Foreword

**Preface** 

Acknowledgments

Chapter 1. Hazards of Electricity

Introduction

**Hazard Analysis** 

Shock

Description

**Influencing Factors** 

Arc

**Definition and Description** 

Arc Energy Release

Arc Energy

Arc Energy Input

**Arcing Voltage** 

Arc Surface Area

**Incident Energy** 

Arc Burns

Blast

**Affected Body Parts** 

General

Skin

The Nervous System

Muscular System

The Heart

The Pulmonary System

Summary of Causes—Injury and Death

Shock Effect

Arc-Flash Effect

Causes of Injury

Causes of Death

**Protective Strategies** 

References

Chapter 2. Basic Physics of Electrical Hazards

Introduction

Electromagnetism

Introduction

The Four Fundamental Forces (Interactions) of Nature

The Electromagnetic Spectrum

**Electrical Properties of Materials** 

Conductors

Nonconductors

**Physics Considerations in Electrical Fault Conditions** 

Risks

**Bolted Fault** 

**Arcing Fault** 

Review of Foundational Approaches to Interpreting Arcing Phenomena

Summary

References

Chapter 3. Electrical Safety Equipment

Introduction

General Inspection and Testing Requirements for Electrical Safety Equipment

Arc-Flash and Thermal Protection

A Note on When to Use Thermal Protective Clothing

Thermal Performance Evaluation

**Clothing Materials** 

Non-Arc-Rated Materials

**Arc-Rated Materials** 

**Work Clothing** 

**Arc-Flash Suits** 

Head, Eye, and Hand Protection

Head and Eye Protection

**Hard Hats** 

Safety Glasses, Goggles, and Face Shields

**Rubber Insulating Equipment** 

**Rubber Gloves** 

**Rubber Mats** 

**Rubber Blankets** 

**Rubber Covers** 

Line Hose

**Rubber Sleeves** 

In-Service Inspection and Periodic Testing of Rubber Goods

**Hot Sticks** 

**Description and Application** 

When to Use

How to Use

**Testing Requirements** 

**Insulated Tools** 

**Description and Application** 

When to Use

How to Use and Care For

**Barriers and Signs** 

Barrier Tape

Signs

When and How to Use

Safety Tags, Locks, and Locking Devices

Safety Tags

Locks and Multiple-Lock Devices

**Locking Devices** 

When and Where to Use Lockout-Tagout

Voltage-Measuring Instruments

Safety Voltage Measurement

**Proximity Testers** 

**Contact Testers** 

Selecting Voltage-Measuring Instruments

**Instrument Condition** 

Low-Voltage Voltmeter Safety Standards

Three-Step Voltage Measurement Process

General Considerations for Low-Voltage Measuring Instruments

Safety Grounding Equipment

The Need for Safety Grounding

**Safety Grounding Switches** 

Safety Grounding Jumpers

**Selecting Safety Grounding Jumpers** 

Installation and Location

**Ground-Fault Circuit-Interrupters** 

**Operating Principles** 

**Applications** 

**Arc-Fault Circuit-Interrupters** 

Safety Electrical One-Line Diagram

The Electrician's Safety Kit

References

Chapter 4. Safety Procedures and Methods

Introduction

**Electrical Hazard Risk Assessments** 

Working While Exposed to Electrical Hazards

The Six-Step Safety Method

Think—Be Aware

**Understand Your Procedures** 

**Follow Your Procedures** 

Use Appropriate Safety Equipment

Ask If You Are Unsure, and Do Not Assume

Do Not Answer If You Do Not Know

Job Briefings

Definition

What Should Be Included?

When Should Job Briefings Be Held?

Energized or De-Energized?

The Fundamental Rules

A Hot-Work Decision Tree

After the Decision Is Made

Safe Switching of Power Systems

Introduction

**Remote Operation** 

Operating Medium-Voltage Switchgear

Operating Low-Voltage Switchgear

Operating Molded-Case Breakers and Panelboards

**Operating Enclosed Switches and Disconnects** 

**Operating Open-Air Disconnects** 

**Operating Motor Starters** 

**Energy Control Programs** 

**General Energy Control Programs** 

**Specific Energy Control Programs** 

**Basic Energy Control Rules** 

Lockout-Tagout

**Definition and Description** 

When to Use Locks and Tags

Locks without Tags or Tags without Locks

Rules for Using Locks and Tags

Responsibilities of Employees

Sequence

Lock and Tag Application

**Isolation Verification** 

Removal of Locks and Tags

**Safety Ground Application** 

**Control Transfer** 

Nonemployees and Contractors

**Lockout-Tagout Training** 

**Procedural Reviews** 

Voltage-Measurement Techniques

**Purpose** 

**Instrument Selection** 

Instrument Condition

**Three-Step Measurement Process** 

What to Measure

How to Measure

Placement of Safety Grounds

Safety Grounding Principles

Safety Grounding Location

**Application of Safety Grounds** 

The Equipotential Zone

Removal of Safety Grounds

**Control of Safety Grounds** 

Arc-Flash Hazard Calculations and Approach Distances

Introduction

**Approach Distance Definitions** 

**Determining Shock Hazard Approach Distances** 

Calculating the Arc-Flash Hazard Minimum Approach Distance (Arc-Flash Protection Boundary)

Calculating the Required Level of Arc Protection (Arc-Flash Hazard Calculations)

Introduction

The Lee Method

Methods Outlined in NFPA 70E

IEEE Std 1584-2018

**Software Solutions** 

Required PPE for Crossing the Arc-Flash Hazard Boundary

A Simplified Approach to the Selection of Protective Clothing

**Barriers and Warning Signs** 

Illumination

**Conductive Clothing and Materials** 

**Confined Work Spaces** 

**Tools and Test Equipment** 

General

**Authorized Users** 

**Visual Inspections** 

**Electrical Tests** 

Wet and Hazardous Environments

Field Marking of Potential Hazards

The One-Minute Safety Audit

References

Chapter 5. Grounding and Bonding of Electrical Systems and Equipment

Introduction

**Electric Shock Hazard** 

General Requirements for Grounding and Bonding

**Grounding of Electrical Systems** 

**Grounding of Electrical Equipment** 

Bonding of Electrically Conductive Materials and Other Equipment

Performance of Fault Path

Arrangement to Prevent Objectionable Current

Alterations to Stop Objectionable Current

Temporary Currents Not Classified as Objectionable Current

Connection of Grounding and Bonding Equipment

**Protection of Ground Clamps and Fittings** 

Clean Surfaces

**System Grounding** 

**Purposes of System Grounding** 

**Grounding Service-Supplied Alternating-Current Systems** 

Conductors to Be Grounded—Alternating-Current Systems

Main Bonding Jumper

**Grounding Electrode System** 

**Grounding Electrode System Resistance** 

**Grounding Electrode Conductor** 

**Grounding Conductor Connection to Electrodes** 

Bonding

**Equipment Grounding** 

Equipment to Be Grounded

Grounding Cord- and Plug-Connected Equipment

**Equipment Grounding Conductors** 

Sizing Equipment Grounding Conductors

Use of Grounded Circuit Conductor for Grounding Equipment

Ferroresonance

Summary

Chapter 6. Electrical Maintenance and Its Relationship to Safety

Introduction

The Safety-Related Case for Electrical Maintenance

Overview

Regulatory

Relationship of Improperly Maintained Electrical Equipment to the Hazards of Electricity

Maintenance and the Potential Impact on an Electrical Arc-Flash

Hazards Associated with Electrical Maintenance

The Economic Case for Electrical Maintenance

Reliability-Centered Maintenance (RCM)

What Is Reliability-Centered Maintenance?

A Brief History of RCM

RCM in the Industrial and Utility Arena

The Primary RCM Principles

Failure

Maintenance Actions in an RCM Program

Impact of RCM on a Facilities Life Cycle

Conclusion

The Eight-Step Maintenance Program

Introduction

Step 1—Plan

Step 2—Inspect

Step 3—Clean

Step 4—Tighten

Step 5—Lubricate

Step 6—Test

Step 7—Record

Step 8—Evaluate

Summary

Frequency of Maintenance

**Determining Testing Intervals** 

Condition-Based Maintenance (CBM)

Introduction

The Elements of CBM

Data Analysis Methods for CBM

Maintenance Requirements for Specific Equipment and Locations

**General Maintenance Requirements** 

Substations, Switchgear, Panelboards, Motor Control Centers, and Disconnect Switches

**Fuse Maintenance Requirements** 

Molded-Case Circuit Breakers

Low-Voltage Power Circuit Breakers

Medium-Voltage Circuit Breakers

**Protective Relays** 

**Rotating Equipment** 

Portable Electric Tools and Equipment

Personal Safety and Protective Equipment

Electrical Safety by Design

Introduction

Including Safety in Engineering Design Criteria

**Improved Engineering Standards** 

Conclusion

References

Chapter 7. Regulatory and Legal Safety Requirements and Standards

Introduction

The Regulatory Bodies

International Electrotechnical Commission (IEC)

American National Standards Institute (ANSI)

Institute of Electrical and Electronics Engineers (IEEE)

National Fire Protection Association (NFPA)

American Society for Testing and Materials (ASTM)

American Society of Safety Engineers (ASSE)

Occupational Safety and Health Administration (OSHA)

Other Electrical Safety Organizations

The National Electrical Safety Code (NESC)—IEEE C-2

**General Description** 

**Industries and Facilities Covered** 

Technical and Safety Items Covered

The National Electrical Code (NEC)—NFPA 70

**General Description** 

Industries and Facilities Covered

Technical and Safety Items Covered

Electrical Equipment Maintenance—NFPA 70B

**General Description** 

Industries and Facilities Covered

Technical and Safety Items Covered

Standard for Electrical Safety in the Workplace—NFPA 70E

**General Description** 

**Industries and Facilities Covered** 

Technical and Safety Items Covered

American Society for Testing and Materials (ASTM) Standards

Occupational Safety and Health Administration (OSHA) Standards

Overview

**General Industry** 

**Construction Industry** 

Chapter 8. Accident Prevention, Accident Investigation, Rescue, and First Aid

Introduction

**Accident Prevention** 

**Individual Responsibility** 

**Installation Safety** 

**Power System Studies** 

First Aid

General First Aid

Resuscitation (Artificial Respiration)

**Heart-Lung Resuscitation** 

Automated External Defibrillator (AED)

How an AED Works

When Should an AED Be Used?

How to Use an Automated External Defibrillator

What Risks Are Associated with Using an Automated External Defibrillator?

Key Points about Automated External Defibrillators

**Rescue Techniques** 

**General Rescue Procedures** 

**Elevated Rescue** 

Confined-Space Rescue

**Ground-Level Rescue** 

**Accident Investigation** 

**Purpose** 

**General Rules** 

**Data Gathering** 

**Accident Analysis** 

Chapter 9. Medical Aspects of Electrical Trauma

Introduction

**Statistical Survey** 

Nonoccupational Electrical Trauma

**Electrical Events** 

**Electrocution and Electrical Fatalities** 

**Medical Aspects** 

Nonelectrical Effects in Electrical Events

**Survivor Experience** 

**Worker Reflexes** 

Triage and Medical Evacuation

Medical and Surgical Intervention

**Hospitalization Experience** 

**Outpatient Care** 

Rehabilitation Focus and Return to Work Planning

**Reentry to Employment Settings** 

Plateau in Recovery

References

Chapter 10. Low-Voltage Safety Synopsis

Introduction

Low-Voltage Equipment

**Extension Cords** 

**Electric Hand Tools** 

**Current Transformers** 

**Grounding Low-Voltage Systems** 

What Is a Ground?

**Bonding versus Grounding** 

Voltage Hazards

**System Grounds** 

**Equipment Grounds** 

**Ground-Fault Circuit Interrupters** 

**Arc-Fault Circuit Interrupters** 

Safety Equipment

Overview

**Hard Hats** 

**Eye Protection** 

**Arc Protection** 

**Rubber Insulating Equipment** 

**Voltage-Testing Devices** 

Safety Procedures

General

**Approach Distances** 

Voltage Measurement

**Locking and Tagging** 

Closing Protective Devices After Operation

**Electrical Safety Around Electronic Circuits** 

The Nature of the Hazard

**Special Safety Precautions** 

Stationary Battery Safety

Introduction

**Basic Battery Construction** 

Safety Hazards of Stationary Batteries

**Battery Safety Procedures** 

Electrical Hazards of the Home-Based Business

Electrical Hazards in the Home

Working Alone

Working with Employees

**Evaluating Electrical Safety** 

**Electrical Safety Checklists** 

**Electrical Inspections by Professionals** 

Chapter 11. Medium- and High-Voltage Safety Synopsis

Introduction

High-Voltage Equipment

**Current Transformers** 

Grounding Systems of over 1000 V

What Is a Ground?

**Bonding versus Grounding** 

Voltage Hazards

**System Grounds** 

**Equipment Grounds** 

Safety Equipment

Overview

**Hard Hats** 

**Eye Protection** 

Arc Protection

**Rubber Insulating Equipment** 

**Voltage-Testing Devices** 

**Safety Procedures** 

General

**Approach Distances** 

Voltage Measurement

**Locking and Tagging** 

Closing Protective Devices after Operation

Chapter 12. Human Factors in Electrical Safety

Introduction

Overview

Defense in Depth

**Evolution of Human Factors** 

Visualization

**Cognitive Ergonomics** 

Summary

References

**Recommended Readings** 

Chapter 13. Safety Management and Organizational Structure

Introduction

Changing the Safety Culture

**Electrical Safety Program Structure** 

**Electrical Safety Program Development** 

Company Electrical Safety Team

**Company Safety Policy** 

Assessing the Need

**Problems and Solutions** 

Program Implementation

**Examples** 

**Company Safety Procedures** 

**Results Assessment** 

**Employee Electrical Safety Teams** 

Reason

Method

Safety Meetings

Who Attends

What Material Should Be Covered

When Meetings Should Be Held

Where Meetings Should Be Held

How Long Meetings Should Be

**Evaluation of Safety Meetings** 

**Outage Reports** 

Safety Audits

Description

Purposes

Procedure

The Audit Team

**Audit Tools** 

Follow-Up

Internal versus External Audits

Chapter 14. Safety Training Methods and Systems

Introduction

**Safety Training Definitions** 

**Training Myths** 

Conclusion

Comparison of the Four Most Commonly Used Methods of Adult Training

Introduction

**Classroom Presentation** 

Computer-Based Training (CBT) and Web-Based Training (WBT)

Video Training

Conclusion

**Elements of a Good Training Program** 

**Element 1: Classroom Training** 

Element 2: On-the-Job Training (OJT)

Element 3: Self-Training

Conclusion

On-the-Job Training

Setup

Implementation

Evaluation

Conclusion

**Training Consultants and Vendors** 

**Canned Programs and Materials** 

**Tailored Programs** 

**Training Analysis** 

**Evaluating Training Vendors and Consultants** 

Conclusion

Training Program Setup—A Step-by-Step Method

Introduction

Background

A Plan

Analyze

Design

Develop

Implement

Evaluate

Modify

Glossary

Index