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

IEEE Power Engineering Society

Sponsored by the
Insulated Conductors Committee

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

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Approved 10 December 2003

IEEE-SA Standards Board

Abstract: Design guidelines for cables with aluminum sheaths on low-, medium-, and high-voltage cables are provided. The aluminum sheath is an impervious aluminum or aluminum alloy tube applied either smooth or corrugated over the cable core. The sheath provides mechanical or electrical protection to the cable core and may or may not have an overall jacket or plastic over-sheath. The guide provides information on the application, selection, installation, and use parameters of aluminum sheaths. References and a bibliography related to the use of aluminum sheaths are included.
Keywords: aluminum sheath, high-voltage power cable, low-voltage power cable, medium-voltage power cable, metal-clad cables

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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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Contents

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 SF_6 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]

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[1] This 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.

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

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

[4] The 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/).

[5] UL 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. 123-1996[6]

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 dieletric 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.

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[6] Information 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.

Table 2—Composition of some typical pure aluminum metals by weight

Aluminum minimum (%)	Iron maximum (%)	Silicon maximum (%)	Other elements maximum (%)	
			Each	Total
99.80	0.10	0.06	0.03	0.10
99.75	0.12	0.08	0.03	0.10
99.70	0.20	0.10	0.03	0.10

7. Smooth and corrugated sheaths

Selection of smooth or corrugated sheath is dictated by the requirements of the specific application. The order of importance of the various properties has been ranked to enable a proper selection. In general, smooth-aluminum sheaths may offer advantages for core diameters up to about 25 mm (1 in). Beyond that size, corrugated sheaths are preferred, because large diameter cables with smooth-aluminum sheaths become difficult to handle during manufacture and installation. It should be recognized that even below 25 mm (1 in) core diameter, cables with corrugated-aluminum sheaths are much easier to install than smooth-sheathed cables.

7.1 Smooth-aluminum sheath

7.1.1 Advantages

A smooth sheath offers the following advantages:

a) It is easier to manufacture because of the absence of corrugations, although the latter are normally applied in tandem with the sheathing process.

b) It is easier to wipe than a corrugated sheath.

c) It is less susceptible to elongation during pulling and to elongation that may occur in long vertical installations.

7.1.2 Limitations

A smooth sheath has the following limitations:

a) It is stiffer than a corrugated sheath; therefore, a larger bending force is needed.

b) It requires a larger bending radius because it is susceptible to buckling in sharp bends, which means larger shipping reels and larger manholes are needed. This increases shipping and installation costs. It should be noted that for larger cables, European practice employs bending diameters from 25–35 times the cable's diameter. Once bent into place, it is difficult to reinstall the cable in another configuration. A smooth sheath is more likely to be kinked during installation, especially in small sizes, because installers tend to bend it to smaller radii than recommended. Recommended bending diameters are given in Clause 11.

c) On large cables, a smooth sheath could introduce higher stress on wipes.

7.2 Corrugated-aluminum sheath

7.2.1 Advantages

A corrugated-aluminum sheath offers the following advantages:

a) It features high crush resistance, and therefore, less susceptibility to mechanical damage.
b) A corrugated sheath offers a higher degree of flexibility than smooth sheaths, requiring a smaller bending force, smaller shipping reels, and smaller manholes. The corrugated sheath may be at least 25% thinner than a smooth sheath, resulting in substantial material savings.

7.2.2 Limitations

A corrugated sheath has the following limitations:

a) The cable diameter of a corrugated sheath is larger than its smooth counterpart.
b) The materials savings of a thinner sheath are somewhat offset by the extra metal that goes into the corrugations and the additional jacket material required due to the larger cable diameter.
c) The use of thinner sheaths applies only in cases where the thickness is not dictated by electrical conductance requirements (for example, raceway as the equipment grounding conductor) or hoop stress in high-pressure fluid-filled cables.

8. Selection of sheath thickness

8.1 Mechanical factors

Handling, installation, and service considerations are major factors in determining the thicknesses of coverings for power cable. These factors are mechanical in nature, and an indication of performance can be obtained by testing such parameters as follows:

a) Crush resistance
b) Fatigue resistance
c) Bendability

In addition, those cable constructions involving internal fluid pressures, such as self-contained gas- or fluid-filled paper-insulated types or paper-insulated riser cables, require adequate hoop strength to resist bursting or rupture of the aluminum sheath.

8.2 Grounding and relaying considerations

Metallic sheaths may be used for ground equipment and to ensure relay operation under fault conditions, but electrical codes do not permit their use as a current-carrying conductor. While conductance may dictate a minimum thickness for single-conductor cables, in multiple-conductor constructions the cross-sectional area of the sheath required to satisfy the mechanical factors is more than sufficient to ensure adequate grounding. Wherever electrical codes govern, they must be followed.

8.3 Thickness constraints

There are three distinct methods of applying aluminum sheaths; namely, direct extrusion, seam welding, and tube sinking or die swaging (see Clause 10). A review of the various standards suggests that the thicknesses were the result of constraints imposed by processing as well as the considerations covered in 8.1 and 8.2.

8.3.1 Smooth sheaths

When looking for a guide to thickness for nonpressurized cables, it was natural to turn to lead sheath practice. Accordingly, Table 3 was originally established on the basis of 66% of the recognized lead-sheath wall thickness for rubber-insulated conductors and was then modified from information gained on experimental cables.

If the wall thickness is plotted against maximum core size, the result is a straight line except at the lower end. Experience has shown that with normal installation practices, no buckling or deformation of the sheath occurs with these wall thicknesses.

Table 3 is basic and may be found in CSA Std C22.2, No. 123-1996 and UL 1569-1999. There are other thickness requirements in North America. Table 4 shows thicknesses as specified by the Canadian Standards Association (CSA) for smooth seamless aluminum sheaths (CSA Std C22.2, No. 123-1996). Except for core diameters below 15 mm (0.59 in), they are somewhat more conservative than in Table 3.

Table 3—Average thickness of smooth finish aluminum sheaths

Calculated diameter of core mm (in)	Sheath thickness mm (mil)
0–10.16 (0–0.400)	0.89 (35)
10.19–18.80 (0.401–0.740)	1.14 (45)
18.82–26.67 (0.741–1.050)	1.40 (55)
26.70–33.02 (1.051–1.300)	1.65 (65)
33.05–39.37 (1.301–1.550)	1.90 (75)
39.40–45.72 (1.551–1.800)	2.16 (85)
45.72–52.07 (1.801–2.050)	2.41 (95)
52.10–58.42 (2.051–2.300)	2.67 (105)
58.45–64.77 (2.301–2.550)	2.92 (115)
64.80–71.12 (2.551–2.800)	3.18 (125)
71.15–77.47 (2.801–3.050)	3.43 (135)
77.50–83.82 (3.051–3.300)	3.68 (145)
83.85–90.17 (3.301–3.550)	3.94 (155)
90.20–96.52 (3.551–3.800)	4.19 (165)
96.55–102.9 (3.801–4.050)	4.45 (175)

8.3.2 Corrugated sheaths

The improved bendability resulting from the corrugations enables the thick sheaths associated with large power cables to be handled with less risk of buckling and rupturing. For this reason, directly extruded sheaths may be corrugated.

Corrugations provide improved mechanical characteristics, and therefore, corrugated sheaths are designed with thicknesses that are less than those in Table 3 or Table 4. These reduced thicknesses also permit a faster welding process and, of course, decrease the amount of sheath metal, thereby improving the economics.

Table 4—Minimum thickness of smooth seamless sheath per CSA Std 22.2, No. 123-1996

Calculated diameter of core mm (in)	Sheath thickness mm (mil)
0–7.0 (0–0.276)	0.7 (27.5)
7.01–10.0 (0.276–0.394)	0.9 (35.4)
10.01–15.0 (0.394–0.591)	1.0 (39.4)
15.01–20.0 (0.591–0.787)	1.2 (47.2)
20.01–25.0 (0.787–0.984)	1.5 (59.0)
25.01–30.0 (0.985–1.181)	1.7 (66.9)
30.01–35.0 (1.181–1.378)	2.0 (78.7)
35.01–40.0 (1.378–1.575)	2.2 (86.6)
40.01–50.0 (1.575–1.968)	2.7 (106.3)
50.01–60.0 (1.969–2.362)	3.2 (126.0)
60.01–70.0 (2.363–2.756)	3.7 (145.7)
70.01–80.0 (2.756–3.150)	4.2 (165.4)
80.01–90.0 (3.150–3.543)	4.7 (185.0)
90.01–100.0 (3.544–3.937)	5.2 (204.7)

Table 5 presents the thicknesses for longitudinally applied, formed, welded, and corrugated-aluminum strip sheaths per CSA Std C22.2, No. 123-1996 and UL 1569-1999. Table 6 provides the thicknesses specified by CSA Std C22.2, No. 123-1996 for corrugated sheaths. These vary in relation to those for smooth in Table 4, but generally run from 90% of the thicknesses in Table 4 for the smaller core diameters to 33% of the thicknesses in Table 4 for the larger core diameters.

Table 5—Minimum thickness of corrugated, longitudinally welded aluminum sheaths

Calculated diameter of core mm (in)	Sheath thickness mm (mil)
0–55.37 (0–2.180)	0.56 (22)
55.40–81.03 (2.181–3.190)	0.74 (29)
81.05–106.7 (3.191–4.200)	0.86 (34)

8.3.3 Performance standards for thickness

Underwriters Laboratories (UL), for example, does not specify the thickness of smooth or the thickness and number of corrugations per unit length for corrugated-aluminum tape armor. These items are judged on the basis of performance of the finished cable in specified tests (UL 1569-1999).

8.4 Functional design considerations

8.4.1 Solid-type impregnated-paper-insulated cables

Where cables are installed on poles, vertically in buildings, or in conduit runs with a considerable change in elevation, cables could be subject to compound migration, causing fluid pressure in excess of the strength of the sheath and particularly, the joint sleeve. Therefore, the critical sheath thickness may be greater than the thickness shown in Table 3, Table 4, Table 5, and Table 6. The change in elevation will determine the need for increased thickness. The permissible hoop stress for corrugated and smooth sheaths is 24 MPa (3500 lbf/in^2).

Table 6—Minimum thickness of corrugated-aluminum sheath per CSA Std C22.2, No. 123-1996

Calculated diameter of core mm (in)	Sheath thickness mm (mil)
0–7.0 (0–0.276)	0.6 (23.6)
7.01–13.0 (0.276–0.512)	0.7 (27.5)
13.01–18.0 (0.512–0.707)	0.8 (31.5)
18.01–21.0 (0.709–0.827)	0.9 (35.4)
21.01–25.0 (0.827–0.968)	1.0 (39.4)
25.01–35.0 (0.968–1.378)	1.1 (43.3)
35.01–50.0 (1.378–1.968)	1.2 (47.2)
50.01–60.0 (1.969–2.362)	1.3 (51.2)
60.01–70.0 (2.363–2.756)	1.4 (55.1)
70.01–80.0 (2.756–3.150)	1.5 (59.0)
80.01–90.0 (3.150–3.543)	1.6 (63.0)
90.01–100.0 (3.544–3.937)	1.7 (66.9)

8.4.2 Self-contained

The internal hydraulic pressure should be considered in designing an aluminum sheath for low-pressure fluid-filled cable. The critical sheath thickness may need to be greater than that shown in Table 3, Table 4, Table 5, and Table 6 to accommodate the internal pressure.

8.4.3 Medium- and high-voltage polymeric-insulated cables

Because of the absence of hydraulic pressure in these types of cables, the main determinant may be short-circuit requirements, which can be calculated by several methods (ICEA P-45-482-1999). The referenced method does not take heat dissipation into account and therefore provides a very conservative estimate. Methods that take heat dissipation into account provide a more accurate calculation. These are available from several commercial sources.

The sheath must withstand the short-circuit energy (current magnitude and duration) without damage to the underlying components or the outer jacket.

8.4.4 Manufacturing considerations

In some cases, thicknesses greater than those indicated in Table 3, Table 4, Table 5, and Table 6 will be required for manufacturing reasons.

9. Types of corrugation

9.1 General

Sheath corrugations can either be helical or annular. In the helical type, the corrugation step is performed by a rotating die or disk as the cable moves longitudinally. There are many possible variations of the helical corrugation type. The mechanical characteristics of the corrugated sheath can be largely influenced by choice of wall thickness and corrugation contour. In the annular type, the corrugation contour is perpendicular to the cable axis. The helical type is the most popular.

9.2 Helical corrugations

9.2.1 Nonsymmetrical type

This type of corrugation (see Figure 1) features a helical rib extending radially outward with a relatively long pitch so that there is a cylindrical portion of the sheath in contact with the cable core between the ribs. The hardening due to cold-working covers a relatively large area of the sheath. Although a hinge effect tends to occur about the top of the profile, which is not work-hardened during the corrugating process, there is a chance of cracking or fracture due to the stress concentration at the root of the helical rib. Long-term experience with this type of corrugation has shown satisfactory performance in both extruded dielectric and fluid-filled cables.

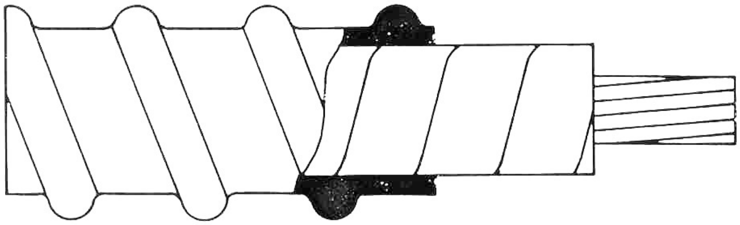

Figure 1—Nonsymmetrical type (helical) corrugation

9.2.2 Symmetrical and near-symmetrical corrugations

This type of corrugation (see Figure 2), which features a nearly sinusoidal configuration, was developed in the early 1950s and has found wide acceptance.

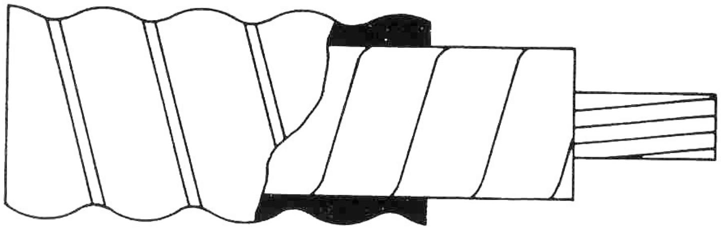

Figure 2—Symmetrical type (helical) corrugation

A very large number of variations in the sinusoidal corrugation configuration is possible. Some designs feature a valley or trough radius that is smaller than that of the peak, thus approaching an arch design. In other designs, the proportions of the peak and valley radii are more nearly equal. Since the mechanical characteristics of the corrugated sheath depend on the interaction of several factors, that is, type of metal, temper, thickness, shape of helical corrugation and pitch, it is very difficult to isolate the effect of subtle changes in the shape of the sinusoidal corrugations. In determining the shape of the sinusoidal or near-sinusoidal corrugations, the design engineer strives for an optimum compromise of desirable mechanical characteristics, cable diameter, and cost.

One important characteristic of the symmetrical corrugation shape is that the corrugated sheath has a uniform cross section in any plane perpendicular to its axis, resulting in a uniform bending characteristic. This corrugation contour features good metal fatigue resistance.

9.3 Annular corrugations

Annular corrugations (see Figure 3) of the near-symmetrical type have been used for some special applications. The cross section of the corrugated sheath along its longitudinal axis is nonuniform. In an annularly corrugated sheath, the trough of the corrugations can be impressed into the cable core, thus constituting an impediment to the migration of impregnating fluid between the core and the cable sheath. This is an advantage in mass-impregnated primary distribution cables where fluid flow due to temperature changes can be restricted.

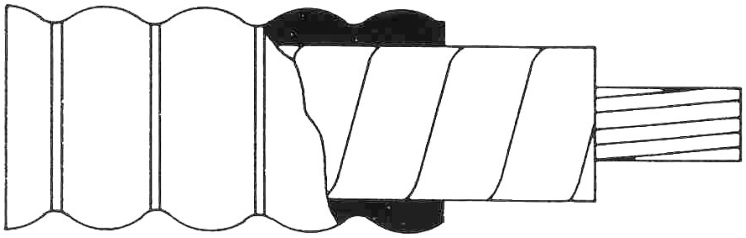

Figure 3—Symmetrical type (annular) corrugation

10. Methods of manufacture

10.1 Direct extrusion process

Using a ram press, the aluminum billet is loaded into a container, heated, and by hydraulic pressure on the ram, the metal is forced around a hollow mandrel and through a die, forming a tube. The insulated core travels through the hollow mandrel and is thereby inserted into the tube or sheath.

There are two types of aluminum sheathing presses, as follows:

a) Double horizontal ram type: Comprises a double-billet horizontal system
b) Continuous single-billet type: Comprises a single-billet (with reservoir) vertical system

To minimize overheating of the cable insulation, extrusion of the aluminum sheath over the core is carried out through the use of lower temperatures (430 °C or 806 °F) and higher pressures than those used in extrusion of tube alone. Normally, some tube sinking is involved in the extrusion process.

Direct extrusion offers the following advantages:

1) The economy of scale achieved in long production runs.
2) The aluminum sheath is softer than that obtained by other processes because of the annealing effect from the hot-working inherent in direct extrusion. Therefore, the sheath has better bending and handling characteristics.

The drawbacks of the direct extrusion process are as follows:

- High capital cost of equipment and a high bay building are needed to accommodate the press.
- The successive charges of billets, particularly those needed for extrusion of large-size sheaths with the discontinuous type of press, could introduce an element of risk of air or oxide inclusions at the billet joints.
- Small-size branch circuit cables are difficult, and in some cases uneconomical, to process in short lengths with direct extrusion due to the relatively long setup time.

For direct extrusion or the extrusion of tube stock, the aluminum has to be of high purity to permit processing.

10.2 Seam welding

Using argon (argon/helium) for the aluminum arc-welding process, an oversized tube is formed around the cable core from a longitudinally folded and welded strip; a simultaneous reducing operation brings the tube to sheath dimensions.

The seam-welding process features lower capital cost and allows the manufacture of small-size cables without the attendant difficulty normally experienced with the direct extrusion method. The same equipment may also be used for copper or steel sheath welding. Furthermore, there are no practical limitations to the diameter of cable for which this process can be used.

10.3 DIDD or the *sinking* process

The DIDD (draw-in-draw-down) process entails drawing the cable core into an aluminum tube, which has an inside diameter larger than the core, and swaging down or corrugating the sheath until the desired fit is obtained. This sinking operation of an aluminum sheath is practicable due to the ability of the metal to sustain a moderate amount of cold-working without significant changes in structure and properties.

The tube is extruded separately and delivered to the sheathing line on reels. The tube is laid out horizontally in a straight line, using rounding dies at the pay-off end or special rollers. A steel line is threaded through the tube directly by magnetic means or by first blowing in a light line to pull in the steel line. The tube containing the insulated core is then passed through a draw-down or corrugation die located near the take-up end.

With the tube-sinking process, optimum mechanical properties develop after about 25% reduction of the tube and the finished sheath exhibits properties of the 1/4-hard temper. The resulting physical or electrical properties, or both, are a fortuitous occurrence with respect to design.

11. Parameters dictating bending radii

11.1 Bending during installation

Bending radii during installation are governed by allowable pulling tensions and sidewall pressures. Experience has shown that the allowable sidewall pressure known to be safe in extruded-dielectric cables and in paper-insulated fluid-filled cables results from tension of 5–6 kN/m (350–400 lbf/ft) of radius at the bend.

When pulling tension is applied to the cable while it is moving through a bend during installation, it is generally considered safe to use twice the radius specified for the cable fixed in its final position.

Sharp concentrated bends can, to some extent, be avoided by the use of suitable guides or mandrels.

For corrugated-aluminum sheaths, it is desirable to establish the allowable sidewall pressure experimentally as the corrugations may cause imprints on the outer layers of the insulation. Resistance to sidewall pressure may be improved by a suitable choice of insulation shielding materials and cushioning binders between sheath and insulation or shield. Corrugations as described in 9.2.1 are the most favorable in terms of sidewall pressures.

11.2 Curves with cable firmly anchored or embedded in position

Bending radii that equal the cable drum diameter are generally considered acceptable. For sharper bends, mandrels or guides must be used, and the cable may be trained to radii approaching those of the drum of the cable reel.

11.3 Expansion loops, offsets in manholes

Expansion loops and offsets in manholes are necessary to accommodate the thermal expansion and contraction of the cable; their length and radius are therefore governed by the fatigue performance of the cable.

After establishing the appropriate minimum bending radius for the type of cable to be installed either experimentally or according to 11.4, cable support systems and manholes may be designed in accordance with practices well established for lead-sheathed cable.

When using the fatigue-resistance calculating methods, special consideration should be given to particularly rigid cable structures, such as those having conductors larger than 1000 mm^2 (2000 kcmil) or to smooth-sheathed high-voltage power cables. For these cables, movement at the entrance of the duct will be greater than that of cables having other conventional metallic sheaths.

In some duct installations, cables are spliced without offset in the manholes, the joints are aligned with the center of the duct, and both cables and joint are firmly clamped at frequent intervals. This installation method permits considerable reduction in the length of manholes. Special attention, however, ought to be given to the resistance of the joint connectors to pulling forces. The design of the cable-support system should prevent buckling and axial movement of the cable and also remove axial stress from the wipes or cast plumbs.

11.4 Bending performance of aluminum sheaths

11.4.1 Smooth sheath

The following are factors influencing the bending performance of a smooth sheath:

a) Hardness of the sheath metal, which is governed by the method of manufacture, composition, degree of cold-working or nonheat-treatable metals, etc.

b) Direct extrusion and higher purity aluminum can improve the bending performance, because in general, the harder the sheath, the more it tends to be susceptible to fatigue and fracture.

c) Bending diameter (in relation to cable diameter).

d) Looseness of the sheath—for example, a tight-fitting sheath improves the bending performance by preventing sheath deformation. (Tight-fitting sheaths are not desirable for fluid-filled cable).

e) Method of bending—for example, bending performance can, in certain cases, improve if the cable is under tension while bending takes place.

f) Radius of the groove of the bending mandrel in relation to the radius of the cable.

g) The ratio of the sheath diameter to sheath thickness, which should be in the order of 20:1 for satisfactory results at practical bending diameters.

Good cable design combined with good installation practice helps to ensure that the sheath does not buckle or deform significantly when the cable is bent to its minimum bending radius.

Because of the complex mechanical structure of an insulated conductor enclosed in a metal sheath, the bending radius at which buckling will occur is difficult to predict, but it is established that increasing the sheath thickness decreases the buckling radius and the minimum permitted bending radius. However, increasing the sheath thickness increases both the force required to bend the cable and the cost of the cable. Furthermore, smooth-aluminum-sheathed cable is already much more difficult to bend than lead-sheathed cable of equal sheath thickness. Because of these factors, the practice has been to select thinner walls for aluminum sheaths and to accept values of bending radii larger than those for lead sheaths.

The bending radius at the inner edge of any bend of type metal-clad (MC) cable with smooth-aluminum sheath is specified to be no less than in the National Electrical Code® (NEC®) (NFPA 70-2002), as follows:

a) Ten times the external diameter of the sheath for cable not more that 19 mm (0.748 in) in external diameter; if conductors are shielded, the bending radius shall not be less than twelve times the overall diameter of the cable.

b) Twelve times the external diameter of the sheath for cable more than 19 mm (0.748 in), but not more than 38 mm (1.496 in) in external diameter.

c) Fifteen times the external diameter of the sheath for cable more than 38 mm (1.496 in) in external diameter.

For solid-type impregnated-paper-insulated cable with a smooth-aluminum sheath, the bending radii recommended in Canada are as shown in Table 7.

In Japan, the allowable bending diameters are as shown in Table 8.

For fluid-filled cables, there are no established industry recommendations. Investigations are underway to determine the optimum bending radii.

Table 7—Minimum bend radius for solid-type impregnated-paper-insulated cable with smooth-aluminum sheath in Canada

Cable overall diameter	Minimum bending radius
≤ 50 mm (2.0 in)	15 × D_0
> 50 mm (2.0 in)	18 × D_0

Table 8—Minimum bend radius for solid-type impregnated-paper-insulated cable with smooth-aluminum sheath in Japan

Cable type	Diameter over aluminum sheath D_0		
	≤ 30 mm (1.181 in)	3–50 mm (1.181–1.969 in)	≥ 50 mm (1.969 in)
Single core	40 D_0	50 D_0	60 D_0
Three core	23 D_0	23 D_0	23 D_0

For solid dielectric cable with a smooth sheath, the recommended bending radii (NEC) are shown in Table 9.

Table 9—Minimum bend radius for dielectric cable with smooth-aluminum sheath in USA

Cable overall diameter D_0	Minimum bending radius
< 19 mm (0.748 in)	10 × D_0
≥ 19 mm < 38 mm (0.748–1.496 in)	12 × D_0
≥ 38 mm (1.496 in)	15 × D_0

11.4.2 Corrugated sheath

A corrugated sheath is more flexible than a smooth sheath. The corrugated-aluminum sheath accommodates bending by distributing bending forces uniformly on the corrugations, and bending diameters approach those determined by insulation and core diameter constraints.

The bending radius at the inner edge of any bend of type MC cable with solid dielectric insulated conductor with a corrugated-aluminum sheath is specified to be no less than seven times the external diameter of the sheath (NEC).

For solid-type impregnated-paper-insulated cable with a corrugated-aluminum sheath, the bending radii recommended in Canada are as shown in Table 10.

For fluid-filled cables, there are no established industry recommendations (see Clause 12). Current practice is to treat corrugated-aluminum sheaths with sinusoidal corrugations and lead sheath as equal as far as the design of bending radii is concerned. Larger bending radii, however, are called for when greater than standard thicknesses or special alloys are used to resist high hoop stresses.

Table 10—Minimum bend radius for solid-type impregnated-paper-insulated cable with corrugated-aluminum sheath in Canada

Cable overall diameter D_0	Total conductor area	Minimum bending radius	
		≤ 20 kV	> 20 kV
≤ 25 mm (1.0 in)		8 × D_0	
> 25 mm (1.0 in)	≤ 760 mm^2 (≤ 1500 kcmil)	8 × D_0	10 × D_0
	> 760 mm^2 (> 1500 kcmil))	10 × D_0	12 × D_0

12. Fatigue characteristics of large-size corrugated-aluminum-sheathed cables installed in restricted manholes

The fatigue resistance of corrugated-aluminum-sheathed cables is influenced mainly by the type of aluminum (Clause 6), the type of corrugation profile (Clause 9), and by the electrical and mechanical loading.

Work done on the fatigue resistance of smooth and relatively small corrugated-aluminum sheaths has led to the establishment of standards on the allowable bending radii (Clause 11). The experience with the existing field installations provides sufficient assurance of the fatigue strength of corrugated sheaths.

Large-size aluminum-sheathed cables are used in duct and manhole installations. The increase in power transmission has led to increased voltages, and therefore, large diameter cables (incorporating large conductors and large insulation thicknesses) are being used. Physical limitations in urban areas and economic considerations restrict the maximum manhole size, forcing the cables to be bent to a radius smaller than generally recommended (see 11.4). Thus the strain on the sheath at the bends in the manhole becomes severe, which increases the probability of fatigue failure. Hence, it is essential to study the fatigue resistance of large-size cables under these conditions.

Fatigue failure in an aluminum sheath can arise from two sources. Mechanical strains, due to expansion or contraction of the cable as a unit, can accumulate at bends in cable runs or in manholes. The second source of fatigue failure can be cyclic thermal stresses introduced by differential expansion of various cable components. The magnitude of this damage depends on the material properties of the aluminum, the geometry of the sheath, the type of electrical loading, and the thermal conductivity of the backfill.

These two components of loading can be either additive or subtractive. However, because of the corrugated shape of the sheath and because the bending strains are in opposite directions on the two sides of the cable, the worst effects of these two components could be present.

An example of a fatigue study is included as Annex B.

13. Installation practices in shafts

13.1 Self-contained fluid-filled cables

In general, installation practices for aluminum-sheathed cables in vertical and inclined shafts are quite similar to those for other types of cable. Because of the susceptibility of aluminum to corrosion, additional care must be taken at the clamping points.

Several vertical and inclined installations involving aluminum-sheathed cables have been in-service in various parts of the world and are operating satisfactorily. The following guidelines are recommended for the selection and installation of aluminum-sheathed cables:

a) The universal metal (99.5% aluminum) is preferred to the pure metal because of its higher hoop strength.
b) Intermittent cable supports are needed to avoid any buckling of the cable under the longitudinal thrust resulting from the thermal expansion of the conductor.

In any splicing area or bay (if existing) in the middle of the shaft, or at bends, the ambient temperature could be substantially higher than the shaft, and therefore the intervals between cable supports would be reduced.

c) Although rigid clamping is the most commonly used technique, in certain cases the clamps are designed to permit rotation of the clamp with the cable as it expands and contracts.
d) Supports can be secured either directly to the wall of the shaft or to an auxiliary steel structure anchored to the wall of the shaft.
e) Fixing the cable to the clamps can be started from the top or bottom of the shaft, depending upon the installation conditions. It is generally preferable to commence securing at the top of the shaft to prevent the full weight of the cable being applied to the lower supports during the clamping operation.
f) Cable fixing can either be rigid or pivotal. In the latter, offsets may be installed if sufficient space is available in the shaft. Installation of offsets generally reduces the number of supports required, thus reducing the cost of cleating, although the actual installation of the cable is more onerous.
g) Several types of cable clamps are available and the choice of a particular design is predicated upon installation conditions. Wedge-type clamps are commonly used, and for sine-wave installation, might be secured to the supporting steel work using a single-bolt fixing to permit some movement of the clamps and to allow the cable expansion bend to assume its normal profile without strain at the clamps.
h) The typical procedure for cable installation is as follows:
    1) The cable reel and control winch are situated above ground.
    2) The cable is fed into the shaft over rollers and is attached to a winch rope. The weight of the cable is supported by the winch rope.
    3) The speed of lowering of the cable is controlled by the winch. Nonrotating mulitstrand steel rope is recommended.

A schematic diagram for this cable installation is shown in Figure 4.

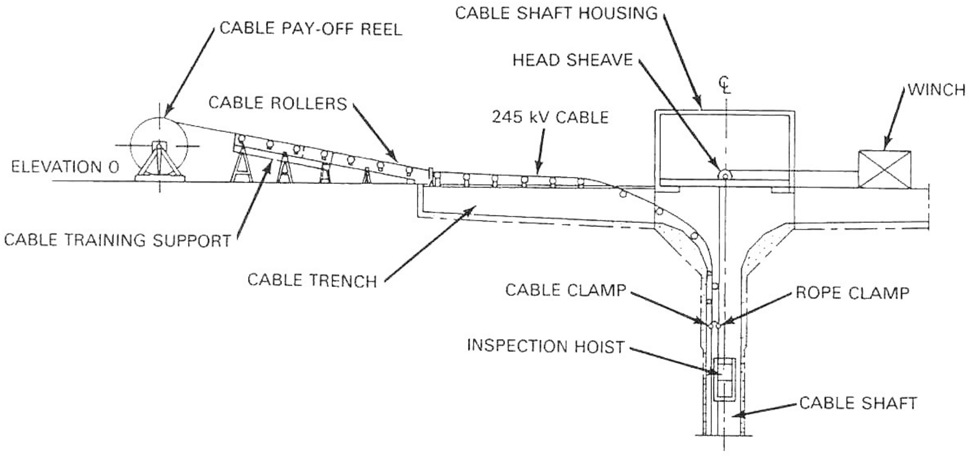

Figure 4—A typical schematic diagram

13.2 Cables with extruded insulations

Either a smooth- or corrugated-aluminum sheath may be used for cables with extruded insulation. Normally, this type of cable is installed in the vertical shaft of high-rise buildings and supported to the shaft wall at intermittent floors. The cable diameter and weight per unit length are normally, by far, smaller than fluid-filled cables, and therefore the installation is less demanding.

According to NEC, the sheath must be close-fitting over the cable core. However, some clearance must be allowed between the core and the sheath in order to facilitate sheath stripping during the splicing and terminating operations. In riser cable installations compromising large conductors (particularly copper) with corrugated-aluminum sheath, there could be incidents of core slippage caused by the weight of the core. It is recommended that offsets be incorporated between supports.

14. Guidelines for splicing and terminating (including pulling eyes)

14.1 Impregnated-paper-insulated and self-contained fluid-filled cables

14.1.1 General

There are three proven methods used to ensure a sound electrical and mechanical connection between the aluminum cable sheath and joints or terminations.

a) The most popular method, wiping, is similar to that used for lead-sheathed cable (see 14.1.2).

b) The second method uses a mold to cast the plumbing metal for increased mechanical strength. It requires similar expertise to that of a plumbing wipe (see 14.1.3).

c) The third method, welding, has been used successfully for special applications and requires special skills and equipment (see 14.1.4).

Additionally, mechanical joints using O-ring seals have been used successfully on a limited number of installations. There have been unsuccessful aerial installations using mechanical joints. However, mechanical joints using heat shrinkable tubing lined with special adhesives have been used. When using these insulating materials for mechanical joints, special care has to be taken to ensure electrical continuity between the aluminum cable sheath and joint sleeves or terminal bases. Also, the heat shrinkable material and the adhesive must be compatible with the insulating liquid.

The first two methods require removal of the aluminum oxide from the cable sheath to establish a metal-to-metal bond. With the wiping and cast plumb methods, this has to be done with extreme care and skill on the part of the installation crew.

It shall be recognized that joints and terminations represent a mechanical discontinuity in the cable core protection. Consideration must be given to the following rigorous conditions that they must be capable of withstanding:

1) The internal hydraulic pressures under both normal and emergency operation

2) The short-circuit and circulating-sheath currents

3) The cable movement caused by thermal cycling due to temperature changes

4) Stresses in rigidly clamped or straight cables, that is, when cables are installed in manholes without offsets to accommodate cable expansion

14.1.2 Wiping

To obtain a firm metal-to-metal bond (that is, without the intervention of aluminum oxide) during wiping, the cable sheath is coated with a nonoxidizing tin alloy while simultaneously removing the aluminum oxide. A number of tinning alloys and fluxes are available for this purpose, with temperature and duration of heat application suitable for the cable insulation and application.

The most frequently used method utilizes a tinning metal or 90/10 tin/zinc, which is wire brushed in a molten state into the aluminum surface.

After tinning, a conventional plumbers' stick wipe can be made between the cable sheath and the joint sleeve or terminal base using a 40/60 tin/lead wiping solder in stick form. Pot wipes are not recommended due to the possibility of residuals or contamination, or both.

For further details, see Annex C.

14.1.3 Cast plumb mold

As an alternative to a plumbing wipe over the tinned sheath or to supplement the plumbing wipe to give increased mechanical strength, a cast plumb may be used. Basically, this method differs from wiping in that after tinning, instead of molding solder by hand, the 63/37 tin/lead solder is cast in a metal mold around the sheath to form an exceptional mechanical reinforcement and seal.

Details of the application of a cast plumb mold are given in Annex C.

14.1.4 Arc welding

Because of the high temperature involved and the proximity of the cable insulation, sheath welding techniques are designed to keep the welds as small and as far from the insulation as possible. This involves forming the end of the cable sheath into a flange, using a specially designed metal upsetting tool and making a small weld between the rim of this flange and a transition piece, which, in turn, is welded or bolted to the joint sleeve or pothead base.

The weld uses the conventional TIG or MIG methods with either argon or helium as the inert gas. Argon is preferred because of better control of the weld pool and arc, and because there is less clouding and the metal stays brighter, enabling the welder to see the weld more clearly.

It should be noted that experience with welded joints for aluminum sheaths, although limited to a few special projects, has been commendable. It should also be noted that all welding on aluminum causes softening and loss of strength in the heat-affected zone. This should be considered when designing any welded connection. The strength cannot normally be recovered since the alloys being used are not heat treatable.

14.2 Polymeric-insulated cables

Specially designed mechanical connectors are used to connect aluminum-sheathed polymeric-insulated cables to termination and connection boxes. Many designs with a proven service record are commercially available.

Solder wiping, as described in 14.1.2, may be employed on cables insulated with thermosetting materials but is not recommended for thermoplastic-insulated aluminum-sheathed cables due to extreme caution needed to avoid damage to the insulation during the tinning and wiping operations.

14.3 Pulling eyes

Conventional pulling eyes are normally installed in the factory at the leading end of the cable on the reel. For self-contained fluid-filled cable, a fitting is provided for fluid feed through the pulling eye.

A typical pulling eye for self-contained fluid-filled cable features a strong connection to the conductor as well as to the cable sheath. The hollow core conductor is clamped against the cylindrical portion of the pulling eye by wedge-shaped steel pieces that force the conductor segments against the inner wall of the pulling eye; the wedge incorporates a hollow channel for continuation of the fluid feed. The aluminum sheath is hammered against the outside surface of the cylindrical portion of the pulling eye and wiped in the normal manner. Several other mechanical designs have been used for special applications and exceptional installation requirements.

Annex A

(informative)

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Annex B

(informative)

Fatigue study of large-size helically corrugated aluminum-sheathed cables

An investigation of the fatigue resistance of large-size corrugated-aluminum cable sheaths is briefly outlined here.

An experimental program on the fatigue strength of 76 mm (3.0 in) and 97 mm (3.8 in) diameter sinusoidal-type corrugated-aluminum (99.7%, see Table 2) cable sheath specimens led to the fatigue life relationship shown in Figure B.1.

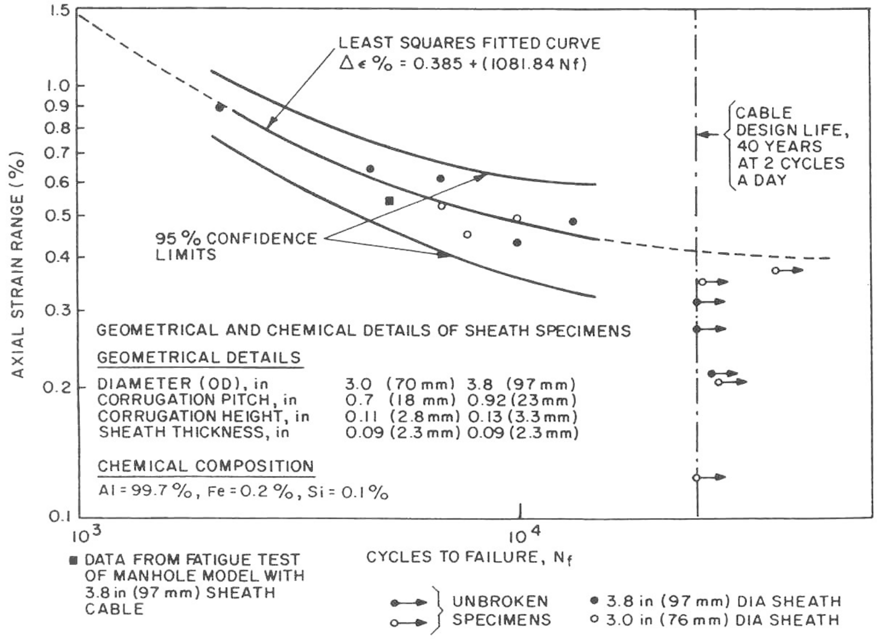

Figure B.1—Example of a fatigue life relationship

The corrugated-sheath specimens were subjected to fully reversed axial push-pull loading without bending. During each test axial strains at various locations on the sheath's surface were measured using long-life fatigue strain gauges.

The specimens were under low internal air pressure. Any sudden drop in this pressure, which indicated the formation of a crack, was considered to indicate failure. This failure criterion determines the usefulness of the cable sheath based on the electrical requirements of the cable.

It is seen from Figure B.1 that a single curve is sufficient to represent the fatigue-life data for both of the corrugated sheaths tested, even though the corrugation profiles are different in each case. However, because strain is a dimensionless parameter, the sheath-strain fatigue-life curve for the usual high-voltage cable sizes would be expected to fall about a single curve with an acceptable narrow band of scatter. More tests on sheath specimens with wide variations of geometrical dimensions are necessary to verify this relationship.

This relationship can be applied to calculate the fatigue resistance of corrugated-sheath cables, if the maximum strain in the cable can be analytically computed or estimated from field measurements.

Annex C

(informative)

Recommended installation practices for hand wipe and cast plumb mold technique for sealing aluminum-sheathed cables

C.1 General

Installation requiring plumbers' wipes on joints or terminations of aluminum-sheathed cables should be viewed by the splicer with the same confidence as would the conventional lead sheath type. Full understanding of the minor but essential differences and practice in their execution will reward the splicer with consistent success in wiping aluminum-sheathed cables.

C.2 Required tools and materials

In addition to standard splicer's tools and splicing materials, the following tools and materials are required:

a) Aluminum file: double cut, rough *bastard* file for removing longitudinal die marks, scores, and oxide film from aluminum-sheath wipe area
b) Brass brush: stiff brass-bristle brush for brushing in the tinning metal to wet under the oxide film (steel wire brushes may leave steel particles, which could hamper the tinning process)
c) Tinning stick: for friction tinning aluminum sheath 200–250 g (0.5 lb) stick of 90/10 tin/zinc alloy
d) Wiping sticks: 40/60 tin/lead alloy wiping sticks for making stick wipe after sheath is tinned
e) Stearine or flux: free wiping pad of moleskin, wipers cloth, or paper pad

C.3 Preparations for jointing or potheading

C.3.1 Training the cable

The aluminum-sheathed cables should be trained for proper manhole offsets or pot-head location. In the case of aluminum-sheathed cables, the stiffer sheath calls for special care and attention and a greater effort to achieve the desired bends. For this reason, the bending and training should be done gradually, with the bending region distributed to avoid a sharp injurious bend. Where possible, bending mandrels or bending tools are worthy assets.

C.3.2 Minimize exposure of the insulation

As much preparatory work as possible should be undertaken prior to cutting open the cables in order to keep exposure of the insulation to a minimum.

C.3.3 Preparatory work

These prior preparations include the following:

a) Location of centerline of joint or measurement of cable ends to be terminated

b) Location of the ends of the sheaths in a joint and partial scoring with a tube or pipe cutter, knife or hacksaw

c) Tinning and tinning protection of the aluminum sheath in the wipe region

C.4 Steps in tinning aluminum-sheathed cables

C.4.1 Cleaning and cleanliness

One of the mandatory requirements for wiping aluminum-sheathed cables is cleanliness in performing the operations and cleanliness of the aluminum sheath and tools directly in contact with the aluminum and the tinned region.

C.4.1.1 Cleaning the sheath

A slight film of fluid may remain on the sheath from the manufacturing process. This fluid film, grease, dirt, tar, or asphalt from protective coverings should be thoroughly removed by solvents such as 1,1,1-tricholoethane or perchloreoethylene. (OSHA regulations should be adhered to in choosing the solvent.) It is a good practice to keep from handling the sheath in the area to be tinned after the cleaning operation.

C.4.1.2 Clean Tools

In both the filing and the brushing steps of the tinning technique, it is essential that any dirt on the file and brush used does not spoil the area tinned during the removal of the oxide. Such contamination as foreign metal particles of lead or copper, dirt, grease, asphalt, etc., prevent the thorough and complete wetting of the parent metal and can lead to a poor wipe or subsequent failure. It is good practice to reserve a clean file and brush for use on aluminum sheath only, keeping both cleansed as often as necessary.

C.4.2 Tinning the sheath

The tinning of the aluminum sheath is done in five definite steps for a length of 100–125 mm (4–5 in) at the wipe region, as follows.

C.4.2.1 Step 1: Filing

The area to be tinned should be uniformly but not deeply filed to remove the heavy oxide film formed on the surface of the aluminum and to remove any longitudinal scores, die marks, or crevices. The filing should be done circumferentially around the sheath, not lengthwise along the sheath. A clean file for aluminum should be used.

C.4.2.2 Step 2: Friction tinning

Immediately after filing, the prepared area should be heated moderately with a blowtorch, to heat sufficient to melt the end of the tinning stick. Excessive heat should be avoided by testing with the end of the tinning stick.

After the prepared surface is sufficiently heated, the tinning solder of 90/10 tin/zinc should be applied by rubbing the stick firmly and evenly over the complete area to be tinned. Light applications of the blowtorch will be required to maintain the required tinning temperature. No flux of any kind is required and is not to be used as it will spoil the tinning metal underneath the ever-forming thin layer of aluminum oxide and prevent the tinning of the virgin metal thus exposed. The rubbing should leave the tinning solder deposited fairly evenly over the surface of the aluminum. Only moderate heat is necessary.

C.4.2.3 Step 3: Brushing

The friction tinning is to be followed immediately by vigorous and methodical brushing of the tinning solder through to the aluminum with a stiff brass-bristle brush, using only as much heat from the blowtorch as is necessary to keep the solder molten and the brush bristles from packing with solder. This brushing assures that any remaining oxide is lifted and promotes the thorough amalgamation of the solder with the aluminum.

C.4.2.4 Step 4: Re-tinning

Since most of the excess tinning solder has been scrubbed off, it is essential to reapply a thin application of tinning solder to the area by rubbing the tinned surface firmly with the tinning stick, aided by moderate heat from the blowtorch. Any difficult to reach places should be closely examined and rubbed at this time to assure complete coverage. The achievement of proper tinning can be checked by touch, brushing the molten solder with a clean cloth or paper pad. If the tinning is complete, the surface will be bright and smooth behind the cloth.

C.4.2.5 Step 5: Protective cover

Immediately after Step 4, the tinned surface should be protected during the course of subsequent splicing or potheading procedures by a light coating of wiping solder. A solder of 40/60 tin/lead in stick form is recommended. The end of the stick should be softened with a blowtorch, and with minimum heating of the tinned surface, the tinned area should be lightly but completely covered with 40/60 solder with little or no rubbing.

Stearine or other flux must not be used in any of the preceding five steps.

C.5 Wiping aluminum-sheathed cables

Subsequent to the tinning procedure, all further operations are as in standard lead sheath wipes except that a stick wipe of 40/60 tin/lead solder is preferred. A pot wipe or ladle wipe where molten solder is poured over the wipe area is not to be used due to the danger of excess heat. The running solder can strip off the tinning. There can be contamination of the pot solder by the zinc from the tinning solder. When a large wipe is to be made, a puddle wipe is satisfactory for extra reinforcement, provided the wiping solder is prepared in a clean ladle or clean pan and applied with a stearine-free wiping sloth. For puddle wipes, it is still necessary to make the initial seal with a stick wipe before adding the bulk of the metal using the puddle wipe.

In stick wiping, the wipe area should be heated with a blowtorch just sufficiently to permit softening of the wiping solder stick while keeping the applied metal plastic. Excess heat can be avoided by testing with the end of the solder stick. It is good practice to apply the solder to the lead sleeve or wiping bell adjacent to rather than on the tinned aluminum sheath, or the metal built up on top of that which was first applied. The main purpose of this procedure is to prevent removal of the tinning solder from the aluminum. The plastic metal should be packed and patted into a nonporous mass rather than dragged using stearine-free wiping cloths or paper pads. The wipe should be shaped and dressed cleanly with a minimum of wiping or brushing and with precautions against excess application of heat.

No stearine or flux is necessary to achieve a satisfactory wipe. Prior to the wiping operation, the sleeve or wiping bell should be tinned away from the tinned surface to prevent any stearine or flux from contaminating the tinned surface.

C.6 Application of cast plumbs

The alternative method to wiping is the use of cast plumb mold. This consists essentially of contoured container applied over the cable sheath and overlapping the joint casing for a distance of 100–150 mm (4–6 in). The container is filled with eutectic metal (63/37), displacing a hot liquid flux of palm fluid to provide a hermetic seal between the cable sheath and the joint. This technique replaces the wipe and has been found to have higher resistance to internal pressures than a wipe. The details of the technique are as follows:

a) When the joint casing or pothead bell is in the correct position for application of the cast plumb molds, the end or ends are sealed with the heat-resistant gasket or packing provided. This seal must be made with great care to prevent the ingress of palm fluid and eutectic metal into the joint sleeves or pothead bell later on.

b) Inspect the tinning of the sheath and wiping ends of the casing for imperfections.

NOTE—It is essential that the tinning be done in the approved manner and done extremely well. Any suspicious portions of the tinning must be redone.

c) Place the cast mold in position and seal the ends with tight wrappings of cotton tape soaked with palm fluid.

d) Proceed with making the cast plumb as follows:

    1) Open top and bottom casing outlets or otherwise vent the accessory to be sealed.

    2) Fill mold with new palm fluid preheated to 220 °C ± 3 °C (428 °F ± 6 °F). Heating the palm fluid higher than this temperature darkens the fluid and causes excess fumes.

    3) Heat the palm fluid in the mold to 175 °C–190 °C (350 °F–375 °F) by placing a torch on the mold, with an accurate dial type thermometer inserted in the mold.

       Hold the palm fluid at this temperature for 5 to 8 minutes.

    4) Fill the mold with the eutectic metal preheated to 250 °C–254 °C (482 °F–489 °F). The palm fluid is thereby displaced. The surface of the molten eutectic in the solder pot should be protected from the formation of oxide by a film of palm fluid during and after heating. Ladles used should be clean and preheated in the heated eutectic metal.

When pouring the eutectic into the mold, avoid as much as possible directing the stream of molten metal into the tinned sheath. The metal should be poured in such a manner as to flow down the side of the mold, filling the mold gradually from the base and displacing the palm fluid.

Allow the mold to cool slowly from the base upwards by periodically placing a blowtorch on the upper section to maintain a molten surface while the lower part cools, as the eutectic alloy shrinks due to cooling. Top up the mold with more molten alloy until the complete mold of metal sets.

C.7 Protection against moisture

Since prolonged exposure (as may be found in direct burial or humid outdoor installations) may be detrimental to the wipe or cast mold, it is recommended that all wipes and the adjacent aluminum sheath be protected from the moisture by careful application of a good waterproof paint, asphalt, heavy waterproof grease, or other impervious protective material.