

**Specification for  
2 PfG 2642/01.22  
Requirements for  
Electric cables with aluminum alloy  
conductors for use in photovoltaic -  
systems**

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## Foreword

This test specification contents requirements evaluated by TUV Rheinland for armored and unarmored, single- or multi-core with solid, stranded or flexible aluminum alloy conductors, cross-linked insulation and sheath for use in photovoltaic – systems.

Caused by market need to save installation cost more and more aluminum cables are installed so they have been considered in this standard.

The test standard was created based on IEC 62930 which covers flexible cables having a copper conductor for DC-voltages up to 1500 V.

**For aluminium alloy conductors special requirements for termination are to be considered. So only suitable terminals specified for aluminium conductors shall be used. Requirements for such terminals are not part of this standard.**

These cables are suitable for permanent outdoor long-term use under variable demanding climate conditions. Relatively stringent requirements are set for these products in line with the expected usage conditions.

## 1 Scope

2 PfG 2642/01.22 applies to halogen-free low smoke armored and unarmored, single- or multi-core electric cables with aluminum alloy conductors, cross-linked insulation and sheath.

These cables are for use at the direct current (DC) side of photovoltaic – systems, with a rated DC voltage up to 1,5 kV between conductors and between conductor and earth.

The cables are suitable for use in class II equipment as defined in IEC 61140.

When installation in air, the cables are designed to operate at a normal continuous maximum conductor temperature of 90 °C. The permissible period of use at a thermal index of 120°C is limited to 20000h.

When installation in ground, the cables are designed to operate at a normal continuous maximum conductor temperature of 90 °C. In any case the maximum temperature at conductor is 90 °C. The permissible period of use at a thermal index of 90°C is limited to 20000h.

The permitted short-circuit-temperature is 250°C referring to a period of 5s.

## 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 60364-5-52, *Erection of low voltage installations –Part 5: Selection and erection of electrical equipment –Chapter 52: Wiring systems*

EN 50267-2-1, *Common test methods for cables under fire conditions – Tests on gases evolved during combustion of materials from cables – Part 2-1: Procedures – Determination of the amount of halogen acid gas;*

- EN 50267-2-2, *Common test methods for cables under fire conditions – Tests on gases evolved during combustion of materials from cables – Part 2-2: Procedures – Determination of degree of acidity of gases for materials by measuring pH and conductivity;*
- EN 50305, *Railway applications – Railway rolling stock cables having special fire performance – Test methods*
- EN 50395, *Electrical test methods for low voltage energy cables;*
- EN 50396, *Non-electrical test methods for low voltage energy cables;*
- EN 60068-2-78, *Environmental testing - Part 2-78: Tests -Test Cab: Damp heat, steady state (IEC 60068-2-78)*
- EN 60216-1, *Electrical insulating materials - Properties of thermal endurance - Part 1: Ageing procedures and evaluation of test results (IEC 60216-1);*
- EN 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria (IEC 60216-2);*
- EN 60228, *Conductor of insulated cables (IEC 60228)*
- EN 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame; (IEC 60332-1-2)*
- EN 60684-2, *Flexible insulating sleeving – Part 2: Methods of test (IEC 60684-2)*
- EN 60811-1-1, *Insulating and sheathing materials of electric cables – Common test methods Part 1-1: General application – Measurement of thickness and overall dimensions – Test for determining the mechanical properties (IEC 60811-1-1)*
- EN 60811-1-2, *Insulating and sheathing materials of electric and optical cables – Common test methods. Part 1-2: General application. Thermal ageing methods (IEC 60811-1-2)*
- EN 60811-1-3, *Insulating and sheathing material of electric and optical cables – Common test methods – Part 1-3: General application – Methods for determining the density – Water absorption tests – Shrinkage test (IEC 60811-1-3)*
- EN 60811-1-4, *Insulating and sheathing materials of electric and optical cables – Common test methods. Part 1-4: General application. Tests at low temperature. (IEC 60811-1-4)*
- EN 60811-2-1, *Insulating and sheathing materials of electric and optical cables – Common test methods – Part 2-1: Methods specific to elastomeric compounds – Ozone resistance, hot set and mineral oil immersion tests (IEC 60811-2-1)*
- EN 60811-3-1, *Insulating and sheathing materials of electric cables – Common test methods Part 3-1: Methods specific to PVC compounds – Pressure test at high temperature, test for resistance to cracking (IEC 60811-3-1)*
- EN 50525-3-21, *Rubber insulated cables of rated voltages up to and including 450/750 V Part 13: Single and multicore flexible cables, insulated and sheathed with crosslinked polymer and having low emission of smoke and corrosive gases;*
- HD 605, *Power cables – Part 605: Additional test methods*

HD 60364-5-52, *Erection of low voltage installations –Part 5: Selection and erection of electrical equipment –Chapter 52: Wiring systems (IEC 60364-5-52, modified)*

HD 60364-7-712 *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems (IEC 60364-7-712, modified)*

IEC 62930 Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC

IEC 60502-1:2021 Power cables with extruded insulation and their accessories for rated voltages from 1 kV ( $U_m = 1,2$  kV) up to 30 kV ( $U_m = 36$  kV) – Part 1: Cables for rated voltages of 1 kV ( $U_m = 1,2$  kV) and 3 kV ( $U_m = 3,6$  kV)

GB/T 4909.5-2009, Test methods for bare wires-Part 5: Bend test - Reverse bend test;

GB/T 31840.1-2015, Aluminum alloys power cables with extruded insulation for rated voltages from 1 kV ( $U_m=1.2$ kV) up to 35kV ( $U_m=40.5$  kV)-Part 1: Cables for rated voltages of 1kV ( $U_m=1.2$ kV) and 3kV ( $U_m=3.6$ kV);

GB/T 30552-2014, Aluminium alloy wires for conductor of insulated cables;

### 3 Terms and definitions

For the purposes of this document, following definitions apply.

#### 3.1

##### **Type test (symbol T)**

Tests required to be made before supplying a type of cable covered by this standard on a general commercial basis, in order to demonstrate satisfactory performance characteristics to meet the intended application.

NOTE: These tests are of such a nature that, after they have been made, they need not be repeated, unless changes are made in the cable materials or design or manufacturing process which might change the performance characteristics.

#### 3.2

##### **sample tests (symbol S)**

Tests made on samples of completed cable or components taken from a completed cable, at a specified frequency, so as to verify that the finished product meets the specified requirements.

#### 3.3

##### **Routine tests (symbol R)**

Tests made by the manufacturer on each manufactured length of cable to check that each length meets the specified requirements

#### 3.4 halogen free material

material complying with the requirements of IEC 62821-1, Annex B

## 4 Rated voltage

The cables specified by this standard are in particular designed for use at the direct current (d.c.) side of photovoltaic – systems, with a rated d.c. voltage up to 1,5 kV between conductors as well as between conductor and earth.

## 5 Requirements for the construction of cables

### 5.1 Conductors

#### 5.1.1 Material

The material of conductors shall be aluminum alloy, and in accordance with IEC 60228 and annex A.

#### 5.1.2 Construction

The classes of the conductors shall be Class 1, 2 in accordance with IEC 60228 or Class 5 in accordance with annex A.

NOTE Cables with Class 5 conductors are suitable for free movable, free hanging and fixed installation.

Cables with Class 1, 2 conductors are limited to fixed installations where no flexing.

The conductors can be circular or shaped.

Preferred diameters for Class 1, 2 conductors: 10 to 400 mm<sup>2</sup>

Preferred diameters for Class 5 conductors: 2.5 to 400 mm<sup>2</sup>

The nominal cross-sectional areas for each conductor class are given in Table 1 and Table 2.

#### 5.1.3 Separator between conductor and insulation

A non-metallic separator may be applied between the conductor and the insulation. It shall be halogen free.

#### 5.1.4 Check of construction

Compliance with the requirements of 5.2.1, 5.2.2 and 5.2.3, including the requirements of Annex A, shall be checked by inspection and by measurement.

### 5.2 Insulation

#### 5.2.1 Material

When installation in air, the insulation material shall be a 120°C cross-linked compound and fulfil the requirements as specified in table 5.

When installation in ground, the insulation material shall be a 90°C cross-linked compound and fulfil the requirements as specified in table 6, or 120°C cross-linked compound and fulfil the requirements as specified in table 5.

### 5.2.2 Application to the conductor

The insulation shall be applied by extrusion, such that it fits closely on the conductor, but it shall be possible to remove it without damage to the insulation itself or to the conductor. It is permitted to apply the insulation in a single layer, or in a number of non-separable layers. Where more than one layer is used, all testing shall be carried out on the complete insulation as though it were a single layer.

Compliance shall be checked by inspection and by manual test.

### 5.2.3 Thickness

The average of the measured values, rounded to 0,1 mm, shall be not less than the specified value for each size shown in Table 1 and Table 2.

The smallest value measured shall not fall below 90 % of the specified value by more than 0,1 mm, i.e.:

$$t_m > 0,9t_s - 0,1$$

where:

$t_m$  is the minimum insulation thickness at any point in millimeters  $t_s$  is the specified insulation thickness, in millimeters

Compliance shall be checked using the test given in 1.9 of IEC 60245-2.

## 5.3 Core identification

### 5.3.1 General

Identification of the cores of a cable shall be achieved by the use of colored insulation or numbering.

The colours shall be clearly identifiable and durable. Durability shall be checked by the test given in 5.1 of EN 50396.

### 5.3.2 Identification by colour

Each core shall have only one colour. The colours green and yellow shall be not used.

The preferred colours are black and red, unless otherwise agreed between manufacturer and customer. The color shall be throughout the whole of the insulation.

### 5.3.3 Identification by numbering

Where use identification by numbering, it shall conform to EN 50334.

## 5.4 Assembly of cores

The cores of unarmored cables shall be individually sheathed and comply with all requirements set in this document.

The cores of armored cables can be twisted together or parallel.

A suitable binder is permitted before application of an extruded inner covering.

Preferred number of cores for multicore cables: 2.

## 5.5 Inner coverings and fillers

### 5.5.1 Material

The armored cable shall have an extruded inner coverings.

The materials used for inner coverings and fillers shall be suitable for the operating temperature of the cable and compatible with the insulating material. It shall be halogen free.

### 5.5.2 Application

The inner coverings shall be extruded.

### 5.5.3 Thickness

The average of the measured values, rounded to 0,1 mm, shall be not less than the specified value for each size shown in Table 1 and Table 2.

The smallest value measured shall not fall below 80 % of the specified value by more than 0,2 mm, i.e.:

$$t_m > 0,8t_s - 0,2$$

where:

$t_m$  is the minimum inner coverings thickness at any point in millimeters  $t_s$  is the specified inner coverings thickness, in millimeters

Compliance shall be checked using the test given in 1.10 of IEC 60245-2.

## 5.6 Metal Armour/ Humidity protection barrier

Only cable with metal armour can be used for direct burial installation.

The metal armour shall consist of double tapes of steel, galvanized steel, aluminium or aluminium alloy. Steel tapes shall be hot- or cold-rolled of commercial quality.

When choosing the material of the armour, the possibility of corrosion shall be taken into consideration, not only for mechanical safety, but also for electrical safety, especially when the armour is used as a screen.

The metal armour shall be self-contained as humidity protection.

The manufacturer shall, where necessary, apply a suitable binder tape over the metallic layer.

NOTE: The mentioned humidity barrier can be considered as rodent protection and as basic mechanical protection.

The nominal thickness of tapes shall be not less than each size shown in Table 3.

The smallest value measured shall not fall below 80 % of the specified value.

The metal armour shall be applied on an inner covering complying with clause 5.6.

Cables with section of 6mm<sup>2</sup> and below, the armor can be wrapped longitudinally or in other suitable methods.

Cables with section above 6mm<sup>2</sup>, the tape armour shall be applied helically in two layers so that the outer tape is approximately central over the gap of the inner tape. The gap between adjacent turns of each tape shall not exceed 50 % of the width of the tape.

## 5.7 Outer Sheath



### 5.7.1 Material

When installation in air, the sheath material shall be a 120°C cross-linked compound and fulfil the requirements as specified in Table 5.

When installation in ground, the sheath material shall be a 90°C cross-linked compound and fulfil the requirements as specified in table 6, or 120°C cross-linked compound and fulfil the requirements as specified in Table 5.

### 5.7.2 Application

The sheath shall be applied homogeneously by extrusion. It is permitted to apply the sheath in a single layer, or in a number of non-separable layers. Where more than one layer is used, all testing shall be carried out on the complete sheathing as though it were a single layer.

The application of the sheath shall give the finished cable a practically circular shape.

### 5.7.3 Thickness

The average of the measured values, rounded to 0,1 mm, shall be not less than the specified value for each size shown in Table 1 and Table 2.

For unarmored cables, the smallest value measured shall not fall below 85 % of the specified value by more than 0,1 mm, i.e.:

$$t_m > 0,85t_s - 0,1$$

where:

$t_m$  is the minimum sheath thickness at any point in millimetres

$t_s$  is the specified sheath thickness, in millimetres

For armored cables, the smallest value measured shall not fall below 80 % of the specified value by more than 0,2 mm, i.e.:

$$t_m > 0,8t_s - 0,2$$

where:

$t_m$  is the minimum sheath thickness at any point in millimetres

$t_s$  is the specified sheath thickness, in millimetres

Compliance shall be checked using the test given in 1.10 of IEC 60245-2.

### 5.7.4 Color

The sheath shall be colored black, unless otherwise agreed between manufacturer and customer. The color shall be throughout the whole of the sheath.

### 5.8 Ovality

Ovality of the cables shall be limited: the difference between any two values of the overall diameter of a sheathed cable at the same cross-section shall not exceed 15 %.

## 6 Marking

### 6.1 General

The sheath of the cable shall be marked by printing, embossing or indenting.

### 6.2 Indication of origin

Cables shall be provided with an identification of origin consisting of the continuous marking of the manufacturer's name or trademark, or (if legally protected) identification number.

### 6.3 Code designation

PV1500DC-AL

with

#### Code of conductors characteristic:

Class 1, 2 solid conductors and stranded conductors .....omit

Class 5 flexible conductors ..... -K

#### Code of thermal endurance characteristic:

Thermal index 90 °C ..... omit

Thermal index 120 °C ..... 120 °C

#### Code of armour:

Unarmored cables ..... omit

Direct burial armored cables ..... DB

### 6.4 Additional Marking

Halogen free low smoke cables shall be marked "HALOGEN FREE LOW SMOKE".

### 6.5 Nominal cross-sectional area of conductor

Cables shall be marked with number of cores and the nominal cross-sectional area, for example '2X4 mm<sup>2</sup>'.

## 6.6 Continuity of marking

Each specified marking shall be regarded as continuous if the distance between the end of the mark and the beginning of the next identical mark does not exceed 550 mm.

NOTE 1 A 'Specified Marking' is any mandatory marking covered by this standard.

NOTE 2 Other marking, such as that required under recognized voluntary 3rd party approval schemes, may also follow the requirements of this subclause.

The diagram below shows an example of the marking as used on the outer sheath of the cable.

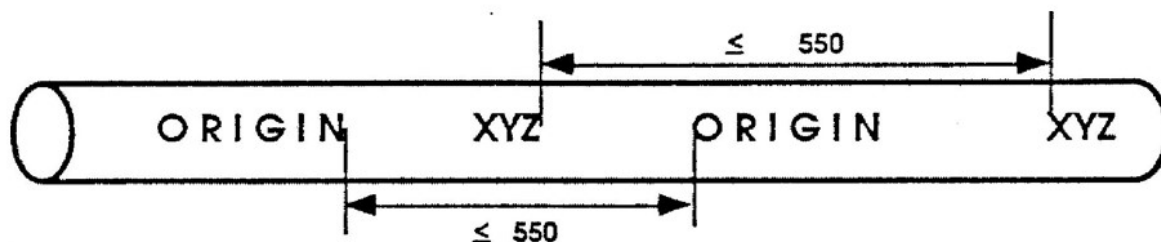


Figure 2 - Example of the marking as used on the outer sheath of the cable

## 6.7 Additional requirements

### 6.7.1 Durability

Printed markings shall be durable. Compliance with this requirement shall be checked by the test given in 1.8 of IEC 60245-2.

### 6.7.2 Legibility

All markings shall be legible.

## 7 Requirements for complete cables

### 7.1 General

The tests to be carried out on cables specified in this standard shall be as scheduled in Table 4, which refers to the relevant clauses of the standard specifying the requirements and test methods as well as the category of each test which applies, i.e. Type Test (T); Sample Test (S) or Routine Test (R) (as defined in Clause 3).

Requirements for tests not previously specified are as given in 7.2 to 7.3.

## 7.2 Electrical tests

### 7.2.1 Check for absence of faults on the insulation or on the complete cable

The cable shall be tested during manufacturing for faults in accordance with IEC 62230, following maximum voltages:

AC 15kV  
DC 25kV  
HF 16kV (>3 kHz)

In case checking of the insulation only is impossible, testing shall be performed on the complete cable in case of no humidity barrier. Cables having a metallic humidity barrier shall be tested before application of the metallic layer.  
No fault shall be detected.

## 7.3 Non electrical tests

### 7.3.1 Dimensions

Following values, given in Tab 1 and Tab 2 are applicable.

Table 1

Dimensional and insulation resistance values for class 1, 2 aluminum alloy conductor cables

Nominal cross-sectional area of conductors	Thickness of insulation specified value	Thickness of sheath specified value (unarmored /armored)	Thickness of coverings specified value (only for armored cables)	Minimum insulation resistance at 20°C	Minimum insulation resistance at 90°C
mm <sup>2</sup>	mm	mm	mm	MΩ·km	MΩ·km
1×10	0,8	0,8/1,5	1,0	489	0,489
1×16	0,9	0,9/1,5	1,0	374	0,374
1×25	1,0	1,0/1,5	1,0	384	0,384
1×35	1,1	1,1/1,5	1,0	327	0,327
1×50	1,2	1,2/1,5	1,0	317	0,317
1×70	1,2	1,2/1,5	1,0	291	0,291
1×95	1,3	1,3/1,6	1,0	251	0,251
1×120	1,3	1,3/1,6	1,0	244	0,244
1×150	1,4	1,4/1,7	1,0	254	0,254
1×185	1,6	1,6/1,7	1,0	261	0,261
1×240	1,7	1,7/1,8	1,2	243	0,243
1×300	1,8	1,8//1,9	1,2	231	0,231
1×400	2,0	2,0/2,0	1,2	227	0,227
2×10	0,8	0,8/1,8	1,0	489	0,489
2×16	0,9	0,9/1,8	1,0	374	0,374
2×25	1,0	1,0/1,8	1,0	384	0,384
2×35	1,1	1,1/1,8	1,0	327	0,327
2×50	1,2	1,2/1,8	1,0	317	0,317
2×70	1,2	1,2/1,9	1,2	291	0,291
2×95	1,3	1,3/2,0	1,2	251	0,251
2×120	1,3	1,3/2,2	1,4	244	0,244
2×150	1,4	1,4/2,3	1,4	254	0,254
2×185	1,6	1,6/2,5	1,6	261	0,261
2×240	1,7	1,7/2,6	1,6	243	0,243
2×300	1,8	1,8/2,8	1,6	231	0,231
2×400	2,0	2,0/3,1	1,8	227	0,227

Table 2

Dimensional and insulation resistance values for class 5 aluminum alloy conductor cables

Nominal cross-sectional area of conductors	Thickness of insulation specified value	Thickness of sheath specified value (unarmored /armored)	Thickness of coverings specified value (only for armored cables)	Minimum insulation resistance at 20°C	Minimum insulation resistance at 90°C
mm <sup>2</sup>	mm	mm	mm	MΩ·km	MΩ·km
1×2,5	0,7	0,8/1,5	1,0	862	0,862
1×4	0,7	0,8/1,5	1,0	709	0,709
1×6	0,7	0,8/1,5	1,0	610	0,610
1×10	0,8	0,8/1,5	1,0	489	0,489
1×16	0,9	0,9/1,5	1,0	395	0,395
1×25	1,0	1,0/1,5	1,0	393	0,393
1×35	1,1	1,1/1,5	1,0	335	0,335
1×50	1,2	1,2/1,5	1,0	314	0,314
1×70	1,2	1,2/1,5	1,0	291	0,291
1×95	1,3	1,3/1,6	1,0	258	0,258
1×120	1,3	1,3/1,6	1,0	249	0,249
1×150	1,4	1,4/1,7	1,0	268	0,268
1×185	1,6	1,6/1,7	1,0	260	0,260
1×240	1,7	1,7/1,8	1,2	249	0,249
1×300	1,8	1,8//1,9	1,2	237	0,237
1×400	2,0	2,0/2,0	1,2	230	0,230
2×2,5	0,7	0,8/1,8	1,0	862	0,862
2×4	0,7	0,8/1,8	1,0	709	0,709
2×6	0,7	0,8/1,8	1,0	610	0,610
2×10	0,8	0,8/1,8	1,0	489	0,489
2×16	0,9	0,9/1,8	1,0	395	0,395
2×25	1,0	1,0/1,8	1,0	393	0,393
2×35	1,1	1,1/1,8	1,0	335	0,335
2×50	1,2	1,2/1,8	1,0	314	0,314
2×70	1,2	1,2/1,9	1,2	291	0,291
2×95	1,3	1,3/2,0	1,2	258	0,258
2×120	1,3	1,3/2,2	1,4	244	0,244
2×150	1,4	1,4/2,3	1,4	254	0,254
2×185	1,6	1,6/2,5	1,6	261	0,261
2×240	1,7	1,7/2,6	1,6	243	0,243
2×300	1,8	1,8/2,8	1,6	231	0,231
2×400	2,0	2,0/3,1	1,8	227	0,227

**Table 3**  
**Nominal thickness of armour tapes**

<b>Fictitious diameter under the armour</b>		<b>Nominal thickness of tape</b>	
<b>Above</b>	<b>Up to and including</b>	<b>Steel or galvanized steel</b>	<b>Aluminium or aluminium alloy</b>
mm	mm	mm	mm
–	30	0,2	0,5
30	70	0,5	0,5

NOTE The Fictitious diameter under the armour shall be calculated according to IEC 60502-1:2021.

Table 4 – Tests for completed cables

1	2	3	3	4	5	6
Ref. No.	Test	Units	Requirements	Category of test	Test method described in	
					standard	clause
<b>1</b>	<b>Electrical tests</b>					
1.1	Resistance of conductors			T,S	IEC 60228	Annex A
1.2	Voltage test on completed cable with AC or DC			T,S	IEC 60245-2	2.2
1.2.1	Conditions					
	Length of sample	m	20			
	Temperature of the water	°C	20 ± 5			
	Min. period of immersion in water	h	1			
1.2.2	Voltage applied AC or Voltage applied DC	kV kV	6,5 15			
1.2.3	Duration of application of voltage	min	5			
1.2.4	Result to be obtained:		No breakdown			
1.3	Check for absence of faults on insulation (or on complete cable) kV	see 7.2.1		R	IEC 62230	10
1.3.1	Voltage applied AC HF OR DC					
1.3.2	Result to be obtained:		No fault shall be detected			
1.4	Measurements of insulation resistance					
1.4.1	Cables at 20°C			T		
1.4.1.1	Test conditions				IEC 60245-2	2.4
	length of cable	m	5			
	Min. period of immersion in water	h	2h			
	temperature of the water	°C	20 ± 2			
1.4.1.2	values to be obtained	MC) x km	minimum as stated in table 1&2			
1.4.2	Cables at 90°C			T	IEC 60245-2	2.4
1.4.2.1	Test conditions					
	length of cable	m	5			
	Min. period of immersion in water	h	2h			
	temperature of the water	°C	90 ± 2			
1.4.2.2	values to be obtained	MC) x km	minimum as stated in table 1&2			
1.5	Long term resistance of insulation to d.c. on completed cables without metallic layer and on cables with metallic layer and outer sheath			T	IEC 62821-2	5.1.1
1.5.1	Test conditions:					
	length of sample	m	5			
	Duration of tests	h	240			
	temperature of the water	°C	85 ± 5			
	DC-voltage applied	kV	1,8			
1.5.2	Result to be obtained:		No breakdown and no signs of damage			



1	2	3	3	4	5	6
Ref. No.	Test	Units	Requirements	Category of test	Test method described in	
					standard	clause
1.6	Surface resistance of sheath			T	IEC 62821-2:2015	5.1.3
1.6.1	Test conditions: - voltage applied, DC	V	100 to 500			
	- duration of test	min	1			
1.6.2	Values to be obtained	$\Omega$	$\geq 1,0 \times 10^9$			
<b>2</b>	<b>Constructional and dimensional tests</b>					
2.1	Checking of compliance with constructional provisions			T,S		Inspection and manual tests
2.2	Conductor					
2.2.1	Construction of conductor		see 5.1.2	T,S	IEC 60228 Annex A	5
2.3	Insulation					
2.3.1	Measurement of insulation thickness	mm	see 5.2.3	T,S	IEC 60245-2:1994	1.9
2.4	Inner covering					
2.4.1	Measurement of insulation thickness	mm	see 5.5.3	T,S	IEC 60502-1:2021	7.2.3
2.5	Metallic layer					
2.5.1	Measurement of metallic layer thickness	mm	see 5.6	T,S	IEC 60502-1:2021	12.7
2.6	Outer Sheath					
2.6.1	Measurement of sheath thickness	mm	see 5.7	T,S	IEC 60245-2:1994	1.10
2.8	Ovality					
2.8.1	- Ovality	%	$\leq 15$	T,S	IEC 60245-2:1994	1.11
<b>3</b>	<b>Insulation material</b>			T	Table 5 Table 6	
<b>4</b>	<b>Sheath material</b>			T	Table 5 Table 6	
<b>5</b>	<b>conductor mechanical properties</b>			T	Annex A	
<b>6</b>	<b>Compatibility test</b>			T	IEC 60811-401	
6.1	Test conditions: - duration of test	h	168			
	- temperature	$^{\circ}\text{C}$	$135 \pm 2$			
6.2	Results to be obtained		Table B.1 of IEC 62930:–			
<b>7</b>	<b>Cold impact test</b>			T	IEC 60811-506 Annex C of IEC 62930:–	
7.1	Test conditions:  Results to be obtained:		No cracks			

1	2	3	3	4	5	6
Ref. No.	Test	Units	Requirements	Category of test	Test method described in	
					standard	clause
<b>8</b>	Ozone resistance on complete cables			T	60811-403	
8.1	<ul style="list-style-type: none"> <li>– temperature</li> <li>– duration</li> <li>– Ozone concentration(by volume)</li> </ul>	°C h %	$25 \pm 2$ 24 (250 to 300) $\times 10^{-4}$			
8.2	Result to be obtained – visual check		No cracks			
<b>9</b>	<b>Weathering/UV resistance on sheath</b>			T	IEC 62930	Annex E
9.1	Test conditions:					
9.2	Results to be obtained		Annex E of IEC 62930:–			
<b>10</b>	<b>Dynamic Penetration Test (only for unarmored cables)</b>			T	IEC 62930	Annex D
10.1	Test conditions:					
10.2	Results to be obtained		Annex D of IEC 62930:–			
<b>11</b>	<b>Damp heat test</b>			T	60068-2-78	
11.1	Test conditions:					
	<ul style="list-style-type: none"> <li>– temperature</li> <li>– duration</li> <li>– relative humidity min.</li> <li>– reconditioning period</li> </ul>	°C h % h	$90 \pm 2$ 1000 85 16 to 24			
11.2	Result to be obtained on the sheath:					
	<ul style="list-style-type: none"> <li>– for tensile strength, variation maximum</li> <li>– for elongation at break, variation maximum</li> </ul>	% %	-30 -30			

1	2	3	3	4	5	6
Ref. No.	Test	Units	Requirements	Category of test	Test method described in	
					standard	clause
<b>12</b>	<b>Shrinkage test</b>			T	IEC 60811-503	
11.1	Test conditions: - temperature - duration of each cycle - length of sample	°C h mm	120 ± 2 1 300			
11.2	Results to be obtained: - maximum shrinkage	%	2			
<b>13</b>	<b>Test for vertical flame propagation on complete cable</b>			T	IEC 60332-1-2	
13.1	Result to be obtained		Annex A of IEC 60332-1-2:2004			
<b>14</b>	<b>Smoke emission of complete Cable (For halogen free low smoke cables only)</b>			T	IEC 61034-2	
14.1	Result to be obtained - light transmittance, min.	%	60		IEC 61034-2 IEC 61034-2	
<b>15</b>	<b>Assessment of halogens for all non-metallic materials</b>			T, S	IEC 62821-1:2015	
15.1	Result to be obtained		Comply with requirements of Annex B of IEC 62821-1:2015		IEC 62821-1:2015	Annex B

<sup>a</sup> This test may be performed on test samples of insulation and sheath compound.

**Table 5 – Requirements for 120° C insulation and sheath compounds**

1	2	3	4	5	6
Ref. No.	Test	Unit	Test method	Type of compound	
			standard	insulation and inner covering	sheath
<b>1</b>	<b>Mechanical characteristics</b>				
<b>1.1</b>	<b>Properties before ageing<sup>c</sup></b>		IEC 60811-501		
1.1.1	Values to be obtained for the tensile strength: – median, min.	N/mm <sup>2</sup>		8,0	8,0
1.1.2	Values to be obtained for the elongation at break: – median, min.	%		125	125
<b>1.2</b>	<b>Properties after ageing in oven</b>		IEC 60811-501		
1.2.1	Ageing conditions: <sup>c</sup> – temperature – duration of treatment	°C h		150 ± 2 7 × 24	150 ± 2 7 × 24
1.2.2	Values to be obtained for the tensile strength: <sup>c</sup> – median, min. – variation, max.	N/mm <sup>2</sup> %		– –30 <sup>a</sup>	– –30 <sup>a</sup>
1.2.3	Values to be obtained for the elongation at break: <sup>c</sup> – median, min. – variation, max.	% %		– –30 <sup>a</sup>	– –30 <sup>a</sup>
<b>1.3</b>	<b>Hot set test<sup>c</sup></b>		IEC 60811-507		
1.3.1	Conditions – Temperature – Time under load – mechanical stress	°C min N/cm <sup>2</sup>		200± 3 15 20	200± 3 15 20
1.3.2	Values to be obtained – elongation under load, max. – permanent elongation after cooling, max.	% %		100 25	100 25
<b>1.4</b>	<b>Thermal endurance properties</b>		IEC 60216-1 and IEC 60216-2		
1.4.1	Test conditions: ° Elongation at break shall be performed.  - temperature index corresponding to 20 000 h  – elongation at break, min.	%		≥ 120  50	≥ 120  50

1	2	3	4	5	6
Ref. No.	Test	Unit	Test method	Type of compound	
			standard	insulation and inner covering	sheath
<b>1.5</b>	<b>Bending at low temperature</b> Insulated conductor/cable overall diameter $\leq 12,5$ mm		IEC 60811-504		
1.5.1	Test conditions: – temperature – duration	$^{\circ}\text{C}$ h		$-40 \pm 2$ b	$-40 \pm 2$ b
1.5.2	Results to be obtained:			No cracks	No cracks
<b>1.6</b>	<b>Elongation at low temperature</b> Insulated conductor/cable overall diameter $>12,5$ mm		IEC 60811-505		
1.6.1	Test conditions: <sup>c</sup> – temperature – duration	$^{\circ}\text{C}$ h		$-40 \pm 2$ b	$-40 \pm 2$ b
1.6.2	Results to be obtained: - elongation at break, min.	%		30	30
<b>1.7</b>	<b>Sheath-resistance against acid and alkaline solution</b>		IEC 60811-404		
1.7.1	Test conditions: <sup>d</sup> - acid solution: N-Oxalic acid - alkaline solution: N-Sodium hydroxide solution				
1.7.2	temperature duration	$^{\circ}\text{C}$ h			$23 \pm 2$ $7 \times 24$
1.7.3	Values to be obtained for tensile strength: – variation, max. Values to be obtained for the elongation at break: – median, min.	%  %			$\pm 30$  100
<b>1.8</b>	<b>Compatibility test</b>		4.2.3.4 of IEC 60811- 401:2012		
1.8.1	Test conditions: – temperature – duration of treatment	$^{\circ}\text{C}$ h		$135 \pm 2$ 7x24	$135 \pm 2$ 7x24
1.8.2	Values to be obtained for tensile strength – variation, maximum Values to be obtained for the elongation at break – variation, maximum			$\pm 30$  $\pm 30$	$- 30^{\text{a}}$  $- 30^{\text{a}}$
<p>a No positive value for variation defined.</p> <p>b See test method in column 4.</p> <p>c This test shall be performed on test samples of insulation and sheath compound obtained from completed cables.</p> <p>d N means 1 Normal concentration.</p>					

**Table 6 – Requirements for 90° C insulation and sheath compounds**

1	2	3	4	5	6
Ref. No.	Test	Unit	Test method	Type of compound	
			standard	insulation and inner covering	sheath
<b>1</b>	<b>Mechanical characteristics</b>				
<b>1.1</b>	<b>Properties before ageing<sup>c</sup></b>		IEC 60811-501		
1.1.1	Values to be obtained for the tensile strength: – median, min.	N/mm <sup>2</sup>		6.5	8,0
1.1.2	Values to be obtained for the elongation at break: – median, min.	%		125	125
<b>1.2</b>	<b>Properties after ageing in oven</b>		IEC 60811-501		
1.2.1	Ageing conditions: <sup>c</sup> – temperature – duration of treatment	°C h		120 ± 2 7 × 24	120 ± 2 7 × 24
1.2.2	Values to be obtained for the tensile strength: <sup>c</sup> – median, min. – variation, max.	N/mm <sup>2</sup> %		– –30 <sup>a</sup>	– –30 <sup>a</sup>
1.2.3	Values to be obtained for the elongation at break: <sup>c</sup> – median, min. – variation, max.	% %		– – 30 <sup>a</sup>	– – 30 <sup>a</sup>
<b>1.3</b>	<b>Hot set test<sup>c</sup></b>		IEC 60811-507		
1.3.1	Conditions – Temperature – Time under load – mechanical stress	°C min N/cm <sup>2</sup>		200± 3 15 20	200± 3 15 20
1.3.2	Values to be obtained – elongation under load, max. – permanent elongation after cooling, max.	% %		100 25	100 25
<b>1.4</b>	<b>Thermal endurance properties</b>		IEC 60216-1 and IEC 60216-2		
1.4.1	Test conditions: ° Elongation at break shall be performed.  - temperature index corresponding to 20 000 h  – elongation at break, min.	%		≥ 90  50	≥90  50

1	2	3	4	5	6
Ref. No.	Test	Unit	Test method	Type of compound	
			standard	insulation and inner covering	sheath
<b>1.5</b>	<b>Bending at low temperature</b> Insulated conductor/cable overall diameter $\leq 12,5$ mm		IEC 60811-504		
1.5.1	Test conditions: – temperature – duration	$^{\circ}\text{C}$ h		$-40 \pm 2$ b	$-40 \pm 2$ b
1.5.2	Results to be obtained:			No cracks	No cracks
<b>1.6</b>	<b>Elongation at low temperature</b> Insulated conductor/cable overall diameter $>12,5$ mm		IEC 60811-505		
1.6.1	Test conditions: <sup>c</sup> – temperature – duration	$^{\circ}\text{C}$ h		$-40 \pm 2$ b	$-40 \pm 2$ b
1.6.2	Results to be obtained: - elongation at break, min.	%		30	30
<b>1.7</b>	<b>Sheath-resistance against acid and alkaline solution</b>		IEC 60811-404		
1.7.1	Test conditions: <sup>d</sup> - acid solution: N-Oxalic acid - alkaline solution: N-Sodium hydroxide solution				
1.7.2	temperature duration	$^{\circ}\text{C}$ h			$23 \pm 2$ $7 \times 24$
1.7.3	Values to be obtained for tensile strength: – variation, max. Values to be obtained for the elongation at break: – median, min.	%  %			$\pm 30$  100
<b>1.8</b>	<b>Compatibility test</b>		4.2.3.4 of IEC 60811- 401:2012		
1.8.1	Test conditions: – temperature – duration of treatment	$^{\circ}\text{C}$ h		$105 \pm 2$ 7x24	$105 \pm 2$ 7x24
1.8.2	Values to be obtained for tensile strength – variation, maximum Values to be obtained for the elongation at break – variation, maximum			$\pm 30$  $\pm 30$	$- 30^{\text{a}}$  $- 30^{\text{a}}$
<p>a No positive value for variation defined.</p> <p>b See test method in column 4.</p> <p>c This test shall be performed on test samples of insulation and sheath compound obtained from completed cables.</p> <p>d N means 1 Normal concentration.</p>					

## **Annex A** (normative)

### **Requirement of aluminum alloy conductors**

#### **A.1 Material**

The material of aluminum alloy conductors shall comply with the chemical composition corresponding to any composition code in table A.1.

#### **A.2 Construction of class 5 flexible aluminum alloy conductors**

- a) The conductors shall consist of plain aluminum alloy.
- b) The wires in each conductor shall have the same nominal diameter.
- c) The diameter of the wires in each conductor shall not exceed the appropriate maximum value given in Table A.2

#### **A.3 Resistance of class 5 flexible aluminum alloy conductors**

The resistance at 20 °C shall not exceed the appropriate maximum value given in Table A.2.

#### **A.4 Mechanical properties of class 5 flexible aluminum alloy conductors**

##### **A.4.1 Tensile strength, Elongation and bending performance of conductor**

The requirement of tensile strength, elongation and bending performance of the individual wires of aluminum alloy conductors shall meet the value given in Table A.3.

The test method of bending test is specified in Annex C (GB/T 4909.5-2009).

##### **A.4.2 Compressive creep of aluminum alloy conductor**

When required by the demander, the supplier shall provide the creep curve of aluminum alloy wire or aluminum alloy rod with the same chemical composition and state as the purchased aluminum alloy wire under long-term load conditions.

The compressive creep test shall be measured. The test requirements are given in Table A.3.

The test method of compressive creep test is specified in Annex D (Annex B of GB/T 30552-2014).



**Table A.1**  
**Chemical composition of aluminum alloy**

Alloys		Composition, % by Mass								
ANSI	UNS	Aluminum	Silicon	Iron	Copper	Magnesium	Zinc	Boron	Other (each)	Other (total)
8017	A98017	Remainder	0.10	0.55 to 0.8	0.10 to 0.20	0.01–0.05	0.05	0.04	0.03 <sup>A</sup>	0.10
8030	A98030	Remainder	0.10	0.30 to 0.8	0.15 to 0.30	0.05	0.05	0.001 to 0.04	0.03	0.10
8076	A98076	Remainder	0.10	0.6 to 0.9	0.04	0.08–0.22	0.05	0.04	0.03	0.10
8130	A98130	Remainder	0.15 <sup>B</sup>	0.40 to 1.0 <sup>B</sup>	0.05 to 0.15	...	0.10	...	0.03	0.10
8176	A98176	Remainder	0.03–0.15	0.40 to 1.0	...	...	0.10	...	0.05 <sup>C</sup>	0.15
8177	A98177	Remainder	0.10	0.25 to 0.45	0.04	0.04 to 0.12	0.05	0.04	0.03	0.10

<sup>A</sup> 0.003 max lithium.

<sup>B</sup> 1.0 max silicon and iron.

<sup>C</sup> 0.03 max gallium.

**Table A.2**  
**Class 5 flexible aluminum alloy conductors**

Nominal cross-sectional area mm <sup>2</sup>	Maximum diameter of wires in conductor mm	Maximum diameter of conductor mm	Maximum resistance of conductor at 20°C Ω/km
2,5	0,31	2,4	13,20
4	0,31	3,0	8,10
6	0,31	3,9	5,05
10	0,41	5,1	3,08
16	0,41	6,3	1,91
25	0,41	7,8	1,200
35	0,41	9,2	0,868
50	0,41	11,0	0,641
70	0,51	13,1	0,443
95	0,51	15,1	0,320
120	0,51	17,0	0,253
150	0,51	19,0	0,206
185	0,51	21,0	0,164
240	0,51	24,0	0,125
300	0,51	27,0	0,1000
400	0,51	31,0	0,0778

**Table A.3**  
**Mechanical properties of class 5 flexible aluminum alloy conductors**

1	2	3	3	4	5	6
Ref. No.	Test	Units	Requirements	Category of test	Test method described in	
					standard	clause
1	<b>Tensile strength</b>			T,S	ISO 6892-1: 2019	
	Values to be obtained for the tensile strength					
	–median, min.	N/mm <sup>2</sup>	98 to 159			
2	<b>Elongation at break</b>			T,S	ISO 6892-1: 2019	
	Values to be obtained for the elongation at break:					
	–median, min.	%	10			
3	<b>Bending test</b>			T		Annex C (GB/T 4909.5- 2009)
	Bending angle	°	90			
	– Number of times not damaged		≥ 25			
4	<b>Compressive Creep</b>			If required		Annex D (GB/T 30552- 2014 Annex B)
	Pressure stress	MPa	55			
	Temperature	° C	90			
	Duration	h	100			
	- Compressive creep curve		-			

## **Annex B** (normative)

### **Guide for use**

#### **B.1 Use of cables for PV systems**

**The requirements of IEC 62930 apply for this clause when installation in air.**

**When installation in ground,**

General guidance information given in IEC 62440 (Guide to Use for low voltage cables) must be used, excepting the requirement concerning direct burial installation (clause 4.1). Cables according to this standard are intended for use in PV-systems according to IEC 60364-7-712 and IEC 62548. They are intended for fixed installation in ground. They are also intended for installation in conduits and trunkings.

They are suitable for the application in/at equipment with protective insulation (class II)

They are inherently short-circuit and earth fault proof acc. to IEC 60364-5-52.

Only cables with metallic layer as humidity protection are applicable to be direct buried. Cables without metallic layer for humidity protection shall be installed in metallic conduits if intended to be installed in ground.

The metallic layer might be considered as a screen and shall be grounded.

In addition, the following specific information shall be taken into account for the products specified in this standard.

The DC voltage rating of the cables is 1,5 kV, both between conductors as well as between conductors and earth. The maximum permitted operating DC voltage of the systems, in which the cables specified in this standard are applied, shall not exceed 1,8 kV.

The AC voltage rating of the specified cables is 1/1 kV ( $U_0/U$ ). The rated voltage in an AC system, is expressed by the combination of two values  $U_0/U$ , expressed in (k)volts, where:

- $U_0$  is the r.m.s. value between any insulated conductor and earth
- $U$  is the r.m.s. value between any two phases

<b>Table B.1 - Intended use of cables for PV systems (environmental conditions)</b>	
Shape of cable	Round
Conductor construction	Class 1, 2, 5
1 DUTY <sup>a</sup>	
1.4 Heavy	+
2 PRESENCE OF WATER	
2.1 Cables without metal layer: Condition AD 7 <sub>b</sub>	+
2.2 Cables with metal layer: Condition AD 8 <sub>b</sub>	+
3 CORROSIVE OR POLLUTING SUBSTANCES	
3.1 Condition AF 3 <sub>b</sub>	+
4 IMPACT	
4.1 Condition AG 2 <sub>b</sub>	+
5 VIBRATIONS	
5.1 Condition AH 3 <sub>b</sub>	Class 5 +
6 FLORA	
6.1 Condition AK 2 <sub>b</sub>	+
7 FAUNA	
7.1 Condition AL 2 <sub>b</sub>	Metallic layer+ -
8 OUTDOOR USE	
8.1 Condition AN 3 <sub>b</sub>	+
8.2 Permanent <sup>c</sup>	+
9 FREQUENT FLEXING	
10 FREQUENT TORSION	
"+" = acceptable "-" = not suitable a see Annex C of IEC 62440 for definitions. b see Annex A of IEC 62440 for definitions. c see Annex B of IEC 62440 for definitions.	

## Annex C (normative)

### Bending Test of Aluminum Alloy Conductor

#### C.1 Apparatus

##### C.1.1 General

In this test, one end of the test piece is fixed, and the free end is subject to 90 ° bending test in the positive and negative directions along the cylindrical surface with the specified radius, until the specified number of times or the test piece is broken.

The apparatus shall be similar to the one shown in Figure C.1.

##### C.1.2 Bending Cylinder and Clamping Block

The bending cylinder and clamping block shall have sufficient hardness, the surface of the cylinder in contact with the test piece shall be polished, and the surface roughness shall be  $R_a 0,63 \mu m$ .

The radius of the curved cylinder shall be comply with the nominal dimension given in Table C.1.

The axis of the bending cylinder shall be perpendicular to the bending plane and parallel to each other, and the deviation in the same plane shall not exceed 0,1mm.

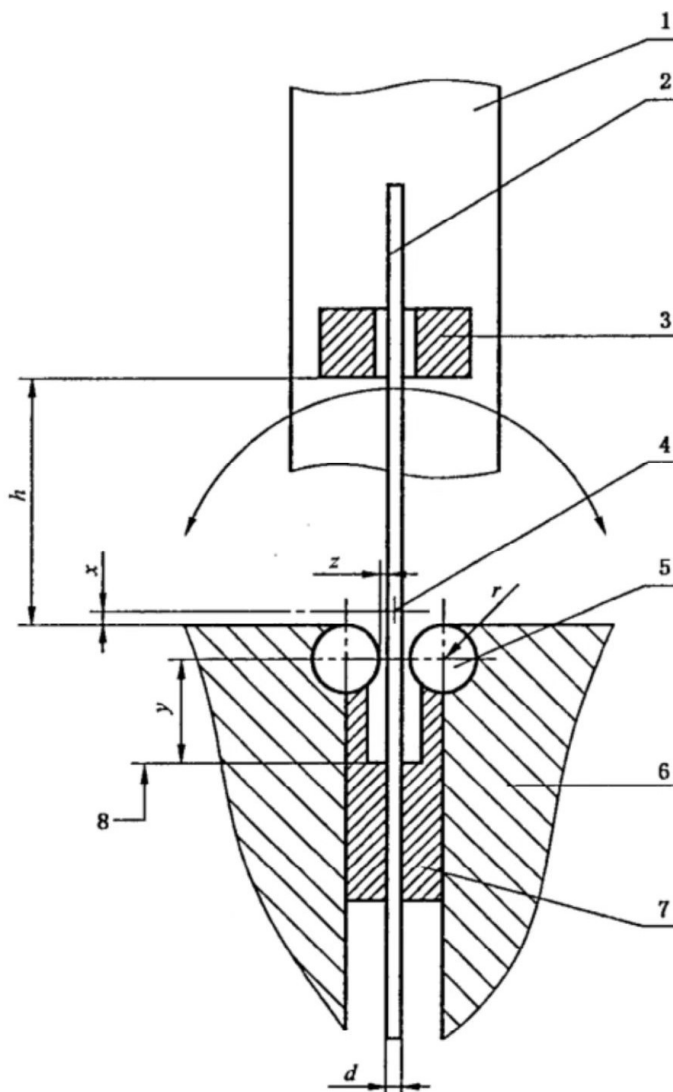
The clamping surface of the clamping block shall protrude slightly from the curved cylinder, but shall not exceed 0.1mm, that is, the spacing between the sample and the curved cylinder on the line connecting the curvature centers of the two curved cylinders shall not be greater than 0,1mm.

The top surface of the clamping block shall be lower than the connecting line between the curvature centers of two curved cylinders. When the radius  $r$  of the bending cylinder is equal to or less than 2,5 mm, the distance  $y$  from the plane of the axis of the bending cylinder to the nearest point in contact with the test piece shall be 1,5 mm; When the radius  $r$  of the bending cylinder is greater than 2,5 mm, the distance  $y$  from the plane of the axis of the bending cylinder to the nearest point of contact with the test piece shall be 3 mm.

##### C.1.3 Bending Arm and Lever

For curved cylinders of all sizes, the distance from the axis of rotation of the bending arm to the top of the curved cylinder shall be 1,0mm.

Both ends of the lever hole shall be slightly larger, and the diameter of the hole shall comply with the value of Table 1.



- 1 --- lever or sleeve.
- 2 --- test piece;
- 3 --- guide block;
- 4 --- rotation axis of the shift lever;
- 5 --- bending cylinders A and B;
- 6 --- support;
- 7 --- clamping surface of support;
- 8 --- the closest contact point of the test piece
- d --- diameter of circular conductor
- h --- distance from the top surface of the support to the ground of the guide block
- r --- radius of bending cylinder
- x --- the distance from the rotation axis of the operating handle to the top plane of the cylindrical support
- y --- the distance from the plane of the bending cylinder to the nearest point of contact with the test piece
- z --- clearance between the test piece and the cylindrical support

Figure C.1 Bending test Apparatus

## C.2 Test samples

### C.2.1 Sampling

Take 5 test samples of 300 mm in length from one end.

Avoid stretching, torsion, bending or other mechanical damage during sampling.

### C.2.2 Straightening specimens

Carefully straighten the specimens by hand. If necessary, it is allowed to place the specimens on the wood or plastic plane and straighten it gently with a wooden hammer. When straightening, the surface of the specimens shall not be damaged or distorted. Specimens with partial hard bending should not be straightened.

## C.3 Test

### C.3.1 Clip selection

Select  $r$  radius of bending cylinder,  $h$  distance from the top surface of the support to the ground of the guide block and  $d$  diameter of circular conductor according to table C.1.

Install the clip on the test Apparatus.

### C.3.2 Fix specimens

As shown in Figure 1, make the bending arm in the vertical position, insert the test piece through the lever hole, and clamp the test piece when the position of the test piece is perpendicular to the plane of the axis of the two bending cylinders of the fixture.

### C.3.3 Apply Load

At the upper end of the test piece extending out of the lever hole, apply appropriate load along the axis direction of the test piece to tension the test piece, so that the test piece can maintain good contact with the curved cylindrical surface without distortion. Generally, the load shall not exceed the stress of 2% of the tensile strength of the test piece.

### C.3.4 Bend specimens

Start the testing apparatus and bend the test piece at a uniform and stable speed. The bending speed shall be limited so that the possible heat does not affect the test results. Unless otherwise specified, it is generally 1 cycle per a second.

From the starting position perpendicular to the axis plane of the bending cylinder, the specimen bends  $90^\circ$  along cylinder a and then returns to the original position, which is the first bending, then bends  $90^\circ$  along cylinder B in the opposite direction in the same plane, and then returns to the original position, which is the second bending, as shown in Figure C.2. Repeat until reach the specified number of bends or the specimen breaks. Record the bending times  $N$ .

When the test piece is broken before it finally returns to the initial position, the last bending will not be included in the test results.

Continue the test until the specified bending times or cracks are visible to the naked eye.

The bending test process shall be continuous without interruption. Bending can be done manually.

**Table C.1. Bend test Parameters**

Diameter of test sample d	Radius of bending cylinders r	Distance h	Diameter of lever hole d <sub>s</sub>
0,3<d≤0,5	1,25±0,05	15	2,0
0,5<d≤0,7	1,75±0,05	15	2,0
0,7<d≤1,0	2,5±0,05	15	2,0
1,0<d≤1,5	3,75±0,05	20	2,0
1,5<d≤2,0	5,0±0,05	20	2,0 or 2,5
2,0<d≤3,0	7,5±0,05	25	2,5 or 3,5
3,0<d≤4,0	10±0,05	35	3,5 or 4,5
4,0<d≤6,0	15±0,05	50	4,5 or 7,0
6,0<d≤8,0	20±0,05	75	7,0 or 9,0
8,0<d≤10,0	25±0,05	100	9,0 or 11,0
d>10,0	30±0,05	125	d+1,0

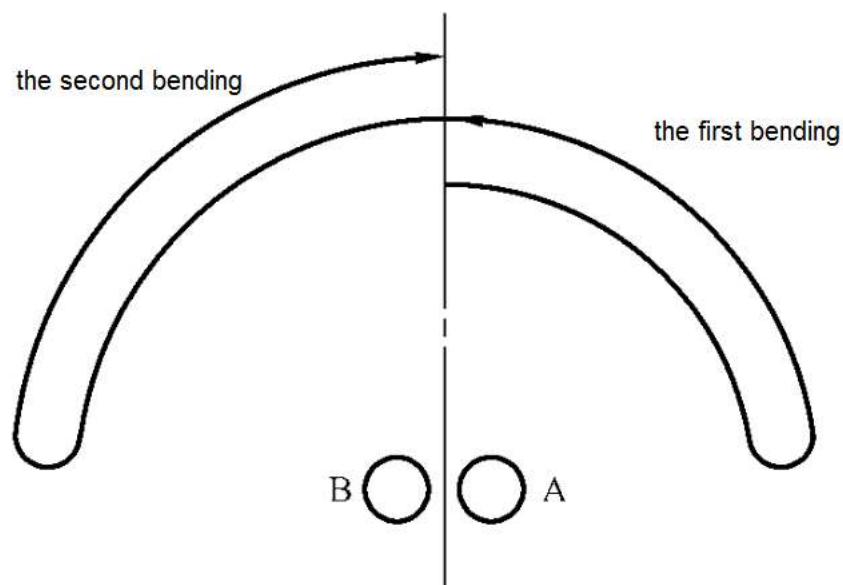


Figure C.2 Counting method of reverse bend test



#### **C.4 Requirement**

The test result is expressed by the average value of the bending times of the 5 test pieces.

The test results shall meet the specified times in Table A.3.

## Annex D (normative)

### Compressive creep of aluminum alloy conductor

#### D.1 General

This test is intended to verify creep resistance of aluminium alloy conductor.

#### D.2 Test samples

Compressive creep specimens for aluminium alloy wire shall be sampled from products of the same chemical composition and state.

The sample shall be selected to prepare in accordance with Figure D1.

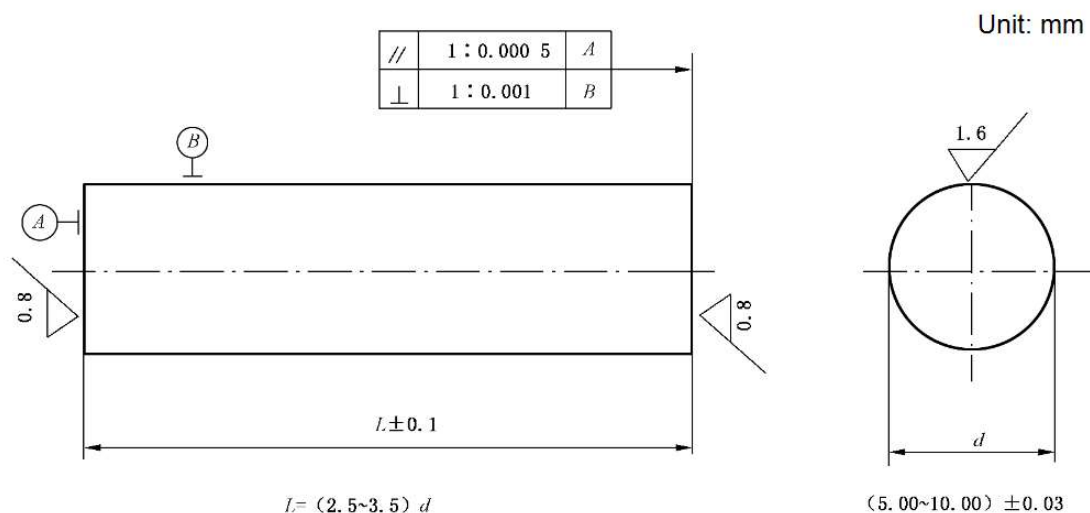


Figure D1. Compressive creep specimens

#### D.3 Apparatus

D.3.1 Machine test should be able to provide applied axial force and make the sample on the bending moment and torque is minimal. Test before dealing with testing machine for appearance inspection to ensure that the torque tester rod, clamp, universal joint and connection devices are in good condition. The vibration and impact testing machine should be far away from the outside world. Compressive should be stable and no vibration test force imposed on the sample. Test force loading alignment should be less than 10%.

B.3.2 Creep deformation measuring instrument resolution should be not greater than 0.001 mm, the error should be not more than  $\pm 1.0\%$  of total creep deformation.

B.3.3 Temperature heating device heating sample to test regulations and rules between temperature and display of temperature deviation should be allowed no more than  $\pm 3\text{ }^{\circ}\text{C}$ . The maximum allowable temperature deviation in the length direction of the sample is  $3\text{ }^{\circ}\text{C}$ . The resolution of the temperature display device should be at least  $0.5\text{ }^{\circ}\text{C}$ , the accuracy of the temperature measuring device shall be equal to or better than  $1\text{ }^{\circ}\text{C}$  and the temperature drift of the thermocouple during the calibration period shall not exceed  $\pm 1\text{ }^{\circ}\text{C}$ .

B.3.4 The working surface of the test machine and the lower pressing plate shall be parallel, and the parallelism of the installed sample area within the range of 100mm shall not be less than 1:0,0002 mm /mm. During the trial, there should have no relative lateral displacement and rotation between the upper and down clamp. The hardness of clamp and sample clamp shall be not less than 55 HRC.

#### D.4 Test

Compressive creep test temperature should select 90 °C, Stress test pressure should be 55 MPa. The sample shall be installed vertically between the upper and down clamps of the creep endurance testing machine. When the specimen is installed, adjust the longitudinal axis of the specimen to coincide with the longitudinal axis of the presser. Close the chamber and heat the sample to the specified test temperature. In order to achieve thermal balance for the test specimen, clamping device and extensometer, the test specimen shall be held for at least 1h but not more than 24h before the test force is applied. When testing with an extensometer installed, a certain initial load (less than 10% of the test force) may be applied during the heating process to keep the sample loading chain coaxial (e.g., before  $t=0$ ). Test force should be to produce the smallest bending moment and torque axis exert upward in sample. The test force should be accurate to  $\pm 1\%$  at least. The test force should be applied without vibration and as quickly as possible. The creep test ( $t=0$ ) begins when all the loads corresponding to the test force are applied to the sample and the creep deformation shall be recorded. The compressive creep test was carried out for 100h. During the test, the load should be kept constant and the temperature fluctuation should be no more than  $\pm 3^\circ\text{C}$ .

#### D.5 Data

The whole test process should be continuous record or creep deformation data were enough to draw “creep strain – time” curve. In “creep strain – time” curve on the double logarithmic coordinate axis of collected data will be close to a straight line, In order to make the data collection points evenly distributed along the fitting line, the creep data should be taken at an interval of 20min in the first 20h after the test begins, After 20h, The creep data are taken at the time interval of  $[60^{(2,73+0,03 \times n)}]$  s (  $n= 0, 1, 2, 3, \dots$ ), and modify the time point to about 0.5h, that are 20h, 22,5h, 28,5h, 32,5h, 36,5h, 41,5h, 47,0h, 53,0h, 60,0h, 76,5h, 86,5h, 100,0h.

#### D.6 Data processing

D.6.1 According to the obtained original creep data, calculate the creep strain of the sample at each time point, and draw the “creep strain – time” curve.

D.6.2 In one of the following cases, the test result is invalid and the test shall be repeated.

- a) When the test has not reached the test purpose, obvious plastic deformation occurs;
- b) When the test has not reached the test purpose, the end of the sample is partially crushed;
- c) Improper operation during the test;
- d) During the test, the test instrument failed, which affected the test results.