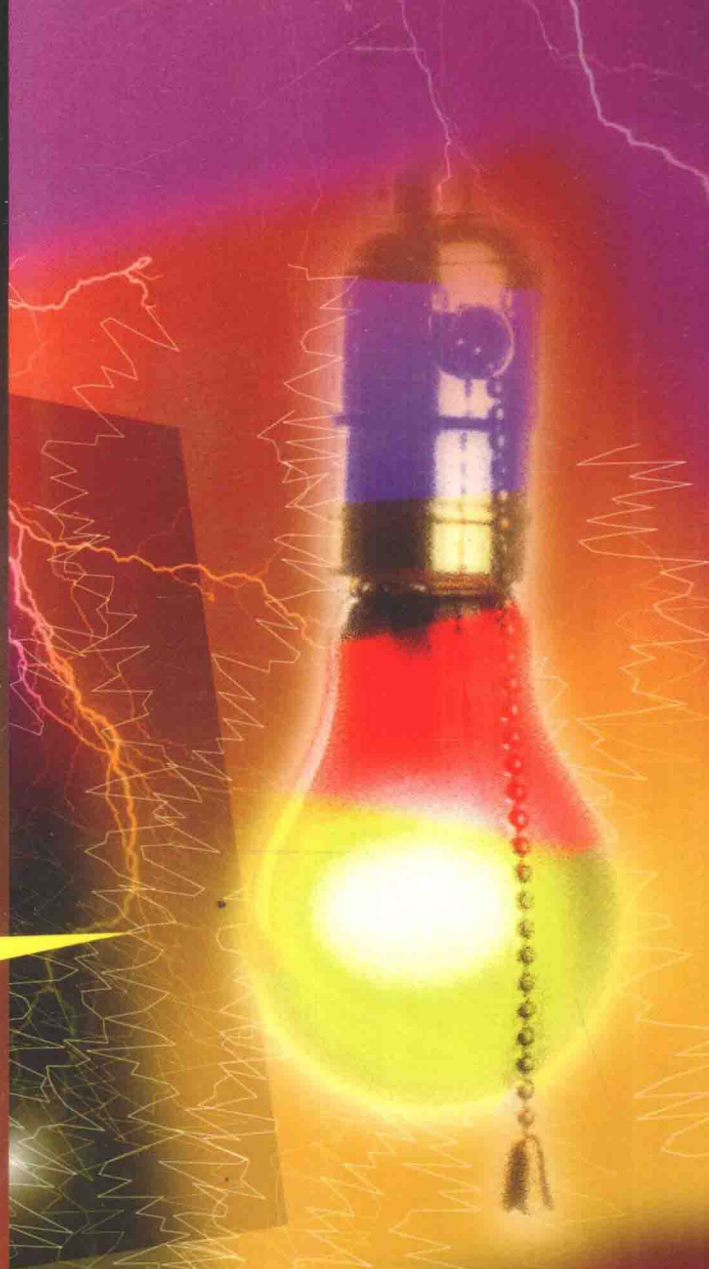


Electrical Wiring COMMERCIAL

9th Edition

Ray C. Mullin
Robert L. Smith



Based on the

1996

National Electrical Code®

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

Electrical Wiring Commercial Ninth Edition

Ray C. Mullin Robert L. Smith



Delmar Publishers

I(T)P An International Thomson Publishing Company

Albany • Bonn • Boston • Cincinnati • Detroit • London • Madrid • Melbourne • Mexico City
New York • Pacific Grove • Paris • San Francisco • Singapore • Tokyo • Toronto • Washington

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 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 representation 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.

Cover Image by Mick Brady.

Delmar Staff

Publisher: Susan Simpfenderfer

Acquisitions Editor: Paul Shepardson

Developmental Editor: Jeanne Mesick

Project Editor: Patricia Konczeski

Production Coordinator: Toni Bolognino

Art/Design Coordinator: Cheri Plasse

COPYRIGHT © 1996

By Delmar Publishers

a division of International Thomson Publishing

The ITP logo is a trademark under license.

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 Birchmount 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

All rights reserved. No part of this work covered by the copyright hereon may be reproduced or used in any form or by any means — graphic, electronic, or mechanical, including photocopying, recording, taping, or information storage and retrieval systems — without the written permission of the publisher.

1 2 3 4 5 6 7 8 9 10 XXX 01 00 99 98 97 96

Library of Congress Cataloging-in-Publication Data

Mullin, Ray C.

Electrical wiring: commercial / Ray C. Mullin, Robert L. Smith. —

9th ed.

p. cm.

“Based on the 1996 National Electrical Code.”

Includes index.

ISBN 0-8273-6655-8

1. Electric wiring, Interior. 2. Commercial buildings — Electric equipment. 3. Electric wiring — Insurance requirements. I. Smith, Robert L., 1926– II. Title.

TK3284.M85 1996

621.319'24 — dc20

95-13501

CIP

PREFACE

INTRODUCTION

The ninth edition of ELECTRICAL WIRING — COMMERCIAL is based on the 1996 *National Electrical Code*®.* The new edition thoroughly and clearly explains the *NEC*® changes that relate to 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 text 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. In this case, the electrician must know the installation procedures, must be able to read plans, and must be able to understand and interpret specifications. 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.

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 text.

Readers should be aware that many of the electrical loads used as *examples in the text were contrived in order to create Code problems*. The authors' purpose in putting this building together is to demonstrate, and thus enhance learning, as many Code problems as possible. As an example, there is a single-phase feeder to the Doctor's office. This could have been a three-phase feeder similar to those in the other occupancies. However, using the single-phase feeder allows us to demonstrate many additional Code applications.

This is not a typical or an ideal design for a commercial building. It is a composite

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

to demonstrate a range of Code applications. 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. Then, if the reader wants to back off from this level, based upon installation requirements, it can be done intelligently.

THE NINTH 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 the electrician will use on the job. Revised review questions test the student's understanding of the new content. New tables and figures summarizing Code requirements for commercial installations provide a quick reference for students. Another reference aid is the tables reprinted directly from the 1996 edition of the *National Electrical Code*®. This combination of new and existing information makes ELECTRICAL WIRING — COMMERCIAL the most up-to-date and well-organized guide to commercial wiring.

CHANGES FOR THIS EDITION

- Safety in the Workplace. A review of Federal Legislation — Occupational Safety and Health Act (OSHA). Discusses the terms *qualified*, *lock out*, *tag out*. Emphasis on why electrical equipment should be turned off before working on the equipment.
- More on National Recognized Testing Laboratories (NRTL).
- A new comprehensive metric system conversion chart has been added to the Appendix.
- New material and method of calculating increase in temperature and shortened expected life of electric motors when running on systems experiencing unbalanced voltage problems.
- New text discussing proper grounding of electronic computer/data processing equipment. Many new detailed wiring diagrams.
- Harmonics and non-linear loads, and their effect on electronic computer/data processing equipment.
- Greatly expanded coverage of conductor color coding for branch circuits and feeders.
- Additional coverage on the use of 60°, 75°, and 90°C conductors, and how to “Meet Code” by properly matching the conductors with the equipment to be connected.
- History and current problems with overheated neutrals of 3-phase, 4-wire wye connected systems. New diagrams show recommendations of installing separate neutrals instead of using a common shared neutral on multi-wire branch circuits supplying electronic computer/data processing equipment.
- Some simple rules for installing *series-rated* equipment.
- Additional material regarding short-circuit withstand ratings for copper conductors. The melting values for copper conductors are easily calculated, so as not to install equipment grounding conductors that are too small to safely carry fault currents.
- Required illumination for switchboards and other major electrical equipment to establish adequate visibility around such equipment.

CHANGES IN THIS EDITION AS A RESULT OF CHANGES IN THE 1996 NATIONAL ELECTRICAL CODE®

- How to use the new tables in *Chapter 9* and *Appendix C* of the *NEC*® that show conductor cross-sectional areas.
- How to calculate raceway fill based upon the new tables in *Chapter 9* and *Appendix C* of the *NEC*® that show the various types of conduit and tubing.
- New chart excerpted from the *Table 5, Chapter 9, NEC*® that shows the revised conductor cross-sectional area values. The old tables are no longer valid.
- Examples of the new method for calculating the maximum number of conductors permitted in a box. The *1996 NEC*® uses “volume allowance” instead of “deducting.”
- New information on Design E “premium efficiency” motors and how the *NEC*® tables have been revised to reflect higher starting currents for these types of motors. New charts have been added to text.
- Latest changes for motor short-circuit, branch-circuit, and ground-fault protection . . . the “round down” issue has been changed to “round up” under specific conditions.
- Latest information on “continuous loading,” and how this affects the sizing of over-current devices and conductors.
- New requirements on how to handle “non linear” loads when it comes to sizing neutral conductors. New wiring diagrams illustrating this.
- Clarification of where the utility codes stop and the *National Electrical Code*® starts.
- New material on clearances and illumination around electrical equipment.
- For instantaneous trip circuit breakers, there are higher maximum ampere ratings now permitted when applied to Design E motors, but only under certain conditions.
- New note added to *Table 250-95* indicating that equipment grounding conductors may need to be larger than shown in *Table 250-95* to accomplish “effective grounding.”

ABOUT THE AUTHORS

This text was prepared by Ray C. Mullin and Robert L. Smith. 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 a member of the International Association of Electrical Inspectors, the Institute of Electrical and Electronic Engineers, and 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 serves on the Executive Board of the Western Section, International Association of Electrical Inspectors. He also serves on their National Electrical Code Committee and on

their Code Clearing Committee. He also serves on 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 serves on their Code panels.

Mr. Mullin is past Director, Technical Liaison, and Code Coordinator for a large electrical manufacturer.

Robert L. Smith, P. E., is an Emeritus Professor of Architecture at the University of Illinois where he taught courses in electrical systems, lighting design, acoustics and energy-conscious design. He worked in electrical construction for more than 25 years, and has taught electrical apprentice classes and courses in industrial electricity.

Professor Smith has been affiliated with a number of professional organizations, including the Illinois Society of Professional Engineers, the International Association of Electrical Inspectors, and the National Academy of Code Administration. He is a life-long honorary member of the International Brotherhood of Electrical Workers. He gives frequent public lectures on the application of the *National Electrical Code*® and was a regular presenter at the University of Wisconsin Extension.

Delmar Publishers Is Your Electrical Book Source!

Whether you're a beginning student or a master electrician, Delmar Publishers has the right book for you. Our complete selection of proven best-sellers and all-new titles is designed to bring you the most up-to-date, technically accurate information available.

DC/AC THEORY

Electricity 1–4/Kubala-Alerich/Keljik

Electricity 1 Order # 0-8273-6574-8

Electricity 2 Order # 0-8273-6575-6

Electricity 3 Order # 0-8273-6594-2

Electricity 4 Order # 0-8273-6593-4

Delmar's Standard Textbook of Electricity—Revised Edition/Herman

This full-color, highly illustrated book sets the new standard with its comprehensive and up-to-date content, plus a complete teaching/learning package, including: Lab-Volt and “generic” lab manuals and transparencies.

Order # 0-8273-6849-6

CODE & CODE-BASED

1996 National Electrical Code®/NFPA

The standard for all electrical installations, the 1996 NEC® is now available from Delmar Publishers!

Order # 0-87765-402-6

Understanding the National Electrical Code®, 2E/Holt

This easy-to-use introduction to the NEC® helps you find your way around the NEC® and understand its very technical language. Based on the 1996 NEC®.

Order # 0-8273-6805-4

Illustrated Changes in the 1996 NEC®/O'Riley

Illustrated explanations of Code changes and how they affect a job help you learn and apply the changes in the 1996 NEC® more effectively and efficiently!

Order # 0-8273-6773-2

Interpreting the National Electrical Code®, 4E/Surbrook

This excellent book provides the more advanced students, journeyman electricians, and electrical inspectors with an understanding of NEC® provisions. Based on the 1996 NEC®.

Order # 0-8273-6803-8

Electrical Grounding, 4E/O'Riley

This illustrated and easy-to-understand book will help you understand the subject of electrical grounding and Article 250 of the 1996 NEC®.

Order # 0-8273-6657-4

WIRING

Electrical Wiring—Residential, 12E/Mullin

This best-selling book takes you through the wiring of a residence in compliance with the *1996 NEC*®. Complete with working drawings for a residence. *Order # 0-8273-6841-0 (SC) # 0-8273-6842-9 (HC)*

Smart House Wiring/Stauffer & Mullin

This unique book provides you with a complete explanation of the hardware and methods involved in wiring a house in accordance with the Smart House, L.P. system. *Order # 0-8273-5489-4*

Electrical Wiring—Commercial, 9E/Mullin & Smith

Learn to apply the *1996 NEC*® as you proceed step-by-step through the wiring of a commercial building. Complete with working drawings of a commercial building. *Order # 0-8273-6655-8*

Electrical Wiring—Industrial, 9E/Smith & Herman

Learn industrial wiring essentials based on the *1996 NEC*®. Complete with industrial building plans. *Order # 0-8273-6653-1*

Cables and Wiring/AVO Multi-Amp

Your comprehensive practical guide to all types of electrical cables. *Order # 0-8273-5460-6*

Raceways and Other Wiring Methods, 2E/Loyd

This excellent new edition provides you with complete information on metallic and nonmetallic raceways and other common wiring methods used by electricians and electrical designers.

Order # 0-8273-6659-0

Illustrated Electrical Calculations/Sanders

Your quick reference to all of the formulas and calculations electricians use.

Order # 0-8273-5462-2

Electrician's Formula and Reference Book/Holt

A concise and easy-to-use pocket reference that features up-to-date formulas for proper electrical calculations as they apply to any and all electrical installations. This handy pocket reference is a great companion to the NFPA's *National Electrical Code*® and any other electrical book.

Order # 0-8273-6961-1

MOTOR CONTROL

Electric Motor Control, 5E/Alerich

The standard for almost 30 years, this best-selling textbook explains how to connect electromagnetic and electric controllers. *Order # 0-8273-5250-6*

Industrial Motor Control, 3E/Herman

This text combines a solid explanation of theory with practical instructions and information on controlling industrial motors with magnetic and solid-state controllers. *Order # 0-8273-5252-2*

Electric Motors and Motor Controls/Keljick

This new book focuses on the hows and why behind all types of motors and controls. Special attention is given to why electrical systems work, thoroughly explaining the function and purpose behind all types of electric motors and controllers. *Order # 0-8273-6174-2*

EXAM PREPARATION

Journeyman Electrician's Review, 2E/Loyd

Order # 0-8273-6680-9

Master Electrician's Review, 2E/Loyd

Order # 0-8273-6678-7

Master Electrician's Preparation Exam/Holt

Order # 0-8273-7623-5

Journeyman's Exam Preparation/Holt

Order # 0-8273-7621-9

To request examination copies or a catalog of all our titles, call or write to:

Delmar Publishers

3 Columbia Circle

P.O. Box 15015

Albany, NY 12212-5015

Phone: 1-800-347-7707 • 1-518-464-3500 • FAX: 1-518-464-0301

ACKNOWLEDGMENTS

ELECTRICAL WIRING — COMMERCIAL, ninth edition, has been thoroughly reviewed and tested to ensure its accuracy and usefulness as a learning tool.

The authors also appreciate the contributions made by the following instructors who provided detailed reviews of the manuscript.

Larry A. Catron
Scott County Vocational Center
Eric David
Tennessee State Area Vocational-Technical School
Robert Hayden
Atlantic County Vocational Technical School

The authors would also like to thank Mel Sanders for his many contributions to the new edition of this text. His suggestions were very helpful in updating the text. Mr. Sanders teaches Code seminars in all areas of the country and contributes regularly to the *Electrical Construction and Maintenance* magazine and to the International Association of Electrical Inspectors.

The following companies provided technical information and figures used in the text.

American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.
Appleton Electrical Company, 1747 W. Wellington Avenue, Chicago, IL 60657.
Boltswitch, Inc., 6107 West Lou Avenue, Crystal Lake, IL 60014.
Bussmann Division, Cooper Industries, P.O. Box 14460, St. Louis, MO 63178-9977.
Canadian Standards Association, 178 Rexdale Blvd., Rexdale, Ontario, Canada, M9W 1R3.
Carlson Electrical Products, 25701 Science Park Drive, Cleveland, OH 44122.
Cutler Industries, Inc., 7425 Croname Road, Niles, IL 60648.
General Electric Co., 225 Service Avenue, Warwick, RI 02886.
Cooper Lighting, 400 Busse Road, Elk Grove Village, IL 60007.
Honeywell, Inc., Commercial Div., 2701 Fourth Ave. S., Minneapolis, MN 55408.
Harvey Hubbell, Inc., Wiring Device Div., P.O. Box 3999, Bridgeport, CT 06605.
Illuminating Engineering Society, 345 East 47th Street, New York, NY 10017.
International Association of Electrical Inspectors, 930 Busse Highway, Park Ridge, IL 60068.
Jefferson Electric Co., Div. Litton Industries, 840 South 25th Ave., Bellwood, IL 60104.
Juno Lighting, Inc., 2001 S. Mt. Prospect Road, Des Plaines, IL 60618.
Kurt Versen Company, 10 Charles Street, P.O. Box 677, Westwood, NJ 07675.
National Electrical Code, National Fire Protection Association, Batterymarch Park,
Quincy, MA 02269.
National Electrical Manufacturers Association, 2101 L Street NW, Washington, DC 20037.
Onan Division, Onan Corporation, 1400 73rd Ave. NE, Minneapolis, MN 55432.
Square D Co., Distribution Equip., Group Headquarters, 1601 Mercer Rd., Lexington,
KY 40505.
The Trane Co., 3600 Pammel Creek Rd., LaCrosse, WI 54601.
Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062.

CONTENTS

Preface	xi
Acknowledgments	xvii
Unit 1 COMMERCIAL BUILDING PLANS AND SPECIFICATIONS	1
Safety in the Workplace	1
Commercial Building Specifications (Overview)	2
Specification	2
Supplementary General Conditions	4
Commercial Building Plans	5
Codes and Organizations	11
NEC® Use of SI (Metric) Measurements	15
Unit 2 READING ELECTRICAL AND ARCHITECTURAL DRAWINGS (PRINTS) — DRUGSTORE	19
Prints	19
The Drugstore Prints	19
Unit 3 BRANCH CIRCUITS AND FEEDERS	24
Branch-Circuit Calculation	24
General Lighting Loads	26
Motor Loads (Appliances and Air-Conditioning and Refrigeration Equipment)	27
Other Loads	29
Loading Schedule	29
Branch Circuits	31
Determining Conductor Size and Type	31
Correction Factors for Ambient Temperature	33
Ampacity Adjustment for More Than Three Current-Carrying Conductors in a Raceway or Cable	33
Maximum Ampacity Check	35
Feeders	35
Overcurrent Protection and Circuit Rating	36
Introduction: Circuit Component Selection	37
Conductor Use Procedure	38
Conductor Selection Procedure	40
Voltage Drop	43
Determining Volt Loss	45
Energy Savings Considerations	46
Aluminum Conductors	47
Proper Installation Procedures	48

Unit 4	READING ELECTRICAL DRAWINGS — BAKERY	51
	Prints	51
	The Bakery Prints	51
Unit 5	SWITCHES AND RECEPTACLES	55
	Receptacles	55
	Hospital Grade Receptacles	59
	Electronic Equipment Receptacles	59
	Electronic Equipment Grounding	59
	Ground-Fault Circuit Interrupter Receptacles (<i>NEC® Section 210-8</i>)	62
	Receptacles in Electric Baseboard Heaters	62
	Snap Switches	62
	Switch and Receptacle Covers	69
Unit 6	BRANCH-CIRCUIT INSTALLATION	75
	Branch-Circuit Installation	75
	Rigid Metal Conduit (<i>NEC® Article 346</i>)	75
	Intermediate Metal Conduit	75
	Electrical Metallic Tubing (<i>NEC® Article 348</i>)	77
	Flexible Connections (<i>NEC® Articles 350 and 351</i>)	78
	Rigid Nonmetallic Conduit	80
	Raceway Sizing	82
	Special Considerations	84
	Box Styles and Sizing	84
	Selecting the Correct Size Box	87
	Raceway Support	91
Unit 7	MOTOR AND APPLIANCE CIRCUITS (BAKERY)	97
	Appliances (<i>NEC® Article 422</i>)	97
	The Exhaust Fan (Connected to a Lighting Branch Circuit)	98
	The Basics of Motor Circuits	99
	Conductors Supplying Several Motors	107
	Several Motors or Loads on One Branch-Circuit	107
	Several Motors on One Feeder	107
	Disconnecting Means	108
	Grounding	108
	Overcurrent Protection	108
	Typical Bakery Equipment	109
	The Doughnut Machine	110
	The Bake Oven	111
Unit 8	READING ELECTRICAL DRAWINGS — INSURANCE OFFICE	115
	Prints	115
	Loading Schedule	115
Unit 9	SPECIAL SYSTEMS	119
	Surface Metal Raceways (<i>NEC® Article 352</i>)	119
	Multioutlet Assemblies	120
	Communication Systems	122
	Floor Outlets	123
	Computer Room Circuits	126
Unit 10	READING ELECTRICAL DRAWINGS — BEAUTY SALON AND DOCTOR'S OFFICE	131

	Water Heater Circuits	131
	Panelboard Schedules	133
Unit 11	SPECIAL CIRCUITS (OWNER'S CIRCUITS)	138
	Loading Schedule	138
	Lighting Circuits	138
	Sump Pump Control	140
	Boiler Control	140
Unit 12	PANELBOARD SELECTION AND INSTALLATION	146
	Panelboards	146
	The Feeder	151
	Neutral Sizing (<i>NEC® Section 220-22</i>)	152
Unit 13	THE ELECTRIC SERVICE	159
	Liquid-Filled Transformers	159
	Dry-Type Transformers	159
	Transformer Overcurrent Protection	159
	Transformer Connections	160
	The Service Entrance	164
	Metering	166
	Service-Entrance Equipment	167
	Service Disconnecting Means	172
	Working Space Around the Main Switchboard	172
	Grounding	177
	Grounding Electrode Systems	179
	Ground-Fault Protection	186
	Safety in the Workplace	188
Unit 14	LAMPS FOR LIGHTING	193
	Lighting Terminology	193
	Incandescent Lamps	194
	Low-Voltage Incandescent Lamps	197
	Fluorescent Lamps	198
	High-Intensity Discharge Lamps (HID)	204
Unit 15	LUMINAIRES	207
	Definitions	207
	Installation	207
	Labeling	210
	Loading Allowance Computations	215
	Location of Luminaires in Clothes Closets	222
	Watts Per Square Foot Calculations	222
Unit 16	EMERGENCY POWER SYSTEMS	227
	Sources of Power (<i>NEC® Article 700, Part C</i>)	227
	Special Service Arrangements	227
	Emergency Generator Source [<i>Section 700-12(b)</i>]	227
Unit 17	OVERCURRENT PROTECTION: FUSES AND CIRCUIT BREAKERS . .	237
	Disconnect Switches	238
	Fuses and Circuit Breakers	238
	Types of Fuses	241
	Cartridge Fuses (<i>NEC® Article 240, Part F</i>)	244

	Testing Fuses	252
	Delta, Three-Phase, Grounded “B” Phase System	253
	Time-Current Characteristic Curves and Peak Let-Through Charts	255
	Circuit Breakers (<i>NEC® Article 240, Part G</i>)	260
	Series-Rated Equipment	265
	Current-Limiting Breakers	266
	Cost Considerations	266
	Motor Circuits	266
	HACR Circuit Breakers	267
Unit 18	SHORT-CIRCUIT CALCULATIONS AND COORDINATION OF OVERCURRENT PROTECTIVE DEVICES	271
	Short-Circuit Calculations	272
	Short-Circuit Current Variables	278
	Coordination of Overcurrent Protective Devices	280
	Single Phasing	285
Unit 19	EQUIPMENT AND CONDUCTOR SHORT-CIRCUIT PROTECTION	288
	Conductor Withstand Rating	289
	Conductor Heating	293
	Calculating an Insulated (75°C Thermoplastic) Conductor’s Short Time Withstand Rating	293
	Calculating a Bare Copper Conductor and/or its Bolted Short-Circuit Withstand Rating	295
	Calculating the Melting Point of a Copper Conductor	296
	Using Charts to Determine a Conductor’s Short Time Withstand Rating	296
	Magnetic Forces	297
	Tap Conductors	299
Unit 20	LOW-VOLTAGE REMOTE-CONTROL LIGHTING	302
	Low-Voltage Remote-Control Lighting	302
	Wiring Methods	304
Unit 21	THE COOLING SYSTEM	309
	Refrigeration	309
	Evaporator	310
	Compressor	310
	Condenser	311
	Expansion Valve	311
	Hermetic Compressors	312
	Cooling System Control	314
	Cooling System Installation	314
	Electrical Requirements for Air-Conditioning and Refrigeration Equipment	314
	Special Terminology	317
Appendix	325
	Electrical Specifications	325
	Heating and Air-Conditioning Specifications	328
	Plumbing Specifications	329
	Metric System of Measurement	330

Glossary	339
Code Reference Index.....	343
Index.....	347
Plans for a Commercial Building (Attached to the inside back cover):	
Sheet A1	Plot Plan, East Elevation, West Elevation
Sheet A2	Architectural Floor Plan: Basement
Sheet A3	Architectural Floor Plan: First Floor
Sheet A4	Architectural Floor Plan: Second Floor
Sheet A5	Elevations: North and South
Sheet A6	Sections: Longitudinal, Transverse
Sheet E1	Electrical Layout Drawing: Basement
Sheet E2	Electrical Layout Drawing: First Floor
Sheet E3	Electrical Layout Drawing: Second Floor
Sheet E4	Luminaire-Lamp Schedule, Electrical Symbol Schedule, Electrical Power Distribution Diagram, Detail of Typical Roof-Type Cooling System Unit, Panelboard Summary

UNIT 1

Commercial Building Plans and Specifications

OBJECTIVES

After studying this unit, the student will be able to

- 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 specification.
 - locate specific information on the building plans.
 - obtain information from industry-related organizations.
 - apply and interchange SI and English measurements.
-

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 is dangerous! Working on electrical equipment with the power turned on can result in death or serious injury, either as a direct result of electricity or from an indirect secondary reaction such as falling off a ladder or falling into 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 blast* that can cause deadly burns. The heat of an electrical arc has been determined to be hotter than the sun. Pressures developed during an arc blast can blow a person clear across the room. Dirt, debris, and moisture can also set the stage for catastrophic equipment failures and personal injury. Neatness and cleanliness in the workplace are a must.

The Federal Regulations in the Occupational

Safety and Health Act (OSHA) Number 29, Subpart S, in Part 1910.332 discusses the training needed for those who face a 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 delve into the OSHA requirements in great detail.

The *National Electrical Code*® defines a *qualified person* as “one familiar with the construction and operation of the equipment and the hazards involved.” Merely telling someone or being told “be careful” does not meet the definition of proper training, and does not make the person qualified.

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

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

Working on equipment “live” 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 nonflammable clothing, rubber gloves, protective shields and goggles, and in some cases, rubber blankets.

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 tagging” 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.

The National Fire Protection Association’s publications *Safety Related Work Practices* NFPA 70E and *Electrical Equipment Maintenance* NFPA 70B present much of the same material regarding electrical safety as do the OSHA regulations.

Safety cannot be compromised.

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

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

COMMERCIAL BUILDING SPECIFICATIONS (OVERVIEW)

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 affects the electrician; however, summaries of the other specification sections are presented to acquaint the electrician with the full scope of the document.

SPECIFICATION

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, titled *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
- Instruction to Bidders
- Proposal
- Agreement
- General Conditions

Some of these items will affect 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 and how it affects either the electrician on the job or the contractor.

Notice to Bidders. This item is of value to the contractor and his 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 if all the drawings required are at hand, the estimator to do a take-off and formulate a bid, and the electrician to determine if 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 upon 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: (a) the contractor completes the proposal properly, (b) the contractor does not forfeit the bid bond, (c) the owner accepts the proposal, and (d) 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 since 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. Once 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, this item defines the owner, contractor, architect, engineer, and other people and objects involved in the project.
- **Contract Documents:** a listing of 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:** materials used must be as specified or equivalent materials must be shown to have the required properties.
- **Shop Drawings:** this item identifies the drawings that must be submitted by the contractor to show how the specific pieces of equipment are to be installed.
- **Payments:** the method of paying the contractor during the construction is specified.
- **Coordination of Work:** each contractor on the job must cooperate with every other contractor to insure that the final product is complete and functional.