

Nuclear radiation — Fibre optic guidance

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National foreword

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- monitor related international and European developments and promulgate them in the UK.

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Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

Summary of pages

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Guide d'application sur les fibres optiques**

**Nuclear radiation –
Fibre optic guidance**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

NUCLEAR RADIATION – FIBRE OPTIC GUIDANCE

FOREWORD

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IEC 62283, which is a technical report, has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86A/758/DTR	86A/798/RVC

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

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

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

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- withdrawn;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

INTRODUCTION

In order to restrict the test method of IEC 60793-1-54, *Optical fibres – Part 1-54: Measurement methods and test procedures – Gamma irradiation* to a clear, concise listing of instructions, the background knowledge necessary to perform correct, relevant and expressive irradiation tests is presented here separately as a “guidance document”.

NUCLEAR RADIATION – FIBRE OPTIC GUIDANCE

1 Scope

This technical report gives a short survey of the radiation exposure in certain environments and applications and the different radiation effects on fibres. It also describes the most important radiation effect, i.e., the increase of transmission loss, and its strong dependence on a variety of fibre properties and test conditions. These dependencies need to be known in order to perform appropriate tests for each specific application.

2 Reference documents

IEC 60793-1-54,— *Optical fibres – Part 1-54: Measurement methods and test procedures – Gamma irradiation* ¹⁾

3 Radiation units, dose calculation

The interaction of radiation with matter depends on charge, mass and energy in the case of particle radiation (for example, electrons, protons, neutrons, alphas and heavy ions) and on energy in the case of electromagnetic radiation such as X-ray or gamma quanta. The interaction causes an energy transfer to the respective matter. This leads to ionization and warming up.

The higher the radiation's energy, the stronger its penetrability, the longer its range. The energy unit is the electron Volt (eV). Usual radiation energies in natural or technical environments range from tens of keV (medical X-rays) to several MeV (fission or fusion reactors and nuclear weapons). Current energies at high-energy physics accelerators vary depending on the particles which are collided. The highest energy for electron-positron collisions is 100 GeV per beam. For proton-proton collisions the energy per beam is 1 TeV. Future proton-proton machines, for example the "Large Hadron Collider" (LHC) at CERN, will have beams with an energy of 7 TeV. In addition, there are quite a number of other accelerators which operate between these limits.

Note that these energies refer to the colliding particles. The secondary particles, i.e. the ones likely to affect fibres, have much lower energies.

The energy deposited by ionizing radiation in matter is called "energy dose" (or absorbed dose). The old unit is rad, (rd or rad), $1 \text{ rad} = 100 \text{ erg/g}$ ($1 \text{ erg} = 10^{-7} \text{ J}$). The SI unit is the gray [Gy], $1 \text{ Gy} = 1 \text{ J/kg} = 100 \text{ rad}$.

Some dosimeter types measure the charge released in a gas (for example, ionization chambers). This was used to define another type of dose, the "ion dose". The ion dose unit is the röntgen, [R], $1 \text{ R} = 2,58 \cdot 10^{-4} \text{ C/kg}$, with C = charge unit (coulomb).

Conversion of ion dose, D' , to energy dose, D , can be performed for ^{60}Co gamma rays (about 1,2 MeV) by

¹⁾ To be published.

$$D = 0,879 \frac{\text{Gy}(\text{air})}{R} D' . \quad (1)$$

The energy transfer of gammas and X-rays to matter depends on their energy as well as on the irradiated material. Therefore, the material has to be added to the dose unit (for example [Gy(Si)], [rad(SiO₂)], [Gy(air)] etc.), and the dose D(d) measured with a dosimeter material d (for example, air) can differ significantly from the dose D(m) deposited in the investigated material m (for example, Si, SiO₂, InGaAs, etc.).

The dose ratio between both materials D(m) is given by the ratio of their “photon mass energy absorption coefficient” μ_{en}/ρ :

$$D(m) = \frac{(\mu_{\text{en}}/\rho)_m}{(\mu_{\text{en}}/\rho)_d} D(d) . \quad (2)$$

The μ_{en}/ρ -values can differ significantly, especially for materials of high and low atomic number at energies < 300 keV. They are tabulated for various elements and compounds in reference [1]²⁾.

The intensity of particle radiation is usually characterized by the fluence Φ . The unit is particles/cm² or only cm⁻². The dose of charged particles (in a certain material depth) can be calculated from their fluence and their (energy-dependent) energy loss per unit of length, dE/dx (= stopping power):

$$D = \frac{\Phi}{\rho} \cdot \frac{dE}{dx} , \quad (3)$$

with ρ = material density. The stopping power can be calculated with the software package “SRIM2000.38”³⁾, see [2].

The neutron dose D_n can be calculated from their fluence Φ_n and the energy and material dependent “fluence dose conversion factor” or “kerma factor” $k(E_n, \text{Mat.})$:

$$D_n = \Phi_n \cdot k(E_n, \text{Mat.}) . \quad (4)$$

The kerma-factors are tabulated for a variety of elements and compounds in [3].

4 Radiation shielding

Shielding of optical fibres against (especially gamma) radiation is in most cases not reasonably achievable since, for example, gamma rays of 1 MeV are attenuated to 1/10 of their initial intensity only by 5 cm of iron.

However, buried fibre cables that are layed in at least 1 m depth are shielded against 1 MeV gamma rays by about a factor of 10⁴.

2) Figures in square brackets refer to the bibliography.

3) SRIM2000.38 is the trade name of a product supplied by IBM. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5 Radiation environments and exposure

5.1 Natural radioactivity

The predominant radiation type is gamma rays. Typical annual dose value for earth cables or undersea cables is $\leq 0,004$ Gy. The total dose during an expected cable life time of 25 years would thus be $\leq 0,1$ Gy. Distinctly higher values are possible, for example, above uranium or thorium ore deposits. The dosage and dosage rates are typical and may vary depending on the specific application.

5.2 Nuclear reactors (fission)

Optical fibres can be exposed to gamma rays as well as to thermal and fast neutrons. Dose and fluence values depend strongly on the place within the reactor building and the operating conditions of the reactor (for example, the power delivery, normal operation or accident).

Within the containment area, exposure levels range from 0,001 Gy/h to 0,03 Gy/h up to about 1 Gy/h near the primary coolant lines. The dose rate around the fuel rods is of the order of 10^3 Gy/h. In the early stage of an accident, dose rates as high as 10^4 Gy/h will occur within the containment. [36].

The neutron flux (= fluence Φ per unit of time) within the containment can range from about 10^4 n/cm²h up to about 10^{15} n/cm²h near the fuel rods. The dosage and dosage rates are typical and may vary depending on the specific application.

5.3 Fusion reactors

The primary radiation emitted after the fusion of deuterium (D) and tritium (T) nuclei are 14 MeV neutrons and ⁴He nuclei (energy about 3,5 MeV). The ⁴He ions are very short-ranged and will not reach optical fibres that might be used as sensors or to transfer data, whereas the fast neutrons are very penetrating and will also activate the structural materials around the reaction chamber. These materials then emit high gamma ray intensities also after reactor turn-off.

Again, the total dose and neutron fluence values depend strongly on location and operation conditions.

For the experimental "Joint European Torus" (JET) facility estimated radiation exposure levels for a two-year test series are

- neutron fluence from about 10^{13} cm⁻² (basement of torus hall) to about $5 \cdot 10^{16}$ cm⁻² (near the torus);
- total dose (gamma plus neutron) from about 30 Gy to about $4 \cdot 10^5$ Gy.

For future test facilities, gamma dose rates within the reaction chamber of about $3 \cdot 10^4$ Gy/h and life dose values of 10^7 Gy to 10^8 Gy are expected. The dosage and dosage rates are typical and may vary depending on the specific application.