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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

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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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International Standard IEC 62397 has been prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

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

FDIS	Report on voting
45A/650/FDIS	45A/656/RVD

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.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated 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- withdrawn;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.

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) being 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.

When the project was proposed in October 2002 during the SC 45A meeting held in Beijing, China, there was no other known IEC standard currently available on this subject.

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

The top-level document of the IEC SC 45A standard series is IEC 61513. It provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 61513 structures the IEC SC 45A standard series.

IEC 61513 refers directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation of systems, defence against common-cause failure, software aspects of computer-based systems, hardware aspects of computer-based systems, and control room design. The standards referenced directly at this second level should be considered together with IEC 61513 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 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 technical reports, which are not normative.

IEC 61513 has adopted a presentation format similar to the basic safety publication IEC 61508 with an overall safety life-cycle framework and a system life-cycle framework and provides an interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. Compliance with IEC 61513 will facilitate consistency with the requirements of IEC 61508 as they have been interpreted for the nuclear industry. In this framework, IEC 60880 and IEC 62138 correspond to IEC 61508-3 for the nuclear application sector.

IEC 61513 refers to ISO as well as to IAEA 50-C-QA (now replaced by IAEA 50-C/SG-Q) for topics related to quality assurance (QA).

The IEC SC 45A series of standards consistently implements and details the principles and basic safety aspects provided in the IAEA code on the safety of NPPs and in the IAEA safety series, in particular the requirements NS-R-1 establishing safety requirements related to the design of NPPs, and safety guide NS-G-1.3 dealing with instrumentation and control systems important to safety in NPPs. The terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

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

1 Scope

This International Standard describes the requirements for resistance temperature detectors (RTDs) suitable for nuclear power plant (NPP) services. The requirements of RTDs include design, materials, manufacturing, testing, calibration, procurement, and inspection. In nuclear application, both "direct-immersion" and "thermowell-mounted" RTD are commonly used; however, this standard does not exclude any other design of RTD which may be required for certain special applications in various types of reactors.

RTDs can be supplied in 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, as well as the qualification tests specified by the user[1]. The use of a flexible mineral-insulated (MI) cable between the RTD and the connector is commonly adopted, and the user may also adopt any other construction. A variation of this design may include a rigid exterior sheath over the MI cable between the RTD and the connector, these being welded to each other.

The scope of this standard does not cover the design, material selection, and construction of the thermowell, the guide tube, the extension cable, and the temperature transmitter or bridge which may be associated with the RTD.

2 Normative references

The following referenced documents are indispensable for the application 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 60780:1998, *Nuclear power plants – Electrical equipment of the safety system – Qualification*

IEC 60980:1989, *Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations*

IEC 61224, *Nuclear reactors – Response time in resistance temperature detectors (RTD) – In situ measurements*

3 Terms and definitions

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

[1] The user corresponds to the party or the company that uses the RTD in a 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.

3.1
accuracy of measurement
closeness of the agreement between the result of a measurement and the conventional true value of the measurand

[IEV 394-40-35]

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

[IEV 394-40-43]

3.3
drift
variation in sensor or instrument channel output that may occur between calibrations that cannot be related to changes in the process variable or environmental conditions

[IEC 62385, definition 3.6]

3.4
performance monitoring
process of demonstrating that an installed instrument channel continues to perform its intended function of monitoring the process variable with the expected accuracy, response time, and stability

[IEC 62385, definition 3.14]

3.5
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 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 standard.

NOTE 2 In this standard, 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. For air temperature measurement, a direct sensor may be used.

3.6
response time
the time required for the output signal of a component to reach a specified fraction (generally 90 %) of its final variation after a step change of its input signal

3.7
self-heating error
rise in the indicated temperature due to the power dissipated in the sensor

3.8
thermowell
protective jacket for RTDs, thermocouples, and other temperature sensors. The thermowell is also used to facilitate replacement of the temperature sensor

[IEC 62385, definition 3.21]

3.9
time constant
in the case of a first order system, the time required for the output signal of a system to reach 63,2 % of its final variation after a step change of its input signal.

If the system is not first order system, the term "time constant" is not appropriate. For a system of a higher order, the term "response time" should be used.

4 Design and construction requirements

4.1 General

The RTD and its associated devices shall meet the requirements described in this standard but shall not necessarily be limited to these requirements.

4.2 Reliability

The design philosophy for RTDs in an NPP requires a device which is capable of continuous successful operation at rated service conditions throughout the design life of the plant. The equipment should have a failure rate less than 5×10^{-3} failures per year.

RTDs operated in safety systems should have their design lives defined. For RTD whose design life is less than the design life of the NPP or the safety system, then arrangement shall be made for the RTD to be replaced or re-assessed before its design life is reached.

4.3 Materials

Materials, processes and standard parts which are not specifically designated herein and which are necessary for the manufacturing and installation of the RTD shall be of high quality and in accordance with the highest calibration practice pertinent to the manufacture and application of instrumentation equipment.

All equipment, material, and articles incorporated in the products covered by this standard shall be new but may be fabricated using components produced from recycled materials to the maximum extent practicable without jeopardizing the intended use.

4.3.1 Radiation dose to materials

The maximum radiation dose may be about 900 kGy (90 Mrad) depending on the application and the mission time after a design basis accident.

Some devices may be exposed to neutron fluxes. The user shall review and approve the use of the materials, which may be subject to activation.

4.3.2 Resistance element material

Platinum is used extensively for resistance thermometers in an NPP for both safety- and non-safety-related instrument applications. Platinum is a noble metal, relatively stable and unaffected by its surrounding environment. It resists corrosion, oxidation, and other forms of chemical attack. It is easily workable and can be drawn into fine wires. Platinum has a high melting- point, which shows little volatilization below 1 000 °C. Platinum can be obtained to a high degree of purity, which has a reproducible electrical and chemical characteristic over a wide range of temperatures. All this is evidenced by a simple linear and stable resistance temperature relationship that characterizes the platinum sensor. However, the electrical resistance of platinum wire is extremely sensitive to minute quantities of contaminating impurities and to strains; both of these characteristics may alter the simple resistance-temperature relationship.

Other metals may also be used for resistance thermometers provided their accuracy, repeatability, response time, and reliability comply with the requirements of the applications.

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.

4.3.3 Seals and adhesives

The RTD shall be hermetically sealed. The connector may or may not be an integral part of the RTD assembly. RTD used in a harsh environment, such as under high-temperature and/or radiation areas, shall be designed without organic material. The use of ceramic material is recommended. The tightness of the insulating termination shall be tested according to an adequate and proven procedure. Commonly suggested seals of the connector are glass-to-metal or ceramic-to-metal, which should have less than 10^{-8} cm^3/s leak rate when tested with helium at an atmospheric differential pressure.

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

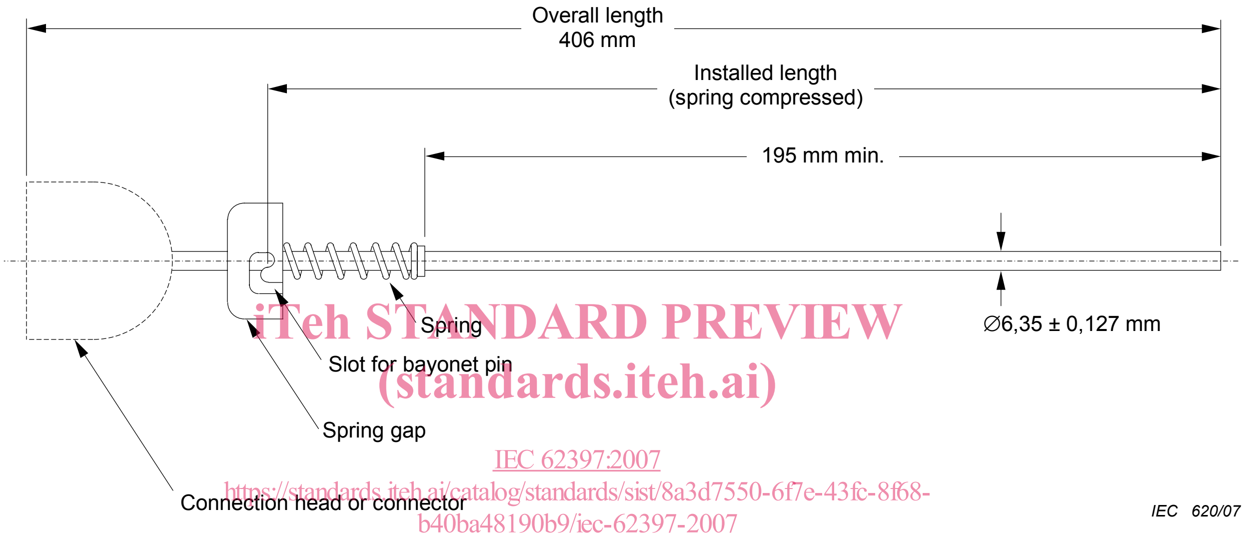
4.4.1 Electrical connection

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 without a quick disconnect and is referred to as Type I (standard). Figures 3 and 4 are rigid RTDs with quick disconnectors, and are referred to as Type II with long insertion and short insertion, respectively. A user may specify any other form of RTD and construction, depending on its particular applications.

Type I (standard): The electrical connection is made within a metallic housing (connection head) and is achieved by screw-type terminals. The housing shall be waterproof when closed and shall permit ready withdrawal of the RTD when open. The removable cap shall be joined to the body by a corrosion-resistant chain. The nipple and the extension may be specified as part of the application or recommended by the temperature-sensor manufacturer[2].

Type II (quick disconnect): The electrical connection is achieved by using a multi-pin connector. The connector need not be a hermetic type, but it shall be splash-proof when mated and shall meet the insulation resistance requirements in 4.7.6. In addition, the contact resistance across a mated connector shall not exceed 0,25 Ω. For high-accuracy application, the user may consider gold or silver plating for the pins and sockets of the connector.



NOTE Spring may be enclosed inside connection head.

Figure 1 – Form and dimensions of an RTD

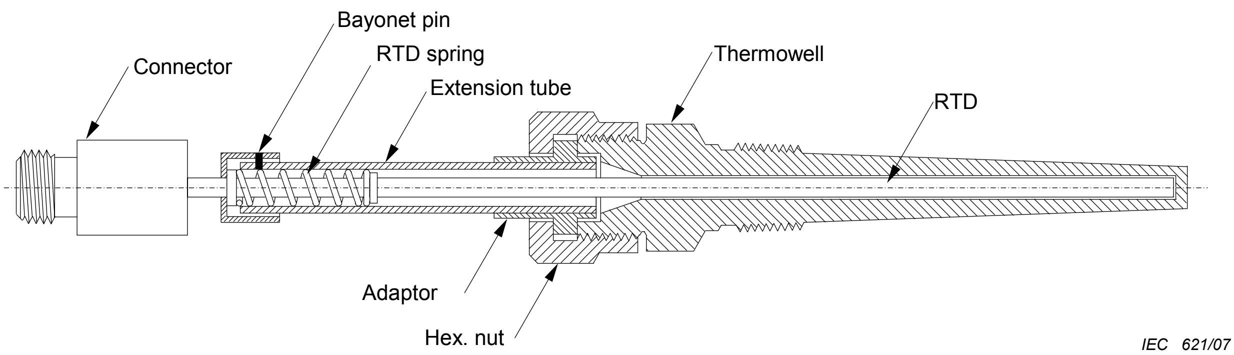


Figure 2 – Installation of a rigid RTD (Type I)

2 The manufacturer corresponds to the party or the company that manufactures the RTD. The term manufacturer may also refer to the supplier or the vendor of the RTD.

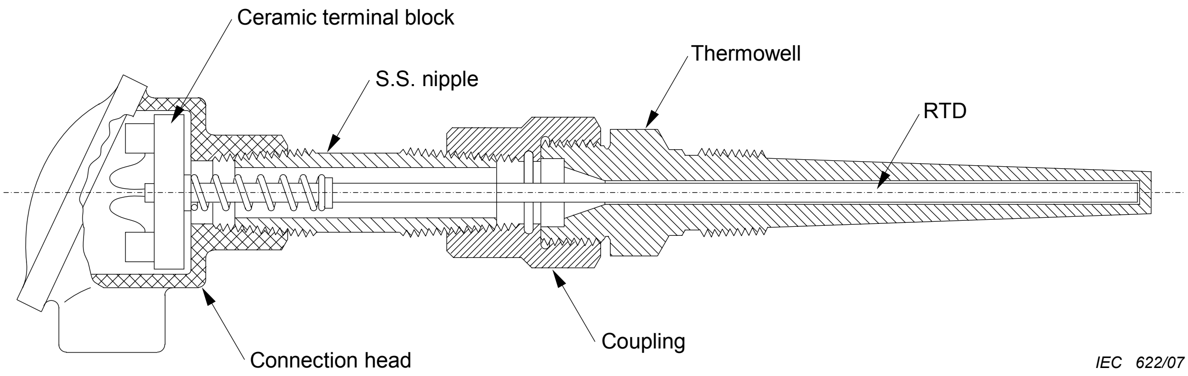


Figure 3 – Installation of a rigid RTD (Type II) long insertion

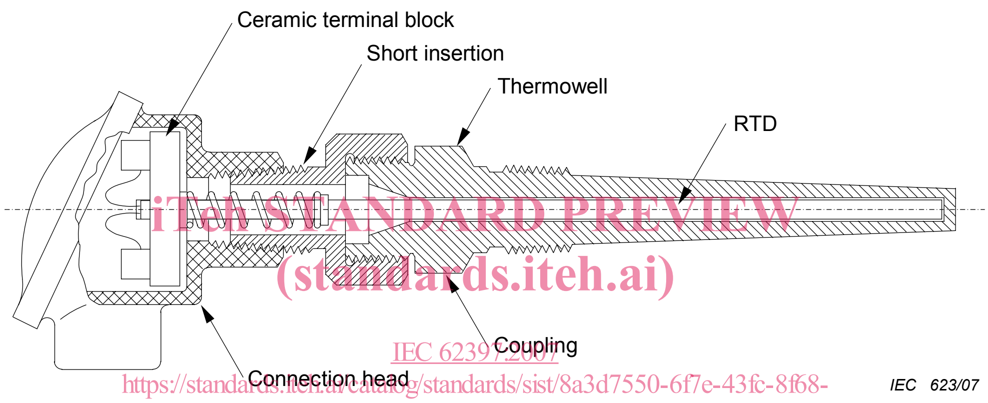


Figure 4 – Installation of a rigid RTD (Type II) short insertion

The temperature rating of the connector shall be at least 150 °C or the accident temperature specified by the user. Unless otherwise specified, the manufacturer shall supply the mating connector half with the RTD. The adapter and the extension tube shall be supplied by the manufacturer.

Electrical continuity

All circuits shall maintain electrical continuity throughout the normal and accident operating conditions.

Contact resistance

Resistance in the contacts of each circuit shall not be greater than 0,25 Ω.

Lead wires

Three or four lead wires may be used depending on their applications and degree of required accuracy. The RTD should normally be used as a three-wire device unless a four-wire device is required for specific design reasons. The lead wires of the RTD shall be continuously supported by an insulating material in such a manner that the completed RTD is insensitive to vibration. The lead-wire material shall be so chosen as to reduce the resistance of the leads to the practicable minimum.