2 PfG 2577/08.16
Requirements for Cables used in Robot System

Content

1 Scope

This test specification applies to cables for high flexibility with rated voltages at AC U_0/U up to and including 450/750 V, intended for use in in-door robot systems but excluding arc or spot welding systems.

The cables are intended to operate at a maximum conductor temperature of 70 °C (made of ordinary and crosslinked PVC material) and 90°C (made of materials other than ordinary and crosslinked PVC specified in clause 4.1.1).

2 Normative references

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

EN 50334	Marking by inscription for the identification of cores of electric cables
EN 50363 Series	Insulating, sheathing and covering materials for low-voltage energy cables
EN 50395	Electrical test methods for low voltage energy cables
EN 50396+A1:2011	Non electrical test methods for low voltage energy cables
EN 50525-1	Electrical Cables – Part 1: General requirements
EN 60228	Conductors of insulated cables
HD 308 S2	Identification of cores in cables and flexible cables
HD 361 S3	System for cable designation
EN60811 Series	Electric and optical fiber cables – test methods for non-metallic materials
HD 605 S2	Electrical cables – additional test methods
DIN VDE 0250-106	ETFE single-core-nonsheathed cables for internal wiring
IEC 60445	Basic and safety principles for man-machine interface, making and identification - Identification of conductors by colours or alphanumerics
IEC 60189 series	Low-frequency cables and wires with PVC insulation and PVC sheath
EN 50618	Electrical Cables for Photovoltaic Systems
EN 50288 Series	Multi-element metallic cables used in analogue and digital communication and control

3 Definitions

3.1 Definition concerning the tests

3.1.1
Type tests (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, design or type of manufacturing process, which might change the performance characteristics.

3.1.2
Sample tests (Symbol S)

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

3.1.3
Routine tests(Symbol R)

Tests made on all production cable lengths to demonstrate their integrity

3.2
Rated voltage

The rated voltage of a cable is the reference voltage for which the cable is designed, and which serves to define the electrical tests.

The rated voltage is expressed by the combination of two values U_0/U expressed in volts:

U_0 being the r.m.s. value between any insulated conductor and "earth" (metal covering of the cable or the surrounding medium);

U being the r.m.s. value between any two phase-conductors of a multicore cable or of a system of single-core cables.

In an alternating current system, the rated voltage of a cable shall be at least equal to the nominal voltage of the system for which it is intended.

This condition applied both to the value U_0 and to the value U.

NOTE The operating voltage of a system may permanently exceed the nominal voltage of such a system by 10%. A cable can be used at a 10% higher operating voltage than its rated voltage if the latter is at least equal to the nominal voltage of the system.

3.3
Cable class

Cable class is defined for cables in this standard according to their mechanical strength.

Ref. no. in Table A.1	Class I	Class II	Class III	Class IV	Class V
8.1 Flexing test	X	X	X	X	X
8.2 Bending & rotating test			X		X
8.3 bending test			X		X
8.4 Cableveyor test		X			
8.5 90 ° bending test	X	X	X	X	X
8.6 2D Torsion test				X	X
8.7 Vertical torsion test				X	X
8.8 3D Torsion test				X	X
Remark: Except Class V cables, besides 8.1 or 8.5 the cables of other classes shall fulfill any of the tests tacked. All the tacked tests shall be done to Class V cable.					

4. Cables used in robot systenms

4.1 Code Designation

The cable designation shall be composed of four parts indicating the essential characteristics of a cable:

Part	Basic elements of the description
1	Relationship to standards Rated voltage or kind of communication cables
2	Construction of the cable, generally in a radial sequence and starting with the insulation material; then, after a dash, material and form of conductor(s)
3	Number and size of conductors
5	Cable class

Part 1 and Part 2 of the designation are generally written without a space and constitute the "type designation" of a cable or cord.

Part 3 of the designation constitutes specific information on the number and size of conductors.

4.1.1 Systems for code designation

Part 1:

IRS..industrial robot systems

07..rated voltage 450/750 V

05...rated voltage 300/500 V

LF ....low frequency communication cables designed as IEC 60189 sereis

HF ....high frequency communication cables designed as EN 50288 series

Part 2:

V... PVC for a continous operating temperature of 70° C

V2...PVC for a continous operating temperature of 90° C

V4..XLPVC insulation(XI1)

V4 ....XLPVC sheath(XM1)

Z...crosslinked compound (EI5)

Z...corsslinked compound (EM8)

N... polyethylene (PE)

E... thermoplastic elastomer (TPE)

Q... polyurethane

7Y.. ETFE

C4.. copper braid screen over the assembled cores

MP...combination screen of a braid with tape over the assembled cores

MS...tape sceen over the assembled cores

H2...flat construction of non-divisible cables

H6...flat cable having three or more cores

-H.. highly flexible conductor of a flexible cable or cord (flexibility according to Class 6 of EN 60228)

Part 3:

Number... number, n, of cores

X... times, where a green/yellow core is not included

G... times, where a green/yellow core is included

Number after times.............................. nominal cross-section, s, of conductor in mm^2

Part 4:

Number.. number, n, of copper signal/control cores

X... times

Number after times........................... nominal cross-section, s, of conductor in mm

C4...copper screen over the signal/control cores

MP...combination screen of a braid with tape over the assembled cores

MS...tape sceen over the assembled cores

Part 5:

Cable class ....see clause 3.3

EXAMPLE For code designation: 2 PfG 2577 IRS07VVC4V-H 5X2,5+4X0,5/C4 Class I

4.2 Rated Voltage

AC U_0/U 300/500V or 450/750V

4.3 Construction

4.3.1 Conductor

The conductor shall be in accordance with the requirements given in EN 60228 for Class 6 conductors. The wires may be plain, tinned, silvered, nickeled or copper alloy. The recommended cross-sectional area is from 0,12mm^2 to 6mm^2.

NOTE Cable with other conductor size than specified in EN 60228 can be tested according to this specification. The dimensional requirements as well as electrical characteristics (conductor resistance, etc.) need to be recalculated for the actual conductor size, using applicable EN/IEC standard methods. Alternatively, the severe requirements of the next EN/IEC conducter size can be used instead.

4.3.2 Separator

A separation of suitable material may be applied around each conductor.

4.3.3 Insulation

The insulation shall be extruded. The insulation materials shall be selected from the follows: TI1, TI3, EI8 and XI1 in accordance with EN 50363. Thermoplastic material (TI6), PE material(N) and EFTE material(7Y) are also recommended, the requirements of which refer to Table 3 to Table 5.

The insulation shall be so applied that it fits closely on the conductor or the separator. It shall be possible to remove it without damage to the insulation itself, to the conductor or to the tin coating if any, or screen.

The thickness at any place shall not be less than 0,1mm.

4.3.4 Assembly of cores and filler, if any

The cores shall be twisted together.

A centre-core is not permitted. A centre-filler of suitable material may be applied.

Assemblies with three or more cores for cable without screen shall have one core coloured green-and-yellow and for cable with screen may haven't one core coloured green-and-yellow.

For drag chain cable, the cores may be laid parallel and covered with the sheath. If so, the cores shall be grouped, lying closely side by side in groups.

4.3.5 Core identification

Identification of the cores of a cable shal be achieved by the use of coloured insulation or by a coloured surface. The colours shal be cleary identificable and durable. Durability shall be checked by the test given in 5.1 of EN 50396.

Each core of multicore cable shall have only one colour, except the core identified by a combination of the colours green-and-yellow. In multicore cables, the colours green and yellow shall not be used separately as single colours except that the cable is designed as low-frequency communication cable.

For multicore cables with two to five cores, the core colours, and their rotational position in the cable, shall be in accordance with HD 308.

Where the cores are more than five, the identification of the cores of multicore cables is permitted by numbering, which shall conform to EN 50334, or by color scheme identified by IEC 60446.

Cables designed as data processing purpose could use the colour scheme of IEC 60189. For low-frequency cables, additional tests of conductor loop resistance, conductor resistance unbalance and mutual capacitance in Table 1 of EN 50288 standards shall be performed before and after tests in Ref. no. 8 of Table A.1. For high-frequency cables, additional tests specificied in Table 2 of EN 50288 standards shall performed before and after tests in Ref. no. 8 of Table A.1.

4.3.6 Signal- and control core

Insulation of signal and control core must be made of the same compound as the ones for main cores.

The signal- and control cores shall be twisted with main cores.

The mimimum value of the thickness of insulation of the core is is 0,1mm.

The screen, if any, shall be applied over the signal- and control core, in the form of a braid of plain or metal coated copper wires, or one or more tapes, a braid or a combination of a braid with tape(s). When choosing the material of the screen, special consideration shall be given to the possibility of corrosion, not only for mechanical safety but also for electrical safety.

The tape screen shall be applied helically in two layers so that the outertape 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. The minimum thickness of metal tape shall be 0,04mm.

Polyster tape of either 0,023mm or 0,050mm nominal thickness shall be applied over the screen with a minimum overlap of 15% of its total width.

The laminated electrostatic screening tape shall be applied with the metallic side in electrical contact with a braid. The minimum overlap of the laminated tape shall be 15% of its total width, to ensure coverage in case of bending the cable. The laminated tape shall be either alumminium bonded to polyester having a minimum thickness of aluminium of 0,008mm and a minimum thickness of polyster of 0,010mm, or copper bonded to polyester having a minimum thickness of copper of 0,018mm and a minimum thickness of polyster of 0,023mm.

The braid shall be composed of a number of strands of tinned annealed copper wires in the case of aluminium tape and either plain or tinned annealed copper wires in the case of copper laminated tape.

For a braid screen of wires there shall be no more than one splice in any spindle over any 100 mm length of the screen. The screen shall be applied evenly.

The filling factor K_r shall be according to the formula:

$$Kr = \frac{m \cdot n \cdot d}{2\pi\phi} \times \left[1 + \frac{\pi^2\phi^2}{L^2}\right]^{0,5}$$

The filling factor K_r shall be 0,55 minimum. . For a combination of a braid with tape(s), the filling factor Kr shall be 0,37 minimum.

ϕ = diameter under the screen+ 2d
d = nominal diameter of a wire
m = total number of spindles
n = number of wires per spindle
L = screening pitch

4.3.7 Other components

4.3.7.1 Gerneral

Apart from a sheath, any of the following components may be included in the construction of the cables:

a) interstitial fillier;

b) inner covering;

c) inner sheath;

d) metallic screen;

e) textile braid covering.

The inclusion of one or more of the above components shall given in the particular specification. Where a component is specified, it shall comply with the appropriated requirements of 4.3.7.2 to 4.3.7.7 below.

4.3.7.2 Intersticial fillers

4.3.7.2.1 Composition

Fillers shall be composed of one of the following or of any combination of the following:

- a compound based on polymeric materials; or
- naterual or synthetic textiles; or
- papar

4.3.7.2.2 Assembly

The assembly of cores and fillers may be held together by a film or tape.

In multicore cable, a centre filler is permitted.

4.3.7.3 Requirements

Fillers shall fill the spaces between the cores, and shall not adhere to the cores. The fillers shall be capable of being removed without damage to the cores.

Note Incorporation of fillers should lead to the finished cable having a practically circular shape.

There shall be no harmful interactions between the fillers and the insulation and/or the sheath. Compliance shall be checked as part of the compatilibity test requirements.

4.3.7.4 Inner covering

Extruded inner coverings shall be composed of a compound based on polymeric materials.

No dimensional measurements shall be required for inner coverings.

There shall be no harmful interactions between inner coverings and the insulation and/or sheath. Compliance shall be checked as part of the compatibility test requirements for the particular cable.

Inner covering shall surround the cores.

Note Incorporation of an inner covering should lead to the finished cable having a practically circular shape.

An inner covering shall not adhere to the cores, and shall be capable of being removed without damage to the cores. Where indicated in the particular specification the inner covering may penetrate between the cores, thus forming a filling.

4.3.7.5 Inner sheath

The twisted cores may be covered by an extruded inner sheath of a same compound of oversheath, if a screen is applied.

The thickness of inner sheaths shall be no less than 0,1mm.

There shall be no harmful interactions between inner sheaths and the insulation and/or sheath. Compliance shal be checked as part of the compatibility test requirements.

Extruded inner sheaths shall surround the cores.

Note Incorporation of an inner sheath should lead to the finished cable having a practically circular shape.

An inner sheath shall not adhere to the cores, and shall be capable of being removed without damage to the cores. Where indicated in the particular specification the inner sheath may penetrate between the cores, thus forming a filling.

4.3.7.6 Metallic screen

The screen, if any, shall be applied over the assembled cores, in the form of a braid of plain or metal coated copper wires, or one or more tapes, a braid or a combination of a braid with tape(s). When choosing the material of the screen, special consideration shall be given to the possibility of corrosion, not only for mechanical safety but also for electrical safety.

The tape screen shall be applied helically in two layers so that the outertape 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. The minimum thickness of metal tape shall be 0,04mm.

Polyster tape of either 0,023mm or 0,050mm nominal thickness shall be applied over the screen with a minimum overlap of 15% of its total width.

The laminated electrostatic screening tape shall be applied with the metallic side in electrical contact with a braid. The minimum overlap of the laminated tape shall e 15% of its total width, to ensure coverage in case of bending the cable. The laminated tape shall be either alumminium bonded to polyester having a minimum thickness of aluminium of 0,008mm and a minimum thickness of polyster of 0,010mm, or copper bonded to polyester having a minimum thickness of copper of 0,018mm and a minimum thickness of polyster of 0,023mm.

The braid shall be composed of a number of strands of tinned annealed copper wires in the case of aluminium tape and either plain or tinned annealed copper wires in the case of copper laminated tape.

For a braid screen of wires there shall be no more than one splice in any spindle over any 100 mm length of the screen. The screen shall be applied evenly.

The filling factor K_r shall be according to the formula:

$$Kr = \frac{m \cdot n \cdot d}{2\pi\phi} \times \left[1 + \frac{\pi^2\phi^2}{L^2}\right]^{0,5}$$

The filling factor Kr shall be 0,55 minimum. For a combination of a braid with tape(s), the filling factor Kr shall be 0,37 minimum.

ϕ = diameter under the screen+ 2d
d = nominal diameter of a wire
m = total number of spindles
n = number of wires per spindle
L = screening pitch

4.3.7.7 Textile braid

The material for the yarns may be based on natural material (cotton, or treated cotton) or on synthetic material (polyamide, etc.) or else may be filaments made of glass or equivalient material.

The braid shall have a uniform texture, without knots or gaps. Braids made from glass filaments shall be prevented from fraying.

Note Fraying of glass braids may be prevented by use of a suitable quality of glass, or by treatment of each filament or the compelte braid with a suitable coating.

4.3.8 Sheath

4.3.8.1 Material

The sheath materials shall be selected from the follows: TM1, TM3, EM8, TMPU and XM1 in accordance with EN 50363. Thermoplastic material (TM7) is also recommended, the requirement of which refers to Table 3.

4.3.8.2 Application

The sheath shall be applied by extrusion and shall consist of a single layer.

Assemblies of cores shall be surrounded by tapes, or an inner covering, or an inner sheath or by the sheath itself, or by a combination of these according to the particular specification. In all cases there shall be no substantial cavities between the assembled cores and the next immediate layer.

4.3.8.3 Thickness

The minimum value of thickness shall not be less than 0,4mm.

4.3.8.4 Colour

The colour shall be throughout the whole of the sheah or on its suface.

Where surface colouring is applied, the surface colour shall be essentially the same materials as the underlying material and shall be applied as part of the extrusion process. The surface colour shall not be separable from the underlying material and shall be durable. Durability shall be checked by the test given in 5.1 of EN 50396.

4.3.9 Marking

4.3.9.1 General requirements

The cable should be marked as follows:

a) Trade mark;
b) Code designation;
c) Number and size of conductors.
d) Approval mark (TÜV mark,TÜV Rheinland logo or other approval mark.)
e) Cable class

The marking may be provided by printing, indenting or embossing on the outside surface.

4.3.9.2 Trade mark

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.

4.3.9.3 Code designation

Each cable shall be provided with a code designation according to clause 4.1.1 applied consecutively.

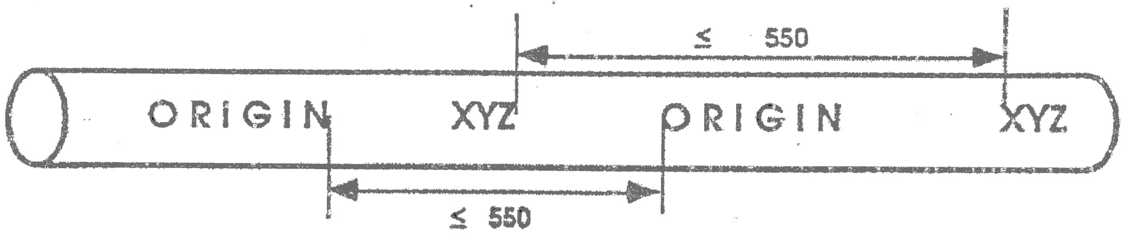
4.3.9.4 Arrangement of marking

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

– 550mm, for marking on sheath;

Following figure shows an example of marking on sheath.

Dimensions in millimetres



Picture 1

4.3.9.5 Durability

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

4.3.9.6 Legibility

All markings shall be legible.

4.4 Guideline for use (informative)

Table 1 – compound of insulation and sheath

1	2	3	4
Code designation	Compound of insulation	Compound of sheath	max. conductor operating temperature
IRS05VV IRS07VV	Ordinary PVC	Ordinary PVC	+70°C
IRS05V4V4 IRS07V4V4	XLPVC	XLPVC	+70°C
IRS05NV IRS07NV	PE	Heat resistant PVC	+90°C
IRS05V2V2 IRS07V2V2	Heat resistant PVC	Heat resistant PVC	+90°C
IRS05EE IRS07EE	Thermoplastic elastomer(TPE)	Thermoplastic elastomer(TPE)	+90°C
IRS05EQ IRS07EQ	Thermoplastic elastomer(TPE)	Polyurethane	+90°C
IRS05V2Q IRS07V2Q	Heat resistant PVC	Polyurethane	+90°C
IRS05YQ IRS07YQ	ETFE	Polyurethane	+90°C
IRS05ZZ IRS07ZZ	Crosslinked insulating compound	Crosslinked sheathing compound	+90°C

4.5 Tests on complete cables

4.5.1 Gerneral

The tests to be carried out on complete cables shall be as scheduled in each part. Each test shall be designated as a Type test (T); Sample test (S) or Routine test(R).

4.5.2 Electrical requirements

The cables shall have adequate dielectric strength and insulation resistance.

Compliance shall be checked by carring out the relevant tests using the methods specified in Table 3. The cables shall meet the requirements shown in Table 3.

Where single core cables are spark tested in accordance with EN 50395, 10.2 and the thickness of the insulation and sheath combined, is greater than 3mm the test voltage shall be either 19kV a.c. or 28kV d.c.

Table 2 – Requirements for electrical tests for cables

1	2	3	4	5		6
Ref No	Test	Unit	Test method described in EN 50395	requirement		Category of test
				300/500V	450/750V	
1	**Measurement of the resistance of conductor**		5			S, T
1.1	Values to be obtained, max.			a		
2	**Voltage test on complete cable**		6			S, T
2.1	Test conditions:					
	- minimum length of the sample	m		20		
	- minimum period of immersion in water	h		1		
	- temperature of the water	°C		20±5		
2.2	Voltage applied (a.c.)	V		2000	2500	
2.3	Duration of each application of voltage, minimum	min		15		
2.4	Result to be obtained			No breakdown		
3	**Voltage test on cores**		7			T
3.1	Test conditions:					
	- minimum length of the sample	m		5		
	- minimum period of immersion in water	h		1		
	- temperature of the water	°C		20±5		
3.2	Voltage applied (a.c.)	V		1500	2000	
3.3	Duration of each application of voltage, minimum	min		5		
3.4	Result to be obtained			No breakdown		

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Table 2 – Requirements for electrical tests for cables *(continued)*

1 **Ref No**	2 **Test**	3 **Unit**	4 **Test method described in EN 50395**	5 **requirement**	6 **Category of test**
4	**Measurement of insulation volume resistivity**				T
4.1	Cables ≤ 90°C		8.1		
4.1.1	Test conditions:				
	- length of sample fro the previous voltage test (ref no. 2)	m		5	
	- minimum period of immersion in hot water	h		2	
	- temperature of the water	°C		20	
4.1.1.1	Result to be obtained (minimum value)	Ω.cm		e	
4.1.2	Test conditions:				
	- length of sample fro the previous voltage test (ref no. 2)	m		5	
	- minimum period of immersion in hot water	h		2	
	- temperature of the water	°C		b	
4.1.2.1	Result to be obtained (minimum value)	Ω.cm		e	
5	**Long term resistance of insulation to d.c.**		9		T
5.1	Test conditions:				
	- length of the sample	m		5	
	- duration of test	h		240	
	- temperature of the water	°C		60±5	
	- d.c.voltage applied	V		220	
5.2	Result to be obtained			No breakdown or damage to the surface	
6	**Check on absence of faults o insulation**				R
6.1	Spark test		10.2		
6.1.1	Test condition			c	
6.1.2	Result to be obtained			No breakdown	

Table 2 – Requirements for electrical tests for cables *(continued)*

1 Ref No	2 Test	3 Unit	4 Test method described in EN 50395	5 requirement	6 Category of test
7	**Surface resistance of sheath**		**11**		**T**
7.1	Test conditions:				
	- voltage applied, d.c.	V		100 to 500	
	- duration of test	min		1	
7.2	Result to be obtained	Ω		$\geq 10^9$	
8	**Transfer impendance[d]**		**12**		**T**
	- frequency	MHz		30	
	Result to be obtained	mΩ/m		250	

[a] See EN 60228 and particular specifications

[b] maximum conductor temperature in normal operation

[c] See test method referred to in column 4

[d] This test shall be done to signal/control cores with screen and complete cable with screen before and after the mechanical testing .

[e] See table C.1

4.5.3 Sheath marking

The marking on the sheath shall comply with the requirements stated in clause 4.3.9. They shall be checked by visual examination and measurement.

4.5.4 Overall dimensions

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

The difference between any two values of the overall diameter of sheathed circular cables at the same cross-section (ovality) shall not exceed 15% of the upper limit specified for the mean overall diameter. This requirement is not valid for drag chain cable.

Compliance shall be checked by the tests given in 4.4 of EN 50396.

4.5.6 Assessment of halogen

Where a particular requirements is specified by the manufacturer, such as cable descried as “halogen-free”, the procedure descriebed in Annex B of EN 50525-1 shall be used.

4.5.7 Weathering/UV resistance on sheath

Where a particular requirements is specified by the manufacturer, such as cable descried as “UV resistance”, the procedure descriebed in Annex E of EN 50618:2014 shall be used.

4.5.8 Special test requirements for LF or HF cables

Where a robot cable is identified as LF or HF, a special test requirement shall be followed as table M.1

4.5.9 Explosion atmosphere

Where a particular requirements is specified by the manufacturer, such as cable descried as “EX”, the procedure descriebed in Annex E of EN 60079-14:2013 shall be used.

Table 3 – Requirements for thermoplastic materials

1	2	3	4		5	6
Ref No	Test	Unit	Test method described in		Insulation	Sheath
			EN	Clause	TI6	TM7
1	**Mechanical properties**					
1.1	Properties before ageing		60811-501			
1.1.1	Values to be obtained for tensile strength					
	- median value, min.	N/mm^2			10,0	10,0
1.1.2	Values to be obtained for elongation at break					
	- median value, min.	%			300	300
1.2	Properties after ageing in oven		60811-401			
1.2.1	Test conditions					
	- temperature	°C			135	135
	- duration of treatment	h			168	168
1.2.2	Values to be obtained for tensible strength					
	- median value, min.	N/mm^2			-	-
	- Variation, max.	%			±25	±25
1.2.3	Values to be obtained for elongation at break					
	- median value, min.	%			-	-
	- Variation, max.	%			±25	±25
2	Shrinkage test		60811-503			
2.1	Test conditions					
	- temperature	°C			200	-
	- duration	h			1	-
	- length of sample	mm			300	-
2.2	Results to be obtained					
	- max. shrinkage	%			2	-

Table 3 – Requirements for thermoplastic materials *(continued)*

1	2	3	4		5	6
Ref No	**Test**	**Unit**	**Test method described in**		**Insulation**	**Sheath**
			EN	**Clause**	**TI6**	**TM7**
3	Pressure at high temperature		60811-508			
3.1	Test conditions					
	- force exerted by blade (K-value)				See column 4	See column 4
	- temperature	°C			90±2	90±2
	- Duration of heating under load	h			See column 4	See column 4
3.2	Results to be obtained					
	- Median of the depth of penetration, max.	%			50	50
4	Cold bending test		60811-504			
4.1	Test conditions					
	- temperature	°C			-15±2	-15±2
	- duration	h			16	16
4.2	Results to be obtained				No cracks	No cracks
5	Cold elongation test		60811-505			
5.1	Test conditions					
	- temperature	°C			-15±2	-15±2
	- duration	h			16	16
5.2	Results to be obtained				No cracks	No cracks
	- elongation, min.	%			30	30
6	Ozone reistance		50396	8.1.3		
6.1	Test conditions					
	- temperature	°C			40±2	40±2
	- relative humidity	%			55±5	55±5
	- duration	h			72	72
	- ozone concentration (by volumn)	%			$(200\pm50)X10^{-6}$	$(200\pm50)X10^{-6}$
6.2	Results to be obtained				No cracks	No cracks

Table 3 – Requirements for thermoplastic materials *(continued)*

1	2	3	4		5	6
Ref No	Test	Unit	Test method described in		Insulation	Sheath
			EN	Clause	TI6	TM7
7	Water immersion test		60811-508			
7.1	Test conditions					
	- temperature	°C			-	80±2
	- duration				-	168
7.2	Mechanical properties after immersion		50525-3-11	Annex D		
7.2.1	Values to be obtained of tensile strength					
	- varation, max.	%			-	±30
7.2.2	Values to be obtained of elongation at break					
	- varation, max.	%			-	±35
8	Tear strength		50396	10.2		
	- mean value to be obtained, min.	N/mm			30	30

Table 4 – Requirements for polyethlene insulation material (PE)

1	2	3	4		5
Ref No	**Test**	**Unit**	**Test method described in**		**Requirements**
			EN	**Clause**	
1	**Mechanical properties**				
1.1	Properties before ageing		60811-501		
1.1.1	Values to be obtained for tensile strength				
	- median value, min.	N/mm^2			12,5
1.1.2	Values to be obtained for elongation at break				
	- median value, min.	%			300
1.2	Properties after ageing in oven		60811-401		
1.2.1	Test conditions				
	- temperature	°C			110
	- duration of treatment	h			168
1.2.2	Values to be obtained for tensible strength				
	- median value, min.	N/mm^2			-
	- Variation, max.	%			±30
1.2.3	Values to be obtained for elongation at break				
	- median value, min.	%			-
	- Variation, max.	%			±30
2	Shrinkage test		HD 605	2.4.4.3	
2.1	Test conditions				
	- temperature	°C			80
	- duration	h			5
	- length of sample	mm			500
2.2	Results to be obtained				
	- max. shrinkage	mm			7

Table 4 – Requirements for polyethlene insulation material (PE) *(continued)*

1	2	3	4		5
Ref No	**Test**	**Unit**	**Test method described in**		**Requirements**
3	Pressure at high temperature		60811-508		
3.1	Test conditions				
	- force exerted by blade (K-value)				-
	- temperature	°C			115
	- Duration of heating under load	h			6
3.2	Results to be obtained				
	- Median of the depth of penetration, max.	%			50
4	Cold bending test		60811-504		
4.1	Test conditions				
	- temperature	°C			-15±2
	- duration	h			16
4.2	Results to be obtained				No cracks
5	Cold elongation test		60811-505		
5.1	Test conditions				
	- temperature	°C			-15±2
	- duration	h			16
5.2	Results to be obtained				No cracks
	- elongation, min.	%			30
6	Carbon black content (max.)	%	60811-607		2,5±0,5

Table 4 – Requirements for ETFE insulation material (7Y)

1	2	3	4		5
Ref No	**Test**	**Unit**	**Test method described in**		**Requirements**
			EN	**Clause**	
1	**Mechanical properties**				
1.1	Properties before ageing		60811-501		
1.1.1	Values to be obtained for tensile strength				
	- median value, min.	N/mm^2			30
1.1.2	Values to be obtained for elongation at break				
	- median value, min.	%			150
1.2	Properties after ageing in oven		60811-401		
1.2.1	Test conditions				
	- temperature	°C			190±3
	- duration of treatment	h			336
1.2.2	Values to be obtained for tensible strength				
	- median value, min.	N/mm^2			30
	- Variation, max.	%			-
1.2.3	Values to be obtained for elongation at break				
	- median value, min.	%			150
	- Variation, max.	%			-
1.3	Heat shock		60811-508		
1.3.1	Test conditions				
	- temperature	°C			200±5
	- duration of treatment	h			6
1.3.2	Result to be obtained				No cracks
1.4	Melting point		DIN VDE 0472-621		
	Result to be obtained	°C			275±10
1.5	Density		60811-606	Suspension method	
	Result to be obtained	g/ml			1,6...1,8

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Annex A
(normative)

Tests for complete cable
Table A.1

1	2	3	4		5	6
Ref No	Test	Unit	Test method described in		requirement	Category of test
			standard	ciause		
1	Constructional and dimensional tests					S, T
1.1	Checking of compliance with constructional provisions		This standard	4.3		
1.2	Meansurenent of thickness of insualtion	mm	EN 50396	4.1	No less than stated in 4.3.3	
1.3	Meansurenent of thickness of sheath	mm	EN 50396	4.2/4.3	No less than stated in 4.3.9.3	
1.4	Measurement of overall dimensions					
1.4.1	- mean value	mm	EN 50396	4.4.1		
	- ovality	%	EN 50396	4.4.2	15%(max.)	
2	Insulation material test				As stated in 4.3.3 of this standard	T
3	Sheath material test				As stated in 4.3.9.1 of this standard	T
4	Compatility test		EN 60811-401		As stated in Annex B of this standard	T
5	Impact test at -15°C		EN 60811-506		No cracks	T
6	Test under fire condition		EN 60332-1-2			S, T
7	Fluid compatibility					
7.1	Resistance to mineral oil IRM902		EN 60811-404			T
7.1.1	Conditions					
	- Temperature	°C			50	
	- Duration of treatment	h			20	
7.1.2	Values to be obtained					
	- Tensile strength, variation	%			±30	
	- Elongation at break, variation	%			±30	

Tests for complete cable

Table A.1

1	2	3	4		5	6
Ref No	Test	Unit	Test method described in		requirement	Category of test
			standard	clause		
7.2	Resistance of sheath to against N-oxalic acid		EN 60811-404			T
7.2.1	Conditions					
	- Temperature	°C			23±5	
	- Duration of treatment	h			168	
7.2.2	Values to be obtained					
	- Tensile strength, variation	%			±30	
	- Elongation at break, min.	%			100	
7.3	Resistance of sheath to against N-sodium hydroxide		EN 60811-404			T
7.3.1	Conditions					
	- Temperature	°C			23±5	
	- Duration of treatment	h			168	
7.3.2	Values to be obtained					
	- Tensile strength, variation	%			±30	
	- Elongation at break, min.	%			100	

Tests for complete cable

Table A.1

1	2	3	4		5	6
Ref No	Test	Unit	Test method described in		requirement	Category of test
			standard	clause		
8	Life-Cycle estimation of mechanical strength on complete cable					
8.1	Flexing test for cables up to 4mm^2		EN 50396	6.2	1 000 000 cycles	T
8.2	Bending & Rotating test		This standard	Annex C	50 000 cycles	If required
8.3	Bending test		This standard	Annex D	30 000 flexing	If required
8.4	Cableveyor test		This standard	Annex E	5 000 000 flexing	If required
8.5	90 ° bending test for cables larger than 4mm^2		This standard	Annex F	1 000 000 cycles	T
8.6	2D Torsion test		This standard	Annex G	5 000 000 rotation	If required
	- Value of θ	°			±90 or ±180	
8.7	Vertical torsion test		This standard	Annex H	500 000 cycles	If required
8.8	3D torsion test		This standard	Annex I	5 000 000 moving	If required

Explanatory Remarks & Requirements:

The requirements of Ref. no. 8 are the minimum flexings, higher numbers can be tested if specified by the manufacturer.

The cables shall be loaded during the tests 8 with $I_n = I_3\sqrt{\frac{3}{n}}$ (in accordance with EN 50396 clause 6.2.4). For flexing test 8.1 the currect I_3 is 16 A for thermoplastic cables with a cross-sectional area of 4 mm^2.

Any deviation in regard to the loading shall be clearly recorded and shall be part of the specification and any certification documents.

For the tests Ref. no. 8.2 to 8.9 the test can be conducted with, without or differnet loading as agreed between manufacturer and user/testing organization.

For flexing test of Ref. no. 8.1 the cables with cross-sectional area less than 0,5mm^2 are usually not be required to be tested under load, loading is optional.

All tests except Ref. no. 8.1[4)] listed in Ref. No. 8 shall be done on three new specimens of each test by all of three checking methods mentioned below.

Evaluation / Results to be obtained:

1. There should be no cracks in sheath checked by normal or corrective vision.
2. The test samples should be immersed in water by a voltage at 1500V on cores for 1 minute (test method according to Clause 7 of EN 50395). No breadown shall occure.
3. The conductor resistance of the cables after test, shall comply with the requirements of IEC 60228 and with the specification of the manufacturer for new cable. The increase of conductor resistance after each test shall not exceed 5% of the value measured before the test.

Annex B
(normative)

Test of mutual influence

B.1 Conditions

The samples shall be aged in accordance with the designated test method, and for the following periods:

a) cables with a 70°C conductor operating temperature – 7 days at (80±2) °C;

b) cables with a 90°C conductor operating temperature – 14 days at (100±2) °C

B.2 Requirements

At the conlustion of the ageing period, the insulation and sheath shall meet the requirements given in table B.1 below.

Table B.1 –Requirements

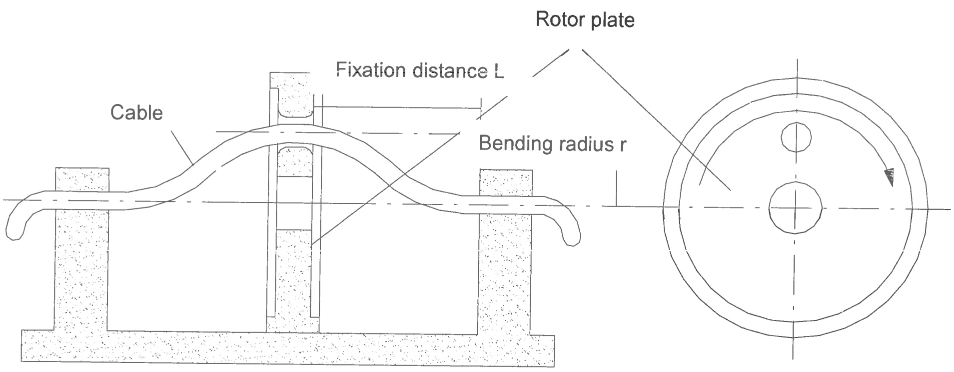
Tests		Units	Insulation						
			TI1	TI3	XI1	N	7Y	TI6	EI8
Tensile strength	– Median, min.	N/mm²	12,5	15,0	10,0	-	30	-	-
	– Variation[a]	%	± 20	± 25	± 25	± 25	-	±25	± 30
Elongation at break	– Median, min.	%	125	150	150	-	150	-	-
	– Variation[a]	%	± 20	± 25	± 20	± 25	-	±25	± 30

Tests		Units	sheath					
			TM1	TM3	XM1	TMPU	TM7	EM8
Tensile strength	– Median, min.	N/mm²	12,5	10,0	10,0	-	-	–
	– Variation[a]	%	± 20	± 25	± 25	± 30	±25	- 30
Elongation at break	– Median, min.	%	125	150	150	300	-	100
	– Variation[a]	%	± 20	± 25	± 20	± 30	±25	± 30

Annex C
(normative)

Bending & Rotating Test

Take three test samples with a length of 1,5m of each from the complete cable. Fix the test sample onto the tester by fully following Picture 2. In the picture, the fixation distance L is 300mm and the bending radius of the sample is 150mm. The rotor, onto which the sample is secured, rotates at a rate of 50 cycles per minute(shown in Picture 2).

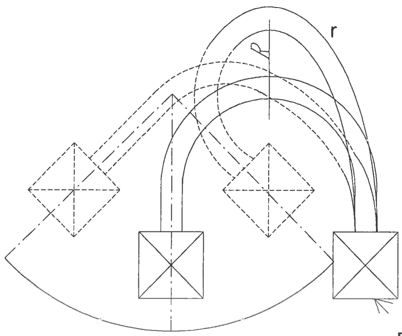


Picture 2

Annex D
(normative)

Bending Test

Take three samples of a length with 0,5m of each from the complete cable. Fix the sample shown as in Picture 3 below. The bending radius “r” is 6 times as much as the cable diameter “D”. The tester bends the sample at a rate of 200 flexing per minute.

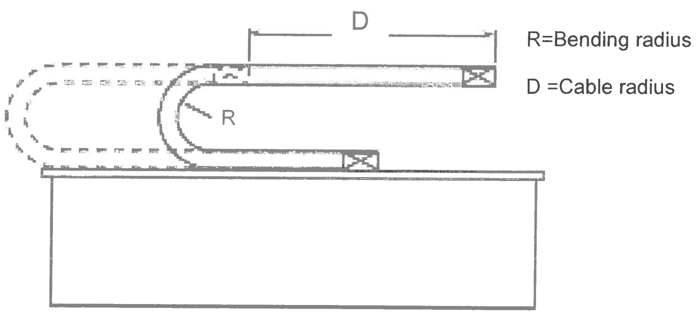


Picture 3

Annex E
(normative)

Cableveyor Test (Drag Chain Cable)

Take three samples of a length with 1,5m of each from the complete cable and put it in the cableveyor. The bending radius "R" is 6 times as much as the cable diameter "D". The cableveyor tester moves back and forth at a rate of 88 flexing per minute (as shown in picture 4).



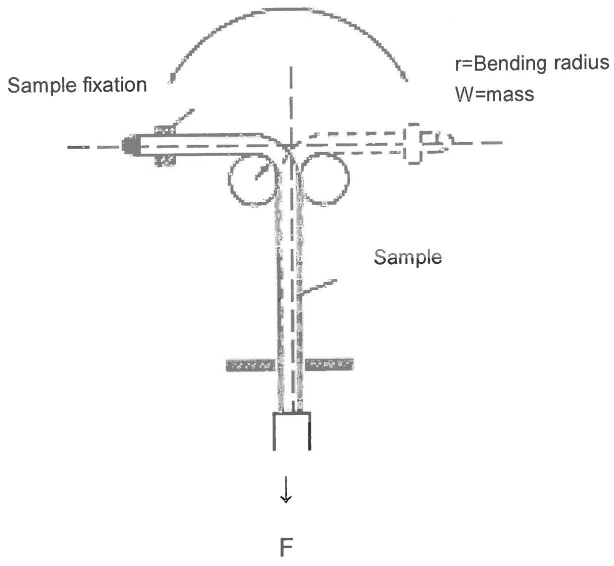
Picture 4

Annex F
(normative)

90 ° Bending Test

Take three samples of a length with 1m of each from the complete cable. As shown in Picture 5, fix one end of the sample onto the 90 ° tester with the other end tied with a force F. The tester bends at a rate of 40 cylces per minute. One cycle is bending through 180°.

- Bending radius r=2,5 x overall diameter of the cable
- A force F, which produces a tension of 5 N/mm^2 in the conductors



Picture 5

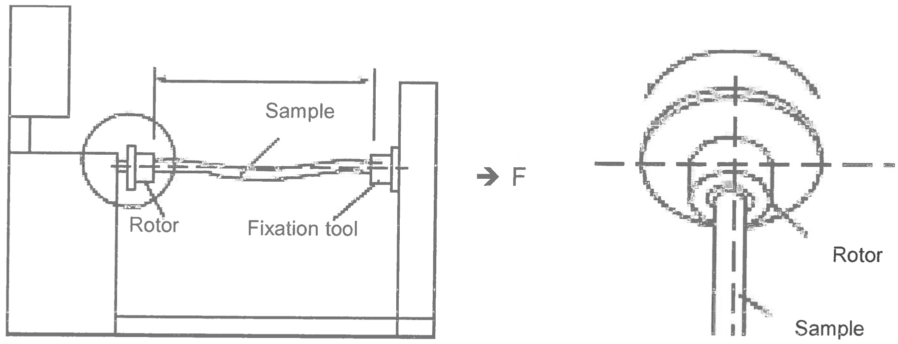
Annex G
(normative)

2D Torsion Test

This torsion test can be selected: straight-line torsion or curve torsion.

a. Straight-line Torsion: Picture 6-(a)

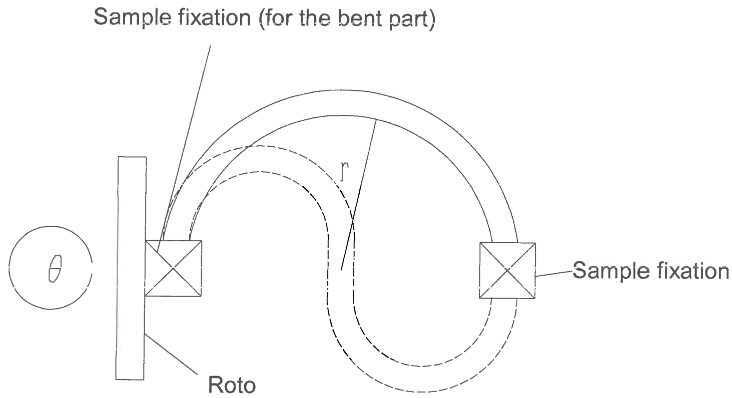
Take a sample of a length with 1m from the complete cable and fix it onto the tester by referring to Picture 6-(a). The rotor, with an angle of "θ", rotates at a rate of 60 rotations per minute. A force F, which produces a tension of 5 N/mm^2 in the conductors.



Picture 6-(a)

b. Curve Torsion: Picture 6-(b)

Take a sample of a length with 1m from the complete cable. Following Picture 6-(b), fix both sides onto the tester with a bending radius "r" 6 times as much as the cable diameter "D". The rotor, with an angle of "θ", rotates at a rate of 60 rotations per minute.



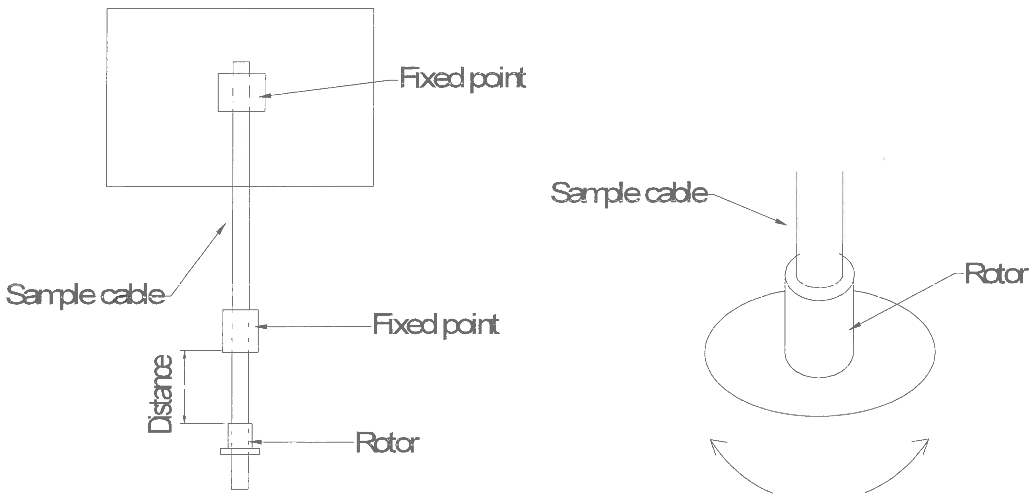
Picture 6（b）

Annex H
(normative)

Vertical Torsion Test

This test was developed that both positive torsion stress and negative torsion stress are applied on the cable during the test.

Take a sample of a length with 1,7m from the complete cable. Fix the sample onto the vertical torsion tester. The distance between the fixed point and the rotor is 20cm. The rotor, with a rotational angle of up to ±180°, turns at a rate of 12 cylces per minute. One cycle is moving through 360°.



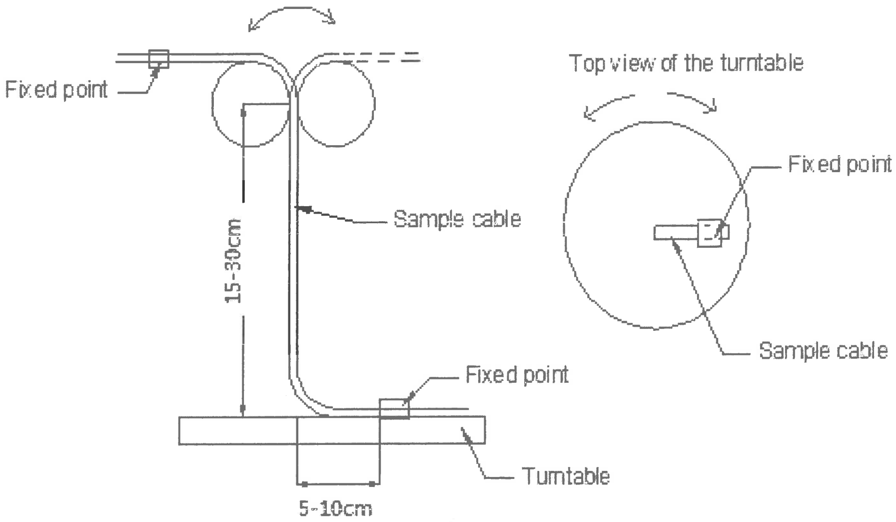
Picture 7

Annex I
(normative)

3D Torsion Test

The 3D torsion test was developed to make sure that torsion stress is applied on the sample cable from different directions during the test.

Take three samples of a length with 0,6m of each from the complete cable. Fix one end of the sample onto the upper part of the tester, where the upper part of the sample will bend in a range of 0 and 90°. Fix the other end of the sample table onto the turntable (the lower part of the tester) which moves in a range of 0 to ±180°. The tester rotates and bends the sample cable at a rate of 30 movings per minute. One moving is through 360°.



Picture 8

Annex J
(normative)

Insulation volume resistivity

Table K.1 –Requirements for insulation volume resistivity

Tests		Units	Insulation materials					
			PVC	XLPVC	PE	ETFE	Thermoplastic material	Crosslinked material
Insulation volumn resistivity	– 20°C	Ω.cm	10^{12}	10^{12}	10^{13}	10^{14}	$5X10^{12}$	10^{12}
	– note	Ω.cm	10^{9}	10^{9}	10^{10}	10^{11}	$5X10^{9}$	10^{9}
Note maximum conductor temperature in normal operation								

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ANNEX K
(normative)

Optional Test: B10 B10 / MCTF Estimation of Mechanical Life

The tests are carried our in accordance with Table A.1 for the selected test(s) 8.x. The selection of the tests is manufacturer's choice. All details on mechanical configuration and loading shall be recorded.

A minimum of 10 samples need to be testetd under identical conditions/severities, until failure occurs. The number of cycles at failure and a detailed failure description to be recorded. The MCTF and B10 shall be calculated from the test data using Maximum Likelyhood Estimate (MLE) or graphical method for the Weibull parameters β and η.

Failure modes to be detected during test:

- interruption of individual conductors (cores)
- short-circuit between cores or core and screen

MLE of Weibull Parameter β (shape parameter):

$$\left[\frac{\sum_{i=1}^{r} c_i^{\beta}\ln(c_i)+(n-r)\,C^{\beta}\,\ln(C)}{\sum_{i=1}^{r} c_i^{\beta}+(n-r)\,C^{\beta}}-\frac{1}{\beta}\right]-\frac{1}{r}\sum_{i=0}^{r}\ln(c_i)=0 \qquad (1)$$

n – number of items under test (sample size)
r – number of failed items (r ≤ n)
c_i – cycles to the i-th failure
C – cycles at which the test is stopped
β - shape parameter of the Weibull distribution

To be found is the value β for which the left side of equation (1) becomes zero.

MLE of Weibull Parameter η (scale parameter):

$$\hat{\eta}=\left\{\frac{1}{r}\left[\sum_{i=1}^{r} c_i^{\hat{\beta}}+(n-r)\,C^{\hat{\beta}}\right]\right\}^{\frac{1}{\hat{\beta}}} \qquad (2)$$

η – scale parameter of Weibull distribution

Point estimate of B_{10}:

$$\hat{B}_{10}=\hat{\eta}\left[\ln\left(\frac{1}{0,9}\right)\right]^{\frac{1}{\hat{\beta}}} \qquad (3)$$

$\hat{\beta}$ - result for β of equation (1)
(point estimate of shape parameter)

Lower confidence limit of B10

$$h_1 = \ln[-\ln(0{,}9)]$$

$$\delta_1 = \frac{-A_6 x^2 - r\,h_1 + x\sqrt{(A_6^{\,2} - A_4 A_5)\,x^2 + rA_4 + 2rh_1 A_6 + rA_5 h_1^{\,2}}}{r - x^2 A_5}$$

with $x = u_p$
(from table D.2 IEC 61649,
fractiles of the normal distribution)

p	0,010	0,025	0,050	0,100	0,4
u_p	2,326 3	1,960 0	1,644 9	1,281 6	0,253 3

Unless otherwise specified: $p = 0{,}1 \rightarrow u_p = 1{,}2816$

$$A_4 = 0{,}49\left(\frac{r}{n}\right) - 0{,}134 + 0{,}622\left(\frac{r}{n}\right)^{-1}$$

$$A_5 = 0{,}2445\left(1{,}78 - \frac{r}{n}\right)\left(2{,}25 + \frac{r}{n}\right)$$

$$A_6 = 0{,}029 - 1{,}083\,\ln\left(1{,}325\,\frac{r}{n}\right)$$

Factor Q_1 (quality):

$$Q_1 = \exp\left(-\frac{\delta_1 + h_1}{\hat{\beta}}\right)$$

$B_{10\,|\,\text{lower limit}}$:

$$\underline{B_{10} = Q_1 \cdot \hat{B}_{10}} \qquad (4)$$

ANNEX L
(informative)

Application Guide – Current Carrying Capacity

Table L.1 – examples of current-carry capacity of cables under steady-state conditions in an ambient air temperature of +40°C for different mtehods of installation

	Installation method			
	B1	**B2**	**C**	**E**
Cross-sectional area mm²	**Current-carrying capacity I_z for three phase circuits A**			
0,75	8,6	8,5	9,8	10,4
1,0	10,3	10,1	11,7	12,4
1,5	13,5	13,1	15,2	16,1
2,5	18,3	17,4	21	22
4	24	23	28	30
6	31	30	36	37
10	44	40	50	52
16	59	54	66	70
25	77	70	84	88
35	96	86	104	110
50	117	103	125	133
70	149	130	160	171
95	180	156	194	207
120	208	179	225	240
Electronic (pairs)				
0,20	Not applicable	4,3	4,4	4,4
0,5	Not applicable	7,5	7,5	7,8
0,75	Not applicable	9,0	9,5	10

NOTE 1 The values of the current-carrying capacity are based on:

- one symmetrical three-phase for cross-sectional areas 0,75mm^2 and greater
- one control circuit pair for cross-sectional areas between 0,2mm^2 and 0,75mm^2

Where more loaded cables/pairs are installed, derate the values the of Table 6 in accordance with Table D.2 or D.3 of IEC 60204-1:2005.

Note 2 For ambient temperatures other than 40°C, correct the current-carrying capacities by using values given in Table D.1 of IEC 60204-1:2005.

Note 3
Method B1: using conduits and cable trunking systems for holding and protecting conductors or single core cables
Method B2: same as B1but used for multicore cables
Method C: multicore cables installed in free air, horizontal or vertical without gap between cables on walls
Method E: multicore cables in free air, horizontal or vertical laid on open cables trays

ANNEX M
(normative)

Special requirements for HF and LF cables

Table M.1 – Electrical requriements of robot cables for communication purpose

<table>
<tr><th colspan="2">Conductors</th><th colspan="3">Test Requirements</th></tr>
<tr><th>Cross-sectional area
mm²</th><th>Maximum conductor resistance at 20°C
Ω/km</th><th>Voltage test on cores test voltage
V</th><th>Voltage test on complete cable
V</th><th>Duration of each application of voltage
min</th></tr>
<tr><td>0,12</td><td>153</td><td>500 a.c.</td><td>1000 a.c.</td><td rowspan="4">1</td></tr>
<tr><td>0,2</td><td>97,8</td><td rowspan="2">1000 a.c.</td><td rowspan="2">1500 a.c.</td></tr>
<tr><td>0,3</td><td>67,9</td></tr>
<tr><td>0,5</td><td>37,5</td><td>1500 a.c.</td><td>2000 a.c.</td></tr>
<tr><td colspan="5">NOTE
1. When an energy cable is combined with LF or HF cores, the test condition of voltage test on communication cores shall be in accordance with the conditions of this table.
2. HF and LF cables or cores are not intended for direct connection to main power supply.</td></tr>
</table>