IEC 62765-2

Edition 1.0 2019-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Nuclear powers plants – Instrumentation and control important to safety – Management of ageing of sensors and transmitters – Part 2: Temperature sensors

Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Gestion du vieillissement des capteurs et des transmetteurs – Partie 2: Capteurs de température

IEC 62765-2:2019-01(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 27.120.20

ISBN 978-2-8322-6171-2

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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NUCLEAR POWERS PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – MANAGEMENT OF AGEING OF SENSORS AND TRANSMITTERS –

Part 2: Temperature sensors

FOREWORD

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International Standard IEC 62765-2 has been prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
45A/1218/FDIS	45A/1227/RVD

Full information on the voting for the approval of this International Standard 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.

A list of all parts in the IEC 62765 series, published under the general title *Nuclear power plants – Instrumentation and control important to safety – Management of ageing of sensors and transmitters*, can be found on the IEC website.

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- withdrawn,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
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INTRODUCTION

a) Technical background, main issues, and organisation of the standard

With the majority of NPPs over 30 years old, the management of ageing of temperature sensors is currently a relevant topic, especially for those plants that have extended their operating licenses or are considering this option. This standard is intended to be used by operators of NPPs (utilities), systems evaluators, vendors, and by licensors. In the international temperature measurement, the scale of temperature has been updated with ITS-90 since it was published in 1990, so it is necessary that ITS-90 should be addressed in the standard to cover the calibration of measuring and test equipment for temperature sensors.

b) Situation of the current standard in the structure of the IEC SC 45A standard series

IEC 62765 is the third level IEC SC 45A document comprised of several parts to tackle the specific issue of management of ageing of sensors and transmitters in nuclear power plants (NPPs) for I&C systems important to safety. Part 2 of IEC 62675 is dedicated to temperature sensors.

IEC 62342 is the second level standard of SC 45A covering the domain of the management of ageing of nuclear instrumentation systems used in NPPs to perform functions important to safety. IEC 62342 is the introduction to a series of standards to be developed by IEC SC 45A covering the management of the ageing of specific I&C systems or components such as electrical cabling systems (IEC 62465), and sensors and transmitters (IEC 62765).

IEC 62765-2 is to be read in association with IEC 62342 and IEC TR 62096, which is the appropriate IEC SC 45A Technical Report that provides guidance on the decision for modernisation when the management of ageing techniques is no longer successful. For more details on the structure of the IEC SC 45A standard series, see item d) of this introduction.

c) Recommendations and limitations regarding the application of this standard

It is important to note that this standard establishes no additional functional requirements for safety systems. Ageing mechanisms have to be prevented and thus identified by performance measurements in order to minimize their impact on sensor reliability. Aspects for which special recommendations and limitations have been provided in this standard are:

- criteria for the evaluation of ageing of temperature sensors in NPPs;
- steps to be followed to establish the temperature sensor testing requirements for an ageing management program for NPP instrumentation systems; and
- relationships between on-going qualification analysis and ageing management program with regard to temperature sensors.

It is recognised that testing and monitoring techniques used to evaluate the ageing condition of NPPs' sensors and transmitters are continuing to develop at a rapid pace and that it is not possible for a standard such as this to include references to all modern technologies and techniques.

This standard identifies minimum requirements aimed at ensuring that any potential impacts on NPP safety due to the ageing of temperature sensors of NPPs can be identified and that suitable actions are undertaken to demonstrate that the safety of the plant will not be impaired. To ensure that this standard will continue to be relevant in future years, the emphasis has been placed on issues of principle, rather than specific technologies.

d) Description of the structure of the IEC SC 45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

The top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046. IEC 61513 provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 63046 provides general requirements for electrical power systems of NPPs; it covers power supply systems including the supply

systems of the I&C systems. IEC 61513 and IEC 63046 are to be considered in conjunction and at the same level. IEC 61513 and IEC 63046 structure the IEC SC 45A standard series and shape a complete framework establishing general requirements for instrumentation, control and electrical systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of ageing. The standards referenced directly at this second level should be considered together with IEC 61513 and IEC 63046 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 or by IEC 63046 are standards related to specific equipment, technical methods, or specific activities. Usually these documents, which make reference to second-level documents for general topics, can be used on their own.

A fourth level extending the IEC SC 45A standard series, corresponds to the Technical Reports which are not normative.

The IEC SC 45A standards series consistently implement and detail the safety and security principles and basic aspects provided in the relevant IAEA safety standards and in the relevant documents of the IAEA nuclear security series (NSS). In particular this includes the IAEA requirements SSR-2/1, establishing safety requirements related to the design of nuclear power plants (NPPs), the IAEA safety guide SSG-30 dealing with the safety classification of structures, systems and components in NPPs, the IAEA safety guide SSG-39 dealing with the design of instrumentation and control systems for NPPs, the IAEA safety guide SSG-34 dealing with the design of electrical power systems for NPPs and the implementing guide NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

IEC 61513 and IEC 63046 have adopted a presentation format similar to the basic safety publication IEC 61508 with an overall life-cycle framework and a system life-cycle framework. Regarding nuclear safety, IEC 61513 and IEC 63046 provide the interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. In this framework IEC 60880, IEC 62138 and IEC 62566 correspond to IEC 61508-3 for the nuclear application sector. IEC 61513 and IEC 63046 refer to ISO as well as to IAEA GS-R part 2 and IAEA GS-G-3.1 and IAEA GS-G-3.5 for topics related to quality assurance (QA). At level 2, regarding nuclear security, IEC 62645 is the entry document for the IEC SC 45A security standards. It builds upon the valid high level principles and main concepts of the generic security standards, in particular ISO/IEC 27001 and ISO/IEC 27002; it adapts them and completes them to fit the nuclear context and coordinates with the IEC 62443 series. At level 2, IEC 60964 is the entry document for the IEC/SC 45A control rooms standards and IEC 62342 is the entry document for the ageing management standards.

NOTE 1 It is assumed that for the design of I&C systems in NPPs that implement conventional safety functions (e.g. to address worker safety, asset protection, chemical hazards, process energy hazards) international or national standards would be applied.

NOTE 2 IEC SC 45A domain was extended in 2013 to cover electrical systems. In 2014 and 2015 discussions were held in IEC SC 45A to decide how and where general requirements for the design of electrical systems were to be considered. IEC SC 45A experts recommended that an independent standard be developed at the same level as IEC 61513 to establish general requirements for electrical systems. Project IEC 63046 is now launched to cover this objective. When IEC 63046 is published this NOTE 2 of the introduction of IEC SC 45A standards will be suppressed.

NUCLEAR POWERS PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – MANAGEMENT OF AGEING OF SENSORS AND TRANSMITTERS –

Part 2: Temperature sensors

1 Scope

This part of IEC 62765 identifies minimum requirements and applicable practices for correcting and preventing any potential impacts on nuclear power plant (NPP) safety due to the ageing of temperature sensors, such as NPP resistance temperature detectors (RTDs) and thermocouples (TCs).

This document provides strategies, technical requirements, and recommended practices for the management of the ageing of temperature sensors important to safety in nuclear power plants (NPPs) to ensure that ageing can be identified and that suitable remedial actions are undertaken as necessary to demonstrate that the safety of the plant will not be impaired. This document is aligned with IEC 62342, which provides guidance on ageing management for instrumentation and control (I&C) systems important to safety in NPPs.

IEC 62765 standard series covers pressure transmitters (Part 1) and temperature sensors (Part 2). Part 1 covers pressure transmitter (PT), level transmitter (LT) and flow transmitter (FT). Part 2 consists of resistance temperature detector (RTD) and thermocouple (TC) with respect to instrumentation and control (I&C) important to safety. Detector of neutron power (Part 3) will be covered in a separate standard.

Interfaces of temperature sensors with processes such as thermowells, seals, sheathes, extension/compensating cables, and connectors are within the scope of this document. Ageing management of temperature sensors used as M&TEs are beyond the scope of this document.

Temperature units of this document are in terms of International Temperature Scale-1990 (ITS- 90), because of consistency with normative references.

IAEA SSR-2/1 and SSR-2/2 address the requirements of ageing management in the design, as well as in the operation of the lifetime of the plant.SSG-39 recommends design consideration for ageing management specific to I&C system.

The requirements of temperature sensors for industrial and nuclear application in the normative references are indispensable to this document whereas this document focuses on the ageing management of temperature sensors to meet the requirements.

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 60584-1:2013, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 60584-3:2007, *Thermocouples – Part 3: Extension and compensating cables – Tolerances and identification system*

IEC 60671:2007, *Nuclear power plants – Instrumentation and control systems important to safety – Surveillance testing*

IEC 60737:2010, *Nuclear power plants – Instrumentation important to safety – Temperature sensors (in-core and primary coolant circuit) – Characteristics and test methods*

IEC 60751:2008, *Industrial platinum resistance thermometers and platinum temperature sensors*

IEC/IEEE 60780-323:2016, *Nuclear facilities – Electrical equipment important to safety – Qualification*

IEC 61226:2009, *Nuclear power plants – Instrumentation and control important to safety – Classification of instrumentation and control functions*

IEC 61515:2016, *Mineral insulated metal-sheathed thermocouple cables and thermocouples*

IEC 62138:2004, *Nuclear power plants – Instrumentation and control important to safety – Software aspects for computer-based systems performing category B or C functions*

IEC 62342:2007, *Nuclear power plants – Instrumentation and control systems important to safety – Management of ageing*

IEC 62385:2007, *Nuclear power plants – Instrumentation and control important to safety – Methods for assessing the performance of safety system instrument channels*

IEC 62397:2007, *Nuclear power plants – Instrumentation and control important to safety – Resistance temperature detectors*

IEC 62465:2010, *Nuclear power plants – Instrumentation and control important to safety – Management of ageing of electrical cabling system*

IEC/IEEE 62582-1:2011, *Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods – Part 1: General*

IEC 62651:2013, *Nuclear power plants – Instrumentation important to safety – Thermocouples: Characteristics and test methods*

IAEA Safety Standard Series No. SSR-2/1:2016, *Safety of Nuclear Power Plant: Design, specific safety requirements*

IAEA Safety Standard Series No. SSR-2/2:2016, *Safety of Nuclear Power Plant: Commissioning and Operation, specific safety requirements*

IAEA Safety Standard Series No. NS-G-2.12:2009, *Ageing management for nuclear power plants: safety guide*

IAEA Specific Safety Guide No. SSG-39:2016, *Design of instrumentation and control systems for nuclear power plants*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
adjustment <of a measuring instrument>
set of operations carried out on a measuring instrument in order that it provides given indications corresponding to given values of the measurand

Note 1 to entry: An adjustment can be carried out during cross-calibration of temperature sensors in the temperature measurement channel.

[SOURCE: IEC 60050-311:2001, 311-03-16]

3.2
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by measurement standards

[SOURCE: IAEA Safety Glossary, edition 2016]

3.3
calibration diagram
portion of the co-ordinate plane, defined by the axis of indication and the axis of results of measurement, which represents the response of the instrument to different values of the measurand

[SOURCE: IEC 60050-311:2001, 311-01-10]

3.4
compensating cables
manufactured from conductors having a composition different from the corresponding thermocouple. They are designated by the letter "C" following the designation of the thermocouple, for example "KC". In some cases different tolerances apply for the same thermocouple type over different temperature ranges. These are distinguished by additional letters such as, for example, KCA and KCB

[SOURCE: IEC 60584-3:2007, 3.1.2]

3.5
cross-calibration
procedure of inter-comparing the indications of redundant instruments (e.g., temperature sensors) to identify outlier sensors as a means of verifying calibration or identifying calibration changes. A more appropriate term for this definition is "cross-validation," although cross-calibration is more commonly used

Note 1 to entry: A calibration test of temperature sensors in some NPPs can be different from this definition mainly because an adjustment of the temperature channel during cross-calibration may be allowed within a predetermined allowable value.

[SOURCE: IEC 62385:2007, 3.6]

3.6
drift
change in the indication of a measuring instrument, generally slow, continuous, not necessarily in the same direction and not related to a change in the measurand

Note 1 to entry: Stability and shift are sometimes used interchangeably with drift.

[SOURCE: IEC 60050-311:2001, 311-06-13]

3.7
electromagnetic interference
EMI
degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-06]

3.8
extension and compensating cables
cables used for the electrical connection between the open ends of a thermocouple and the reference junction in those installations where the conductors of the thermocouple are not directly connected to the reference junction. The thermoelectric properties of extension and compensating cables shall be close to the properties of the corresponding thermocouple

[SOURCE: IEC 60584-3:2007, 3.1]

3.9
extension cables
cables manufactured from conductors having the same nominal composition as those of the corresponding thermocouple. They are designated by the letter "X" following the designation of the thermocouple, for example "JX"

[SOURCE: IEC 60584-3:2007, 3.1.1]

3.10
measurand
particular quantity subject to measurement

[SOURCE: IEC 60050-311:2001, 311-01-03]

3.11
platinum resistance thermometer
PRT
temperature responsive device consisting of one or more sensing platinum resistors within a protective sheath, internal connecting wires and external terminals to permit connection of electrical measurement instruments. Mounting means and connection heads may be included. Not included is any separable protection tube or thermowell

Note 1 to entry: The term PRT also refers to "resistance temperature detector (RTD)".

[SOURCE: IEC 60751:2008, 3.5]

3.12
resistance temperature detector
RTD

detector generally made up of a stainless steel cylindrical barrel protecting a platinum resistor whose resistance varies with temperature. This detector is placed in the piping containing the fluid whose temperature is measured in this way. It can be directly immersed in the fluid or protected by an intermediate casing called the thermowell

[SOURCE: IEC 62397:2007, 3.5]

3.13
response time
period of time necessary for a component to achieve a specified output state from the time that it receives a signal requiring it to assume that output state

[SOURCE: IAEA Safety Glossary, 2016 edition]

3.14
self-heating error
rise in the indicated temperature due to the power dissipated in the sensor

[SOURCE: IEC 62397:2007, 3.7]

3.15
sensor
measuring element; part of a measuring instrument, or measuring chain, which is directly affected by the measurand and which generates a signal related to the value of the measurand

[SOURCE: IEC 60050-311:2001, 311-05-01]

3.16
thermocouple
TC
pair of conductors of dissimilar materials joined at one end and forming part of an arrangement using the thermoelectric effect for temperature measurement

[SOURCE: IEC 60584-1:2013, 2.3]

3.17
thermoelectric effect
Seebeck effect
production of an electromotive force EMF due to the difference of temperature between two junctions of different metals or alloys forming part of the same circuit

Note 1 to entry: The term Seebeck also refers to " thermoelectric effect".

[SOURCE: IEC 60584-1:2013, 2.1]

3.18
thermowell
protective jacket for temperature sensors (RTDs and TCs). The thermowell is also used to facilitate replacement of temperature sensor

[SOURCE: IEC 62385:2007, 3.19]

3.19
tolerance of RTD
initial maximum allowable deviation expressed as temperature in ℃ from nominal temperature/resistance relationship in RTD

3.20
tolerance of TC
initial maximum allowable deviation from the EMF specification of thermocouple

Note 1 to entry: The tolerance is expressed as the temperature equivalent, in °C.

4 Abbreviated terms

AFV	As Found Value
AV	Allowable Value
AMP	Ageing Management Program
CT	Calibration Tolerance
DBE	Design Basis Event
EMF	Electromotive Force
EMI	Electromagnetic Interference
EQ	Equipment Qualification
FSAR	Final Safety Analysis Report
HELB	High Energy (Steam) Line Break
IR	Insulation Resistance
ITS-90	The International Temperature Scale of 1990
LCSR	Loop Current Step Response
MIMS	Mineral Insulated Metal Sheathed
M&TE	Measurement and Test Equipment
NPP	Nuclear Power Plant
PRT	Platinum Resistance Thermometer
PT	Pressure Transmitter
R&D	Research and Development
RTD	Resistance Temperature Detector
QA	Quality Assurance
TC	Thermocouple
V&V	Verification and Validation

5 Technical background

5.1 General

IAEA SSR-2/1 describes the requirements of ageing management in the design for safe operation over a lifetime. It is also necessary that a design margin be provided to take account of the ageing mechanism, neutron embrittlement, and wear out, as well as the potential for ageing degradation. SSR-2/2 also requires an effective ageing management program over the operating lifetime of the plant. Subclauses 6.135 to 6.152 of SSG-39:2016 recommend design consideration for ageing management specific to I&C systems to meet the requirements of SSR-2/1.

The baseline of requirements of ageing management is to understand and identify the ageing phenomena, which cover the ageing mechanism, causes and potential effects of temperature sensors. Annex A summarises various kinds of tests for performance verification in order to identify a degradation in lifetime and to assess an ageing mechanism. IEC 62342 guides the general aspect of ageing management of instruments including temperature sensors, whereas IEC 60737 and others listed in Annex B cover characteristics and test methods of temperature sensors. Existing IAEA and IEC standards for ageing management standards are summarised in Annex B.