IEC 62397

Edition 2.0 2022-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Instrumentation and control important to safety – Resistance temperature detectors

Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Sondes à résistance

IEC 62397:2022-11(en-fr)

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Nuclear power plants – Instrumentation and control important to safety – Resistance temperature detectors

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – RESISTANCE TEMPERATURE DETECTORS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62397 has been prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation. It is an International Standard.

This second edition cancels and replaces the first edition, published in 2007; it also cancels and replaces the first edition of IEC 61224:1993. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

1) The definitions, terms, references, test methods, test requirements and other contents in IEC 61224 are incorporated into the corresponding clauses of IEC 62397, including the situ response time test methods;
2) Move the second paragraph of Scope to 4.1 and add "certain design extension conditions" in the text;
3) Add the definition of temperature units of ITS-90;

4) Add reference standards, including IEC 60737:2010, IEC 60751:2022, IEC 62765-2:2019, IEC 62342:2007, IEC 62385:2007, IEC 61298-2, IEC 60068-2;
5) Update the reference IEC 60780 to IEC/IEEE 60780-323:2016; update the reference IEC 60980 to IEC/IEEE 60980-344:2020;
6) Delete the outdated definition of "accuracy (measurement)" and modify the definition of "calibration", "drift" and "response time";
7) Add the terms and definitions of "cross-calibration (cross-validation)", "self-heating index", "tolerance of RTD", "sheath", "*in situ* measurement", and some abbreviated terms (e.g., NPP);
8) Delete the reference values of failure rate, radiation dose, contact resistance and leak rate, environmental conditions and test conditions in 4.2, 4.3.2, 4.4.2.2, 4.6, 5.4.7;
9) Clarify 4.3.1;
10) Add "fast neutron damage" and "β irradiation" in 4.3.2 and correct the requirement for material change to be "shall not";
11) Replace platinum description with general material requirement in 4.3.3;
12) Delete the statement on sealant elements and flat sealants;
13) Add labels of dust cover, spring and extension tube in Figure 3 and Figure 4 and correct a typo in Figure 6;
14) Add electrical connector configuration requirement referring to IEC 60751 in 4.4.2.1;
15) Modify the temperature rating requirement of type I connector in 4.4.2.2 and add the definition of manufacturer in the footnote;
16) Add the type of connection for RTD mounted in pipe and relax the statement on spring force in 4.4.3.1;
17) Modify the type I and type II statement in 4.4;
18) Change the subtitle to "Manufacturing Quality" and add detailed requirements in 4.5;
19) Considering the application for difference types of nuclear power plants, in 4.6 and 4.7 introduce the concept that the user shall specify the requirements, test method and acceptance criteria for tests depending on the application of the subject RTD;
20) Delete the last three paragraphs in 4.6;
21) Add detailed performance requirements in 4.7 and move the test requirements to a new subclause 5.4 "Test method";
22) Replace "330 °C" in the standard with the (highest) operating temperature;
23) Add a new subclause "4.7.1 General" to describe the general requirements and restate *in situ* response time measurement requirement;
24) Add the Callendar formula for temperature range of -200 °C to 0 °C and delete the temperature tolerance values and refer to IEC 60751 in 4.7.3;
25) Supplement detailed requirements of "self-heating error" in 4.7.4;
26) Change the subtitle to "thermal response time" in 4.7.5 and delete the definition of thermal response time;
27) Relax the performance requirements to "should" in 4.7.8, 4.7.9, 4.7.10, 4.7.11 and 4.7.13, and relax the steam test requirement to only RTDs used in steam environment;
28) Merge "Insulation resistance test after storage" into "Electrical insulation resistance", reduce the requirement and change insulation resistance under 200 °C to be 10 MΩ in 4.7.7;
29) Add "Dielectric inspection" and "Hydraulic strength" as 4.7.12 and 4.7.13;
30) Revise description on *in situ* response time testing in 4.7.14;
31) Add identifications in 4.8;
32) Delete the insulation breakdown test;
33) Refer to IEC 60751 for self-heating test in 5.4.3;

34) Delete the vibration spectrum for vibration test, and refer to IEC 60068-2-6 in 5.4.7;
35) Revise thermal cycling test requirement to be more general and refer to IEC 60068-2-30 in 5.4.9;
36) Add 5.4.13 "Cross-calibration testing";
37) Add dielectric inspection test and hydraulic test as product tests in 5.5 and note that the user can specify the test requirement;
38) Add dielectric inspection test and hydraulic test as qualification tests in 5.6, note that the user can specify the test requirement, and refer to IEC/IEEE 60780-323 and IEC/IEEE 60980-344 or pertinent national guides and regulations;
39) Change title from "Technical information required" to "Documentation" of Clause 6 and add "the regular maintenance strategy" in performance specification;
40) Add an informative annex "Annex A *In situ* response time test methods" to include the related information from IEC 61224, update figures and cross-references, and cite it in 4.7.13 and 5.4.12;
41) Add the IAEA documents in bibliography.

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

Draft	Report on voting
45A/1447/FDIS	45A/1454/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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.

INTRODUCTION

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

This standard describes the requirements for the design, material selection, procurement, construction, and testing of resistance temperature detectors (RTDs) used in nuclear power plants (NPPs). These RTDs may be used in both the nuclear safety I&C systems and/or in the non-safety-related instrumentation systems.

This standard is a revision merger of IEC 62397 and IEC 61224 and was initiated in November 2019.

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

IEC 62397 is not directly referenced by IEC 61513 and is a third-level SC 45A document tackling the issue of RTDs.

For more details on the structure of the SC 45A series of standards, see item d) of this introduction.

c) Recommendations and limitations regarding the application of this standard

There is no particular recommendation or limitation regarding the application of this standard.

d) Description of the structure of the IEC SC45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

The IEC SC 45A standard series comprises a hierarchy of four levels. The top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046.

IEC 61513 provides general requirements for instrumentation and control (I&C) systems and equipment that are used to perform functions important to safety in nuclear power plants (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 power systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general requirements for specific topics, such as categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, human factors engineering, 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 requirements for specific equipment, technical methods, or activities. Usually these documents, which make reference to second-level documents for general requirements, can be used on their own.

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

The IEC SC 45A standards series consistently implements and details 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, the IAEA safety guide SSG-51 dealing with human factors engineering in the design of NPPs and the implementing guide NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by the 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 9001 as well as to IAEA GSR 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, IEC 63351 is the entry document for the human factors engineering 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 TR 64000 provides a more comprehensive description of the overall structure of the IEC SC 45A standards series and of its relationship with other standards bodies and standards.

NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – RESISTANCE TEMPERATURE DETECTORS

1 Scope

This document describes the requirements for resistance temperature detectors (RTDs) suitable for applications in I&C systems important to safety of nuclear power plants. The requirements of RTDs include design, materials, manufacturing, testing, calibration, procurement, and inspection. RTDs used for safety applications in Nuclear Power Plants can be categorized into direct-immersed and thermowell-mounted RTDs. Furthermore, there are RTDs with specific design which cannot be assigned to the categories mentioned above. However, they are also covered by the requirements stated in this document.

This document does not cover the design, material selection, and construction of the thermowell, the guide tube, the extension cable, and the temperature transmitter or resistance bridge which may be associated with the RTD.

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 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60751:2022, *Industrial platinum resistance thermometers and platinum temperature sensors*

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

IEC/IEEE 60980-344:2020, *Nuclear facilities – Equipment important to safety – Seismic qualification*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Terms and definitions

3.1.1
calibration
set of operations that establishes, by referring to standards, the relationship which exists under specified conditions between an indication and a result of a measurement

Note 1 to entry: This term is based on the "uncertainty" approach.

Note 2 to entry: The relationship between the indications and measurement results can be expressed, in principle, using a calibration diagram.

3.1.2
cross-calibration
cross-validation
procedure of intercomparing 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," but, 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]

3.1.3
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

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

3.1.4
***in situ* measurement**
measurement of RTD performance (calibration or response time) while the RTD remains installed in normal configuration for service

3.1.5
protective tube
tubular material used to protect one or more sensing resistors and inner leads assembly from environmental impact

3.1.6
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

Note 1 to entry: Mounting means or connection heads may be included. The temperature-sensing resistor can be made of platinum, nickel tungsten, copper, or other metals. However, a platinum sensor is commonly used in the RTD in an NPP; therefore, a platinum resistance thermometer is referred to in this document.

Note 2 to entry: In this document, the term "sensor" describes the RTD unit with all its associated protection, for example, barrel or thermowell. For most applications of measuring process fluid temperature in an NPP, the platinum resistor sensor is installed inside a stainless steel thermowell, and the thermowell is mounted on a pipe or container by means of external threads or welding. For air temperature measurement, a direct sensor may be used.

3.1.7
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

Note 1 to entry: Thermal response time used in this document is the time required for the temperature detector to reach 63,2 % of the total change in resistance for a step change in temperature.

[SOURCE: IAEA Safety Glossary, 2018]

3.1.8
self-heating error
rise in the indicated temperature due to the power dissipated in the sensor by the measurement

3.1.9
self-heating index
self-heating coefficient
SHI
coefficient with the dimension °C/mW is characteristic for a resistor/thermometer and describes the temperature increase of the resistor per unit power dissipated. This coefficient is evaluated under specified operating conditions of the resistor or thermometer. The medium, its flow conditions and temperature should be specified

[SOURCE: IEC 60751:2008, 3.9]

3.1.10
thermowell
protective jacket for RTDs, thermocouples, and other temperature sensors. The thermowell is also used to facilitate replacement of the temperature sensor

[SOURCE: IEC 62385:2007, 3.19]

3.1.11
tolerance of RTD
initial maximum allowable deviation expressed as temperature in °C from nominal temperature/resistance relationship in RTD

[SOURCE: IEC 62765-2:2019, 3.19]

3.2 Abbreviated terms

HELB	High-energy Line Break
ITS-90	The International Temperature Scale of 1990 (Temperature units in this document are in terms of International Temperature Scale-1990)
LCSR	Loop Current Step Response
LOCA	Loss of Coolant Accident
M&TE	Measurement and Test Equipment
NPP	Nuclear Power Plant
PRT	Platinum Resistance Thermometer
RTD	Resistance Temperature Detector
SHI	Self-heating index of RTD
QA	Quality Assurance

4 Design and construction requirements

4.1 General

RTDs can be supplied with different internal constructions, which depend on the manufacture, qualifications, and applications. For RTD being used in an NPP, the design and structure of the RTD should consider the environmental conditions in which the detector is being used under normal operating and under design basis accident conditions and certain design extension conditions, as well as the qualification tests specified by the user[1].

The RTD shall meet or exceed the requirements specified in this document.

4.2 Reliability

The design philosophy for RTDs that are used in NPPs requires a device which is capable of continuous successful operation at rated service conditions throughout its specified design life. The required reliability of the RTD shall be derived from the overall reliability specified for the temperature measurement function.

RTDs that operate as part of a safety system should have their design lives defined. The features of the RTD that are necessary to fulfill safety functions shall be ensured for the complete service life of the equipment, except for parts which have a short design life and can be replaced periodically. The preservation of these features should be ensured by appropriate maintenance and testing strategies. Arrangements shall be made for the RTD to be replaced or re-assessed before its design life is reached.

4.3 Materials

4.3.1 General

With the exception of parts which have a lower design life, all materials within the construction of the RTD shall retain their required features, attributes and design parameters for the required service life of the RTD.

4.3.2 Radiation dose to materials

The total integrated radiation dose shall be derived from postulated environmental conditions during normal operation and postulated accidents.

If neutron radiation is expected at the installation position of the RTD, the neutron fluence shall be taken into consideration when selecting the design and materials of the RTD. Material changes due to activation or fast neutron damage shall not affect adversely the safety function of the equipment. Some devices may be exposed to beta radiation in a severe accident. Beta and gamma radiation cause different types of damage.

4.3.3 Resistance element material

In addition to meeting the required temperature characteristics (including accuracy, repeatability, response time and reliability) the resistance element material shall be selected to meet the following material property requirements:

– high resistance to corrosion and chemical attack;

– high resistance to radiation damage;

1 The user corresponds to the party or the company that uses the RTD in an NPP for measuring the temperature in a safety or a non-safety system. The term user may also refer to the purchaser or the buyer, or the operator of the RTD.

– suitable strength and mechanical stability throughout the required temperature range and design life.

Because of its outstanding properties, the resistance element may consist of platinum. Other materials may be used if these requirements are met.

The sensing wire shall be mounted so as to be almost free of strains to avoid the strain gauge effect from causing extraneous changes in resistance. Furthermore, the thermometer shall be manufactured with the resistance element free of contaminants.

4.3.4 Seals and adhesives

The RTD shall be hermetically sealed. RTDs used in a harsh environment, such as under high-temperature and/or radiation areas, may be designed without organic material. The tightness of the insulating termination shall be tested according to an adequate and proven procedure.

All cements, adhesives, or seals used internally in the device shall be capable of withstanding the service conditions without functional deterioration and without emitting gases. All non-metallic materials, when used for seals, protective finishes, and so forth, shall be moisture- and flame-resistant. These non-metallic materials shall not support fungus growth and shall not be adversely affected by the ambient environments specified in the performance requirements of this standard.

4.4 Connections

4.4.1 Structural type

RTDs shall have lead wires terminated through a qualified hermetic seal.

There are two common types of electrical connections used in an NPP. Figure 1 provides the general form and dimensions of an RTD without any thermowell. Figure 2 is a rigid RTD with a quick disconnector and is referred to as Type I (quick disconnect). Figure 3 and Figure 4 are rigid RTDs without quick disconnectors, and are referred to as Type II (standard) with long insertion and short insertion, respectively. A user may specify any other form of RTD and construction, depending on its particular applications.

For resistance thermometer with connector, the spring gap, as part of the dust cover, should completely cover the end of the extension tube.

Dimensions in millimetres

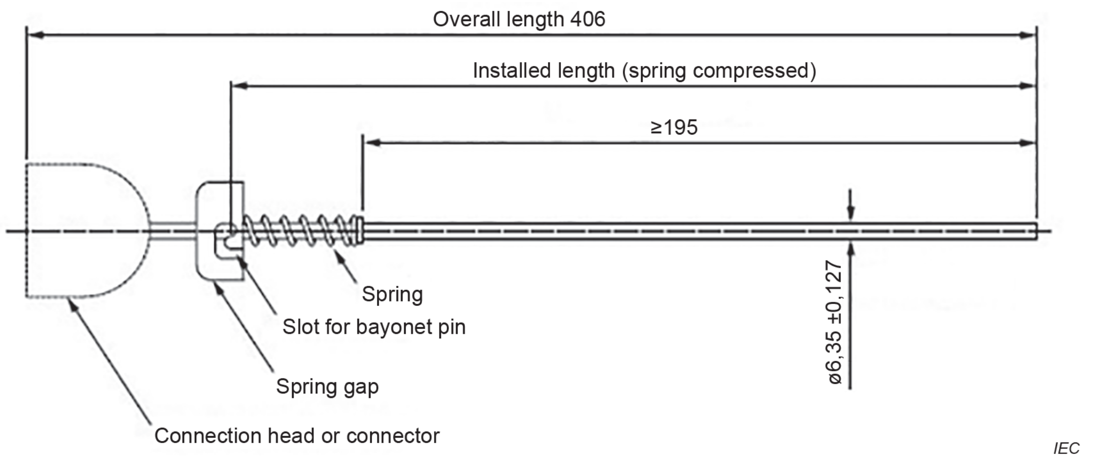

Figure 1 – Form and dimensions of an RTD