

INTERNATIONAL STANDARD

**Electrical installations in ships –
Part 378: Optical fiber cables**

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INTERNATIONAL STANDARD

**Electrical installations in ships –
Part 378: Optical fiber cables**

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IEC 60092-378 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.

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

Draft	Report on voting
18A/488/FDIS	18A/493/RVD

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 parts in the IEC 60092 series, published 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

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ELECTRICAL INSTALLATIONS IN SHIPS –

Part 378: Optical fibre cables

1 Scope

This part of IEC 60092 is applicable to shipboard and offshore optical fibre cables, intended for fixed installations.

Cables designed to maintain functional integrity during fire given in 6.1 and to be installed in explosive atmospheres given in 6.2 are included.

The various types of optical fibre cables are given in Clause 6. 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 60092-401 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.

All cables described in this document, are halogen-free as per Table 4.

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 (IEV) – 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 60092-352, *Electrical installations in ships – Part 352: Choice and installation of electrical cables*

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 60092-401, *Electrical installations in ships – Part 401: Installation and test of completed installation*

IEC 60304, *Standard colours for insulation for low-frequency cables and wires*

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 60331-25, *Tests for electric cables under fire conditions – Circuit integrity – Part 25: Procedures and requirements – Optical fibre cables*

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 60332-3-24, *Tests on electric and optical fibre cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C*

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

IEC 60754-2:2011, *Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement) and conductivity*

IEC 60794-1-1:2023, *Optical fibre cables – Part 1-1: Generic specification – General*

IEC 60794-1-21, *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical tests methods*

IEC 60794-1-22, *Optical fibre cables – Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods*

IEC 60794-1-23, *Optical fibre cables – Part 1-23: Generic specification – Basic optical cable test procedures – Cable element test methods*

IEC 60793-1-40, *Optical fibres – Part 1-40: Attenuation measurement methods*

IEC 60794-1-111, *Optical fibre cables – Part 1-111: Generic specification – Basic optical cable test procedures – Mechanical tests methods – Bend, method E11*

IEC 61892-4, *Mobile and fixed offshore units – Electrical installations – Part 4: Cables*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60092-350, IEC 60050-461 and IEC 60794-1-1 apply.

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

4 General requirements

4.1 Temperature range of the cables

The optical fibre cables specified in this document shall be designed for an operating temperature range from $-25\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$. Another temperature range can be agreed between manufacturer and customer.

4.2 Markings

4.2.1 Indication of origin and fibre identification

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

- a) indication of origin,
- b) fibre type and cable construction (number of fibres and type of fibres),
- 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 beginning of any marking and the beginning of the next does not exceed 1 000 mm if the marking is on the outer surface of the cable. If the marking contains a length/meter indication, it shall be continuous and not restart from 000.

4.3 Fibre identification

4.3.1 General

Fibres shall be clearly identified by colours.

4.3.2 Colours of fibres in loose tubes

Colours for cables with up to 12 fibres in a loose tube shall be a match to IEC 60304. Fibres in cables with more than 12 fibres in a loose tube shall be coded in suitable manner.

4.4 Colours of units as buffer tubes, loose tubes and subunits of breakout cables

Units of the cable shall be uniquely identified.

The colours of loose tubes shall be a match to IEC 60304.

Colour code or colour sequence of loose tubes shall be agreed between customer and manufacturer.

Subunits of breakout cables shall be identified by number printing or colour code and shall be agreed between customer and manufacturer.

NOTE Examples of colour code for buffer tubes in breakout cables are given in IEC 60794-2.

Tight-buffered fibres in distribution cables shall be identified by colour code and shall be agreed between customer and manufacturer.

5 Construction requirements

5.1 General description

5.1.1 Overview

Shipboard and offshore cables for fixed installations shall be loose tube design or breakout design or tight-buffered distribution cable design cables generally constructed as follows and adhering to the designs found in IEC 60794 series.

Other designs can be agreed between manufacturer and purchaser.

5.1.2 Unarmoured cables

Unarmoured single or double-sheathed cable.

- optical fibres, see 5.2;
- tensile strength elements see 5.3;
- cabling (for multicore cables), see 5.4;
- inner covering (optional), see 5.5;
- inner sheath (optional), see 5.6;
- outer sheath applied as either one- or two-layer systems, see 5.8.

5.1.3 Armoured cables

Armoured double-sheathed cable with inner and outer sheath.

- optical fibres, see 5.2;
- tensile strength elements see 5.3;
- cabling (for multicore cables), see 5.4;
- inner covering (optional), see 5.5;
- inner sheath, see 5.6;
- braid armour, see 5.7;
- outer sheath applied as either one- or two-layer systems, see 5.8.

NOTE The use of a thermoplastic inner sheath (SHF1) is not compatible with cross-linking technology of elastomeric outer sheath.

5.2 Optical fibres

Fibres can be single mode optical fibres according to IEC 60793-2-50 or multimode optical fibres according to IEC 60793-2-10. Different fibre types can be mixed in the cable.

Cabled fibre attenuation requirements are given in Table 1 and Table 2.

Table 1 – Multimode fibre maximum cable attenuation coefficient (dB/km)

Cabled optical fibre category	Attenuation coefficient at 850 nm	Attenuation coefficient at 1 300 nm
ISO/IEC 11801-1, OM1 ^a category	3,5	1,5
ISO/IEC 11801-1, OM2 ^a category	3,5	1,5
ISO/IEC 11801-1, OM3 category	3,5	1,5
ISO/IEC 11801-1, OM4 category	3,5	1,5
ISO/IEC 11801-1, OM5 category	3,0	1,5
^a OM1 and OM2 are no longer supported by ISO/IEC but are shown here for completeness.		

Table 2 – Single-mode fibre maximum cable attenuation coefficient (dB/km)

Cabled optical fibre category	Attenuation coefficient at 1 310 nm	Attenuation coefficient at 1 550 nm	Attenuation coefficient at 1 625 nm
ISO/IEC 11801-1, OS1a category	1,0	1,0	n/a
ISO/IEC 11801-1, OS2 category	0,4	0,4	n/a

5.3 Tensile strength elements

The cable shall be designed with sufficient strength members to meet the requirements of this document.

Either the strength members or the anti-buckling members or both can be non-metallic and can be located in the cable core or under the sheath or in the sheath.

5.4 Cabling

Cabling shall be according to IEC 60092-350:2020, 4.5.

The units of multi loose tube cables and breakout cables as well as the tight-buffered fibres in distribution cables shall be stranded around a central element.

The interstices can be filled if necessary, with fillers or binders.

Cables with only one loose tube cannot be stranded.

5.5 Inner covering

5.5.1 General

The inner covering, if any, can be extruded 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 nominal thickness of extruded inner covering shall be minimum 1,0 mm.

5.6 Inner sheath

5.6.1 General

Inner sheath is optional for unarmoured cables and mandatory for armoured cables with braid armour.

5.6.2 Material

The inner sheathing compound and its designation shall be one of the halogen-free types given in IEC 60092-360.

5.6.3 Application

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

5.6.4 Thickness of inner sheath

The nominal sheath thickness (Dt) is defined as follows:

Sheath thickness $Dt = 0,04 \cdot Df + 0,5$ mm with a minimum thickness of 1,0 mm.

Df is the diameter under the sheath.

The mean value of the thickness, and the thickness at any point, shall satisfy the descriptions given in IEC 60092-350:2020, 4.9.3.

5.7 Braid armour

5.7.1 General

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

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

5.7.3 Coverage density

The coverage density G of the braid is calculated with the following method:

$$F = (mnd / 2\pi(D + 2d)) \left(1 + \pi^2(D + 2d)2/L^2\right)^{1/2} \quad (1)$$

$$G = \pi \times F \times 100/2 \quad (2)$$

F is the filling factor

d is the diameter of the braid wire

m is the total number of spindles

n is the total number of ends per spindle

D is the measured diameter below braid (diameter of inner sheath)

L is the lay length of the braiding wire

C coverage density of the braid in %

The coverage density G shall be ≥ 60 %.

5.7.4 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.

5.8 Outer sheath

5.8.1 Material

The outer sheathing compound and its designation shall be one of the halogen-free types given in IEC 60092-360.

5.8.2 Application

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

5.8.3 Thickness of the sheath

The nominal sheath thickness (Dt) is defined as follows:

Sheath thickness $Dt = 0,04 \cdot Df + 0,5$ mm with a minimum thickness of 1,0 mm.

Df is the diameter under the sheath.

The mean value of the thickness, and the thickness at any point, shall satisfy the descriptions given in IEC 60092-350:2020, 4.9.3.

5.8.4 Colour of the outer sheath

In case of fire-resistant cables, the outer sheath shall be orange.

In case of cables for hazardous areas, the outer sheath shall be blue.

For all other cables, the outer sheath shall be coloured depending on fibres category used in the cable according to Table 3.

Otherwise, the colour can be specified by the purchaser at the time of ordering.

Table 3 – Colour of outer sheath

Fibre category	Sheath colour
IEC 60793-2-10, A1-OM1 sub-category	grey
IEC 60793-2-10, A1-OM2 sub-category	green
IEC 60793-2-10, A1-OM3 sub-category	aqua
IEC 60793-2-10, A1-OM4 sub-category	magenta
IEC 60793-2-10, A1-OM5 sub-category	lime
IEC 60793-2-50, all categories	yellow

6 Construction for special applications

6.1 Fire resistant cables

Fire resistant cables shall guarantee complete functional integrity during fire, including defined data transmission characteristics according to Table 7.

6.2 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 5.7.

Braided armouring of cables installed in areas with explosive atmospheres to be effectively earthed at least on both ends. Where there is risk of intermitted contact between armour and exposed metalwork, non-metallic sheath is to be appeared over metallic armour of cables.

This design shall be applied to all the hazardous areas.

6.3 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.

Cables should contain as little open space as possible in the cross section of the cable. Therefore, the spaces shall be filled out with solid fillers or other materials for inner covering.

6.4 Cables with special metallic identification element

Fibre optic cables can contain special metallic identification elements. These elements can be realized by copper wires, metallic braid or metallic foil.

7 Test methods and requirements

7.1 General requirements

The tests shall be carried out according to Table 4 to Table 6 where applicable. The terms and definitions given in IEC 60092-350 apply for type tests, sample tests and routine tests.

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
Check of cable dimensions Thickness of non-metallic sheaths (excluding inner coverings) External diameter		Sample and type	6.6 and 8.3 6.7	
Hot set test	SHF2 sheaths only	Sample	6.8	IEC 60092-360
Coverage density of braid	Braid armoured cables	Type		The coverage density shall be $\geq 60\%$
Mechanical properties of sheath before and after ageing		Type	8.5	IEC 60092-360
Additional ageing compatibility test		Type	8.6	IEC 60092-360
Behaviour at high temperature	SHF1 sheaths	Type	8.8	IEC 60092-360
Behaviour at low temperatures	SHF1 and SHF2 sheaths	Type	8.9	IEC 60092-360
Galvanizing test		Type	8.12	
Resistance to cracking heat shock	SHF1 sheaths	Type	8.13	IEC 60092-360
Ozone resistance	SHF2 sheaths	Type	8.14	IEC 60092-360
Hot oil immersion	SHF2 sheaths	Type	8.15.1	IEC 60092-360
Flame-spread tests: IEC 60332-1-2 and IEC 60332-3-24		Type	8.17.1 8.17.2	IEC 60332-1-2 and IEC 60332-3-24 in which case cables shall be installed in the touching configuration on the front of the ladder.
Durability of marking		Type	8.20	-
Attenuation		Routine	IEC 60793-1-40, method C	See 5.2, Table 1 and Table 2
Tensile performance		Type	IEC 60794-1-21, method E1	$T_S = 1\,000\text{ N}$ (minimum value) or the weight of 1 km cable, the higher value is valid. No attenuation change after remove of load; maximum fibre strain during load 0,6 %; after remove of load no fibre strain.
Temperature cycling		Type	IEC 60794-1-22, method F1 cable sample length at least 100 m, length of the fibre under test 100 m; $T_{A2} -25\text{ }^{\circ}\text{C}$; $T_{B2} +70\text{ }^{\circ}\text{C}$; number of cycles 3	Maximum change of attenuation 0,3 dB at 1 550 nm for single mode fibres and 0,5 dB at 1 300 nm for multi mode fibres; no change of attenuation after the test.

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
Crush		Type	IEC 60794-1-21, method E3A 1 500 N 10 min (long-term); 3 tests with at least 500 mm spacing between Multimode measured at 1 300 nm Singlemode measured at 1 550 nm	No change of attenuation during the test and after the test.
Crush		Type	IEC 60794-1-21, method E3A 2 500 N 1 min (short-term); 3 tests with at least 500 mm spacing between Multimode measured at 1 300 nm Singlemode measured at 1 550 nm	No change of attenuation after the test.
Impact		Type	IEC 60794-1-21, method E4 3 impacts on one place frequency 30 impacts per minute Impact energy 2 Nm; striking surface radius 300 mm Multimode measured at 1 300 nm Singlemode measured at 1 550 nm	No change of attenuation after the test.
Kink		Type	IEC 60794-1-21, method E10 Minimum loop diameter 20 x cable diameter	No kink.
Tube kinking	Loose tube cables	Type	IEC 60794-1-23, method G7 L = 60 mm L1 = 350 mm L2 = 100 mm 5 cycles	No kinking of the tube.

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
Bend		Type	IEC 60794-1-111, method E11A diameter of mandrel for unarmoured cables 20x cable diameter diameter of mandrel for armoured cables 40x cable diameter 4 turns 3 cycles Multimode measured at 1 300 nm Singlemode measured at 1 550 nm	No change of attenuation after the test.
Acid gas emission		Type	8.17.4	-
pH and conductivity		Type	8.17.5	IEC 60754-2:2011+AMD1:2019 weighted values according to 8.3. The requirement is in IEC 60092-350 for the complete cable performance.
Fluorine content test		Type	8.17.6	IEC 60684-2
No change in attenuation shall be according to IEC 60794-1-1.				
NOTE See IEC 60794-1-1:2023, Annex B for guidelines for fibre selection for cable testing.				

Table 5 – 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 at least 60 % throughout the test.

Table 6 – Additional tests required for specific performances

Test	Status	Method – subclause number given in IEC 60092-350	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

7.2 Additional tests on cables with functional integrity during fire

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 Multimode measured at 1 300 nm Singlemode measured at 1 550 nm	The test shall be carried out in accordance with IEC 60331-1 or IEC 60331-2 or IEC 60331-25. During the flaming period shall be measured the attenuation of the fibres. The attenuation increase during the test shall not be higher than 3 dB and the minimum time of the flaming period shall be 90 min, 120 min or 180 min.
NOTE The test apparatus for the test procedure defined in IEC 60331-25 is detailed in IEC 60331-11.			

7.3 Tests on cables for installation in explosive atmospheres

Tests shall be provided according to Table 4 for armoured cables, and if required according to Table 5 and Table 6.

7.4 Tests on cables for installation between areas with and without explosive atmospheres

Tests shall be provided according to Table 4 to Table 6 where applicable and Table 8.

Table 8 – 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	See IEC 60079-14:2013, Annex E Test shall be provided without armour.

7.5 Tests on cables with special metallic identification element

Tests shall be provided according to Table 4 to Table 6 where applicable and Table 9.

Table 9 – Additional test on cables with special metallic identification element

Test	Status	Method – given in IEC 60092-350:2020	Requirement
Test for electrical continuity of the metallic identification element	Routine	5.2.3	Test of electrical continuity with a voltage rate of max. 50 V RMS

8 Recommendations for the installation of fibre optic cables on board of ships and offshore units

Recommendations for the installation of fibre optic cables on board of ships and offshore units are given in Annex A.