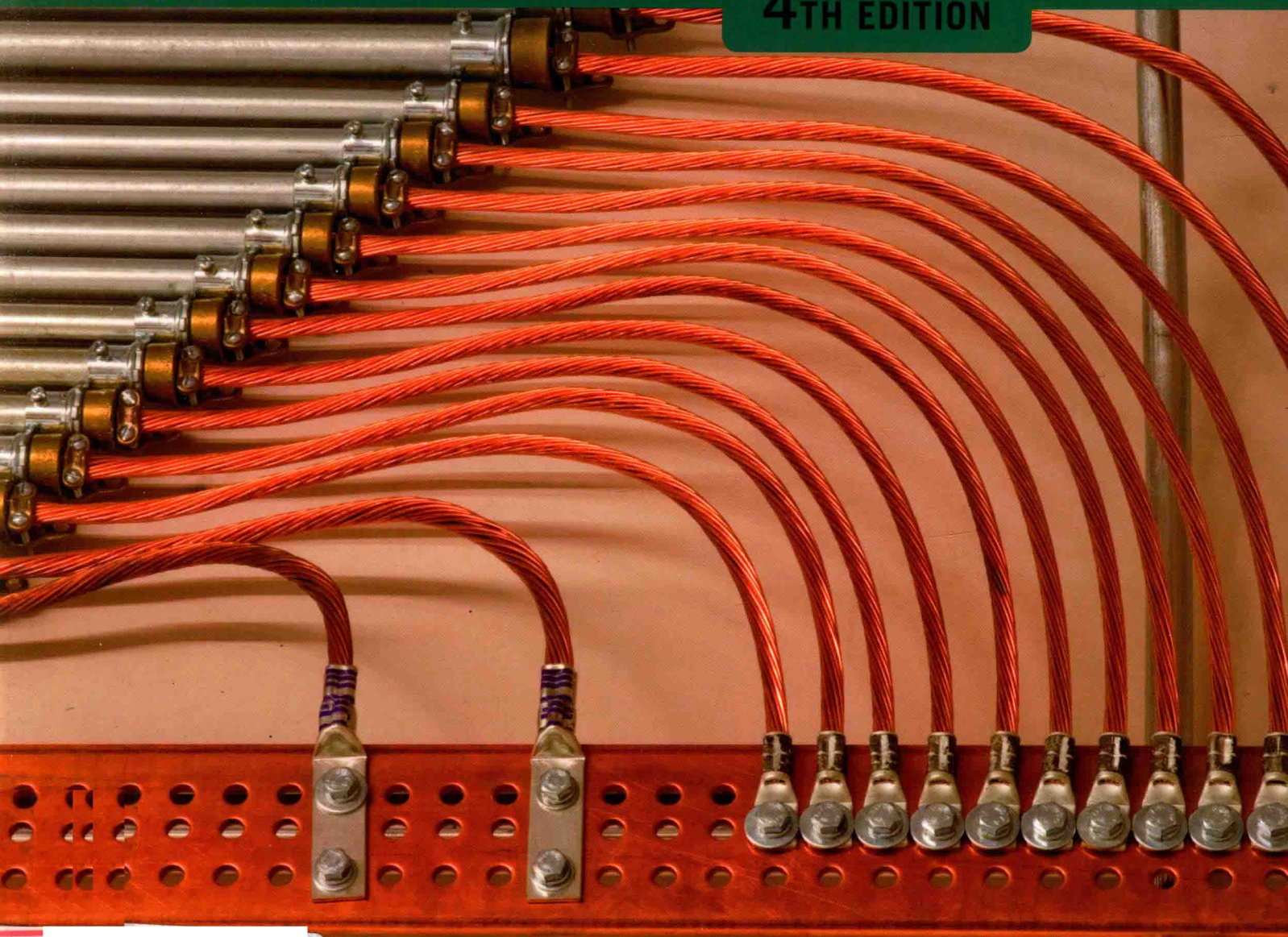


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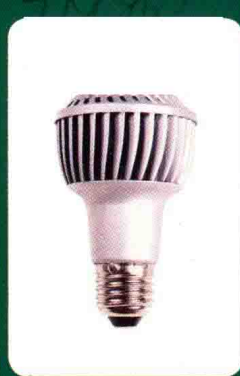
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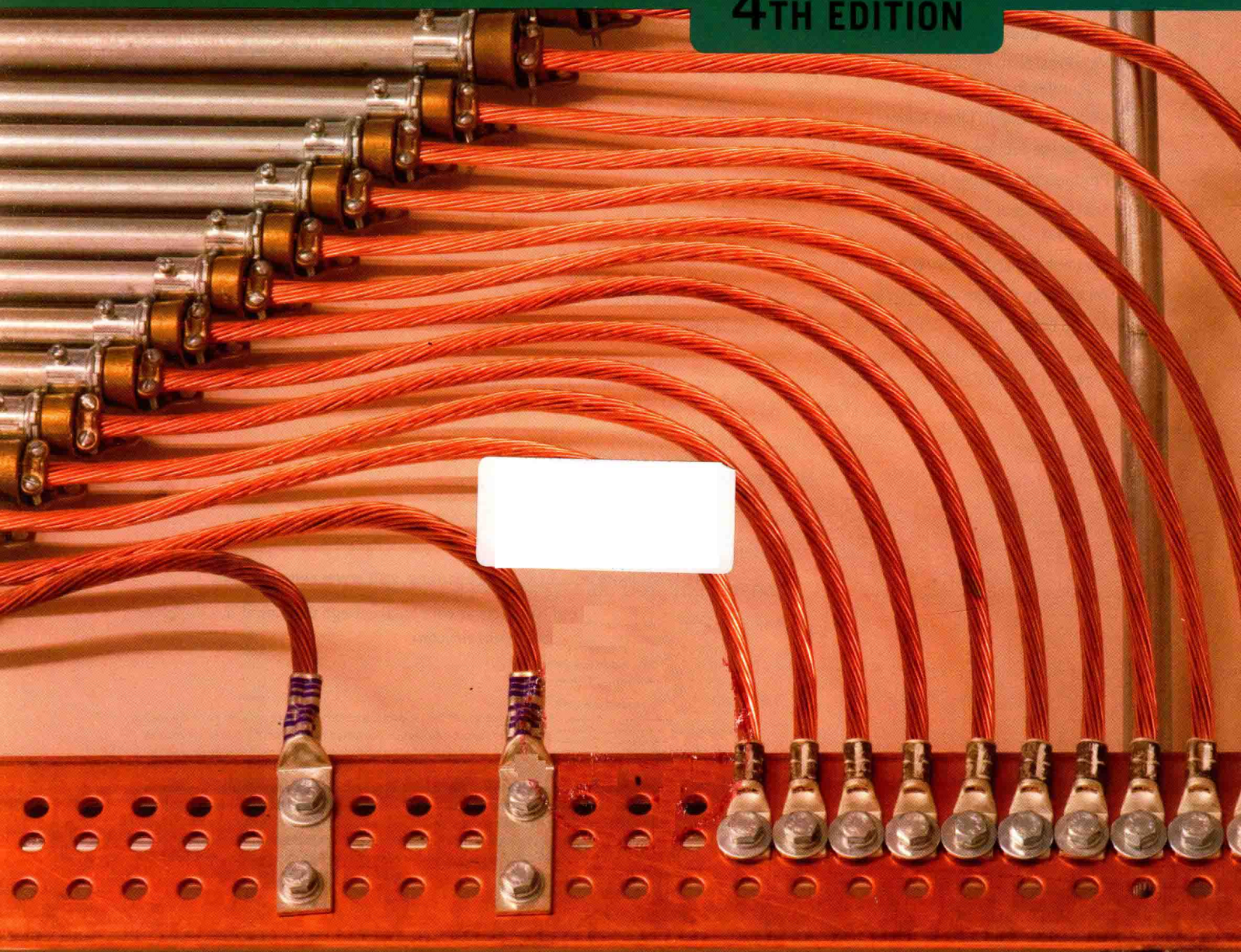
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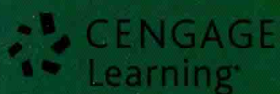


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Electrical Grounding and Bonding,
Fourth edition
Phil Simmons

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Library of Congress Control Number: 2013947427

ISBN-13: 978-1-133-94860-5

ISBN-10: 1-133-94860-X

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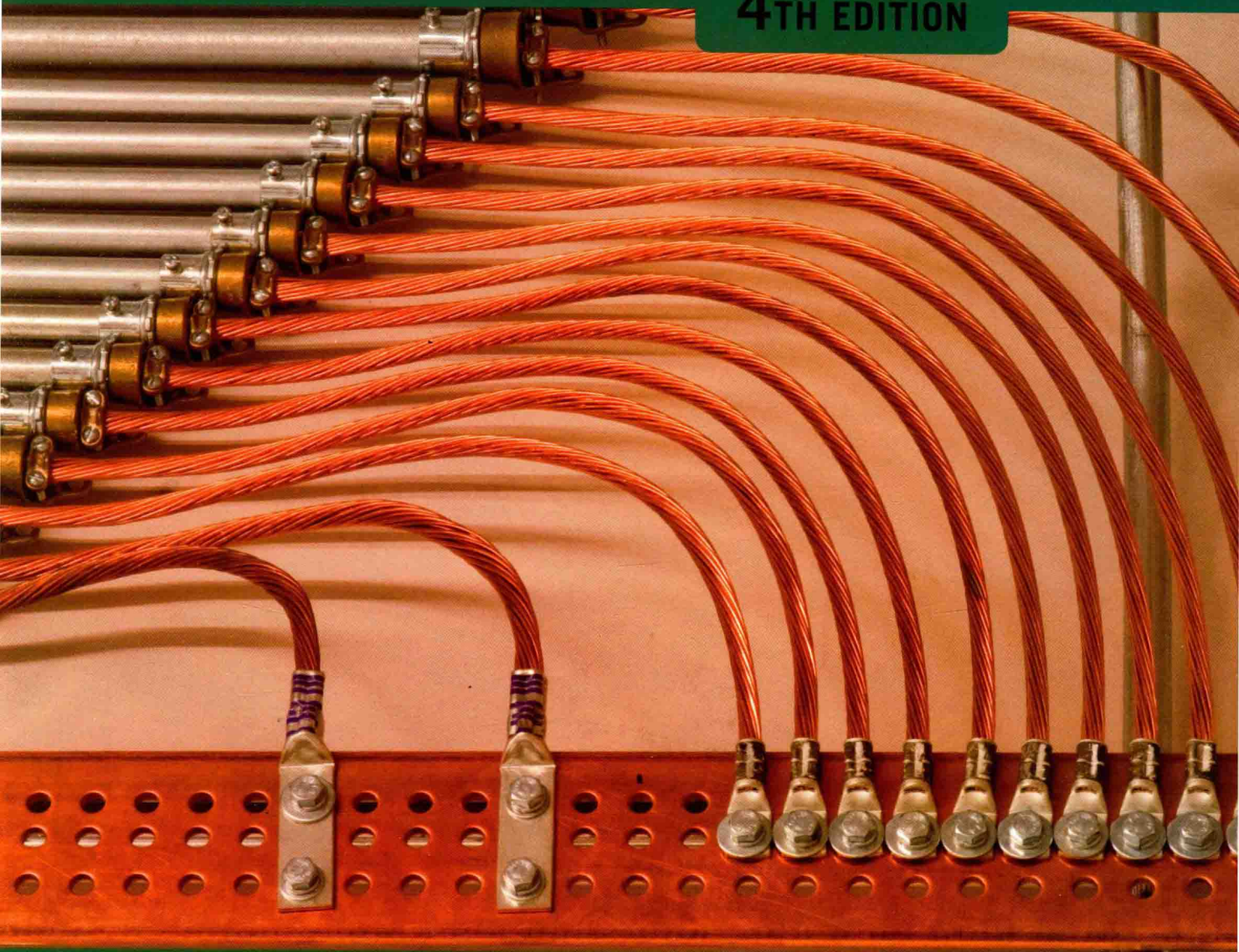
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ELECTRICAL GROUNDING AND BONDING

Based on the 2014 National Electrical Code®

4TH EDITION





Foreword

Just who is Phil Simmons, the author of this book, *Electrical Grounding and Bonding*? I have known Phil for a long time. He has been involved in the electrical industry for many years. Phil is one of the most knowledgeable individuals I know when it comes to the electrical industry and the *National Electrical Code*[®] (*NEC*[®]).*

Phil's credentials are endless. He has held many high-level positions. He was the Executive Director of the International Association of Electrical Inspectors (IAEI), where he orchestrated the writing, producing, editing, revising, and reviewing of many of the technical manuals available from the IAEI. As editor-in-chief of the *IAEI News*, he saw to it that this bimonthly magazine became one of the finest technical publications available today. He was Chief Electrical Inspector for the State of Washington. He has worked with many state and national code officials.

Phil served as Acting Chairman of Code Making Panel 5 a few *Code* cycles back and was responsible for the major reorganization of *Article 250* in the *NEC*. *Article 250* is all about grounding and bonding.

Phil served on the Underwriters Laboratories Electrical Council and their Board of Directors.

Phil has conducted numerous seminars for many large organizations, such as General Motors, Ford Motor Company, Daimler/Chrysler, the University of Wisconsin, the University of Missouri, the U.S. Navy, and the U.S. Marines. He has conducted continuing education seminars for electrical inspectors, electrical contractors, electricians, and electrical apprentices.

Phil also is a master electrician and was an electrical contractor. When electrical installations and the *NEC* are discussed, he can say: "Been there . . . done that." This tremendous experience in the real world is the basis for his outstanding knowledge of the *NEC*.

In addition, Phil has made major contributions to efforts at standardization within the electrical industry. Many of you may not be aware that Phil brought the IAEI Soares grounding book up to date and contributed to the IAEI *Analysis of the NEC*, the *Neon Sign Manual*, *Ferm's Fast Finder*, and videos on the *NEC*. Over the years, he has served on the *Code* panels at IAEI Section and Chapter meetings. He has conducted innumerable seminars under the auspices of the National Fire Protection Association and the IAEI.

As most of you know, the *NEC* is not the most "user-friendly" document. Some individuals know the *Code* but find it difficult to teach others. Phil has the innate ability to explain the *NEC* in words and diagrams that can be understood by everyone.

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Phil has written textbooks and examinations and has developed diagrams, PowerPoint presentations, slides, and transparencies. All of this knowledge is apparent in this excellent textbook on the difficult subject of electrical grounding and bonding.

Like the three legs of a stool that provide its stability, Phil's expertise has three essential components, each of which ensures the effectiveness of the others. "Leg one" is the experience he has had in the electrical field. "Leg two" is his incredible knowledge of electrical codes and standards. "Leg three" is his ability to share this wealth of experience and knowledge with the reader of this book.

I congratulate Phil for a job well done in writing this book. It will be an important addition to your collection of electrical books.

Ray C. Mullin

Author/Owner, Ray C. Mullin Books

Electrical Wiring—Residential

Electrical Wiring—Commercial

Smart House

Illustrated Electrical Calculations



Preface

Electricity follows the basic laws of physics, regardless of whether it is current flow over ungrounded (“hot”) conductors, over grounded conductors (sometimes neutral conductors), or in the grounding system. So, if we can understand basic circuit flow, we can understand the requirements and performance rules for grounding and bonding of electrical systems and equipment. You will find several of the illustrations in this book to be fairly basic and uncomplicated. This complements the overall effort to make the rules for grounding and bonding as easy to understand as possible and to take the concepts of grounding and bonding back to the basics.

I want to mention here and applaud the efforts of Ronald P. O’Riley, who wrote a book titled *Electrical Grounding: Bringing Grounding Back to Earth*, through the sixth edition. Mr. O’Riley is now deceased. Although this book is not based on or intended to be a continuation of Mr. O’Riley’s efforts, our goals in presenting a book on grounding and bonding of electrical systems are very similar. Quoting from the preface to Mr. O’Riley’s sixth edition:

“The author’s wish is for this book to be a learning experience for members, and those in training for a career in the electrical industry. It is the author’s hope that simplifying, illustrating, reasoning through, and coordinating the grounding requirements, as contained in *Article 250* of the *National Electrical Code*®, will promote better understanding and use of the *Code*. This can result in safer, cleaner electrical installations and maintenance. The first rule is to make it safe: the second is to make it work. Both can be done. With this thought in mind, this book is directed at vocational instructors of electricity, electrical engineers, design engineers, construction electricians making installations in the field, maintenance electricians at factories or buildings, electrical inspectors, and many other members of the electrical industry. It is also the author’s hope that the apprentice or person preparing for a career in the electrical industry and studying the *National Electrical Code*® will find the detailed explanations and accompanying diagrams in this book to be an interesting learning experience.”

Electrical Grounding and Bonding is based on my many years of experience in teaching subjects related to the *NEC*, field experience in the electrical construction industry, and association with the International Association of Electrical Inspectors (IAEI).

Other than the Introduction, which includes an explanation of many definitions applicable to electrical grounding and bonding along with a brief review of electrical theory, this book is organized by section number of the *NEC*. For example, if you’re interested in learning about requirements for a grounding electrode system, you can follow the rule from the *NEC Section 250.50* to an identical code reference in this book.

Other features of the organization of this book are as follows:

1. The requirement from the *NEC* is included. Note that in most cases, the requirement is paraphrased rather than being a direct quote.
2. The requirement is discussed and explained.
3. An illustration of the requirement is provided.
4. Where appropriate, there is an explanation of how to comply with the rules, such as determining the appropriate size system bonding conductor.

ABOUT THE AUTHOR

Phil Simmons is owner of Simmons Electrical Services. The firm specializes in training, writing and illustrating of technical publications related to the electrical industry, inspecting complex electrical installations, and consulting on electrical systems and safety.

Phil has served the International Association of Electrical Inspectors (IAEI) in the following capacities:

- Secretary-treasurer of the Puget Sound Chapter
- Secretary-treasurer of the Northwestern Section
- International President in 1987
- Executive Director (1990–1995)
- Codes and Standards Coordinator (1995–1999)
- Editor of *IAEI News*

Phil is a licensed master electrician and former electrical contractor in the State of Washington. He is also a licensed journeyman electrician in the state of Montana. He was chief electrical inspector for the State of Washington from 1984 to 1990, after serving as an electrical plans examiner and field electrical inspector.

Phil has had extensive experience for several years in preparing and presenting training at many locations on the following and additional subjects:

- Update to the *National Electrical Code*
- Electrical Systems in One- and Two-Family Dwellings

- Grounding and Bonding of Electrical Systems
- Wiring for Hazardous Locations
- Motors and Transformers
- Electrical Safety in Employee Workplaces

Phil is author of several technical articles that have been published in the *IAEI News*. He is also the author and illustrator of several technical books on electrical codes and safety, including these:

- *IAEI Analysis of the National Electrical Code*
- *Ferm's Fast Finder Index*
- *Electrical Systems in One- and Two-Family Dwellings*
- *IAEI Soares Book on Grounding of Electrical Systems*
- *NJATC Significant Changes in the National Electrical Code*

Beginning with the 2011 *NEC*, Phil is coauthor, with Ray Mullin, of *Electrical Wiring Commercial* and *Electrical Wiring Residential*. Both are published by Cengage Learning.

Phil has served the National Fire Protection Association (NFPA) in several capacities, including the following:

- Standards Council (six years)
- *National Electrical Code* Technical Correlating Committee
- Code Making Panel (CMP)-17, Chairman of CMP-19, CMP-1, Acting Chair of CMP-5, and CMP-5 member
- Chair of the NFPA Electrical Section
- Electrical Codes Coalition Committee
- Instructor at NFPA's *NEC*, Electrical Safety in the Workplace (NFPA 70E), and related seminars

Phil is a past member of the Underwriters Laboratories Electrical Council and is a past UL Trustee. He is a member of the Standards Technical Panel for Grounding and Bonding Equipment. He is also a retired member of the International Brotherhood of Electrical Workers.

Phil has passed the electrical inspector certification examinations for One- and Two-Family, General, and Plan Review. He served for several

years on the Educational Testing Service Electrical Advisory Committee for national electrical inspector certification examinations. He also served on the joint IAEI/NFPA Electrical Inspector Certification Examination development committee.

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ACKNOWLEDGMENTS

I first want to thank the Lord Jesus Christ for giving me the abilities I have as well as the tremendous opportunities I have enjoyed over my career. I feel blessed in so many ways. "In Him we live and move and have our being."

I have been blessed with several friends who deserve special mention for their assistance, encouragement, contributions, wisdom, and support over the years: Ray Mullin, Mike Holt, Richard Loyd, and Mike Johnston.

Finally, I want to thank my wife Della for her support while I had to spend so much time devoted to this project, as well as keep the consulting business going. I promise I will really get after the "Honey-Do" list as soon as this project is completed!

Phil Simmons

CHANGES TO NEC ARTICLES 100 AND 250 FOR THE 2014 EDITION

Once again, many changes were made to the portions of the *NEC* Code for which Code Panel 5 is responsible. For the 2014 edition of the *NEC*, most of the changes can be accurately described as editorial.

The most significant changes are shown in the following table.



Significant Changes in the NEC 2014 Edition for Articles 100 and 250

Section	Change
<i>Article 100: Effective Ground-Fault Current Path</i>	This definition has been relocated without change from 250.2 to <i>Article 100</i> as the term is used in more than one article in the <i>NEC</i> .
<i>Article 100: Ground-Fault Current Path</i>	This definition has been relocated without change from 250.2 to <i>Article 100</i> as the term is used in more than one article in the <i>NEC</i> .
<i>Article 100: Intersystem Bonding Termination</i>	The change in the definition is intended to limit the intersystem bonding termination device for connection of only intersystem bonding conductors.
<i>Article 100: Separately Derived System</i>	This definition is significantly changed to clarify that a separately derived system may be connected to other systems by grounding and bonding connections.
250.8(A)	The words "or more" are added to indicate that more than one method may be used for connection of grounding in bonding conductors to equipment.
250.21(C)	Marking requirements for ungrounded systems has been changed to agree with <i>NEC 408.3(F)(2)</i> .
250.30	Multiple separately derived systems that are connected in parallel are required to comply with this section.
250.30(A)(1) Exception No. 2	The exception is revised to clarify that if a building or structure is supplied by a feeder from an outdoor transformer, a system bonding jumper at both the source and the first disconnecting means are permitted, so long as a parallel path for neutral current is not created.
250.30(A)(2)(b) Exception	A new exception that a supply-side bonding jumper is not required between enclosures is added to complement the revised rule in 250.30(A)(1) Exception No. 2.
250.62	Editorial changes were made to add copper-clad aluminum conductors as well as the grounding electrodes permitted in 250.68(C). Conductors of the wire type are permitted to be solid or stranded, insulated, covered, or bare.
250.64(B)	A new sentence added to state that grounding electrode conductors and grounding electrode bonding jumpers are not required to comply with the burial depths of <i>NEC 300.5</i> .
250.64(D)	This section, which relates to making grounding electrode conductor connections is revised so it applies to buildings or structures with multiple disconnecting means in separate enclosures for services and feeders.
250.64(D)(1)	Details were added regarding the aluminum or copper bus bar used to connect grounding electrode conductor taps.
250.64(D)(2)	Details were added regarding making connections to the multiple disconnecting means enclosures by individual grounding electrode conductors.
250.64(D)(3)	Details were added regarding making connections to the multiple disconnecting means enclosures that have a common location.
250.64(E)	The previously long paragraph relating to raceways and enclosures for grounding electrode conductors was broken up into several subsections with bold faced titles.
250.66(A) and (B)	Changes were made to clarify that the size of the grounding electrode conductor does not have to be increased if it connects to more than one of the same type of grounding electrode such as two ground rods.
250.68(C)(3)	A new subsection regarding concrete encased electrodes has been added to allow the conductor, reinforcing rod or bar that has been installed in accordance with 250.52(A)(3) to be extended to an accessible location above the concrete to facilitate a connection to the grounding electrode conductor.
250.102(C)(1)	A new <i>Table 250.102(C)(1)</i> has been added to provide sizing and installation information for the grounded conductor, main bonding jumper, system bonding jumper, and supply-side bonding jumper for alternating current systems. This table and the accompanying notes provide almost identical information to that in <i>Table 250.66</i> , which relates to sizing grounding electrode conductors.
250.104(B)	This section applies to bonding other metal piping. Five locations have been added where the bonding connection is permitted.

(Continues)



(Continued)

Section	Change
250.119 Exception No. 2	New exception has been added that will allow flexible cords having an integral insulation and jacket without an equipment grounding conductor to have a continuous outer finish that is green. And informational note has been added to indicate an example of this flexible cord is type SPT-2, 2 conductor.
250.119 Exception No.3	A new exception has been added to allow conductors with green insulation to be permitted as ungrounded signal conductors for traffic signal control and traffic signal indicating heads.
250.121 Exception	A new exception has been added, which will allow a wire-type equipment grounding conductor to be used as both an equipment grounding conductor and grounding electrode conductor if it meets the sizing and installation rules for both types of conductor.
250.130(C)	A new section has been added for a location for termination of an equipment grounding conductor that is installed for nongrounding receptacle replacements or branch circuit extensions.



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