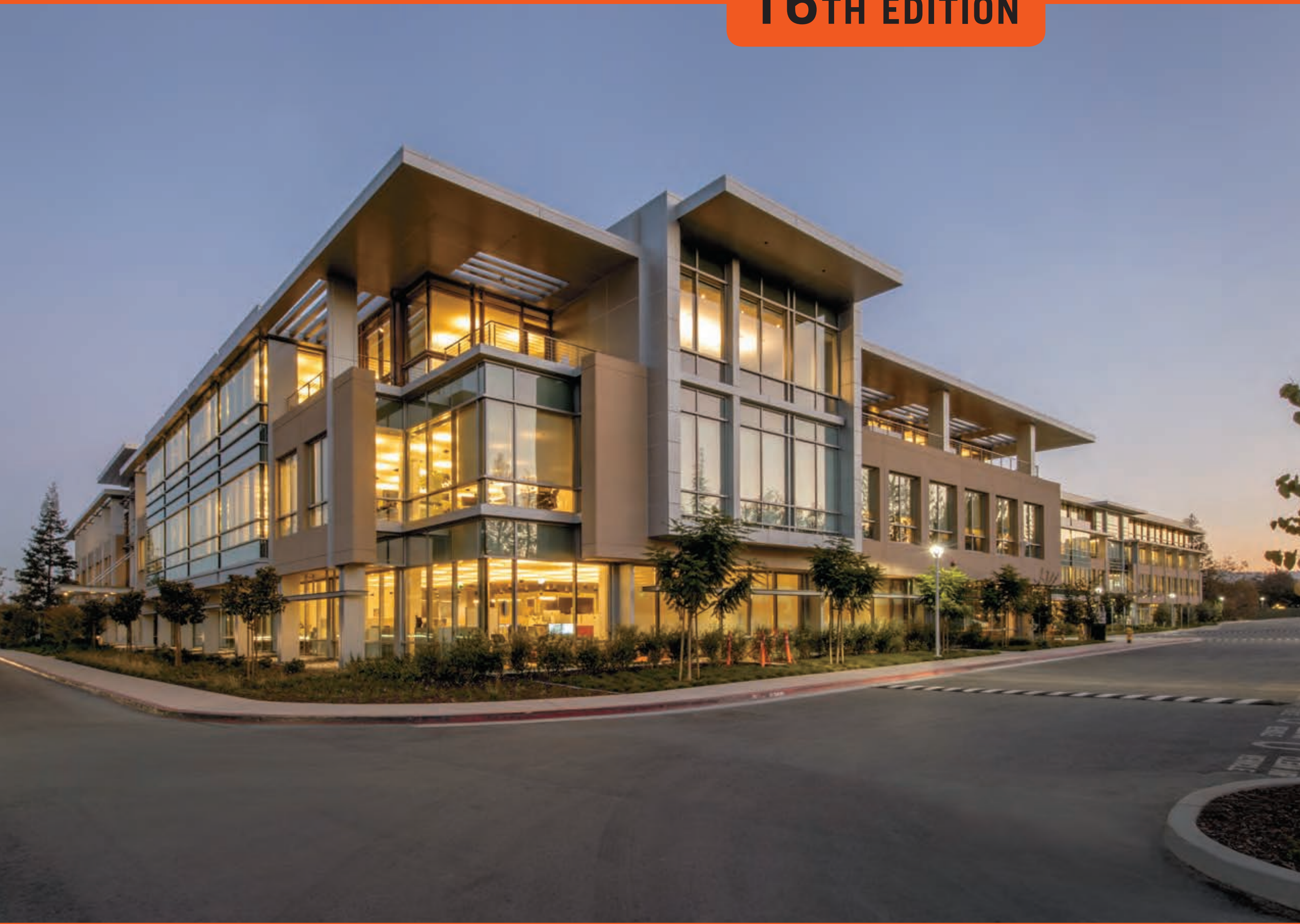

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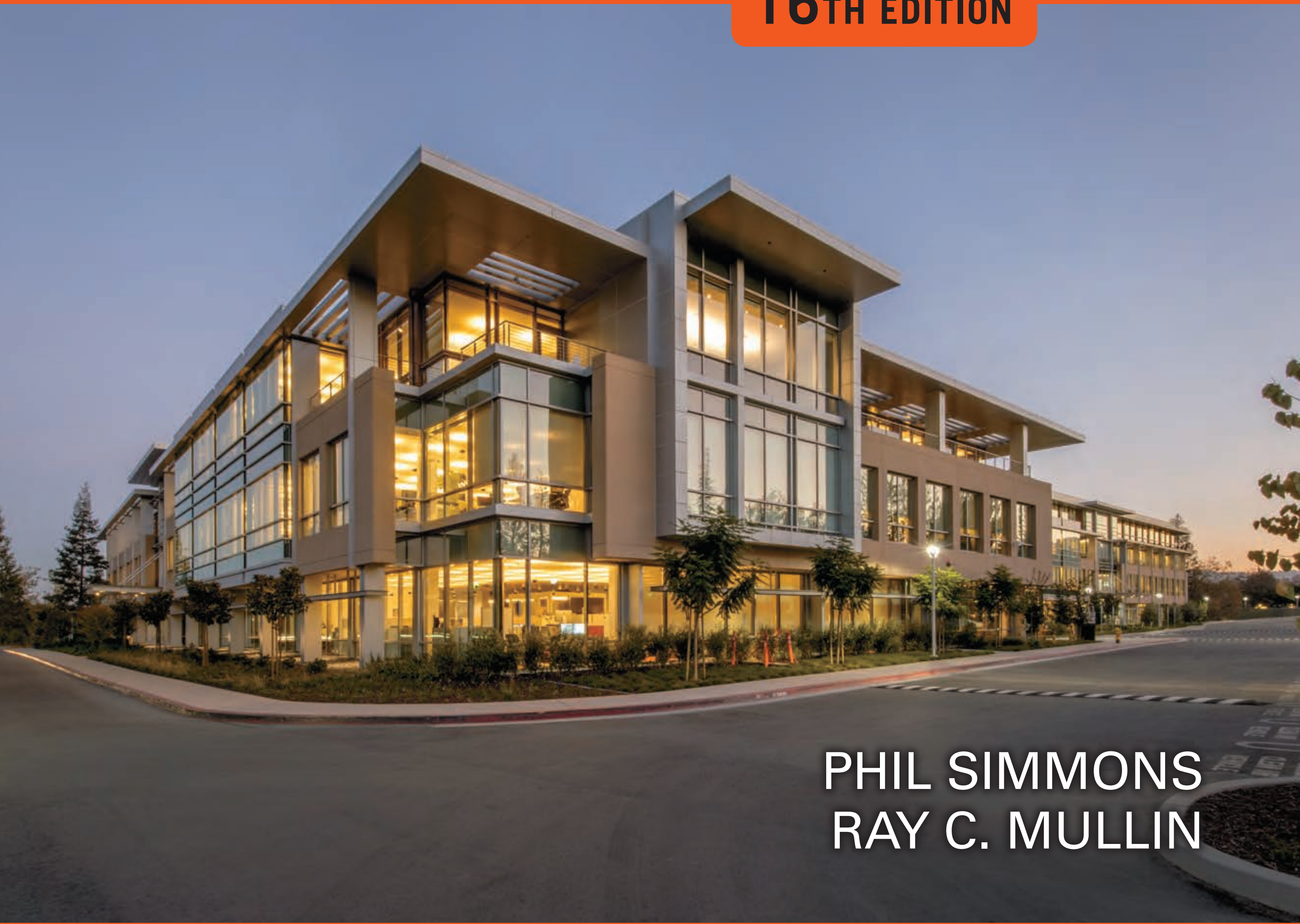

PHIL SIMMONS
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Preface

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 sixteenth edition of *Electrical Wiring—Commercial* is based on the 2017 *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 in the back of 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 2014 and 2017 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 sixteenth edition of *Electrical Wiring—Commercial* is the result of comparing each and every past *Code* reference with the 2017 *NEC*. As always, the authors review 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 "Readily Accessible" and "Structure" were revised.
- *110.14(D)*: The use of a calibrated torque measuring device is required for tightening wire terminals.
- *210.8*: Direction is provided for measuring the distance from a sink for GFCI protection.
- *210.8(B)(9)*: GFCI protection required in nondwelling crawl spaces.

- *210.71*: Receptacle requirements added for meeting rooms.
- *225.27*: Sealing requirements for raceways that enter a building.
- *250.66(A), (B), and (C)*: clarification of connection to grounding electrodes.
- *250.122(F)*: Rules for equipment grounding conductors in parallel significantly revised.
- *310.15(B)(3)(c)*: derating for raceways on rooftops significantly revised.
- *314.15*: sizing of weep holes revised.
- *406.15*: rules on dimmer-controlled receptacles removed.
- *440.9*: equipment grounding conductor required in some raceways installed on rooftops for HVAC equipment.
- *445.20*: requirements for receptacles on portable receptacles revised.
- Extensive changes were made to *Article 690* for photovoltaic systems. The chapter in this text was revised to update these requirements.
- Revisions were made to the branch circuit tables and load calculation tables for consistency.
- 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 2017 *NEC*. Changes between the 2014 and 2017 editions of the *NEC* are marked with these symbols: ▶◀

Supplement Package

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

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- An **Image Gallery** that offers a database of hundreds of images in the text. These can easily be imported into the PowerPoint® presentation.
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- *Measure Skills and Outcomes*: Analytics and reports provide a snapshot of class progress, time on task, engagement, and completion rates.

About the Authors

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

Mr. Mullin is a former electrical circuit instructor for the Electrical Trades, Wisconsin Schools of Vocational, Technical and Adult Education. A former member of the International Brotherhood of Electrical Workers, Mr. Mullin is presently an honorary member of the International Association of Electrical Inspectors, an honorary member of the Institute of Electrical and Electronic Engineers, and an honorary member of the National Fire Protection Association, Electrical Section. He served on Code Making Panel 4 for the *National Electrical Code*, NFPA-70 for the National Fire Protection Association.

Mr. Mullin completed his apprenticeship training and has worked as a journeyman and supervisor. He has taught both day and night electrical apprentice and journeyman courses and has conducted engineering seminars. Mr. Mullin has contributed to and assisted other authors in their writing of texts and articles relating to overcurrent protection and conductor withstand ratings. He has had many articles relating to overcurrent protection published in various trade magazines.

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

He served on the Executive Board of the Western Section, International Association of Electrical Inspectors. He also served on their National Electrical Code Committee and on their Code Clearing Committee. He is past chairman of the Electrical Commission in his hometown.

Mr. Mullin has conducted many technical Code workshops and seminars at state chapter and section meetings of the International Association of Electrical Inspectors and served on their Code panels.

Mr. Mullin is past Director, Technical Liaison, and Code Coordinator for a large electrical manufacturer and contributed to their technical publications.

Phil Simmons is self-employed as Simmons Electrical Services. Services provided include consulting on the *National Electrical Code* and other Codes, writing, editing, illustrating, and producing technical publications and inspection of complex electrical installations. He develops training programs related to electrical codes and safety and has been a presenter on these subjects at numerous seminars and conferences for Universities, the NFPA, IAEI, Department of Defense, and private clients. Phil also 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 co-author and illustrator of *Electrical Wiring—Residential* (17th through this edition) and *Electrical Wiring—Commercial* (14th through this edition) and author and illustrator of *Electrical Grounding and Bonding*, all 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) on *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. He is also a licensed journeyman electrician in Montana. Phil passed the certification examinations for Electrical Inspector General, Electrical Plan Review, and Electrical Inspector One- and Two-Family.

He previously served as Chief Electrical Inspector for the State of Washington from 1984 to 1990 as well as an Electrical Inspector Supervisor, Electrical Plans Examiner and field Electrical Inspector. While employed with the State, Phil performed plan review and inspection of health care facilities including hospitals, nursing homes, and boarding homes.

Phil served the 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.

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We would also like to thank Vince Saporita for his detailed review of the overcurrent protection subject matter in Chapters 17, 18, and 19.

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.

CHAPTER 1

Commercial Building Plans and Specifications

OBJECTIVES

After studying this chapter, you should be able to

- understand how the *NEC* is organized and how the articles relate.
- understand the process for updating the *NEC*.
- understand 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 2017 edition of the *NEC* from the previous 2014 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 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 so fast that it is difficult to react quickly enough to get

*Source: NFPA 70-2017

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-2015

*Source: NFPA 70-2017

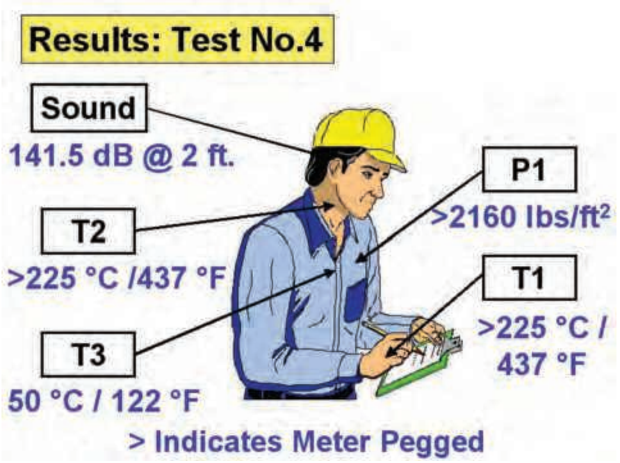
Arc Flash and Arc Blast

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 310.15(B)(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. Check out the Bussmann FC2 app for smartphones. It is advertised to easily calculate single and three-phase fault current and to produce one-line diagrams and calculation labels. Look for it at your smartphone app store.

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.

Although not required for dwelling units, *NEC 110.16* specifies that, Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that are in other than dwelling units, and are likely to require examination, adjustment, servicing, or maintenance while energized, shall be field or factory marked to warn qualified persons of potential electric arc flash hazards. The marking shall meet the requirements in 110.21(B) and shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.*

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 70-2017

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 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 hertz.

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