IEC 60951-3

Edition 3.0 2022-11
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Nuclear ~~power plants~~ facilities – Instrumentation systems important to safety – Radiation monitoring for accident and post-accident conditions – Part 3: Equipment for continuous high range area gamma monitoring

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Part 3: Equipment for continuous high range area gamma monitoring

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60951-3:2009. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 60951-3 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.

This standard is to be read in conjunction with IEC 60951-1.

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

Draft	Report on voting
45A/1441/FDIS	45A/1450/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.

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.

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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

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

This IEC standard specifically focuses on radiation monitoring systems (RMSs) used for accident ~~and post-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 ~~product~~ equipment characteristics when developing systems for accident monitoring conditions. Some specific instrument characteristics such as measurement range, ~~required~~ energy response, and ~~ambient environment requirements~~ environmental withstanding conditions will depend upon 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 ~~covering post-accident radiation monitors important to safety~~ 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. ~~The relationship between these various radiation monitoring standards is given in the Table 1 below.~~ 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 presented in Table 1.

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	SC 45A – Process and safety monitoring		SC 45B – Radiation protection and effluents monitoring
Scope	Sampling circuits and methods	Accident and post-accident conditions	Normal and incident conditions	
Gas, particulate and iodine with sampling (OFF LINE)	ISO 2889	IEC 60951-1 and IEC 60951-2	IEC 60761 series and IEC 62302 (noble gases only)	
Liquid with sampling (OFF LINE)	N/A	N/A	IEC 60861	
Process streams (gaseous effluents, steam or liquid) without sampling (ON or IN-LINE)	N/A	IEC 60951-1 and IEC 60951-4	IEC 60768	N/A
Area monitoring	N/A	IEC 60951-1 and IEC 60951-3	IEC 60532	
Central system	N/A	IEC 61504		IEC 61559

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 ~~safety~~ systems important to safety.

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 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 the 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 standards as well as to IAEA 50-C-QA (now replaced by IAEA GS-R-3) for topics related to quality assurance (QA).~~

~~The IEC SC 45A standards series 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 Nuclear Power Plants, and the Safety Guide NS-G-1.3 dealing with instrumentation and control systems important to safety in Nuclear Power Plants. The terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.~~

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

Part 3: Equipment for continuous high range area gamma monitoring

1 Scope

This part of IEC 60951 provides general guidance on the design principles and performance criteria for equipment for continuous high range area gamma monitoring in nuclear ~~power plants~~ facilities for accident and post-accident conditions. This document categorizes accident conditions into design basis accidents (DBA) and design extension conditions (DEC), including severe accident (SA).

General requirements for technical characteristics, test procedures, radiation characteristics, electrical, mechanical, and environmental characteristics are given in IEC 60951-1. These requirements are applicable in this document, unless otherwise stated.

The purpose of this document is to lay down general requirements for equipment for continuous high range area gamma monitoring of radiation within the facility during and after accident conditions in nuclear facilities.

This document is applicable to installed dose rate meters that are used to monitor high levels of gamma radiation during and after an accident. It covers equipment intended to isotropically measure air kerma, ambient dose or other exposure quantities due to gamma radiation of energy between 80 keV and 7 MeV. The equipment is intended primarily for the purpose of nuclear ~~plant~~ facility safety.

Portable instruments for emergency purposes and installed area radiation monitors used to determine continuously the radiological situation in working areas during normal operation are in the scope of IEC 60532.

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 60951-1:~~2009~~2022, *Nuclear ~~power plants~~ facilities – Instrumentation systems important to safety – Radiation monitoring for accident and post-accident conditions – Part 1: General requirements*

~~IEC 60780, *Nuclear power plants – Electrical equipment of the safety system – Qualification*~~

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

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

ISO 4037 (all parts), *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy*

ISO 6980 (all parts), *Nuclear energy – Reference beta-particle radiation*

ISO 8529 (all parts), ~~*Reference neutron radiations*~~ *Neutron reference radiations fields*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60951-1 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

4 Design principles

4.1 General

The general requirements of IEC 60951-1 are applicable to all types of monitors within the scope of the present document, unless otherwise stated.

The radiation monitor classified for functions important to safety shall comply with the requirements relating to the characteristics and lifecycle of RMS defined in IEC 62705 and the standards referenced in IEC 62705 (e.g. IEC 61226).

4.2 Range of measurement

The purchaser shall specify the required effective range of measurement and the radiation sources specific to the ~~plant~~ facility design. The range shall be suitable for the level of and the variation in radiation in the area during accident and post-accident conditions. It shall be at least six decades. The low end of the required range shall overlap the highest decade of dose rate monitors designed for normal operation conditions.

The energy response of the detector in relation to the expected radiation energy spectrum shall also be specified. Typically, detectors should respond to gamma radiation within any energy range from 80 keV to 7 MeV.

4.3 Accuracy (relative error)

In addition to 4.6 of IEC 60951-1:2022, the following requirements shall apply.

When a detector assembly utilizes more than one radiation detector to cover the full range of dose equivalent rates indicated by the detector assembly, these requirements apply to the relevant ranges for each detector separately.

4.4 Location of sensors

The requirements for such equipment are ~~plant~~ facility specific. Therefore, the locations in which the monitoring equipment is required shall be determined according to the ~~plant~~ facility design.

For nuclear power plants, usually equipment is located within the reactor containment. It shall be located to provide maximum coverage of the areas being monitored and to minimize

shielding effects from other equipment or structures. As far as is practical, locations should be selected so as to facilitate maintenance and calibration operations.

Because of the high level of radiation, the equipment is usually designed with a detector assembly located remotely from any processing assembly (electronics), taking into account the length of the cable between detector and remote electronics which should be minimized.

4.5 ~~Detector radiation response characteristics~~ Response for other radiation sources

The detector assembly shall be designed to be effectively insensitive to beta and neutron radiation (compared to its gamma sensitivity) expected to be present during the accident conditions for which the equipment is intended to operate.

4.6 Requirements related to accident conditions

In addition to 4.12 of IEC 60951-1:2022, the following requirements shall apply.

~~The type of equipment covered by this standard is typically regarded as essential safety related equipment. It shall be therefore classified according to IEC 61226 guidance and environmentally qualified in accordance with the requirements of IEC 60780.~~

For nuclear power plants, the detector assembly of such equipment is usually located within the reactor building which is submitted to a harsh environment during and after an accident. The qualification program, agreed upon between the manufacturer and the purchaser, shall take into account specific conditions such as very high integrated dose (up to 1×10^6 Gy) as well as combined high temperature, pressure and humidity.

There may be cases where diversity or multiplexing in detector assembly or monitoring channel is required for facility accident countermeasures.

5 Functional testing

5.1 General

Except where otherwise specified, all the tests specified in Clause 5 of IEC 60951-1:2022 shall be carried out.

The tests described hereinafter are only additional tests dedicated to the type of monitors within the scope of the present document. As for tests stated in IEC 60951-1, these tests are to be considered as type tests, although any or all may be considered as acceptance tests by agreement between manufacturer and purchaser.

These tests are carried out under standard conditions or with variation of the influence quantities. They are listed in ~~Table 1~~ Table 2.

Table 2 – Additional tests to complement the general tests required in IEC 60951-1

Tests	Tests conditions	Limits of variation of indication	Reference (subclause)
Reference response	Range of photon radiation energy between 80 keV and 7 MeV	±30 % ~~of the medium sensitivity~~ between 100 keV and 3 MeV Value to be stated by agreement otherwise if necessary	5.3.1
Response to beta radiation	Range of beta radiation energy from a Sr-90/Y-90 source up to 4 MeV	In accordance with manufacturer's specifications	5.3.2.2
Variation of response with angle of incidence	Different angles of incidence (±15°, ±30°, ±45° ±60°) in the plane including the reference direction and in a plane perpendicular to that.	±30 %	5.3.3
NOTE For assemblies having a non-linear scale, a linear instrument may be substituted for the indicating meter of the assembly to verify the performance specified in this table.			

5.2 Reference sources

5.2.1 General

In addition to 5.2.5 of IEC 60951-1:2022, the following requirements shall apply.

All tests shall be carried out using a monodirectional radiation field, unless otherwise agreed between manufacturer and purchaser.

5.2.2 Gamma

All tests shall be conducted with Cs-137, unless specified otherwise. As an alternative, Co-60 may be used. In this case correction shall be made for the difference in response of the detector assembly between Co-60 and Cs-137. These radiation qualities are specified in the ISO 4037 series. For very high dose rates an electron beam may be used.

The conventional ~~true~~ value of dose rate shall be known with an accuracy better than 5 %.

5.2.3 Beta

If the detector is sensitive to beta radiation, a test for the detector assembly response to gamma radiation in the presence of beta radiation shall be conducted when agreed between manufacturer and purchaser. The response of the detector assembly to beta radiation from a Sr-90/Y-90 source shall be stated by the manufacturer. The reference beta radiation fields are specified in the ISO 6980 series.

If the detector is not sensitive to beta radiation, the manufacturer should provide a demonstration of this non-sensitivity by analysis.

5.2.4 Neutron

If the detector is sensitive to neutron radiation, the response to neutron radiation shall be stated when agreed between manufacturer and purchaser. A test for neutron response shall be carried out if the detector assembly is intended to be used in the presence of neutron radiation. Cf-252 should be used for neutron tests. The reference neutron radiation fields are specified in the ISO 8529 series.

If the detector is not sensitive to neutron radiation, the manufacturer should provide a demonstration of this non-sensitivity by analysis.

5.3 Performance characteristics

5.3.1 Reference response

In addition to 5.3.1 of IEC 60951-1:2022, the following requirements shall apply.

The variation of response with photon radiation energy between 100 keV and 3 MeV shall be within ±30 %.

For assemblies intended for use in energies higher than 3 MeV, the variation shall be subject to agreement between the purchaser and manufacturer.

In principle, this test should be performed at the same dose rate for each radiation energy. In practice, this may not be possible, in which case the indicated dose rate of each radiation energy should be corrected for the non-linearity (interpolated if necessary) at the indicated dose rate and for the reference gamma radiation.

The following energies should be used for low air kerma rates (taken from the ISO 4037 series):

- Mean energy (keV): quality (tube voltage, kV);
- 100 keV(N-120) or 109 keV(L-125);
- 118 keV(N-150);
- 164 keV(N-200) or 149 keV(L-170);
- 208 keV(N-250) or 211 keV(L-240);
- 662 keV (Cs-137);
- 1 250 keV (Co-60).

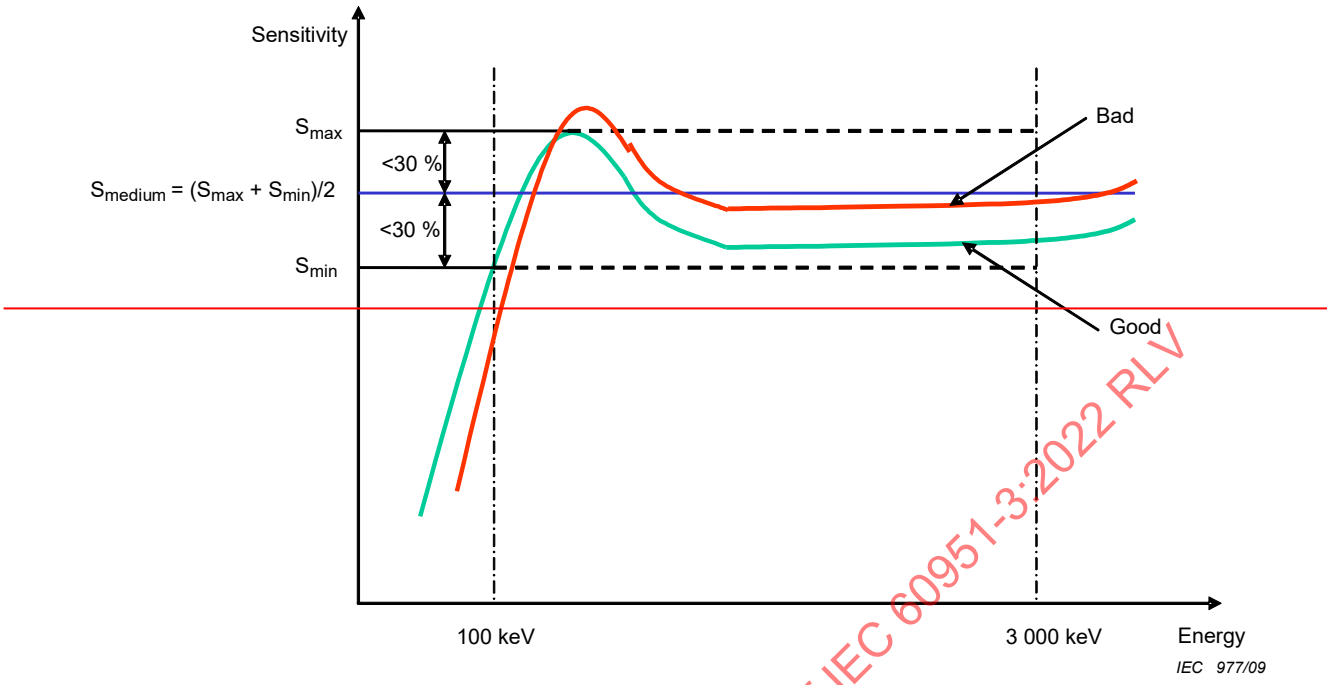
Energy response to other photon energies might be demonstrated by real tests or Monte Carlo simulations.

~~The energy corresponding to the medium sensitivity: $S_{medium} = (S_{max} + S_{min})/2$, shall be taken as a reference,~~

~~with S_{max} the maximum sensitivity in the energy range (between 100 keV and 3 MeV),~~

~~and S_{min} the minimum sensitivity in the energy range (between 100 keV and 3 MeV).~~

~~In this condition, S_{max} shall not exceed more than 30 % of S_{medium}, and S_{min} shall not go below 30 % of S_{medium}, which means $(S_{max} - S_{medium})/S_{medium} < 30$ % and $(S_{medium} - S_{min})/S_{medium} < 30$ % (see Figure 1).~~



~~**Figure 1 – Energy response**~~

The energy corresponding to the average energy range shall be taken as a reference energy. For this purpose, Cs-137 or Co-60 should be chosen.

The variation of response for other energies within the energy range shall be within ±30 % of the reference response to the reference energy.

If for specific applications it is necessary to extend the energy range, the energy response shall be defined and agreed between the manufacturer and the purchaser. In this case it can be performed either by real tests or by Monte Carlo simulations.

For specific severe accident applications, additional thermal shielding may be required. This may additionally affect the energy response of the system; in this case the required energy response shall be agreed between purchaser and manufacturer.

5.3.2 Sensitivity and relative response for ~~solid~~ other radiation sources

5.3.2.1 General

In addition to 5.3.2 of IEC 60951-1:2022, the following requirements shall apply.

5.3.2.2 Response to beta radiation

The response of the detector assembly to beta radiation from a Sr-90/Y-90 source shall be stated by the manufacturer who shall also indicate the response to beta radiation for energies up to 4 MeV.

If agreed upon between the manufacturer and the purchaser, the test for the response to beta radiation shall be carried out and the response shall be expressed as the ratio of the detector assembly indication to the conventional ~~true~~ value of absorbed dose rate (due to the Sr-90/Y-90 source) in air at the detector reference point when the detector is not present.

The detector assembly shall be exposed at 0° angle of radiation incidence to beta reference radiation specified in ISO 6980.

5.3.3 Variation of response with angle of incidence

5.3.3.1 Requirements

The response to a reference gamma source shall be within ±30 % of the reference response (corresponding to 0°) for the following angles of incidence: ±15°, ±30°, ±45° ±60° in the plane including the reference direction and in a plane perpendicular to that and also including the reference direction.

The manufacturer shall state the relative variation of the response for ±90°.

The results should be expressed as a ratio of the response per unit dose rate for each radiation source utilized to the response per unit dose rate for zero degrees angle of incidence.

If another range of angles is required, it shall be selected according to the agreement between the manufacturer and the purchaser.

5.3.3.2 Test method

The assembly shall be mounted so as to most conveniently enable measurements to be made at the required angle.

For this test, the reference point of the detector assembly shall be placed at a point of test where the dose rate is known. The photon radiation qualities of the narrow spectrum series and the gamma sources Cs-137 specified in the ISO 4037 series should be used if possible.

~~Firstly, the direction of radiation shall be changed in steps of 15° in a plane including the reference direction specified by the manufacturer (reference response as determined in 5.2.1).~~

~~Secondly, the direction of radiation shall be changed in steps of 15° in a plane perpendicular to that used above and also including the reference direction.~~

a) The direction of radiation shall be changed in steps of 15° in a plane including the calibration direction specified by the manufacturer and the response determined throughout the range of angles specified in 5.3.3.1.

b) The procedure of a) above shall be repeated for the plane perpendicular to that used in a), but still including the calibration direction.

5.3.4 Environmental performance

Tests considering the dose rate, temperature, pressure, humidity and vibration shall be performed by assuming the environment of design extension conditions (DEC) including severe accident (SA).

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IEC 60761-3:2002, *Equipment for continuous monitoring of radioactivity in gaseous effluents – Part 3: Specific requirements for radioactive noble gas monitors*

IEC 60761-4:2002, *Equipment for continuous monitoring of radioactivity in gaseous effluents – Part 4: Specific requirements for radioactive iodine monitors*

IEC 60761-5:2002, *Equipment for continuous monitoring of radioactivity in gaseous effluents – Part 5: Specific requirements for tritium monitors*

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IEC 60861:2006, *Equipment for monitoring of radionuclides in liquid effluents and surface waters*

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

IEC 60951-2:2009, *Nuclear power plants – Instrumentation important to safety – Radiation monitoring equipment for accident and post-accident conditions – Part 2: Equipment for continuous off-line monitoring of radioactivity in gaseous effluents and ventilation air*

IEC 60951-4:2009, *Nuclear power plants – Instrumentation important to safety – Radiation monitoring equipment for accident and post-accident conditions – Part 4: Equipment for continuous in-line or on-line monitoring of radioactivity in process streams*

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IEC 62303:2008, *Radiation protection instrumentation – Equipment for monitoring airborne tritium*

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IEC TR 63123, *Nuclear power plants – Instrumentation, control and electrical power systems – Guidance for the application of IEC 63147:2017/IEEE Std 497™ -2016 in the IAEA / IEC framework*

IEC 63147/IEEE Std 497™, *Criteria for accident monitoring instrumentation for nuclear power generating stations*

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

IEC 60951-3

Edition 3.0 2022-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear facilities – Instrumentation systems important to safety – Radiation monitoring for accident and post-accident conditions –
Part 3: Equipment for continuous high range area gamma monitoring

Installations nucléaires – Systèmes d'instrumentation importants pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles –
Partie 3: Ensemble de surveillance locale en continu des rayonnements gamma à large gamme

IEC 60951-3:2022-11 (en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 3: Equipment for continuous high range area gamma monitoring

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 60951-3 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.

This standard is to be read in conjunction with IEC 60951-1.

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

Draft	Report on voting
45A/1441/FDIS	45A/1450/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.

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.

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 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 upon 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 presented in Table 1.

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.

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).

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

Part 3: Equipment for continuous high range area gamma monitoring

1 Scope

This part of IEC 60951 provides general guidance on the design principles and performance criteria for equipment for continuous high range area gamma monitoring in nuclear facilities for accident and post-accident conditions. This document categorizes accident conditions into design basis accidents (DBA) and design extension conditions (DEC), including severe accident (SA).

General requirements for technical characteristics, test procedures, radiation characteristics, electrical, mechanical, and environmental characteristics are given in IEC 60951-1. These requirements are applicable in this document, unless otherwise stated.

The purpose of this document is to lay down general requirements for equipment for continuous high range area gamma monitoring of radiation within the facility during and after accident conditions in nuclear facilities.

This document is applicable to installed dose rate meters that are used to monitor high levels of gamma radiation during and after an accident. It covers equipment intended to isotropically measure air kerma, ambient dose or other exposure quantities due to gamma radiation of energy between 80 keV and 7 MeV. The equipment is intended primarily for the purpose of nuclear facility safety.

Portable instruments for emergency purposes and installed area radiation monitors used to determine continuously the radiological situation in working areas during normal operation are in the scope of IEC 60532.

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 60951-1:2022, *Nuclear facilities – Instrumentation systems important to safety – Radiation monitoring for accident and post-accident conditions – Part 1: General requirements*

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

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

ISO 4037 (all parts), *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy*

ISO 6980 (all parts), *Nuclear energy – Reference beta-particle radiation*

ISO 8529 (all parts), *Neutron reference radiations fields*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60951-1 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

4 Design principles

4.1 General

The general requirements of IEC 60951-1 are applicable to all types of monitors within the scope of the present document, unless otherwise stated.

The radiation monitor classified for functions important to safety shall comply with the requirements relating to the characteristics and lifecycle of RMS defined in IEC 62705 and the standards referenced in IEC 62705 (e.g. IEC 61226).

4.2 Range of measurement

The purchaser shall specify the required effective range of measurement and the radiation sources specific to the facility design. The range shall be suitable for the level of and the variation in radiation in the area during accident and post-accident conditions. It shall be at least six decades. The low end of the required range shall overlap the highest decade of dose rate monitors designed for normal operation conditions.

The energy response of the detector in relation to the expected radiation energy spectrum shall also be specified. Typically, detectors should respond to gamma radiation within any energy range from 80 keV to 7 MeV.

4.3 Accuracy (relative error)

In addition to 4.6 of IEC 60951-1:2022, the following requirements shall apply.

When a detector assembly utilizes more than one radiation detector to cover the full range of dose equivalent rates indicated by the detector assembly, these requirements apply to the relevant ranges for each detector separately.

4.4 Location of sensors

The requirements for such equipment are facility specific. Therefore, the locations in which the monitoring equipment is required shall be determined according to the facility design.

For nuclear power plants, usually equipment is located within the reactor containment. It shall be located to provide maximum coverage of the areas being monitored and to minimize shielding effects from other equipment or structures. As far as is practical, locations should be selected so as to facilitate maintenance and calibration operations.

Because of the high level of radiation, the equipment is usually designed with a detector assembly located remotely from any processing assembly (electronics), taking into account the length of the cable between detector and remote electronics which should be minimized.

4.5 Response for other radiation sources

The detector assembly shall be designed to be effectively insensitive to beta and neutron radiation (compared to its gamma sensitivity) expected to be present during the accident conditions for which the equipment is intended to operate.

4.6 Requirements related to accident conditions

In addition to 4.12 of IEC 60951-1:2022, the following requirements shall apply.

For nuclear power plants, the detector assembly of such equipment is usually located within the reactor building which is submitted to a harsh environment during and after an accident. The qualification program, agreed upon between the manufacturer and the purchaser, shall take into account specific conditions such as very high integrated dose (up to 1×10^6 Gy) as well as combined high temperature, pressure and humidity.

There may be cases where diversity or multiplexing in detector assembly or monitoring channel is required for facility accident countermeasures.

5 Functional testing

5.1 General

Except where otherwise specified, all the tests specified in Clause 5 of IEC 60951-1:2022 shall be carried out.

The tests described hereinafter are only additional tests dedicated to the type of monitors within the scope of the present document. As for tests stated in IEC 60951-1, these tests are to be considered as type tests, although any or all may be considered as acceptance tests by agreement between manufacturer and purchaser.

These tests are carried out under standard conditions or with variation of the influence quantities. They are listed in Table 2.

Table 2 – Additional tests to complement the general tests required in IEC 60951-1

Tests	Tests conditions	Limits of variation of indication	Reference (subclause)
Reference response	Range of photon radiation energy between 80 keV and 7 MeV	±30 % between 100 keV and 3 MeV Value to be stated by agreement otherwise if necessary	5.3.1
Response to beta radiation	Range of beta radiation energy from a Sr-90/Y-90 source up to 4 MeV	In accordance with manufacturer's specifications	5.3.2.2
Variation of response with angle of incidence	Different angles of incidence (±15°, ±30°, ±45° ±60°) in the plane including the reference direction and in a plane perpendicular to that.	±30 %	5.3.3
NOTE For assemblies having a non-linear scale, a linear instrument may be substituted for the indicating meter of the assembly to verify the performance specified in this table.			

5.2 Reference sources

5.2.1 General

In addition to 5.2.5 of IEC 60951-1:2022, the following requirements shall apply.

All tests shall be carried out using a monodirectional radiation field, unless otherwise agreed between manufacturer and purchaser.

5.2.2 Gamma

All tests shall be conducted with Cs-137, unless specified otherwise. As an alternative, Co-60 may be used. In this case correction shall be made for the difference in response of the detector assembly between Co-60 and Cs-137. These radiation qualities are specified in the ISO 4037 series. For very high dose rates an electron beam may be used.

The conventional value of dose rate shall be known with an accuracy better than 5 %.

5.2.3 Beta

If the detector is sensitive to beta radiation, a test for the detector assembly response to gamma radiation in the presence of beta radiation shall be conducted when agreed between manufacturer and purchaser. The response of the detector assembly to beta radiation from a Sr-90/Y-90 source shall be stated by the manufacturer. The reference beta radiation fields are specified in the ISO 6980 series.

If the detector is not sensitive to beta radiation, the manufacturer should provide a demonstration of this non-sensitivity by analysis.

5.2.4 Neutron

If the detector is sensitive to neutron radiation, the response to neutron radiation shall be stated when agreed between manufacturer and purchaser. A test for neutron response shall be carried out if the detector assembly is intended to be used in the presence of neutron radiation. Cf-252 should be used for neutron tests. The reference neutron radiation fields are specified in the ISO 8529 series.

If the detector is not sensitive to neutron radiation, the manufacturer should provide a demonstration of this non-sensitivity by analysis.

5.3 Performance characteristics

5.3.1 Reference response

In addition to 5.3.1 of IEC 60951-1:2022, the following requirements shall apply.

The variation of response with photon radiation energy between 100 keV and 3 MeV shall be within ±30 %.

For assemblies intended for use in energies higher than 3 MeV, the variation shall be subject to agreement between the purchaser and manufacturer.

In principle, this test should be performed at the same dose rate for each radiation energy. In practice, this may not be possible, in which case the indicated dose rate of each radiation energy should be corrected for the non-linearity (interpolated if necessary) at the indicated dose rate and for the reference gamma radiation.

The following energies should be used for low air kerma rates (taken from the ISO 4037 series):

- Mean energy (keV): quality (tube voltage, kV);
- 100 keV(N-120) or 109 keV(L-125);
- 118 keV(N-150);
- 164 keV(N-200) or 149 keV(L-170);
- 208 keV(N-250) or 211 keV(L-240);
- 662 keV (Cs-137);
- 1 250 keV (Co-60).

Energy response to other photon energies might be demonstrated by real tests or Monte Carlo simulations.

The energy corresponding to the average energy range shall be taken as a reference energy. For this purpose, Cs-137 or Co-60 should be chosen.

The variation of response for other energies within the energy range shall be within ±30 % of the reference response to the reference energy.

If for specific applications it is necessary to extend the energy range, the energy response shall be defined and agreed between the manufacturer and the purchaser. In this case it can be performed either by real tests or by Monte Carlo simulations.

For specific severe accident applications, additional thermal shielding may be required. This may additionally affect the energy response of the system; in this case the required energy response shall be agreed between purchaser and manufacturer.

5.3.2 Sensitivity and relative response for other radiation sources

5.3.2.1 General

In addition to 5.3.2 of IEC 60951-1:2022, the following requirements shall apply.

5.3.2.2 Response to beta radiation

The response of the detector assembly to beta radiation from a Sr-90/Y-90 source shall be stated by the manufacturer who shall also indicate the response to beta radiation for energies up to 4 MeV.

If agreed upon between the manufacturer and the purchaser, the test for the response to beta radiation shall be carried out and the response shall be expressed as the ratio of the detector assembly indication to the conventional value of absorbed dose rate (due to the Sr-90/Y-90 source) in air at the detector reference point when the detector is not present.

The detector assembly shall be exposed at 0° angle of radiation incidence to beta reference radiation specified in ISO 6980.

5.3.3 Variation of response with angle of incidence

5.3.3.1 Requirements

The response to a reference gamma source shall be within ±30 % of the reference response (corresponding to 0°) for the following angles of incidence: ±15°, ±30°, ±45° ±60° in the plane including the reference direction and in a plane perpendicular to that and also including the reference direction.

The manufacturer shall state the relative variation of the response for ±90°.

The results should be expressed as a ratio of the response per unit dose rate for each radiation source utilized to the response per unit dose rate for zero degrees angle of incidence.

If another range of angles is required, it shall be selected according to the agreement between the manufacturer and the purchaser.

5.3.3.2 Test method

The assembly shall be mounted so as to most conveniently enable measurements to be made at the required angle.

For this test, the reference point of the detector assembly shall be placed at a point of test where the dose rate is known. The photon radiation qualities of the narrow spectrum series and the gamma sources Cs-137 specified in the ISO 4037 series should be used if possible.

a) The direction of radiation shall be changed in steps of 15° in a plane including the calibration direction specified by the manufacturer and the response determined throughout the range of angles specified in 5.3.3.1.

b) The procedure of a) above shall be repeated for the plane perpendicular to that used in a), but still including the calibration direction.

5.3.4 Environmental performance

Tests considering the dose rate, temperature, pressure, humidity and vibration shall be performed by assuming the environment of design extension conditions (DEC) including severe accident (SA).

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IEC 60761-3:2002, *Equipment for continuous monitoring of radioactivity in gaseous effluents – Part 3: Specific requirements for radioactive noble gas monitors*

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

IEC 60861:2006, *Equipment for monitoring of radionuclides in liquid effluents and surface waters*

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

IEC 60951-2:2009, *Nuclear power plants – Instrumentation important to safety – Radiation monitoring equipment for accident and post-accident conditions – Part 2: Equipment for continuous off-line monitoring of radioactivity in gaseous effluents and ventilation air*

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

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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INSTALLATIONS NUCLÉAIRES – SYSTÈMES D'INSTRUMENTATION IMPORTANTS POUR LA SÛRETÉ – SURVEILLANCE DES RAYONNEMENTS POUR LES CONDITIONS ACCIDENTELLES ET POST-ACCIDENTELLES –

Partie 3: Ensemble de surveillance locale en continu des rayonnements gamma à large gamme

AVANT-PROPOS

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L'IEC 60951-3 a été établie par le sous-comité 45A: Systèmes d'instrumentation, de contrôle-commande et d'alimentation électrique des installations nucléaires, du comité d'études 45 de l'IEC: Instrumentation nucléaire. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2009. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- Le titre a été modifié.
- La catégorisation des conditions accidentelles a été harmonisée.

- Les références aux nouvelles normes publiées depuis la deuxième édition ont été mises à jour.
- Les termes et définitions ont été mis à jour.

La présente norme doit être lue conjointement avec l'IEC 60951-1.

Le texte de cette norme est issu des documents suivants:

Projet	Rapport de vote
45A/1441/FDIS	45A/1450/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 60951, publiées sous le titre général *Installations nucléaires – Systèmes d'instrumentation importants pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles*, se trouve sur le site web de l'IEC.

Les futurs documents de cette série porteront le nouveau titre général cité ci-dessus. Le titre des documents qui existent déjà dans cette série sera mis à jour lors de leur prochaine édition.

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- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

INTRODUCTION

a) Contexte technique, questions importantes et structure de la norme

La présente norme IEC traite spécifiquement des systèmes de surveillance des rayonnements (RMS, *Radiation Monitoring System*) utilisés en conditions accidentelles.

A la lueur des enseignements tirés de l'accident de Fukushima-Daiichi, elle réaffirme le besoin de fournir aux opérateurs des données de surveillance des rayonnements fiables pour leur permettre de comprendre l'état de la centrale en conditions accidentelles et post-accidentelles. Afin d'assurer la conception appropriée d'une telle instrumentation, il est nécessaire de fournir des recommandations générales sur les principes de conception et les critères de performance de l'instrumentation de surveillance des rayonnements utilisée en conditions accidentelles et post-accidentelles. En outre, le domaine d'application de l'IEC 63147, qui fournit des critères applicables à l'instrumentation de surveillance des accidents dans les centrales nucléaires de puissance, a été élargi afin d'inclure les accidents graves (SA, *Severe Accident*) dans les conditions accidentelles.

Par conséquent, afin de tirer des enseignements de l'accident de Fukushima-Daiichi, la présente norme classe les conditions accidentelles en accidents de dimensionnement (DBA, *Design Basis Accident*) et en conditions additionnelles de dimensionnement (DEC, *Design Extension Accident*), incluant les accidents graves (SA).

La présente norme est destinée aux acheteurs pour élaborer des spécifications pour les systèmes de surveillance des rayonnements spécifiques à leurs installations et aux fabricants pour identifier les caractéristiques des matériels nécessaires lors du développement de systèmes de surveillance des rayonnements utilisés en conditions accidentelles. Certaines caractéristiques d'instruments spécifiques comme l'étendue de mesure, la réponse en énergie et la tenue aux conditions d'environnement dépendent de l'application spécifique. Dans ce cas, des recommandations sont fournies pour déterminer les exigences spécifiques, mais aucune exigence spécifique proprement dite n'est spécifiée.

La présente norme fait partie d'une série de normes applicables aux matériels de surveillance en continu des niveaux de rayonnement, importants pour la sûreté, destinés à être utilisés lors d'accidents de dimensionnement (DBA), en conditions additionnelles de dimensionnement (DEC), incluant les accidents graves (SA), et en conditions post-accidentelles. La série complète comprend les normes suivantes.

– IEC 60951-1 – Exigences générales
– IEC 60951-2 – Matériels pour la surveillance des rayonnements en continu avec prélèvements dans les effluents gazeux et l'air de ventilation
– IEC 60951-3 – Ensemble de surveillance locale en continu des rayonnements gamma à large gamme
– IEC 60951-4 – Equipement pour la surveillance en continu des rayonnements internes ou externes aux flux de procédé

b) Positionnement de la présente norme dans la structure de la collection de normes du SC 45A de l'IEC

Les normes de la série IEC 60951 se situent au troisième niveau de la hiérarchie des normes du SC 45A. Elles fournissent des recommandations pour la spécification, la conception et les essais des matériels de surveillance des rayonnements utilisés dans des conditions accidentelles et post-accidentelles.

D'autres normes élaborées par le SC 45A et le SC 45B fournissent des recommandations concernant les instruments utilisés pour surveiller les rayonnements dans le cadre des opérations normales. La série IEC 60761 fournit des exigences applicables aux matériels pour la surveillance en continu des rayonnements avec prélèvements dans les effluents gazeux en conditions normales. L'IEC 60861 fournit des exigences applicables aux matériels pour la surveillance en continu des rayonnements avec prélèvements dans les effluents liquides en conditions normales. L'IEC 60768 fournit des exigences applicables aux matériels pour la surveillance en continu, interne et externe, des rayonnements au niveau des fluides de procédés pour les conditions de fonctionnement normal et incidentel. Enfin, l'ISO 2889 fournit des recommandations pour l'échantillonnage de gaz et de particules. En outre, l'IEC 62705 fournit des recommandations pour l'application des normes IEC/ISO existantes qui traitent de la conception et de la qualification des RMS. Le Tableau 1 fournit une vue d'ensemble des normes qui traitent de la surveillance des rayonnements dans les installations nucléaires.

L'IEC 63147/IEEE Std 497™ fournit des recommandations générales pour l'instrumentation de surveillance des accidents. L'IEEE Std 497™ a été adoptée directement en tant que norme double logo et un rapport technique, l'IEC TR 63123, a été établi pour étudier l'application de la norme commune dans le contexte de l'IEC.

La structure de la présente norme est alignée sur la structure de l'IEC 63147/IEEE Std 497™, et les exigences techniques de la présente norme sont cohérentes avec les exigences spécifiées dans l'IEC 63147/IEEE Std 497™ ainsi qu'avec les recommandations d'application fournies dans l'IEC TR 63123.

Tableau 1 – Vue d'ensemble des normes qui traitent de la surveillance des rayonnements dans les installations nucléaires

Développeur	ISO		IEC			
			SC 45A			SC 45B
Domaine d'application	Echantillonnage (fonctionnement normal)	Etalonnage (fonctionne-ment normal)	Fonctionnement normal, IFP	DBA	DEC	Fonctionnement normal
Surveillance avec prélèvements des gaz rares radioactifs	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
Surveillance avec prélèvements des aérosols radioactifs	ISO 2889	ISO 4037-1, ISO 4037-3	N/A	IEC 60951-1, IEC 60951-2	N/A	IEC 60761-1, IEC 60761-2
Surveillance avec prélèvements de l'iode radioactif	ISO 2889	ISO 4037-1, ISO 4037-3	N/A	IEC 60951-1, IEC 60951-2	N/A	IEC 60761-1, IEC 60761-4
Surveillance avec prélèvements des liquides	N/A	N/A	N/A	N/A	N/A	IEC 60861
Surveillance avec prélèvements du tritium	N/A	N/A	N/A	N/A	N/A	IEC 62303, IEC 60761-1, IEC 60761-5
Surveillance interne ou externe	N/A	ISO 4037-1, ISO 4037-3	IEC 60768	IEC 60951-1, IEC 60951-4	N/A	N/A
Surveillance de zone	N/A	ISO 4037-1, ISO 4037-3	IEC 61031	IEC 60951-1, IEC 60951-3		IEC 60532
Système centralisé	N/A	N/A	IEC 61504, IEC 60960		N/A	IEC 61559-1
Exigences de classement/de base	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

Pour plus d'informations sur la structure de la collection de normes du SC 45A de l'IEC, voir le point d) de la présente introduction.

c) Recommandations et limites relatives à l'application de la présente norme

Il est important de noter que la présente norme n'établit pas d'exigences fonctionnelles supplémentaires pour les systèmes importants pour la sûreté.

d) Description de la structure de la collection de normes du SC 45A de l'IEC et des relations avec d'autres documents de l'IEC, et avec les documents d'autres organisations (AIEA, ISO)

La collection de normes établies par le SC 45A de l'IEC est structurée en quatre niveaux. Les documents de niveau supérieur dans la collection de normes du SC 45A de l'IEC sont les normes IEC 61513 et IEC 63046.

La norme IEC 61513 établit les exigences générales relatives aux matériels et systèmes d'instrumentation et de contrôle-commande (I&C) utilisés pour réaliser des fonctions importantes pour la sûreté des centrales nucléaires de puissance. La norme IEC 63046 établit les exigences générales relatives aux systèmes d'alimentation électrique des centrales nucléaires de puissance; elle couvre les systèmes d'alimentation électrique y compris les alimentations des systèmes d'I&C.

Les normes IEC 61513 et IEC 63046 doivent être prises en compte ensemble et au même niveau. Les normes IEC 61513 et IEC 63046 structurent la collection de normes du SC 45A de l'IEC et forment un cadre complet qui établit les exigences générales relatives aux systèmes d'I&C et d'alimentation électrique des centrales nucléaires de puissance.

Les normes IEC 61513 et IEC 63046 font directement référence à d'autres normes du SC 45A de l'IEC qui établissent les exigences générales relatives à des sujets spécifiques, tels que la catégorisation des fonctions et le classement des systèmes, la qualification, la séparation des systèmes, la défense contre les défaillances de cause commune, la conception des salles de commande, la compatibilité électromagnétique, l'ingénierie des facteurs humains, la cybersécurité, les aspects logiciels et matériels relatifs aux systèmes numériques programmables, la coordination des exigences de sûreté et de sécurité, et la gestion du vieillissement. Il convient de considérer que ces normes, auxquelles il est fait référence à ce deuxième niveau, forment, avec les normes IEC 61513 et IEC 63046, un ensemble documentaire cohérent.

Au troisième niveau, les normes du SC 45A de l'IEC, qui ne sont généralement pas citées en référence directement par les normes IEC 61513 ou IEC 63046, établissent les exigences particulières aux matériels, méthodes techniques ou activités spécifiques. Généralement, ces documents, qui font référence aux documents de deuxième niveau pour les exigences générales, peuvent être utilisés de façon isolée.

Un quatrième niveau qui est une extension de la collection de normes du SC 45 de l'IEC correspond aux rapports techniques qui ne sont pas des documents normatifs.

Les normes de la collection du SC 45A de l'IEC mettent en œuvre de manière systématique et décrivent les principes de sûreté et de sécurité et les aspects fondamentaux donnés dans les normes de sûreté de l'AIEA pertinentes et dans les documents pertinents de la collection de l'AIEA pour la sécurité nucléaire de puissance (NSS), en particulier avec le document d'exigences SSR-2/1 qui établit les exigences de sûreté relatives à la conception des centrales nucléaires de puissance, avec le guide de sûreté SSG-30 qui traite du classement de sûreté des structures, systèmes et composants des centrales nucléaires de puissance, avec le guide de sûreté SSG-39 qui traite de la conception des systèmes d'I&C des centrales nucléaires de puissance, avec le guide de sûreté SSG-34 qui traite de la conception des systèmes d'alimentation électrique des centrales nucléaires de puissance, avec le guide de sûreté SSG-51 qui traite de l'ingénierie des facteurs humains lors de la conception des centrales nucléaires de puissance et avec le guide de mise en œuvre NSS17 qui traite de la sécurité informatique pour les installations nucléaires. La terminologie et les définitions utilisées pour la sûreté et la sécurité dans les normes établies par le SC 45A sont conformes à celles utilisées par l'AIEA.

Les normes IEC 61513 et IEC 63046 ont adopté une présentation similaire à celle de la publication fondamentale de sécurité IEC 61508, avec un cycle de vie d'ensemble et un cycle de vie des systèmes. En ce qui concerne la sûreté nucléaire, les normes IEC 61513 et IEC 63046 donnent l'interprétation des exigences générales des parties 1, 2 et 4 de l'IEC 61508 pour le secteur nucléaire. Dans ce cadre, l'IEC 60880, l'IEC 62138 et l'IEC 62566 correspondent à la partie 3 de l'IEC 61508 pour le secteur nucléaire.

Les normes IEC 61513 et IEC 63046 font référence à la norme ISO 9001, ainsi qu'aux documents AIEA GSR partie 2 et AIEA GS-G-3.1 et AIEA GS-G-3.5 pour ce qui concerne l'assurance qualité.

Au second niveau, en ce qui concerne la sûreté nucléaire, la norme IEC 62645 est le document chapeau des normes du SC 45A de l'IEC applicables à la cybersécurité. Elle se fonde sur les principes pertinents de haut niveau et sur les concepts principaux des normes génériques de sûreté, en particulier l'ISO/IEC 27001 et l'ISO/IEC 27002; elle les adapte et les complète pour qu'ils deviennent pertinents pour le secteur nucléaire; elle est coordonnée étroitement avec la norme IEC 62443. Au second niveau, la norme IEC 60964 est le document chapeau des normes du SC 45A de l'IEC applicables aux salles de commande, la norme IEC 63351 est le document chapeau des normes du SC 45A de l'IEC applicables à l'ingénierie des facteurs humains et la norme IEC 62342 est le document chapeau des normes du SC 45A de l'IEC applicables à la gestion du vieillissement.

NOTE 1 On considère que pour la conception des systèmes d'I&C qui mettent en œuvre des fonctions de sûreté conventionnelle (par exemple, pour couvrir la sécurité des travailleurs, la protection des biens, la prévention contre les risques chimiques, la prévention contre les risques liés au procédé énergétique), des normes nationales ou internationales sont appliquées.

NOTE 2 L'IEC TR 64000 décrit plus en détail la structure générale de la collection de normes du SC 45A de l'IEC, ainsi que ses relations avec les autres organismes de normalisation et normes.

INSTALLATIONS NUCLÉAIRES – SYSTÈMES D'INSTRUMENTATION IMPORTANTS POUR LA SÛRETÉ – SURVEILLANCE DES RAYONNEMENTS POUR LES CONDITIONS ACCIDENTELLES ET POST-ACCIDENTELLES –

Partie 3: Ensemble de surveillance locale en continu des rayonnements gamma à large gamme

1 Domaine d'application

La présente partie de l'IEC 60951 fournit des recommandations générales relatives aux principes de conception et aux critères de performance de l'ensemble de surveillance locale en continu des rayonnements gamma à large gamme utilisé dans les installations nucléaires en conditions accidentelles et post-accidentelles. Le présent document classe les conditions accidentelles en accidents de dimensionnement (DBA) et en conditions additionnelles de dimensionnement (DEC), incluant les accidents graves (SA).

Les exigences générales relatives aux caractéristiques techniques, aux procédures d'essai, aux caractéristiques des rayonnements, aux caractéristiques électriques et mécaniques, ainsi qu'aux caractéristiques d'environnement sont fournies dans l'IEC 60951-1. Sauf indication contraire, ces exigences s'appliquent dans le présent document.

Le présent document a pour objet d'établir les exigences générales relatives à l'ensemble de surveillance locale en continu des rayonnements gamma à large gamme dans les installations nucléaires en conditions accidentelles et post-accidentelles.

Le présent document s'applique aux moniteurs de débit de dose à poste fixe qui sont utilisés pour surveiller les rayonnements gamma de niveau élevé pendant et après un accident. Elle couvre les matériels destinés à mesurer de façon isotropique le kerma dans l'air, la dose ambiante ou les autres valeurs relatives à l'exposition aux rayonnements gamma d'énergie comprise entre 80 keV et 7 meV. L'objectif principal du matériel est d'assurer la sûreté de l'installation nucléaire.

Les instruments portables utilisés en cas d'urgence et les moniteurs de rayonnement de zone à poste fixe utilisés pour évaluer en continu la situation radiologique dans les zones de travail en fonctionnement normal relèvent du domaine d'application de l'IEC 60532.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60951-1:2022, *Installations nucléaires – Systèmes d'instrumentation importants pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles – Partie 1: Exigences générales*

IEC 61226, *Centrales nucléaires de puissance – Systèmes d'instrumentation, de contrôle-commande et d'alimentation électrique importants pour la sûreté – Catégorisation des fonctions et classement des systèmes*

IEC 62705, *Installations nucléaires – Instrumentation et contrôle-commande importants pour la sûreté – Systèmes de surveillance des rayonnements (RMS): Caractéristiques et cycle de vie*