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TECHNICAL REPORT

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Optical fibre cables – Shrinkage effects on cable and cable element end termination – Guidance

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Optical fibre cables – Shrinkage effects on cable and cable element end termination – Guidance

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OPTICAL FIBRE CABLES – SHRINKAGE EFFECTS ON CABLE AND CABLE ELEMENT END TERMINATION – GUIDANCE

FOREWORD

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IEC TR 62959, 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/2032/DTR	86A/2058/RVDTR

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

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- withdrawn,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.

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INTRODUCTION

Cable shrinkage is sometimes used as a part of the performance criteria for optical fibre cables, including standard glass optical fibres for telecommunication application. However, there is only a partial correlation between shrinkage and other important cable parameters such as temperature performance and optical transmission characteristics, particularly during mechanical and environmental stress, since shrinkage strongly depends on the cable materials, the cable construction and the manufacturing processes.

The environmental performance of optical fibre cables is mainly determined using a suitable temperature cycling test while continuously measuring the change in attenuation during and after the test. Low shrinkage performance is not guaranteed by such a test method, so any cable shrinkage observed during and/or after the temperature cycle test can be used as an additional indicator for the characterisation of cables.

Cable shrinkage should be understood to include shrinkage of the entire cable, shrinkage of cable sub-assemblies such as units, and shrinkage of cable elements. It should also be understood that shrinkage of portions of the cable might be expressed as "growth" of other elements, such as fibres, strength members. Specific issues of cable shrinkage – buffer shrinkage, strength member growth, sheath shrinkage, etc. – should be carefully addressed when applying the principles of this document.

A combination of the passive component design (connectors, passive components, protective housings or cable management components) and cable shrinkage influences the cable/component performance. Excessive shrinkage at the cable/device interface can cause extra process steps and/or extra precautions to be taken at the interface and can cause degradation of the interface in service, for example the failure of strain relief effectiveness at a connector as the sheath shrinks back in use compromising the continuously optimal optical transmission parameters. Component manufacturers use a number of compensations for cable shrinkage in the design or assembly process of their components and will often select cables used in finished components for their low shrinkage performance. On the other hand, shrinkage can be compensated by installation technique.

To cover all relevant aspects of cables to be terminated, the recommended tests for performance evaluation of cables for different termination cases in addition to the optional tests for evaluation of shrinkage effects are included in this document.

This study into cable shrinkage was triggered by a CENELEC/TC86 BXA liaison letter sent to IEC/SC 86A in April 2016. The letter pointed out observed inconsistencies in indoor cable standards from a user point of view and asked for their concerns and recommendations to be addressed. The main subject was that jacket shrinkage should be a specified parameter for all indoor cables that are normally terminated by connectors, passive components or closures/enclosures.

A correspondence group in IEC/SC 86A/WG 3 was formed in 2016 to address issues about cable shrinkage. After discussion about relevant issues, cable shrinkage tests were performed, and the test results were collected and recorded. Annex A shows these test results and Clause 7 gives the conclusions of the cable shrinkage study. Generally, optical fibre cable types with a small outer diameter were involved in shrinkage testing. The results of different cable types from only a few cable manufactures were included, hence the number of cable types was limited and does not represent all cable types in the worldwide market. Subsequent work was done on recommendations for performance evaluation of cables to be terminated with connectors.

OPTICAL FIBRE CABLES –
SHRINKAGE EFFECTS ON CABLE AND CABLE ELEMENT END TERMINATION – GUIDANCE

1 Scope

This document, which is a Technical Report, provides information on cable shrinkage characterisation of optical fibre cables that consist of standard glass optical fibres for telecommunication application. The characterisation is directed to the effects of cable shrinkage or cable element shrinkage on the termination of cables. Shrinkage can or cannot be a concern depending on the method of termination. Examples of different cable termination cases are included and described. Tests for the evaluation of cable shrinkage are recommended that can be used as indicators, and shrinkage classification by several grades are given.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60794-1-1 and the following apply.

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

3.1
shrinkage
irreversible contraction after extrusion of plastic materials caused by heating or over time at ambient temperature

Note 1 to entry: The irreversible contraction in the direction of the cable axis is usually called "cable shrinkage".

Note 2 to entry: This behaviour is also called "shrinkback".

3.2
thermal contraction
decrease in length of an element or assembly when subjected to a temperature increase or decrease

3.3
thermal expansion
increase in length of an element or assembly when subjected to a temperature increase or decrease

3.4
cable end effect
effect that occurs at the cable's ends

Note 1 to entry: End effects can take different forms. For example, during winding/unwinding or over time, the cable elements can move at the ends relative to the sheath.

4 Abbreviated terms

CTE	coefficient of thermal expansion
FMC	field mountable connector
FMS	fibre management system
HFFR	halogen free flame retardant
LSZH	low smoke zero halogen
ODFM	optical distribution frame module

5 Characteristics of optical fibre cables

5.1 General

For continuously good optical cable performance, the materials, design and manufacturing of the cable should be optimised. Subclauses 5.1 to 5.5 give detailed information about these factors.

5.2 Cable materials

5.2.1 Plastic materials

Many different plastic materials, primarily thermoplastics, are optimised for commercially available extrusion processes. Some are specifically promoted as having a low post-extrusion shrinkage. Nonetheless, all extruded plastic materials expand and contract reversibly and shrink irreversibly.

It should be noted that plastic materials used for optical fibre cables have to meet many more requirements beyond shrinkage, depending on customer technical requirements and local market conditions and regulations. This can include, but is not limited to: free of hazardous substances and halogens, high tensile strength, good UV resistance, good weathering and abrasion resistance, high flame retardancy, high thermal stability, good bend behaviour, easy strippability of the cable sheath and fibre buffer and several other attributes.

5.2.2 Reversible thermal expansion and contraction

Temperature changes cause thermal expansion or contraction of materials. Each material has a certain linear coefficient of thermal expansion (CTE). Typical coefficients of ten materials are listed in Table 1.

Table 1 – Linear coefficients of thermal expansion of materials (informative)

Material	Linear coefficient of thermal expansion $\times 10^{-6}$ K^{-1} [a]	Reference of data (see Bibliography)	Typical application in cables
Aramid [b]	−5	[1]	Strength member for optical fibre cables
Copper	+17	[2]	Power conductor in power and hybrid cables
E glass [c]	+5,5	[2]	Central strength member for optical fibre cables
Glass (fused silica)	+0,5	[2]	Optical fibre
Polybutylenterephthalate (PBT)	+108 to +144	[3]	Tube for fibres in optical fibre cables
Polyethylene (PE)	+100 to +200	[2]	Sheath
Polypropylene(PP)	+58 to +100	[2]	Tube for fibres in optical fibre cables
Polyvinylchloride (PVC)	+70 to +210	[4]	Sheath
Low-carbon steel [d]	+9,9	[5]	Strength member for optical fibre cables
Stainless steel (18-8)	+17	[2]	Armour

[a] To +20 °C reference.

[b] Longitudinal to the fibres.

[c] Same coefficient for glass-reinforced strength member with thermosetting resin coating (glass > 80 % weight).

[d] Ferritic – 410.

Because different materials are used within cables, when the temperature changes, the cable elements and the sheath expand or contract differentially. If the elements cannot move freely, forces are generated within the cable. If the fibre is stressed by such forces, then optical performance can degrade temporarily. After the temperature reverts to its original value, cable elements return to or close to their original lengths, unless they have undergone shrinkage or are restrained by internal coupling. This reversible thermal material dimension change is seldom independently addressed as a cable characteristic.

Annex B describes a suitable test method for determination changes in cable sheath length, and optionally cable's elements, on short cable samples during a climatic exposure test. Information about the thermal expansion and contraction can be helpful when classifying a cable and to understand the higher attenuation observed during climatic tests.

5.2.3 Irreversible thermal contraction (shrinkage)

Irreversible thermal contraction is specifically relevant for extruded plastic materials in optical fibre cables. During the cooling stage of an extrusion process, the polymer orientation is "frozen". If the extruded material is exposed to a high temperature, or kept for a long time at room temperature, the frozen-in polymer orientation can relax, and the extruded plastic material can shrink in direction of the extrusion in an irreversible way [6][1]. The amount and speed of post-extrusion shrinkage can be influenced significantly by the process parameters during extrusion and by the choice of the base material. Zero or negligible shrinkage can be achievable in some cases.

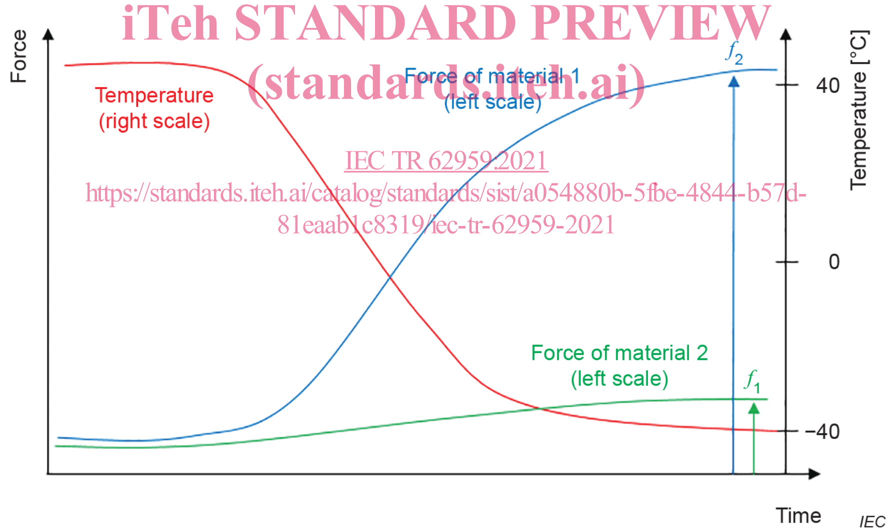
1 Numbers in square brackets refer to the Bibliography.

This post-extrusion shrinkage can be reduced by the inclusion of strength members coupled to the plastic. The more rigid the strength members are and the more tightly the plastic materials are extruded onto them or otherwise coupled, the more the force caused by shrinkage is compensated for by the strength members and the more the potential shrinkage is reduced. If the fibre is stressed by such a force within the cable, then optical performance can degrade permanently.

5.2.4 Forces between cable elements caused by thermal changes

Thermal changes cause forces between cable elements that are made of different materials due to different CTEs as well as different shrinkages. Such forces can induce stress on the optical fibres within the cable. In a general sense, the higher the shrinkage or interactive force, the more likely attenuation can be elevated (see 5.5.2). This shrinkage force is a good indicator for the stress applied to the fibre, but still it is not the only influencing factor (see 5.5.3).

For measurement of the force of a polymer material caused by temperature changes, dynamic-mechanical analysis (DMA) can be used. A defined material sample is fixed at two points and the force between those two points is continuously measured while the temperature is changed. After exposure at high temperature and during lowering of the temperature, a pulling force between the two points is generated resulting from the shrinkage of the material. As shown in Figure 1, as a qualitative example, the measured forces (f_1, f_2) of two tested polymer materials are significantly different (by approximately a factor of 5 when the temperature is reduced to −40 °C).



Key

f_1 measured force of material 1

f_2 measured force of material 2

Figure 1 – Qualitative example of force during decreasing temperature of two polymer materials

Another method is described in ISO 14616 [28] for heat-shrinkable films where shrinkage stress and contraction stress can be determined using a heating hood, a bracket, a force meter and shrinkage measurement.

5.3 Cable design

As well as the materials used and the extrusion processes, the cable construction itself can have a marked influence on the shrinkage performance of a cable.