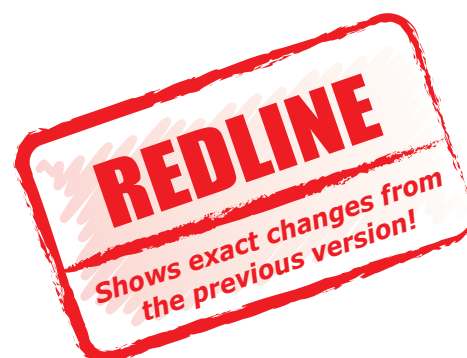




IEEE Guide for Selecting and Testing Jackets for Power, Instrumentation, and Control Cables

IEEE Power Engineering Society

Sponsored by the
Insulated Conductors Committee



IEEE
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IEEE Guide for Selecting and Testing Jackets for Power, Instrumentation, and Control Cables

Sponsor

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

Approved 27 September 2007
IEEE-SA Standards Board

Abstract: This guide covers properties of commonly used jackets as well as selection and testing of jackets. It is written for those responsible for optimizing cable designs. 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 avoid the highly technical language and theory commonly used by electrical engineers and chemists to discuss the more detailed application of jackets.

Keywords: cables, jackets, testing

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Introduction

This introduction is not part of IEEE Std 532-2007, IEEE Guide for Selecting and Testing Jackets for Power, Instrumentation, and Control Cables.

This guide is concerned with jackets as they are defined in *The Authoritative Dictionary of IEEE Standards*, Seventh Edition (“A thermoplastic or thermosetting plastic 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 to provide cable users guidance in the selection of jackets and protective covers for the purpose of optimizing cable design. A secondary purpose is to present a reasonably complete picture of the types and functions of jackets so that the user can approach the subject in an orderly and logical manner.

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

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 should reduce the danger to the user or surroundings. 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.

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IEEE Guide for Selecting and Testing Jackets for Underground Power, Instrumentation, and Control Cables

1. Overview

This guide provides recommendations for the properties, characteristics, design, and testing of various types of extruded 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~~ to reduce danger to the user or surroundings.

1.1 Scope

This guide covers the selection and testing of jackets and other protective coverings for power, instrumentation, and control cables. It is written for those individuals responsible for optimizing cable designs. 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 avoid the highly technical language and theory commonly used by electrical engineers and chemists to discuss the more detailed application of jackets.

1.2 Purpose

The purpose of this guide is to provide cable users guidance in the selection of jackets and protective covers to optimize cable design. A secondary purpose is to present a reasonably complete picture of the types and functions of jackets so that the user can approach the subject in an orderly and logical manner.

1.3 General historical perspective

Various compounded-textile sandwich-type coatings were the predominant jackets used up to and into the

1950s. Experience has indicated that the electrical resistivity required to isolate effectively the metallic sheath or shield, or both, from their environment could not be satisfied by these jackets. In many situations, the dielectric integrity of the jacket is more important than the resistivity.

Factors that influenced improvement of jackets for cable sheaths/shields include:

- a) Consideration of the destructive effects of galvanic and electrolytic corrosion.
- b) The use of amphoteric metals (lead or aluminum) for cable sheaths, which are difficult to protect cathodically.
- c) The use of metals (tinned copper, brass, or steel) to reinforce lead sheaths requiring a jacket that would reliably protect the pressure-retaining metallic components from deterioration when placed in earth or ducts.
- d) The introduction of aluminum-sheathed cables requiring a protective jacket of good mechanical and dielectric properties.

- e) The use of single-conductor cable systems that, by their nature, involve induced voltages on the sheath/shield (see Eaton and Issa [B6]¹ and Kellam [B9]). It is desirable that the sheath/shield be isolated from its environment.
- f) Practices to reduce electrical losses by minimizing circulating sheath/shield currents result in the appearance of voltages on the sheath/shield (see Halperin et al. [B7], Halperin and Miller [B8], and Watson and Erven [B11]); under transient conditions, these voltages may be substantial.

2. Acronyms and abbreviations

The following abbreviations are used in this guide:

CPE	chlorinated polyethylene
~~CSPE~~	~~chlorosulfonated polyethylene~~
CPE-TP	thermoplastic chlorinated polyethylene
CPE-XL	cross-linked chlorinated polyethylene
CSPE	chlorosulfonated polyethylene
DRTP	deformation-resistant thermoplastic
EBA	ethylene butyl acrylate polyethylene copolymer
ECTFE	ethylene chlorotrifluoroethylene
EEA	ethylene ethyl acrylate polyethylene copolymer
EPDM	ethylene propylene diene monomer
EPR	ethylene propylene rubber
EVA	ethylene vinyl acetate polyethylene copolymer
FEP	fluorinated ethylene propylene
HDPE	high-density polyethylene
IRM oils	industry reference material
LDPE	low-density polyethylene
LLDPE	linear low-density polyethylene
LSHF-FR	low-smoke/halogen-free flame retardant
LSZH	low-smoke zero halogen
MDPE	medium-density polyethylene
NBR	nitrile butadiene rubber
PE	polyethylene
PE-TP	thermoplastic polyethylene
PP	polypropylene
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
TPE	thermoplastic elastomer
UD-CN	underground distribution concentric neutral
URD	underground residential distribution
VLDPE	very low-density polyethylene
XLPE	cross-linked polyethylene

¹ The numbers in brackets correspond to those of the bibliography in Annex A.

⁴ IEC 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.

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

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

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.~~

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

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

³~~ASTM 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.~~

3. 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.~~ service in several properties that are highlighted in 3.1 through 3.6. Evaluation criteria for these properties 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.

3.1 Physical properties

Jackets furnish mechanical protection during installation and service. Certain types of ~~Note that certain~~ jackets can be modified by the addition of fillers, plasticizers, activators, inhibitors, and other additives to enhance particular physical or performance characteristics. Depending on the application, the properties of importance may include one or more of the following:

- Toughness, tear, and abrasion resistance
- Sufficient flexibility to facilitate cable installation
- Flexibility at ~~abnormally~~ low temperatures
- Resistance to sunlight and weather
- Reliability for extra-heavy-duty service such as required of portable power cables

3.2 Chemical and moisture resistance

Jackets retard the ingress of water and environmental chemicals into the underlying core. Depending on the application, the properties of importance may include one or more of the following:

- Resistance to high concentrations of organic and inorganic chemicals
- Resistance to ozone concentrations higher than normally encountered in the atmosphere
- Low moisture absorption
- Oil resistance
- Jackets over metallic shields, sheaths, and concentric neutral wires provide protection against corrosion and oxidation

3.3 Thermal stability

The jackets are chosen for their thermal resistance and aging characteristics. Depending on the application, the properties of importance may include one or more of the following:

- 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 terminations]

- Resistance to heat aging for the operating conditions of the cable
- Resistance to deformation for the operating conditions of the cable
- Sufficient insulating value to prevent excessive surface leakage at conductor terminations of low voltage power and control cables

~~Sufficient insulating value to isolate the metallic shield from ground.~~
3.4 Electrical characteristics of non-conducting jackets

For shielded insulated conductors, non-conducting jackets should pass the appropriate electrical tests in industry standards to isolate the metallic shield effectively from the environment. This will facilitate isolation is required on bonding schemes, which include single-point grounding and special bonding systems grounded systems and cross-bonding schemes to minimize shield-circulating current losses. Non-conducting jackets provide a level of isolation between the metallic sheath and the system ground during short-circuit operation.

For unshielded insulated conductors, non-conducting jackets provide resistance to electrical discharge likely to be experienced on power cables and prevent excessive surface leakage at conductor terminations of unshielded power and control cables.

- 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

3.5 Electrical conductivity of semi-conducting jacket

Semi-conducting jackets are used most often in areas of high lightning incidents where it is considered desirable to have a relatively low resistance between the concentric neutral wires or shield and the earth. Semi-conducting jackets are rarely used on control and instrumentation cable. The general properties of importance include:

- Electrical conductivity when required to function as an insulation shield or as a jacket on a shielded cable buried in the earth and when required to be grounded along its entire length
- Resistance to abnormal concentrations of organic chemicals, especially for which could increase the resistivity of 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~~

3.6 Flame retardance

This jacket material is capable of resisting, retarding, or minimizing the propagation of flame. The flame retardance is accomplished with additives or is inherent in the chemical composition of the material (such as in halogenated polymers). Different applications (such as cable tray, riser, and plenum) require different levels of flame retardancy. Riser and plenum applications often have additional requirements such as low heat generation, low smoke, and low toxicity. Flame-retardant materials are not the same as fire-resistant or fire-rated materials that are used in cables designed to withstand a high-temperature fire and continue to operate during the fire for a period of time.

4. 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~~ An overall cable jacket provides a barrier between the metallic shield or sheath and the local environment, which interrupts the dc corrosion cell. See IEEE Std 1617™ [B21] for more information on 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~~ designs discussed in 5.1 interact 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 a non-conducting 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.~~

Corrosion of the metallic sheath or metallic shield can be prevented or greatly reduced by the use of a non-conducting or semi-conducting 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 several ways, including:

- Mechanical damage resulting from 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.

- Electrical puncture after installation resulting from excessive voltage on the sheath or shield or by ground currents from lightning. Methods of preventing voltages high enough to puncture ~~insulating~~ non-conducting jackets are discussed in Clause 7.
- Damage caused by rodents or insects.
- Degradation caused by aging, chemical action, or bacterial action.

4.1 Corrosion protection of semi-conducting jackets on underground distribution concentric neutral cables

Semi-conducting jackets have also been employed over the concentric neutral wires of UD-CN cables for protection against corrosion where the soil conditions are known to be corrosive to exposed copper and where it is considered desirable to have a relatively low resistance between the concentric neutral wires and the earth. Semi-conducting jackets would not be recommended in the vicinity of pipeline cathodic protection systems.

5. Protective jackets

Protective jackets can have beneficial effects besides corrosion protection. They can provide mechanical protection, especially during installation of the cable, and some degree of electrical isolation during system disturbances when a metallic sheath or metallic shield may carry high-fault current.

5.1 Jacket design configurations for shielded power cable

5.1.1 Overlaying jacket design

The conventional overlaying (sleeved) jacket design uses a layer of polymer film over the metallic shields, and the jacket is extruded over the polymer film. This approach provides a cable that has (1) no or minimum [less than 0.125 mm (5 mils)] indentation into the insulation shield; (2) easy jacket removal that can be facilitated even more by incorporation of rip cords, reducing even more the need for cutting tools; and (3) flexibility because the wires have some mobility to allow less force to be required for bending.

A potential problem with overlaying jackets is that water can gain entrance to the cable at open ends or from jacket faults and can freely flow within the void spaces between the jacket and the metallic shield. For applications where water ingress is an issue, this deficiency can be overcome by water-blocking systems. The sleeved jacket design allows for easy incorporation of a variety of longitudinal water-blocking materials. Most commonly, water-swellaable tapes are applied over the metallic shield.

The use of a polyester tape or water-swellaable tape over the metallic shield also has the benefit of limiting jacket irregularities resulting from the presence of the shield. To get a smooth cylindrical jacket, some support is needed during extrusion, and these tapes can provide that support.