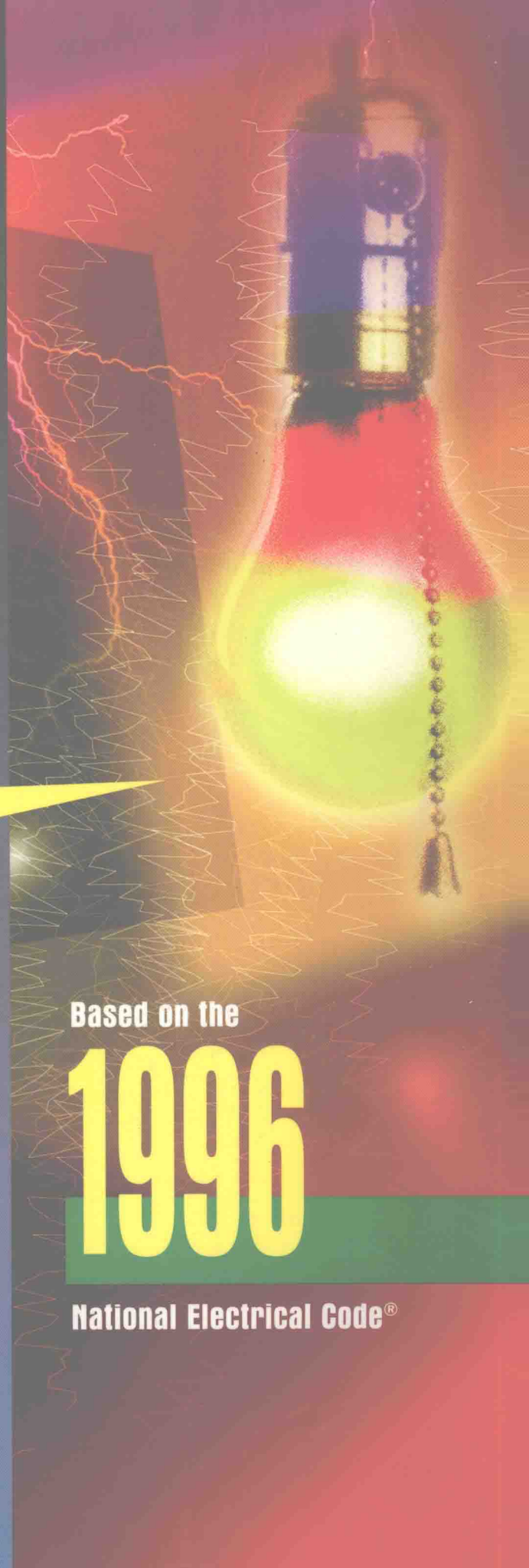
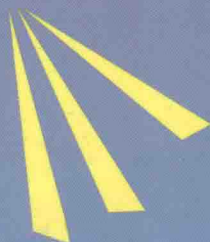


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12th Edition

Ray C. Mullin



Based on the

1996

National Electrical Code®

***Based on the 1996
NATIONAL ELECTRICAL CODE®***

Electrical Wiring

Residential Twelfth Edition

Ray C. Mullin



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Cover Image by Mick Brady

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Printed in the United States of America

For more information, contact:

Delmar Publishers

3 Columbia Circle, Box 15015

Albany, New York 12212-5015

International Thomson Publishing Europe

Berkshire House 168-173

High Holborn

London, WC1V 7AA

England

Thomas Nelson Australia

102 Dodds Street

South Melbourne, 3205

Victoria, Australia

Nelson Canada

1120 Birchmont Road

Scarborough, Ontario

Canada, M1K 5G4

International Thomson Editores

Campos Eliseos 385, Piso 7

Col Polanco

11560 Mexico D F Mexico

International Thomson Publishing GmbH

Königswinterer Strasse 418

53227 Bonn

Germany

International Thomson Publishing Asia

221 Henderson Road

#05-10 Henderson Building

Singapore 0315

International Thomson Publishing—Japan

Hirakawacho Kyowa Building, 3F

2-2-1 Hirakawacho

Chiyoda-ku, Tokyo 102

Japan

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5 6 7 8 9 10 XXX 01 00 99 98 97

Library of Congress Cataloging-in-Publication Data

Mullin, Ray C.

Electrical wiring, residential / Ray C. Mullin. — 12th ed.

p. cm.

“Based on the 1996 National Electrical Code®.”

Includes index.

ISBN 0-8273-6842-9 (hc). — ISBN 0-8273-6841-0 (softcover)

1. Electric wiring, Interior. I. Title.

TK3285.M84 1995

621.319'24'0218 — dc20

95-9817

CIP

Electrical Wiring Residential

FOREWORD

THE ROLE OF THE ELECTRICAL INSPECTOR AND THE IMPORTANCE OF PROPER TRAINING

When one considers how different groups within the electrical industry affect the end product used by consumers, it is easy to see the importance of those groups working together in a coordinated manner. From the time electrical products are designed to the time when electrical installations are completed or when electrical equipment is purchased by the consumer, many steps must be taken to make it all possible. During this process, close attention to safety standards must be given to the design, installation, and use of electrical products. Product safety standards include testing guidelines which can be used to help ensure that products perform in a safe manner. Products so evaluated by appropriate third party testing laboratories may label the electrical equipment with authorized markings as a means of verifying that the product complies with the minimum requirements of the safety standard.

The *National Electrical Code*® is an electrical safety standard containing rules affecting products, installation procedures and use of electrical equipment. It is the most widely recognized safety standard in this country. The *NEC*® is usually adopted through a legislative process of a governmental agency and becomes enforceable as a law within that jurisdiction. The *NEC*® is amended every three years in response to such things as the development of new products, the recognition of different installation and use procedures, and the discovery of potential hazards to persons and property. Electrical inspectors have the responsibility of enforcing the safety requirements of the *National Electrical Code*®.

Electrical inspectors are an important part of the safety program. They are involved in the development of safety rules as well as in the application of those rules to electrical installations. The responsibility borne by electrical inspectors is significant. To be responsible for knowing safety rules, making proper interpretation of those rules, and properly applying them to a job site is a major endeavor. In order for the electrical inspector to properly do his or her job, knowledge and skill must be developed. This is achieved through adequate education and experience. It is vital that electrical inspectors be knowledgeable of the rules in the *National Electrical Code*® and know how to apply those rules.

The need for adequate training and experience is not limited to the electrical inspector. All who are a part of the electrical construction industry can benefit by it. In order for one to maintain an acceptable level of proficiency in a profession or trade, one must stay current with the ever changing electrical field. That proficiency is achieved through continuing education and training. There is no substitute for such training and experience. To emphasize this point, I refer to a philosophy taught by Ray Mullin: "The cost of education is small when compared to the price paid for ignorance."

Philip H. Cox
Executive Director
International Association
of Electrical Inspectors

PREFACE

INTRODUCTION

The twelfth edition of **ELECTRICAL WIRING—RESIDENTIAL** is based on the 1996 *National Electrical Code (NEC)*.[®] The *NEC*[®] is used as the basic standard for the layout and construction of residential electrical systems. In this text, thorough explanations are provided of Code requirements as they relate to residential wiring. To gain the greatest benefit from this text, the student must use the *National Electrical Code*[®] on a continuing basis.

Why Is This Text Different Than Other House Wiring Books?

It is extremely difficult to learn the requirements of the Code by merely reading the *National Electrical Code*.[®] Try reading a dictionary from beginning to end. Do you remember what you read? Probably not. But, look up the definition of a word at the time you need to know about it, and you will remember its definition. In much the same manner, *Residential Wiring* does not cover the *National Electrical Code*[®] in a boring manner. Instead, it stresses specific Code requirements at the appropriate time. For example, the Code requirements for electric clothes dryers are discussed when studying about the electric clothes dryer hook-up.

This text is unique in that it includes a full set of an actual house plan. The format is for the student to simultaneously use the text, the plans, and the *National Electrical Code*,[®] taking the learner through a typical house, room by room, circuit by circuit. Also included are many recommendations that are above and beyond the basic *National Electrical Code*[®] requirements.

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

There are also instances where a governing body has legislated action that waives specific *NEC*[®] requirements, feeling that the *NEC*[®] was too restrictive on that particular issue. Such instances are very rare. The Instructor is encouraged to furnish students with

National Electrical Code[®] and *NEC*[®] are registered trademarks of the National Fire Protection Association, Inc. Quincy, MA 02269.

any local variations from the *NEC*® that would affect this residential installation in a specific locality.

Electrical wiring is a skilled trade. Wiring should not be done by anyone not familiar with the hazards involved. It is a highly technical skill that requires much training. This text provides all of the electrical codes and standards information needed to approach house wiring in a safe manner. That is why the *National Electrical Code*® defines a **Qualified Person** as “one familiar with the construction and operation of the equipment and the hazards involved.”

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

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

ELECTRICAL WIRING—RESIDENTIAL is the most comprehensive text available anywhere. It covers residential wiring topics from the most advanced *National Electrical Code*® standpoint, to the fundamental requirements necessary for someone wanting to learn the basics. Every code rule is covered by text, illustrations, examples, and wiring diagrams.

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

THE ELECTRICAL TRADE

Electricity is safe when it is handled properly. If electrical installations are made in an unsafe manner, great potential exists for damage to property as a result of fire. But more importantly, electrical installations that do not meet the minimum requirements of applicable codes and standards can and do result in personal injury and/or death.

Most communities, cities, counties, and states have regulations that adopt by reference the *National Electrical Code*®. These regulations also specify any exceptions to the Code to cover local conditions.

Most building codes and standards contain definitions for the various levels of competency of workers in the electrical industry.

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

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

Journeyman Electrician shall mean a person having the necessary qualifications, training, experience, and technical knowledge to wire for, install, and repair electrical apparatus and equipment for light, heat, power and other purposes, in accordance with standard rules and regulations governing such work.

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

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

THE TWELFTH EDITION

Continuing in the tradition of previous editions, this text thoroughly explains how Code changes affect wiring installations. New and revised illustrations supplement the explanations to ensure that electricians understand the new Code requirements. New photos reflect the latest wiring materials and components available on the market. Revised review questions test student understanding of the new content. New tables that summarize Code requirements offer a quick reference tool for students. Another reference aid is the tables reprinted directly from the 1996 edition of the *National Electrical Code*.® The extensive revisions for the twelfth edition make ELECTRICAL WIRING—RESIDENTIAL the most up-to-date and well-organized guide to house wiring.

A modern residence blueprint serves as the basis for the wiring schematics, cable layouts, and discussions provided in the text. Additional plans may be obtained by contacting Delmar Publishers Inc. Each unit dealing with a specific type of wiring is referenced to the appropriate plan sheet. All wiring systems are described in detail—lighting, appliance, heating, service entrance, and so on.

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

This text does *not* focus on such basic skills as drilling a hole, splicing two wires together, stripping insulations from wire, or fishing a wire through walls. These skills are certainly necessary for good workmanship, but it is assumed that the learner (electrical apprentice or journeyman electrician) has mastered the mechanical skills on the job.

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

CHANGES FOR THIS EDITION

The following list highlights changes and additions made in this twelfth edition. Many of these changes and additions are the result of suggestions sent to the author by users of the text.

- An introduction to the new National Fire Protection Association *Residential Electrical Maintenance Code for One- and Two-Family Dwellings*.
- More suggestions for wiring homes for the physically handicapped.
- A new comprehensive table of Conversion Multipliers for changing customary English terms to metrics.
- Current information on the background impact of Nationally Recognized Testing Agencies (NRTL).
- An introduction to the *harmonizing* of standards between Underwriters Laboratories (UL) and the Canadian Standards Association (CSA).
- Building Code regulations *now in effect* that are often overlooked, and that can prevent the spread of fire in residential construction. New materials are discussed and illustrated for use in preventing the spread of fire. Watch out when installing electrical wall boxes in the same partition between a residential garage and habitable rooms!
- New illustrations of electrical boxes for use in remodel work.
- New illustrations of electrical boxes for use with metal framing members.
- Clarification on where switch control of stairway lighting is required.
- The hazards of burying old knob-and-tube wiring in insulation.
- A new, simplified chart showing how to match conductor insulation temperature ratings and the terminals to which they will be connected, and “Meet Code.”
- An update on the conductor temperature ratings in nonmetallic-sheathed cable and armored cable, and where they are permitted and/or required to be used.
- More wiring diagrams for three-way switches. Some are not so common.
- What a GFCI does? What a GFCI does not do?
- An update on the installation and wiring of recessed fixtures.
- A total rewrite and much additional text on incandescent and fluorescent lighting, dimming, color rendition, high-efficiency electronic ballasts, energy-saving lamps, lamp life and light output as affected by supply voltage.
- How many outlets are permitted on one branch-circuit?
- The latest technology for submersible water pumps and how to wire them.
- A complete rewrite on water heaters, required temperature settings, Shriner Burn Institute data on hot water hazards, corrosion problems, how pressure/temperature safety valves function, different types of electrical hook-ups showing *utility-controlled* and *customer-controlled* installations, time-of-use metering, and how to determine how long it will take an electric water heater to recover.
- New diagrams for the heat controls used on electric ranges.
- Latest wiring diagrams for bathroom *heat/vent/light* fixtures.
- Cord and plug connections not permitted for furnaces.

- Understanding the terms found on the nameplates of air conditioners and heat pumps, and what these mean to the electrician. Examples and calculations provided.
- Photos, diagrams, and the latest technical information on *digital satellite* systems that use a small 18-inch antenna instead of the large “dishes.”
- The latest on telephone Standard Network Interfaces, the latest on color coding of telephone conductors and cables.
- How many telephones can be connected to one line before running into problems.
- “Cross-talk” on telephone lines, and how this nuisance can be avoided.
- Latest National Fire Protection Association Code requirements for household fire warning equipment. This is the new NFPA Standard 72.
- A complete rewrite of the low-voltage, remote-control systems chapter to show how the new relays, switches, master controls, and sequencers are used. New color coding of the cables and conductors is presented. Many new photos and diagrams.
- A complete rewrite and reorganization on the subject of grounding and bonding of service equipment for more clarity in the understanding of the subject. Many new diagrams.
- Added coverage on how to figure the cost of using electricity.
- A set of *blank* floor plans to use upon completion of studying the text. Students can design their own electrical layout.
- Extra *blank* forms for use in the proper sizing of residential services.
- A *Membership Application Form* for joining the International Association of Electrical Inspectors organization has been included in the Appendix of this text. Students and instructors are encouraged to become members of this educational association.

NEW CODE REQUIREMENTS FOR THE 1996 NATIONAL ELECTRICAL CODE®

Throughout this new edition of *Electrical Wiring—Residential, 1996 Code* changes are identified by the symbol ► before the change and ◄ after the change.

- New rule for “rounding up” overcurrent ratings for motor branch-circuits.
- New requirements for grounding electric ranges, dryers, ovens, and counter-mounted cooktops. Grounding to the neutral no longer permitted for new work.
- New and simplified requirements for locating receptacles on islands and peninsulas.
- New requirements that *all* 125-volt, single-phase 15- and 20-ampere receptacles in kitchens that serve countertops must be GFCI protected.
- New Code requirements for control circuit wiring.
- New rules that *only* service-drop conductors be supported by a service mast.
- New rule prohibiting the use of sheet metal screws for terminating equipment grounding conductors.
- Clarification on where to attach equipment grounding conductors and neutrals in a panel.
- New rules for reducing service neutrals on residences.

- New rules for waiving the bonding requirements of swimming pool double-insulated pump motors.
- New requirements for boxes that will support ceiling fans.
- New requirement that bathroom receptacles must be connected to a separate 20-ampere branch-circuit.
- New rules for outdoor receptacles.
- Clarification on terminating conductors based upon the conductor's insulation rating.
- New rules for supporting, securing, and protecting cables through framing members.
- New rules on using 3-wire and 4-wire cord- and plug-connection for electric ranges and dryers.
- New strict rules for temporary wiring.
- New requirements for hooking up the receptacle for refrigerators.
- New rules for low-voltage landscape lighting.
- New rules on when to install GFCI receptacles for appliances located in a dedicated space.
- Many changes have been made to Code section references because of editorial rearranging of numerous Code sections. These editorial changes have been picked up in this revision.

SUPPLEMENTS

An Instructor's Guide is available and consists of the following information: selected text references, answers to unit-end reviews, a final examination covering the content of the entire text, blank service-entrance calculation form, and answers to the final examination.

ABOUT THE AUTHOR



This text was written by Ray C. Mullin, former electrical instructor for the Wisconsin Schools of Vocational, Technical, and Adult Education. He is a former member of the International Brotherhood of Electrical Workers. He is a member of the International Association of Electrical Inspectors, the Institute of Electrical and Electronic Engineers, and the National Fire Protection Association, and has served on Code Making Panel 4 of the *National Electrical Code*.®

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

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

Mr. Mullin presents his knowledge and experience in this text in a clear-cut manner that is easy to understand. This presentation will help learners to fully understand the essentials required to pass the residential licensing examinations and to perform residential wiring that “meets Code.”

Mr. Mullin is co-author of *Electrical Wiring—Commercial*, co-author of *Illustrated Electrical Calculations*, and co-author of *The Smart House*. He has contributed technical material for *Electrical Grounding*, and to the International Association of Electrical Inspectors text on *Grounding*.

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

Mr. Mullin is past Director, Technical Liaison, for a large electrical manufacturer. He has developed extensive technical literature for use by this company’s field engineering personnel.

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

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ACKNOWLEDGMENTS

Helen J. Mullin, my wife for her editing, typing, and encouragement.

Special thanks to everyone on the Delmar team who worked so hard at “pulling it all together” as we focused on specific target dates to get this text off the presses at the same time the 1996 *National Electrical Code*® became available. They did an outstanding job! Congratulations!

The author and Delmar Publishers would like to thank the following reviewers of the 1993 edition, who offered their technical expertise and suggestions for this revision. Our appreciation goes out to:

Robert S. Boiko, Vice President
Northbrook Heater and Parts Supply, Inc.
Northbrook, IL 60062

Samuel J. Geisler
Career Institute of Technology
Easton, PA 18042
Dallas Phillips
Kentucky Tech LaGrange Vocational
Education Center
LaGrange, KY 40031

George Wilson
Mississippi Gulf Coast Community
College
Long Beach, MS 39560
A. J. Pearson, Executive Director
National Joint Apprenticeship and
Training Committee
Upper Marlboro, MD 20772

Special appreciation is expressed to Charles W. Talcott and Home Planners, Inc. for the basic plans upon which the residence plans found at the back of the text are based.

The author wishes to thank the following companies for their contributions of data, illustrations, and technical information:

Advance Transformer Company
AFC/A Nortek Co.
American Home Lighting Institute
Anchor Electric Division, Sola Basic Industries
Appleton Electric Co.
Arrow-Hart, Inc.
BRK Electronics, A Division of Pittway Corporation
Bussmann Division, Cooper Industries
Carlson, A Lamson & Sessions Company
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