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TECHNICAL REPORT

colour inside

Hydrogen effects in optical fibre cables – Guidelines

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HYDROGEN EFFECTS IN OPTICAL FIBRE CABLES – GUIDELINES

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IEC TR 62690, 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/1586/DTR	86A/1605/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 the stability dateindicated 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

There is extensive application of optical fibre cables worldwide, both for terrestrial and submarine environments, with the provision of stable transmission characteristics over many years.

In the early 1980s, it was established that some optical fibre designs in certain cable constructions were prone to hydrogen-induced attenuation increases. The mechanism of the hydrogen induced loss was quickly established and after extensive research and development programs, fibre designs were optimized to minimize the effects. Cable designers established suitable design rules and optimized the selection of cable materials so as to also minimize the effects of hydrogen induced attenuation increases during service life.

HYDROGEN EFFECTS IN OPTICAL FIBRE CABLES – GUIDELINES

1 Scope

The purpose of this technical report is to provide information concerning the behaviour of fibres and cables when exposed to hydrogen effects.

The application of multimode fibres is very rarely subject to hydrogen effects. For that reason, this technical report only highlights the effects of hydrogen to single-mode fibres.

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 60794-3, *Optical fibre cables – Part 3: Sectional specification – Outdoor cables*

IEC 60794-4, *Optical fibre cables – Part 4: Sectional specification – Aerial optical cables along electrical power lines*

IEC 60794-5,*Optical fibre cables – Part 5: Sectional specification – Microduct cables for installation by blowing*

3 General

The magnitude of any hydrogen induced effect depends on the cable type (including fibre design) and its operational environment.

In the case of suitably designed, single-mode fibre cables for terrestrial applications, there is sufficient experience to not require any test in cables for significant concentrations of hydrogen which could cause an increase in optical attenuation.

The induced loss for single-mode fibre due to hydrogen at a partial pressure of up to $1,0 \times 10^4$Pa ($9,9 \times 10^{-2}$ atm) is no greater than 0,03 dB/km and 0,06 dB/km, at 1 310 nm and 1 550 nm, respectively. The dynamic equilibrium pressure or balance of hydrogen within a terrestrial cable with no hermetic barrier will be significantly less than $1,0 \times 10^4$Pa, and therefore, optical reliability is ensured. Typical values of 40,5 Pa equivalent to $4,0 \times 10^{-4}$ atm have been measured for duct cable several years after installation [1][1]. At these partial pressures, the attenuation increase is insignificant.

4 Evaluation of hydrogen induced effects

Depending on the cable type and its planned operational environment, an evaluation of hydrogen induced effects [2] may or may not be warranted. Table 1 offers a guide to the necessity to evaluate cables for hydrogen induced attenuation increases.

1 Numbers in square brackets refer to the Bibliography

Table 1 – Evaluation criteria for single-mode (SM) optical fibre cables

Cable construction	Application / environment				
	Direct-buried IEC 60794-3-10	Duct IEC 60794-3-10	Aerial IEC 60794-3-20	Shallow water [a] IEC 60794-3-10	Underwater[a] IEC 60794-3-30
Metallic	1(See Note)	1	1	2	2
Non-metallic	1	1	1	1	[b]
Hermetic barrier (i.e. metallic tube)	2[c]	2	2	2	2
NOTE No evaluation.					

[a] Shallow water – Less than 10 m water depth, short distance.
Underwater – 10 m or greater water depth, as for true submarine cable and the like.

[b] Cable constructions not applicable. Other cable types of IEC 60794-3, IEC 60794-4 and IEC 60794-5 may be evaluated for testing, in accordance with this report.

[c] Evaluation is recommended at the research and developement phase of the cable construction involved. Use of hydrogen-absorbing materials in the cable construction may obviate the need for evaluation in cable form.

5 Hydrogen effects in optical fibre cables

NOTE As indicated in Clause 1, the application space of multimode fibres is rarely subject to hydrogen effects. The theoretical effects of hydrogen on multimode fibres is presented in this clause for the information of users.

Both single-mode and multimode optical fibre cables can optically degrade due to the accumulation of hydrogen gas within the cable structure during its operational lifetime. The magnitude of the effect depends on the following factors:

- the fibre type, its dopant composition/concentration and its intrinsic susceptibility to hydrogen;
- the levels of hydrogen gas (i.e. partial pressure) generated in the cable during its operational lifetime;
- the design of the cable and, in particular, the choice and combination of materials used in its construction;
- the installation environment, including its operational temperature.

Hydrogen gas may build up within a cable from:

- hydrogen released from the cable components, including that associated with long-term ageing effects of the materials;
- hydrogen contained in pressurised air pumped into the cable;
- corrosion action of metallic elements in the presence of moisture;
- biological corrosion by sulphate reducing bacteria.

The optical loss mechanisms due to hydrogen can be classified as follows:

- a reversible interstitial effect associated with diffusion of the H_2 molecules into the silica glass fibre. The effect is very similar for all fibre types (both multimode and single-mode) and its magnitude is linear with the partial pressure of hydrogen;
- a permanent chemical effect due to hydroxyl formation through chemical combination of diffused hydrogen molecules and defect sites in the silica glass fibre. The magnitude of the effect is related to the square root of the partial pressure of hydrogen.

  For single-mode fibres, the permanent loss will be much smaller than the interstitial loss even after 25 years in a hostile operational environment:
- a wavelength dependent loss, which is only experienced at elevated temperatures (in excess of 60 °C) in single-mode fibres, and is again much smaller than the interstitial loss observed at ambient temperature;