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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Optical fibres – Part 1-54: Measurement methods and test procedures – Gamma irradiation

Fibres optiques – Partie 1-54: Méthodes de mesure et procédures d'essai – Irradiation gamma

IEC 60793-1-54:2018-01(en-fr)

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International Standard IEC 60793-1-54 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition published in 2012. This edition constitutes a technical revision.

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

a) test conditions related to photobleaching have been changed;
b) the test length has been modified to yield a total induced attenuation in the test sample at the end of the irradiation between 3 dB and 10 dB.

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

FDIS	Report on voting
86A/1833/FDIS	86A/1848/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60793 series, published under the general title *Optical fibres*, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

OPTICAL FIBRES –

Part 1-54: Measurement methods and test procedures – Gamma irradiation

1 Scope

This document outlines a method for measuring the steady state response of optical fibres and optical cables exposed to gamma radiation. It can be employed to determine the level of radiation-induced attenuation produced in Class B single-mode or Class A, category A1 and A2 multimode optical fibres, in either cabled or uncabled form, due to exposure to gamma radiation.

The attenuation of cabled and uncabled optical fibres generally increases when exposed to gamma radiation. This is primarily due to the trapping of radiolytic electrons and holes at defect sites in the glass (i.e. the formation of "colour centres"). This test procedure focuses on two regimes of interest: the low dose rate regime suitable for estimating the effect of environmental background radiation, and the high dose rate regime suitable for estimating the effect of adverse nuclear environments. The testing of the effects of environmental background radiation is achieved with an attenuation measurement approach similar to IEC 60793-1-40 method A, cut-back. The effects of adverse nuclear environments are tested by monitoring the power before, during and after exposure of the test sample to gamma radiation. The depopulation of colour centres by light (photo bleaching) or by heat causes recovery (lessening of radiation induced attenuation). Recovery can occur over a wide range of time which depends on the irradiation time and annealing temperature. This complicates the characterization of radiation induced attenuation since the attenuation depends on many variables including the temperature of the test environment, the configuration of the sample, the total dose and the dose rate applied to the sample and the light level used to measure it.

This test is not a material test for the non-optical material components of a fibre optic cable. If degradation of cable materials exposed to irradiation is studied, other test methods will be used.

This test method is written to contain a clear, concise listing of instructions. The background knowledge that is necessary to perform correct, relevant and expressive irradiation tests as well as to limit measurement uncertainty is presented separately in IEC TR 62283.

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 60793-1-40, *Optical Fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

IEC 60793-1-44, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 60793-1-46, *Optical fibres – Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance*

IEC 61280-4-1, *Fibre-optic communication subsystem test procedures – Part 4-1: Installed cable plant – Multimode attenuation measurement*

3 Terms and definitions

No terms and definitions are listed in this document.

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 Apparatus

4.1 General

Attention is drawn to the fact that strict regulations and suitable protective facilities are to be adopted in the laboratory for this test. Carefully selected trained personnel shall be used to perform this test. It can be extremely hazardous to test personnel if it is improperly performed or without qualified conditions.

4.2 Radiation source

4.2.1 Testing of environmental background radiation

A ^{60}Co or equivalent ionising source shall be used to deliver gamma radiation. This environment is characterised by relatively low total dose and dose rate.

4.2.2 Testing of adverse nuclear environments

A ^{60}Co or equivalent ionizing source(s) shall be used to deliver gamma radiation. This environment is characterised by higher total dose and dose rate.

4.3 Optical source

An optical source such as a white light source, laser or light emitting diode emitting at wavelengths compatible with the optical fibres under test shall be used. The wavelength of the source shall be according to the detailed specification.

The optical source shall be stable in intensity over a time period sufficient to perform the measurement. The power coupled from the source into the test sample shall be −30 dBm (1,0 µW) with a tolerance of ± 2 dBm or as specified in the detail specification. The optical source may be modulated with a pulsed signal at a 50 % duty cycle, if a lock-in amplifier is used.

4.4 Optical filters/monochromators

Unless otherwise specified, wavelength tolerances of ± 20 nm shall be obtained by filtering the optical source with a set of optical filters or a monochromator. The 3 dB optical bandwidth of the filters shall be less than or equal to 25 nm.

4.5 Cladding mode stripper

When necessary, a device that extracts cladding modes shall be employed at the input end and output end of the test sample. If the fibre coating materials are designed to strip cladding modes, a cladding mode stripper is not required.

4.6 Fibre support and positioning apparatus

A means of stable support for the input end of the test sample, such as a vacuum chuck, shall be arranged. This support shall be mounted on a positioning device so that the end of the test sample can be repeatedly positioned in the input beam.

4.7 Optical splitter

An optical splitter shall divert a small portion of the input light to a reference detector. The reference path shall be used to monitor system fluctuations for the duration of the test.

4.8 Input launch conditions

4.8.1 Class A, Category A1 fibres (graded index multimode fibres)

An equilibrium mode simulator shall be used to attenuate higher order propagation modes and to establish a steady-state mode condition near the input end of the fibre. The requirements

for the launch conditions for sub-category A1a graded index multimode fibre measurements are defined in IEC 61280-4-1.

4.8.2 Class A, Category A2 fibres (quasi-step and step index fibres)

Launch conditions shall be created as specified in the detail specification.

4.8.3 Class B fibres (single-mode fibres)

An optical lens system or fibre pigtail may be employed to excite the test fibre. The power coupled into the test sample shall be stable for the duration of the test. If an optical lens system is used, a method of making the positioning of the fibre less sensitive is to overfill the fibre end spatially and angularly. If a pigtail is used, it may be necessary to use index matching material to eliminate interference effects. A high order mode filter shall be employed to remove high order propagating modes in the wavelength range greater than or equal to the cut-off wavelength of the test fibre. The test condition specified in IEC 60793-1-44, method C, satisfies this requirement.

4.9 Detector – Signal detection electronics

An optical detector that is linear and stable over the range of intensities that are encountered shall be used. A typical system might include a photovoltaic mode photodiode amplified by a current input preamplifier, with synchronous detection by a lock-up amplifier.

4.10 Optical power meter

A suitable optical power meter shall be used to determine that the power coupled from the optical source into the test sample is equal to 1,0 µW or the level specified in the detail specification.

4.11 Radiation dosimeter

Thermo luminescent LiF or CaF crystal detectors (TLDs) or an ion chamber detector shall be used to measure the total radiation dose received by the specimen fibre.

4.12 Temperature-controlled container

Unless otherwise specified, the temperature-controlled container shall have the capability of maintaining the specified temperatures to within ± 2 °C.

4.13 Test reel

The test reel shall not act as a shield or sink for the radiation used in this test. Reels of wood, plastic or similar non-conducting materials would, in principle, act as transparent to the radiation. The additional absorption shall be taken into account for exact measurements.

An appropriate dose build-up layer of similar material shall be used.

5 Sampling and specimens

5.1 Specimens

5.1.1 Fibre specimen

The test specimen shall be a representative sample of the fibre specified in the detail specification.

5.1.2 Cable specimen

The test specimen shall be a representative sample of the cable described in the detail specification and shall contain at least one of the specified fibres.

5.2 Test sample length

Unless otherwise specified in the detail specification, the length of the test sample shall be chosen according to the expected induced attenuation and depends on the fibre type to be tested. The length shall be selected to yield a total induced attenuation in the test sample at the end of the irradiation of between 3 dB and 10 dB. The influence of the fibre leads connecting the test sample shall be minimised below 10 % of the total induced attenuation by

reducing their length, application of shielding, and selection of fibres with low radiation sensitivity. The irradiated length of the test sample shall be reported.

5.3 Test reel

The test sample shall be spooled onto a reel with a drum diameter of more than or equal to 10 cm, or that as specified in the detail specification. Allowance shall be made for the unspooling of a measured length of the test sample from each end of the reel to allow for attachment to the optical measurement equipment. An alternative deployment method allows the fibre to be loosely wound in a coil of specified diameter. The minimum bending radius shall be considered.

5.4 Ambient light shielding

The test sample shall be shielded from ambient light to prevent external photobleaching.

6 Procedure

6.1 General

The radiation tests differ in exposure dose, dose rate, exposure time and temperature. The tests are an environmental background radiation test and an adverse nuclear radiation test.

6.2 Calibration of radiation source

Calibration of the radiation source for dose uniformity and level shall be made prior to the test sample being set up in the chamber. Dose and dose rate measurements at four positions shall be made in the area of exposure where the test reel will be placed (four positions are used to get a representative average value).

6.3 Preparation and pre-conditioning

The test sample shall be preconditioned in the temperature chamber at (25 ± 5) °C for 1 h prior to testing, or at the test temperature for a preconditioned time as specified in the detail specification.

The input end of the short test length shall be placed in the positioning device and aligned in the test set to obtain maximum optical power as measured with a calibrated power meter.

The power at the input end of the test sample shall be measured with a calibrated power meter. If necessary, the source power level shall be adjusted so that the power at the input end of the fibre is 1,0 µW or as specified in the detail specification.

With the radiation source off, the input end of the test sample shall be positioned to obtain maximum optical power at the detector. Once set, the input launch conditions shall not be changed during the gamma irradiation portion of the test.

A suitable continuous measurement device shall be connected to the detection system so that a continuous power measurement can be made. The measurement equipment shall be set up such that the detection signal does not exceed the limits of the equipment.

Before starting the irradiation the stability of the measurement setup shall be obtained. The total fluctuation shall be below 10 % of the total induced attenuation at the end of irradiation.

A ^{60}Co or equivalent ionizing source(s) shall be used to deliver gamma radiation at a desired dose rate. The time required to turn the radiation source on or off shall be < 10 % of the total exposure time.

It is important that the temperature is kept constant during the tests. If the test should be performed at different temperatures, then the attenuation prior to irradiation has to be measured for different temperatures for each specified wavelength.

6.4 Attenuation measurement for environmental background radiation

An attenuation measurement of the test sample shall be performed, at the specified test wavelengths, in accordance with IEC 60793-1-40, method A, cut-back. The attenuation a_1 of

the fibre prior to exposure to the gamma radiation source shall be recorded. The environmental temperature shall be the same as during the up-coming irradiation tests when the initial attenuation measurement is performed.

Unless otherwise specified in the detailed specification, environmental background radiation effects, due to exposure to gamma radiation, shall be determined by subjecting the test sample to a nominal dose rate of 0,02 Gray/hour (Gy/h). The test sample shall be exposed to a total dose of 0,1 Gray (Gy). Different dose rates and total dose can be called for in the detail specification in order to simulate particular specific conditions.

Upon completion, and within 2 h of the irradiation process, an attenuation measurement of the test sample shall be performed in accordance with IEC 60793-1-40, method A, cut-back. The attenuation a_2 of the test sample after exposure to the gamma radiation source shall be recorded.

6.5 Attenuation measurement for adverse nuclear environment

The monitoring of the change of optical transmittance of the test sample shall be performed, at the specified test wavelengths, in accordance with method IEC 60793-1-46.

The output power P_B from the sample prior exposure to the gamma radiation source shall be recorded.

Unless otherwise specified in the detailed specification, adverse nuclear radiation effects, due to exposure to gamma radiation, shall be determined by subjecting the test sample to a nominal dose rate of 1 000 Gy/h. The test sample shall be exposed to a dose of 1 000 Gy. Different dose rates and total dose can be called for in the detail specification in order to simulate particular specific conditions.

The output power from the sample shall be recorded for the duration of the gamma irradiation cycle. With help of the initial attenuation measurements, prior irradiation, one can determine the radiation induced attenuation in the fibre.

The power shall also be recorded for at least 15 min after completion of the irradiation process or as specified in the detail specification. The power level of the reference detector shall also be recorded during the recovery time after completion of the irradiation process.

7 Calculations

7.1 Change in optical attenuation Δa (environmental background radiation test)

$$\Delta a = a_2 - a_1 \text{ dB} \quad (1)$$

where

a_1 is the attenuation of the test sample prior to exposure to gamma radiation;

a_2 is the attenuation of the test sample after exposure to gamma radiation.

7.2 Change in optical transmittance, a (adverse nuclear environmental radiation test)

The change in optical transmittance a shall be calculated for each wavelength by using the following formula (testing of adverse nuclear environment):

$$a_0 = -10 \lg (P_0/P_B) \text{ dB} \quad (2)$$

$$a_{15} = -10 \lg (P_{15}/P_B) \text{ dB} \quad (3)$$

where

P_0 is the power output of the test sample within 1 s after irradiation is discontinued, unless otherwise specified;

P_{15} is the power output of the test sample 15 min after irradiation is discontinued, unless otherwise specified;