IEC 61757-2-2

Edition 1.0 2016-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Fibre optic sensors –
Part 2-2: Temperature measurement – Distributed sensing

Capteurs à fibres optiques –
Partie 2-2: Mesure de température – Détection répartie

IEC 61757-2-2:2016-05(en-fr)

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FIBRE OPTIC SENSORS –

Part 2-2: Temperature measurement – Distributed sensing

FOREWORD

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International Standard IEC 61757-2-2 has been prepared by subcommittee SC 86C: Fibre optic systems and active devices of IEC technical committee 86: Fibre optics.

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

CDV	Report on voting
86C/1323/CDV	86C/1354/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.

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

A list of all parts in the IEC 61757 series, published under the general title *Fibre optic sensors*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 61757-1:2012.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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- withdrawn,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.

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INTRODUCTION

It has been decided to restructure the IEC 61757 series with the following logic. From now on, the sub-parts will be renumbered as IEC 61757-*M*-*T* where *M* denotes the measure and *T* the technology.

The existing part IEC 61757-1:2012 will be renumbered as IEC 61757 when it will be revised and will serve as an umbrella document over the entire series.

FIBRE OPTIC SENSORS –

Part 2-2: Temperature measurement – Distributed sensing

1 Scope

This part of IEC 61757 defines detail specifications for distributed temperature measurement by a fibre optic sensor, also known as fibre optic distributed temperature sensing (DTS). DTS includes the use of Raman scattering, Brillouin scattering and Rayleigh scattering effects. In addition, Raman scattering and Rayleigh scattering based measurements are performed with a single-ended fibre configuration only. Brillouin scattering based measurements are performed with a single-ended fibre or fibre loop configuration. The technique accessible from both sides at same time (e. g. Brillouin optical time domain analysis, BOTDA) is referred to here as a loop configuration. Generic specifications for fibre optic sensors are defined in IEC 61757-1:2012.

This part of IEC 61757 specifies the most important DTS performance parameters and defines the procedures for their determination. In addition to the group of performance parameters, a list of additional parameters has been defined to support the definition of the measurement specifications and their associated test procedures. The definitions of these additional parameters are provided for informational purposes and should be included with the sets of performance parameters.

A general test setup is defined in which all parameters can be gathered through a set of tests. The specific tests are described within the clause for each measurement parameter. This general test setup is depicted and described in Clause 4 along with a list of general information that should be documented based upon the specific DTS instrument and test setup used to measure these parameters as per IEC 61757-2-2.

Annex A provides a blank performance parameter table which should be used to record the performance parameter values for a given DTS instrument and chosen optical test setup configuration.

Annex B provides guidelines for optional determination of point defect effects.

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 60050 (all parts), *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

IEC 61757-1:2012, *Fibre optic sensors – Part 1: Generic specification*

IEC TR 61931, *Fibre optic – Terminology*

ISO/IEC Guide 99, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the definitions given in IEC 61757-1:2012, IEC 60050, IEC TR 61931, ISO/IEC Guide 99 (VIM), as well as the following apply.

3.1
attenuation range
total cumulated optical loss (one way loss) tolerated by the DTS system without affecting the specified measurement performance more than a given factor at a given location, spatial resolution, and measurement time

Note 1 to entry: Part of the total cumulative loss can be the fibre attenuation, point defect losses introduced by components such as connectors, splices, kink in the fibre, attenuators.

Note 2 to entry: The attenuation range is expressed in decibels (dB).

3.2
distance measurement range
maximum distance from the DTS instrument output connector along the fibre optic sensor within which the instrument measures a temperature with specified measurement performance under defined conditions

Note 1 to entry: This supporting parameter is closely related to the attenuation range of the instrument. In test cases used to prove or verify the reported specifications, the total fibre length shall be equal to or greater than the specified distance measurement range.

Note 2 to entry: The distance measurement range is expressed in length units (m or km).

3.3
environmental temperature repeatability
difference of the measured constant fibre optic sensor temperature at a specified instrument temperature (e. g. nominal operating temperature) before and after temperature cycling of the instrument across the entire instrument operating temperature range

Note 1 to entry: This parameter is derived from environmental temperature stability.

3.4
environmental temperature stability
difference of the measured constant fibre optic sensor temperature before, during and after temperature cycling of the DTS instrument across the entire instrument operating temperature range

Note 1 to entry: Worst case environmental temperature effect, high/low environmental temperature effect, and environmental temperature repeatability are derived from this definition.

3.5
high/low environmental temperature effect
difference of the measured constant fibre optic sensor temperature at the high and low temperature limit of the instrument temperature operating range

Note 1 to entry: This parameter is derived from environmental temperature stability.

3.6
hot spot
length of fibre optic sensor (ΔL) which is exposed by a measurable temperature change (ΔT) which is significantly bigger than the instrument temperature repeatability and which is confirmed by reference temperature devices in the two thermal chambers.

Note 1 to entry: See Clause 4 and Figure 7.

3.7
L
location
optical distance (specified in length units) from the DTS instrument output connector to a desired temperature sample point along the fibre optic sensor

Note 1 to entry: The furthest location from DTS instrument output connector for the particular test is quantified as *Z* m and is often chosen to be the same as the distance measurement range for purposes of comparing the measurement results with quoted specifications.

3.8
measurement time
time between independent temperature measurements when making successive measurements on a single fibre optic sensor

Note 1 to entry: This parameter includes acquisition time and processing time for measured data. This parameter is selectable by the user typically in some limited fashion. Multiple independent temperature measurements may be averaged together to provide an overall measurement time.

Note 2 to entry: Equivalently, it is the time interval between successive temperature trace timestamps under these conditions.

3.9
point defect
local deviation of a fibre optic sensor from its nominal optical and mechanical properties occurring at a single location, or over a length substantially less than the DTS spatial resolution

Note 1 to entry: The definition of a point defect encompasses a wide range of situations, which may produce similar effects on the temperature trace. Examples include

– a point loss, such as a bad fibre splice;
– a back reflection, such as may arise from a fibre connector;
– a localized region of high loss, such as a bend or kink in the fibre;
– a physical discontinuity in the fibre, such as a splice between two fibres of different core diameters.

3.10
point defect temperature offset
difference between the average values of the temperature sample points in two zones on the temperature trace, one each side of a point defect, where the actual fibre optic sensor temperatures are the same

Note 1 to entry: The point defect temperature offset may be positive, negative or zero.

3.11
sample spacing
distance between two consecutive temperature sample points in a single temperature trace

Note 1 to entry: See Figure 1.

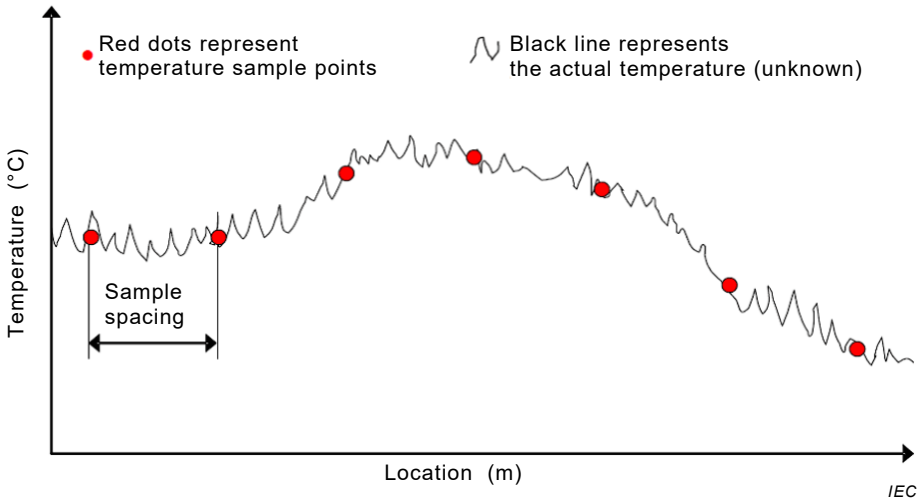

Figure 1 – Example of a temperature trace with temperature sample points

Note 2 to entry: Sample spacing may be a user-selectable instrument parameter.

Note 3 to entry: The distance measurement range is expressed in length units (in m).

Note 4 to entry: In case of very high spacing resolution, the distance measurement range can be expressed in cm or mm.

3.12
spatial resolution
smallest length of a temperature-affected fibre optic sensor for which a DTS system can measure the reference temperature of the hot spot fibre condition within the specified temperature measurement error of the DTS system

3.13
spatial temperature uncertainty
uncertainty of location of temperature data in a single temperature trace expressed by twice the standard deviation of a specified number of adjacent temperature sample points, with the fibre optic sensor held at constant temperature

3.14
temperature dead zone
limited zone of a temperature trace, where the temperature sample points deviate from the undisturbed parts of the trace by a specified limit due to a point defect

3.15
temperature measurement error
maximum difference between a centred and uniformly weighted moving average of the measured temperature and a reference temperature for all data points of the fibre optic sensor over the full operating temperature range and all acquisition times

Note 1 to entry: Single value (worst case) is specified in temperature units (e.g. ± 0,8 °C).

Note 2 to entry: The number of elements used for the moving average is defined in Clause 5. In practical applications, other methods of smoothing might be applicable.

3.16
temperature repeatability
precision of temperature data based on repeated temperature traces at a given location expressed by twice the standard deviation of corresponding temperature sample points in each temperature trace, with the fibre optic sensor held at constant temperature

3.17
temperature sample point
measured temperature value associated with a single point at a known location along a fibre optic sensor

Note 1 to entry: Due to thermodynamic effects, the measured value represents the temperature along a very small section of the fibre optic sensor that includes the point.

3.18
temperature trace
set of temperature sample points distributed along a fibre optic sensor and spaced by the sample spacing

Note 1 to entry: All the sample points are associated with a common time of measurement, often called the trace timestamp. The measured values represent the temperature during a period that includes the timestamp.

Note 2 to entry: All the sample points in a temperature trace are measured values produced by the DTS instrument, and not interpolated or smoothed values produced by subsequent processing outside the instrument.

3.19
Z
total fibre length
distance from the DTS output connector to the final end of the fibre optic sensor

Note 1 to entry: Final end of the fibre optic sensor can either be a purposefully cut or terminated end of the fibre physically far from the instrument (in a single-ended configuration), or the end of a loop consisting of a connector that is connected to the same instrument (in a loop configuration).

Note 2 to entry: This parameter is either equal to or greater than the distance measurement.

Note 3 to entry: The distance measurement range is expressed in length units (m or km).

3.20
warm-up time
duration of time starting from the initiation of the first temperature measurement until the DTS instrument complies with specified measurement specifications

3.21
worst case environmental temperature effect
maximum difference of the measured constant fibre optic sensor temperature at different locations along the sensor during a complete temperature cycling of the DTS instrument across the entire instrument operating temperature range

Note 1 to entry: This parameter is derived from environmental temperature stability.

4 General test setups for measurement of performance parameters

4.1 General and test setup requirements

General test setups for single and loop configurations are schematically shown in Figure 2 and Figure 3 respectively. Their aim is to provide a common base for determining the measurement specifications while at the same time minimizing complexity, cost, reconfiguration requirements, and test execution time.

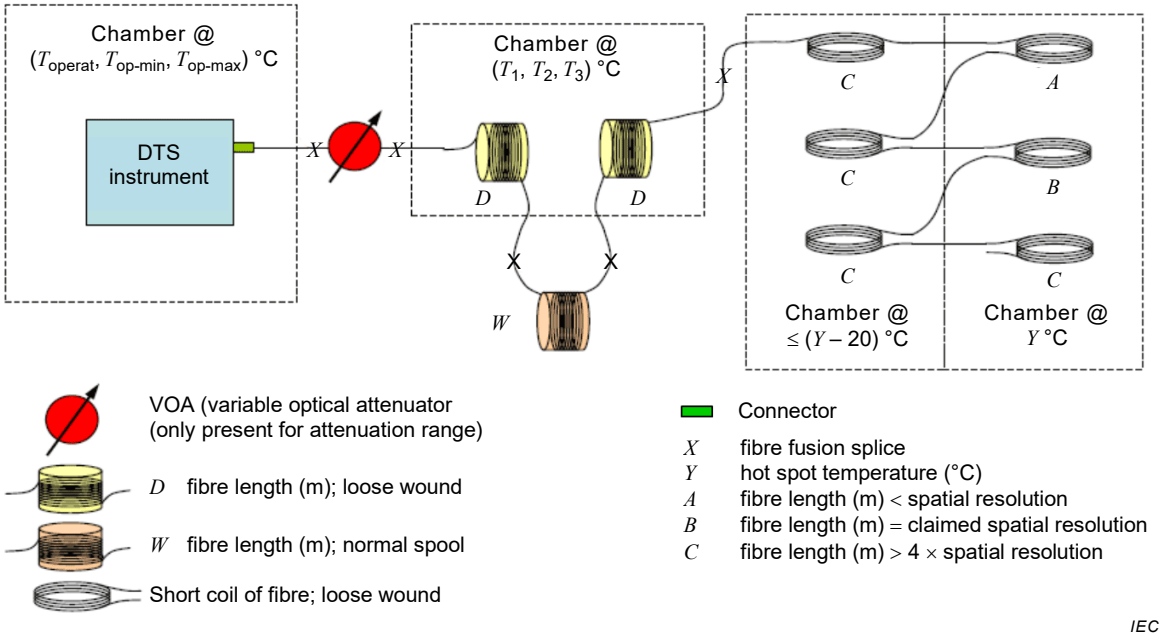

Figure 2 – General test setup: single-ended

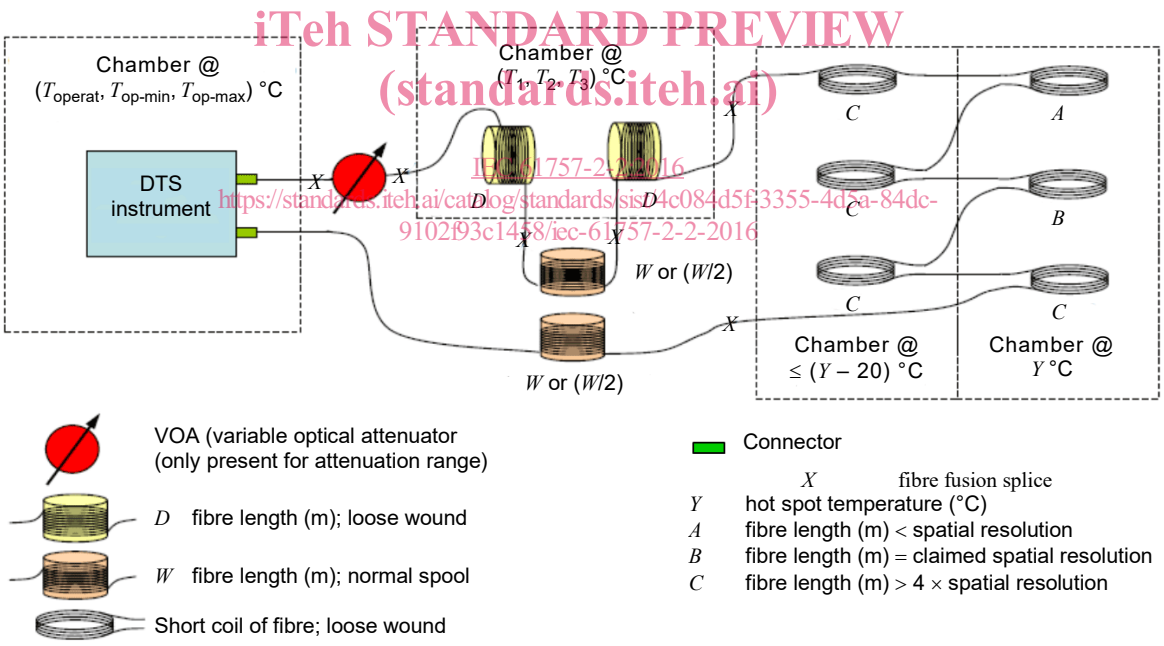

Figure 3 – General test setup: loop configuration

Individual evaluation procedures may be performed with a modified type of setup providing the required measurement conditions. In this case, a detailed setup description and documentation is required.

The fibre lengths *A, B, C* of the fibre coils in the thermal chambers at the end of the setup shall be selected based upon the expected spatial resolution of the DTS system. The fibre lengths *D* and *W* within and outside the centre chamber shall be chosen to make the total fibre length *Z* match the distance measurement range of the particular DTS model being tested. The use of fibre length *D*, located before and after a long length *W* of fibre (which makes up the total fibre length *Z*), provides a test setup capable of accommodating various instruments with different distance measurement ranges. Fibre length *D* shall be equal to 10 % of the total fibre length *Z*.

However, the use of a length of fibre outside the central chamber is optional – all fibre may be contained within the chamber, if desired, as single or multiple coils. The total fibre length Z is equal to the total length of fibre from the instrument connector up to the end of the spatial resolution fibre section represented by fibre lengths A, B, C.

A symmetric test setup represents the normal field operation setup. This is reflected by the test setup described in Figure 3. Fibre length W makes up the total fibre length Z. In case of a system comparison with a single-ended test setup, the length of the normal spools shall be ($2 \times W/2$). This guarantees the same overall attenuation. In all other cases the length of the normal spools shall be ($2 \times W$).

Fusion splices should be used for fibre connection to minimize additional optical losses and unwanted back-reflections. Low insertion loss and back-reflections shall be accomplished when connecting the fibres by connectors.

The fibres in the chambers shall be coiled in such a way (loose wound) that the fibre is completely exposed by the surrounding temperature, and that there is no fibre strain. Normal spool in this case means a fibre spool as delivered from the fibre supplier.

It shall be noted that the general test setup provides a schematic diagram only. The real implementation may differ in certain respects, such as replacing any of the fibre containing chambers with liquid filled calibration baths or replacing the double chamber with an alternative implementation that provides a large and sharp enough temperature difference between the coils (at least 20 °C occurring over no longer than 50 % of the rated spatial resolution).

It is required that the uncertainty of the reference temperature measurement is at least a factor of 5 smaller than the temperature measurement error that is being assessed. Such reference temperature sensors are not shown in the setup diagrams but are required to be present and properly calibrated within each temperature chamber and/or bath.

Setting requirements on the homogeneity or stability of the chambers or the sharpness of the realized temperature step is not necessary. Failure to realize these test setup qualities at a sufficient level will only produce measurement data that is more conservative (worse performance).

The DTS instrument-under-test shall be calibrated according to manufacturer's recommendations before performing any measurements.

4.2 General required information to be documented

The general required information to be documented is as follows:

- completion date of all testing;
- name of the organization executing the testing;
- test setup configuration;
- operating mode of the DTS instrument (single-ended or loop configuration as shown in Figures 2 and 3, or channel(s) tested in case of a multi-channel system using the same hardware);
- wavelength(s) of the launched signals (operating wavelength(s));
- manufacturer, model, and serial number of the DTS instrument;
- manufacturer, model, and length of the fibre optic sensor in the test setup (inside the temperature chamber(s));
- optical loss (one-way in dB) of the optical setup to the end of the sensor (Z m);
- wavelength used to measure the loss to end of the sensor (Z m);
- distance measurement range of the DTS instrument;