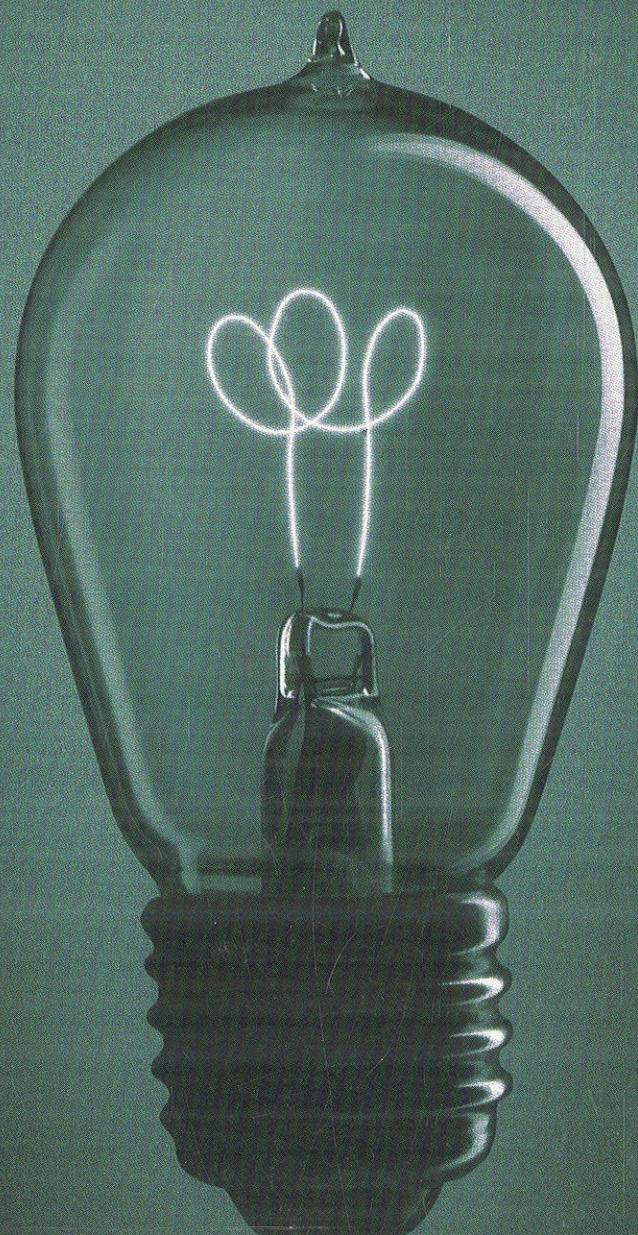


DELMAR
THOMSON LEARNING™

ELECTRICAL GROUNDING

BASED ON THE 2002
NATIONAL ELECTRICAL CODE®

6TH EDITION



Ronald P. O'Riley

CONTENTS

Preface	xi
List of NFPA Materials	xvii
Introduction	xix
Chapter 1 <i>ARTICLE 250, GROUNDING</i>	1
Overview of Article 250, <i>Grounding</i>	3
Definitions.....	6
Chapter 2 ELECTRICAL THEORY APPLICABLE TO GROUNDING....	14
Current Flow	14
The Electron.....	15
Ohm's Law.....	16
Direct Current	17
Series Circuit.....	17
Alternating Current.....	19
Impedance	21
Amps and Overcurrent Protective Devices	21
Parallel Circuit	22
Series-Parallel Circuit	23
Chapter 3 GROUNDING FOR SAFETY	24
Electric Shock	24
Potential Difference	26
Grounding and Electric Shock.....	27
Chapter 4 FAULTS	30
Types of Faults.....	31
Stresses Caused by Faults.....	32
Ionization	32
Grounded-System Faults.....	33
Impedance-Grounded Systems	35
Ungrounded System Faults.....	37
Ground Fault Detectors.....	39
Chapter 5 GROUNDING ELECTRODE SYSTEM	40
Grounding Theory.....	40
Responsibility of the Grounding Electrode	41
The Ground Rod	43
Grounding Electrode System.....	47
Metal Water Pipe Electrodes.....	48
Supplemental Electrodes.....	49
Building Steel as an Electrode.....	50

Concrete-Encased Electrodes	51
Ground Ring Electrodes	52
Rod and Pipe Electrodes.....	53
Plate Electrodes.....	53
Dwelling Unit Electrode	54
Summary	59
 Chapter 6 GROUNDING ELECTRODE CONDUCTOR	61
Definition of <i>Grounding Electrode Conductor</i>	62
Materials	63
Splicing	63
Installation and Protection	64
Connecting the Grounding Electrode Conductor	68
Sizing the DC Grounding Electrode Conductor.....	71
Sizing the AC Grounding Electrode Conductor	72
Sizing Grounding Electrode Conductors.....	74
Summary	80
 Chapter 7 CIRCUIT AND SYSTEM GROUNDING.....	82
Why Ground Circuits and Systems?.....	83
Definitions.....	83
Direct-Current Systems.....	85
Alternating-Current Systems	86
AC Systems Not Required to Be Grounded.....	91
High-Impedance Grounding	92
 Chapter 8 GROUNDED CONDUCTOR	97
Definition of <i>Grounded Conductor</i>	97
Grounded Conductor Connection in a Direct-Current System ...	98
Grounded Conductor Connection in an Alternating-Current System.....	98
Bringing the Grounded Conductor to Service	99
Sizing the Grounded Conductor	101
Installing the Grounded Conductor	105
System or Circuit Conductor to be Grounded.....	106
Identifying the Grounded Conductor.....	106
Grounded Conductor Overcurrent Protection.....	108
 Chapter 9 MAIN BONDING JUMPER	110
Definition of <i>Main Bonding Jumper</i>	111
Location of the Main Bonding Jumper.....	112
Materials for the Main Bonding Jumper	112
Connections.....	114
Sizing the Main Bonding Jumper	114
 Chapter 10 EQUIPMENT GROUNDING CONDUCTOR	122
Definition of <i>Equipment Grounding Conductor</i>	123
Definition of <i>System</i>	123
Definition of <i>Circuit</i>	125
Performance of Fault Current Path.....	126

Types of Equipment Grounding Conductors	127
Wire Used for Equipment Grounding Conductor.....	127
Identification of Equipment Grounding Conductor	128
Installation of Equipment Grounding Conductor	130
Raceways as Equipment Grounding Conductors	133
Earth as an Equipment Grounding Conductor	142
Equipment Grounding Conductor Connections	142
Equipment Grounding Conductor Continuity	143
Sizing Equipment Grounding Conductors.....	144
Equipment Grounding Conductor in Boxes	151
Agricultural Buildings	154
 Chapter 11 EQUIPMENT AND ENCLOSURE BONDING.....	156
Definitions.....	157
Materials	159
Connections.....	159
Bonding at Service Equipment	159
Sizing Bonding Jumpers on Supply Side of Service.....	165
Grounding Electrode Conductor Enclosure Bonding.....	173
Flexible Metal Conduit in Service-Entrance Raceway	174
Bonding Other Than at Service	174
Structural Bonding Steel.....	176
Sizing Load Side of Service Bonding Jumpers.....	178
Bonding Grounding Electrode Systems	180
Bonding Receptacles.....	183
Bonding Lightning Protection System	183
Establishing an Equipotential Plane in an Agricultural Building	184
Swimming Pool Bonding Grid	184
Summary	187
 Chapter 12 EQUIPMENT AND ENCLOSURE GROUNDING	188
Why Ground Metal Enclosures and Equipment?.....	188
Enclosure and Raceway Grounding	189
Part VI. Equipment Grounding.....	191
Methods of Grounding Enclosures and Equipment	197
Grounding Panelboards.....	198
Isolated Equipment Grounding Receptacles.....	200
Tower Grounding.....	204
Computer Grounding	204
 Chapter 13 GROUNDED CIRCUIT CONDUCTOR FOR GROUNDING EQUIPMENT	209
The Basic Rule.....	210
Supply-Side Use	210
Second Building.....	211
Separately Derived System.....	211
Load-Side Use.....	212
Summary	215

Chapter 14	GROUND-FAULT PROTECTIVE EQUIPMENT	216
	Ground-Fault Protection of Equipment	217
	Ground-Fault Protection Equipment Required at Service.....	218
	Ground-Fault Protection Equipment Required—Feeder	221
	Definition of <i>Ground-Fault Circuit Interrupter</i>	221
	Receptacles Requiring GFCI Protection.....	223
	Replacing Nongrounded Type Receptacles	224
	Arc Fault Circuit Interrupter (AFCI)	232
Chapter 15	SYSTEM AND CIRCUIT GROUNDING 1 kV AND OVER ...	234
	Neutral Grounded Systems	235
	Neutral Grounded Systems Required and Permitted.....	235
	Solidly Grounded Systems	237
	Impedance-Grounded Systems	238
	Equipment Grounding.....	239
Chapter 16	SEPARATELY DERIVED SYSTEMS.....	242
	Definition of <i>Separately Derived System</i>	242
	Bonding Jumper	245
	Grounding Electrode Conductor.....	246
	Grounding Electrode	247
	The Grounding Electrode Conductor	247
	Bonding at Separately Derived Systems	250
	Dedicated Five-Wire System	251
	Portable Generators.....	251
	Vehicle-Mounted Generators	251
Chapter 17	TWO OR MORE BUILDINGS SUPPLIED BY ONE SERVICE	254
	Disconnecting Means.....	255
	Grounded and Ungrounded Systems	255
	Second Building Grounding Electrode System.....	261
	Sizing the Grounding Electrode Conductor at the Second Building	261
	Sizing the Equipment Bonding Jumper at the Second Building	262
	Disconnecting Means at the Second Building.....	262
	No Disconnecting Means at the Second Building.....	263
	Agricultural Buildings	263
Chapter 18	CALCULATING FAULT CURRENTS AND GROUNDING CONDUCTOR WITHSTAND RATING	269
	Introduction.....	269
	Purpose of Grounding.....	270
	Short-Circuits and Ground Faults.....	271
	Protective-Device Terms.....	271
	Important Code Requirements	273
	Fault-Current Path.....	273

Available Fault Current.....	273
Factors Affecting Amount of Fault-Current	276
Transformer Secondary Current	276
Transformer Impedance	277
Other Factors Affecting Fault-Current Values	278
Point-to-Point Calculations.....	278
Fault-Current and Parallel Conductors	281
Combining Fuse and Circuit Breaker for Protection.....	282
Summary	283
Appendix	287
Index	295