BS IEC 60951-1:2022

BSI Standards Publication

Nuclear facilities — Instrumentation systems important to safety — Radiation monitoring for accident and post-accident conditions

Part 1: General requirements

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National foreword

This British Standard is the UK implementation of IEC 60951-1:2022. It supersedes BS IEC 60951-1:2009, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NCE/8, Instrumentation, Control & Electrical Systems of Nuclear Facilities.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Installations nucléaires – Systèmes d'instrumentation importants pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles – Partie 1: Exigences générales

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NUCLEAR FACILITIES – INSTRUMENTATION SYSTEMS IMPORTANT TO SAFETY – RADIATION MONITORING FOR ACCIDENT AND POST-ACCIDENT CONDITIONS –

Part 1: General requirements

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 60951-1 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 third edition cancels and replaces the second edition published in 2009. This edition constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows.

- Title modified.
- To be consistent with the categorization of the accident condition.
- To update the references to new standards published since the second edition.
- To update the terms and definitions.

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

Draft	Report on voting
45A/1440/FDIS	45A/1449/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.

A list of all parts of IEC 60951 series, under the general title *Nuclear facilities – Instrumentation systems important to safety – Radiation monitoring for accident and post-accident conditions,* can be found on the IEC website.

Future documents in this series will carry the new general title as cited above. Titles of existing documents in this series will be updated at the time of the next edition.

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.

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INTRODUCTION

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

This IEC standard specifically focuses on radiation monitoring systems (RMSs) used for accident operations.

According to the lessons learned from the Fukushima-Daiichi accident, it re-acknowledges a need to provide operators with reliable radiation monitoring data to allow them to understand the plant state during and after the accident conditions. To support the design of such instrumentation, it is necessary to provide general guidance on the design principles and performance criteria for radiation monitoring instrumentation applied during and after the accident conditions. In addition, the scope of IEC 63147 which provides criteria for accident monitoring instrumentation for nuclear power generating stations has evolved to include severe accident (SA) to accident conditions.

Thus, to address the specific lessons learned from the Fukushima-Daiichi accident, this standard categorizes accident condition into design basis accidents (DBA) and design extension conditions (DEC), including severe accident (SA).

This standard is intended for use by purchasers in developing specifications for their plant-specific radiation monitoring systems and by manufacturers to identify needed equipment characteristics when developing systems for accident monitoring conditions. Some specific instrument characteristics such as measurement range, energy response, and environmental withstanding conditions will depend on the specific application. In such cases, guidance is provided on determining the specific requirements, but specific requirements themselves are not stated.

This standard is one in a series of standards applicable to equipment for continuous monitoring of radiation level important to safety intended for use during design basis accidents (DBA) and design extension conditions (DEC) including severe accident (SA), and post-accident conditions. The full series is comprised of the following standards.

– IEC 60951-1 – General requirements
– IEC 60951-2 – Equipment for continuous off-line monitoring of radioactivity in gaseous effluents and ventilation air
– IEC 60951-3 – Equipment for continuous high range area gamma monitoring
– IEC 60951-4 – Equipment for continuous in-line or on-line monitoring of radioactivity in process streams.

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

The IEC 60951 series of standards are at the third level in the hierarchy of SC 45A standards. They provide guidance on specification, design and testing of radiation monitoring equipment used for accident and post-accident conditions.

Other standards developed by SC 45A and SC 45B provide guidance on instruments used for monitoring radiation as part of normal operations. The IEC 60761 series provides requirements for equipment for continuous off-line monitoring of radioactivity in gaseous effluents in normal conditions. IEC 60861 provides requirements for equipment for continuous off-line monitoring of radioactivity in liquid effluents in normal conditions. IEC 60768 provides requirements for equipment for continuous in-line and on-line monitoring of radioactivity in process streams in normal and incident conditions. Finally, ISO 2889 gives guidance on gas and particulate sampling. In addition, IEC 62705 provides guidance on the application of existing IEC/ISO standards covering design and qualification of RMS. An overview of the standards covering the radiation monitoring in nuclear facilities is given in Table 1.

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IEC 63147/IEEE Std 497™ provides general guidance for accident monitoring instrumentation. IEEE Std 497™ was directly adopted as a joint logo standard and a technical report, IEC TR 63123, was prepared to discuss the application of the joint standard within the IEC context.

The structure of this standard is adapted from the structure of IEC 63147/IEEE Std 497™, and the technical requirements of this standard are consistent with the requirements given in IEC 63147/IEEE Std 497™ together with the application guidance given in IEC TR 63123.

Table 1 – Overview of the standards covering the domain of radiation monitoring in nuclear facilities

Developer	ISO		IEC			
			SC45A			SC45B
Scope	**Sampling (Normal operation)**	**Calibration (Normal operation)**	**Normal operation, AOO**	**DBA**	**DEC**	**Normal operation**
Radioactive noble gas off-line monitoring	ISO 2889	ISO 4037-1, ISO 4037-3	N/A	IEC 60951-1, IEC 60951-2	N/A	IEC 62302, IEC 60761-1, IEC 60761-3
Radioactive aerosol off-line monitoring	ISO 2889	ISO 4037-1, ISO 4037-3	N/A	IEC 60951-1, IEC 60951-2	N/A	IEC 60761-1, IEC 60761-2
Radioactive iodine off-line monitoring	ISO 2889	ISO 4037-1, ISO 4037-3	N/A	IEC 60951-1, IEC 60951-2	N/A	IEC 60761-1, IEC 60761-4
Liquid off-line monitoring	N/A	N/A	N/A	N/A	N/A	IEC 60861
Tritium off-line monitoring	N/A	N/A	N/A	N/A	N/A	IEC 62303, IEC 60761-1, IEC 60761-5
On-line or in-line monitoring	N/A	ISO 4037-1, ISO 4037-3	IEC 60768	IEC 60951-1, IEC 60951-4	N/A	N/A
Area monitoring	N/A	ISO 4037-1, ISO 4037-3	IEC 61031	IEC 60951-1, IEC 60951-3		IEC 60532
Centralized system	N/A	N/A	IEC 61504, IEC 60960		N/A	IEC 61559-1
Classification/basic requirements	N/A	N/A	IEC 61513, IEC 60880, IEC 60987, IEC 61226, IEC 62138, IEC 62566, IEC 62566-2, IEC 62645, IEC 61250		N/A	N/A
Qualification	N/A	N/A	IEC/IEEE 60780-323, IEC/IEEE 60980-344, IEC 62003		N/A	IEC 62706

For more details on the structure of the IEC SC 45A standard series, see the 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 systems important to safety.

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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 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).

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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.

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NUCLEAR FACILITIES – INSTRUMENTATION SYSTEMS IMPORTANT TO SAFETY – RADIATION MONITORING FOR ACCIDENT AND POST-ACCIDENT CONDITIONS –

Part 1: General requirements

1 Scope

This part of IEC 60951 provides general guidance on the design principles and performance criteria for equipment to measure radiation and fluid (gaseous effluents or liquids) radioactivity levels at nuclear facilities during and after design basis accidents (DBA) and design extension conditions (DEC), including severe accident (SA). This document is limited to equipment for continuous monitoring of radioactivity in design basis accidents (DBA), design extension conditions (DEC), including severe accident (SA) and post-accident conditions.

The purpose of this document is to lay down general requirements and give examples of acceptable methods for equipment for continuous monitoring of radioactivity within the facility during and after design basis accidents (DBA), design extension conditions (DEC), including severe accident (SA) in nuclear facilities.

It specifies, for the equipment described above, the general characteristics, general test procedures, radiation, electrical, safety and environmental characteristics and the identification and certification of the equipment. If this equipment is part of a centralized system for continuous radiation monitoring in a nuclear facility, there may be additional requirements from other standards related to this system.

Sample extraction and laboratory analysis, which are essential to a complete programme of effluent monitoring, are not within the scope of this document.

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 60038:2009, *IEC standard voltages*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

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

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

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

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

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IEC 60529, *Degrees of protections provided by enclosures (IP code)*

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

IEC 60880, *Nuclear power plants – Instrumentation and control systems important to safety – Software aspects for computer-based systems performing category A functions*

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

IEC 60987, *Nuclear power plants – Instrumentation and control important to safety – Hardware requirements*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8:2009, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-12:2017, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61000-4-18:2019, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

IEC 61000-6-4:2018, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61069-1:2016, *Industrial-process measurement, control and automation – Evaluation of system properties for the purpose of system assessment – Part 1: Terminology and basic concepts*

IEC 61226, *Nuclear power plants – Instrumentation, control and electrical power systems important to safety – Categorization of functions and classification of systems*

IEC 61504:2017, *Nuclear facilities – Instrumentation and control systems important to safety – Centralized systems for continuous monitoring of radiation and/or levels of radioactivity*

IEC 61513:2011, *Nuclear power plants – Instrumentation and control important to safety – General requirements for systems*

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

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IEC 62262:2002, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

IEC 62566:2012, *Nuclear power plants – Instrumentation and control important to safety – Development of HDL-programmed integrated circuits for systems performing category A functions*

IEC 62566-2:2020, *Nuclear power plants – Instrumentation and control important to safety – Development of HDL-programmed integrated circuits – Part 2: HDL-programmed integrated circuits for systems performing category B or C functions*

IEC 62705, *Nuclear facilities – Instrumentation and control important to safety – Radiation monitoring systems (RMS): Characteristics and lifecycle*

ISO 2889:2015, *Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities*

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

3.1
absolute error of measurement
difference between the measured value and the conventional quantity value of the measurand

3.2
acceptance test
contractual test to prove to the customer that the device fulfils certain specifications

3.3
aerodynamic equivalent diameter
diameter of unit-density sphere having the same gravitational settling velocity as the particle of concern

Note 1 to entry: The aerodynamic equivalent diameter concerns particles with a diameter from 0,1 µm to 2 mm.

[SOURCE: IEC 60050-395:2014, 395-02-34]

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3.4
coefficient of variation
ratio of the standard deviation s to the arithmetic mean $\bar{x}$ of a set of n measurements x_i given by the following formula:

$$V = \frac{s}{\bar{x}} = \frac{1}{\bar{x}} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}$$

3.5
collection efficiency
percentage retained by the filter of the total amount of particles initially in a known volume of air passed through the filter

3.6
conventional quantity value
quantity value attributed by agreement to a quantity for a given purpose

Note 1 to entry: The term "conventional true quantity value" is sometimes used for this concept, but its use is discouraged.

Note 2 to entry: Sometimes a conventional quantity value is an estimate of a true quantity value.

Note 3 to entry: A conventional quantity value is generally accepted as being associated with a suitably small measurement uncertainty, which might be zero.

3.7
effective range of measurement
absolute value of the difference between the two limits of a nominal range

Note 1 to entry: In the nominal range the performance of a piece of equipment or an assembly meets the requirements of its specifications.

3.8
electron beam
electron flux emitted from one source and moving along the exactly determined tracks with very great velocities

Note 1 to entry: Such beam routed to a detector causes extremely high dose rates.

[SOURCE: IEC 60050-841:2004, 841-30-01]

3.9
experimental standard deviation
for a series of n measurements of the same measurand, the quantity s characterizes the dispersion of the results and is given by the formula:

$$s = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n-1}}$$

x_i being the result of the ith measurement and $\bar{x}$ being the arithmetic mean of the n results considered

Note 1 to entry: The expression $s/\sqrt{n}$ is an estimate of the standard deviation of the distribution of x and is called the experimental standard deviation of the mean.

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