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Aluminium conductors, galvanized steel reinforced (ACSR) for overhead power transmission and Distribution — Specification

Draft East African Standard for Public Review

EAST AFRICAN COMMUNITY

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Second Edition

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0 Foreword

Development of the East African Standards has been necessitated by the need for harmonizing requirements governing quality of products and services in the East African Community. It is envisaged that through harmonized standardization, trade barriers that are encountered when goods and services are exchanged within the Community will be removed.

The Community has established an East African Standards Committee (EASC) mandated to develop and issue East African Standards (EAS). The Committee is composed of representatives of the National Standards Bodies in Partner States, together with the representatives from the public and private sector organizations in the community.

East African Standards are developed through Technical Committees that are representative of key stakeholders including government, academia, consumer groups, private sector and other interested parties. Draft East African Standards are circulated to stakeholders through the National Standards Bodies in the Partner States. The comments received are discussed and incorporated before finalization of standards, in accordance with the Principles and procedures for development of East African Standards.

East African Standards are subject to review, to keep pace with technological advances. Users of the East African Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

The committee responsible for this document is Technical Committee EASC/TC 053, Electric Cables Transmission and Distribution Systems.

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INTRODUCTION

In view of the rapid growth of electricity demand coupled with manufacture of electrical conductors for overhead transmission and distribution of electricity from generating plants, necessity has been felt for standardizing the different types of overhead conductors.

This standard is therefore addressing the technical requirements relating to aluminium conductor's steel reinforced (ACSR) used for overhead transmission and distribution purposes.

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Aluminium conductors, galvanized steel reinforced (ACSR) for overhead power transmission and Distribution — Specification

1 Scope

This Draft East African Standard specifies the requirements and methods of tests for aluminium conductors, steel-reinforced (ACSR) for overhead power transmission and distribution purposes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

EAS 124:1999, *Rounding off numerical values*

IEC 62641, Conductors *for overhead lines - Aluminium and aluminium alloy wires for concentric lay stranded conductors*

IEC 63248, Conductors for overhead lines - Coated or cladded metallic wire for concentric lay stranded conductors

IEC 60227-1, Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 1: General requirements

3 Terms and definitions

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

3.1
aluminium conductor steel-reinforced
conductor consisting of seven or more aluminium and galvanized steel wires built up in concentric layers. The centre wire or wires are of galvanized steel and the outer layer or layers of aluminium

3.2
diameter
the mean of two measurements at right angles taken at the same cross-section

3.3
direction of lay
defined as right-hand or left-hand. With right-hand lay, the wires conform to the direction of the central part of the letter Z when the conductor is held vertically. With left-hand lay, the wires conform to the direction of the central part of the letter S when the conductor is held vertically

3.4
lay ratio
the ratio of the axial length of a complete turn of the helix formed by an individual wire in a stranded conductor to the external diameter of the helix

3.5
wire
a conductor material, uniform in diameter and circular in cross-section produced by drawing

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4 Physical characteristics

4.1 Materials

The conductor shall consist of hard-drawn aluminium wires conforming to A1 of IEC 62641 and zinc-coated steel wires conforming to ST1A of IEC 63248.

4.2 Material properties

4.2.1 The electrical and physical properties of aluminium wires used in the construction of the conductors, including resistivity, density , coefficient of linear expansion , and mass temperature coefficient shall be in accordance to A1 of IEC 62641

4.2.2 The electrical and physical properties of zinc coated wires used in the construction of the conductors, including resistivity, density , coefficient of linear expansion , and mass temperature coefficient shall be in accordance with ST1A of IEC 63248

4.3 Grease

Where greasing of the conductor is specified, the grease shall comply with IEC 61394

The grease shall be applied to the specified strand or layers of the conductor before the closing die. The nominal mass of grease shall be calculated in accordance with Annex D

5 Dimensions and construction

5.1 Joints in wire strands

The wires shall be smooth and free from inequalities, spills and splits.

5.1.1 For conductors containing only one steel wire, there shall be no joints made after heat treatment of the wire or rod. There shall be no joints of any kind made in the finished zinc coated core or wires during manufacture of the conductor.

5.1.2 No more than one jointed aluminium finished wire before stranding, as permitted in the relevant standard given in clause 2, shall be used per length of conductor.

5.1.3 Transgressing no aluminium wire welds shall be made for the purpose of achieving the required conductor length.

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

The number of joints in aluminium wires shall not exceed those specified in **Table 1**. 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, cold pressure welding or other methods approved by the purchaser. The first type of joint shall be electrically annealed for approximately 250 mm on both sides of the weld.

5.1.5 While the joints specified in 5.1.4 are not required to meet the requirements of unjointed wire, they shall withstand a stress of not less than 75 N/mm² for annealed electric butt-welded joints, and not less than 130 N/mm² for cold pressure joints.

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Table 1 - Number of joints permitted in a given length

Conductor length L (m)				Number of joints permitted
Number of aluminium layers				
1	2	3	4	
L ≤ 1 500	-	-	-	2
1 500 < L ≤ 2 000	L ≤ 1 500	-	-	3
L > 2 000	1 500 < L ≤ 2 000	L ≤ 1 500	-	4
-	2 000 < L ≤ 2 500	1 500 < L ≤ 2 000	L ≤ 1 500	5
-	L > 2 500	2 000 < L ≤ 2 500	1 500 < L ≤ 2 000	6
-	-	2 500 < L ≤ 3 000	2 000 < L ≤ 2 500	7
-	-	L > 3 000	2 500 < L ≤ 3 000	8
-	-	L > 3 500	3 000 < L ≤ 3 500	9
-	-	-	3 500 < L ≤ 4 000	10
-	-	-	L > 4 000	11

5.2 Standard sizes, resistances and mass of wires

Before stranding, the aluminium and steel wires for the standard constructions covered by this specification shall have the physical properties specified in **Table 2**.

5.3 Standard sizes, resistances and mass of aluminium conductors steel-reinforced

The sizes of standard aluminium conductors, steel-reinforced shall be as given in **Table 2.** The mass (excluding the mass of grease for corrosion protection) and resistances shall be taken as being in accordance with the given values in Table 2.

Table 2- Standard aluminium conductors steel reinforced

Code	Areas			No. of wires		Wire diameter				kg/km	kN	Ω/km
	Al	Steel	Total	Al	Steel	Al	Steel	Core mm	Cond. mm			
	mm²	mm²	mm²			mm	mm	mm	mm			
11-AL1/2-3ST1A	10,6	1,77	12,4	6	1	1,50	1,50	1,50	4,50	42,8	4,14	2,702 7
21-AL1/3-ST1A	21,0	3,50	24,5	6	1	2,11	2,11	2,11	6,33	84,7	7,87	1,365 9
26-AL1/4-ST1A	26,2	4,37	30,6	6	1	2,36	2,36	2,36	7,08	106,0	9,58	1,091 1
32-AL1/5-ST1A	31,6	5,27	36,9	6	1	2,59	2,59	2,59	7,77	127,6	11,38	0,906 5
37-AL1/6-ST1A	36,7	6,11	42,8	6	1	2,79	2,79	2,79	8,37	148,1	13,21	0,781 2
42-AL1/7-ST1A	42,4	7,07	49,5	6	1	3,00	3,00	3,00	9,00	171,2	15,27	0,675 7
53-AL1/9-ST1A	52,9	8,81	61,7	6	1	3,35	3,35	3,35	10,1	213,5	18,42	0,541 9

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63-AL1/11-ST1A	63,1	10,5	73,6	6	1	3,66	3,66	3,66	11,0	254,9	21,67	0,454 0
63-AL1/37-ST1A	63,2	36,9	100,1	12	7	2,59	2,59	7,77	13,0	463,0	52,79	0,456 8
75-AL1/13-ST1A	75,0	12,5	87,5	6	1	3,99	3,99	3,99	12,0	302,9	25,76	0,382 0
73-AL1/43-ST1A	73,4	42,8	116,2	12	7	2,79	2,79	8,37	14,0	537,3	61,26	0,393 6
79-AL1/13-ST1A	78,8	13,1	92,0	6	1	4,09	4,09	4,09	12,3	318,3	27,06	0,363 5
84-AL1/14-ST1A	83,9	14,0	97,9	6	1	4,22	4,22	4,22	12,7	338,8	28,81	0,341 5
95-AL1/16-ST1A	95,4	15,9	111,3	6	1	4,50	4,50	4,50	13,5	385,3	32,76	0,300 3
105-AL1/17-ST1A	105,0	17,5	122,5	6	1	4,72	4,72	4,72	14,2	423,8	36,04	0,273 0
105-AL1/14-ST1A	105,0	13,6	118,5	6	7	4,72	1,57	4,71	14,2	394,0	32,65	0,273 3
132-AL1/20-ST1A	131,7	20,1	151,8	26	7	2,54	1,91	5,73	15,9	520,7	45,86	0,219 2
132-AL1/7-ST1A	131,5	7,31	138,8	18	1	3,05	3,05	3,05	15,3	418,8	29,74	0,218 8
131-AL1/31-ST1A	131,2	30,6	161,9	30	7	2,36	2,36	7,08	16,5	602,2	57,87	0,220 2
158-AL1/37-ST1A	158,1	36,9	194,9	30	7	2,59	2,59	7,77	18,1	725,3	68,91	0,182 9
159-AL1/9-ST1A	158,7	8,81	167,5	18	1	3,35	3,35	3,35	16,8	505,2	35,87	0,181 4
183-AL1/43-ST1A	183,4	42,8	226,2	30	7	2,79	2,79	8,37	19,5	841,6	79,97	0,157 6
184-AL1/10-ST1A	184,2	10,2	194,5	18	1	3,61	3,61	3,61	18,1	586,7	40,74	0,156 2
212-AL1/49-ST1A	212,1	49,5	261,5	30	7	3,00	3,00	9,00	21,0	973,1	92,46	0,136 3
211-AL1/12-ST1A	210,6	11,7	222,3	18	1	3,86	3,86	3,86	19,3	670,8	46,57	0,136 6
238-AL1/56-ST1A	238,3	55,6	293,9	30	7	3,18	3,18	9,54	22,3	1 093,4	100,47	0,121 3

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264-AL1/62-ST1A	264,4	61,7	326,1	30	7	3,35	3,35	10,1	23,5	1 213,4	111,50	0,109 3
324-AL1/76-ST1A	324,3	75,7	400,0	30	7	3,71	3,71	11,1	26,0	1 488,2	135,13	0,089 1
375-AL1/88-ST1A	375,1	87,5	462,6	30	7	3,99	3,99	12,0	27,9	1 721,3	156,30	0,077 1
374-AL1/48-ST1A	374,1	48,5	422,6	54	7	2,97	2,97	8,91	26,7	1 413,8	118,88	0,077 3
382-AL1/49-ST1A	381,7	49,5	431,2	54	7	3,00	3,00	9,00	27,0	1 442,5	121,30	0,075 8
430-AL1/100-ST1A	429,6	100,2	529,8	30	7	4,27	4,27	12,8	29,9	1 971,4	179,00	0,067 4
294-AL1/56-ST1A	428,9	55,6	484,5	54	7	3,18	3,18	9,54	28,6	1 620,8	131,92	0,067 4
477-AL1/111-ST1A	477,1	111,3	588,5	30	7	4,50	4,50	13,5	31,5	2 189,5	198,80	0,060 6
476-AL1/62-ST1A	476,0	61,7	537,7	54	7	3,35	3,35	10,1	30,2	1 798,8	146,40	0,060 8
528-AL1/69-ST1A	528,5	68,5	597,0	54	7	3,53	3,53	10,6	31,8	1 997,3	159,92	0,054 7

5.4 Stranding

The wires used in making aluminium conductors, steel-reinforced shall, before stranding, satisfy all the relevant requirements of this standard.

5.4.1 The lay ratios for the zinc coated steel wire layers shall be as given in Table 3 and that of aluminium layers shall be as given in Table 4

5.4.2 In all constructions the successive layers shall be in opposite directions of lay, the outermost layer being right-handed. The wires in each layer shall be even and closely stranded.

5.4.3 For conductors with multiple layers of aluminium wires, the lay ratio of any aluminium layer shall be greater than the lay ratio of the aluminium layer immediately beneath it.

5.4.4 Steel wires shall be formed during stranding that they remain inert when the conductor is cut.

5.5 Complete conductors

5.5.1 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.

5.5.2 All 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

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Table 3 - Lay ratios for zinc coated steel layers

Number of steel wires	Lay ratio							
	3 wire layer		6 wire layer		12 wire layer		18 wire layer	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
3	16	26	-	-	-	-	-	-
7	-	-	16	26	-	-	-	-
19	-	-	16	26	14	22	-	-
37	-	-	17	25	16	22	14	18
For zinc coated steel core constructions exceeding 37 wires, the lay ratio of the outer layer shall lie between 14 and 18, and the lay ratio of the inner layers shall lie between 16 and 26.								

Table 4 - Lay ratios for aluminium layers

All inner layers		Outer layer	
Min.	Max.	Min.	Max.
10	16	10	14

5.6 Length and variations in lengths

Unless otherwise agreed between purchaser and manufacturer, conductors shall be supplied in the manufacturer's usual production lengths and with permitted variation of 5 %, in the length of any conductor lengths.

Random lengths may constitute up to 5 % of the total conductor length in an order, provided that each random length is not less than one-third of the manufacturer’s standard production length.

6 Packing and marking

The conductor shall be wound in reels or drums.

The drum, and reel shall be legibly and indelibly marked with the following information:

a) trade name, if any;
b) name and address of the manufacturer;
c) size and type of conductor;
d) length of conductor; and country of origin.
e) Gross weight and net weight
f) Standard of manufacture
g) Specification for reels and drums for bare wire:

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The conductor may also be marked with respective Bureau of Standards' Certification Mark.

NOTE The Certification Mark may be used by manufacturers only under licence from respective Bureau of Standards. Particulars of conditions under which the licences are granted may be obtained from the respective Bureau of Standards.

7 Testing

7.1 Selection of test samples

7.1.1 Samples of individual wires for the tests specified in Clause **8** shall normally be taken by the manufacturer from the outer ends of not less than 10 % of the drums.

7.1.2 If desired by the purchaser at the time of placing an order that the tests be made in the presence of representative, samples of wire shall be taken from lengths of stranded conductors. Samples shall then be obtained by cutting 1.2 metres from the outer end of the finished conductor from not more than 10 % of the finished reels or drums. If there is more than one length on any reel or drum, the sample shall be taken from an outer length.

7.1.3 Drums offered for inspection shall be divided into equal lots, the number of lots being equal to the number of samples to be selected, a fraction of a lot being counted as a complete lot. One sample drum shall be selected at random from each lot.

[1]) This may be done physically or on the basis of identification numbers of the drums offered for supply.

7.2 Place of testing

Unless otherwise agreed between purchaser and the manufacturer at the time of ordering, all the tests and inspection shall be made at the place of manufacture prior to shipment.

8 Tests **8.1** The test samples of aluminium wires taken in accordance with 7.1.1 and 7.1.2 shall be subjected to the relevant tests specified in Table 5.

8.2 The test samples of galvanized steel wires taken in accordance with 7.1.1 and 7.1.2 shall be subjected to the relevant tests specified in Table 5.

8.3 Properties of Grease

8.3.1 Mass per unit length

Using apparatus capable of achieving an accuracy of ± 0.1 %, the mass of grease in a 1m sample of conductor shall be determined from the difference between the mass of the conductor with grease and its mass after removing the grease with the aid of a suitable solvent.

The mass of grease shall not vary by more than ± 20 % from the calculated value obtained using the method described in **Annex D.**

8.3.2 Drop point

A sample of grease removed from the conductor shall meet the drop point requirement of IEC 61394 without preconditioning, after allowing for a reduction of 5 °C due to the sampling process.

8.4 Welding of aluminium wires

For type tests, the manufacturer shall demonstrate that the method used for jointing aluminium wires meets the strength requirement of **5.1.5** by performing the tensile test in the relevant wire standard given in clause 2

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Table 5-Schedule of tests for wires and conductors

Type test		Sample test	Clause	Clause
Conductor	- surface condition	x	x	8.5.1
	- diameter	x	x	8.5.2
	- inertness	x	x	8.5.3
	- lay ratio and direction of lay	x	x	8.5.4
	- number and type of wires	x	x	8.5.5
	- mass per unit length	x	x	8.5.6
	- stress-strain curve	(1)	-	8.5.7
	- tensile breaking strength	(1)	-	8.5.8
	- stringing test	(1)	-	8.5.9
Aluminium wires	- diameter	x	x	C.2
	- tensile strength	x	x	C.2
	- elongation (2)	x	x	C.2
	- resistivity	x	x	C.2
	- wrapping test	x	x	C.2
	- welding	x	-	8.4
Zinc coated Steel wires	- diameter	x	x	C.2
	- tensile strength	x	x	C.2
	- stress at 1 % extension	x	x	C.2
	- elongation or torsion test	x	x	C.2
	- wrapping test	x	x	C.2
	- mass of zinc	x	x	C.2
	- zinc dip test	x	x	C.2
	- adhesion of zinc coating	x	x	C.2
Grease	- mass per unit length	x	x	8.3.1
	- drop point	x	x	8.3.2
(1) By agreement between the purchaser and manufacturer.				
(2) Elongation test for AL1 is not required.				

8.5 Properties of conductor

8.5.1 Surface condition
The surface of the conductor shall comply with the requirements o**f 5.5.1**.

8.5.2 Conductor diameter
The conductor diameter shall be measured either:

(a) midway between the closing die and the capstan on the stranding machine, or

(b) at the middle of a portion of conductor, at least 3 m long and more than 5 m from either end of the conductor, under a tension of at least 2 % of the conductor rated tensile strength. 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.

The value obtained shall comply with the requirement of **5.2.**

8.5.3 Inertness
The requirement of **5.5.2** shall be met.

8.5.4 Lay ratio and direction of lay
The lay ratio of a given layer of the conductor shall be obtained by dividing the measured lay length by the diameter of the layer. The values obtained shall comply with the requirements of **5.4.1**. In addition, the direction of each layer shall be noted and shall also comply with the requirements of **5.4.1**.

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8.5.5 Number and type of wires
The number and type of wires shall be confirmed as being in accordance with the conductor designation stated on the order.

8.5.6 Mass per unit length
The mass per unit length of a 1m sample of conductor shall be determined by using apparatus capable of achieving an accuracy of ± 0.1 %. The value obtained shall comply with the requirement of **5.3**

8.5.7 Stress-strain curves
8.5.7.1 If the provision of stress-strain curves is agreed between the manufacturer and purchaser at the time of placing the order, the method described in annex E shall be used.
8.5.7.2 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 conductor under load.

8.5.8 Tensile breaking strength

8.5.8.1 The sample length, between end terminations, shall be at least 400 times the conductor diameter but not less than 10 m. A shorter length may be agreed between the manufacturer and purchaser.

8.5.8.2 The breaking strength of the conductor shall be determined by pulling a conductor in a suitable tensile testing machine having an accuracy of at least ± 1 %. The rate of increase of load shall be as in E.6.8 of annex E.

8.5.8.3 At the request of the purchaser, an intermediate load may be held for a period during the test in order to allow tension fittings to be tested at the same time as the conductor.

8.5.8.4 The breaking strength of the conductor shall be determined by the load attained at which one or more wires of the conductor are fractured. The test shall be considered satisfactory if 95 % of the rated tensile strength is reached without the fracture of any wires. If fracture occurs within 5cm of the end terminations before 95 % of the rated tensile strength has been reached, the fracture shall be deemed to have been caused by the end termination and the test shall be repeated. In this case, a change in the end terminations shall be considered. If a single wire fractures more than 5cm from the end terminations before 95 % of the rated tensile strength has been reached, two re-tests shall be carried out on samples taken adjacent to the original sample. Both re-tested samples shall withstand 95 % of the rated tensile strength without the fracture of any wire.

8.5.9 Stringing test
Where the purchaser requires evidence that the conductor is capable of being installed using the purchaser's recommended installation method, this may be satisfied by a stringing test, an example of which is given in annex E. Alternative tests or evidence of satisfactory service experience may also be agreed.

9 Rejection and retests

9.1 Should anyone of the test pieces first selected fail to pass the test, two further samples from the same batch shall be selected for testing, one of which shall be from the length from which the original test sample was taken unless that length has been withdrawn by the supplier.

9.2 Should the test pieces from both these additional samples satisfy the requirements of the tests, the batch represented by these samples shall be deemed to comply with the standard. Should the test pieces from either of the two additional samples fail, the batch represented shall be deemed not to comply with the standard.

10 Certificate of compliance
The manufacturer shall, if requested, furnish the purchaser with a certificate giving the results of the tests made on samples taken in accordance with 7.1

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NOTE 1 The electrical conductivity of the galvanized steel wire should be neglected, and the resistance of the conductor is calculated with reference to the resistance of the aluminium wires only.

NOTE 2 Tolerances on nominal diameter of galvanized steel wires should not differ from the nominal diameters (over the zinc coating) by more than the following:

Nominal diameter	Tolerance
Less than 2,00 mm	± 0.04 mm
2.00 mm and greater	± 2 %

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Annex A

(Normative)

Notes on the calculation of conductor properties

A.1 Increase in length due to stranding

When straightened out each, wire in any particular layer of a stranded conductor, except the central wire, is longer than the stranded conductor by an amount depending on the lay ratio of that layer.

A.2 Resistance and mass of conductor

The resistance of any length of stranded conductor is the resistance of the same length of any one aluminium wire multiplied by a constant as set out in Table 5.

The mass of each wire in any particular layer of stranded conductor, except the central wire will be greater than that of an equal length of a straight wire by an amount depending on the lay ratio of the layer (see A.1).

The total mass of any length of a conductor is, therefore, obtained by multiplying, the mass of an equal length of straight wire by the appropriate constant set out in Table 5. The masses of the steel core and aluminium wires are calculated separately and added together.

In calculating the stranding constants in Table 5, the mean lay ratio, that is, the arithmetic mean of the relevant minimum and maximum values in Table 4 has been assumed for each layer.

Table 1 — Stranding constants

Number of wires in Conductors		Stranding constants		
		Mass		Electrical resistance
Aluminium	Steel	Aluminium	Steel	
6	1	6.091	1.000	0.1692
6	7	6.091	7.032	0.1692
30	7	30.67	7.032	0.03408
54	7	55.23	7.032	0.01894

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Annex B

(Normative)

Note on modulus of elasticity and coefficient of linear expansion

B.1 The practical moduli of elasticity given below are based on an analysis of the final moduli determined from a large number of short term stress strain tests and may be taken as applying to conductor stressed between 15 % and 50 % of the breaking load of the conductor.

B.2 The coefficients for linear expansion given in Table 6 have been calculated from the practical (final) moduli for the aluminium and steel components of the conductors and coefficients of linear expansion of 23.0 x 10^{-6} /°C and 115 x 10^{-6}/°C for aluminium and steel respectively.

Table 2 — Modulus of elasticity and coefficient of linear expansion

Number of wires in conductor		Practical (final) modulus of elasticity, (N/mm^2)	Coefficient of linear expansion per deg.
Aluminium	Steel		
6	1	79 000	19.8 x 10^{-6}
6	7	75 000	19.1 x 10^{-6}
30	7	80 000	17.8 x 10^{-6}
54	7	69 000	19.3 x 10^{-6}

NOTE 1 These values are given for information only.

NOTE 2 Moduli values quoted may be regarded as being accurate to within 3000 N/mm^2.

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Annex C
(Normative)
Tests on properties of wires after stranding

C.1 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.

C.2 The properties of the individual wires after stranding, including tests on the coating of steel wires, shall meet the requirements of the wire as specified in the standard referenced in clause 2 with the exceptions that permitted reductions in wire properties after stranding, given in Table C.1, shall apply.

Table C.1-Permitted reductions in wire properties after stranding

Material		**Reduction after stranding**
Aluminium (AL1)	Tensile strength	5 %
Zinc coated steel (ST1A)	Stress at 1 % extension (1):	5 %
	Tensile strength:	5 %
	Torsion:	subtract 2 turns
	Elongation (2):	subtract 0,5
(1) Measurements of stress at 1 % extension on steel wires other than the centre wire are unreliable. If these measurements are required to be made on wires other than the centre wire, then the minimum value may be agreed between the purchaser and the manufacturer. (2) Example: A minimum elongation value of 3,0 % for wire before stranding is reduced to 2,5 % for wire after stranding.		

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Annex D
(normative)

Calculation of nominal mass of grease for stranded conductors

D.1 When it is required for bare conductors to be greased in order to reduce the risk of corrosion in some environments, the mass of grease shall be calculated using the methods given in this annex.

D.2 Four cases of grease application are:

Case 1: Inner layer only greased (Figure D.1(a)).

Case 2: All the conductor is greased except the outer layer (Figure D.1(b)).

Case 3: All the conductor is greased including the outer layer (Figure D.1(c)).

Case 4: All the conductor is greased except the outer surface of the wires in the outer layer (Figure D.1(d)).

Other cases may be specified by the purchaser.

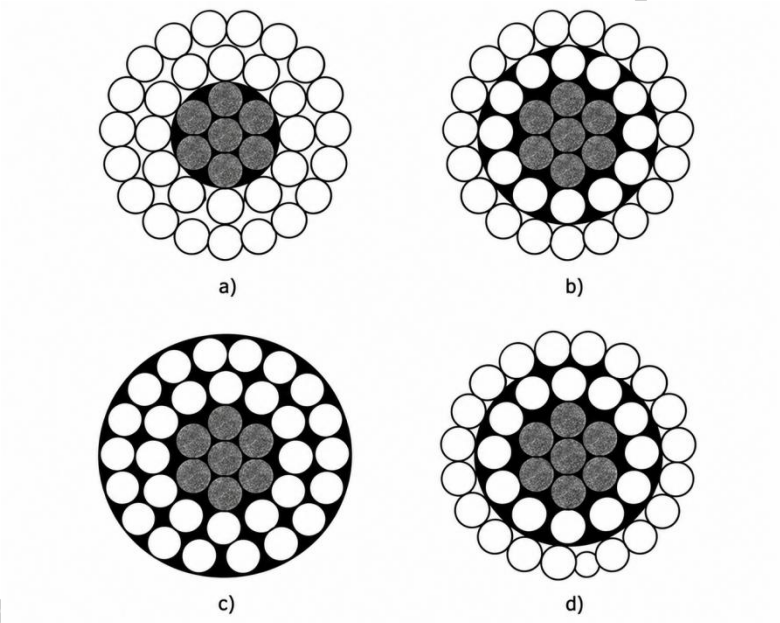


Figure D.1 – Application of grease to bare conductors

D.3 Assuming the grease completely fills the voids between the wires, the volume of grease in any given conductor shall be calculated from the following equations:

Case 1: $Vg = 0.25\ \pi\ (Ds^2 - ns\ ds^2)$

Case 2: $Vg = 0.25\ \pi\ \{(Do - 2da)^2 - (na - no)\ da^2 - ns\ ds^2\}$

Case 3: $Vg = 0.25\ \pi\ (Do^2 - da^2\ na - ds^2\ ns)$

Case 4: $Vg = 0.125\ no\ (Do - da^2)\ \sin(360/no) - 0.125\ \pi\ (2na - no - 2)\ da^2 - 0.25\ \pi\ ns\ ds^2$

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where:

Vg is the volume of grease, per unit length, in the conductor.
Do is the external diameter of the conductor.
Ds is the diameter of the steel core.
da is the diameter of the aluminium wire in the outer layer.
ds is the diameter of the steel wire.
na is the number of aluminium wires in the conductor.
no is the number of wires in the outer layer.
ns is the number of steel wires in the conductor.

Since there is a geometric relationship between the parameters of these equations, it is possible to express the total mass of grease in a conductor with the following relation:

$Mg = k\, d_a^2$

where:

Mg is the mass of grease (kg/km).
k is a factor which depends on the conductor stranding and the grease density and the fill factor (ratio of theoretical volume).

Values of k are given in Table B.1 for four cases of grease application, a grease density of 0.87 g/cm³, and a fill factor of 0.8.

Table D.1 - Coefficients k for mass of grease

Stranding		k_1 Case 1	k_2 Case 2	k_3 Case 3	k_4 Case 4
Aluminium	**Steel**				
7	-	-	-	1,09	0,17
19	-	-	1,09	3,28	1,79
37	-	-	3,28	6,56	4,52
61	-	-	6,56	10,93	8,35
91	-	-	10,93	16,40	13,27
127	-	-	16,40	22,92	19,28
6	1	-	-	1,09	0,17
8	1	-	-	1,46	0,34
18	1	-	1,09	3,28	1,79
9	3	0,90	-	2,88	1,46
6	7	0,12	-	1,21	0,29
10	7	0,68	-	2,48	1,18
12	7	1,09	-	3,28	1,79
14	7	1,63	-	4,18	2,51
18	7	0,12	1,21	3,40	1,91
22	7	0,34	1,80	4,35	2,67
24	7	0,49	2,13	4,86	3,10
26	7	0,66	2,48	5,40	3,54
28	7	0,86	2,87	5,97	4,02
30	7	1,09	3,28	6,56	4,52

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32	7	1,35	3,72	7,18	5,05
36	7	1,94	4,68	8,50	6,19
42	7	0,34	4,35	7,99	5,77
45	7	0,49	4,86	8,69	6,37
48	7	0,66	5,40	9,41	7,01
54	7	1,09	6,56	10,93	8,35
72	7	0,49	8,69	13,61	10,75
84	7	1,09	10,93	16,40	13,27
14	19	1,76	-	4,31	2,64
15	19	2,10	-	4,83	3,07
16	19	2,46	-	5,38	3,52
18	19	3,28	-	6,56	4,52
30	19	1,18	3,37	8,65	5,16
32	19	1,46	3,83	7,28	5,16
36	19	2,10	4,83	8,68	6,35
42	19	3,28	5,66	10,93	8,35
54	19	1,18	6,65	11,02	8,44
38+22	19	1,42	5,42	9,43	7,03
42+20	19	1,30	4,33	7,98	5,76
66	19	2,48	9,39	14,49	11,54
78	19	4,21	12,59	18,43	15,11
96	19	2,10	13,58	19,59	16,19
100	19	2,46	14,49	20,68	17,19
18	37	3,35	-	6,63	4,59
24	37	6,56	-	10,93	8,35
72	37	3,35	11,00	16,47	13,33
84	37	4,39	16,44	23,00	19,33
150	37	3,35	23,03	30,68	26,45

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Annex E

(normative)

Stress - strain test method

C.1 Sample length

The sample length, between end terminations, shall be at least 400 times the conductor diameter but not less than 10 m. A shorter length may be agreed between the manufacturer and purchaser. The gauge length shall be a minimum of 100 times the conductor diameter.

C.2 Test temperature

Temperature readings shall be taken at the beginning and end of each hold period. If the temperature varies by more than 2 °C from that at the commencement of the test then allowance for the thermal expansion of the conductor shall be made.

C.3 Sample preparation

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

C.3.1 Before removing the sample from the drum, fit a bolted clamp 5 m ± 1 m from the end of the conductor length. The clamp shall apply sufficient pressure to prevent relative wire movements in the conductor.

C.3.2 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.

C.3.3 During transportation to the test laboratory, the sample shall be properly protected from damage. The diameter of the coil or drum of conductor shall be at least 50 times the conductor diameter.

C.3.4 End fittings such as compression, epoxy type or solder type approved by the purchaser shall be used for stress-strain tests. The wires shall not be unwound, cleaned or greased prior to application of the end fittings.

C.3.5 Care shall be taken not to damage any wire during the end preparation of the sample.

C.3.6 The application of the end fitting shall not induce any slack in the wires which might alter the stress-strain curves of the conductor.

C.4 Requirements for compression fittings

When compression fittings are used for AL1/STyz conductors, the method indicated in C.4.1 to C.4.3 shall be followed.

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C.4.1 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 the 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 steel core. Crimp the steel terminal, with a 2 % to 10 % maximum overlap, starting from the outer core end.

C.4.2 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 % on 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 towards the eye, on the other side of the terminal pad to lock the sleeve on to the expanded portion of the steel terminal.

C.4.3 The aluminium sleeve shall be oriented so that there is no interference with conductor movement during the test.

C.5 Test set-up

C.5.1 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.

C.5.2 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.

NOTE 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.

C.6 Test loads for the conductor

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

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C.6.1 Load initially to 5 % of RTS (rated tensile strength) to straighten the conductor and set the strain gauges to zero.

C.6.2 For non-continuous stress-strain data recordings, take the strain readings at intervals of 2,5 % RTS, rounded to the nearest kN, during both loading and unloading.

C.6.3 Load to 30 % RTS and hold for 0,5 h. Take readings after 5 min, 10 min, 15 min, and 30 min during the hold period. Release to the initial load.

C.6.4 Re-load to 50 % RTS and hold for 1 h. Take readings after 5 min, 10 min, 15 min, 30 min, 45 min and 60 min during the hold period. Release to the initial load.

C.6.5 Re-load to 70 % RTS and hold for 1 h. Take readings after 5 min, 10 min, 15 min, 30 min, 45 min and 60 min. Release to the initial load.

C.6.6 Re-load to 85 % RTS and hold for 1 h. Take readings after 5 min, 10 min, 15 min, 30 min, 45 min and 60 min. Release to the initial load.

C.6.7 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 least at the same time intervals as for the previous loading.

C.6.8 The rate of application of loads shall be uniform during testing. The time required to reach 30 % RTS shall not be less than one minute nor more than two minutes. The same rate of loading shall thereafter be maintained throughout the tests.

C.7 Test loads for steel core only

The loading conditions for stress-strain tests of the steel core of ALx/STyz, ALx/yzSA, or yzSA conductors shall be as follows:

C.7.1 The test shall consist of successive application of load applied in a manner similar to that for the conductor at 30 %, 50 %, 70 % and 85 % RTS of the steel core.

C.7.2 The steel 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 of the steel core, respectively.

C.8 Stress / strain curve

The data shall be presented graphically.

Obtain the characteristic initial stress-strain curve by drawing a smooth line through the strain point after 0,5 h at 30 % RTS, and the strain points after 1h at 50 %, 70 % and 85 % RTS. Adjust the curve to pass through zero.

The characteristic final stress-strain curve shall be determined from the unloading (from 50 %, 70 % and/or 85 % RTS) portions of the graph as agreed between the manufacturer and purchaser.

All measurement data and the characteristic curves shall be submitted to the purchaser.

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