BS EN 50540:2010

BSI Standards Publication

Conductors for overhead lines — Aluminium Conductors Steel Supported (ACSS)

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee GEL/7, Overhead electrical conductors.

A list of organizations represented on this committee can be obtained on request to its secretary.

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ISBN 978 0 580 68886 7

ICS 29.240.20

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2010.

Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 50540

April 2010

ICS 29.240.20

English version

Conductors for overhead lines - Aluminium Conductors Steel Supported (ACSS)

Conducteurs pour lignes aériennes - Conducteurs à faible dilatation (ACSS)

Leiter für Freileitungen - Aluminiumleiter, von beschichtetem Stahl getragen (Ausführung ACSS)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 50540:2010 E

Foreword

This European Standard was prepared by CENELEC BTTF 132-1, Aluminium conductors steel supported (ACSS type) for overhead electrical lines, based on the text of BT/ES0023/NOT. It was submitted to the CENELEC Unique Acceptance Procedure and was approved by CENELEC as EN 50540 on 2010-04-01.

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The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-04-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-04-01

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1 Scope

This European Standard specifies the electrical and mechanical characteristics of ACSS conductors made of round or formed annealed aluminium wires and steel wires stranded in alternate directions, made of one or a combination of any of the following.

1.1 Outer/conductive layers

Annealed Aluminium wire as per requirements of Clause 5.

1.2 Steel core

a) Galvanized steel wire type ST6A according to EN 50189 and requirements of Clause 5;

b) Zn95Al5 alloy coated steel wire with MM (mischmetal) as per EN 10244-2 and mechanical and mass of coating requirements as per Tables 2 and 3, in the following options:

   i Extra High Strength;

   ii Ultra High Strength.

   NOTE MM elements are mandatory. Coatings without MM can be used, if agreed between Supplier and Purchaser. Tests without MM must show the same behaviour than the MM coatings.

c) Aluminium-clad steel wire 20,3 % conductivity in the following options:

   - as per EN 61232 with class designation 20 SA;
   - aluminium-clad steel wire Extra High Strength with designation 20 EHSA as per Table 4.

d) Aluminium-clad steel wire 14 % conductivity, Extra High Strength with designation 14 EHSA as per Table 5.

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.

EN 10244-2 Steel wire and wire products. Non-ferrous metallic coating on steel wire Part 2: zinc or zinc alloy coatings

EN 50182 Conductors for overhead lines - Round wire concentric lay stranded conductors

EN 50189 Conductors for overhead lines - Zinc coated steel wires (for testing purposes only)

EN 60889 Hard-drawn aluminum wire for overhead line conductors (for testing purposes only) (IEC 60889)

EN 61232 Aluminium-clad steel wires for electrical purposes (IEC 61232)

EN 62219 Overhead electrical conductors - Formed wire, concentric lay, stranded conductors (IEC 62219)

IEC 60050-466 International Electrotechnical Vocabulary (IEV) - Chapter 466: Overhead lines

IEC 60468 Method of measurement of resistivity of metallic materials

3 Definitions

In addition to the definitions given in IEC 60050-466, EN 50182 and EN 62219, the following definitions apply.

3.1
aluminium
the most abundant of all metals. It is a ductile metal, silver-white in colour, which can be readily worked by rolling, drawing, spinning, extruding, and forging. For the purpose of this European Standard, the aluminium must be annealed

3.2
conductor
material intended to be used for carrying electric current consisting of a plurality of uninsulated wires twisted together

3.3
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

3.4
lay length
axial length of one complete turn of the helix formed by an individual wire in a stranded conductor

3.5
lay ratio
ratio of the lay length to the external diameter of the corresponding layer of wires in the stranded conductor

3.6
direction of lay

3.6.1
direction of lay (general definition)
direction of twist of a layer of wires as it moves away from the viewer

NOTE A right-hand lay is a clockwise direction and a left-hand lay is an anti-clockwise direction.

3.6.2
direction of lay (alternative definition)
the direction of lay is defined as right-hand or left-hand

NOTE 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.

3.7
round wire
filament of drawn metal having a constant circular cross-section

3.8
formed wire
filament of metal having a constant cross-section and a non-circular shape

3.9
equivalent wire diameter
the diameter of a round wire which would have the same cross-sectional area, mass and electrical resistance as a given formed wire of the same material

3.10
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.

3.11
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.

3.12
rated tensile strength
an estimate of the conductor breaking load calculated using the specified tensile properties of the component wires

4 Designation system

a) Annealed aluminium wire: **AL0**

b) Galvanized steel wire according to EN 50189: **ST6A**

c) Zn95Al5 coated steel: M**EHST** or M**UHST with mischmetal elements**

Zn95Al5 coated steel: **EHST** or **UHST without mischmetal elements** (see note in Scope)

d) Aluminium clad steel 20,3 % according to EN 61232 classes: **20SA** or **20EHSA**

e) Aluminium clad steel 14 % EHS: **14EHSA**

EXAMPLES:

401-AL0/28-ST6A	Conductor made of AL0 wires around a core of ST6 class A zinc coated steel wires. The integer area of AL0 is 401 mm^2 and that of ST6A wires, 28 mm^2.
401-AL0/28-MEHST	Conductor made of AL0 wires around a core of Zn95Al5 coated MEHST steel wires. The integer area of AL0 is 401 mm^2 and that of Zn95Al5 wires, 28 mm^2.
401-AL0/28-20EHSA	Conductor made of AL0 wires around a core of Aluminium clad steel 20,3 % wires. The integer area of AL0 is 401 mm^2 and that of Aluminium clad steel 20,3 %, 28 mm^2.
401-AL0/28-14EHSA	Conductor made of AL0 wires around a core Aluminium clad 14 % EHS steel wires. The integer area of AL0 is 401 mm^2 and that Aluminium clad steel 14 % wires, 28 mm^2.

f) Generic designations:

- **ACSS:** Concentric-Lay –Stranded Aluminium Conductors, Coated Steel Supported
- **ACSS/TW**: Formed Wire Compact Concentric-Lay –Stranded Aluminium Conductors, Coated Steel Supported.

5 Requirements for ACSS stranded conductors

5.1 Material

5.1.1 ACSS conductors shall consist of a supporting core made of the following:

a) Galvanized steel wire type ST6A according to Table 1 (based on EN 50189)

Table 1 - Mechanical characteristics steel ST6A wires before stranding

Nominal wire diameter mm		Diameter tolerance		Stress at 1 %	Ultimate tensile strength R_m		Elongation at breaking on 250 mm A_{250}	Mandrel diameter for wrapping and adherence test	Nº of 1 min immersions	Mass of coating	Number of torsions[a]
					Individual wires	Average					
Over	Up to	mm		MPa	N/mm^2		%	xD	Nº	g/m^2	Nº
		+	-		min.	min.	min.			min.	min.
1,75	2,25	0,04	0,04	1 450	1 700	1 800	2,0	4	2 1/2	215	14
2,25	2,75	0,04	0,04	1 410	1 650	1 750	2,0	4	3	230	14
2,75	3,00	0,05	0,05	1 410	1 650	1 750	2,5	4	3	230	12
3,00	3,50	0,05	0,05	1 380	1 600	1 700	2,5	4	3 1/2	245	12
3,50	4,25	0,06	0,06	1 340	1 600	1 700	2,5	5	3 1/2	260	10
4,25	4,75	0,06	0,06	1 340	1 600	1 700	2,5	5	4	275	10

[a] In case of galvanizing before final drawing, minimum number of torsions will be increase by 2 and minimum elongation will be decreased in 1 %.

b) Round steel wires coated by Zn95Al5 alloy, complying with the requirements of Tables 2 and 3
Rest of characteristics according to EN 50189 and zinc alloy coatings according to EN 10244-2

Table 2 - Characteristics of Extra High Strength Zn95Al5 steel wires (before stranding)

Nominal wire diameter mm		Diameter tolerance		Stress at 1 %	Ultimate tensile strength R_m	Elongation at breaking on 250 mm A_{250}	Mandrel diameter for wrapping test	Mandrel diameter for adherence test	Mass of coating
Over	Up to	mm		MPa	MPa	%			g/m^2
		+	-	min.	min.	min.	xD	xD	min.
1,91	2,28	0,038	0,025	1 550	1 825	3,0	4	4	214
2,29	2,64	0,051	0,051	1 515	1 790	3,0	4	4	229
2,65	3,04	0,051	0,051	1 515	1 790	3,0	4	4	244
3,05	3,55	0,076	0,051	1 480	1 760	3,5	4	4	259
3,56	4,57	0,102	0,076	1 450	1 725	3,5	4	5	274
4,58	4,82	0,102	0,076	1 450	1 725	3,5	4	5	305

Table 3 - Characteristics of Ultra High Strength Zn95Al5 steel wires (before stranding)

Nominal wire diameter mm		Diameter tolerance		Stress at 1 %	Ultimate tensile strength R_m	Elongation at breaking on 250 mm A_{250}	Mandrel diameter for wrapping test	Mandrel diameter for adherence test	Mass of coating
Over	Up to	(mm)		MPa	MPa	(%)			g/m^2
		+	-	min.	min.	min.	xD	xD	min.
1,91	2,28	0,038	0,025	1 580	1 965	3,0	4	4	214
2,29	2,64	0,051	0,051	1 550	1 900	3,0	4	4	229
2,65	3,04	0,051	0,051	1 550	1 900	3,0	4	4	244
3,05	3,55	0,076	0,051	1 515	1 860	3,5	4	4	259
3,56	4,57	0,102	0,076	1 480	1 825	3,5	4	5	274
4,58	4,82	0,102	0,076	1 480	1 825	3,5	4	5	305

c) Round aluminium clad steel wires type 20 SA, fully complying with the requirements of EN 61232

d) Round aluminium clad Extra High Strength steel wires type 20 EHSA, as per the requirements of Table 4

Table 4 - Characteristics of Extra High Strength aluminium clad steel wires 20EHSA (before stranding)

Diameter		Diameter tolerance	Stress at 1%	Tensile strength	Elongation at 250 mm	Torsions
mm		mm	MPa	MPa	%	Nº
Over	**Up to**		**min.**	**min.**	**min.**	**min.**
1,28	2,28	± 0,04	1 390	1 620	1,5	20
2,29	3,04	± 0,05	1 360	1 580	1,5	20
3,05	3,55	± 0,05	1 330	1 545	1,5	20
3,56	4,82	± 0,06	1 300	1 515	1,5	20

e) Round aluminium clad Extra High Strength steel wires type 14EHSA, as per the requirements of Table 5

Table 5 - Characterístics of Extra High Strength aluminium clad steel wires 14EHSA (before stranding)

Diameter		Diameter tolerance	Stress at 1%	Tensile strength	Elongation at 250 mm	Torsions
mm		mm	MPa	MPa	%	Nº
Over	**Up to**		**min.**	**min.**	**min.**	**min.**
1,75	2,25	± 0,04	1 550	1 825	1,5	20
2,26	3,00	± 0,05	1 500	1 790	1,5	20
3,01	3,50	± 0,05	1 470	1 760	1,5	20
3,51	4,75	± 0,06	1 430	1 725	1,5	20

Table 6 - Physical constants

Characteristics of wires	Coated steel wires				
	Unit	Galvanized steel wire	Zn95Al5 wire	Aluminium clad steel wire 20 SA	Aluminium clad steel wire 14 SA
Final modulus of elasticity (practical)	GPa	207	207	162	174
Coefficient of linear expansion	K^{-1}	$11,5 \times 10^{-6}$	$11,5 \times 10^{-6}$	13×10^{-6}	$11,9 \times 10^{-6}$
Temperature coefficient of resistance to constant mass (α)	K^{-1}	-	-	0,003 6	0,003 6
Density	kg/dm³	7,78	7,78	6,59	7,29
Resistivity max.	$\eta\Omega$.m	-	-	84,8	123,15
Aluminium thickness, min.	% radio	-	-	10	4,6
Aluminium proportion in cross section	%	-	-	25	10

5.1.2 Over the supporting core, ACSS conductors will have one or several layers of the following material:

Round or formed annealed aluminium wires helically stranded, having the following requirements for all range of sizes:

Aluminium wires (before and after stranding):

- tensile strength: min.: 60 Mpa - max: 95 Mpa;
- elongation at breaking: min.: 20 % in 250 mm;
- electrical resistivity: max.: 0,027899 ohm.mm^2/m.

5.2 Stranding

5.2.1 All wires of the conductor shall be concentrically stranded. The Al wires should be fully annealed before stranding.

In case of formed wire, the only process acceptable is first to shape the wires in one process and after to strand them in another one.

Adjacent wire layers shall be stranded with reverse lay directions. The direction of lay of the external layer shall be right hand except when otherwise specified by the purchaser.

5.2.2 The lay ratios for the galvanized steel, Zn95Al5 alloy coated or aluminium-clad steel wire layers shall be as given in Table 7.

5.2.3 In a multi-layer conductor, the lay ratio of any layer shall be equal to or less than the lay ratio of the layer immediately beneath it.

Table 7 - Lay ratios for galvanized steel, Zn95Al5 coated steel or aluminium-clad steel layers

Number of steel wires	6 wire layer		12 wire layer		18 wire layer	
	min.	max.	min.	max.	min.	max.
7	16	26	-	-	-	-
19	16	26	14	22	-	-
37	17	25	16	22	14	18

The lay ratios for the aluminium layers of all types of conductor shall be as given in Table 8.

Table 8 - Lay ratios for aluminium layers

All inner layers		Outer layer	
min.	max.	min.	max.
10	16	10	14

5.2.4 All steel 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. This requirement also applies to the aluminium wires of a conductor.

5.2.5 Before stranding, aluminium and steel wires shall have approximately equal temperatures.

5.2.6 The conductor shall have the ability to be installed, using the purchaser's recommended installation method, without damage to the conductor. If required, this shall be demonstrated according to 6.4.11.

5.3 Surface condition

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 Conductor diameter

The conductor diameter shall not vary from the nominal value, specified by the purchaser, by more than

- ± 1 % for diameters larger or equal to 10 mm,
- ± 0,1 mm for diameters smaller than 10 mm.

5.5 Mechanical characteristics

The rated tensile strength of an ACSS conductor shall be the sum of the 96 % of minimum tensile strength of the aluminium portion (based on a minimum tensile strength of 60 MPa plus the 100 % of the minimum tensile strength of galvanized, Zn95Al5 steel coated or aluminium clad steel (based on the minimum tensile strength required for the component wires). In case of ST6C wires, the minimum average tensile strength should be used for the calculation.

5.6 Joints

5.6.1 During stranding, no aluminium wire welds shall be made for the purpose of achieving the required conductor length. There shall be no joints of any kind made in the finished galvanized, Zn95Al5 coated wire or aluminium-clad steel core wire during stranding.

5.6.2 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 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 9. 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.

The manufacturer shall, if required by the purchaser, demonstrate that the method used for jointing aluminium wires meets the strength requirement of 60 MPa by performing the tensile test.

Table 9 - Number of joints permitted in a given length

Conductor length *L* m				**Number of joints permitted**
Number of aluminium layers				
1	**2**	**3**	**4**	
$L \leq 1\,500$	-	-	-	2
$1\,500 < L \leq 2\,000$	$L \leq 1\,500$	-	-	3
$L > 2\,000$	$1\,500 < L \leq 2\,000$	$L \leq 1\,500$	-	4
-	$2\,000 < L \leq 2\,500$	$1\,500 < L \leq 2\,000$	$L \leq 1\,500$	5
-	$L > 2\,500$	$2\,000 < L \leq 2\,500$	$1\,500 < L \leq 2\,000$	6
-	-	$2\,500 < L \leq 3\,000$	$2\,000 < L \leq 2\,500$	7
-	-	$3\,000 < L \leq 3\,500$	$2\,500 < L \leq 3\,000$	8
-	-	$L > 3\,500$	$3\,000 < L \leq 3\,500$	9
-	-	-	$3\,500 < L \leq 4\,000$	10
-	-	-	$L > 4\,000$	11

5.7 Conductor mass per unit length

The increments, in per cent, for mass due to stranding, shall be as given in Tables 10 and 11, which have been calculated using the commonly used lay ratios for each applicable layer of aluminium or steel wire given in Annex B.

The mass per unit length of the conductor shall be calculated by using the following specific weights:

- Aluminium: 2,703 g/cm^3;
- Galvanized or covered with Zn95Al5 steel wire (all types): 7,78 g/cm^3;
- Aluminium clad steel wire 20SA or 20EHSA: 6,59 g/cm^3;
- Aluminium clad steel wire 14EHSA: 7,29 g/cm^3.

Table 10 - Increments due to stranding for formed Al wires

		Increment (increase) %			
Stranding of ACSS/TW mass and electrical resistance					
Ratio C. Sections Steel/Al %	Number of Steel Wires	Mass		Electrical resistance	
		Aluminium	ST6A, Zn95Al5 or Al clad steel	Aluminium	Aluminium-clad steel
Two –Al Layers Designs					
7	7	2,0	0,52	2,0	0,52
10	7	2,11	0,52	2,11	0,52
13	7	2,27	0,52	2,27	0,52
16	7	2,21	0,52	2,21	0,52
23	7	2,31	0,52	2,31	0,52
24	19	2,32	0,86	2,32	0,86
25	19	2,32	0,86	2,32	0,86
28	19	2,35	0,86	2,35	0,86
Three –Al Layers Designs					
5	7	2,21	0,52	2,21	0,52
7	7	2,22	0,52	2,22	0,52
8	19	2,27	0,79	2,27	0,79
10	7	2,31	0,52	2,31	0,52
13	19	2,33	0,79	2,33	0,79
26	37	2,67	0,96	2,67	0,96
Four–Al Layers Designs					
8	19	2,46	0,79	2,46	0,79

Table 11 - Increments due to stranding for round Al wires

Stranding of conductor				Increment (increase) %			
Aluminium		Steel		Mass		Electrical resistance	
Number of wires	Number of layers [a]	Number of wires	Number of layers [a]	Aluminium	ST6A, Zn95Al5 or Al clad steel	Aluminium	Aluminium-clad steel
10	1	7	1	2,01	0,52	2,01	0,52
12	1	7	1	2,17	0,52	2,17	0,52
14	1	7	1	2,30	0,52	2,30	0,52
18	2	7	1	1,94	0,52	1,94	0,52
22	2	7	1	2,07	0,52	2,07	0,52
24	2	7	1	2,13	0,52	2,13	0,52
26	2	7	1	2,18	0,52	2,18	0,52
28	2	7	1	2,22	0,52	2,22	0,52
30	2	7	1	2,26	0,52	2,26	0,52
32	2	7	1	2,30	0,52	2,30	0,52
36	2	7	1	2,37	0,52	2,37	0,52
42	3	7	1	2,20	0,52	2,20	0,52
45	3	7	1	2,23	0,52	2,23	0,52
48	3	7	1	2,26	0,52	2,26	0,52
54	3	7	1	2,31	0,52	2,31	0,52
72	4	7	1	2,40	0,52	2,40	0,52
84	4	7	1	2,46	0,52	2,46	0,52
14	1	19	2	2,50	0,82	2,50	0,82
15	1	19	2	2,56	0,82	2,56	0,82
16	1	19	2	2,61	0,82	2,61	0,82
18	1	19	2	2,70	0,82	2,70	0,82
30	2	19	2	2,36	0,86	2,36	0,86
32	2	19	2	2,41	0,86	2,41	0,86
36	2	19	2	2,48	0,86	2,48	0,86
42	2	19	2	2,57	0,86	2,57	0,86
54	3	19	2	2,26	0,79	2,26	0,79
38+22	3	19	2	2,22	0,79	2,22	0,79
42+20	3	19	2	2,18	0,79	2,18	0,79
66	3	19	2	2,34	0,79	2,34	0,79
78	3	19	2	2,40	0,79	2,40	0,79
96	4	19	2	2,46	0,79	2,46	0,79
100	4	19	2	2,47	0,79	2,47	0,79
18	1	37	3	2,70	1,09	2,70	1,09
24	1	37	3	2,91	1,09	2,91	1,09
72	3	37	3	2,43	0,96	2,43	0,96
54+66	4	37	3	2,32	0,86	2,32	0,86
150	5	37	3	2,38	0,86	2,38	0,86

[a] Number of layers of each type of wire, not including the centre wire.

5.8 Nominal DC resistance

The nominal DC resistance at 20 °C of a conductor, expressed in Ω/km to three significant figures, is based on the resistivity value for calculation purposes and on the nominal cross section of the aluminium and aluminium clad steel wires referenced in Clauses 2 and 5, increased by the increments in Tables 10 or 11. The resistivity to be used in the calculations, for the different Aluminium clad steel cores, is shown in Table 6. The resistivity for aluminium wire is shown in 5.1.2.

5.9 Variation in Aluminium area

The area of cross section of the aluminium wires of a conductor shall be between ± 2 % of the nominal.

6 Tests

6.1 Classification of tests

6.1.1 Type tests are intended to verify the main characteristics of a conductor which depend mainly on its design. They shall be carried out once . be it for a new design, a new manufacturer or manufacturing process of conductor and then subsequently repeated only when the design, manufacturer or manufacturing process is changed. The type tests are listed in Table 12.

6.1.2 Sample tests are intended to guarantee the quality of conductors and compliance with the requirements of this standard. The sample tests are also listed in Table 12.

Table 12 - Type and sample tests for conductors and wires

		Type test	Sample test	Clause
Conductor	- Surface condition	x	x	6.4.1
	- Diameter	x	x	6.4.2
	- Inertness	x	x	6.4.3
	- Lay ratio and direction of lay	x	x	6.4.4
	- Number and type of wires	x	x	6.4.5
	- Aluminium cross-section	x	x	6.4.6
	- Mass per unit length	x	x	6.4.7
	- DC Electrical Resistance	x	-	6.4.8
	- Stress-strain curve	[a]	-	6.4.9
	- Tensile breaking strength	[a]	-	6.4.10
	- Stringing test	[a]		6.4.11
	- AC Electrical resistance	[b]		6.4.8
Aluminium wires				
	- Tensile strength	x [c]	x [c]	6.5.2
	- Elongation	x [c]	x [c]	6.5.2
	- Resistivity	x [c]	x [c]	6.5.2
	-Cross section	x [c]	x [c]	6.5.2
Galvanized or Zn95Al5 steel wires	- Diameter	x	x [c]	6.5.2
	- Tensile strength	x	x [c]	6.5.2
	- Elongation or torsion test	x	x	6.5.2
	- Mass of Zn coating	x	x	6.5.2
	- Zinc dip test	x	x	6.5.2
	- Adhesion of zinc coating	x	x	6.5.2
Aluminium-clad Steel wires	- Diameter	x	x [c]	6.5.2
	- Tensile strength	x	x [c]	6.5.2
	- Elongation	x	x	6.5.2
	- Torsion	x	x	6.5.2
	- Thickness of Al	x	x	6.5.2
	- Resistivity	x	x	6.5.2

[a] By agreement between the purchaser and manufacturer.

[b] By agreement between the purchaser and manufacturer, in case of uneven number of Al layers.

[c] All these tests must be carried out also before stranding.

6.2 Sample size

When agreed by the manufacturer and the purchaser at the time of ordering, tests shall be carried out on a minimum of 10 % of the drums offered for inspection and, in such cases, each wire shall be tested. Where the manufacturer has a demonstrated capability of meeting or exceeding the requirements, the number of test samples may be reduced, with the agreement of the purchaser and manufacturer, to a level which ensures that each production lot of conductor is given adequate monitoring.

Drums to be sampled shall be selected at random, and samples taken from the outer end of the drums.

The length of the sample of conductor taken shall be sufficient to allow all tests to be performed on the same specimens of wire.

6.3 Rounding rules

The following rounding rules shall be used for determination of compliance with this standard.

6.3.1 When the figure immediately after the last figure to be retained is less than 5, the last figure to be retained remains unchanged.

6.3.2 When the figure immediately after the last figure to be retained is greater than 5 or equal to 5 and followed by at least one figure other than zero, the last figure to be retained is increased by one.

6.3.3 When the figure immediately after the last figure to be retained is equal to 5 and followed by zeros only, the last figure to be retained remains unchanged if even and is increased by one if odd.

6.4 Properties of conductor

6.4.1 Surface condition

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

6.4.2 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 5.4.

6.4.3 Inertness

The requirement of 5.2.4 shall be met.

6.4.4 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 5.5. In addition the direction of each layer shall be noted and shall also comply with the requirements of 5.5.

6.4.5 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.

6.4.6 Determination of cross sectional area of Al

Determination of cross sectional area of one aluminium wire shall be made dividing the unit weight of an Al wire sample of min. 1 m long, by the specific weight of aluminium, 2,703 kg/dm³.

Total conductor cross section is the addition of all individual wires cross sectional areas. The tolerance in cross section is ± 2 % of the nominal.

6.4.7 Mass per unit length

The mass per unit length of a 1 m sample of conductor shall be determined by using apparatus capable of achieving an accuracy of ± 0,1 %. The value obtained shall be within a tolerance of ± 2 %.

6.4.8 Electrical resistance of complete conductor

DC resistance of complete conductor will be measured according to reference method of IEC 60468.The value obtained shall not exceed the maximum DC resistance calculated by means of the electrical resistivity of the materials involved ,nominal cross sections and application of the increments due to stranding shown on Table 5.

NOTE By agreement between purchaser and manufacturer, AC electrical resistance measurements can also be performed. Reference method is given in Annex D.

6.4.9 Stress-strain curves

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 A shall be used. Stress strain curves should be carried out without pre-stress on overall conductor and on steel core. In case pre-stressing is foreseen during the installation, stress-strain curves should be carried out with pre-stress.

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.

6.4.10 Tensile breaking strength

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 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 A.6.8.

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.

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 5 cm 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 5 cm 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.

6.4.11 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 C. Alternative tests or evidence of satisfactory service experience may also be agreed.

6.5 Properties of wires

6.5.1 Properties of wires before stranding

The properties of the individual wires before stranding, including tests on the coating of steel wires, shall meet the requirements of the wire as specified in the standards referenced in Clauses 2 and 5.

6.5.2 Properties of wires 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 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, where applicable and Clause 5, with the exceptions:

The allowed reductions on the wire properties for wires after stranding indicated in Table 13 shall apply.

Table 13 - Permitted reductions in wire properties after stranding

Material	Reduction after stranding	
ST6A, Zn95Al5 and Aluminium-clad steel wires, 20 SA and 14 SA	Tensile strength:	5 %
	Torsion:	subtract 2 turns
	Elongation [a]:	subtract 0,5
	Thickness of Al cladding (SA wire):	25 % of minimum
[a] EXAMPLE: A minimum elongation value of 3,0 % for wire before stranding is reduced to 2,5 % for wire after stranding.		

The formed aluminium wires after stranding shall conform to the requirements of Clause 5 except for shape and diameter tolerance requirements .The tensile strength and elongation requirements of formed wires shall be the same as for round wires of equal area. The area tolerances for this type of wires shall be such that the finished conductor conforms to 5.9. Test procedures will be in accordance with EN 60889.

6.6 Inspection

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

6.6.2 When inspection is to be made by the purchaser before shipment, the tests shall all be made within 14 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 expiry of the said 14 days, the manufacturer shall make the tests herein provided for and furnish to the purchaser, when requested, official copies of the results of such tests, and the purchaser shall accept or reject the material in accordance with the results of such tests. Alternatively, the manufacturer may provide relevant test results if these have already been carried out during production.

6.7 Acceptance or rejection

6.7.1 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.

6.7.2 If any lot is so rejected, the manufacturer shall have the right to test, only once, all individual drums of conductor in the lot and submit those which meet the requirements for acceptance. Only those tests which do not meet the requirements for acceptance on the original specimen, shall be carried out.

7 Packaging and marking

7.1 Packaging

The conductor shall be suitably protected against damage or deterioration which could occur in ordinary handling and shipping. Except specifically requested from purchaser, one length of conductor will be supplied per reel.

Protection of the inner side of reel flanges and core battens is highly recommended. In order to prevent damages due to transportation and handling, a layer separation made of suitable material between the individual layers of conductor on the reel, is also recommended.

The following shall be agreed upon between the manufacturer and the purchaser at the time of placing the order or at the earliest possible time:

a) the type and size of package and method of packing;

b) the packaging size and drum bore requirements and also the availability of the inner end of the conductor for grounding purposes, where the conductor stringing practices require special consideration.

7.2 Marking and tare

The gross, net and tare weight, length (or length and number of conductors, 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.

7.3 Random lengths

Unless otherwise agreed between the purchaser and manufacturer, random lengths of conductors unavoidably obtained during production should not exceed 5 % of the purchased quantity providing that no piece is less than 50 % of the contractual length.

7.4 Accuracy of lengths

The manufacturer shall use equipment to measure the length to an accuracy of ± 1 %.

7.5 Drum barrel dimensions

The diameter of the drum barrel shall be sufficiently large not to cause problems during subsequent use of the conductor. The experience of some countries is that this value should be at least 30 times the conductor diameter or 60 times the steel core diameter, whichever is the greater.

8 Information to be clarified by the purchaser and manufacturer

When making an enquiry or placing an order the following information shall be clarified between the purchaser and manufacturer:

a) quantity of conductor;
b) conductor design (round or formed Al wires) number of wires, total cross section.
c) length of conductor per drum, its tolerance, and where applicable, matching of conductor lengths;
d) direction of lay. If this information is omitted, the direction of the external lay shall be right-hand;
e) type and size of package and method of packing;
f) special packaging requirements, if any;
g) lagging requirements, if any;
h) whether tests on wires after stranding are required;
i) nominal conductor diameter and method of measurement;
j) whether conductor breaking strength tests are required;
k) whether conductor stress-strain tests are required;
l) recommended or specified installation methods, or purchaser requirements for tests designed to demonstrate capability for satisfactory installation;
m) if inspection is required and place of inspection;
n) whether AC resistance tests are required.

This list is given for guidance only and may not be complete.

Annex A
(normative)

Stress-strain test method [1)]

A.1 Sample length

The sample length, between end terminations, shall be 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.

A.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.

A.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.

A.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.

A.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.

A.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.

A.3.4 End fittings such as compression or solder type approved by the purchaser shall be used for stress-strain tests. Epoxy type end should be the preferred option in order to avoid the risk of aluminium layers looseness. The wires shall not be unwound, cleaned or greased prior to application of the end fittings.

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

A.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.

A.4 Requirements for compression fittings

When compression fittings are used, the method indicated in A.4.1 to A.4.3 shall be followed.

[1)] Test to be performed if required by the purchaser.

A.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.

A.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.

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

A.5 Test set-up

A.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.

A.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.

A.6 Pre-stress method

If a pre-stress is needed it shall be done according to the following procedure:

Before stress-strain test, conductor shall be pre-stressed at the purchaser specified value X. Stress- strain data shall be recorded and written down in the test report during all the test. A constant mechanical tension of X is applied to the conductor. First hour strain ($\varepsilon 1$ expressed in mm) is compared with second hour strain ($\varepsilon 2$ in mm). If $\varepsilon 2/\varepsilon 1 > 5$ %, pre-stress duration is set at 4 h. Otherwise, pre-stress can be stopped after the two first hours.

A.7 Test loads for the conductor

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

A.7.1 Load initially to 5 % of RTS (Rated Tensile Strength) to straighten the conductor and set the strain gauges to zero.

A.7.2 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.

A.7.3 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.

A.7.4 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.

A.7.5 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.

A.7.6 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.

A.7.7 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.

A.7.8 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.

A.8 Test loads for steel core only

The loading conditions for stress-strain tests of the steel core ,shall be as follows.

A.8.1 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.

A.8.2 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.

A.9 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 1 h 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.

Annex B
(informative)

Lay ratios used for calculation of increments due to stranding in Tables 10 and 11

Table B.1 - Lay ratios used for calculation of increments due to stranding in Tables 10 & 11

Aluminium wires		Steel wires		Lay ratio							
No. [a]	Layers	No.	Layers	1	2	3	4	5	6	7	8
10	1	7	1	19	12	-	-	-	-	-	-
12	1	7	1	19	12	-	-	-	-	-	-
14	1	7	1	19	12	-	-	-	-	-	-
18	2	7	1	19	14	11,5	-	-	-	-	-
22	2	7	1	19	14	11,5	-	-	-	-	-
24	2	7	1	19	14	11,5	-	-	-	-	-
26	2	7	1	19	14	11,5	-	-	-	-	-
28	2	7	1	19	14	11,5	-	-	-	-	-
30	2	7	1	19	14	11,5	-	-	-	-	-
32	2	7	1	19	14	11,5	-	-	-	-	-
36	2	7	1	19	14	11,5	-	-	-	-	-
42	3	7	1	19	15	13	11,5	-	-	-	-
45	3	7	1	19	15	13	11,5	-	-	-	-
48	3	7	1	19	15	13	11,5	-	-	-	-
54	3	7	1	19	15	13	11,5	-	-	-	-
72	4	7	1	19	15,5	13,5	12	11,5	-	-	-
84	4	7	1	19	15,5	13,5	12	11,5	-	-	-
14	1	19	2	20	17,5	11,5	-	-	-	-	-
15	1	19	2	20	17,5	11,5	-	-	-	-	-
16	1	19	2	20	17,5	11,5	-	-	-	-	-
18	1	19	2	20	17,5	11,5	-	-	-	-	-
30	2	19	2	20	17	13	11,5	-	-	-	-
32	2	19	2	20	17	13	11,5	-	-	-	-
36	2	19	2	20	17	13	11,5	-	-	-	-
42	2	19	2	20	17	13	11,5	-	-	-	-
54	3	19	2	20	18	15	13,5	11,5	-	-	-
38+22	3	19	2	20	18	15	13,5	11,5	-	-	-
42+20	3	19	2	20	18	15	13,5	11,5	-	-	-
66	3	19	2	20	18	15	13,5	11,5	-	-	-
78	3	19	2	20	18	15	13,5	11,5	-	-	-
96	4	19	2	20	18	15	13,5	12,5	11,5	-	-
100	4	19	2	20	18	15	13,5	12,5	11,5	-	-
18	1	37	3	20	18	16	11,5	-	-	-	-
24	1	37	3	20	18	16	11,5	-	-	-	-
72	3	37	3	22	19	17	15	13	11,5	-	-
54+66	4	37	3	24	20	18	16,5	15	12,5	11,5	-
150	5	37	3	24	20	18	16,5	15	14	12,5	11,5

NOTE For more accurate calculations, measured values may be used.

[a] Number of wires may be different in formed wire constructions. Lay ratios shown in this table are fully applicable depending on the number of aluminium layers (1, 2, 3 or 4).

Annex C
(normative)

Test for ability of a conductor to be erected using tension stringing [2)]

C.1 Introduction

This test is intended to simulate the tensions existing during tension stringing and to verify, in particular, the absence of bird-caging, which is the opening up of individual wires by an unacceptable amount.

C.2 Procedure

C.2.1 Test set-up

The test arrangement is given in Figure C.1.

Drum holder: the drum shall be installed on an unwinding drum holder equipped with an adjustable disc brake which is not under automatic control from the tensioner. The conductor shall unwind from the top of the drum.

Tensioner: one of the characteristics of the tensioner bull wheels is the maximum conductor diameter, D_M, which is recommended for use. The tensioner to be used for this test shall have a D_M value as close as possible to the diameter of the conductor being tested (preferably, the tensioner to be used shall have polychloroprene coated grooves).

The tensioner shall be installed 15 m from the drum.

Figure C.2 gives the input direction of the conductor in the tensioner grooves. The horizontal input angle shall be set at 5° max. The drum shall be staggered with respect to the tensioner on the side where the conductor enters the top of the tensioner (right-hand side for the left-hand lay, left-hand side for the right-hand lay).

Conductor pulling winch: the winch shall be 400 m from the tensioner and the conductor pulled by means of a pilot cable (attached to the conductor with a suitable grip and a swivel).

Block: a running block, selected by the purchaser, shall be installed at mid-distance between the pulling winch and the tensioner at adequate height, so that the conductor does not touch the ground during unwinding.

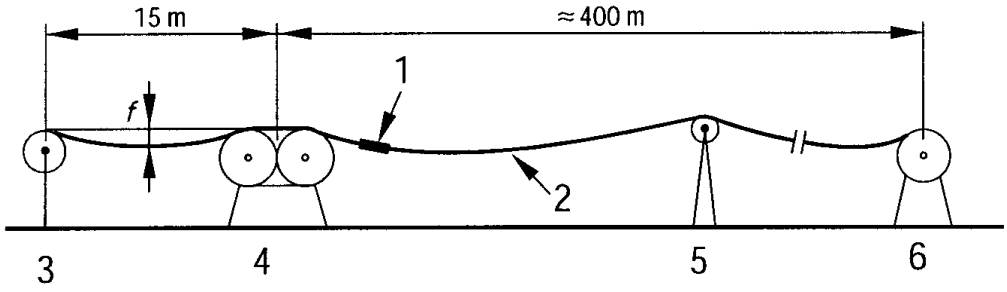
C.2.2 Unwinding

During unwinding, a mid-span sag, *f*, of approximately 1,5 m shall be maintained in the part of the conductor between the drum and the tensioner. Very sudden changes of the tension shall be avoided in this part. The tension at the output of the tensioner shall be maintained at 10 % of the RTS for Extra High Strength steel wires and 5 % of the RTS for Ultra High Strength steel wires of the conductor under test, and the unwinding speed shall be approximately 20 m/min.

C.3 Acceptance criterion

During the unwinding of the conductor length, observation shall be made and if an individual outer layer wire is raised above the normal position of that wire by more than one wire diameter the conductor shall deemed unacceptable. Additional acceptance criteria may be specified by the purchaser.

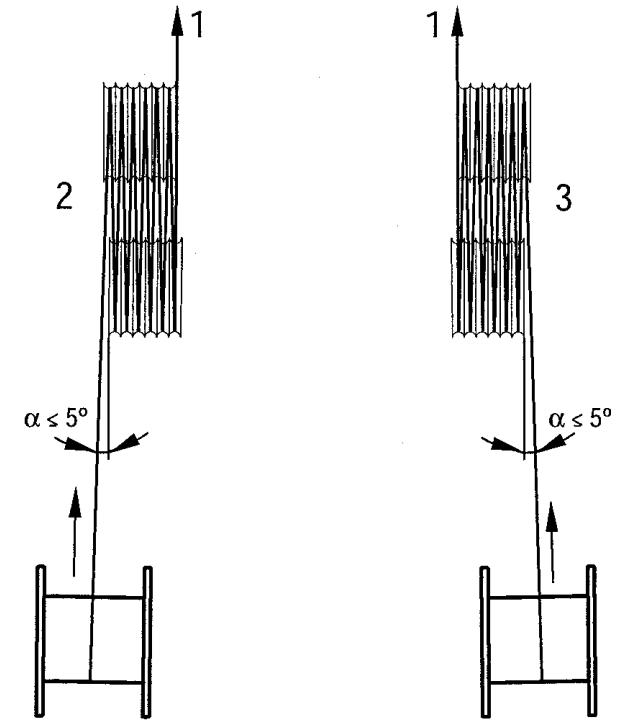
[2)] Test to be performed if required by the purchaser.



Key

1 Woven grip
2 Pilot cable
3 Drum holder
4 Tensioner
5 Block
6 Pulling winch

Figure C.1 - Test arrangement



Key

1 Pulling towards the winch
2 Right-hand cable lay
3 Left-hand cable lay

Figure C.2 – Drum holder and tensioner set–up

Annex D
(informative)

AC resistance measurement method

D.1 Introduction

If an odd aluminium layers design is defined by ACSS manufacturer, magnetic phenomenon occur an increase of conductor alternative resistance. This test aims at assessing AC resistance change according to electrical current in the conductor. This test protocol is inspired by TB345 published by Cigre (see Clause D.5).

D.2 Sample preparation

The sample length, between end terminations, shall be not less than 5 m. A shorter length may be agreed between the manufacturer and purchaser. The end terminations shall be dead end sized by the manufacturer. A mechanical force of 20 % RTS shall be applied to the conductor. This mechanical force shall be maintained during all the test even at high temperature.

D.3 Test set-up

Appropriate measuring instruments shall be used in order to determine DC & AC resistance. Generally voltage (U), current (I) and phase angle (φ) between voltage & current are measured.

$$R_{ac} = \frac{U \cos \varphi}{I}$$

Difference between AC and DC resistance is few %, accurate instrumentation shall be chosen.

Reference length for voltage measurement shall be at least 2 m and 1.5 m from span extremities. Laboratory shall check that no thermal effect due to dead end impacts reference length temperature.

Specific cares shall be taken in order to avoid voltage induced by current loop. One solution consists to reduce loop by leading the cable measurement alongside the conductor to its middle.

D.4 Test protocol

In order to measure AC resistance according to current, 3 methods are possible. The well adapted method according to laboratory capabilities shall be chosen:

- DC resistance shall be measured before the beginning of test. Apply 10 short current pulses from 0 A to maximum current at room temperature. Pulse duration shall be determined in order to have no conductor temperature change and enough time to perform measurement. Between each current pulse, 30 min have to be kept. This shall allow temperature to be homogeneous along and inside the conductor.
- DC resistance shall be measured before the beginning of test and if possible at each current step. 10 current steps shall be determined in order to assess AC resistance between 0 A and maximum current. Current shall be applied to the conductor and maintained during at least 60 min before AC resistance measurement. Laboratory shall check temperature is stabilized before performing measurements. Specific cares shall be taken in order to avoid uneven temperature on reference length. DC resistance and AC resistance shall be corrected according to temperature.
- Up-to-date devices giving the same results can be used for the AC resistant measurements.

D.5 Reference

TB345: Alternating current (AC) resistance of helically stranded conductors – April 2008.

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