IEEE Guide for the Properties of Identifiable Jackets for Underground Power Cables and Ducts

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Abstract: Identification markings of jacketed underground power cables and ducts are established in this guide. Included are various methods of identifying underground power cables and ducts, and the visual, chemical, and mechanical properties of the identification materials and/or methods, and their impact on the properties of the overall jacket or duct as well as their impact on installation practices.
Keywords: duct, identification, jacket, power cables, raised ridge, red stripe

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Introduction

(This introduction is not part of IEEE Std 1235-2000, IEEE Guide for the Properties of Identifiable Jackets for Underground Power Cables and Ducts.)

This guide is concerned with the identification of a jacket as it is defined in The IEEE Standard Dictionary of Electrical and Electronic Terms, Sixth 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), and other organizations.

This guide is written for the many persons with responsibilities for selecting underground power cable jackets and ducts. The purpose of the guide is to present methods for defining and selecting red stripes or raised ridges used in conjunction with underground power cable and duct. Other methods of power cable and duct identification, all red jackets, stripes other than red, and the National Electrical Safety Code identifier are beyond the scope of this guide and will not be covered in this guide.

At the time this guide was completed, the Working Group on the Properties of Identifiable Jackets for Underground Power Cables and Ducts had the following membership:

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IEEE Guide for the Properties of Identifiable Jackets for Underground Power Cables and Ducts

1. Overview

Many methods have been used to identify underground power cables and ducts. They range from marker tapes, raised ridges, indent printing, and colored or striped jackets. In 1993, the National Electrical Safety Code® (NESC®) adopted rule 350G, which applies to all direct buried jacketed supply cable meeting rule 350B and all direct buried communication cables. NESC® rule 350G stipulates a lightning bolt be indented or embossed in the outermost cable jacket of supply cable or duct at a repeating frequency of not more than 1 meter (40 inches). The symbol may be sequentially combined with other data or symbols, or both, printed on the jacket, but shall be separated as indicated in Figure 350-1 of the NESC®. Some utilities are using additional identification, such as red stripes or raised ridges, to supplement the NESC® requirement.

It is left to the utility's discretion to determine the appropriate type of cable identification, as well as what size and type installation merits being identified. Since the red stripes and raised ridges are extruded (or co-extruded) with the outer protective jacket material, it is the intent of this guide to ensure that the red stripe materials be fully compatible and firmly bonded to the overall outer protective jackets or ducts. The red stripes should not discolor significantly during limited outdoor storage of cable reels at cable manufacturers and utilities, or when buried underground. This guide recommends 1000 hours Xenon-Arc aging to demonstrate acceptable outdoor exposure, and 672 hours aging at 60 °C in tap water, 5% hydrochloric acid (HCL) solution, and 5% sodium hydroxide (NaOH) to demonstrate acceptable color stability when buried.

1.1 Scope

This guide provides recommendations for red stripe and raised ridge identification markings on insulating and semiconducting linear low density polyethylene (LLDPE), medium density polyethylene (MDPE), high density polyethylene (HDPE) and polyvinyl chloride (PVC) jacketed underground power cables, and HDPE duct containing jacketed or unjacketed underground power cables. The red stripe recommendations include the number of stripes, color, width, thickness, retention characteristics, physical properties, storage criteria, and testing methods. The raised ridge recommendations include physical properties, width, height, and circumferential spacing. It is the intent of this guide to provide a minimum level of physical, chemical, and color durability on red stripes used to identify underground power cables and ducts.

1.2 Purpose

Jacketed underground power cables and their related duct systems are similar in size and appearance to communication cables and underground pipes. Identification and differentiation of underground power cables and ducts has been attempted by marker tapes, raised ridges, indent printing, colors (other than black), and striped jackets. In the absence of a standard or guide on the properties of red stripes used as identification markings, some utilities have reported that red stripes whiten after limited (in some cases, less than one year) outdoor storage. This guide provides recommendations for the properties, design, dimensional requirements, and testing of red stripes used as identification markings on underground power cables and ducts. In addition, this guide provides physical attribute recommendations for raised ridge identification.

2. References

This guide shall be used in conjunction with the following references. When the following standards are superseded by an approved revision, the revision shall apply:

Accredited Standards Committee C2-1997, National Electrical Safety Code® (NESC®).[1]

ANSI/ICEA S-94-649-1997, Standard for Concentric Neutral Cables, 5–46 kV.[2]

ASTM G66-99, Standard Test Method for Visual Assessment of Exfoliation Corrosion Susceptibility of 5XXX Series Aluminum Alloys (ASSET Test).[3]

ASTM D1712-96, Standard Practice for Resistance of Plastics to Sulfide Staining.

NEMA WC3-1992/ICEA S-19-81, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (Rev.1, 1994).[4]

NEMA WC5-1992/ICEA S-61-402, Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (Rev. 2, 1996).

NEMA WC7-1988/ICEA S-66-524, Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (Rev. 4, 1998).

NEMA WC8-1988/ICEA S-68-516, Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (Rev. 3, 1996).

UL 44-1999, UL Standard for Safety for Thermoset-Insulated Wires and Cables.[5]

UL 1072-1997, UL Standard for Safety for Medium-Voltage Power Cables.

UL 1569-2000, UL Standard for Safety for Metal-Clad Cables.

[1]The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[2]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (http://www.ansi.org/). ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (http://www.icea.org/).

[3]ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).

[4]NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).

[5]UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).

3. Dimensional criteria

3.1 Red stripe

Where red stripe identification is specified, there should be three (3) longitudinal red stripes spaced approximately 120° apart, extruded into the outer protective jacket or duct.

The thickness of the measured extruded red stripes may vary from 0.125 mm to 0.635 mm at the thickest point across the section of the sample.

The red stripe thickness should be included as part of the overall jacket or duct thickness.

The width of each individual extruded red stripe should be a minimum of 5% of the cable jacket or duct circumference, and the total width of the three stripes combined should not exceed 50% of the cable jacket or duct circumference.

The stripe width should not vary more than 50% along the cable jacket or duct longitudinal axis.

3.2 Raised ridge

Where raised ridge identification is specified, there should be three (3) longitudinal ridges spaced approximately 120° apart.

The height of each ridge may vary from 1.4 mm to 2.2 mm.

The width may vary from 1.4 mm to 2.2 mm.

4. Measurement technique

4.1 Red stripe

Stripe thickness measurements should be made at a frequency of once per manufacturer's master reel or once per every 3000 m. Specimens for measurement should be obtained by cutting the jacket or duct using any suitable means that produces a uniform wafer. The measurement should be made with a minimum of 15× magnification using an optical measuring device, capable of measuring within an accuracy of 0.025 mm. The thickness of all three stripes should be determined. The measurement should be made at the thickest point of each stripe.

Stripe width measurements should be made at the widest point of the stripe on the outer circumference of the sample, at a frequency of once per master reel or once per every 3000 m. The measurement should be made with a device capable of measuring with an accuracy of 0.75 mm. The width of each individual stripe should be determined.

4.2 Raised ridge

Raised ridge measurements should be made with a device capable of measuring with an accuracy of 0.025 mm at a frequency of once per master reel or once per every 3000 m. The measurements should include the height and width. The height should be measured from one side of the ridge base to its vertical height. The width should be the average of the measurements taken at the base and top of the ridge.

5. Color stability

Color being used for cable and duct identification may not remain stable during the entire life expectancy of a cable or duct in underground installations, either direct buried, in air, or exposed to sunlight. Soil conditions may vary and may change the identification markings over a period of time. Investigation indicates there is no test that will predict stability of color in all types of environments.

5.1 Outdoor color stability

Photodegradation of polyolefins from ultraviolet light (UV) can lead to reduced performance due to a loss in physical and chemical properties of the polymer. The autoxidation cycle is identified as the mechanism for this process. Free radicals are formed by incident UV light providing excitation energy to a chromophoric species present in the polymer. Pigments and other additives can act as sensitizing agents, detrimentally impacting the polymer, upon exposure to UV radiation. These components can also help protect the polymer and extend its useful life.

Colored pigments (other than carbon black) do not impart significant UV stability. Colored compounds, such as red, are therefore formulated with UV absorbers (UVA) to minimize degradation due to radiation. Light stabilizers (LS) are an alternative or complimentary form of UV stabilizer designed to inhibit the autoxidation cycle by quenching free radicals and hydroperoxides. These species targeted by the LS would otherwise go on to multiply by a factor of four, if allowed to fully carry out the autoxidation cycle. Optimum stabilization can be achieved by selecting the proper UVA and LS combination and the appropriate ratio for polymer (and pigment) protection from UV stabilization.

State-of-the-art stabilized red polyolefin identification compounds have approximately five years weathering protection. This should adequately cover the time most cables are stored outdoors at cable manufacturers and utilities. Black polyethylene jacketing compounds using the appropriate carbon black, well dispersed at a concentration level in excess of 2%, will resist the harmful effects of outdoor exposure to the sunlight's UV radiation for over 40 years. Characterized by relatively high level of UV absorption, carbon black will act as a screen to prevent interactions leading to free radical formation.

To evaluate the weatherability of red identification compounds by way of accelerated weathering, it is recommended that the spectral distribution of the light source used during the test simulates natural sunshine. Xenon arc lamps, when properly filtered, have an emission spectrum much like terrestrial sunshine for the critical wavelengths between 290 nm and 350 nm. As a general rule of thumb, when discussing xenon exposure data, one year in Florida is equivalent to 1300–1500 hours (approximately 585 kJ/cm2).

5.2 In-ground color stability

Both organic and inorganic pigments may be used as colorants for underground power cable and duct identification. In some cases inorganic pigments are avoided for environmental reasons. Some inorganic red pigments darken significantly when exposed to 5% HCL. This discoloration can be accelerated at elevated temperatures. Organic red pigments typically retain color after acid exposure and they do not have the environmental problems associated with some inorganics. The acid exposure test recommended in this guide is designed to alert the user of potential in-service color stability issues.

Plastic compositions containing salts of lead, cadmium, copper, antimony, and certain other metals (as stabilizers, pigments, driers, or fillers) may stain due to the formation of a metallic sulfide when in contact with external materials that contain sulfide. The external sulfide source may be liquid, solid, or gas. Red PVC cable and duct identification materials that incorporate a lead stabilizer should be tested for resistance to hydrogen sulphide staining.

6. Additional markings

The user is advised to consult the National Electrical Safety Code® (NESC®) (Accredited Standards Committee C2-1997)[6] for additional recommendations on identification markings for underground power cables and ducts.

7. Physical properties

7.1 Red stripe

The red identification stripe material and the black jacket material should be compatible. It is incumbent upon the cable or duct supplier to demonstrate compatibility of the red stripe material with the jacket or duct. To facilitate compatibility, the red stripe material should be similar to the overall black weather resistant jacket material with which it will be used. The physical property requirements of the red stripe material should be equivalent to the black jacket material requirements as defined in the appropriate ICEA or UL standard. In addition, the red stripe material should demonstrate acceptable retention of physical properties and color after 1000 hours Xenon-Arc exposure and acceptable retention of color when exposed to 672 hours aging at 60 °C in tap water, 5% HCL, and 5% NaOH as specified in Table 1.

Table 1—Physical property requirements of red stripe

Test method	Requirement type	Requirement description	Value
Visual	Physical	Color	Red
Method A of ASTM G66-99	Aging	*After 1000 hours Xenon-Arc exposure:* Tensile strength, % unaged value Elongation at rupture, % unaged value Maximum color deviation from unexposed sample	 ≥75 ≥75 *Minimal*: color should still be red with no significant fading
Visual	Aging	*After 672 hours exposure in the following solutions, the maximum color deviation from the unexposed sample:* Tap water at 60°C 5% HCL at 60°C 5% NaOH at 60°C	*Minimal*: color should still be red with no significant fading or darkening
ASTM D1712-96	Aging	Resistance to hydrogen sulphide staining	No staining

7.2 Raised ridge

The raised ridges should be of the same material as the cable jacket.

[6]Information on references can be found in Clause 2.

8. Storage criteria

Storage methods for underground power cables and ducts can have various effects on the longevity of the red stripe materials. Past experience has shown that red color fading can occur during outdoor storage for both relatively short and longer periods of time. The color permanence can be very sensitive to the color formulation selected by the supplier.

Underground power cables and ducts, with red stripes produced in conformance with this guide, should show acceptable limited color changes for up to 1000 hours Xenon-arc weatherometer aging or one (1) year outdoor exposure. For underground power cables or ducts in stock for longer than one year, consideration should be given to providing physical protection from the effects of the weather to maintain the red color and physical properties of the stripe prior to cable installation. Some suggested methods are:

a) *Cable reel wrappers:* paper, plastic, or wood depending on the type of climate expected and the storage duration.

b) *Covered storage:* more versatile without the environmental costs of discarding reel wrappers, yet usually more expensive.

9. Duct for power cable

Since there is a wide range of duct installations, from direct burial of single duct in rural areas to concrete-encased duct banks in urban areas, it is left to the utility's discretion to determine what size and type installation merits being identified. Some duct installations obviously need not be identified, but serious consideration should be given to those isolated ducts that are similar in size, color, and texture to other utilities' cables, ducts, or pipes. This guide is not intended to require marking of underground cable jackets and ducts, but to help ensure durability and consistency where marking is specified.

9.1 Duct

Underground power cable is sometimes placed in buried duct. When the duct is provided with the cable prior to installation as a flexible loose duct or pipe of high density polyethylene (HDPE), then the cable and duct system is called preassembled cable-in-duct. This particular underground power cable and duct system does have similar size, color, and texture as other utilities' cable systems, and could very well be the duct/cable system most susceptible to being misidentified.

The duct is much like a loose cable jacket; therefore, the methods of identification are the same for cables-in-duct as for jackets. When cable-in-duct is required to be marked, all the requirements of Clause 3 through Clause 8 apply, along with the additional consideration of compatibility of the striping material with HDPE. The striping material must not separate from the HDPE. An HDPE-based red stripe material should be used on HDPE duct.