IEC 60793-1-54

Edition 2.0 2012-10

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 60793-1-54:2012

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FOREWORD

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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 second edition cancels and replaces the first edition, published in 2003. It constitutes a technical revision.

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

– launching conditions and optical sources have been reviewed and are better defined.

This bilingual version (2013-07) corresponds to the monolingual English version, published in 2012-10.

The text of this standard is based on the following documents:

CDV	Report on voting
86A/1413/CDV	86A/1433/RVC

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

The French version of this standard has not been voted upon.

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

A list of all parts of the IEC 60793 series can be found, under the general title *Optical Fibres*, on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication 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- withdrawn,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 part of IEC 60793 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 may 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 to be studied, other test methods will be required.

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.

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.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 Apparatus

3.1 Radiation source

3.1.1 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.

3.1.2 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.

3.2 Optical source

An optical source such as a lamp, laser or light emitting diode emitting at wavelengths compatible with the optical fibres under test shall be used.

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) or as specified in the detail specification. The optical source shall be modulated with a pulsed signal at a 50 % duty cycle.

NOTE If a source that couples more than 1,0 µW is used, photo bleaching may occur.

3.3 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.

3.4 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.

3.5 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.

3.6 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.

3.7 Input launch conditions

3.7.1 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.

3.7.2 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.

3.7.3 Class A, category A2 fibres (quasi-step and step index fibres)

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

3.8 Detector – Signal detection electronics

An optical detector which 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.

3.9 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 less than or equal to 1,0 µW or the level specified in the detail specification.

3.10 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.

3.11 Temperature controlled container

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

3.12 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.

4 Sampling and specimens

4.1 Specimens

4.1.1 Fibre specimen

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

4.1.2 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.

4.2 Specimen for environmental background radiation test

Unless otherwise specified in the detail specification, the length of the test sample shall be (3 000 ± 30) m. (Where reactor constraints dictate smaller lengths, the length of the test sample may be (1 100 ± 20) m.) A minimum length at the ends of the test sample (typically 5 m) shall reside outside of the test chamber and be used to connect the optical source to the detector. The irradiated length of the test sample shall be reported.

4.3 Specimen for testing adverse nuclear environments

Unless otherwise specified in the detail specification, the length of the test sample shall be (250 ± 2,5) m. (When test conditions require a high total dose and dose rate a shorter test sample length may be necessary). A minimum length at the ends of the test sample (typically 5 m) shall remain outside of the test chamber and be used to connect the optical source to the detector. The irradiated length of the test sample shall be reported.

4.4 Test reel

The test sample shall be spooled onto a reel with a drum diameter that is 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.

4.5 Ambient light shielding

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

5 Procedure

5.1 General

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

5.2 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. Four TLDs shall be placed in the area of exposure and the centre of the TLDs shall be placed where the axis of the test reel will be placed. (Four TLDs are used to get a representative average value.) A dose equal to or greater than the actual test dose shall be used to calibrate the system. To maintain the highest possible accuracy in measuring the test dose, the TLDs shall not be used more than once.

5.3 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 less than 1,0 µW or as specified in the detail specification.

NOTE If a source that couples more than 1,0 µW is used, photobleaching may occur.

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 chart recorder or 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.

A ^{60}Co or equivalent ionizing source(s) shall be used to deliver gamma radiation at a desired dose rate.

Dose rate levels are only approximate levels since the radiation source characteristics change. A variation in dose rate as high as ± 50 % can be expected between sources. 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.

5.4 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.

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 Gy/h (Gray/hour). The test sample shall be exposed to a total dose of 0,1 Gy (Gray). Different dose rates and total dose values may 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.

5.5 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 from the sample prior exposure to the gamma radiation source shall be recorded.

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 total dose of 1 000 Gy. Different dose rates and total dose values may 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.

6 Calculations

6.1 Change in optical attenuation Δ*a* (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.

6.2 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):

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

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

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;

P_B is the power output of the test sample before irradiation begins;

a_0 is the change in optical transmittance of the test sample immediately after irradiation;

a_{15} is the change in optical transmittance of the test sample 15 min after irradiation.

6.3 Normalization of the results

The results of the reference measurements should be used to normalize the test results if significant system instability is noted.

$$a_{REF} = -10 \lg (P_{E'}/P_{B'}) \quad \text{dB} \quad (4)$$

where

$P_{E'}$ is the power measured by the reference detector at the end of the measurement;

$P_{B'}$ is the power measured by the reference detector before irradiation begins.

Normalized test results that account for system instability are calculated with the following formula:

$$a_{0NOR} = a_0 - a_{REF} \quad \text{dB} \quad (5)$$