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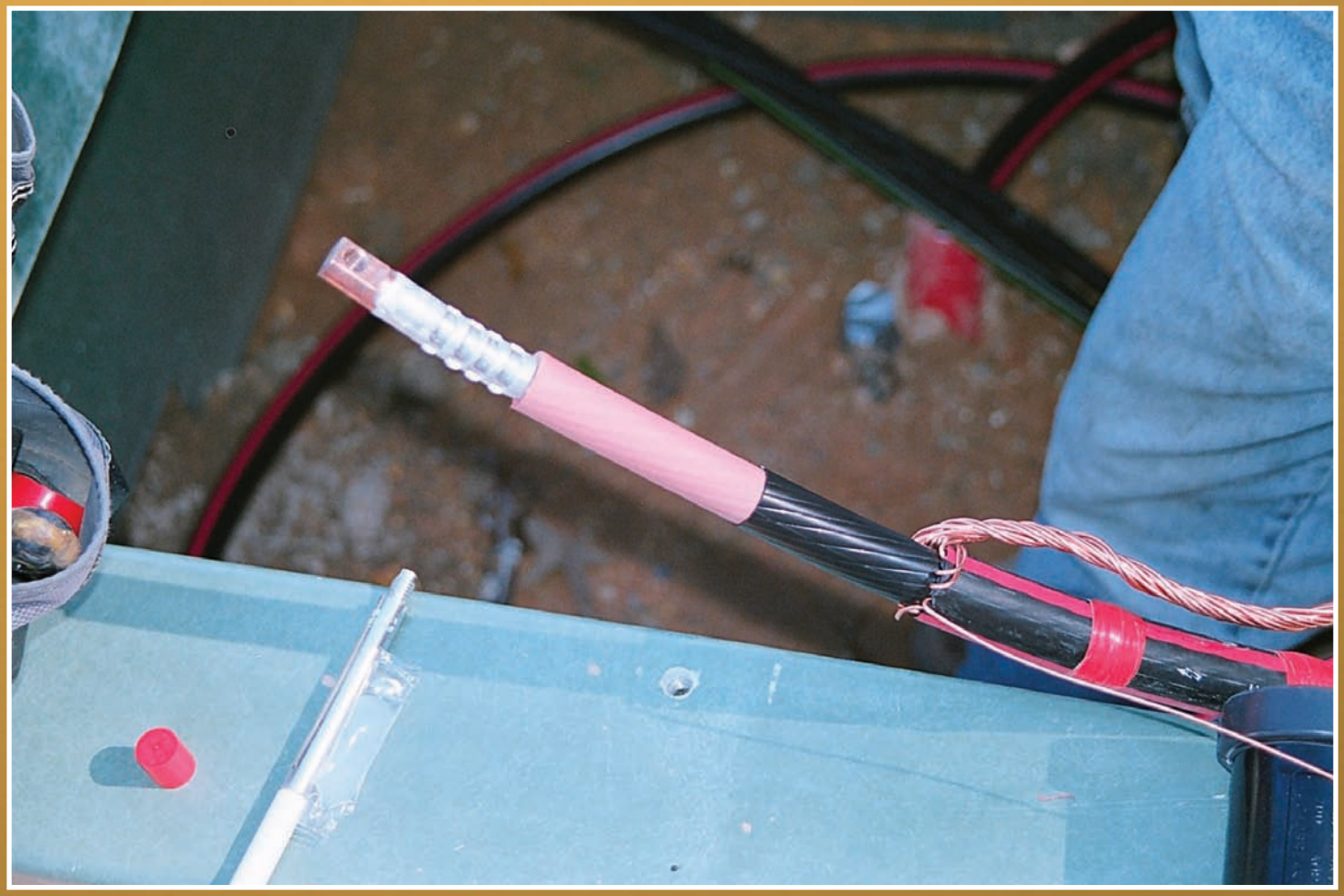
EPRI Underground Distribution Systems Reference Book



EPRI Underground Distribution Systems Reference Book

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Technical Update, December 2006

EPRI Project Manager

M. Olearczyk

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

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CITATIONS

Portions of this document prepared by:

RTI Group, LLC
910 Bestgate Road
Annapolis, MD 21401

Principal Investigator
J. Reynolds

Electric Power Research Institute (EPRI)
1300 W.T. Harris Blvd.
Charlotte, NC 28262

Principal Investigator
M. Olearczyk

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ABSTRACT

EPRI is sponsoring the development of a first edition of the *Underground Distribution Systems Reference Book.* The first volume will be published in 2008 and join the EPRI colored book series and become commonly known throughout the industry as "the EPRI Brown Book."

In 1931, the first definitive treatise had been published as the Underground Systems Reference Book by the National Electric Light Association. As operating voltages and load demands increased after the Second World War, changes were then driven by technical improvements of insulating materials and protection devices to increase the reliability of service. At the same time, the need for the optimization of safety and aesthetics drove distribution systems underground with a designed life expectancy of 40 years. The original industry reference noted above was revised by the Edison Electric Institute in 1957. Unknown to the designers of those early underground distribution systems; customer demand would exceed their projections, the weather phenomenon of what was coined as a "heat storm" would occur repeatedly at the turn of the 21st century, with no signs of reversal, and the utilities would be deregulated, experience more frequent operational disruptions, and witness the loss of its experienced staff.

It is well appreciated that each utility is unique and that its distribution systems must reflect the requirements of its customers. However, all utilities share the same customer demands and technical resources, and indeed the same type of equipment and cables, hence the same problems. This has become a very serious reliability and maintainability issue for all distributions power utilities now operating in a deregulated industry.

EPRI is very aware of this dilemma from its members and the industry as a whole.

EPRI intends to provide a definitive reference book from the best sources of current information and thinking for the benefit of those now responsible and future caretakers of underground distribution systems. The final deliverable publication is being written as a training tool for new engineers, operators and planners, as well as a reference manual for experienced personnel. Publication and release of this document is currently scheduled for December 2008.

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INTRODUCTION

EPRI is sponsoring the development of a first edition of the *Underground Distribution Systems Reference Book.* The plan is to publish the reference book in 2008 and add it to the EPRI colored book series commonly known throughout the industry. This publication will be called the EPRI Brown Book. There have been significant changes in both technology and the needs of utilities since the last relevant publication on this topic. This project will compile the most up-to-date technical information on underground distribution systems. The main thrust this year was to complete a comprehensive and detailed historical background review on relevant industry publications to identify a meaningful and appropriate "Table of Contents" for the Brown Book publication. Effort was also directed to developing a production approach to create the first edition of the book based on a 2008 completion schedule.

Utility companies that own and operate underground distribution systems face a number of challenges. They must reduce costs, improve system reliability, increase power throughput, and ensure health and safety. At the same time, many of these companies are losing their core of experienced cable engineers. The Edison Electric Institute published several underground distribution industry reference books in the past which have provided underground distribution companies with a valuable tool for meeting these challenges. The EEI books provide a desk and field compendium on the general principles involved in the planning, design, manufacture, installation design, installation, testing, operation, and maintenance of underground cable systems. The books were written by leading utility and industry experts, and represent practices from all parts of the United States. However, despite the value and popularity of the EEI books, elements of the books' content have become increasingly outdated, and do not reflect the latest developments in technology and utility practices. Furthermore, the EEI books were last updated in 1957 and no other body of work is available for utilities today. EPRI intends to bridge this gap with the Brown Book. The Brown Book will join as another in a series of landmark EPRI reference "colored" books published for the industry. The EPRI reference colored books—on topics such as overhead line transmission, underground transmission, wind-induced conductor motion, and compact line design—brought together leading experts to compile state-of-science information on the design, construction, and maintenance of these systems.

The EPRI Brown Book will compile a wealth of information, however, it is not intended to provide an exhaustive treatment of all subjects associated with underground distribution systems; more detail is available in the references cited in the book. Instead the book will serve as a handy reference guide, compiling a large amount of information in one place.

The book will also serve as basis for training new distribution engineers in underground distribution systems. When used in conjunction with in-house training, it enables new engineers to come up to speed more quickly, thereby saving time and money.

Objectives and Approach

The goal of the EPRI *Underground Distribution Systems Reference Book* will be to document the latest information on underground distribution theory and practice, and to ensure the functionality and ease-of-use of the book.

The approach to publish the *Underground Distribution Systems Reference Book* is as follows.

- **Historical Review Stage.** In 2006, EPRI selected industry experts to review the most relevant underground distribution reference books and determine what materials were still relevant and what updating and changes are needed to the existing available content and what new information needs to be added. The reviewers were chosen to review particular references based on their knowledge and experience in specific aspects of underground distribution systems. The review identified changes required, missing information, errors, dated information, etc. This stage was completed at end 2006 and follows in Chapter 2.

- **Macro-Review Stage.** In early 2007, EPRI will convene a meeting of the reviewers—together with the EPRI *Underground Distribution Systems Reference Book* Working Group and EPRI staff—to present and debate the content and make-up of the proposed chapters derived from the Historical Review Stage. The meeting is intended as a first step to develop a consensus on the scope and scale of the initial chapters, a final table of contents for the book, content and scope of new chapters, new information to be provided across chapters, and the level of effort needed. The meeting is also intended to begin identification of experts interested in writing and reviewing the new edition.

- **Chapter Production Stage.** A Statement of Work has been developed for revision of existing reference books and production of new materials, and contract offers will be issued to selected prospective authors and reviewers. Teams of one to three experts, depending on the chapter, will be hired to write the chapters. The start date for writing is March 2007. One or more meetings of writing teams and project advisors will be held during 2007 to discuss issues arising in the writing and to review drafts. In addition, periodic teleconferences will be held during the year to review progress and share results among the writing teams. A technical writer has been retained and assigned to the project to help with the drafting and layout of each chapter. The current schedule calls for writing of half the book to be complete by 2007, and for the publishing stage to be complete by the end of 2008.

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HISTORICAL PERSPECTIVE

The history of electric power distribution systems in the United States indicates that they were first designed, constructed and operated by the Edison Companies to serve urban areas of major cities about 100 years ago. Overhead installations became commonplace by the First World War and underground installations were limited. By 1931 the first definitive treatise had been published as the Underground Systems Reference Book by the National Electric Light Association. As operating voltages and load demands increased after the Second World War, changes were then driven by technical improvements of insulating materials and protection devices to increase the reliability of service. At the same time, the need for the optimization of safety and aesthetics drove distribution systems underground with a designed life expectancy of 40 years. The original industry reference noted above was revised by the Edison Electric Institute in 1957. Unknown to the designers of those early underground distribution systems; customer demand would exceed their projections, the weather phenomenon of what was coined as a "heat storm" would occur repeatedly at the turn of the 21st century, with no signs of reversal, and the utilities would be deregulated, experience more frequent operational disruptions, and witness the loss of its experienced staff.

Most notably, since 1990 there have been an increasing number of underground distribution system failures resulting in large blackouts lasting days. With the current level of knowledge it is clear that these outages will most likely continue and perhaps accelerate if proper measures are not taken to improve service reliability. It is well appreciated that each utility is unique and that its distribution systems must reflect the requirements of its customers. However, all utilities share the same customer demands and technical resources, and indeed the same type of equipment and cables, hence the same problems. This has become a very serious reliability and maintainability issue for all distributions power utilities now operating in a deregulated industry. EPRI is very aware of this dilemma from its members and the industry as a whole. At this point in time the brain trust for all the experience and knowledge related to the existing underground power distribution systems has been depleted by most utilities due to attrition and downsizing, and some underground equipment manufacturers no longer exist. To help remedy this situation for its members, and the industry as a whole, EPRI intends to provide a definitive reference book from the best sources of current information and thinking for the benefit of those now in charge and future caretakers of underground distribution systems. The final deliverable publication is being written as a training tool for new engineers, operators and planners, as well as a reference manual for experienced personnel. Publication and release of this document is currently scheduled for December 2008.

The history of electric power distribution systems has been understandably driven by that of its lifeline of power delivery, the electric cable. The nature of the electrical insulation employed in medium voltage distribution cables has changed dramatically over the years. Today, the major insulation materials used are either tree-retardant crosslinked polyethylene (TR-XLPE) or ethylene-propylene rubber (EPR). Prior to this, many different insulation types were used by utilities.

First efforts to achieve insulations for underground application were focused on telegraph lines in the early to mid 1800s. These early efforts applied a variety of materials available at the time, and were designed to protect the metallic component. As summarized in the 1931 Underground Systems Reference book, materials employed in those early days included India rubber, glass sealed in wax (in a creosote-containing wood trough), cotton saturated with shellac or rosin, jute saturated in pitch (tar) covered with India rubber strips, and cotton or jute in lead-filled tubes filled with rosin or beeswax. None of these approaches, as might be assumed with today's knowledge, were satisfactory. By the mid-1800s, gutta percha was used and was found to be susceptible to oxidation over time. Edison's early work in lower Manhattan in the late 1800s, which focused on low voltage power distribution, employed gutta percha but it softened at elevated temperatures (apparently not an issue for the telegraph lines). Further approaches employed copper rods wrapped in jute and covered with bitumen in a pipe. Eventually, the concept changed as it was realized that a better approach was to apply a superior covering to the conductor itself, for best insulation and moisture resistance properties. Paper was applied helically around the conductor and saturated in rosin-based oil, and placed in a lead pipe. The construction is similar to that being used today for PILC cables. Paper-insulated lead covered (PILC) cables were first employed for distribution voltages at the beginning of the 20th century. By the early 1930s, three types of insulations dominated the distribution cable system (a) natural rubber (simply referred to as 'rubber' as synthetic rubbers had not yet been developed), (b) varnished cambric (woven cotton cloth coated with varnish and with a moisture repellent material between the layers), and (c) oil-impregnated paper. The natural rubber was compounded with (~40%) fillers to achieve mechanical strength (much like today's EPRs). However, oil-impregnated paper was favored due to its lower cost and superior high temperature resistance.

Of interest also in reviewing the almost 80 year old literature (1931 handbook) is how lessons of that day still apply today (and have either been forgotten or not emphasized adequately). For example it is stated "Any unqualified statement about breakdown strength of a piece of cable is meaningless. Any statement about breakdown strength must be accompanied by qualification as to frequency, time of application and rate of raising voltage etc. if it is to have any significance". Use of the term 'meaningless' is pretty strong language. This is a lesson that applies equally well today regardless of the advances in insulation materials, shields, jackets, and manufacturing technology and total distribution system designs.

As noted, small quantities of PILC are still used today, but the market has been overshadowed by use of synthetic polymers. Butyl rubber was the first synthetic polymeric elastomer to be used, and this was later replaced by EPR (late 1950s-early 1960s). EPR had maintained a constant share of the market until the early 1980s when its use started to increase. Polyethylene (PE) was developed prior to World War 2, and its application as an insulation material became immediately apparent due to its low dielectric constant, low power factor, and high dielectric strength. It was initially used for communication cables. PE was demonstrated to be resistant to water transmission, had high dielectric strength, low dissipation factor and was easier to handle (install and maintain) than paper-insulated cables. Among other things, it allowed for the elimination of a lead sheath. In the 1960s it rapidly replaced PILC for utility use at distribution voltages. It was used for low voltages (600V to 46 kV). Most installations to this time were overhead, but during the Johnson administration in the mid-1960s, a move accelerated to 'beautify' the landscape/environment, and high molecular weight polyethylene (HMWPE) insulated cables were installed underground and direct buried. Unlike today, these cables were unjacketed.

By the early 1970s it was becoming apparent the PE-insulated cables were failing much sooner than their projected (40 year) life; although HMWPE had excellent resistant to moisture transmission, when applied as insulation and operating under applied voltage stress, water did indeed penetrate into the insulation and induced a slow but steady degradation process called 'water treeing'. This slow degradation process led to a reduction in the dielectric strength and eventually to premature failures. Laboratory work had demonstrated that XLPE was more resistant to water treeing than HMWPE; it became available as a substitute for HMWPE in the late 1960s-early 1970s, and resistance to water treeing in service aged cables did indeed improve. XLPE gradually became accepted as replacement insulation for HMWPE. Nevertheless, over time, XLPE insulation was also demonstrated to be susceptible to water treeing. In the 1970s, jackets were coming into use more often in underground cables (to reduce water penetration) on primary cable constructions and, while jackets did assist in extending the life of the extruded cables, their use did not prevent premature failures. Different polymeric materials were used for jackets; e.g., low, medium or high density polyethylene or polyvinyl chloride, and each possessed a different degree of resistance to water penetration. It was later demonstrated that XLPE-insulated cables of the same construction survived longer with a superior jacket, or if installed in ducts. It perhaps should be noted that even though the nature of the insulation employed for new cables improved, the utilities still had significant quantities of the older insulated cables installed. When a failure occurred and the failed section removed, it often became necessary to splice older constructions to newer (improved) constructions. The need for improvements advanced on several fronts in the late 70s-late 80s. The search for means to keep water out of the insulation led to changes in the manufacturing process, it had been common to produce XLPE-insulated cables by inducing crosslinking via steam processing in a catenary tube (followed by cooling in a water trough). It was felt that water could be introduced into the construction in that manner. A move away from steam curing to dry curing took place.

The nature of the shield materials gained more attention also, and it was learned that the commonly used insulation and conductor shield materials were processed in such a manner that they retained ions in the carbon black compounds employed during extrusion. It had previously been shown that ions were contaminants and were water treeing sites; the concern now was that the ions would be migrating into the insulation during normal operation. Suppliers began to modify the manufacturing process to prevent ions from being present. Alternate grades of carbon black were also introduced. Thus the approaches employed were to find better ways to keep water out or, if water entered, prevent the water from inducing migration of ionic contaminants into the insulation. XLPE held the major share of the market into the mid-1980s.

However, a major improvement came with the introduction of TRXLPE insulation in the mid-1980s. Laboratory work, and later field installed cables, demonstrated that TRXLPE was superior to XLPE in preventing water treeing. [Tree retardant properties were generated by incorporating several additives into XLPE; that subject goes beyond the scope of this Chapter] The use of TRXLPE began to grow and steadily replaced XLPE (regardless of shield nature or processing technology). TRXLPE today possesses a major share of the medium voltage market. Note that this approach accepts that some water will enter the insulation and the concept involves technology to mitigate its influence. While these developments were taking place, the use of EPR remained steady at first, but then began to slowly grow. The slow but steady increase in the use of EPR took place throughout the 1980s and 1990s.

By the mid-1990s, EPR usage 'challenged' TRXLPE for the major market share, which exists to this day. As EPR usage has grown, it is necessary to provide some clarification of the term 'EPR'. While XLPE is a single material, and while there may be two or three TRXLPE grades on the market, there is no single EPR compound on the market that is employed by utilities. 'EPR' itself is one of several possible polymer systems that are compounded with 10-20 different ingredients to render it functional as insulation for cables. (TRXLPE is a single polymer type, and has about three to five additives.) In addition, the fact that there is a significant amount of inorganic materials present (mostly special clays) in EPRs to provide the toughness (yet flexibility) needed. Caution should therefore be exercised in referring to 'EPR'. For further information comparing TRXLPE and EPRs, references should be reviewed.

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EVALUATION METHODOLGY

The methodology for the evaluation as to relevancy of selected publications of interest included the following six industry reference books:

1. 1931 Underground Systems Reference Book, National Electric and Light Assn
2. 1957 Underground Systems Reference Book, Edison Electric Institute
3. ABB Distribution Handbook, fifth edition
4. 1993 Underground Distribution System Design and Installation Guide, NRECA
5. 2003 EPRI Report 1001890, Fundamentals of Forensic Investigation Procedures Guidebook
6. 2003 Electrical Power Cable Engineering , Ed by W.A.Thue, 2nd Edition

The review process began with a scan of all documents. Then the books were reviewed in the order noted above. The 1931 book and, more pointedly, the 1957 book required most time. When the latter was reviewed, it was determined that much of the information in the1931 book was superseded by the 1957 volume. Nevertheless (it was concluded) the 1931 book did have some key information to be offered. This was so noted in the evaluation chart. However, both of those books were considered to possess severe limitations in that information on extruded cable systems was missing or minimal (not surprising as those systems did not come into usage until the 1960s).

Hence cable, joint and termination technology approaches have changed dramatically. Regardless, the PILC information included and discussed there is relevant today, as many IOUs continue to purchase and employ PILC cables.

Future analysis for this effort will separate the transmission cable discussions that are often woven in with the distribution voltage cable systems. The ABB book was found /determined to have many chapters not considered of relevance, and was ‘quickest’ to rank the chapters/subjects.

The NRECA book has much useful information and received high grades. The EPRI Forensics Investigation Guidebook possessed a surprising amount of useful information, which almost completely falls under the category of 'diagnostics'; i.e., how the user should consider proceeding after distribution system equipment fails. The Thue book applies only to cables; as it was developed for the University of Wisconsin course on Power Cable Engineering. It was not intended to be a book on Distribution Systems. However, the concepts therein can be applied to broader Distribution Handbook needs. Several additional EPRI reports were scanned, but input from these was not incorporated into the Draft Table of Contents, as of this date.

To strengthen the material evaluation actitivity a criteria matrix was used by the expert reviewer panel. Each publication was carefully reviewed and ranked using the matrix. The tables of contents for the six publications of interest were listed and ranked by five criteria. This enabled the expert panel to flesh out the proposed table of contents backed by a quantitative process. The review panel members were encouraged to provide additional comments and identify gaps. The following guidelines were provided to the publications-of-interest reviewers for defining the relevancy of specific sections of text:

Very Relevant – Having high current and future bearing to fully understanding key aspects of Underground Systems; crucially noteworthy or significantly important details with regards to the knowledge of Underground Systems; extremely useful information to prevent the reinvention of wheels.

Relevant – Pertinent and germane information that relates fully and has a direct bearing to understand and operate current Underground Systems.

Partially Relevant – Material that is to a degree, but not totally, relevant and will require editing.

Basics that are Relevant – Look for tutorials or foundational reviews of basic scientific knowledge or fundamental engineering principles and discoveries necessary to understand the technology applied to Underground Systems. This selection criterion is in addition to the three grading levels above.

Not Relevant – These materials were considered and deleted for reason. The content is not applicable to present and future Underground Systems; it may be obsolete and is not important to understanding existing or future systems, equipment and materials.

The results of this effort can be found in Appendix A, Proposed Table of Contents.

4
PROJECT PLANS

Progress was made in 2006 on defining the scope and direction of the *Underground Distribution Systems Reference Book* and in identifying those who will participate in writing and reviewing the book.

Production Launch Workshop

EPRI plans a production launch workshop in early 2007 (location TBD), to discuss the *Underground Distribution Systems Reference Book*. Attendees will include industry experts who had been retained to review chapters. Also participating in the meeting will be EPRI staff and members of the *Underground Distribution Systems Reference Book* Working Group, which consists of utility advisors responsible for guiding the review and rewriting of the book. The purpose of the meeting is to refine and clarify the mission statement for the book—which will further define the audience, level of understanding, and the kind of book to be developed—and to discuss revision of each chapter. Chapters will be discussed one by one, for each chapter; the expert who had reviewed the chapter will make a brief formal presentation, followed by debate and discussion among the group as a whole. One to three hours is planned for each chapter. It's expected that the meeting will result in consensus on the work plan for 2007 and each chapter, including its content and level of effort, will be determined. It's also expected that agreement on new information and chapters will be added to the book.

Following the workshop Statements of Work and contract "offers" will be developed and sent to selected authors and reviewers in early 2007. However, funding for 2007 will determine the scale and scope of work for prospective authors and reviewers.

A number of utility advisors expressed interest in having an electronic version of the *Underground Distribution Systems Reference Book.* In addition, participants have indicated the need for focused training using the *Underground Distribution Systems Reference Book* as text for course and continuing education units. EPRI intends to explore these requests and, if feasible, deliver the volume in electronic media and offer training using the reference as a textbook.

5
PRODUCTION

Utility advisors agreed on the general approach to identification of new chapters and or the revision of each existing chapter, and the organization and table of contents for the new edition would be based largely on the results of the historical review.

General Approach to Production

The general approach to production of the Underground Distribution Reference book includes the following:

- **Audience.** The audience for the update will be utility personnel (primarily underground distribution engineers) and consultants.
- **Purpose.** The book will be an advanced explanatory guide and a ready desk and field reference.
- **International.** The primary focus of the book will be North American designs and practices, but international technologies and methods will be added as needed.
- **Length.** The length of the book is yet to be determined.
- **Level of Information.** The book will not include fundamental derivations and tables.
- **Value judgments.** Value judgments unsupported by facts are to be avoided. The approach should be to state the facts or to define the factors.
- **Chapter Structure.** In each chapter, information that is common to all will be consolidated at the beginning of the chapter. Information on differing issues will be presented after that.
- **Author Recognition Page.** Each chapter will begin with an Author Recognition page, which will consist of a single page having the name, affiliation, contact information, picture and brief bio of each author of that chapter.
- **Figures.** The book will include many new and updated pictures and graphics.
- **Applets.** The book will not be accompanied by “applets,” which are simple software applications.

A
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20.7 Stray Voltage Checks

20.8 Relaying

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20.10 Microprocessors

20.11 Distribution Automation SCADA

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21.1 Splicing

21.2 Terminations

21.3 Elbows

21.4 Salvage of Lead and PCB's

21.5 Safety

22. Safety

22.1 PPE and Arc Deflection and Blast Suppression Blankets

22.2 OSHA 1910.269 & .335

22.3 ASTM 10.03

22.4 NESC

B
PUBLICATIONS REVIEWED

Publications Reviewed

	PUBLICATION TITLES	VERY Relevant (X)	RELEVANT (X)	PARTIALLY Relevant (X)	BASICS Relevant (X)	NOT Relevant (X)	Attach Comments on Separate Page (record line reference as below) EX: A. III. 2.
Underground Systems Reference Book, National Electric Light Association, 1931							
I.	INTRODUCTION						
II.	CABLE AND CABLE INSULATION						
	1. Introduction						
	2. Cable Design						
	3. Theory of Dielectrics						
	4. Characteristics of Paper Insulated Cables and Their Significance						
	5. Specifications						
	6. Acceptance Inspection and Testing of Cables						
	7. Research Activities Paper Insulated Cable						
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III.	CONDUIT AND MANHOLES						
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	4. Arrangement and Support of Cable in Manholes						
	5. Installation of Buried Cable						
	6. Installation of Aerial Cable						
	7. Installation of Submarine Cable						
	8. Installation of Cable in Shafts and Tunnels						
	9. Fireproofing of Cables and Duct Entrance Protection						
	10. Bonding						
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	APPENDIX I. GENERAL INFORMATION						

	PUBLICATION TITLES	VERY Relevant (X)	RELEVANT (X)	PARTIALLY Relevant (X)	BASICS Relevant (X)	NOT Relevant (X)	Attach Comments on Separate Page (record line reference as below) EX: A. III. 2.
Underground Systems Reference Book, Edison Electric Institute, 1957							
I.	APPLICATIONS FOR CABLE AND CABLE SYSTEMS						
	1. Factors Governing Adoption of Underground Construction						
	2. Types of Transmission and Distribution Systems						
	3. Selection of Type of Cable System and Cable						
	4. Economic Studies						
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	d) High-Pressure Gas Systems, Specific Features						
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	c) Medium-Pressure Gas-Filled Systems, Specific Features						
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	7. First Aid, Resuscitation and Rescue						

	PUBLICATION TITLES	VERY Relevant (X)	RELEVANT (X)	PARTIALLY Relevant (X)	BASICS Relevant (X)	NOT Relevant (X)	Attach Comments on Separate Page (record line reference as below) EX: A. III. 2.
	ABB (1997), Fifth Edition, Thirteenth Printing						
I.	General Considerations of Transmission						
II.	Symmetrical Components						
III.	Characteristics of Aerial Lines						
IV.	Electrical Characteristics of Cables						
V.	Power Transformers and Reactors						
VI.	Machine Characteristics						
VII.	Excitation Systems						
VIII.	Application of Capacitors to Power Systems						
IX.	Regulation and Losses of Transmission Lines						
X.	Steady-State Performance of Systems						
XI.	Including Methods of Network Solutions						
XII.	Relay and Circuit Breaker Application						
XIII.	Power-Line Carrier Application						
XIV.	Power-System Stability						
XV.	Power-System Voltages and Currents During Abnormal Conditions						
XVI.	Wave Propagation on Transmission Lines						
XVII.	Lightning Phenomena						
XVIII	Line Design Based on Direct Strokes						
XIX.	Insulation Coordination						
XX.	Grounding of Power-System Neutrals						
XXI.	Distribution System						
XXII.	Primary and Secondary Network Distribution Systems						
XXIII.	Lamp Flicker on Power Systems						
XXIV	Coordination of Power and Communication Systems						
XXV.	Characteristics of Distribution Loads						

	PUBLICATION TITLES	VERY Relevant (X)	RELEVANT (X)	PARTIALLY Relevant (X)	BASICS Relevant (X)	NOT Relevant (X)	Attach Comments on Separate Page (record line reference as below) EX: A. III. 2.
	Underground Distribution System Design and Installation Guide, National Rural Electric Cooperative Association, 1993						
I.	DESIGN OF AN UNDERGROUND DISTRIBUTION SYSTEM						
	1. System Components						
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	4. Ferroresonance When Switching at the Primary Terminals of Overhead and Underground Transformer Banks						
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	with Grounded-Wye Primary Winding and Five-Legged Core						
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	Electrical Power Cable Engineering, Edited By W. A. Thue						
I.	Historical Perspective of Electrical Cables						
II.	Basic Dielectric Theory of Cables						
III.	Conductors						
IV.	Cable Characteristics; Electrical						
V.	Electrical Insulation Materials						
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XXIV	Glossary						
	Other Materials Reviewed						
I.	**UG Cable Fault Location - TD 153 (1976)**						
I.	**Surge Behavior of UD Systems - EL-720 (1978)**						
I.	**Surge Characteristics of Distribution Transformers - EL-3385 (1984)**						
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C
SAMPLE STATEMENT OF WORK FOR AUTHORS AND REVIEWERS

ATTACHMENT A
STATEMENT OF WORK
PROJECT AGREEMENT
Insert EPRI Contractor Number
Insert Contractor Name Here

"Chapter Author(s) for the EPRI Underground Distribution Systems Reference Book"

Introduction & Background

EPRI is presently engaged, through its collaborative membership program, in a project to publish the EPRI Underground Distribution Systems Reference Book (will commonly be referred to in the Industry as the "Brown Book"). The intention is to issue a first volume edition of the Brown Book in 2008.

Special Notice on Author Recognition

Each chapter of the Book will begin with an Author Recognition page. This will consist of a single page having the name, affiliation, contact information, picture and brief bio of each author of that chapter. EPRI views this opportunity for authors and their companies to freely advertise their technical expertise as a substantial part of the total compensation package being negotiated in this contract.

Scope of Work/Task Descriptions

The Contractor, working together with other team members as assigned by EPRI, shall draft and complete the assigned chapter or section as outlined in the Table below.

Version Chap. No.	Chapter Title (Section)	Version Chap. No.	Est. No. of Pages	Anticipated Other Authors	No. of Mtgs
AUTHOR:					

The Table correlates the New Chapter No. with the new chapter number, if applicable. In some cases the New Chapter consists of only part of one or older version chapters.

In cases where Contractor is being asked to share the work effort with another author in a different organization, that author's name and company are shown in the Table. Unless otherwise indicated, the total work for the chapter shall be divided equally among all authors shown in the Table, including the Contractor. Thus, for example, if a chapter is estimated to require 28 pages and one other author is shown in the Table, then the Contractor would be responsible for the equivalent of 14 pages and the other Author 14 pages. In cases where one or more additional team members are assigned to the same chapter, the Contractor shall be responsible to work with the other team member(s) to come up with an equitable distribution of effort. This agreed-upon distribution of effort shall be documented in a formal letter to EPRI, signed by all team members, and submitted to EPRI prior to beginning any work. In the event that changes in the work distribution or assignments agreed upon become necessary during the work, these shall be mutually agreed by all team members and by EPRI. The Contractor shall carry out the work in accordance with the detailed revision and/or scope requirements set forth, including the number of pages and number of new or revised figures. The scope of this contract includes the following tasks; (1) Preparation of work plan and content outline, (2) Preparation of draft, (3) Preparation of final, and (4) Attendance at review meetings.

Task 1: Preparation of Work Plan and Content Outline

The Contractor, working with its team (if applicable), shall thoroughly study the project plans documents. For the specific chapter(s) assigned, the Contractor shall then note the pertinent information and re-write requirements documented. The Contractor shall also review the *Authors Guide*, which documents the requirements for writing the assigned chapter. Questions as to expected content shall be addressed early in the project rather than later, and shall be directed to the EPRI Project Manager for resolution. From this review the Contractor team shall prepare and submit to EPRI two documents:

1. An annotated outline of proposed content for the chapter showing major sections, number of (two-column) pages per section, number of figures and tables per section, and a brief description of section content.

2. A Statement of distribution of effort among team members (if applicable), and identification of the chapter Lead Author. The Lead Author shall be the principal contact with EPRI with respect to questions about chapter content, etc.

The distribution of effort items shall be indicated on the annotated outline as well.

Task 2: Preparation of First Draft

The Contractor, working with its team (if applicable), shall prepare a First Draft of the chapter using Microsoft Word, version 2000 or later (Word 2003 preferred). This draft shall follow the formatting and other guidelines established in the Author's Guide. The content of the draft shall be essentially that envisioned during the Macro-Review stage, as documented in the Minutes. Questions as to content or apparent contradictions shall be directed immediately to the EPRI Project Manager for clarification. Many of the chapters will contain cross-references to other chapters and/or will rely on material developed by other chapter teams. The historical review documents many of these cross-references and content dependencies. Periodic teleconferences and/or review meetings will assist Contractor in communicating with other chapter teams to promote proper cross-referencing and content harmonization. In addition, the Contractor shall actively communicate by email or telephone with other chapter teams to ensure proper coordination among chapters. Some chapters will contain detailed discussions of one or more "Core Topics." However, in any given chapter discussion involving a reference to core topic material in another chapter, specific application or elaboration of the core topic chapter material shall be made as needed and as appropriate. The First Draft shall be fully complete as to all content, including figures, tables, and equations, unless otherwise approved by EPRI. The First Draft shall be submitted to EPRI electronically by uploading to EPRI's dedicated FTP site. At the time of posting to the FTP site the Contractor shall notify both EPRI's Publication Editor and the EPRI Project Manager of the posting. The First Draft will be provided to Reviewers for the review process. EPRI's Publication Editor will be responsible for coordinating reviews and review comment incorporation. Each reviewer's commented version will be posted on the FTP site and the Contractor notified. Reviewers may either mark up the draft using Word's tracking feature, or may draft a detailed review memo, or both. All Reviewer comments will be posted to the FTP site.

Task 3: Preparation of Final

The Contractor shall take the lead in resolving all the review comments to its work. The use of email and telephone is encouraged in this process. The Contractor shall keep both the EPRI Project Manager and the Publications Editor apprised of any problems arising during this process. It shall be the Contractor's responsibility to notify EPRI if its committed delivery schedule is negatively impacted by difficulties in the review process (e.g., slowness of response from the Reviewer). After all review comments are received and resolved, and a consensus achieved as to content among the Contractor team, EPRI, and Reviewers, the Contractor shall prepare the Final Draft for Copyedit, which will revise the text for spelling, punctuation, grammar, and adherence to the style guidelines (see Author's Guide). The copyedited chapter will be posted back on the FTP site for review and approval by the authors before proceeding.

The Contractor shall review and resolve changes from copyediting, and post the chapter back on the FTP site. The production team will lay out chapters in a two-column page format. Pages will be modeled on the format and look of EPRI's *AC Transmission Line Reference Book, 200 kV*

and Above (Red Book). For review by authors, the book will be converted to Adobe Acrobat 7.0 (commonly known as PDF files). Authors can open and review these files using the Acrobat Reader, which is available free at www.adobe.com. Important: Substantive revisions to chapters should be made BEFORE layout—as much as possible. Once the book is in layout, changes are more time consuming. (Compression ratio: The laid-out pages reduce the chapter page counts by about half.)

Task 4: Attendance at Review Meetings

This task involves both face to face review meetings with other chapter authors and reviewers, and periodic teleconferences. Con tractor shall attend one or more, 2 to 3-day review meetings, during 2007 in accordance with the number of meetings shown in the Table in the SOW. It is EPRI's intention to pay for all meals and lodging for these meetings. EPRI will reimburse travel costs (airplane, train, automobile) and any un-reimbursed meals and lodging costs for attendance at these meetings, by means of a separately submitted travel expense report. These Contractor expenses are not included in the fixed price for this contract. The Contractor must obtain EPRI approval in advance for its travel arrangements for which it expects reimbursement and shall submit a standard EPRI expense report form together with original receipts for all expenses over $25.

Deliverables

Task 1: Outline and Distribution of Effort

Task 2: First Draft of Chapter

Task 3: Delivery to EPRI of Final Draft for Copy-Edit

Task 4: Review of Final Formatted Chapter

Task 5: Attendance at Review Meetings and Teleconferences

Sample Schedule

Task Description	**Completion Date**
Task 1: Outline and Distribution of Effort	1 month after Award
Task 2: First Draft of Chapter	4 months after Award
Task 3: Delivery to EPRI of Final Draft for Copy-Edit	6 months after Award
Task 4: Review of Final Formatted Chapter	8 months after Award
Task 5: Review Meetings	(Tentative)

D
AUTHOR'S GUIDE

EPRI Underground Distribution Systems Reference Book (Brown Book)

December 2006

Contents

Figures

Introduction

This Author's Guide is designed to provide guidelines for authors to follow in the writing of chapters of the *Brown Book.* These guidelines will help to ensure that the completed book has a consistency and uniformity of presentation and style.

Sources

The guidelines are based on several sources—including the EPRI Editorial Style Guide, the 1992 edition of the Green Book, and the EPRI *AC Transmission Line Reference Book, 200 kV and Above* (Red Book).

Production Process

The production process is designed to be easy for authors to use, and to require no additional purchase of software for writing or review. The production will take place in five steps (see Figure 1):

First Drafts

First drafts are written by authors or author-teams. First drafts should not be submitted for production until the entire chapter is complete and the draft has been reviewed and approved by all members of the chapter team.

Technical Review

Once the first draft is complete, post a copy on the FTP site for Technical Review. The reviewer(s) may draft a detailed review memo. Alternately, reviewers may also choose to comment on and suggest revisions using the "Track Changes" mode in Microsoft Word (Tools, Track Changes). Authors will review these suggestions and accept or reject these changes using Track Changes to produce a clean manuscript.

Copyedit

Once you have reviewed and resolved changes from the Technical Review, post the chapter on the FTP site for copyediting. Copyediting will revise the text for spelling, punctuation, grammar, and adherence to the style guidelines. The copyedit will be made in the Track Changes mode. The copyedited chapter will be posted back on the FTP site for review and approval by the authors before proceeding. There will be two files of the chapter—labeled "Markup" and "Clean." The "Markup" files will show the editorial changes in Track Changes. The "Clean" files will show the changes accepted. Please make your comments in the "Clean" files.

Layout

Once you have reviewed and resolved changes from copyediting, post the chapter back on the FTP site. The production team will lay out chapters in a two-column page format. Pages will be modeled on the format and look of EPRI's *AC Transmission Line Reference Book, 200 kV and Above* (Red Book). For review by authors, the book will be converted to Adobe Acrobat 7.0 (commonly known as PDF files). Authors can open and review these files using the Acrobat Reader, which is available free at www.adobe.com. Important: Substantive revisions to chapters should be made BEFORE layout—as much as possible. Once the book is in layout, changes are

more time consuming. (Compression ratio: The laid-out pages reduce the chapter page counts by about half.)

Publication

Once the page layout has been laid out and approved by authors, the book will be published.

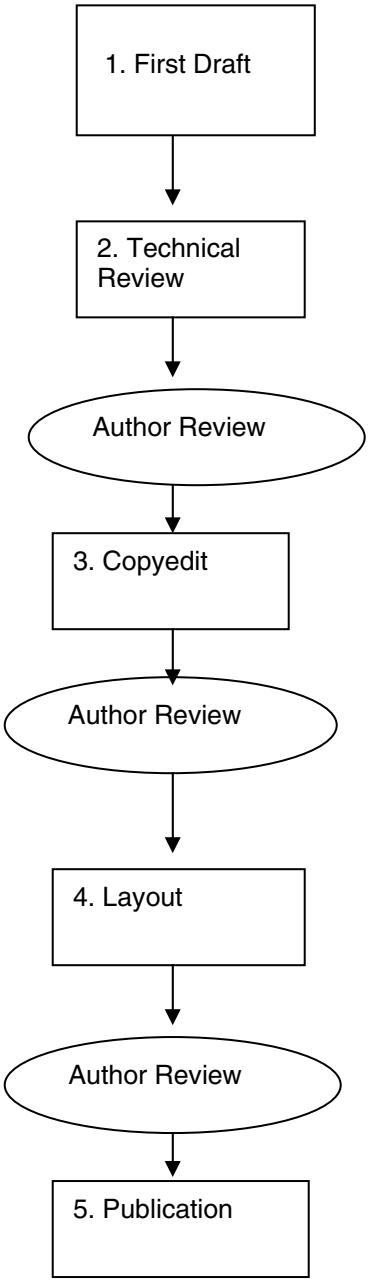

Figure 1. Production Process

How to Set Up Files

When writing first drafts, please use the following guidelines for creating your files:

Text

Write files in Microsoft Word. Drafts should be in 12 point type, Times New Roman, single-spaced, in one column, with 1-inch margins. For new paragraphs, do not indent first line. Just do a double return between paragraphs. Include all text, tables, equations, and figures in the file.

Equations

Write equations in Microsoft Equation 3.0.

Figures—Graphs and Photographs

Important: If graphs or photos are created in any other program than Word, PowerPoint or Excel, please go to File, Save As. Then save files as .tif, .jpg, or .bmp format and insert that figure in the document. (.tif is preferable.)

If you include figures in Excel, supply the original spreadsheet. Annotate graphs. Label parts of the graph. Do not use legends. If necessary, hand-drawn figures may be submitted to EPRI to be drawn. Use the font Helvetica for wording in figures, if possible. Do not use the font Arial; it may lose or change characters during production. If you are using existing figures from the second edition that already in Arial and are difficult to change, leave as is. For photos, use a version as close to the original as possible.

Index

Make an alphabetical list of key words and their section location for an Index.

Glossary

Add important terms and definitions from your chapter to the "rolling" glossary on the FTP site.

Completed Files

Post completed files on the FTP site in the folder for your chapter.

If your completed chapter is large (more than a few MB), please post it in separate section files. This will create files that are more manageable for others to handle.

Format: Headings

For consistency, all chapters should have the same style of main headings and subheadings. There are four levels of headings, as shown below.

Main Heading

One-Decimal Number, All Capital Letters, Boldface

Example: **3.3 INSULATION**

First Subheading

Two-Decimal Number, Capital and Lowercase Letters, Boldface

Example: **3.3.1 Crosslinked Polyethylene**

Second Subheading

Capital and Lowercase Letters, Boldface and Italic

Example: ***Thermal Properties***

Third Subheading

Capital and Lowercase Letters, Italic

Example: *Thermal Expansion*

Format: Tables and Figures

Tables and figures should be numbered with the number of the subsection in which they appear. That is, the first table in Subsection 2.2 would be Table 2.2-1. The first figure in Subsection 2.2 would be Figure 2.2-1.

Tables

Table titles should be initial capped. Example: **Table 3.3-27** Typical Physical Properties of EPR-Insulated HV Cables. Table titles appear above tables. Table footnotes are superscript numbers.

Figures

Figure captions should be first-word-only capped and with a period at the end. Example: **Figure 3.3-17** Specific heat of crosslinked polyethylene insulation. Figure captions appear below figures. Photographs are considered figures.

Format: Equations

Equations should be written using Microsoft Equation 3.0, which is available free with Microsoft Word. (To access it, go to Insert, Object, and select Equation 3.0.) Equations should be numbered to the right of the equation, using the same system as for tables and figures. Example, the third equation in Section 3.4 would be 3.4-3. If equations are long, they may need to be broken in the layout. Please indicate where they can broken. When identifying symbols in an equation, put them in a vertical list, not run-in on one line.

SI Units and English Measures

Wherever reasonable, use the International System of Units (SI), with the English Units following in parentheses. Please note: If existing tables or figures use English units, leave as is. If conversion to SI units is difficult, leave as is. English units may be used, but SI units are preferred.

SI Base Units

Quantity	**Name**	**Symbol**
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K

SI Derived Units

Derived Quantity	**Name**	**Symbol**
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
density, mass density	kilogram per cubic meter	kg/m^3
specific volume	cubic meter per kilogram	m^3/kg
speed	kilometer per hour or meter per second	km/hr, m/s
moment of inertia	meter to fourth power	m^4
weight	newton	N
mass/unit length	kilogram per meter	kg/m
weight/unit length	newton/meter	N/m
Young's modulus	pascal	Pa

SI Derived Units with Special Names and Symbols

Derived Quantity	**Name**	**Symbol**
frequency	hertz	Hz
force	newton	N
pressure, stress	pascal	Pa
energy, work, quantity of heat	joule	J
power	watt	W
electric charge	coulomb	C
electric potential difference	volt	V
electric resistance	ohm	Ω
inductance	henry	H
Celsius temperature	Degree Celsius	°C

Usage
Periods are not ordinarily used with abbreviations for units of measure (e.g., m, s, kg). One exception is the abbreviation for inch (in.). When it stands alone (e.g., 6 in.), it should have a period so that it is not confused with the preposition "in". When used with an exponent (in^2) or as part of a compound unit of measure (in/s), the period is omitted.

For more information, see the 1995 edition of the *Guide for the Use of the International System of Units (SI),* NIST Special Publication 811, which is available on the web at http://physics.nist.gov/cuu/pdf/sp811.pdf. Or, see the 2001 edition of *The International System of Units (SI),* NIST Special Publication 330, which is available on the web at http://physics.nist.gov/Pubs/SP330/sp330.pdf.

Writing Principles
Authors should keep in mind a number of general principles to ensure the clarity and uniformity of the book.
Introduction
Each chapter should begin with a brief (5-10 paragraphs) introduction. The introduction should describe the scope of the chapter and its context within the book. It may describe the topic's significance and changing attitudes/approaches toward it. In addition, it should provide a quick "roadmap" to the main sections included within the chapter.
Flow
When writing your chapter, be sure the information is developed logically from section to section and within each section. Be aware of the number of sections: Is it within the average of other chapters? Avoid overly long or overly short sections. If you list three topics at the start of a section, discuss them in that order.
Depth
Present information in an appropriate level of detail. Avoid drilling down too deeply in one area and covering another too shallowly. Be aware of total page count, which will be discussed prior to the start of writing: Are you within the expected range?
Tone
Emulate the tone of other chapters and use clear, declarative sentences.
Appendices
Present data, figures, and other detailed information, which would clutter the main text, in appendices.

Language Guidelines
Guidelines for language should follow the *EPRI Editorial Style Guide*, which is at: http://www.epri.com/corporate/discover_epri/epri_facts/reportspecs/styleguide.html.

Specific guidelines are as follows:

Numbers

Use numerals:

- For all numbers 10 and above.

- In tables and figures.
- With units of measure (5 Hz, 12°C)
- With percentages (67%)

Use words to express:

- All numbers zero through nine in text (e.g., "Acetylene blacks have the disadvantage of being two to three times as costly as furnace blacks.")

A zero is ordinarily used before a decimal point: 0.01%

Percentages
Use %, not percent.

Hyphens
Hyphenate compound adjectives containing units of measure and time.

- a 7.3-m (24-ft) room
  a 2.54-cm (1-in.) diameter pipe
  a 3-m pole

In almost all cases, hyphenate high- and low- adjectival compounds.

- high-voltage distribution

Parallelism
Be aware of parallelism. E.g., if you create a bulleted list in which most lines begin with a verb, start all lines with a verb.

Length
Avoid overly long sentences and paragraphs. Clarity is usually improved by shortening.

Periods/Spaces
Use a single space—not a double space—after the period at the end of a sentence.

Units Spacing
Follow IEEE style. Put one space between number and unit. E.g., 21.1 Hz.

Abbreviations
Follow IEEE spelling. E.g., ac, dc

Page Breaks
In first drafts, do not pay attention to page breaks. Do not worry if tables break over two pages. These breaks will be fixed in page layout.

References
References should be cited using the "author-date" method. The advantages of this system are that it avoids the need to track and revise footnote numbers, and it provides the reference information in the text.

In text, to cite a source, write the author's last name and the date of publication in parentheses. For example: (Whitehead 1951). Two or more authors would be written as: (McMahon and Perkins 1963). If there are more than two authors, use et al. (Silver et al. 1950). If the author has more than one work in one year, use letters to distinguish (Cookson 1950a). If the author is an organization, include enough of the name to enable a reader to locate it in the end-of-chapter list. For example: (IEEE Working Group 1978). If you wish to specify a page number, put that after the date. For example: (Mason 1950, p. 1163).

Citations should be inserted within the sentence as close as possible to the point being referenced. At the end of the chapter, provide a list of references alphabetized by the author's last name. If there is no author, alphabetize by the citation's title. See examples below for the correct format.

Only reference publicly available documents.

Bibliography
If desired, include a Bibliography separate from the References. It should include all major seminal works.

Website References
Website references may be used. In text, include a recognizable short form of the URL. At the end of the chapter, include the full URL.

Reference List Style
Book, One Author
Loeb, L. B. 1965. *Electrical Coronas*. Berkeley, California: University Press. p. 348.

Scientific Journal, One Author
Garton, C. G. 1941. "Dielectric Loss in Thin Films of Insulating Liquids." *Journal of IEE. Vol. 88. Part 2. pp. 103-120.*

Scientific Journal, Multiple Authors
Crine, J. P., S. Pelissou, and H. St. Onge. 1987. "Elemental and Ionic Impurities in Cable Insulation and Shields." *JICABLE.* Paris. September. pp. 206-213.

Conference Paper
Constantinov, T. E. 1964. "Dielectric Materials Measurement and Applications." IEE Conference. London.

Publication, No Author Listed
Allied Chemical Company. 1976. "Sulfur Hexafluoride." Specialty Chemicals Division. Brochure SFBR1. Morristown, New Jersey.

Index
When submitting your chapter, create an alphabetical list of key words and section numbers. This will be merged with lists from other chapters.

Key words in the index will be spelled in adherence with the spelling of the *IEEE Dictionary of Standards Terms*.

Glossary
A glossary, with important terms and definitions, will be developed by the production team for the book. A "rolling glossary" will be maintained on the FTP site. Add your terms and definitions to this glossary. Terms in the glossary will be spelled and defined in adherence with the spelling and definitions of the *IEEE Dictionary of Standards Terms*.

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Lessons Learned from Production of EPRI Red Book

- **Transferring Files/FTP Site.** The FTP site worked well for exchanging files, and enabled team members to avoid attempting to email large files back and forth.

- **Review Process.** Both methods—inserting comments/suggested changes in Track Changes mode and extended reviewer memos—were effective methods of review. Several reviewers chose to do both.

- **Editing Process.** Editing documents in Track Changes and using "markup" and "clean" files worked well. This method allowed authors to see edits and then see the document with the edits accepted.

- **Authors Guide and Style Sheet.** The Author's Guide and Style Sheet helped to establish consistent "ground rules" for the large author team (22 writers) to follow. Much discussion among the team members was necessary to find agreement on consistent use of mathematical symbols.

- **Figures.** For the most part, figures were received from authors in a form that was acceptable in terms of clarity and resolution. In some cases, figures had to be redrawn. Due to the large volume of figures included in the book, the team did not insist on consistency in the typeface and size of words and symbols used in the art.

- **Layout Design.** The design of the page layout generally was appropriate to the subject matter, and allowed the substantial increase in overall text length for the book without sacrificing readability. In some cases, exceptions had to be made to the two-column format in order to accommodate very long equations and extended bulleted lists.

- **Compression Ratio.** The compression ratio—from draft Word files to two-column page layout format—was about 2:1. This varied slightly, depending on the type size and margins used by authors, but it was a good rough estimate.

- **Use of Framemaker for Layout.** The software used for page layout, Adobe Framemaker, proved very flexible for the layout. It easily handled very large files, allowed quick revisions, and in most cases was very compatible with Word and graphics files.

- **Greek Symbols.** In some cases, Greek symbols did not transfer from the Word file to the Framemaker layout file and had to be manually rewritten. This required careful proofreading and vigilance by the production editor and authors.

- **Index.** Compilation of the index proceeded smoothly. Use of section numbers, rather than page numbers, allowed the index to be completed during writing, rather than waiting for the final layout.

- **Copyright Permissions.** EPRI obtained permissions to use all reproduced figures, photos, and tables. In all, there were nearly 100 items reproduced from 27 different sources. EPRI

pays an annual subscription fee to the Copyright Clearance Center (CCC), which provides automatic copyright permissions for publications of CCC member organizations (which include IEEE and many major publishers). CCC was able to clear about one-third of required permissions. The process of obtaining the remaining permissions was time consuming.

Terms

Bibliography. List of documents (books, articles, and websites) related to the subject. (See "References.")

Copyediting. Revision of text to correct spelling and grammar, and to ensure consistency of style, format, and usage.

English Units. Units of measure commonly used in North America (e.g., feet, pounds, miles).

Page Layout. Placement of the text, tables, and figures on pages in a consistent design, with specifications for type size, line spacing, margins, etc.

References. List of documents (books, articles, and websites) cited in the text. (See "Bibliography.")

SI Units. (*Le Système International d'Unités*, or International System of Units). Metric measurement system, dominant measurement system used in international commerce.

Technical Review. Review of draft documents by experts in the content field.

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com