

IEEE Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications

Sponsor

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IEEE Industrial Applications Society**

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Abstract: A guide for installing, splicing, terminating, and field proof testing of cable systems in industrial and commercial applications is provided. It is not intended to be a design document, although many of the problems of installation can be avoided by designing cable layouts within the installation limits of this recommended practice.

Keywords: jamming, minimum bending radius, pulling lubricants, pulling tension, sidewall pressure, splicing

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Introduction

(This introduction is not a part of IEEE Std 576-2000, IEEE Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications.)

This document has been generated to provide guidance for installation of electrical cable systems in industrial and commercial applications. It has long been recognized that the majority of cable failures are a result of mechanical damage during installation. The use of this document should reduce the possibility of electrical failure in a cable system. There are many specific details involved in the installation of cable systems that are subject to differences of opinion. This document covers only the major problem areas.

This document will be revised from time to time to incorporate the latest information available.

This document was prepared by the Cable Installation Working Group of the Petroleum and Chemical Industry Committee of the Industry Applications Society of IEEE. At the time this Recommended Practice was completed, Working Group P576 had the following membership:

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IEEE Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications

1. Overview

1.1 Scope

This recommended practice provides a guide for installing, splicing, terminating, and field proof testing of cable systems in industrial and commercial applications. It is not intended to be a design document, although many of the problems of installation can be avoided by designing cable layouts within the installation limits of this recommended practice.

1.2 Purpose

The purpose of this recommended practice is to provide a uniform guide of installation limits that will avoid premature cable failure due to improper installation and mechanical damage during installation. It is intended to provide a reference that can be specified for cable installations.

2. References

This recommended practice should be used in conjunction with the following publications:

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

¹The 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/>).

AEIC CS8-00, Specifications for Extruded Dielectric Shielded Power Cables Rated 5 than 46 kV.²

AIEE Paper 53-389, Pipe-Line Design for Pipe Type Feeders, R. C. Rifenburg, published December 1953.³

ANSI Std C2-1997, National Electrical Safety Code.⁴

IEEE Std 48-1996, IEEE Standard Test Procedures and Requirements for Alternating Current Cable Terminations 2.5 kV Through 765 kV.⁵

IEEE Std 400-1991, IEEE Guide for Making High-Direct-Voltage Test on Power Cable Systems in the Field.

IEEE Std 404-1993, IEEE Standard for Cable Joints for Use with Extruded Dielectric Cable Rated 5000 V Through 138 000 V and Cable Joints for Use with Laminated Dielectric Cable Rated 2500 V Through 500 000 V.

IEEE Std 442-1981 (Reaff 1996), IEEE Guide for Soil Thermal Resistivity Measurements.

IEEE Std 1242-1999, IEEE Guide for Specifying and Selecting Power, Control, and Purpose Cable for Petroleum and Chemical Plants.

IEEE P1493, Draft Guide for the Evaluation of Solvents Used for Cleaning Electrical Cables and Accessories.⁶

NFPA 70-1999, National Electrical Code[®] (NEC[®]).

3. Definitions

3.1 electrical connection: The point at which two or more electrical conductors are joined together to establish electrical continuity.

3.2 jamming: The wedging of cables in a conduit when three cables lie side by side in a flat plane.

3.3 minimum bending radius: The minimum radius to which an insulated cable can be permanently bent that will not result in mechanical damage to the cable. In a bend, the radius is measured to the inside curve of the cable, not to the centerline of the cable.

3.4 sidewall pressure: The pressure exerted on an insulated cable as the result of the cable's being pulled around a bend during installation.

²AEIC publications are available from the Association of Edison Illuminating Companies, 600 N, 18th Street, P.O. Box 2641, Birmingham, AL 35291-0992, USA (<http://www.aiec.org/>). AEIC publications are also available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112-5704, USA (<http://global.ihs.com/>).

³AIEE...

⁴ANSI 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/>).

⁵IEEE publications are 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/>).

⁶This IEEE standards project was not approved by the IEEE-SA Standards Board at the time this publication went to press. For information on obtaining a draft, contact the IEEE.

3.5 weight: In non-technical work and often in engineering, weight is commonly used as a synonym for mass. In this document, however, it is used as in physics, to refer to the apparent force of gravity on a object. Like other force quantities, it is expressed in newtons in the International System (SI) and in pounds-force in the inch-pound system.

3.6 weight correction factor: A dimensionless factor (≥ 1) by which cable tensions and sidewall pressure are adjusted due to different cable arrangements, when cable is pulled around bends or in conduit. For example, for three cables in a triangular configuration in conduit, the top cable does not touch the conduit, but its weight will cause increased tensions and sidewall pressures for the other two cables.

4. Pulling tensions

4.1 Maximum pulling tension on cable

4.1.1 Pulling eye attachment

With pulling eye attached to copper conductors, the maximum pulling tension should not exceed 0.008 times circular-mil area (C_m). With pulling eye attached to aluminum conductors, the maximum pulling tension should not exceed 0.006 times circular-mil area (C_m).

$$\left. \begin{aligned} T_m &= 0.008 \times n \times C_m \quad (\text{copper}) \\ T_m &= 0.006 \times n \times C_m \quad (\text{aluminum}) \end{aligned} \right\} \quad (1)$$

where

T_m is the maximum tension, lbf,
 n is the number of conductors,
 C_m is the circular mil area of each conductor,

or

$$\left. \begin{aligned} T_m &= 0.036 \times n \times C_m \quad (\text{copper}) \\ T_m &= 0.027 \times n \times C_m \quad (\text{aluminum}) \end{aligned} \right\} \quad (1a)$$

where

T_m is the maximum tension, N,
 n is the number of conductors,
 C_m is the circular mil area of each conductor.

Maximum limitation for this calculation is 22 240 N (2268 kgf) (5000 lbf) for single conductor (1/C) cables and 44 480 N (4536 kgf) (10 000 lbf) for three multi-conductor cables. This limitation is due to unequal distribution of tension forces when pulling multiple conductors.

4.1.1.1 Cable manufacturer

Consult the cable manufacturer for maximum allowable/recommended pulling tension.

4.1.1.2 Tension gauge

When the calculated pulling tension is close to (or within 10% of) the maximum pulling tension, the use of a tension gauge during the pulling is recommended.

4.1.2 Cable grip over lead sheath

With cable grip over lead sheath, with commercial lead, the maximum pulling tension on the lead sheath should not exceed 10.33 N/mm² (1500 lbf/in²).

4.1.3 Cable grip over non-leaded cable

With cable grip over non-leaded cable, the maximum pulling tension should not exceed 4400 N (1000 lbf) and may not exceed the maximum tension as given in Equation (1).

4.2 Maximum pulling lengths

The maximum permissible pulling length, L_m , for one straight section is given by

$$L_m = \frac{T_m}{wfW_c} \quad (2)$$

where

T_m is the maximum tension in kgf (lbf),

w is the weight of cable(s) kg/m (lb/ft),

f is the coefficient of dynamic friction,

W_c is the weight correction factor.

W_c is 1.0 if there is one cable per duct; for more than one cable per duct see Figure 1.

4.3 Small conductor cables

In the case of small conductors where the permissible load is limited by 0.008 times the total circular-mil area of the conductors, the permissible load on the sheath may be added to that permitted on the conductor if the conductor and sheath are joined securely to the pulling eye.

4.4 Pulling tension requirements in duct and conduit

4.4.1 Straight run of cable

For a straight run of cable, the tension is given by the following equation:

$$T = LwfW_c \quad (3)$$

where

T is the pulling tension in kgf (lbf),

L is the length of duct in m (ft),

w is the weight of cable(s) in kg/m (lb/ft),

f is the coefficient of dynamic friction between cable(s) and duct or conduit surface,

W_c is the weight correction factor:

One cable per duct, $W_c = 1.0$

Three cables per duct, W_c is taken from Figure 1 or 5.2.

4.4.2 Curved duct sections

For curved duct sections, the following equation applies:

$$T_o = T_i e^{fa} \quad (4)$$

where

T_o = tension coming out of the bend (N) (lbf),

T_i = tension at the end of a straight section entering a bend (N) (lbf),

a = angle of bend in radians,

f = coefficient of dynamic friction.

Equation (4) is a commonly used approximation in lieu of the exact bend equation.

4.4.2.1 Values of e^{fa}

The values for e^{fa} are given in Table 1 for various values of f . The coefficient of friction is a function of the side wall bearing pressure and appropriate values of e^{fa} should be chosen to reflect this. As sidewall bearing pressure increases, the coefficient of friction decreases. Values of friction from high sidewall pressures may approach 0.1.

Table 1—Values of e^{fa}

Bend angle in degrees	Value of e^{fa}			
	$f = 0.1$	$f = 0.2$	$f = 0.35$	$f = 0.5$
15	1.03	1.05	1.10	1.14
30	1.05	1.11	1.20	1.3
45	1.08	1.17	1.32	1.48
60	1.11	1.23	1.44	1.69
75	1.14	1.3	1.58	1.92
90	1.17	1.37	1.73	2.19
105	1.2	1.44	1.90	2.5
120	1.23	1.52	2.08	2.85

4.4.2.2 Typical values for coefficient of friction

Table 2 gives typical values of the low sidewall bearing pressure dynamic coefficient of friction with properly applied pulling lubricant. The actual values may be obtained from the lubricant manufacturer for the specific type of lubricant used. The coefficient of friction for high sidewall bearing pressure may be a lower value.