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IEEE Guide for Selection and Design of Aluminum Sheaths for Power Cables

IEEE Power Engineering Society

Sponsored by the
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Abstract: This is a guide for determining applicable tests and inspection techniques for various types of large rotating electric machines. It provides short discussions relating to the capabilities and limitations of each test, typical test procedures and in some cases, how to interpret the expected range of results. This is to be a companion document to P62 Part 1-1995.

Keywords: brushless machine, commutator, damper winding, partial discharge, stator core, stator winding, thermocouple

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Introduction

(This introduction is not part of IEEE Std 635-2003, IEEE Guide for Selection and Design of Aluminum Sheaths for Power Cables.)

This guide is concerned with the selection and design of aluminum sheaths for low-, medium-, high-, and extra high-voltage power cables. An aluminum sheath is defined as “an impervious aluminum or aluminum alloy tube, either smooth or corrugated, which is applied over a cable core to provide mechanical protection.” It may or may not have a jacket. Users may note that this guide makes reference to standards developed by other organizations. These references are useful for understanding the content of the guide.

The guide is written for those persons with responsibilities for installing and using cable with an aluminum sheath. The purpose of the guide is to establish design guidelines, basic installation, and use parameters. References and a bibliography related to the subject are also provided.

The guide is aimed at providing more detail for the application of aluminum sheaths. However, the topics covered in this guide are not exhaustive in every aspect of cable sheath design or performance.

The guide represents the work of Working Group A15W of Subcommittee A of the Insulated Conductors Committee, Power Engineering Society. Grateful acknowledgement is given to the individuals who contributed to the revision of this guide. This is the second revision to this guide originally issued in 1980 and revised in 1989.

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 Selection and Design of Aluminum Sheaths for Power Cables

1. Overview

1.1 Purpose

The purpose of this guide is as follows:

- a) Outline requirements and establish design guidelines for the selection of aluminum sheaths for extra high-, high-, medium-, and low-voltage cables
- b) Establish basic installation parameters for aluminum-sheathed cables
- c) Provide references to industry standards and codes incorporating design and installation requirements of aluminum-sheathed cables
- d) Provide a comprehensive bibliography of literature related to the subject

1.2 Scope

This guide covers power cables incorporating an aluminum sheath, except those of the SF₆ rigid-bus type.

2. References

This guide shall be used in conjunction with the following publications. When the following specifications are superseded by an approved revision, the revision shall apply. A specific IEC standard for continuously welded or extruded aluminum sheaths had not been written at the time of publication of this guide.

The cable or part of the cable may be in accordance with one or more of the references listed below. The installation must be in accordance with the applicable electrical code or wiring regulations.

Aluminum Standards and Data, 2003, 12th Edition, The Aluminum Association, Inc.¹

¹This publication is available from The Aluminum Association, Inc., 900 19th Street NW, Washington DC 20006, USA (<http://www.aluminum.org>).

CSA Std C22.1-2002, Canadian Electrical Code, Part I, 19th Edition, Safety Standard for Electrical Installations.²

CSA Std C22.2, No. 123-1996 (R2001), Aluminum Sheath Cables.

ICEA P-45-482-1999, Short-Circuit Performance of Metallic Shields and Sheaths on Insulated Cable.³

NFPA 70-2002, National Electrical Code® (NEC®).⁴

UL 1569-1999, Metal-Clad Cables, Third Edition.⁵

3. Definitions

3.1 aluminum sheath: An impervious aluminum or aluminum alloy tube, either smooth or corrugated, which is applied over a cable core to provide mechanical protection.

3.2 extra high-voltage aluminum-sheathed power cable: Cable used in an electric system having a maximum phase-to-phase rms ac voltage above 242 000 V, the cable having an aluminum sheath as a major component in its construction.

3.3 high-voltage aluminum-sheathed power cable: Cable used in an electric system having maximum phase-to-phase rms ac voltage above 72 500 V to 242 000 V, the cable having an aluminum sheath as a major component in its construction.

3.4 low-voltage aluminum-sheathed power cable: Cable used in an electric system having a maximum phase-to-phase rms ac voltage of 1000 V or less, the cable having an aluminum sheath as a major component in its construction.

3.5 medium-voltage aluminum-sheathed power cable: Cable used in an electric system having a maximum phase-to-phase rms ac voltage above 1000 V to 72 500 V, the cable having an aluminum sheath as a major component in its construction.

4. Advantages and limitations of aluminum sheaths

A cable designer or user should be aware of the merits and limitations of aluminum-sheathed cable and assign an order of importance to each property to satisfy the requirements of the specific application where power cables are involved.

²CSA publications are available from the Canadian Standards Association (Standards Sales), 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3 (<http://www.csa.ca/>).

³ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (<http://www.icea.org/>).

⁴The NEC is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (<http://www.nfpa.org/>). Copies are also 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/>).

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

4.1 Advantages

4.1.1 Weight reduction

The use of an aluminum sheath reduces the weight of the cable compared with those having other metallic sheaths, thereby simplifying installation and lowering shipping costs. Furthermore, longer pulling lengths are possible with reduced cable weight.

4.1.2 Electrical protection

As a sheath, aluminum is characterized by high electrical conductance and consequently by high short-circuit capability. In addition, high conductance offers excellent protection against lightning.

4.1.3 Fatigue resistance

Aluminum has very good mechanical properties, for example, hardness and fatigue resistance. Therefore, the possibility of sheath fatigue failure due to vibrations and movement induced by thermal cycling is minimal.

4.1.4 Mechanical protection

Aluminum has a higher yield point, higher tensile strength, and less creep by comparison with other more ductile sheathing materials. These attributes permit fewer clamps for installations in tunnels or above ground. The high hoop strength of aluminum sheath is particularly important in pressurized cables, since it may permit a reduction in the number of stop joints and pressure tanks.

4.2 Limitations

4.2.1 Corrosion resistance

Aluminum is a relatively active metal chemically, and care must be taken to provide adequate protection against corrosion.

4.2.2 Bend performance

Because of its rigidity, smooth-aluminum-sheathed cable is more difficult to bend than corrugated-aluminum-sheathed cable.

4.2.3 Jointing and terminating

For jointing and terminating, an aluminum sheath requires techniques different from those applicable to other commonly used metals, and retraining of splicing and terminating crews may be necessary.

4.2.4 Sheath losses

Because of its high electrical conductance, losses resulting from induced sheath currents and eddy currents are substantial. These losses can be reduced by selecting thinner sheaths and by using special sheath bonding methods for single-conductor cables.

5. Applications

5.1 Background

In the mid-1940s, attention was focused on aluminum as a sheathing material because of the scarcity of lead. As the technical and economic advantages of aluminum were recognized, its use escalated rapidly.

Initially, aluminum was used in applications previously dominated by lead, namely, solid-type paper-insulated medium-voltage cables. The aluminum sheath was of the smooth type; a corrugated sheath was not used initially because of compound drainage into the corrugations. Subsequently, however, the corrugated sheath found widespread acceptance, mainly in low-voltage extruded-dielectric cables and large-size fluid-filled high-voltage cables, where impregnating compound drainage into the corrugations was not a factor for consideration.

5.2 Products and installation conditions

5.2.1 Cable applications

Considerable experience has been gained in the use of aluminum-sheathed cables in the following products and installation conditions:

- a) Low-voltage cables, type MC in accordance with CSA Std C22.1-2002 and CSA Std C22.2, No. 123-1996⁶
- b) General purpose, pressurized, self-contained paper-insulated fluid-filled medium- and high-voltage cables
- c) Shaft cables, mainly self-contained fluid-filled and extruded-dielectric types
- d) Tunnel cables
- e) Nonpressurized, impregnated-paper-insulated medium-voltage cables with a smooth sheath used in vertical risers
- f) Low- and medium-voltage solid dielectric cables
- g) High-voltage solid dielectric cables

5.2.2 Impregnated-paper-insulated cable

Medium-voltage solid-type impregnated-paper-insulated cables, incorporating annular corrugated-aluminum sheaths, may be used provided that the impregnant is of the nondraining type and that the corrugations are filled with a suitable compound.

5.2.3 Aerial cables

Severe expansion and contraction of the cable in aerial installations may take place during load or ambient cycles. Extreme care must be exercised to provide for this behavior.

⁶Information on references can be found in Clause 2.

6. Aluminum metals and alloys

6.1 General

Aluminum sheathing metals and alloys are characterized by high thermal and electrical conductivity, good mechanical properties, and excellent workability. Furthermore, no instance of failure due to stress corrosion cracking in service or in a laboratory is known. A moderate increase in strength may be obtained by work hardening. Iron and silicon are the major impurities.

Alloys in the categories considered are not normally expected to stress-corrode in any environment. Aluminum corrodes in strong alkalis, mercurial compounds, most strong acids, and aqueous solutions containing copper and other heavy metals. These environments should be avoided. Chloride pitting can be a problem in some environments. These pits can initiate fatigue damage or even penetrate the sheath.

6.2 Selection and application

In general, the selection of the proper sheathing alloy is determined by the manufacturing method, and for the purpose of this guide, the two principal alloys used for sheathing with their respective methods of application are described in 6.2.1 and 6.2.2.

6.2.1 Universal aluminum metals

The metals in this group contain 99.45–99.6% aluminum; the balance includes mainly silicon and iron. The composition of a typical metal is shown in Table 1.

Table 1—Composition of a typical universal aluminum metal by weight

Aluminum minimum (%)	Iron maximum (%)	Silicon maximum (%)	Other elements maximum (%)
99.45	0.3	0.3	0.17

Universal aluminum metals are used for general purpose sheaths of cable installed in vertical shafts, for seam-welded strip, and for aluminum tube used for the *sinking* (draw-down) manufacturing process. For example, aluminum 1350, 1145, 1050, and 1060 belong to this group.

6.2.2 Pure aluminum metals

The metals in this group contain at least 99.7% aluminum. They are normally supplied in the form of billets and used for the direct sheath extrusion process. Typical composition and properties are shown in Table 2.

Other aluminum metals and alloys may be used for applications requiring special properties; none of them are heat-treatable. Alloy 3003 has been used; the conductivity of this alloy is significantly lower than that of aluminum 1350.

For further information on aluminum and aluminum alloys, refer to the appropriate national and international standards or handbooks, such as Aluminum Standards and Data, 2003.