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INTERNATIONAL STANDARD

Electrical installations in ships –
Part 353: Power cables for rated voltages 1 kV and 3 kV

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CONTENTS

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Part 353: Power cables for rated voltages 1 kV and 3 kV

FOREWORD

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IEC 60092-353 has been prepared by Subcommittee 18A: Electric cables for ships and mobile and fixed offshore units of IEC Technical Committee 18: Electrical installations of ships and of mobile and fixed offshore units. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Updated references to IEC 60092-350 for general construction and test methods and IEC 60092-360 for insulating and sheathing materials.
b) Added subclause 5.10: Construction for special applications.
c) Added Table 9: Additional test for cables for installation between areas with and without explosive atmospheres.

d) Deleted the test requirement IEC 60331-21 from Table 7.

e) Deleted the former Annex A (Alternative enhanced insulation thickness for 0,6/1 kV).

The text of this International Standard is based on the following documents:

Draft	Report on voting
18A/476/CDV	18A/482/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all the parts of the IEC 60092 series, under the general title *Electrical installations in ships*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 353: Power cables for rated voltages 1 kV and 3 kV

1 Scope

This part of IEC 60092 is applicable to shipboard and offshore non radial field power cables with extruded solid insulation, having a voltage rating of 0,6/1 (1,2) kV or 1,8/3 (3,6) kV intended for fixed installations.

Cables designed to maintain circuit integrity during a fire are included.

The various types of power cables are given in 5.1. The constructional requirements and test methods are aligned with those indicated in IEC 60092-350, unless otherwise specified in this document.

The object of this document is:

– to standardize cables whose safety and reliability is ensured when they are installed in accordance with the requirements of IEC 60092-352 or IEC 61892-4,

– to lay down standard manufacturing requirements and characteristics of such cables directly or indirectly bearing on safety, and

– to specify test methods for checking conformity with those requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-461, *International Electrotechnical Vocabulary – Part 461: Electric cables*

IEC 60079-14:2013, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 60092-350:2020, *Electrical installations in ships – Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications*

IEC 60092-360, *Electrical installations in ships – Part 360: Insulating and sheathing materials for shipboard and offshore units, power, control, instrumentation and telecommunication cables*

IEC 60228, *Conductors of insulated cables*

IEC 60331-1, *Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*

IEC 60331-2, *Tests for electric cables under fire conditions – Circuit integrity – Part 2: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter not exceeding 20 mm*

IEC 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 60332-3-22, *Tests on electric and optical fibre cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*

IEC 60445, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60684-2, *Flexible insulating sleeving – Part 2: Methods of test*

IEC 60754-1, *Test on gases evolved during combustion of materials from cables – Part 1: Determination of the halogen acid gas content*

IEC 60754-2, *Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement) and conductivity*

IEC 61034-2, *Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60092-350 and in IEC 60050-461 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

4 General requirements

4.1 Rated voltage

The standard method of designating the rated voltages of cables covered by this document shall take the following form:

$$U_o/U\ (U_m)$$

where

U_o is the rated power-frequency voltage between phase conductor and earth or metallic screen, for which the cable is designed;

U is the rated power-frequency voltage between phase conductors for which the cable is designed;

U_m is the maximum value of the “highest system voltage” for which the equipment (including cable) may be used (see IEC 60038).

All voltages are given as RMS values.

The standard rated voltages U_o/U (U_m) of the cables considered in this document are the following:

$$U_o/U\ (U_m) = 0{,}6/1\ (1{,}2)\ \text{kV and } 1{,}8/3\ (3{,}6)\ \text{kV}$$

For 0,6/1 (1,2) kV cables, DC voltage up to a maximum of 1,5 times the AC voltage may be used provided that the voltage to earth does not exceed 0,9 kV.

4.2 Markings

4.2.1 Indication of origin and voltage identification

Cables shall comply with IEC 60092-350:2020, 4.1.3, with respect to

a) indication of origin,
b) rated voltage and cable construction (number of cores and cross-sectional area of the construction),
c) continuity of marking, and
d) durability and legibility.

4.2.2 Continuity of marking

The marking is deemed to be continuous if the distance between the end of any marking and the beginning of the next does not exceed:

a) 550 mm if the marking is on the outer surface of the cable, and
b) 275 mm in all other cases.

4.2.3 Core identification

4.2.3.1 General

Cable cores shall be clearly identified by either colours or numbers.

4.2.3.2 Coloured cores

The core colours shall be in accordance with IEC 60445.

4.2.3.3 Numbered cores – Multicore cables

Identification shall be made by inscription of numbers on each core starting from the center beginning with 1 in accordance with Annex A.

5 Constructional requirements

5.1 General description

5.1.1 Overview

Shipboard and offshore cables for fixed installations shall be single or multicore cables generally constructed as follows.

5.1.2 Unarmoured cables (excluding 1,8/3 kV)

a) Single-core unarmoured unsheathed cable

- copper conductor, see 5.2;
- insulation applied as a single layer of insulating compound of one of the types described in 5.3 with an enhanced thickness equivalent to that of a combined insulation and outer sheath for use in unarmoured cables installed in an adequately protected environment (see 5.3.3 for the thickness).

b) Unarmoured single- or double-sheathed cable

- copper conductor, see 5.2;
- insulation, see 5.3;
- cabling (for multicore cables), see 5.4;
- inner covering (optional, but mandatory when a braided or a metal tape electrostatic screening is applied over the core lay-up), see 5.5;
- electrostatic screening (optional), see 5.6;
- inner sheath (optional), see 5.7;
- outer sheath applied as either one- or two-layer systems, see 5.9.

5.1.3 Armoured cables

a) Armoured single-sheathed cable with outer sheath only

- copper conductor, see 5.2;
- insulation, see 5.3;
- cabling (for multicore cables), see 5.4;
- inner covering below electrostatic screening (optional, but mandatory when a braided or a metal tape electrostatic screening is applied over the core lay-up), see 5.5;
- electrostatic screening (optional), see 5.6;
- inner covering (optional, but mandatory in case of a braid armour of galvanised steel wires in which case the inner covering shall be extruded), see 5.5;
- braid armour, see 5.8;
- outer sheath applied as either one- or two-layer systems, see 5.9.

NOTE Variable frequency drives induce specific electrical constraints on the connected power cables (for example voltage peaks, harmonics, reflection or earthing method among other electrical stresses).

b) Armoured double-sheathed cable with inner and outer sheath

- copper conductor, see 5.2;
- insulation, see 5.3;
- cabling (for multicore cables), see 5.4;
- inner covering (optional, but mandatory when a braided or a metal tape electrostatic screening is applied over the core lay-up), see 5.5;
- electrostatic screening (optional), see 5.6;
- inner sheath, see 5.7;
- braid armour, see 5.8;
- outer sheath applied as either one- or two-layer systems, see 5.9.

c) Armoured single-sheathed cable with inner sheath only

- copper conductor, see 5.2;
- insulation, see 5.3;
- cabling (for multicore cables), see 5.4;
- inner covering (optional, but mandatory when a braided or a metal tape electrostatic screening is applied over the core lay-up), see 5.5;
- electrostatic screening (optional), see 5.6;
- inner sheath, see 5.7;
- braid armour, see 5.8.

Cables for installation in spaces where corrosion can occur, for example weather decks, wet locations, battery compartments, refrigeration rooms, should have an outer sheath over the braid, unless the braid itself is corrosion resistant.

5.2 Conductors

The material, metal coating, class and form of the conductors shall be in accordance with IEC 60092-350. For cables having rated voltage 1,8/3 kV, only circular stranded compacted or non-compacted conductors with a minimum cross-section of 10 mm^2 are permitted. A separator between conductors and insulation is permitted.

5.3 Insulation

5.3.1 Material

The insulating compounds and their designations shall be as given in IEC 60092-360, as follows:

– for 0,6/1 (1,2) kV cables, types EPR, HEPR, XLPE, HF 90 or S 95 shall be used;

– for 1,8/3 (3,6) kV cables, types only EPR, HEPR, XLPE shall be used.

The insulation system shall consist of one of the options a) to c) as listed in IEC 60092-350:2020, 4.3.1.

5.3.2 Application

The application shall be as detailed in IEC 60092-350:2020, 4.3.2.

5.3.3 Thickness of insulation

The thickness of the insulation shall be as specified in Table 1 hereinafter and meet the requirements of IEC 60092-350:2020, 4.3.3.

For single-core unarmoured unsheathed cables (see 5.1.2 a)), the total insulation thickness shall be the sum of

a) the thickness t_j as specified in Table 1, and

b) the thickness as calculated in accordance with 5.9.3 a), with fictitious diameter $D = d_L + 2\ t_i$ (see also IEC 60092-350:2020, A.3.1 and A.3.2). The total thickness shall meet the requirements of IEC 60092-350:2020, 4.3.3.

Table 1 – Insulation thickness

Nominal cross sectional area of conductor	0,6/1 kV		1,8/3 kV	
	EPR S 95	HEPR HF90 XLPE	EPR	HEPR XLPE
mm^2	mm	mm	mm	mm
1	1,0	0,7	–	–
1,5	1,0	0,7	–	–
2,5	1,0	0,7	–	–
4	1,0	0,7	–	–
6	1,0	0,7	–	–
10	1,0	0,7	2,2	2,0
16	1,0	0,7	2,2	2,0
25	1,2	0,9	2,2	2,0
35	1,2	0,9	2,2	2,0
50	1,4	1,0	2,2	2,0
70	1,4	1,1	2,2	2,0
95	1,6	1,1	2,4	2,0
120	1,6	1,2	2,4	2,0
150	1,8	1,4	2,4	2,0
185	2,0	1,6	2,4	2,0
240	2,2	1,7	2,4	2,0
300	2,4	1,8	2,4	2,0
400	2,6	2,0	2,6	2,0
500	2,8	2,2	2,8	2,2
630	2,8	2,4	2,8	2,4

For cables which include inorganic tape(s) or varnished glass braid to confer fire resistance (limited circuit integrity), all the values of insulation given in Table 1 shall be increased by 0,20 mm for subsequent consideration in the calculation of fictitious diameters.

5.4 Cabling (including fillers and binders)

Cores of a multicore cable shall be laid up, and the interstices filled if necessary with fillers, inner covering or inner sheath (outer sheath in the case of unarmoured cables) according to IEC 60092-350:2020, 4.5.

5.5 Inner covering

5.5.1 General

The inner covering, if any, may be extruded (mandatory below galvanized steel wire braid) or lapped. The relevant material and characteristics shall be in accordance with IEC 60092-350:2020, 4.6.

5.5.2 Thickness of inner covering

The values of the (approximate) thickness of extruded inner covering for the calculation of fictitious diameters are given in Table 2.

Table 2 – Thickness of extruded inner covering and fictitious diameters

Fictitious diameter over laid up cores		Thickness of extruded inner covering
Above	Up to and including	(approximate value)
mm	mm	mm
–	25	1,0
25	35	1,2
35	45	1,4
45	60	1,6
60	80	1,8
80	–	2,0

The values of the (approximate) thickness of lapped covering for the calculation of the fictitious diameters are 0,4 mm for fictitious diameter over laid-up cores up to and including 40 mm and 0,6 mm for larger diameters.

NOTE For the calculation of fictitious diameter, see IEC 60092-350:2020, Annex A and Annex C.

5.6 Screen

5.6.1 Construction

5.6.1.1 General

The screen, if any, shall be a collective metallic screen and shall be in accordance with IEC 60092-350:2020, 4.4.2, and shall consist of one or more tapes, a braid or a combination of a braid with tape(s).

5.6.1.2 Combination of connected metal and polyester tape

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

The drain wire shall be composed of a number of strands of tinned annealed copper wires in the case of aluminium laminate tape and either plain or tinned annealed copper wires in the case of copper laminate tape. The drain wire shall have a maximum resistance in accordance with Table 3.

Table 3 – Requirements of drain wire

Nominal area of conductor of the cores	Maximum drain wire resistance
mm^2	Ω/km
1,0 to 1,5	28,3
2,5 and above	21,2

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

A screen consisting of a laminated electrostatic screening tape and a drain wire is not suitable for carrying large short-circuit currents and should not be grounded with the protective earth conductor of the applicable power circuit.

5.6.1.3 Metal tape

The specified nominal thickness for a plain metal tape shall be ≥ 0,1 mm.

5.6.1.4 Braid

The specified nominal diameter for the braiding wires shall be ≥ 0,2 mm.

5.6.2 Application

The screen, if any, shall be applied over the inner covering in case of a braided or a metal tape screen (see 5.1.2 and 5.1.3).

5.7 Inner sheath

5.7.1 Material

The inner sheathing compound and its designation shall be one of those given in IEC 60092-360.

5.7.2 Application

The application shall be as detailed in IEC 60092-350:2020, 4.7.2.

5.7.3 Thickness of inner sheath

The thickness of the inner sheath is given as a function of the internal diameter of the sheath under consideration, the fictitious diameter being calculated by the method given in IEC 60092-350:2020, Annex A and Annex C.

The formula is the following:

a) for double-sheathed unarmoured cable as in 5.1.2 b):

t_1 = 0,025 D + 0,6 mm, with a minimum thickness of 0,8 mm;

b) for armoured cable as 5.1.3 b) and c):

t_1 = 0,04 D + 0,8 mm, with a minimum thickness of 1,0 mm for construction 5.1.3 b) and 1,4 mm for construction 5.1.3 c)

where D is the fictitious diameter under the inner sheath.

The thickness at any point shall satisfy the requirements given in IEC 60092-350:2020, 4.7.3.

5.8 Braid armour

5.8.1 General

In this document, only metal braid armours are specified, the braid wires being of copper, copper alloy, galvanized or stainless steel.

Joints in the braiding wires shall be soldered, twisted or woven-in, and the complete braid shall not be jointed. The braid shall be evenly applied.

The armour may serve as a collective metallic screen (see 5.6).

NOTE In some countries, the use of an armour as an earthing collective metallic screen is prohibited for legal reasons.

5.8.2 Braid wire diameter

Irrespective of the metal used, the nominal diameter of the braid wire shall be

- 0,2 mm, as a minimum, for cables having fictitious diameter under the braid ≤ 10 mm,
- 0,3 mm, as a minimum, for cables having fictitious diameter under the braid > 10 mm and ≤ 30 mm, and
- 0,4 mm, as a minimum, for cables having fictitious diameter under the braid > 30 mm.

5.8.3 Coverage density

The coverage density of the braid shall be in accordance with IEC 60092-350:2020, 4.8.2.

NOTE In case the alternative method in accordance with IEC 60092-350:2020, 4.8.2, is used to evaluate the coverage density, the mean diameter of the braid to be used is the fictitious diameter under the braid plus two times the nominal diameter of the braiding wires.

5.8.4 Application of the armour

The armour shall be applied in such a way that it shall neither adhere to the inner covering or inner sheath nor to the outer sheath.

5.9 Outer sheath

5.9.1 Material

The outer sheathing compound and its designation shall be one of those given in IEC 60092-360.

5.9.2 Application

The application shall be as detailed in IEC 60092-350:2020, 4.9.2.

5.9.3 Thickness of outer sheath

The thickness of outer sheath is given as a function of the internal diameter of the sheath under consideration, the fictitious diameter being calculated by the method given in IEC 60092-350:2020, Annex A and Annex C.

The formula is the following:

a) for unarmoured or armoured single-sheathed cables as in 5.1.2 a) and b) and 5.1.3 a):

t_1 = 0,04 D + 0,8 mm with a minimum thickness of 1,0 mm

where D is the fictitious diameter under the sheath

b) for unarmoured double-sheathed cables as in 5.1.2 b):

t_2 = 0,025 D + 0,9 mm, with a minimum thickness of 1,0 mm

c) for armoured double-sheathed cables as in 5.1.3 b):

t_2 = 0,025 D + 0,6 mm, with a minimum thickness of 0,8 mm

The thickness at any point shall satisfy the requirements given in IEC 60092-350:2020, 4.9.3.

5.9.4 Colour of outer sheath

The outer sheath shall be coloured black or grey, or, for fire resistant cables, orange, unless otherwise specified by the purchaser at the time of ordering.

5.10 Construction for special applications

5.10.1 Cables for installation in areas with explosive atmospheres

Cables for installation in areas with explosive atmospheres (zone 1 or zone 2) shall be armoured with a braid for earth detection according to 5.6.

This design is recommended for all kinds of hazardous areas.

5.10.2 Cables for installation between areas with and without explosive atmospheres

Cables for installation between areas with and without explosive atmospheres shall fulfil the technical requirements of IEC 60079-14, special requirements for cables. Cables shall contain as less as possible open spaced in the geometry. Therefore, they shall be filled out with solid fillers or other materials for inner covering.

6 Tests – Methods and requirements

The tests shall be carried out according to Table 4 to Table 9 where applicable.

Table 4 – Tests applicable to all cables

Test	Applicability – all types of cable unless otherwise stated	Status	Method –subclause number given in IEC 60092-350:2020	Requirement – as in IEC 60092-350 unless otherwise stated
Measurement of electrical resistance of conductors		Routine	5.2.2	IEC 60228
Voltage test		Routine	5.2.3	–
Voltage test on sheath	Armoured cables	Routine	5.2.3.4	–
Insulation resistance test		Sample	7.2	–
Conductor examination		Sample and type	6.4	–
Check of cable dimensions – thickness of insulation – thickness of non metallic sheaths (excluding inner coverings) – external diameter		Sample and type	 6.5 and 8.2 6.6 and 8.3 6.7	 – – –
Hot set test	HEPR, EPR, XLPE, HF 90, S 95 insulations and SH, SE, SHF2 sheaths	Sample	6.8	IEC 60092-360
Coverage density of braid	Braid armoured cables	Type	4.8.2	

Test	Applicability – all types of cable unless otherwise stated	Status	Method –subclause number given in IEC 60092-350:2020	Requirement – as in IEC 60092-350 unless otherwise stated
Insulation resistance measurement at maximum rated temperature		Type	7.2.2	IEC 60092-360
Increase in AC capacitance after immersion in water		Type	7.3	IEC 60092-360
High-voltage test for 4 h		Type	7.7.9	
Mechanical properties of insulation before and after ageing		Type	8.4	IEC 60092-360
Mechanical properties of sheath before and after ageing		Type	8.5	IEC 60092-360
Additional ageing compatibility test		Type	8.6	IEC 60092-360
Loss of mass test	PVC ST2 sheath	Type	8.7	IEC 60092-360
Behaviour at high temperature	PVC ST2 and SHF1 sheaths	Type	8.8	IEC 60092-360
Behaviour at low temperatures	PVC ST2, SHF1 and SHF2 sheaths	Type	8.9	IEC 60092-360
Test for coating of copper wires		Type	8.11	
Galvanizing test		Type	8.12	
Resistance to cracking heat shock	PVC ST2 and SHF1 sheaths	Type	8.13	IEC 60092-360
Ozone resistance	HEPR, EPR, HF90 insulations and SH, SE, SHF2 sheaths	Type	8.14	IEC 60092-360
Hot oil immersion	SE1, SH and SHF2 sheaths	Type	8.15.1	IEC 60092-360
Fire-retardant tests: IEC 60332-1-2 and IEC 60332-3-22		Type	8.17.1 8.17.2	IEC 60332-1-2 and IEC 60332-3-22 in which case cables shall be installed in the touching configuration on the front of the ladder.
Determination of hardness	HEPR insulation	Type	8.18	IEC 60092-360
Determination of modulus of elasticity	HEPR insulation	Type	8.19	IEC 60092-360
Durability of marking		Type	8.20	The marking shall remain legible following the test as given in IEC 60092-350:2020, 8.20.

Table 5 – Additional tests required for halogen-free cables

Test	Status	Method – subclause number given in IEC 60092-350:2020	Requirement – as in IEC 60092-350 unless otherwise stated
Acid gas emission	Type	8.17.4	IEC 60754-1
pH and conductivity	Type	8.17.5	IEC 60754-2
Fluorine content test	Type	8.17.6	IEC 60684-2

Table 6 – Additional test required for low smoke cables

Test	Status	Method – subclause number given in IEC 60092-350:2020	Requirement – as in IEC 60092-350 unless otherwise stated
Smoke emission test for cables insulated and sheathed with halogen-free materials. When tested according to IEC 61034-2	Type	8.17.3	The test is satisfactory for the finished cables if the levels of light transmittance exceed 60 % throughout the test.
NOTE The smoke emission test is in general applicable to halogen-free cables. See also Table 5.			

Table 7 – Additional test required for fire resistant cables

Test	Status	Method –subclause number given in IEC 60092-350:2020	Requirement – as in IEC 60092-350 unless otherwise stated
Test for fire resistance (limited circuit integrity)	Type	8.17.7	The test shall be carried out in accordance with IEC 60331-1 or IEC 60331-2 and the minimum time to failure shall be 90 min.

Table 8 – Additional tests required for specific performances

Test	Status	Method –subclause number given in IEC 60092-350:2020	Requirement – as in IEC 60092-350 unless otherwise stated
Special test for low temperature behaviour	Type	8.10	
Enhanced hot oil immersion	Type	8.15.2	IEC 60092-360
Drilling fluid test	Type	8.16	IEC 60092-360

Tests on cables for installation in explosive atmospheres

Test shall be provided according to Table 4 to Table 8 for braided armoured cables.

Additional tests on cables for installation between areas with and without explosive atmospheres see Table 9.

Table 9 – Additional test for cables for installation between areas with and without explosive atmospheres

Test	Status	Method – given in IEC 60079-14:2013	Requirement
Test for limitation of the gas flow through the cable	Type	Annex E	The test shall be carried out in accordance with IEC 60079-14:2013, Annex E. Test shall be provided without armour.
NOTE IEC 60079-14:2013, Annex E, is informative and could become normative in the future.			