PPP 58209A Rev.00

PPP/2022/09

Electric cables for photovoltaic systems with voltage above 1500V DC and up to 2000V DC

This document applies to flexible, electric cables suitable for 2000 V photovoltaic systems. 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.

2022-09

Contents

Foreword

This document (PPP 58209A) has been prepared by TÜV SÜD.

From the development of photovoltaic industry until now, the need for 2000V PV systems has been raised. Increasing system voltage would provide significant cost reduction and further reduce LCOE as a higher number of serial connected PV-modules would fit in a PV-array.

The Electric cables for photovoltaic systems with voltage above 1500V DC and up to 2000V DC have been considered in this standard.

The system voltage of up to 2000 V DC will become new technology trend sooner rather than later, which would provide a promising new means of cost reduction and higher energy yield

The test standard was created based on IEC 62930:2017.

The following dates are fixed:

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This document of main compile organizations: TÜV SÜD Certification and Testing (China) Co., Ltd.

This document of main compile organizer: Yaqun Liu, Hongxue Wang, Xingxing Liu.

Joint drafting members as follow:

Zhejiang Sowell Electric Co., Ltd.	Tian Hao
Huzhou Shangfu Wire & Cable High Technology Co., Ltd.	Zhang Chengjun
Far East Cable Co., Ltd.	Xu Jing
	Tian Chongjun
TBEA Shandong Luneng Taishan Cable Co., Ltd.	Li Qi

1 Scope

This document applies to single-core cross-linked insulated power cables with cross-linked sheath. These cables are for use at the direct current (DC) side of photovoltaic systems, with a rated DC voltage up to 2,0 kV between conductors and between conductor and earth.

The cables are suitable to be used with Class II equipment as defined in IEC 61140.

The cables are designed to operate at a normal continuous maximum conductor temperature of 90 °C. The permissible period of use at a maximum conductor temperature of 120 °C is limited to 20 000 h.

2 Normative references

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

EN 60228:2005, Conductors of insulated cables (IEC 60228:2004);

IEC 62930:2017, Electric cables for photovoltaic systems with a voltage rating of 1,5kV DC;

ISO 6722-2:2013, Road vehicles – 60 V and 600V single- core cables- Part 2: Dimensions, test methods and requirements for aluminium conductor cables;

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 (Um=1.2kV) up to 35kV (Um=40.5 kV)-Part 1: Cables for rated voltages of 1kV (Um=1.2kV) and 3kV (Um=3.6kV);

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

EN 62230:2007, Electric cables – Spark-test method (IEC 62230:2006);

EN 50396：2005, Non-electrical test methods for low voltage energy cables;

UL 4703:2010, Standard for safety Photovoltaic Wire;

PPP11029:2019, Aluminium conductor cables for fixed installation in PV systems;

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• IEC Electropedia: available at http://www.electropedia.org/

• ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Routine tests(R)

Tests carried out on all production cable lengths to demonstrate their integrity

3.2 Sample tests(S)

Tests carried out on samples of completed cable, or components taken from a completed cable adequate to verify that the finished product meets the design specifications

3.3 Type test(T)

Tests required to be carried out before supplying a type of cable covered by PPP 11029 on a general commercial basis to demonstrate satisfactory performance characteristics to meet the intended application

Note 1 to entry: Type tests are of such a nature that, after they have been made, they need not to be repeated unless changes are made in the cable materials, design or type of manufacturing process which might change the performance characteristics

4 Characteristics

4.1 Rated voltage

The cables specified by this document are in particular designed for use at the direct current (DC) side of photovoltaic-systems, with a rated DC voltage up to 2,0 kV between conductors as well as between conductor and earth.

The maximum permitted operating DC voltage of the systems, in which the cables specified in this document are applied, shall not exceed 2,4 kV(conductor to conductor).

4.2 Temperature range

The cables are designed to operate at a normal continuous maximum conductor temperature of 90 °C.

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

5 Requirements for the construction of cables

5.1 Conductors

The conductors could be copper tin coated, and in accordance with IEC 60228. The wires shall be covered with a continuous layer of tin coating.

The conductors could consist of aluminium alloy. The Aluminum alloy need be a compact or compressed round stranded soft drawn 8XXX series aluminum conductor. Copper-cladded aluminium alloy is allowed to be used. The construction of aluminium alloy conductor shall be Class 2 or similar with Class 5 reference with IEC 60228, the conductor resistance at 20℃ shall fulfil the requirements in table 1. The aluminium alloy cable shall meet the test requirements of table 3 for all conductors.

This standard allows the customer to define conductor structure, needs for additional filings.

There shall be no visible gaps in the continuous layer, when examined with normal or corrected vision.

Table 1 Aluminium alloy conductor resistance at 20℃

Conductor size	Maximum conductor resistance
mm^2	Ω/km
4	7,85
6	5,23
10	3,08
16	1,91
25	1,20
35	0,868
50	0,641
70	0,443
95	0,320
120	0,253
150	0,206
185	0,164
240	0,125

Whether it's a copper conductor or an aluminum conductor, the class of the conductor shall be or similar with Class 5 in accordance with IEC 60228 for cable that is directly connected to PV modules. Class 2 conductors are allowed for cables intended for fixed installation and not directly connected to the PV modules.

5.2 Separation layer

A separation layer of a suitable non-absorbent material may be applied around the conductor.

5.3 Insulation

5.3.1 Material

The insulation material shall be a cross-linked compound and fulfil the requirements as specified in Table C.1 in Annex C, consistent with the material requirements of IEC 62930 Table B.1.

5.3.2 Application

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, to the conductor or to the tin coating. 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.

5.3.3 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 2.

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

$$t_m \geqslant 0{,}9t_s - 0{,}1$$

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 EN 50396:2005, 4.1.

5.3.4 Check for absence of faults on the insulation or on the complete cable

The cable shall be tested for faults in accordance with EN 62230:2007, Annex A to check of the insulation.

5.4 Sheath

5.4.1 Material

The selection of sheath materials should be compatible with the temperature level of the cable.

The sheath material shall be cross-linked and fulfil the requirements as specified in Table C.1 in Annex C, consistent with the material requirements of IEC 62930 Table B.1.

5.4.2 Application

The sheath shall be extruded and shall consist of one or several adjacent adherent layers. It shall be solid and homogeneous, it must be possible to remove it without damage to the sheath itself, to the insulation.

The sheath shall be smooth, consistently applied and largely circular. Compliance shall be checked by inspection and by manual test.

5.4.3 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 3.

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

$$t_m \geqslant 0{,}85t_s - 0{,}1$$

where:

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

t_s is the specified sheath thickness, in millimetres.

Compliance shall be checked using the test given in EN 50396:2005, 4.1.

5.4.4 Outer diameter

The average value of the outer diameter shall be compliance as specified in Table 2.

5.5 Humidity protection

Cables shall have a metallic layer for humidity protection and as screen if installation requires.

For cables without metallic layer, advice in case that the cable is installed in metallic cable ducts.

5.5.1 Metal barrier (if necessary)

The humidity protection barrier shall consist of a single layer of metallic tape. The tensile strength of aluminium shall be not less than 50 N/mm2.

The metal barrier shall be self-contained as humidity protection, allow to apply a suitable binder tape over the metallic layer.

The layer of the humidity barrier shall have a min. thickness of 0,3mm.

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

5.6 Inner sheath (Only applicable for cables with metallic humidity protection)

5.6.1 Material

The selection of inner sheath materials should be compatible with the temperature level of the cable. The material shall compliance with a halogen free low smoke cable, it shall be halogen free.

The sheath material shall be cross-linked and fulfil the requirements as specified in Table B.1 in IEC 62930, Annex B.

5.6.2 Thickness

The thickness of inner sheath shall be same requirements with insulation in table 2.

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

$$t_m \geqslant 0{,}9t_s - 0{,}1$$

where:

t_m is the minimum insulation thickness at any point in millimeters;

t_s is the specified insulation thickness, in millimeters.

Table 2-1 Dimensional and insulation resistance values for class 5

Nominal cross-sectional area of conductor/mm^2	Thickness of insulation Specified value	Thickness of sheath Specified value	Mean overall diameter Upper value [a]
1,5	1,1	0,8	5,8
2,5	1,1	0,8	6,3
4	1,1	0,8	7,0
6	1,1	0,8	7,6
10	1,1	0,8	8,7
16	1,1	0,9	10,2
25	1,15	1,0	12,5
35	1,15	1,1	14,3
50	1,25	1,2	16,6
70	1,35	1,2	19,0
95	1,35	1,3	21,1
120	1,45	1,3	23,3
150	1,65	1,4	26,0
185	1,85	1,6	29,0
240	1,95	1,7	32,6
[a]	Indicative values, for information only.		
Note: Nominal cross-sectional area of conductor could be copper tin coated: 1.5 mm^2~240 mm^2; Nominal cross-sectional area of aluminium alloy conductor: 4 mm^2~240 mm^2;			

Table 2-2 Dimensional and insulation resistance values for class 2

Nominal cross-sectional area of conductor/mm^2	Thickness of insulation Specified value	Thickness of sheath Specified value	Mean overall diameter Upper value [a]
16	1,1	0,9	9,9
25	1,15	1,0	12,1
35	1,15	1,1	13,5
50	1,25	1,2	15,4
70	1,35	1,2	17,6
95	1,35	1,3	19,9
120	1,45	1,3	21,9
150	1,65	1,4	24,3
185	1,85	1,6	27,3
240	1,95	1,7	30,7
300	2,05	1,8	33,8
400	2,25	2,0	38,0
[a]	Indicative values, for information only.		
Note: Note: Nominal cross-sectional area of both copper and aluminium alloy conductor: 16mm^2~400mm^2;			

6 Marking

6.1 General

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

The cable should be marked as follows:

a) Trade mark;

b) Code designation;

c) Nominal cross-sectional area of conductor;

d) Approval mark (TÜV SÜD mark);

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

The cables with copper conductor Class 5 shall be marked PV 2000DC (TC5);

The cables with copper conductor Class 2 shall be marked PV 2000DC (TC2);

The cables with aluminium alloy conductor similar with Class 5 shall be marked PV 2000DC (AL5);

The cables with aluminium alloy conductor Class 2 shall be marked PV 2000DC(AL2);

Note: The cables with copper-cladded aluminium alloy conductor shall be marked PV2000DC (TCA);

6.4 Nominal cross-sectional area of conductor

Cables shall be marked with the nominal cross-sectional area, for example '1×6 mm^2'.

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

Other marking, such as that required under recognized voluntary 3rd party approval schemes, may also follow the requirements of this sub-clause.

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

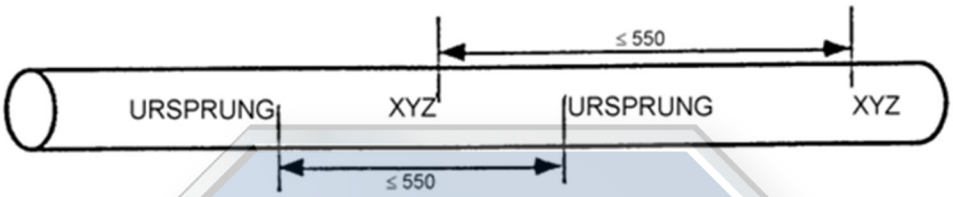


Figure 1 – Arrangement of marking

6.6 Additional requirements

6.6.1 Durability

Printed markings shall be durable. Compliance with this requirement shall be checked : wipe gently with the flooding absorbent cotton or cotton, 10 times, after visual inspection, cable surface printing should be clear.

6.6.2 Legibility

Each marking shall be legible.

7 Requirements for completed cables

7.1 General

The tests to be carried out on cables specified shall be scheduled in this standard, 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 previous specified are as given in Clause 7.2 to 7.5.

7.2 Special tests for aluminium alloy conductor(for aluminium alloy conductor cables)

The special tests for aluminium alloy conductor shall be compliance as specified in Table 3.

7.2.1 Tensile strength of conductor

The aluminium alloy conductor shall be tested in accordance with clause 1 in table 3, refer -ence standard ASTM B800-05.

7.2.2 Elongation of conductor

The aluminium alloy conductor shall be tested in accordance with clause 2 in table 3, reference standard ASTM B800-05.

7.2.3 Bending test of Aluminium alloy conductor for Class 2 conductor

The class 2 single-aluminium alloy conductor after stranded shall test the bending test. Samples shall be tested in accordance with GB/T 4909.5.

7.2.4 Special bending test of complete cable

The completed cables shall be in accordance with GB/T 31840.1, clause17.17.

7.2.5 Compressive creep aluminium alloy conductor

This standard need to assess the long-term creep curve in of load conditions of the same chemical composition and the same state of aluminum alloy rod with purchased aluminium alloy wire.

The sample may be tested compressive creep test in accordance with Annex B.

7.2.6 Flexing test with electricity

Samples shall be tested flexing test with electricity. Imposed current in the process of bending, the circulation speed is 10 times/min, we will record the number of bending when the conductor is broken.

Table 3 Special Requirements for Aluminium alloy Conductor

Ref No.	Test	Unit	Test method described in	Requirements	Category of test
1	Tensile strength of conductor Values to be obtained for tensile strength - median, min. For O(full annealing) conductor For H2X tempers(stain-hardened followed by partial annealing) conductor	 MPa MPa	ASTM B800-05	 59~111 103~152	T, S
2	Elongation at break - median, min. For O(full annealing) conductor For H2X tempers(stain-hardened followed by partial annealing) conductor	 % %		 16 10	T, S
3	Bending test of Aluminium alloy conductor for class 2 conductor -Bending angle -Times	 ° Times	GB/T 4909.5	 90 ≥25	T
4	Special bending test of complete cable - The diameter of cylinder - Cycles - Temperature - Voltage test	 % ℃ 	GB/T 31840.1-2015	 7D±5 3 90 No breakdown	T
5	Compressive Creep of aluminium alloy conductor -Temperature -Time	 ℃ h	Annex B	 120 100	T
6	Flexing test with electricity		Annex A		T

	- Circulation speed Angle of bend Bending radius The temperature rise of the electricity -Number of bending when the conductor is broken	Times/min		10 ±90° 10O.D ΔT=65℃ 3000	

7.3 Electrical tests

All the electrical tests shall be tested in accordance with Table 3.

7.4 Non-electrical tests of completed cables

All the non-electrical tests shall be tested in accordance with Table 3.

7.5 Requirements for insulation and sheathing materials

The requirements for insulation and sheathing materials shall be in accordance with Annex C, TableC.1.

8 Guide for use(normative)

Cables according to this standard are intended for use in PV-systems. They are allowed for cables intended for fixed installation and interconnecting the modules in a PV string, or connecting the string to a combiner box, PCE or other DC loads. Not directly connected to the PV modules.

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

About copper-aluminum transition Connectors for application in photovoltaic systems need conform to PPP 58205A:2021.

Table 4 –Electric tests for cables to PPP 58209A

Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
1	Electrical tests					
1.1	Measurement of the resistance of conductor		60228:2004	Annex A		T, S
1.1.1	Values to be obtained max.	Ω/km			IEC 60228	
1.2	Voltage test on completed cable with AC or DC		60245-2:1994	2.2		T, S
1.2.1	Test conditions:					
	- minimum length of the sample	m			20	
	- minimum period of immersion in water	h			1	
	- temperature of the water	℃			20 ±5	
1.2.2	Voltage applied (AC) or	kV			8,5	
	Voltage applied (DC)	kV			20	
1.2.3	Duration of application of voltage, min.	min			5	
1.2.4	Result to be obtained				No Breakdown	
1.3	Check for absence of faults on the insulation (or on completed cable)		62230			R
1.4	Insulation volume resistivity		60227-2	2.4		T
1.4.1	Test conditions: - temperature of the test	℃				
1.4.2	Values to be obtained at 20℃	Ω.cm			10^{14}	
1.4.3	Values to be obtained at 20℃	Ω.cm			10^{11}	
1.5	Long term resistance of insulation to DC		62821-2:2015	5.1.1		T
1.5.1	Test conditions: - length of sample	m			5	
	- duration of test	h			240	
	- water temperature	℃			85±5	
	- DC voltage applied	V			2,4	
1.5.2	Result to be obtained				No breakdown and no signs of damage	

Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
1.6	Surface resistance of sheath		62821-2:2015	5.1.3		T
1.6.1	Test conditions:					
	- voltage applied, DC	V			100 to 500	
	- duration of test	min			1	
1.6.2	Values to be obtained, min	Ω			$\geqslant 1{,}0 \times 10^9$	
2	Constructional and dimensional tests					
2.1	Conductor					T
2.1.1	Construction of conductor				IEC 60228	
2.2	Insulation					T, S
2.2.1	Insulation thickness	mm	60245-2:1994	1.9	Not less than Stated in 5.2.3 of IEC 62930: -	
2.3	Sheath					T, S
2.3.1	Sheath thickness	mm	60245-2:1994	1.10	Not less than Stated in 5.3.3 of IEC 62930: -	
2.4	Ovality					T, S
	Ovality value	%	60245-2:1994	1.11	As stated in 7.3.1 of IEC 62930: -	
2.5	Sheath colour					T, S
2.5.1	Visual examination				5.3.4 of IEC 62930: -	
2.6	Sheath marking					T, S
2.6.1	Visual examination and measurement				Clause 6 of IEC 62930: –	

Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
3	Insulation material				Table B.1 of IEC 62930:–	T
4	Sheath material				Table B.1 of IEC 62930:–	T
5	Compatibility test		60811-401:2012	4.2.3.4		T
5.1	Test conditions:					
	- duration of test	h			168	
	- temperature	°C			135 ± 2	
5.2	Result to be obtained				Table B.1 of IEC 62930:–	
6	Cold impact test		60811-506			T
6.1	Test conditions				Annex C of IEC 62930:–	
6.2	Results to be obtained				No cracks	
7	Ozone resistance on complete cable		60811-403			T
7.1	- temperature	°C			25 ± 2	
	- duration	h			24	
	- Ozone concentration (by volume)	%			(250 to 300) × 10^{-4}	
7.2	Result to be obtained [b]				No cracks	
8	Weathering/UV resistance on sheath		62930:–	Annex E		T
8.1	Test conditions				Annex E of IEC 62930:–	
8.2	Result to be obtained				Annex E of IEC 62930:–	
9	Dynamic penetration test		62930:–	Annex D		T
9.1	Test conditions				Annex D of IEC 62930:–	
9.2	Result to be obtained				Annex D of IEC 62930:–	
10	Damp heat test		60068-2-78			T
10.1	Test conditions:					
	- temperature	°C			90 ± 2	
	- duration	h			1000	
	- relative humidity min.	%			85	
	- reconditioning period	h			16 to 24	
10.2	Results to be obtained on the sheath:					
	- for tensile strength, variation maximum	%			−30[a]	
	- for elongation at break, variation maximum	%			−30[a]	

Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
11	Shrinkage test on sheath		60811-503			T
11.1	Test conditions:					
	- temperature	°C			120 ± 2	
	- duration of each cycle	h			1	
	- length of sample	mm			300	
11.2	Results to be obtained:					
	- maximum shrinkage	%			2	
12	Test for vertical flame propagation on complete cable		60332-1-2			T
12.1	Result to be obtained				Annex A of IEC 60332-1-2:2004	
13	Smoke emission of complete cable [d]		61034-2			T
13.1	Result to be obtained					
	- light transmittance, min.	%	61034-2		60	
14	Assessment of halogens for all non-metallic materials [d]		62821-1:2015	Annex B		T
14.1	Result to be obtained				Annex B of IEC 62821-1:2015	

[a] No positive value of variation defined.

[b] Any cracks near the fixing point on the mandrel and/or near the clamps when using test strips shall be disregarded.

[c] Discoloration of the insulation should be ignored.

[d] For halogen free low smoke cables only.

Annex A

(normative)

Flexing test with electricity

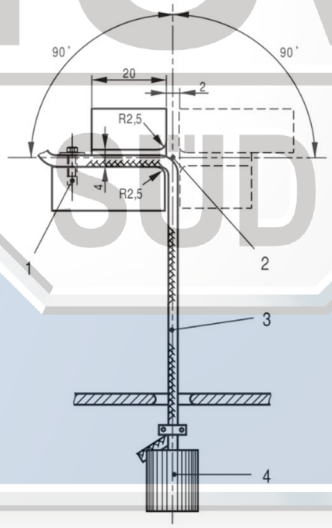
A.1 General

This test is intended to under the condition of electric temperature effect on the exhaustion of the cable.

A.2 Test Condition

Circulation speed	10 times /min
Angle of bend	±90°
ding radius	10O.D
The temperature rise of the electricity	ΔT=65℃

In order to reach the specified temperature ΔT, imposed current in the process of bending. The test device is shown in the figure below.



A.3 Result

The number of bending when the conductor is breken ⩾3000.

Annex B

(normative)

Compressive creep of aluminium alloy conductor

B.1 General

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

B.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 B1 or Figure B2.

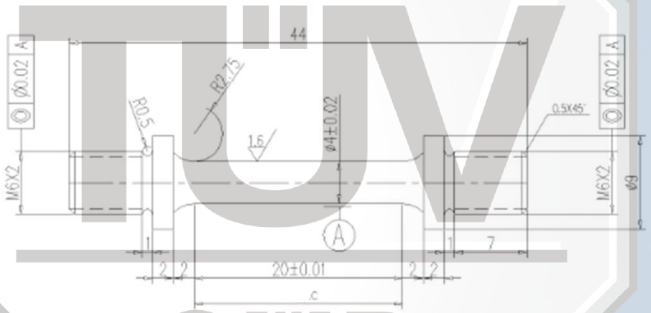


Figure B1

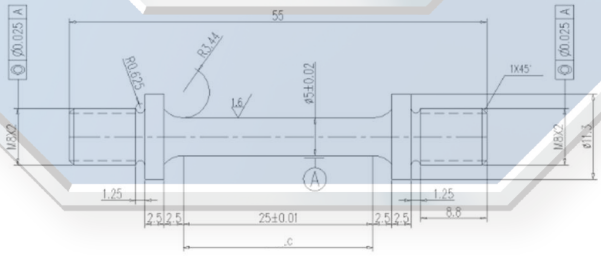


Figure B2

B.3 Apparatus

B.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. Tester should comply with the GB/T16825.2-2005 in the 1st level testing machine. 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 ±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 ± 3 ℃, The maximum allowable temperature deviation in the length direction of the sample is 3 ℃. The resolution of the temperature display device should be at least 0.5 ℃, the accuracy of the temperature measuring device shall be equal to or better than 1℃ and the temperature drift of the thermocouple during the calibration period shall not exceed ±1℃.

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 1:0.0002mm /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.

B.4 Test step

Compressive creep test temperature should select 120 ℃, Stress test pressure should be 70% of yield strength.

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 ±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 ±3℃.

B.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 [$60^{(2.73+0.03x^n)}$] S(n= 0,1,2,3...), 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.

B.6 Data processing

Annex C

Requirements for insulation and sheathing materials

Table C.1 – Requirements for insulation and sheathing materials

Ref no.	Tests	Unit	Test method standard	Type of compound	
				insulation	sheath
1	**Mechanical characteristics** [e]				
1.1	Properties before ageing [c]		IEC 60811-501		
1.1.1	Values to be obtained for tensile strength				
	- median, min.	N/mm^2		8,0	8,0
1.1.2	Values to be obtained for the elongation at break				
	- median, min.	%		125	125
1.2	Properties after ageing in oven		IEC 60811-401		
1.2.1	Test conditions: [c]				
	- temperature	°C		150 ± 2	150 ± 2
	- duration of treatment	h		7 × 24	7 × 24
1.2.2	Values to be obtained for tensile strength				
	- variation, maximum	%		−30[a]	−30[a]
1.2.3	Values to be obtained for the elongation at break				
	- variation, maximum	%		−30[a]	−30[a]
1.3	Hot set test [c]		IEC 60811-507		
1.3.1	Test conditions:				
	- temperature	°C		200 ± 3	200 ± 3
	- time under load	min		15	15
	- mechanical stress	N/cm^2		20	20
1.3.2	Values to be obtained				
	- elongation under load, max.	%		100	100
	- permanent elongation after cooling, max.	%		25	25
1.4	Thermal endurance		IEC 60216-1 and IEC 60216-2		
1.4.1	Test conditions: [c]				
	Elongation at break shall be performed.				
	- temperature index corresponding to 20 000 h			≥ 120	≥ 120
	- elongation at break, min.	%		50	50

Ref no.	Tests	Unit	Test method standard	Type of compound	
				insulation	sheath
1.5	Bending at low temperature		IEC 60811-504		
	Insulated conductor/cable overall diameter ≤ 12,5 mm				
1.5.1	Test conditions:				
	- temperature	°C		−40 ± 2 [b]	−40 ± 2 [b]
	- duration	h			
1.5.2	Results to be obtained:			No cracks	No cracks
1.6	Elongation at low temperature		IEC 60811-505		
	Insulated conductor/cable overall diameter > 12,5 mm				
1.6.1	Test conditions: [c]				
	- temperature	°C		−40 ± 2 [b]	−40 ± 2 [b]
	- duration	h			
1.6.2	Values to be obtained:				
	- elongation at break, min.	%		30	30
1.7	Sheath resistance against acid and alkaline solution		IEC 60811-404		
1.7.1	Test conditions [d]				
	- acid solution: N-Oxalic acid				
	- alkaline solution: N-Sodium hydroxide				
	- temperature	°C			23 ± 2
	- duration of treatment	h			7 × 24
1.7.2	Values to be obtained for tensile strength				
	- variation, maximum	%			±30
1.7.3	Values to be obtained for the elongation at break, min.	%			100
1.8	Compatibility test		4.2.3.4 of IEC 60811-401:2012		
1.8.1	Test conditions:				
	- temperature	°C		135 ± 2	135 ± 2
	- duration of treatment	h		7 × 24	7 × 24
1.8.2	Values to be obtained for tensile strength				
	- variation, maximum	%		±30	−30 [a]
1.8.3	Values to be obtained for the elongation at break				
	- variation, maximum	%		±30	−30 [a]

a No positive value for variation defined.

b See test method in column 4.

c This test shall be performed on test samples of insulation and sheath compound obtained from completed cables.

d N means 1 Normal concentration.

e If the insulation and sheath stick together and it is not possible to prepare separated specimens for insulation and sheath according to IEC 60811-501, the tubular test piece shall be tested and the results applied to both insulation and/or sheath as required.