

IEEE Guide for Selecting and Testing Jackets for Underground Cables

Sponsor

**Insulated Conductors Committee
of the
IEEE Power Engineering Society**

Approved June 17, 1993

IEEE Standards Board

Abstract: This guide covers corrosion protection, properties of commonly used jackets, electrical characteristics of jackets, physical requirements for jackets referenced in industry standards, and selection and testing of jackets. It is written for those responsible for optimizing underground cable installations. The purpose is to present a reasonably complete picture of the role of jackets so that the subject can be approached in an orderly and organized manner. An effort has been made to shun the highly technical language and theory commonly used by electrical engineers, corrosion engineers, and chemists to discuss the more detailed application of jackets.

Keywords: cables, jackets, testing, underground cable

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017-2394, USA.

Copyright © 1994 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 1994. Printed in the United States of America.

ISBN 1-55937-337-7

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE that have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

IEEE standards documents may involve the use of patented technology. Their approval by the Institute of Electrical and Electronics Engineers, Inc. does not mean that using such technology for the purpose of conforming to such standards is authorized by the patent owner. It is the obligation of the user of such technology to obtain all necessary permissions.

Introduction

(This introduction is not a part of IEEE Std 532-1993, IEEE Guide for Selecting and Testing Jackets for Underground Cables.)

This guide is concerned with jackets as they are defined in IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (“A thermoplastic or thermosetting covering, sometimes fabric reinforced, applied over the insulation, core, metallic sheath, or armor of a cable”). Users should note that this guide makes reference to standards developed by the Insulated Cable Engineers Association (ICEA), the Association of Edison Illuminating Companies (AEIC), and other organizations.

This guide is written for the many persons with responsibilities for optimizing underground cable installations. The purpose of the guide is to present a reasonably complete picture of the role of jackets so that the subject can be approached in an orderly and organized manner.

An effort has been made to shun the highly technical language and theory commonly used by electrical engineers, corrosion engineers, and chemists to discuss the more detailed application of jackets. This implies that the various topics covered in this guide are not necessarily exhaustive in every respect.

The users of this guide are cautioned that all data contained herein are presented for information purposes only. Where deemed necessary, additional, as well as more detailed information, should be obtained by consultation with the cable manufacturer and other experts in the field.

This guide represents the work of the Sheaths and Coverings Subcommittee No. 6 of the IEEE Insulated Conductors Committee. Grateful acknowledgment is given to the many individuals who prepared material for this guide, and in particular the members of Task Group 6-3.

At the time this guide was completed, Task Group 6-3 on Guide for Selecting and Testing of Cable Jackets had the following membership:

L. J. Kelly, *Chair*

K. E. Bow
M. Brown
A. A. Carlomagno
W. F. Constantine
R. J. Dashner
W. H. Dittman
E. J. D'Aquanno
E. J. Fisher
R. L. Fleming
B. R. Grosser

A. S. Jones
M. Kopchik
J. H. Lawson
C. C. Landinger
R. D. Lowe
J. D. Medek
W. C. Peterson
J. J. Pickering
J. G. Quin
G. K. Raikos
R. A. Resuali

J. H. Snow
B. A. Sorenson
S. Stanislo
M. D. Sweat
A. C. Tingley
H. D. Thomas
A. Uzee
E. E. Walcott
R. H. Watkins
W. W. Watson

The following persons were on the balloting committee:

Torben Aabo
K. N. Akay
P. Alex
R. W. Allen, Jr.
W. O. Andersen, Jr.
T. P. Arnold
T. A. Balaska
E. W. Bennett
Chas. W. Blades
Robert B. Blodgett
Vincent J. Boliver
R. R. Borowski
Ken E. Bow
John E. Bramfitt
M. D. Buckweitz
R. R. Burghardt
Milton D. Calcamuggio
John L. Carlson
Wayne E. Cole
John T. Corbett
Derek A. Costello
Stan J. Croall
Frank V. Cunningham
E. J. D'Aquanno
S. J. Dale
J. M. Daly
R. A. Decker
James C. Dedman
C. Doench
E. K. Duffy
J. P. Dupont
G. S. Eager, Jr.
R. M. Eichhorn
J. S. Engelhardt
Richard N. Essig
S. L. Fitzhugh
A. Fitzpatrick
E. O. Forster
R. W. Foster
R. D. Fulcomer
J. B. Gardner
J. J. Garland
Alfred Garshick
P. Gazzana-Priaroggia

R. B. Gear
S. M. Gilbert
O. I. Gilbertson
A. Godoshian
R. A. Guba
R. Hartlein
S. V. Heyer
R. W. Higginbottom
Lauri J. Hiivala
R. E. Hoy
W. F. Jensen, Jr.
J. Jurcisin
F. E. Kimsey
Joel Kitchens
H. T. Knox
Frederick B. Koch
S. Kozak
F. E. La Fetra
Carl Landinger
J. S. Lasky
Jack H. Lawson
R. E. Leuch
Raoul H. Leuteritz
T. H. Ling
G. R. Lusk
R. Luther
G. J. Luzzi
Jeffrey P. Mackevich
M. A. Martin, Jr.
I. J. Marwick
S. G. Mastoras
A. R. McCulloch
E. J. McGowan
A. L. McKean
W. J. McNulty
J. D. Medek
David J. Mintz
J. A. Moran, Jr.
D. J. Nichols
Harry E. Orton
J. J. Pachot
Robert N. Pallardy
Cutter D. Palmer
Keith A. Petty

James J. Pickering
Jan S. Pirrong
N. R. Plant
Gary A. Polhill
J. B. Prime, Jr.
Paul F. Pugh
Peter Ralston
Greg P. Rampley
Robert A. Resuali
R. B. Robertson
Candelario J. Saldivar
David Sandwick
E. L. Sankey
John F. Shimshock
David A. Silver
Bynum E. Smith
Joseph H. Snow
N. R. Spencer
Nagu Srinivas
D. R. Stein
Joseph L. Steiner
George A. Straniero
Mike D. Sweat
W. Keith Switzer
John Tanaka
Frank A. Teti
H. D. Thomas
Wm. A. Thue
Austin C. Tingley
Don Tomaszewski
Roger S. Turner
S. E. Turner
C. F. Von Hermann, Jr.
J. G. Waligorski
Steven P. Walldorf
Edw. M. Walton
Verlin J. Warnock
Roland H. W. Watkins
A. C. Westrom
Charles A. White
Robert O. Wilkinson
J. A. Williams
Clarence Woodell
J. T. Zimnoch

When the IEEE Standards Board approved this standard on June 17, 1993, it had the following membership:

Wallace S. Read, *Chair*

Donald C. Loughry, *Vice Chair*

Andrew G. Salem, *Secretary*

Gilles A. Baril
José A. Berrios de la Paz
Clyde R. Camp
Donald C. Fleckenstein
Jay Forster*
David F. Franklin
Ramiro Garcia
Donald N. Heirman

Jim Isaak
Ben C. Johnson
Walter J. Karplus
Lorraine C. Kevra
E. G. "Al" Kiener
Ivor N. Knight
Joseph L. Koepfinger*
D. N. "Jim" Logothesis

Don T. Michael*
Marco W. Migliaro
L. John Rankine
Arthur K. Reilly
Ronald H. Reimer
Gary S. Robinson
Leonard L. Tripp
Donald W. Zipse

*Member Emeritus

Also included are the following nonvoting IEEE Standards Board liaisons:

Satish K. Aggarwal
James Beall
Richard B. Engelman
David E. Soffrin
Stanley I. Warshaw

Valerie E. Zelenty
IEEE Standards Project Editor

Contents

CLAUSE	PAGE
1. Overview.....	1
2. References.....	1
3. Abbreviations.....	2
4. Jacket characteristics.....	3
5. Corrosion protection	3
5.1 Cable-jacket or cable-shield configurations.....	3
5.2 Protective jackets	4
5.3 Insulating and semiconducting protective jackets	4
6. Properties of commonly used jackets	4
6.1 Neoprene	4
6.2 Polyvinyl chloride (PVC)	5
6.3 Polyethylene.....	5
6.4 Chlorinated polyethylene (CPE)	6
6.5 Chlorosulfonated polyethylene (CSPE).....	6
6.6 Nitrile butadiene rubber/polyvinyl chloride (NBR/PVC).....	7
6.7 Ethylene propylene rubber (EPR).....	7
6.8 Thermoplastic rubber	7
6.9 Summary of physical properties	7
6.10 Semiconducting jackets	8
7. Electrical characteristics of jackets.....	8
7.1 Insulating jackets	8
7.2 Semiconducting jackets	11
8. Physical requirements for jackets referenced in industry standards	11
8.1 Jacket requirements—Cables without sheaths.....	12
8.2 Jacket requirements—Metallic-sheathed cables	13
8.3 Special requirements.....	14
9. Discussion on the selection and testing of jackets	14
9.1 General.....	14
9.2 Jackets for metallic-sheathed cable.....	15
9.3 Jackets for cables without sheaths	15
9.4 Semiconducting jackets	17
9.5 Testing of jackets	17
9.6 Jacket shrinkback	18
10. Bibliography	19
Annex Fundamentals of corrosion and methods of corrosion control with protective jackets	21

IEEE Guide for Selecting and Testing Jackets for Underground Cables

1. Overview

This guide provides recommendations for the properties, characteristics, design, and testing of various types of cable jackets. It is the intent of this guide to ensure that jacket materials are suitably specified for their intended applications. Also, jackets should provide a level of electrical, thermal, mechanical, and chemical durability to ensure that cable performance is reliable under normal use, and without danger to the user or surroundings.

2. References

This guide shall be used in conjunction with the following references.

AEIC CS1-90, Specifications for Impregnated-Paper-Insulated Metallic Sheathed Cable, Solid Type, 11th ed., Oct. 1990.¹

AEIC CS4-93, Specifications for Impregnated-Paper-Insulated Low and Medium Pressure Self Contained Liquid Filled Cable, 8th ed., Jan. 1993.

ANSI/ICEA S-56-434-1983 (Reaff 1991), Polyolefin-Insulated Communication Cables For Outdoor Use.²

ASTM D1248-84 (Reaff 1989), Specification for Polyethylene Plastics Molding and Extrusion Materials.³

ICEA S-19-81 (NEMA WC 3-1992), Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

ICEA S-61-402 (NEMA WC 5-1992), Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

ICEA S-66-524 (NEMA WC 7-1991), Cross-Linked-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

ICEA S-68-516 (NEMA WC 8-1991), Ethylene-Propylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

¹AEIC publications are available from the Association of Edison Illuminating Companies, 600 N. 18th Street, P.O. Box 2641, Birmingham, AL 35291-0992, USA.

²ICEA publications are available from the Insulated Cable Engineers Association, Inc., P.O. Box 440, South Yarmouth, MA 02664, USA.

³ASTM publications are available from the Customer Service Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.

ICEA T-25-425, Guide for Establishing Stability of Volume Resistivity for Conducting Polymeric Components of Power Cables (Revised Feb. 1981).

IEC 331-1970, Fire-resisting characteristics of electric cables.⁴

IEC 332-1979, Tests on electric cables under fire conditions.

IEEE Std 383-1974 (Reaff 1992), IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations (ANSI).⁵

IEEE Std 575-1988, IEEE Guide for the Application of Sheath-Bonding Methods for Single-Conductor Cables and the Calculation of Induced Voltages and Currents in Cable Sheaths (ANSI).

UL 44-1991, Rubber-Insulated Wires and Cables.⁶

UL 83-1991, Thermoplastic-Insulated Wires and Cables.

UL 854-1991, Service-Entrance Cables.

UL 1072-1986, Medium-Voltage Power Cables.

UL 1277-1989, Electrical Power and Control Tray Cables With Optional Optical-Fiber Members.

UL 1569-1983, Metal-Clad Cables.

3. Abbreviations

The following abbreviations are used in this guide:

CPE	chlorinated polyethylene
CSPE	chlorosulfonated polyethylene
DRTP	deformation-resistant thermoplastic
EPR	Ethylene propylene rubber
HDPE	high-density polyethylene
LDPE	low-density polyethylene
MDPE	medium-density polyethylene
NBR	nitrile butadiene rubber
PVC	polyvinyl chloride
UD-CN	underground distribution concentric neutral
URD	underground residential distribution

⁴IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁵IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁶UL publications are available from Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096, USA.

4. Jacket characteristics

Jackets furnish mechanical protection for cables during installation and heat cycling. Jackets retard the ingress of water and environmental chemicals into the underlying core. Jackets over metallic shields, sheaths, and concentric neutral wires also provide protection against corrosion.

Evaluation criteria are dependent on the intended use of the product. Variations in applications require that jackets be evaluated to many, but not necessarily all, of the following criteria. Note that certain jackets can be modified by the addition of fillers, plasticizers, activators, inhibitors, etc., to enhance particular physical characteristics.

- a) Toughness, tear, and abrasion resistance
- b) Sufficient flexibility to facilitate cable installation
- c) Flexibility at abnormally low temperatures
- d) Physical stability over a range of temperatures from the minimum installation temperature to the emergency and short-circuit temperatures [excessive shrinkback of the jacket (at cable ends) can lead to physical instability of a cable splice or terminal]
- e) Resistance to heat aging for the operating conditions of the cable
- f) Resistance to deformation for the operating conditions of the cable
- g) Sufficient insulating value to prevent excessive surface leakage at conductor terminations of low-voltage power and control cables
- h) Sufficient insulating value to isolate the metallic shield from ground. This will facilitate single-point grounding and special bonding systems to minimize shield-circulating current losses
- i) Electrical conductivity when required to function as an insulation shield or as a jacket on a shielded cable buried in the earth and required to be grounded along its entire length
- j) Resistance to electrical discharge likely to be experienced on unshielded power cables
- k) Adequate dielectric strength to withstand voltage surges caused by power line switching and power system faults, and induced surges from similar transients
- l) Resistance to abnormal concentrations of inorganic chemicals, especially those that promote corrosion and oxidation of cable shielding materials
- m) Resistance to abnormal concentrations of organic chemicals, especially for conductive shields and jackets
- n) Resistance to ozone concentrations higher than normally encountered in the atmosphere
- o) Low moisture absorption
- p) Flame resistance
- q) Oil resistance
- r) Resistance to sunlight and weather
- s) Reliability for extra-heavy-duty service such as required of portable power cables

5. Corrosion protection

Cable jackets can greatly retard and sometimes prevent corrosion of cable shielding and sheathing materials. Corrosion of metals is often a very complex process. The annex provides a simplified description of some pertinent corrosion mechanisms.

5.1 Cable-jacket or cable-shield configurations

Some of the designs of the cable-jacket or cable-shield configuration are as follows. Each of these interacts with a corrosive environment in its own way.

- a) The metallic sheath or concentric neutral wires may be left bare for direct contact with ducts or earth, or both.
- b) The metallic sheath, metallic shield, or concentric neutral may be covered with a semiconducting protective jacket for electrical contact with the ground.
- c) The metallic components may be insulated from contact with ducts or earth, or both, by the use of an insulating (nonconductive) protective jacket.

5.2 Protective jackets

Protective jackets can have the following beneficial effects:

- a) *Mechanical and electrical protection.* Protective jackets provide mechanical protection, especially during installation of the cable, and electrical protection during system disturbances when a metallic sheath or metallic shield may carry high-fault current.
- b) *Corrosion protection.* Corrosion of the metallic sheath or metallic shield can be prevented or greatly reduced by the use of an insulating jacket. The jacket must be continuous, without punctures, to prevent accelerated corrosion that may occur at a discontinuity. The continuity of the jacket may be destroyed in a number of ways including:
 - 1) Mechanical damage due to poor design of manholes and duct entrances; imperfections or foreign abrasive material in duct and manhole systems; inadequate feeding, exit, and pulling equipment; or poorly trained or inexperienced personnel. Similar hazards exist for direct buried cable, particularly when plowing methods are used.
 - 2) Electrical puncture after installation due to excessive voltage on the sheath or shield or by ground currents due to lightning. Methods of preventing voltages high enough to puncture insulating jackets are discussed in clause 7.
 - 3) Damage by rodents or insects.
 - 4) Degradation due to aging, chemical action, or bacterial action.

5.3 Insulating and semiconducting protective jackets

Insulating protective jackets insulate the metallic sheath or shield from ground and permit the use of sheath or shield bonding schemes to control the magnitude of the induced voltage on the sheath or shield of single-conductor cable circuits. Cable joints and accessories electrically connected to cables must be covered with insulating tape or isolated from electrolytes common to the sheath or shield and ground. This keeps any current leaving the sheath or shield from being concentrated at the cable joint, fittings, oil-feed pipes, reservoirs, or adjacent cables, and thereby prevents concentrated corrosive damage. The effects of corrosion due to dissimilar metals in the sheath or shields and accessories can also be reduced. Shield isolation of separable connectors is complicated. When separable connectors are used, the manufacturer should be consulted.

Semiconducting protective jackets isolate the metallic sheath or shield from its corrosive surroundings while providing a uniform conduction path for the entire system and limiting overvoltages between the shield and the earth.

6. Properties of commonly used jackets

6.1 Neoprene

Neoprene is the generic name for elastomeric polymers derived from the polymerization of chloroprene. Typical compositions contain 40–60% by weight of the neoprene polymer. A treatment is required to cross-link the polymer and thereby impart its thermoset characteristics.