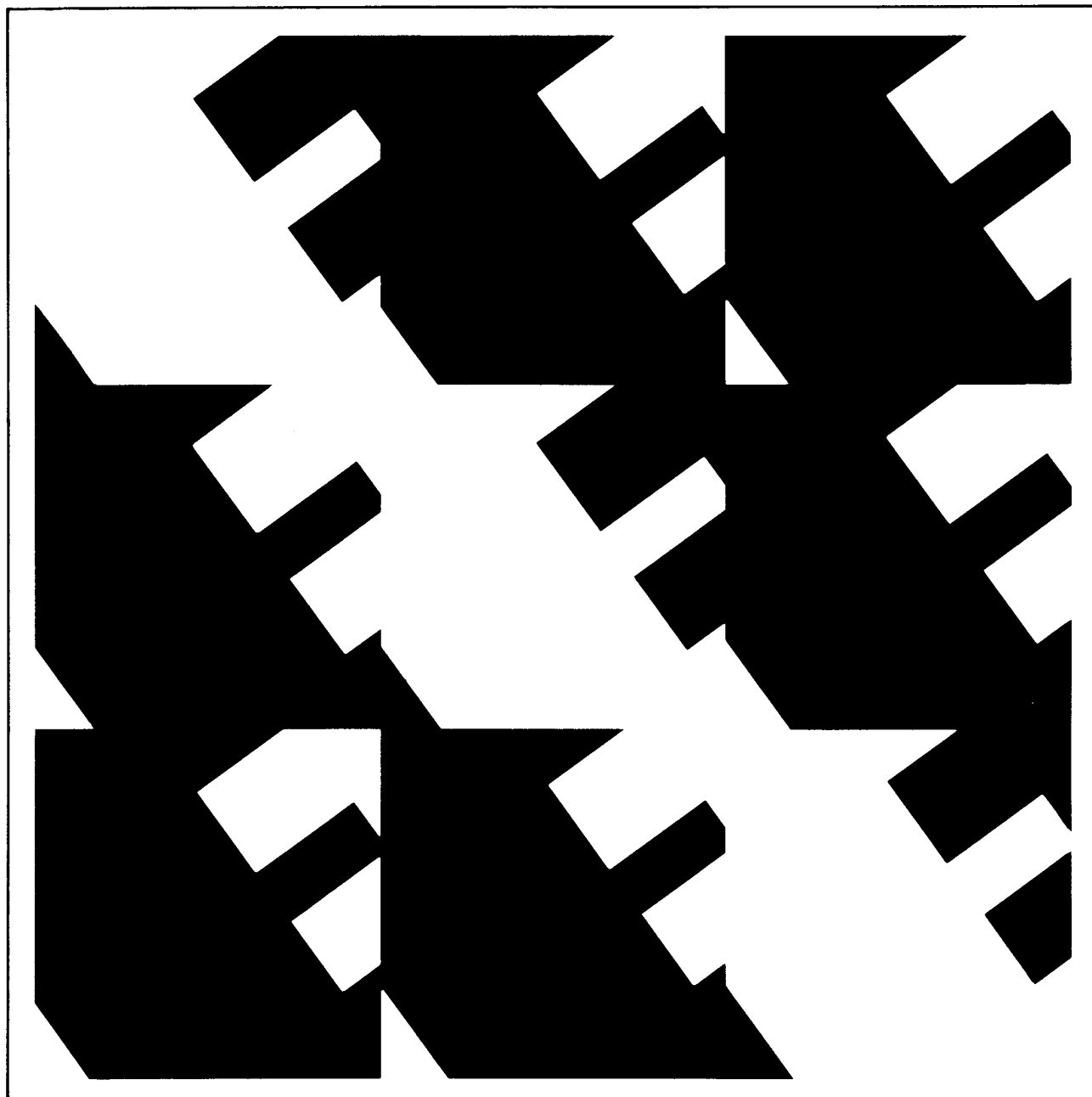


IEEE Guide for Selection and Design of Aluminum Sheaths for Power Cables

IEEE Std 635-1980



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

Sponsor
Insulated Conductors Committee
of the
IEEE Power Engineering Society

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Foreword

(This Foreword is not a part of IEEE Std 635-1980, IEEE Guide for Selection and Design of Aluminum Sheaths for Power Cables.)

This guide has been prepared by the working group of the Insulated Conductors Committee of the IEEE Power Engineering Society. The members of this group are:

Z. S. Paniri, *Chairman*

H. Amino
J. Bentham
G. Buettner
J. Cronin
K. Crook

E. E. McIlveen
S. Krishnasamy
G. Ludasi
N. Spencer
D. Stein

Guidance on protective coverings is not included in IEEE Std 635-1979. This topic will be covered in a separate guide, Guide for Selecting and Testing of Protective Jackets for Underground Power Cables, now in preparation. It is not the intent of this guide to make direct comparison with other sheathing metals.

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

Indebtedness is hereby acknowledged to other engineers, whose names are not listed herein, for offering valuable comments and suggestions.

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

1. Purpose

1.1 The purpose of this guide is to:

(1) Outline requirements and establish design guidelines for the selection of aluminum sheaths for extra-high, high, medium, and low-voltage cables

(2) Establish basic installation parameters for aluminum-sheathed cables

(3) Provide references to industry standards and codes incorporating design and installation requirements of aluminum-sheathed cables

(4) Provide a comprehensive bibliography of literature related to the subject.

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

2. References

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.

[1] ANSI/NFPA No 70-1978, National Electrical Code, 1978 edition.¹

[2] CSA Std C22.1-1978, Canadian Electrical Code, Part 1, Safety Standards for Electrical Insulations.²

[3] CSA Std C22.2, No 123-1964, Canadian Electrical Code, Part 2, *Safety Standards for Electrical Equipment*, Aluminum Sheathed Cables.

[4] CSA Std C68.1-1965, Paper-Insulated Power Cable "Solid" Type.

[5] *Aluminum Standards and Data*, January 1976, (fifth ed), The Aluminum Association, Inc.³

¹The National Electrical Code is published by the National Fire Protection Association, 470 Atlantic Avenue, Boston, Mass 02210. Copies are available from the Sales department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

²In the US, CSA Standards are available from the Sales department of American National Standards Institute, 1430 Broadway, New York, NY 10018. In Canada they are available at the Canadian Standards Association (Standards Sales), 178 Rexdale Blvd., Rexdale, Ontario, Canada M9W 1R3.

³In the US, this document is available from the Sales department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

[6] ICEA P-45-482-1979, (second ed), Short-Circuit Performance of Metallic Shielding and Sheaths of Insulated Cable.⁴

[7] NEMA Pub No WC4-1976 (ICEA S-65-375, second ed), Varnished-cloth-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy, [21], [22], [23], [24].⁵

[8] AEIC No 1-68-1968, Impregnated-paper-insulated lead-covered cable, (tenth ed), Supplement 2.⁶

[9] EEI Pub No 55-16, *Underground Systems Reference Book*. New York: The Edison Electric Institute Transmission and Distribution Committee, 1957.⁷

[10] SCHIFFREEN, C.S. Cyclic Movement of Cable — Its Causes and Effects on Cable Sheath Life. *AIEE Transactions*, vol 63, 1944, pp 1121–29.

[11] SCHIFFREEN, C.S. Thermal Expansion Effects in Power Cables. *AIEE Transactions*, vol 70, part 1, 1951, pp 160–70.

[12] HALFMANN, E.S. Critical Inside Dimensions for Power Cable Manholes. *AIEE Transactions*, vol 69, part 2, 1950, pp 1576–81.

[13] IEC (International Electrotechnical Commission) Publication 141-1 (1976), Part 1, Oil-Filled, Paper-Insulated, Metal-Sheathed Cables and Accessories for Alternating Voltages up to and including 400 kV.⁸

[14] YANAGIUCHI, H. Analysis of Strain in Corrugated Aluminum Sheath of Cables. *Journal of the Institute of Electrical Engineering of Japan*, vol 85–12, no 927, Dec 1965, pp 103–107.

[15] BIANCHI, G., DURSO, M.A., and OCCHINI, E. Design and Test of a Flexible EHV Cable Connection for a Floating Plant. *IEEE*

⁴ICEA publications are available from Insulated Cable Engineers Association, Inc, P.O. Box P, South Yarmouth, MA 02664.

⁵NEMA publications are available from the National Electrical Manufacturers Association (NEMA), 2101 L. Street, N.W., Washington, DC 20037.

⁶AEIC. This document is available from the Publication Department of the Association of Edison Illuminating Companies, 51 East 42nd Street, New York, NY 10017.

⁷EEI publications are available from the Edison Electric Institute, 1111 19th Street, N.W., Washington, DC 20036.

⁸IEC Standards are available in the US from American National Standard Institute, 1430 Broadway, New York, NY 10018.

Transactions on Power Apparatus and Systems, PAS-96, No 2, Mar/Apr 1977.

[16] LANFRANCONI, G.M., GUALTIERE, G., and CAVALLI, M. 330 kV Oil-Filled Cables Laid in 1600 Ft. Vertical Shaft at Kafue Gorge Hydraulic Plant. *IEEE Paper T73-126-0*.

[17] Weld-joints for 115 kV Cable Sheath. *Electrical World*, December 15, 1972.

[18] AEIC No 4, Impregnated-Paper-Insulated Low-Pressure Oil-Filled Cable.

[19] BS 6480-1969, British Standard Impregnated Paper-Insulated Cables for Electricity Supply: Part 1, Lead or Lead Alloy Sheathed Cables for Working Voltages up to and including 33 kV.⁹

[20] JIS C3613-1974, O.F. Type Paper-Insulated Aluminum-Sheathed Power Cable.¹⁰

[21] NEMA Pub No WC3-1969 (R1974) (ICEA Pub No S-19-81, fifth ed), Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

[22] NEMA Pub No WC5-1973 (ICEA Pub No S-61-402, third ed). Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

[23] NEMA Pub No WC8-1976 (ICEA Pub No S-68-516), Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

[24] NEMA Pub No WC7-1971 (R1976) (ICEA Pub No S-66-524), Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electric Energy.

[25] AEIC No 5, Specifications for Polyethylene and Cross-Linked-Polyethylene-Insulated Shielded Power Cables Rated 5 kV through 69 kV.

[26] AEIC No 6, Specifications for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 kV through 69 kV.

[27] Test Program for Corrugated Type ALS Aluminum-Sheathed Cables, Underwriters' Laboratories, Inc.

[28] VDE 0255/1.68, Regulations for Mass-Impregnated Paper-Insulated Metal-Sheathed Cables for Electricity Supply (except external gas-pressure and oil-filled cables).¹¹

⁹BS Standards are published by the British Standards Institution, 101 Pentonville Road, London N1 9ND. Copies are available in the US from American National Standards Institute, 1430 Broadway, New York, NY 10018.

¹⁰JIS Standards are available in the US from American National Standards Institute, 1430 Broadway, New York, NY 10018.

[29] IEC Pub No 55, Paper-Insulated Metal-Sheathed Cables for Rated Voltages up to 18/30 kV, 55-1 (1978) Part 1: Tests, 55-2 (1965), Tests on Impregnated-Paper-Insulated Metal-Sheathed Cables.

[30] VDE 0286/10.5, Vorschriften fuer Probe-weise Verwendbare Starkstromkabel mit Metallmantel.

[31] McILVEEN, E.E. Aluminum-Sheathed Control Cable. *AIEE Transactions on Power Apparatus and Systems*, No 22, 1956, pp 1376-1384.

3. Definitions

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

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.

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.

high-voltage aluminum-sheathed power cable. Cable used in an electric system having a 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.

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.

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.

¹¹VDE Standards are available in the US from American National Standards Institute, 1430 Broadway, New York, NY 10018.

4.1 Advantages

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

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

4.2.3 For jointing and terminating, 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 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-1940's, 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; corrugated sheath was not used initially because of compound drainage. Subsequently, however, the corrugated sheath found widespread acceptance, mainly in low-voltage extruded-dielectric cables, and large-size oil-filled high-voltage cables, where impregnating compound drainage into the corrugations is not a factor for consideration.

5.2 Products and Installation Conditions

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

(1) Low-voltage cables, type MC in accordance with [11]¹² and types RA60, RA75 and RA90 in accordance with [2] and [3].

(2) General purpose, pressurized, self-contained paper-insulated oil-filled medium- and high-voltage cables

(3) Shaft cables, mainly self-contained oil-filled and extruded-dielectric types

(4) Tunnel cables

(5) Nonpressurized impregnated-paper-insulated medium-voltage cables with a smooth sheath used in vertical risers

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

5.2.3 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.

6. Aluminum Metals and Alloys

6.1 **General.** Aluminum sheathing metals and alloys are characterized by good general corrosion resistance, high thermal and electrical conductivity, good mechanical properties and excellent workability. Such metals are typified by those in [5]. Furthermore, no instance of

¹²Numbers in brackets correspond to those of the references listed in Section 2.