2 Pfg 1169/08.2007
Requirements for cables for use in photovoltaic-systems

Contents

Foreword

This test specification contents the requirements listed in a manuscript of the working group AK 411.2.3 „Leitungen für PV-Systeme“ of the German committee for standardization (DKE). This manuscript is intended to be published as German pre-standard. Up to the date of publishing of the pre-standard this test-specification of TUV Rheinland will be used for test and assessment of cables for use in PV-systems (PV-cables).

1 Scope

2 PfG 1169/08.2007 applies to flexible single-core cables (cords) for use at the DC-side of photovoltaic-systems with a maximum permissible voltage of DC 1,8 kV (conductor/conductor, non earthed system).

The cables are suitable for use in safety class II.

It is permitted to connect these cables as multiple-construction.

The cables are intended to operate at ambient temperature until 90℃

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, *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)*

HD 22.13, *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 60364-7-712 *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems (IEC 60364-7-712, modified)*

3 Terms and definitions

For the purposes of this document, following definitions apply.

3.1 Terms for test procedure

3.1.1
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. 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.

3.1.2
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.

3.1.3
Routine tests (symbol R)
Tests made by the manufacturer on each manufactured length of cable to check that each length meets the specified requirements

3.2
Rated voltage
The rated voltage of the cable determines the construction and the tests of the cable with regard to the electrical properties.

The rated voltage is designated by two values of frequency voltage: U_0/U in Volt

U_0 rated power frequency voltage between conductor and earth (metallic screen of cable or ambient medium);
U rated power frequency voltage between two conductors of a multipole cable or of a system of single core cables.

The rated voltage of the cable for a given application shall be suitable for the operating conditions in the system in which the cable is used.

This requirement is applicable for both U_o and U

The rated voltage between two conductors in a DC-system shall not exceed the 1,5 time value of rated voltage U of the cable, and the rated voltage between conductor and earth shall not exceed the 1,5 time value of rated voltage U_o of the cable.

NOTE The operating voltage of a system may exceed is rated voltage permanent for 20%. A cable may be operated with a voltage which value is 20% higher than rated voltage under condition that the rated voltage is not less than the rated voltage of the system.

3.3
DC side
part of a PV installation from a PV cell to the DC terminals of the PV inverter

3.4
open-circuit voltage under standard test conditions $U_{OC\ STC}$
voltage under standard test conditions across an unloaded (open) PV module, PV string, PV array, PV generator or on the DC side of the PV inverter

3.5
short-circuit current under standard test conditions $I_{SC\ TC}$
short-circuit current of a PV module, PV string, PV array or PV generator under standard test conditions

4 Halogen free PV-cable

4.1 Code designation

PV1-F

4.2 Characteristics

4.2.1 Rated voltage 额定电压

AC U_0/U 0,6/1 kV 交流：0.6/1 kv

DC 1,8 kV (conductor-conductor, non earthed system, circuit not under load). 直流：1.8kv

If the cable is used in DC-systems the rated voltage between two conductors shall not exceed the 1,5 time value of rated voltage U of the cable. In with single-phase earthed DC-systems this value shall be multiplied with factor 0,5.

4.2.2 Temperature range

Ambient temperature: 环境温度： –40 °C to +90 °C

Max. temperature at conductor: 120 °C
导体工作温度

The cables are intended to operate at ambient temperature until 90°C. For this a temperature index of 120°C applies to the insulation and the sheath, bas ed on EN 60216-1 (20.000h, 50% residual elongation).
绝缘、护套温度指数120°C

Note The expected period of use is 25 years. 使用寿命25年

The permitted short-circuit-temperature refer to a period of 5s is 200°C. 5秒钟的短路温度是200°C

4.3 Construction

4.3.1 Conductor 导体

Number of conductors: 1

The conductor shall be class 5, according to EN 60228.
导体是EN60228中的第5类导体,而且必须是镀锡的
The single wires must be tinned.

Preferred diameters: 2,5, 4, 6, 10, 16 mm^2
导体直径

4.3.2 Separation layer 隔离层

A separation layer of a suitable halogen free material may be applied around the conductor.

4.3.3 Insulation 绝缘

The insulation shall be a suitable halogen free material applied around the conductor. 无卤

The insulation 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 insulation itself, to the conductor and to the tin coating.

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

The wall thickness of insulation is specified by the manufacturer, but it must not fall short of the minimum value of 0,5mm.

4.3.4 Separation layer

A separation layer of a suitable halogen free material may be applied around the insulation.

4.3.5 Sheath 护套

The core must be covered by a sheath.

The sheath around the core must be of a suitable halogen free material. 无卤

The sheath shall be extruded and shall consist of one or several adjacent adherent layers. The sheath shall be smooth and consistently applied.

The wall thickness of sheath is specified by the manufacturer, but it must not fall short of the minimum value of 0,5mm.

4.3.6 Outer diameter

The average value of the outer diameter shall be within the limits specified by the manufacturer.

4.3.7 Multiple construction

Each single-core cable in a multiple construction shall pass the requirements of this document. Each additional component in a multiple construction shall pass the requirements of this document.

4.3.8 Marking

4.3.8.1 General

The cable shall be marked as follows:

a) Trademark;

b) Code designation;

c) Rated diameter.

Marking may be by printing or by reproduction in relief on or in the sheath.

4.3.8.2 Trademark

Cables shall be provided with an indication of the manufacturer, which consist of a consecutively marking with company name or company sign or with (if trademarked) an identification number.

4.3.8.3 Code designation

Cables shall be provided with an code designation according to 4.1 applied consecutively on sheath.

4.3.8.4 Arrangement of marking

Each marking is considered as consecutive if the spacing between the end of a marking and the begin of the following identical marking does not exceed following value:

– 550mm, for marking on sheath or outer jacket.

Following figure shows an example of marking on sheath.

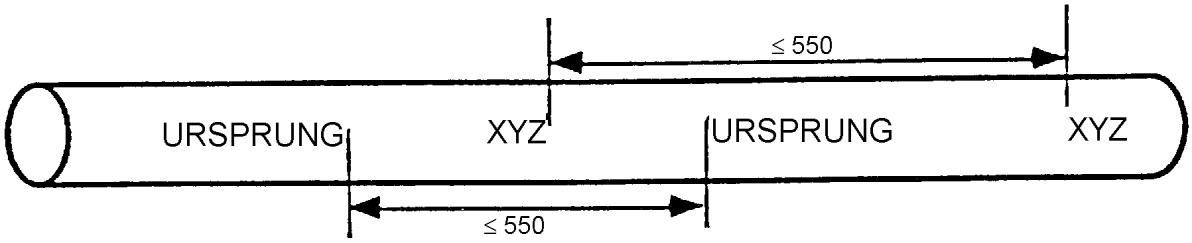


Figure 1 – Arrangement of marking

4.3.8.5 Durability

Printed markings shall be durable. Compliance with this requirement shall be checked by the test given in 5.1 of EN 50396.

4.3.8.6 Legibility

Each marking shall be legible.

4.4 Test

Compliance with the requirements of 4.3 shall be checked by visual inspection and tests according to table 3.

4.5 Guideline for use (informative)

Cables according to this standard are intended for use in PV-systems according to EN 60364-7-712.

4.6 Current carrying capacity载流容量

Ambient temperature: 60℃ 环境温度

Max. temperature at conductor: 120 ℃ 导体最高温度

Table 1 – Current carrying capacity of PV-cables

Rated diameter	Kind of installation		
	Single cable free in air	Single cable on surfaces	To cables adjacent on surfaces
mm^2	A	A	A
1,5	30	29	24
2,5	41	39	33
4	55	52	44
6	70	67	57
10	98	93	79
16	132	125	107
25	176	167	142
35	218	207	176

Table 2 – Conversion factor for deviating temperatures

Ambient temperature	Conversion factor
℃	
Up to 60	1,00
70	0,91
80	0,82
90	0,71
100	0,58
110	0,41

Reduction factor for accumulation according to IEC 60364-5-52, Table B.52-17

Table 3 – Tests for halogen free PV-cable

1	2		3	4	5
Ref. No.	**Test**	**Requirements**	**Category of test**	**Test method described in**	
				standard	**clause**
1	**Electrical tests**				
1.1	Resistance of conductors		T,S	EN 50395	5
1.2	Voltage test on completed cable with AC or DC		T,S	EN 50395	6
	– AC-test-voltage kV – DC- test-voltage kV Length of sample m Duration of test min Temperature of the water ℃	6,5 15 20 5 20 ± 5			
1.3	Absence of faults at complete cable – AC-test-voltage kV	 10	R	EN 50395	10
1.4	Surface resistance of sheath – Minimum value 护套表面电阻 Ω	 10^9	T	EN 50395	11
1.5	Insulation at complete cable Length of sample m Duration of test h Temperature of the water ℃ – Minimum value at 20 ℃ Ω · cm – Minimum value at 90 ℃ Ω · cm	 5 2 20± 5 10^{14} 10^{11}	T	EN 50395	8
1.6	Long term resistance of insulation to d.c.		T		Annex D
2	**Constructional and dimensional tests**				
2.1	Checking of compliance with constructional provisions		T,S		Inspection and manual tests
2.2	Measurement of thickness of insulation		T,S	EN 50396	4.1
2.3	Measurement of thickness of sheath		T,S	EN 50396	4.2
2.4	Measurement of overall dimensions				
2.4.1	– Mean value		T,S	EN 50396	4.4
2.4.2	– Ovality %	≤ 15	T,S	EN 50396	4.4
3	**Pressure test at high temperature at complete cable**		T	EN60811-3-1	
3.1	Test conditions:				
	– temperature ℃	140 ± 3			
	– duration of heating under load min	240			
	– Coefficient k	0,6			
3.2	Results to be obtained:				
	– depth of penetration, max. %	50			
	– Voltage test 10 min after exculpation and cooling				Table 4, 1.2
4	**Damp heat test**		T	EN 60068-2-78	
4.1	Test conditions:				
	– temperature ℃	90			
	– duration h	1000			
	– relative humidity %	85			
4.2	Results to be obtained:				
	– variation of tensile strength max. %	– 30			
	– variation of elongation at break max. %	– 30			

1	2		3	4	5
Ref. No.	**Test**	**Requirements**	**Category of test**	**Test method described in**	
				standard	**clause**
5	**Resistance against acid and alkaline solution**		T	EN 60811-2-1	10
5.1	Chemical stress				
	acid: N-Oxal-acid				
	alkaline solution: N-sodium hydroxide solution				
	temperature ℃	23			
	duration h	168			
5.2	Tensile strength:				
	variation, max. %	± 30			
5.3	Elongation at break, min. %	100			
6	**Test of influence**		T		Annex A
7	**Cold impact test at –40 ℃**		T		Annex E
8	**Cold bending test** Diameter of cable < 12,5 mm		T	EN 60811-1-4	8.2
8.1	Test conditions:				
	– temperature ℃	–40 ± 2			
	– duration of conditioning h	16		EN 60811-1-4	8.2.3
8.2	Results to be obtained	Absence of cracks			
9	**Cold elongation test** Diameter of cable ≥ 12,5 mm				Table 3
10	**Ozone resistance at complete cable**		T		
10.1	Method B			EN 50396	8.1.3
	– temperature ℃	40 ± 2			
	– relative humidity %	55 ± 5			
	– duration h	72			
	– Ozone concentration (by volume) %	$(200 \pm 50) \times 10^{-6}$			
10.2	Results to be obtained	Absence of cracks.			
11	**Weathering/UV-resistance**		T	HD 605/A1	2.4.20
11.1	Conditions:				
	– duration h	720			
	– temperature (Black-Standard-temperature) ℃	63			
	– relative humidity %	65			
	– min. power at wavelength 300 nm to 400 nm W/m^2	60 ± 2			
	– duration spraying/drying min	18/102			
	Results to be obtained	Absence of cracks.			
12	**Dynamic penetration test**		T		Annex F
13	**Notch propagation**		T		Annex G

1	2		3	4	5
Ref. No.	**Test**	**Requirements**	**Category of test**	**Test method described in**	
				standard	**clause**
14	**Shrinkage test at complete cable**		T	EN 60811-1-3	11((sheath))
14.1	Conditions:				
	– temperature ℃	120			
	– duration h	1			
	– Distance L of sample mm	300			
14.2	**Results to be obtained**:				
	– Maximum shrinkage. %	2			
15	**Test under fire conditions**				
15.1	Test for vertical flame propagation at complete cable		T, S	EN 60332-1-2	
15.2	Assessment of halogen		T, S		
15.2.1	Absence of halogen				Annex B
15.2.2	Determination of halogens –				Annex C

Table 4 – Requirements for halogen free insulation and sheath compounds

1	2	3	4	5	6	7
Ref. No.	Test	Unit	Test method described in		Type of compound	
			standard	clause	insulation	sheath
1	**Mechanical characteristics**					
1.1	Properties before ageing		EN 60811-1-1	9.2		
1.1.1	Values to be obtained for the tensile strength:					
	– median, min.	N/mm^2			6,5	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		EN 60811-1-2	8.1		
1.2.1	Ageing conditions:					
	– temperature	°C			150 ± 2	150 ± 2
	– duration of treatment	h			7 × 24	7 × 24
1.2.2	Values to be obtained for the tensile strength:[c]					
	– median, min.	N/mm^2			–	–
	– variation, max.	%			–30[a]	–30[a]
1.2.3	Values to be obtained for the elongation at break:[c]					
	– median, min.	%			–	–
	– variation, max.	%			– 30[a]	– 30[a]
1.3	Hot set test[d]		EN 60811-2-1	9		
1.3.1	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 properties		EN 60216-2			
1.4.1	Conditions					
	Either test of elongation at break or bending test shall be performed.					
	– Temperature index				120	120
	– elongation at break [c]	%			50	50
	– bending test		EN 50305	7.2	2 D	2 D
1.5	Cold elongation test		EN 60811-1-4	8.4		
1.5.1	Conditions:					
	– temperature	°C			–40 ± 2	–40 ± 2
	– duration	h	EN 60811-1-4	8.4.4 und 8.4.5	[b]	[b]
1.5.2	Values to be obtained:					
	– elongation at break, min.	%			30	30

1	2	3	4	5	6	7
Ref. No.	**Test**	**Unit**	**Test method described in**		**Type of compound**	
			standard	**clause**	**insulation**	**sheath**
a No positive value for variation fixed.						
b See test method in column 4 and 5.						
c This test shall be performed at test samples of insulation and sheath compound.						
d This test shall be performed only at cross-linked insulation and sheath compound						

Annex A
(normative)

Test of mutual influence

A.1 Conditions

Test samples must be aged for 7 days at (135 ± 2) °C at conditions according to table 2

A.2 Requirements

After ageing the insulation and the sheath shall pass the requirements of table A.1.

Table A.1 – Requirements

Tests		units	insulation	sheath
Tensile strength	– median, min.	N/mm^2	–	–
	– variation [a], max.	%	± 30	–30 [b]
Elongation at break	– median, min.	%	–	–
	– variation [a], max.	%	± 30	± 30

a Variation: difference between the median value obtained after ageing and the median value obtained without ageing expressed as a percentage of the latter.

b Positive tolerances are not limited.

Annex B
(normative)

Test of absence of halogen

B.1 Requirements of extruded materials

Insulation and sheath shall pass the requirements as follows:

a) Type test

The material must be tested as described in table B.1.

Table B.1 – Test method, measurement, requirements

	Test method	Measurement	requirements
1	EN 50267-2-2	pH and conductivity	pH ≥ 4,3 und conductivity ≤ 10 µS/mm[a]
2	EN 50267-2-1	Chlorine- and Bromine content, expressed in HCl	≤ 0,5 %
3a	Annex C	Halogen: Fluoride	If negative the test should be finished. No further test is necessary. The material shall be accepted.
			If positive, test of 3b shall be performed
3b	EN 60684-2	Fluoride content	≤ 0,1 %
a If discrepancies regarding conductivity appear, e.g. the recommended value is exceeded even if there is compliance with the recommended ph-value, other test method may be applied after agreement with all participants.			

b) Selection test

The material shall be tested according to test sequence of table B.2.

Table B.2 – Test sequence

	Test method	Measurement	Value	Result
Phase 0	HD 22.13, Annex C	Halogen: Fluoride, Chloride and Bromide		If negative the test should be finished. No further test is necessary. The material shall be accepted.
				If positive continue with phase 1.
Phase 1	EN 50267-2-2	pH	< 4,3	The material shall be revised.
			≥ 4,3	Conductivity shall be tested.
		conductivity	≤ 2,5 µS/mm	The material shall be accepted. No further test is necessary.
		conductivity	> 10 µS/mm	The material shall be revised.
		conductivity (s)	> 2,5 µS/mm but ≤ 10 µS/mm	Test according to EN 50267-2-1 shall be performed
Phase 2	EN 50267-2-1	Chlorine- and Bromine content, expressed in HCl	> 0,5 %	The material shall be revised.
			≤ 0,5 %	Test according to EN 60684-2 shall be performed.
Phase 3	EN 60684-2	Fluoride content	> 0,1 %	The material shall be revised.
			≤ 0,1 %	The material shall be accepted.

Annex C
(normative)

Determination of halogens – Elemental test

Warning

Owing to its potentially hazardous nature, the fusion operation should be carried out in a fume cupboard, using a safety screen.

C.1 Equipment

Bunsen burner
3 small/medium soda glass test tubes (approximately 50 mm x 10 mm)
Test tube holder
Evaporating basin/mortar
Wire gauze;
Funnel
Filter paper

C.2 Materials

Unknown sample
Sodium metal
Dilute nitric acid (5 %)
Aqueous silver nitrate (5 %)
Dilute ammonia (10 %)
Freshly made up zirconium-alizarin red S reagent
Glacial acetic acid
Acid/pH indicator papers

C.3 Procedure

C.3.1 Sodium fusion

Place 200 mg – 250 mg of the sample into the bottom of a small soda glass test tube. Add 10 ml of distilled/de-ionized water to the evaporating basin and place this in the fume cupboard behind the safety screen. Whilst holding the test tube firmly with the test tube holder at an angle of 45°- 60°to the vertical, introduce a piece of freshly cut, clean sodium (about the size of a small pea) (200 mg – 250 mg) into the mouth of the test tube without allowing it to come into contact with the sample. With the safety screen in place, heat the sodium gently until it melts and runs down on to the sample (there may be a vigorous reaction when the molten sodium reaches the sample if halogens are present). Heat the tube gently for about 1 min, then more strongly until the lower 20 mm of the tube glows red hot. Plunge the red hot tube into the water in the evaporating basin, immediately placing the gauze on top. (The gauze prevents any loss of material when the tube shatters on contact with the water.) Allow any non reacted sodium to react before grinding up the solution and glass. Filter, and separate the filtrate into two equal portions.

C.3.2 Chlorine and bromine

To the first portion of the filtrate, add sufficient nitric acid to make the solution acidic. Boil this solution until its total volume has been reduced by half (this is to remove any HCN or H_2S, if present, which would interfere with the test). Add 1 ml silver nitrate solution; a white or yellowish-white precipitate indicates the presence of halogen (Cl, Br) in the original sample. (If the liquor is decanted, and the precipitate is white and readily soluble in dilute ammonia, then chloride is present.)

C.3.3 Fluorine

To the second portion of the filtrate, acidify with glacial acetic acid. Boil this solution until its total volume has been reduced by half. Add 2 to 3 drops freshly prepared zirconium lake reagent (equal volumes of: a) Alizarin solution: 0,05 g Alizarin Red-S in 50 ml distilled water, b) Zirconium solution: 0,05 g zirconium nitrate in 10 ml concentrated HCl diluted with 50 ml distilled water). Heat at 40 °C for 1 h. The presence of fluoride is indicated by the red/pink colouration being bleached to yellow.

Annex D
(normative)

Test of long term resistance of insulation to D.C.

A test sample with a length of minimum 5m shall be immersed into water containing 3 % NaCl. Further on minimum 300mm of the sample shall stick out of the water. The water-bath shall be retained for (240 ± 2) h at a high temperature of (85 ± 2) ℃ and a D.C.-vol tage 0,9kV shall be applied between conductor and water whereby the conductor shall be connected to the positive potential.

The current of this circuit shall be measured with a period of not more than 24h. If possible a continuous measurement shall be preferred.

The measured values shall be recorded in a time-current-curve which identifies a stable progress.

NOTE A stable progress is e.g. an increase of less than 10% of leakage current on the average for a time of 24h (This is part of the inspection based on practical experiences)

After storing the samples shall be taken out of the salt-water-solution and a voltage test according to Ref.-No. 1.2 of table 1 shall be performed. The test voltage shall be the rated voltage (U) of the cable.

Annex E
(normative)

Cold impact test

The cold impact test shall be performed at –40℃ ac cording to clause 8.5 of EN 60811-1-4, but the mass of hammer, the mass of test probe and the height shall comply with table 2.

Table E.1 – Parameter for cold impact test

Diameter of cable (D)	**Mass of hammer**	**Mass of test probe**	**height**
mm	g	g	mm
D < 15	1 000	200	100
15 < D ≤ 25	1 500	200	150
D > 25	2 000	200	200

The inner and outer surface of sheath shall be inspected with normal or corrective visual faculty without magnification. Only the outer surface of the insulation shall be inspected. No cracks must be determined

Annex F
(normative)

Dynamic penetration test

A test apparatus for pull test (or a equivalent apparatus) shall be operated in pressure modus and shall be equipped with a measuring device which is able to record the force of penetration of the spring-steel-needle (see figure F.1b) through the insulation or sheath of a completed cable. A circuit with low voltage which finish the test at the moment when the needle penetrates the insulation or the sheath and makes contact with the conductor shall be added.

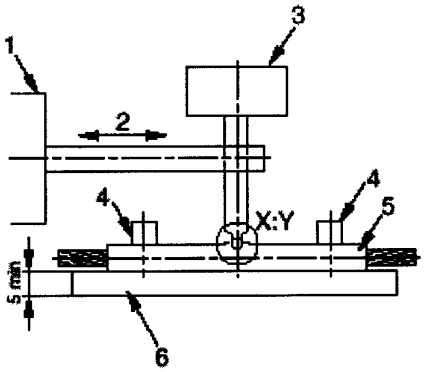
The test shall be performed at room temperature. The force applying to the needle shall be increased continuously with 1 N/s until contact with the conductor has been made. 4 tests at each sample shall be performed and the force at the moment of contact shall be recorded. After each test the sample shall be moved forward and shall be turned clockwise for 90°.

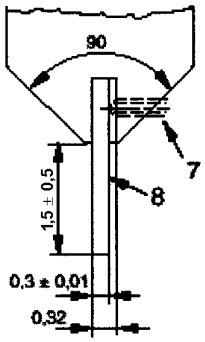
The mean value of the 4 test results must not be less than the minimum value F determined with following formula

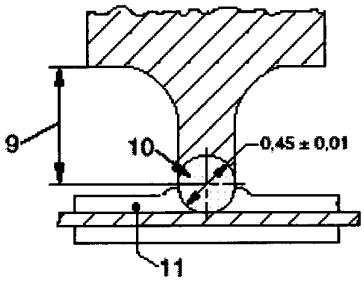
$$F = 50 \cdot D$$

D diameter of cable in mm

Dimensions in mm







a) detail X **b) detail Y**

(edges not broken or rounded, without ridge)

Caption

1	N.A.	7	Fixing screw
2	N.A.	8	Blade
3	Load	9	Shoulder with sufficient depth for testing the insulation
4	Clamp	10	Needle of spring steel
5	Sample	11	Sample
6	Mounting surface		

Figure F.1 – Arrangement for penetration test

Annex G
(normative)

Notch propagation

Three samples of the cable shall be notched, to a depth of 0,05 mm of the insulation or sheathing, at four points equally spaced with respect to one another around the circumference and 25 mm apart along the length, and in a plane mutually perpendicular to the conductor.

One of the samples shall be conditioned at -15 °C, one at ambient temperature and one at 85 °C, in all cases for 3 h, after which time they shall be wound on to a mandrel, (3 ± 0,3) times the minimum specified diameter of the cable, whilst at the conditioning temperature. The notched sample shall be wrapped around the mandrel such that at least one notch is on the outside of the cable.

The sample shall be allowed to return to ambient temperature and then subjected to the voltage test given in no. 1.2 of Table 1 but at half the rated voltage U_0.