

INTERNATIONAL STANDARD

Concentric lay stranded overhead electrical conductors containing one or more gap(s)



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Concentric lay stranded overhead electrical conductors containing one or more gap(s)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CONCENTRIC LAY STRANDED OVERHEAD ELECTRICAL CONDUCTORS CONTAINING ONE OR MORE GAP(S)

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The text of this standard is based on the following documents:

FDIS	Report on voting
7/587/FDIS	7/588/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

CONCENTRIC LAY STRANDED OVERHEAD ELECTRICAL CONDUCTORS CONTAINING ONE OR MORE GAP(S)

1 Scope

This International Standard specifies the electrical and mechanical characteristics of concentric lay stranded overhead electrical conductors, containing one or more self-supporting aluminium or aluminium alloy layer(s) as depicted in Figure 1, made of combinations of any of the following metal wires:

- a) hard-drawn aluminium as per IEC 60889, designated A1;
- b) aluminium alloy type A or B as per IEC 60104, designated A2 or A3;
- c) thermal resistant aluminium alloy type as per IEC 62004, designated AT1, AT2, AT3 or AT4;
- d) regular strength steel as per IEC 60888, designated S1A or S1B;
- e) high strength steel as per IEC 60888, designated S2A or S2B;
- f) extra-high strength steel as per IEC 60888, designated S3A;
- g) aluminium-clad steel as per IEC 61232, designated 20SA, 27SA, 30SA or 40SA.

NOTE This standard covers the construction of self-damping conductors, as well as gap-type conductors. Although both types of conductors share a common design feature and the presence of one or more gaps between layers, they are intended for different purposes. Self-damping conductors (SDC) may have more than one gap to provide increased self-damping, whereas gap-type conductors are so designed as to allow the aluminium layers to slide freely over the core during installation, and therefore usually do not require more than one gap.

The various metal combinations permitted by this standard shall be in accordance with Table 1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60104:1987, *Aluminium-magnesium-silicon alloy wire for overhead line conductors*

IEC 60888:1987, *Zinc-coated steel wires for stranded conductors*

IEC 60889:1987, *Hard-drawn aluminium wire for overhead line conductors*

IEC 61232:1993, *Aluminium-clad steel wires for electrical purposes*

IEC 61395:1998, *Creep test procedures for stranded conductors*

IEC 62004:2007, *Thermal resistant aluminium alloy wire for overhead line conductors*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

aluminium

all types of aluminium and aluminium alloys listed in Clause 1

3.2

annular gap

constant space, void of any material except for air or grease, between two layers of a conductor

3.3**canting**

phenomena by which a formed wire is twisted relative to its own axis, thus producing a protuberance outside the layer

3.4**conductor**

material intended to be used for carrying electric current consisting of a plurality of uninsulated wires twisted together

3.5**concentric lay stranded conductor**

conductor composed of a central core surrounded by one or more adjacent layers of wires being laid helically in opposite directions.

3.6**direction of lay**

direction of twist of a layer of wires as it moves away from the viewer, with a right-hand lay being a clockwise direction and a left-hand lay being an anti-clockwise direction

3.7**equivalent wire diameter**

the diameter of a round wire which would have the same cross-sectional area as a given formed wire

3.8**formed wire**

filament of drawn or rolled metal having a constant, non-circular cross-section

3.9**layer**

group of wires located at a constant radial distance from the centre of the conductor

3.10**lay length**

axial length of one complete turn of the helix formed by an individual wire in a stranded conductor

3.11**lay ratio**

ratio of the lay length to the external diameter of the corresponding layer of wires in the stranded conductor

3.12**lot**

group of conductors manufactured by the same manufacturer under similar conditions of production

NOTE A lot may consist of part or all of the purchased quantity.

3.13**nominal**

name or identifying value of a measurable property by which a conductor or component of a conductor is identified and to which tolerances are applied

NOTE Nominal values should be target values.

3.14**rated tensile strength**

calculated maximum tensile load value at which a conductor may be subjected before one or more of its constituent wires break

3.15**round wire**

filament of drawn metal having a constant circular cross-section

3.16**self-supporting layer**

layer made of formed wires which are designed in such a way as to not rely on the underlying layer for support

4 Designation system

A designation system is used to identify stranded conductors containing one or more gap(s). Conductors are designated AxGy/Syz or AxGy/SA where Ax identifies external wires (or the envelope), Gy denotes the presence and the number of annular gap(s) between two or more layers, and Syz and SA identify the steel core. In the designation of zinc coated wires, y represents the type of steel (regular, high or extra high strength) and z represents the class of zinc coating (A or B).

Conductors are identified as follows:

- a) a code number giving the equivalent conductive section of A1 expressed in mm²;
- b) a code number giving the section of the core material in mm²;
- c) a designation identifying the type of wires constituting the conductor in accordance with the second paragraph of this clause. The first designation (Ax) applies to the envelope, the second designation (Gy) applies to the presence and number of annular gap(s), and the third designation (Syz or SA) applies to the core;
- d) a code number designating the outside diameter of the conductor.

Example: 400/66-A1G2/S1A-274: A conductor made of 400 mm² A1 and 66 mm² S1A (regular strength steel), containing two annular gaps, with a nominal outside diameter of 27,4 mm (274 x 0,1).

5 Requirements for stranded conductors**5.1 Material**

Stranded conductors shall be made up of round and/or formed aluminium wires and of zinc-coated steel or aluminium-clad wires. Before stranding all wires shall have the properties as specified in the International Standards given in Clause 2.

5.2 Conductor sizes

A list of conductor sizes is given as guidance in Annex E. Conductors for existing or established designs of overhead lines as well as sizes and strandings not included in this standard may be designed and supplied as agreed upon by the manufacturer and purchaser and the relevant requirements of this standard shall apply.

5.3 Surface

The surface of the conductor shall be free from all imperfections visible to the unaided eye (normal corrective lenses accepted), such as nicks, indentations, etc., not consistent with good commercial practice.

5.4 Stranding**5.4.1 General**

All wires of the conductor shall be concentrically stranded. Before stranding, aluminium and core wires shall have approximately uniform temperature.

Adjacent wire layers shall be stranded with reverse lay directions. The direction of lay of the external layer shall be right-hand except when specifically indicated in the purchase order.

5.4.2 Lay ratio for core wires

The lay ratios for the zinc-coated (galvanised) steel or aluminium-clad wire layers shall be as follows:

- a) the lay ratio for the six-wire layer of the core shall be not less than 16 nor more than 26;

- b) the lay ratio for subsequent core layers shall be not less than 14 nor more than 22. The lay ratio of subsequent layer(s) shall be not greater than the lay ratio of the core layer immediately beneath it.

All core wires shall lie naturally in their position in the stranded core, and where the core is cut, the wire ends shall remain in position or be readily replaced by hand and then remain approximately in position.

5.4.3 Lay ratio for aluminium layer(s)

The lay ratios for the aluminium layer(s) shall be as follows:

- a) the lay ratio for the outside layer of aluminium wires shall be not less than 10 nor more than 14;
- b) the lay ratios for the inner layers of aluminium wires shall be not less than 10 nor more than 16;
- c) the lay ratio of any aluminium layer shall be not greater than the lay ratio of the aluminium layer immediately beneath it.

Aluminium wires composing the outside layer of the conductor shall lie naturally in their position, and where the conductor is cut, they shall remain in position or be readily replaced by hand and then remain approximately in position.

5.4.4 Joints

There shall be no joints of any kind made in the core wire or wires during stranding.

There shall be no joints in the finished aluminium wire prior to stranding.

During stranding, no aluminium wire welds shall be made for the purpose of achieving the required conductor length.

Joints are permitted in aluminium wires unavoidably broken during stranding, provided such breaks are not associated with either inherently defective wire or with the use of short lengths of aluminium wires. Joints shall conform to the geometry of original wire, i.e. joints shall be dressed smoothly with a shape equal to that of the parent wires and shall not be kinked.

Joints in aluminium wires shall not exceed those specified in Table 2. These joints shall not be closer than 15 m from a joint in the same wire or in any other aluminium wire of the completed conductor.

Joints shall be made by electric butt welding, electric butt cold upset welding or cold pressure welding (see Note 1) and other approved methods. These joints shall be made in accordance with good commercial practice. The first type of joints shall be electrically annealed for approximately 250 mm on both sides of the weld.

While the joints specified in this clause are not required to meet the requirements of unjointed wires (see Note 2), they shall withstand a stress of not less than 75 MPa for annealed electric butt welded joints and not less than 130 MPa for cold pressure and electric butt cold upset welded joints. The manufacturer shall demonstrate that the proposed welding method is capable of meeting the specified strength requirements.

NOTE 1 It is a practice in some countries to require the annealing of cold pressure joints made in A2 or A3 material.

NOTE 2 The behaviour of properly spaced wire joints in stranded conductors is related to both tensile strength and elongation. Because of higher elongation properties, the lower strength annealed electric butt welded joint gives a similar overall performance to that of a cold pressure or an electric butt cold upset welded joint.

5.4.5 Linear mass

The masses given in the Table E.1 of Annex E have been calculated for each size and stranding of conductor using densities for the aluminium, aluminium-clad and zinc-coated steel wires as given in the standards listed in Clause 2, the stranding increments given in Table 3, and the cross-sectional areas for aluminium and core wires based on their theoretical unrounded values.

The increments in per cent, for mass due to stranding, based on the mean lay ratios given in 5.4.2 and 5.4.3, shall be taken as given in Table 3. If greater accuracy is desired, actual lay factors shall be used.

Whenever a conductor is to be greased, the nominal mass of grease shall be calculated according to the method given in Annex C.

5.4.6 Conductor strength

The rated tensile strength at room temperature of composite conductors shall be the sum of the tensile strength of the aluminium portion plus the strength of the core corresponding to an elongation compatible with that of aluminium at rupture load. For the purpose of specification and practicability, the strength of steel and aluminium-clad steel is conservatively established as the stress corresponding to 1 % elongation in a 250 mm gauge length.

The tensile strength of any single wire is the product of its nominal area and the appropriate minimum stress given in the standards listed in Clause 2.

6 Tests

6.1 Classification of tests

Type tests are intended to verify the main characteristics of a conductor which depend mainly on its design. They are carried out once for a new design or manufacturing process of conductor and then subsequently repeated only when the design or manufacturing process is changed.

Sample tests are intended to guarantee the quality of conductors and compliance with the requirements of this standard.

6.2 Type tests

Type tests shall be carried out only on a conductor which meets the requirements of all the relevant sample tests.

Type tests consist of the following:

- a) joints in aluminium wires;
- b) annular gap(s);
- c) stress-strain curves;
- d) breaking strength of conductor;
- e) creep curves.

6.2.1 Length of sample required

The sample length required for tensile and stress-strain tests shall be at least 400 times the diameter of the conductor but not less than 10 m.

The length of samples in this subclause is the minimum required for a good accuracy of stress-strain curves. In cases where the manufacturer can demonstrate to the satisfaction of the purchaser with significant comparative test results that a shorter length can provide equally accurate results then a short length of samples may be used.

6.2.2 Joints in aluminium wires

The manufacturer shall demonstrate to the purchaser that the method used for jointing aluminium wires meets the strength requirements of 5.4.4 by supplying recent test results or by performing the necessary tests.

6.2.3 Annular gap(s)

The method of measurement of the annular gap(s) shall be agreed upon between the purchaser and the manufacturer. Measurements can be done directly on the outside and inside diameters of the concerned layer or alternatively the method described in Annex D shall be used.

When measured in accordance with this subclause, the value of the annular gap shall not vary by more than +0,15 mm and less than -0,25 mm from the value specified by the supplier.

6.2.4 Stress-strain curves

Stress-strain curves shall be supplied as a type test when requested by the purchaser and shall represent the best knowledge of the behaviour of the purchased conductor under load.

If agreed between purchaser and supplier when placing an order, stress-strain tests shall be performed on the conductor and on the core, in accordance with the method given in Annex B.

6.2.5 Breaking strength of conductor

The breaking strength of conductors shall be determined by pulling a conductor in a suitable tensile testing machine having an accuracy of at least $\pm 1\%$. It is recommended that the rate of increase of load should be as in B.6. For the purposes of this test, appropriate fittings shall be installed on the ends of the conductor samples. During this test, the breaking strength of the conductor shall be determined by the load attained at which one or more wires of the conductor are fractured. A retest, up to a total of three tests, may be made if wire fracture occurs within 10 mm of the end fittings and the tensile strength falls below the specified breaking strength requirements.

When tests for breaking strength of conductors are required, these shall withstand, without the fracture of any wire not less than 95 % of their rated tensile strength calculated according to 5.4.6.

When required, the breaking strength of the core shall be determined in accordance with this subclause.

6.2.6 Creep curves

Creep curves shall be supplied as a type test when requested by the purchaser and shall represent the best knowledge of the behaviour of the purchased conductor under load.

If agreed between purchaser and supplier when placing an order, creep tests shall be performed on the conductor, in accordance with IEC 61395.

6.3 Sample tests

Sample tests consist of the following:

- a) on wire before stranding as per applicable wire standards;
- b) on the completed conductor:
 - cross-sectional area
 - overall diameter
 - linear mass
 - surface condition
 - lay ratio and direction of lay
 - breaking strength of wires after stranding (if requested)
 - wire canting on the outside layer (if requested).

Samples for tests specified in a) shall be taken before stranding and tested in accordance with the standards listed in Clause 2.

Samples for the tests specified in b) shall be taken at random from the outer end of 10 % of the drums of conductor. However, the inspection of the surface condition of the conductor shall be carried out on every drum prior to lagging.

Samples for tests of individual wires after stranding, when requested, shall consist of a 1,5 m length cut from the outer end of the drums of conductors.

6.3.1 Cross-sectional area

The cross-sectional area of the conductor shall be taken as the sum of the areas of the wires composing the conductor. The area of round wires shall be based on the measurements made in accordance with 6.3.1.1. The area of formed wires shall be based on the method in accordance with 6.3.1.2.

6.3.1.1 Round wires

The diameter of a round wire shall include the metallic coating, where applicable and shall be measured using a micrometer calliper having flat surfaces on both the anvil and the end of the spindle and graduated to be read in micrometers. The diameter shall be the average of three diameter measurements, each of which is the average of the maximum and minimum readings at a point taken near each end and in the centre of the sample.

When measured in accordance with this subclause, the area shall not vary from the nominal value by more than $\pm 2\%$ in any sample and by more than $\pm 1,5\%$ for the average of any four measured values at locations selected at random with a minimum spacing of 200 mm.

6.3.1.2 Formed wires

The equivalent diameter of a formed wire shall be obtained from the weight measurements made on a sample not less than 1 m in length, and its density as defined in the appropriate standard listed in Clause 2.

When determined in accordance with this subclause, the area shall not vary from the nominal value by more than $\pm 2\%$ in any sample and by more than $\pm 1,5\%$ for the average of any four samples selected at random on the bobbins after drawing.

6.3.2 Overall diameter

The conductor diameter shall be measured half-way between the closing die and the capstan while still under tension on the stranding machine. Measurements shall be made with a calliper graduated to be read in 0,01 mm. The diameter shall be the average of two readings, rounded to two decimals of a millimetre, taken at right angles to each other at the same location.

When measured in accordance with this subclause, the diameter of the conductor shall not vary by more than $\pm 1\%$ for diameters larger than or equal to 10 mm and $\pm 0,1$ mm for diameters smaller than 10 mm.

NOTE The purpose of measuring under tension is to ensure that all layers are resting on the layer underneath. Thus, other means of measurement, such as on a cut sample, are possible.

6.3.3 Linear mass

The linear mass of the conductor shall be determined by using apparatus capable of achieving an accuracy of $\pm 0,1\%$.

The mass of grease in a conductor shall be determined from the difference between the mass of the conductor with grease and its mass after removing all the grease. The mass of grease shall correspond at least to the minimum values specified in Annex C. In case of non-compliance with the values of Annex C, the manufacturer shall demonstrate that the weight of grease is adequate to achieve its intended purpose.

When measured in accordance with this subclause, the mass of the conductor per unit length without grease shall not vary from its nominal value by more than $\pm 2\%$. In case of non-compliance with nominal values, the actual lay factors shall be used.

6.3.4 Surface condition

The surface of the conductor shall comply with the requirements of 5.3.

6.3.5 Lay ratio and direction of lay

The lay ratio of each layer of the conductor shall be obtained through the ratio of the measured lay length to the external diameter of the applicable layer.

When measured in accordance with this subclause, the obtained values shall comply with the requirements of 5.4. In addition, the direction of each layer shall be noted and shall also comply with the requirements of 5.4.

6.3.6 Breaking strength of wires after stranding (if requested)

When required, breaking strength tests shall be made on wires obtained from conductors after stranding. The specimen of wire shall be taken from the conductor sample and shall be removed from its position and straightened, care being taken not to stretch it in so doing.

The cross-sectional area of the wire is determined from the diameter measurements indicated in 6.3.1.1 and 6.3.1.2. The straightened wire shall be installed in a suitable tensile testing machine. The load shall be applied gradually with a rate of separation of the jaws not less than 25 mm/min and not greater than 100 mm/min.

When tested in accordance with this subclause, the load at failure divided by the cross-sectional area of the wire shall be not less than 95 % of the applicable stress requirements prior to stranding (the 5 % reduction accounts for handling and twisting of wires during stranding.).

6.3.7 Wire canting on the outside layer (if requested)

This test is intended for conductors that are to be used for the reduction of aeolian vibrations and for which the outside layer is composed of formed wires.

Wire canting shall be measured on the outside layer of the conductor (as shown in Figure 2). The magnitude of wire canting shall be measured while the conductor is in the stranding equipment, under tension, half-way between the capstan and the closing die. Canting shall be measured on each wire with a feeler gauge and recorded.

When measured in accordance with this subclause, the maximum canting for any wire shall not be more than 0,5 mm.

7 Inspection

7.1 Test location

All tests and inspection shall be made at the manufacturer's plant prior to shipment unless mutually agreed between the manufacturer and the purchaser at the time of purchase and shall be conducted in such a way as not to interfere unnecessarily with the manufacturer's operations. The manufacturer shall afford the inspector, representing the purchaser, all necessary and sufficient testing facilities in order to satisfy purchaser that the material is being furnished in accordance with this standard.

When inspection is to be made by the purchaser before shipment, the tests shall all be made within 10 days after receipt of a notice by the purchaser that the material is ready to test, and the material shall be accepted or rejected at the manufacturer's plant. If the purchaser does not have a representative present at the manufacturer's plant to test the material at the expiration of the said 10 days, the manufacturer shall make the tests herein provided for and furnish to the purchaser, when requested, official copies of the results of these tests. The purchaser shall accept or reject the material in accordance with the results of these tests. Alternatively, the manufacturer may provide relevant test results if these have already been carried out in production.

7.2 Acceptance or rejection

Failure of a test specimen to comply with any one of the requirements of this standard shall constitute grounds for rejection of the lot represented by the specimen.

If any lot is rejected in this manner, the manufacturer shall have the right to test, only once, all individual drums of conductors in the lot and submit those which meet the requirements for acceptance.

8 Packaging and marking

8.1 Packaging

The conductor shall be suitably protected against damage which could occur in ordinary handling and shipping.

NOTE The following should be agreed upon between the manufacturer and the purchaser when placing the order or at the earliest possible time:

- the type and size of package and method of packing;
- the packaging size and drum bore requirements and also the availability of the inner end of the conductor for grounding purposes, where conductors' stringing practices require special considerations.

If required in order to prevent differential movement of the layers during subsequent handling, the trailing end of the conductor on the drum shall be properly secured by an adequate method.

8.2 Marking and tare

The gross, net and tare weight, length (or length and number of pieces, if more than one length is agreed upon to be supplied on the same drum), designation, and any other necessary identification shall be suitably marked inside the package. This same information, together with the purchase order number, the manufacturer's serial number (if any) and all shipping marks and other information shall appear on the outside of each package.

8.3 Random lengths

Random lengths of conductors unavoidably obtained during production shall not exceed 5 % of the length provided that no piece is less than 50 % of the contractual length.

Table 1 – Metal combinations permitted

Envelope (external wires)	Core (internal wires)			
	S1A, S1B	S2A, S2B	S3A	20SA, 27SA 30SA, 40SA
A1	A1G/S1A, A1G/S1B	A1G/S2A, A1G/S2B	A1G/S3A	A1G/20SA, A1G/27SA, A1G/30SA, A1G/40SA
A2	A2G/S1A, A2G/S1B	A2G/S2A, A2G/S2B	A2G/S3A	A2G/20SA, A2G/27SA, A2G/30SA, A2G/40SA
A3	A3G/S1A, A3G/S1B	A3G/S2A, A3G/S2B	A3G/S3A	A3G/20SA, A3G/27SA, A3G/30SA, A3G/40SA
AT1	AT1G/S1A, AT1G/S1B	AT1G/S2A, AT1G/S2B	AT1G/S3A	AT1G/20SA, AT1G/27SA, AT1G/30SA, AT1G/40SA
AT2	AT2G/S1A, AT2G/S1B	AT2G/S2A, AT2G/S2B	AT2G/S3A	AT2G/20SA, AT2G/27SA, AT2G/30SA, AT2G/40SA
AT3	AT3G/S1A, AT3G/S1B	AT3G/S2A, AT3G/S2B	AT3G/S3A	AT3G/20SA, AT3G/27SA, AT3G/30SA, AT3G/40SA
AT4	AT4G/S1A, AT4G/S1B	AT4G/S2A, AT4G/S2B	AT4G/S3A	AT4G/20SA, AT4G/27SA, AT4G/30SA, AT4G/40SA

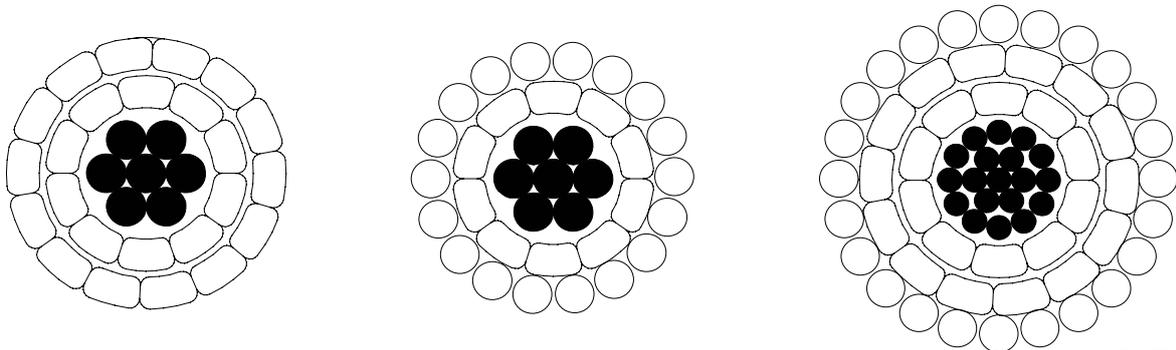
Table 2 – Number of joints permitted in aluminium wires

Number of aluminium layers	Joints permitted per conductor length
1	2
2	3
3	4
4	5

Table 3 – Standard increments^a due to stranding

Conductor stranding		Increment (%)	
No of layer(s) in envelope	Number of wire(s) in the core	Mass and electrical resistance of envelope	Mass of core
1	1	1,5	---
2	1	2,0	---
3	1	2,5	---
1	7	1,5	0,43
2	7	2,0	0,43
3	7	2,5	0,43
1	19	1,5	0,77
2	19	2,0	0,77
3	19	2,5	0,77

^a These increments have been calculated using average lay ratios for each applicable layer of core or envelope.



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Figure 1 – Examples of conductors containing one or more gaps

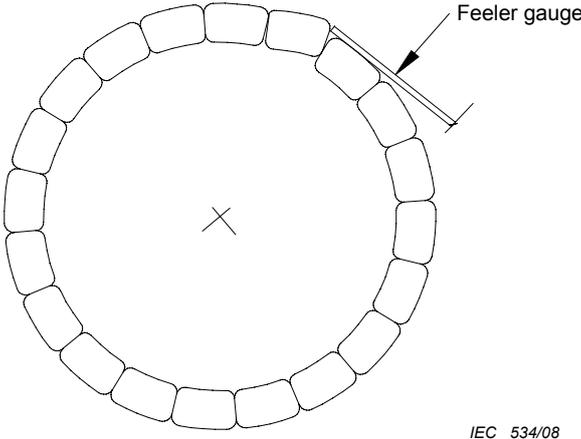


Figure 2 – Method of measuring wire canting

Annex A (normative)

Information to be supplied by purchaser

When making an enquiry or placing an order the purchaser shall furnish the following information:

- a) quantity of conductors;
- b) cross-sectional area and designation;
- c) length of conductor per drum, its tolerance and where applicable, matching of conductor lengths;
- d) type and size of package and method of packing;
- e) special packaging requirements, if any;
- f) lagging requirements, if any;
- g) if inspection is required and the place of inspection;
- h) whether tests on wires after stranding are required;
- i) whether tests on wire canting are required;
- j) whether conductor breaking strength tests are required;
- k) whether conductor stress-strain tests are required;
- l) whether creep tests are required;
- m) if special end preparation is required;
- n) requirements for grease, if any (type, properties, etc.).

Annex B (normative)

Stress-strain test method

B.1 Sample length

A conductor length as given in 6.2.1 shall be tested to obtain representative stress-strain curves.

B.2 Test temperature

The temperature of the sample shall be recorded and shall not vary by more than ± 2 °C during the test. Temperature readings shall be taken at the beginning and end of each hold period.

B.3 Sample preparation

During transportation to the test laboratory, the sample shall be properly protected from damage. The diameter of the coil or drum of the sample shall be at least 50 times the conductor diameter.

Great care shall be taken in the preparation of test samples. Relative displacements as small as 1 mm between the core and the aluminium layers of the conductor cause significant changes in the measured stress-strain curves. The sample preparation shall be as follows:

Before removing the sample from the drum, fit a bolted clamp 5 m \pm 1 m from the end of the conductor length. The clamp shall supply sufficient pressure to prevent relative wire movements in the conductor.

Unwind the desired length of conductor from the drum and install another bolted clamp at the required distance from the first clamp. Apply adhesive tape and cut the conductor at a distance from the clamp just far enough to allow room for applying dead-end fittings.

End fittings such as compression, epoxy type or solder type approved by the purchaser shall be used for stress-strain tests.

Care shall be taken not to damage any wire during the end preparation of the sample.

The application of the end fitting shall not introduce any slack in the wires which might alter the stress-strain curves the conductor.

B.4 Requirements (only for compression fittings)

B.4.1 Whenever compression fittings are used for testing, the methodology indicated in B.4.2 to B.4.4 shall be used.

B.4.2 Slide the aluminium sleeve on to the conductor. Cut back the aluminium wires to allow room for the steel terminal, the extrusion of the steel terminal and the extrusion of aluminium wires by the aluminium compression sleeve. The space required between the aluminium wires and the steel terminal, before crimping, is typically 30 mm to 40 mm. Slide the compression steel dead-end terminal on to the core. Crimp the steel terminal, with a 2 % to 10 % maximum overlap, starting from the other core end.

B.4.3 Pull the aluminium sleeve on to the steel terminal. Leave 40 mm of space if the conductor diameter is less than or equal to 30 mm and 50 mm of space if the conductor diameter is greater than 30 mm, between the end of the aluminium sleeve and the shoulder of the steel terminal for extrusion. Make the first crimp on the tapered mouth of the aluminium sleeve. This locks the sleeve in place and inhibits extrusion of aluminium towards the test span. Proceed to crimp in the direction away from the span in small bites of 20 % of uncompressed metal. Stop crimping before the filler hole in the sleeve is reached; the steel terminal and core are too small to support the crimped aluminium sleeve in this region. Continue crimping towards the eye, on the other side of the terminal pad to lock the sleeve on to the expanded portion of the steel terminal.

B.4.4 The aluminium sleeve shall be oriented so that there is no interference with conductor movement during the test.

B.5 Test set-up

The test sample shall be supported in a trough over its full length and the trough adjusted so that the conductor will not lift by more than 10 mm when under tension. This shall be ascertained by measurement rather than by tensioning the conductor.

The distance between the clamp indicating the gauge length and the mouth of the terminal sleeve shall be monitored with a calliper during the test to ensure that, after the 85 % load cycle, when unloaded to the preload, it does not change by more than 1 mm from the value before the test. (During the test, the distance may change by more than 1 mm.) A resolution of 0,1 mm is adequate.

The conductor strain shall be evaluated from the measured displacements at the two ends of the gauge length of the conductor. The gauge reference targets shall be attached to the bolted clamps which lock the conductor wires together. Target plates may be used with dial gauges or displacement transducers and care shall be taken to position the plates perpendicular to the conductor. Twisting the conductor, lifting it and moving it from side to side by the maximum amounts expected during the test should introduce no more than 0,3 mm error in the reading.

B.6 Test loads for conductors

The loading conditions for stress-strain tests for conductors shall be as follows

- Load initially to 2 % of RTS (Rated Tensile Strength) to straighten the conductor. After straightening remove the load and set the strain gauges to zero at zero tension.
- For non-continuous stress-strain data recordings, take the strain readings at intervals of 2,5 % RTS rounded off to the nearest kN.
- Load to 30 % RTS and hold for 0,5 h. Take readings after 5, 10, 15 and 30 min during the hold period. Release to the initial load.
- Re-load to 50 % RTS and hold for 1 h. Take readings after 5, 10, 15, 30, 45 and 60 min. Release to the initial load.
- Re-load to 70 % RTS and hold for 1 h. Take readings after 5, 10, 15, 30, 45 and 60 min. Release to the initial load.
- Re-load to 85 % RTS and hold for 1 h. Take readings after 5, 10, 15, 30, 45 and 60 min. Release to the initial load.
- After the fourth application of load, again apply tension, increasing uniformly, until the actual breaking strength is reached. Simultaneous readings of tension and elongation shall be taken up to 85 % RTS at the same intervals as for previous loading.
- The rate of increase of load shall be uniform during testing. The time required to reach 30 % RTS should neither be less than 1 min nor more than 2 min. The same rate of loading shall thereafter be maintained throughout the tests.

B.7 Test load for core only

The test shall consist of successive applications of load applied in a manner similar to that for the conductor at 30, 50, 70 and 85 % RTS.

The core shall be loaded until the elongation at the beginning of each hold period corresponds to that obtained on the conductor at 30, 50, 70 and 85 % RTS, respectively.

B.8 Stress-strain curves

Obtain the stress-strain curve by drawing a smooth line through the 0,5 and 1 h points at 30, 50, 70 and 85 % RTS loading. To obtain the typical curve, remove from the lower end the presence of any aluminium slack that can be related to any observed extrusion entering the span from the compression dead-ends. Adjust the typical curve to pass through zero. Both the laboratory and the typical stress-strain curves shall be submitted to the purchaser.

Annex C (normative)

Nominal mass of grease for stranded conductors

C.1 General

When it is required to grease a bare conductor containing one or more gap(s), the mass of grease shall be calculated using the method given in this annex.

Since conductors containing one or more gap(s) have very little interstitial space between shaped wires used to create self-supporting layer(s), the mass of grease is calculated only for the round-wire layer(s), if present, the core layer(s), and the annular gap(s).

The total mass of grease per metre, in the conductor, M_T , is equal to the following sum:

$$M_T = M_{gL} + M_{gC} + M_{gG} \quad \text{(Equation C.1)}$$

where

M_T is the total mass of grease in the conductor, in kg/m;

M_{gL} is the mass of grease in each round-wire layer, in kg/m;

M_{gC} is the mass of grease in the round-wire core, in kg/m;

M_{gG} is the mass of grease in each annular gap, in kg/m.

C.2 Calculation of mass of grease in round-wire-layer(s) (M_{gL})

The volume of void per unit length in a round-wire layer is given by the following equations (see Figure C.1):

$$L_V = \frac{\pi}{4} ((D_e^2 - D_i^2) - nd^2) \quad \text{(Equation C.2)}$$

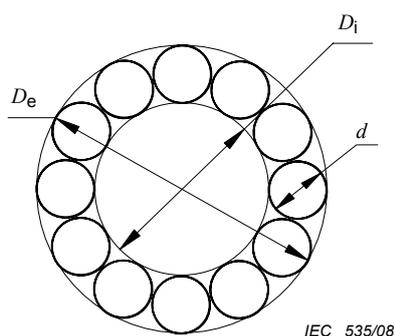


Figure C.1 – Illustration for calculation of mass of grease in round wire layer (s)

However,

$$D_e = D_i + 2d \quad \text{(Equation C.3)}$$

Substituting Equation C.3 into Equation C.2 yields:

$$L_V = \frac{\pi d}{4} (4(D_i + d) - nd) \quad \text{(Equation C.4)}$$

where

D_e is the outside diameter of the round-wire layer, in m;

D_i is the inside diameter of the round-wire layer, in m;

d is the round-wire diameter, in m;

L_V is the volume of void per metre, in m^3/m ;

n is the number of round wires in the layer.

The mass of grease in a round-wire layer is therefore:

$$M_{gL} = f\rho L_V \quad (\text{Equation C.5})$$

where

f is the fill factor, taken as 0,70 (unless otherwise indicated by the supplier);

M_{gL} is the mass of grease in round wire layer, in kg/m;

ρ is the mass density of the grease, typically 870 kg/m^3 .

C.3 Calculation of mass of grease for core layer(s) (M_{gC})

The volume of void per unit length in the core is given by the following equations (see Figure C.2):

$$C_V = \frac{\pi}{4}(D_C^2 - n_C d^2) \quad (\text{Equation C.6})$$

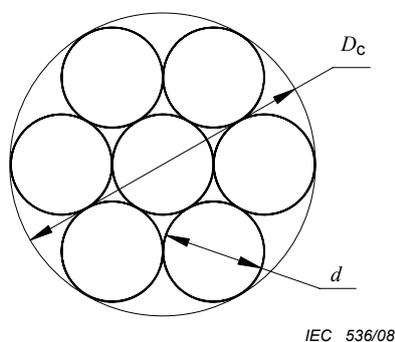


Figure C.2 – Illustration of calculation of mass of grease for core layer(s)

However,

$$D_C = md \quad (\text{Equation C.7})$$

Substituting Equation C.7 into Equation C.6 yields:

$$C_V = \frac{\pi}{4}d^2(m^2 - n_C) \quad (\text{Equation C.8})$$

where

C_V is the volume of void in the core per metre, in m^3/m ;

D_C is the core diameter, in m;

d is the core wire diameter, in m;

m is the factor relating d to D_C ($m = 1, 3, 5, \dots$);

n_C is the number of round wires in the core.

The mass in the core is therefore:

$$M_{gC} = f\rho C_V \quad (\text{Equation C.9})$$

C.4 Calculation of mass of grease for annular gap(s) (M_{gG})

The volume of void per unit of length in the annular gap(s) is given by the following equation (see Figure C.3):

$$G_V = \frac{\pi}{4}(D_{Og}^2 - D_{Ig}^2) \quad (\text{Equation C.10})$$

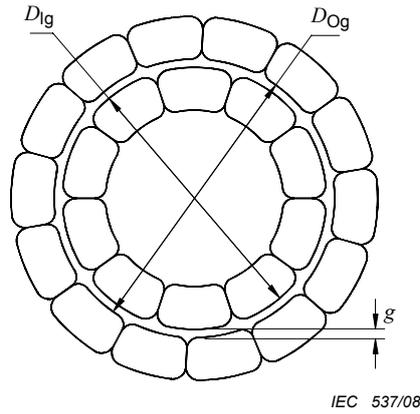


Figure C.3 – Illustration of calculation of grease for annular gap(s)

However,

$$D_{Og} = D_{Ig} + 2g \quad (\text{Equation C.11})$$

Substituting Equation C.11 into Equation C.10 yields:

$$G_V = \pi g(D_{Ig} + g) \quad (\text{Equation C.12})$$

where

G_V is the volume of void in each annular gap per metre, in m^3/m ;

D_{Ig} is the inside diameter of the annular gap, in m;

D_{Og} is the outside diameter of the annular gap, in m;

g is the annular gap, in m.

The mass of grease in each gap is therefore:

$$M_{gG} = f\rho G_V \quad (\text{Equation C.13})$$

Annex D

(informative)

Alternate method of measuring the gap(s) within the conductor

The measurement method described herein is not suitable for greased gap conductors.

The sample for measurement of annular gap(s) shall be taken while the conductor is in the stranding equipment, under tension, half-way between the capstan and the take-up reel.

Two small holes, located approximately 200 mm apart, are drilled through the aluminium layer(s) to the core. A quick-setting epoxy-type compound is then injected in the holes and allowed to set.

This section of conductor is then removed and a shorter sample, polished at one end and encapsulated if necessary, is then examined on a microscope of at least 15 x magnification.

Two pairs of diametrically opposed gap measurements shall be taken, spaced approximately 90° apart, for each annular gap. The value of each annular gap is the arithmetic average of the four readings.

Annex E (informative)

Recommended conductor sizes and tables of conductor properties

This annex contains recommended sizes for some conductor types listed in Table 1. It also contains all the conductor properties listed in the Table E.1.

The conductor sizes follow Renard Series R5, R10, R20, depending on the range of conductor size.

The use of Renard Series does not preclude other sizes to be designed and fabricated in accordance with this standard.

Table E.1 – Properties of some A1G/S1A conductors with gaps

Designation	A1 Area	S1A wires		Conductor diameter	Linear mass			Rated tensile strength	DC resistance at 20°C
		n	Diameter		Al	S1A	Total		
---	mm ²	---	mm	mm	kg/km	kg/km	kg/km	kN	Ω/km
125/20-A1G1/S1A-149	125,2	7	1,91	14,9	342,6	156,7	499,3	43,5	0,2285
160/8-A1 G2/S 1A-162	160,0	1	3,19	16,2	440,8	62,2	502,9	35,2	0,1801
160/26-A1 G1/S 1A-166	160,2	7	2,16	16,6	438,3	200,4	638,7	55,6	0,1786
160/26-A1 G2/S 1A-177	160,4	7	2,16	17,7	443,1	200,4	643,5	57,3	0,1800
200/10-A1 G2/S 1A-184	200,1	1	3,57	18,4	551,3	77,9	629,2	43,0	0,1439
200/32-A1 G2/S 1A-201	200,1	7	2,41	20,1	552,5	249,5	802,0	69,4	0,1443
250/13-A1 G2/S 1A-203	250,2	1	3,99	20,3	689,3	97,3	786,6	53,8	0,1151
250/25-A1 G2/S 1A-213	250,5	7	2,13	21,3	691,1	194,9	886,0	69,3	0,1152
250/33-A1 G2/S 1A-217	250,2	7	2,43	21,7	690,6	253,7	944,2	77,0	0,1154
250/40-A1 G2/S 1A-221	250,6	7	2,70	22,1	692,0	313,2	1005	85,8	0,1152
315/16-A1 G2/S 1A-225	315,1	1	4,48	22,5	868,0	122,6	990,7	67,7	0,0914
315/32-A1 G2/S 1A-236	315,2	7	2,39	23,6	869,7	245,4	1115	86,2	0,0915
315/41-A1 G2/S 1A-240	314,8	7	2,73	24,0	869,0	320,2	1189	97,1	0,0917
315/50-A1 G2/S 1A-245	315,0	7	3,03	24,5	869,9	394,4	1264	105,9	0,0917
400/20-A1 G2/S 1A-253	400,5	7	1,91	25,3	1 104	156,7	1 261	87,6	0,0720
400/28-A1 G2/S 1A-257	400,3	7	2,26	25,7	1104	219,4	1323	96,1	0,0720
400/52-A1 G2/S 1A-264	400,0	7	3,08	26,7	1104	407,5	1512	121,4	0,0722
400/64-A1 G2/S 1A-272	399,9	7	3,41	27,2	1105	499,5	1604	134,3	0,0722
450/23-A1 G2/S 1A-264	450,1	7	2,02	26,7	1240	175,3	1416	98,3	0,0640
450/32-A1 G2/S 1A-271	450,5	7	2,39	27,1	1242	245,4	1488	107,9	0,0640
450/59-A1 G2/S 1A-282	450,3	7	3,26	28,2	1243	456,5	1700	136,3	0,0641
500/25-A1 G2/S 1A-296	500,2	7	2,13	29,6	1382	194,9	1576	109,3	0,0576
500/35-A1 G2/S 1A-285	500,3	7	2,52	28,5	1380	272,8	1652	119,9	0,0576
500/65-A1 G2/S 1A-296	499,8	7	3,44	29,6	1380	508,3	1888	151,5	0,0578
560/28-A1 G2/S 1A-311	560,1	7	2,26	31,1	1545	219,4	1765	121,6	0,0515
560/39-A1 G2/S 1A-316	562,3	7	2,67	31,6	1552	306,2	1858	134,6	0,0513
560/73-A1 G2/S 1A-326	559,1	7	3,64	32,6	1544	569,2	2113	169,6	0,0517
630/32-A1 G2/S 1A-329	629,9	7	2,39	32,9	1738	245,4	1983	136,6	0,0458
630/44-A1 G2/S 1A-333	630,6	7	2,83	33,3	1 740	344,0	2 084	151,1	0,0458
630/82-A1 G2/S 1A-345	630,1	19	2,34	34,5	1 740	640,6	2 381	194,0	0,0458

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