IEC 60951-1

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 1: General requirements

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

Part 1: General requirements

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 60951-1:2009. 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 60951-1 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.

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.

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 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 ~~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 Table 1.~~ 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.

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 series~~

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 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 ~~power plants~~ facilities during and after ~~an accident~~ 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 ~~mandatory~~ general requirements and give examples of acceptable methods for equipment for continuous monitoring of radioactivity within the ~~plant~~ facility during and after ~~accident conditions in nuclear power plants using light water reactors~~ 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:~~2002~~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:~~2001~~2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

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

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

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 60980, *Recommended practices for Seismic qualification of electrical equipment of the safety system for nuclear generating stations*~~

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

IEC 60987, *Nuclear power plants – Instrumentation and control important to safety – Hardware ~~design~~ requirements ~~for computer-based systems~~*

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

IEC 61000-4-3:~~2006~~2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:~~2004~~2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:~~2005~~2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:~~2008~~2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8:~~2001~~2009, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-12:~~2006~~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:~~2006~~2018, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61069-1:~~1991~~2016, *Industrial-process measurement, control and automation – Evaluation of system properties for the purpose of system assessment – Part 1: ~~General considerations and methodology~~ Terminology and basic concepts*

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

IEC 61504:20002017, *Nuclear power plants facilities – Instrumentation and control systems important to safety – Plant-wide radiation monitoring 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 61559-2:2002, *Radiation in nuclear facilities – Centralized systems for continuous monitoring of radiation and/or levels of radioactivity – Part 2: Requirements for discharge, environmental, accident, or post-accident monitoring functions*

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

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 2889:20092015, *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

[IEV 394-40-05]

3.2
accident conditions
deviations from normal operation more severe than anticipated operational occurrences, including design basis accidents and severe accidents

[IAEA Safety Glossary, 2007 edition]

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

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

[SOURCE: ~~IEV 393-11-41~~ IEC 60050-395:2014, 395-02-34]

~~**3.4**~~
~~**anticipated operational occurrence**~~
~~operational process deviating from normal operation which is expected to occur at least once during the operational lifetime of a nuclear power plant but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions~~

~~[IAEA Safety Glossary, 2007 edition]~~

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:

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

~~[IEV 394-40-14]~~

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

~~[ISO 2889]~~

~~**3.7**~~
~~**conventionally true value**~~
~~value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose~~

~~[IEV 394-40-10]~~

~~NOTE For example, a value and its uncertainty determined from a primary or a secondary standard, or by a reference instrument which has been calibrated against a primary or secondary standard, may be taken as the conventionally true value.~~

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.

~~3.8~~
~~**decision threshold**~~
~~fixed value of the activity which allows a decision to be made for each measurement with a given probability of error as whether the registered measurement includes a contribution from the physical effect~~

~~[IEC 60761-1,3.9]~~

~~NOTE The statistical test shall be designed such that the probability of wrongly rejecting the hypothesis (error of the first kind) is equal to a given value α. In the case of this standard, α equals 5 %.~~

~~3.9~~
~~**Design Basis Accident (DBA)**~~
~~accident conditions against which a facility is designed according to established design criteria, and for which the damage to the fuel and the release of radioactive material are kept within authorized limits~~

~~[IAEA Safety Glossary, 2007 edition]~~

~~3.10~~
~~**detection limit**~~
~~smallest true value of the measurand which is detectable by the measuring method~~

~~[IEC 60761-1,3.10]~~

~~NOTE The detection limit is the smallest true value of the measurand which is associated with the statistical test and hypotheses by the following characteristics: if in reality the true value is equal to or exceeds the detection limit, the probability of wrongly not rejecting the hypothesis (error of the second kind) shall be at most equal to a given value β. For this standard, β equals 5 %.~~

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.

~~[IEV 394-40-16]~~

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.

Note 2 to entry: Experimental standard deviation of the mean is sometimes incorrectly called standard error of the mean.

~~[IEV 394-40-40]~~

3.10
measuring assembly
assembly designed to measure a quantity

Note 1 to entry: In this document, the quantity is volumetric activity or dose rate, although the value may be expressed in other units.

3.11
minimum detectable (measurable) activity
~~quantity of radioactivity giving a count which, in the presence of a specified background noise, has a 95 % probability not to be caused by that of background noise alone~~

~~[IEV 394-40-25]~~

radioactivity which, if present in a sample, produces a counting rate that will be detected (i.e. considered to be above background) with a certain level of confidence

Note 1 to entry: The 'certain level of confidence' is normally set at 95 %; that is, a sample containing exactly the minimum detectable activity will, as a result of random fluctuations, be taken to be free of radioactivity 5 % of the time.

Note 2 to entry: The minimum detectable activity is sometimes referred to as the detection limit or lower limit of detection.

Note 3 to entry: The counting rate from a sample containing the minimum detectable activity is termed the determination level.

Note 4 to entry: An example formulation for minimum detectable activity is calculated as follows.

$$MDA = \frac{k_1^2 + 2k_1\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{(t_s)(E)(C)}$$

where:

k_1 is the one-sided coverage factor = 1,645 at 95 % confidence

R_b is the background count rate in s^{-1}

t_s is the sample count time in min

t_b is the background count time in min

E is the detector efficiency in counts per disintegration

C is the conversion factor from dpm to other desired activity unit, if applicable

[SOURCE: IAEA Safety Glossary, 2018 edition]

3.12
particle
aggregate of molecules, forming a solid or liquid ~~of size ranging from a few molecular diameters to some tenths of a milimeter (several hundred micrometers)~~, ranging in size from a few molecular diameters to several millimetres

[SOURCE: ISO 2889:2015, 3.55]

3.13
process streams
fluid which flows through a system intended to provide a useful purpose

Note 1 to entry: Examples of process streams are: primary coolant system, spent fuel cooling system, component cooling system, etc.

Note 2 to entry: The process streams within the scope of this document are those streams in which the level of radioactivity may significantly increase as a result of accident or post-accident conditions.

Note 3 to entry: Monitoring of these process streams for radioactivity provides information on the quality or integrity of the barrier and potential release to the environment.

3.14
reference response
response of the assembly under reference conditions to unit reference dose rate, expressed as:

$$R_{\mathrm{ref}} = \frac{v - v_{\mathrm{B}}}{v_{\mathrm{c}}}$$

where:

v is the value measured by the equipment or assembly under test

v_{B} is the background value of the equipment without external influence

v_{c} is the conventional quantity value of the reference source

Note 1 to entry: The background value may be automatically taken into account by an algorithm included in the measurement systems.

~~[IEV 394-40-22]~~

3.15
relative error
error of measurement divided by a true value of the measurand

~~[IEV 394-40-11]~~

Note 1 to entry: Since a true value cannot be determined, in practice, a ~~conventionally true~~ conventional quantity value is used. For this standard, relative error is calculated as follows.

$$E = \frac{(v - v_{\mathrm{B}}) - v_{\mathrm{c}}}{v_{\mathrm{c}}}$$

where:

v is the value measured by the equipment or assembly under test,

v_{c} is the ~~conventionally true~~ conventional quantity value of the reference source,

v_{B} is the background value of the equipment without external influence.

Note 2 to entry: The background value may be automatically taken into account by an algorithm included in the measurement system.

3.16
relative response
value calculated during type testing equal to the ratio between the reference response of the equipment and the sensitivity of the same equipment to the solid source of interest

Note 1 to entry: The relative response allows determination of the reference response of identical equipment that has been type tested from the measurement of the sensitivity of the solid source.

3.17
response time
period of time necessary for a component to achieve a specified output state from the time that it receives a signal requiring it to assume that output state

Note 1 to entry: For the purposes of the tests described in this document, the input signal is assumed to be a step variation and the ending output state is the point at which the output signal variation reaches 90 % of its final value for the first time.

[SOURCE: IAEA Safety Glossary, 2018 edition]

3.18
routine test
conformity test made on each individual item during or after manufacture

~~[IEV 394-40-03]~~

~~**3.23**~~
~~**sampling assembly**~~
~~set of interconnected devices for collecting a representative sample~~

3.19
sampling collection efficiency
for a given quantity of radioactive material, ratio of the collected activity to the supplied activity, for a specified time interval

~~[IEV 394-39-45]~~

3.20
sensitivity <of a measuring assembly>
~~for a given value of the measured quantity,~~ ratio of the variation of the observed variable to the corresponding variation of the measured quantity for a given value of the measured quantity

[SOURCE: ~~IEV 394-39-07~~ IEC 60050-395:2014, 395-03-105]

~~**3.26**~~
~~**volumetric activity**~~
~~quotient of the activity by the total volume of the sample~~

~~[IEV 393-14-16]~~

~~NOTE 1 For a gas, it is necessary to indicate the temperature and pressure conditions for which the volumic activity is measured, for example standard temperature and pressure (STP).~~

~~NOTE 2 This quantity is expressed in Becquerels per cubic meter (Bq/m^3).~~

4 Design principles

4.1 General

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).

In the case where different radiation monitoring systems for design basis accidents (DBA) and that for design extension conditions (DEC) including severe accident (SA) are required, they should be independent of each other as far as reasonably practicable.

4.2 Basic requirements related to functions

The main purpose of equipment for continuous monitoring of radioactivity in accident or post-accident conditions is to continuously measure radiation levels in appropriate areas and processes. These radiation measurements are displayed locally and/or in control rooms and/or incident control centers to keep plant operators aware of current radiological conditions. This information is used by operators to assess plant conditions, take appropriate actions in order to mitigate the consequences of a plant accident and prevent the inadvertent release of ~~radiation~~ radioactive substance, and by site emergency personnel, national authorities, for actions necessary to safeguard public and plant personnel. Therefore, the equipment concerned by this document is capable of actuating alarms and providing inputs to other plant systems and processes to isolate processes at abnormal radiation levels.

The basic requirements for the design, selection, testing, calibration and functional location of equipment for continuous monitoring of radioactivity in accident or post-accident conditions are plant specific. It is typically split into three key parts, effluent and ventilation radiation monitoring, process radiation monitoring, and area radiation monitoring:

- Effluent and ventilation radiation monitors measure the ~~radioactivity~~ specific activity in gases released into the environment in accident and post-accident conditions to ensure that the ~~radiation levels are~~ specific activity is not hazardous to the public's safety and to help in early warning and process isolations~~, such as containment vent isolation or control room habitability~~ for containment or recirculation of control room heating-ventilation-air conditioning. ~~Effluent radiation monitors are usually of the off-line type (radioactivity is measured in a sample drawn from the effluent or ventilation system).~~
- Process radiation monitors measure the ~~radioactivity~~ specific activity in a fluid (either gas, liquid or steam) and are normally used in plant process to help in early warning and process isolations, such as detecting reactor coolant pressure boundary leaks into containment and other systems. Process radiation monitors can be classified into three basic types:
  - In-line monitors: the detector is located directly in the process stream (pipe, stack, tank, duct, etc.).
  - On-line monitors: the detector is located external to and faced directly ~~faces~~ to the process stream.
  - Off-line monitors: a sample is drawn from the process stream to the detector located at some distance.
- Area radiation monitors (wide range type) are strategically located within buildings subject to high range dose rates in accident and post-accident conditions, such as the reactor building and containment vessel, and serve as post-accident monitoring devices. Area radiation monitors are wall mounted in the area or tank to be monitored. Depending on the radiation level at the detector position, the electronics part of the monitor may be located at some distance from the detector.

For the purpose of critical data collection, these monitors are usually designed to withstand adverse environmental and seismic conditions, during and after an accident.

Radiation monitoring requirements and radiation monitoring system design should be addressed early in plant design to establish effective monitoring at the appropriate sensitivity level. Thus, for maximum performance capability, the following procedure should be followed by the purchaser and the manufacturer:

- Establish the required measurement characteristics (purchaser):
  - Determine the scenarios of normal and accidental operations, and the corresponding source terms (main isotopes to be measured by the monitor), including their chemical composition.
  - Determine the essential information required by the plant operator or the control system to initiate emergency actions, the functions assigned to the equipment for continuous radiation monitoring and classify them according to IEC 61226 guidance.

- Determine the optimum points of measurement taking into account installation conditions (location, interfaces to plant protection features, ambient conditions and qualification requirements, electrical connections through safety barriers, etc.).
- Calculate the activity transfers (propagation through pipes or ducts and through the safety barriers), in order to determine the activity spectrums and the background at the point of measurement.
- Determine the time profile of the postulated release and the required range of measurement and response time of the complete channel (including the sampling system, if any, and the time to send or to display the information to the plant operator or the control system).
- Determine the gross characteristics of the detectors (type of radiation and measurement, sensitivity and range of measurement, energy response and overload performance, etc.) and of the sampling system, if any.
- Determine the acceptable false alarm rate taking into account the plant conditions and the consequences of error in measurement (including losses in sampling), and specify the precision and ~~accuracy~~ linearity needed to stay under this threshold.

• Check the metrological characteristics of the chosen instrument (agreement between the purchaser and the manufacturer):
  - Calculate the response time of the instrument (measure time related to a specified ~~accuracy~~ linearity and time for the apparatus to provide an alarm), and the global response time of the channel (including the response time of the sampling system).
  - Calculate, at the point of measurement, geometric detection efficiency, decision threshold and minimum detectable activity ~~(or limit of detection)~~, taking into account the appropriate shielding.
  - For each characteristic of the instrument, the manufacturer should specify its variations as a function of the corresponding influence quantities (or variable parameters). These influence quantities (or variable parameters) should be, at least:
    i) activity spectrum and time profile of the activity spectrum (during transient operating conditions) of the source to be measured,
    ii) activity spectrum and time profile of the activity spectrum (during transient operating conditions) of the background,
    iii) detection geometry,
    iv) ~~number of standard deviations~~ confidence level (e.g. 95 %) (in order to calculate the minimum detectable activity ~~or limit of detection~~),
    v) flow rate of the effluent to be measured,
    vi) thermodynamic conditions,
    vii) precision and time profile of the precision (in order to calculate the measurement time during steady-state as well as transient operating conditions),
    viii) measurement time and response time (during transient operating conditions).
  - For the influence quantities depending on the process or the location, the purchaser should indicate their range of values. Otherwise, the manufacturer should make any useful hypothesis in order to take into account the probable conditions of use of the instrument.

NOTE The term "manufacturer" includes the designer and the seller of the equipment. The term "purchaser" includes the user.

If the signals are used for initiating protective action to mitigate the consequences of malfunction or failure of structures, systems or components, then the equipment may be part of the safety-related systems or the protection system. In this case, it shall meet the requirements of the respective system in accordance with IEC 61226.

~~If qualification is needed,~~ The equipment shall be environmentally qualified in accordance with the requirements of IEC/IEEE 60780-323 (and IEC/IEEE 60980-344 for seismic testing).

4.3 Measurement range

The purchaser shall specify the required effective range of measurement. The range shall be suitable for the level of radiation during accident and post-accident conditions. The low end of the measurement range shall overlap the measurement range of monitors provided for normal plant conditions for at least one decade (logarithmic scale). The highest measurable activity or dose rate should be at least one decade over the highest activity or dose rate expected during accident and post-accident conditions.

4.4 Energy response

The detector may be selected to measure either beta or gamma radiation. The purchaser shall confirm that the energy response of the detection assembly is suitable for monitoring the potential activity.

4.5 Minimum detectable activity ~~(or limit of detection)~~

~~The minimum detectable activity (or limit of detection) is equal to a number of standard deviations of the estimation of the signal which would be measured by the instrument without any activity except the background, and under specified conditions.~~ The minimum detectable activity should only be considered in steady-state operating conditions. Its calculation by a formula is possible, using the measurement time, however it does not give a rigorous statement of the beginning of the range of measurement.

The required minimum detectable activity ~~(or limit of detection)~~ will depend on the particular application and be subject to local regulations and plant design; it shall be specified by the plant designer.

The manufacturer shall specify the minimum detectable activity ~~(or limit of detection)~~ for nuclides of interest, taking into account the check sources or provisions incorporated to provide an on-scale indication on the monitor, as well as all useful data needed to specify the beginning of the effective range of measurement, even in transient operating conditions. The influence quantities, their range of values and the variation they cause on the minimum detectable activity ~~(or limit of detection)~~ shall be specified.

4.6 Precision (or repeatability)

Precision (or repeatability) is a measure of the dispersion of the estimations around their average value. It shall be given by the manufacturer in the effective range of measurement in % of the signal value for a given confidence interval (or probability of error). Assuming that the estimations follow a Gaussian distribution, this probability should be expressed in terms of a number of standard deviations.

NOTE For example, the precision could be 20 % of the signal value within a part of the effective range of measurement with a probability of 95 % (meaning that all the estimations are within $\pm 2\sigma$, with σ the standard deviation), and 30 % within another part of the effective range of measurement with another probability.

Precision shall be consistent with accident analysis assumptions, operator needs, and requirements imposed by other systems that use the radiation monitoring signals. Moreover, they shall be characterized for signal values below the beginning of the effective range of measurement. The influence quantities, their range of values and the variation they cause on precision shall be specified by the manufacturer.

Typically, the precision should be within 20 % over the entire effective range of measurement, all influence quantities taken into account.

4.7 ~~Accuracy (or relative error)~~ Linearity

~~Accuracy (or relative intrinsic error)~~ Linearity is a measure of the deviation between the ~~conventionally true~~ conventional quantity value and the average of the estimations. It shall be given by the manufacturer in the effective range of measurement in % of the signal value for a given confidence interval (or probability of error). Assuming that the estimations follow a Gaussian distribution, this probability should be expressed in terms of a number of standard deviations.

NOTE For example, the ~~accuracy~~ linearity could be 20 % of the signal value within a part of the effective range of measurement with a probability of 95 % (meaning that all the estimations are within $\pm 2\sigma$, with σ the standard deviation), and 30 % within another part of the effective range of measurement with another probability.

~~Accuracy~~ Linearity shall be consistent with accident analysis assumptions, operator needs, and requirements imposed by other systems that use the radiation monitoring signals. Moreover, they shall be characterized for signal values below the beginning of the effective range of measurement. The influence quantities, their range of values and the variation they cause on ~~accuracy~~ linearity shall be specified by the manufacturer.

Typically, the ~~accuracy~~ linearity should be within 30 % over the entire effective range of measurement, all influence quantities taken into account.

4.8 Measurement time

The measurement time is the average time during which the measurement is to be performed to obtain an estimation of the signal in stated conditions. It should only be considered in steady-state operating conditions. Its calculation by a formula is possible, however it does not take into account the processing algorithms implanted in the monitor.

The manufacturer shall specify the measurement time as well as all useful data (standard deviation or precision) necessary to know the precision of the estimations and the false alarm rate. The influence quantities, their range of values and the variation they cause on the measurement time shall be specified.

4.9 Response time

The response time is the time needed for the monitor, after a sudden variation of the measured signal (for example a step), for its output signal or indication to reach 90 % (increasing transition) or 10 % (decreasing transition) of the variation for the first time.

~~NOTE~~ For integrating systems, it is a percentage of the equilibrium value of the first derivative of the output signal as a function of time that should be considered.

The response time is to be considered only in transient operating conditions. It shall take into account the processing algorithms of the monitor.

Therefore, its calculation by a formula is not relevant, and the manufacturer shall specify it by performing tests or numerical simulations and give all useful data to determine its relationship with the precision of the estimations and the false alarm rate. The influence quantities, their range of values and the variation they cause on the response time shall be specified.

4.10 Overload performance

The indicated measurement shall not decrease or fall to zero during and following exposure beyond the maximum measuring range. It shall maintain a full-scale indication or an unambiguous indication. When the exposure returns to within the maximum range, the system shall recover within the time interval specified by the purchaser.

4.11 Ambient background shielding or compensation devices

Shielding or electronic compensation shall be provided as necessary to reduce the effects of background radiation on the measurement of process radiation.

It may be agreed upon between the manufacturer and the purchaser that significant background radiation is only to be expected from defined directions or sources (vessels, pipes, etc.). In such cases, the construction of shielding may take this into account. In the absence of such an agreement, shielding shall give virtually identical radiation attenuation in all directions seen from the sensitive volume of the detector, taking into account the structural materials of the detection assembly, and the angular response of the detector.

If the equipment cannot easily be removed from the shielding, such shielding should be easily removable. The maximum mass of the elements, or the appropriate handling means, should be agreed upon between manufacturer and purchaser.

When electronic techniques incorporating additional detectors are used to reduce the effect of background radiation, these detectors shall be chosen and located to give the best practical compensation, taking into account the range of energies and the direction of the radiation.

4.12 Requirements related to accident conditions

Equipment design shall ensure that the equipment supports the necessary system functions and that the equipment will not fail due to environmental conditions experienced during normal, accident, or post-accident conditions.

The accident and post-accident time interval during which system operation is required shall be specified by the purchaser.

The local environmental conditions in which the different components of the system can operate during normal operation, accident, and post-accident conditions shall be specified by the purchaser. Specification of environmental conditions shall include, where applicable, temperature and pressure and their rate of change, vibration, humidity, aggressive or corrosive fluids, vapours, or dusts, seismic conditions, electromagnetic environment and other adverse physical conditions as well as the normal and accident radiation dose rate and the integrated radiation dose at the location of the monitoring equipment.

The manufacturer shall provide an equipment designed to operate anywhere in the environmental envelope stated above, unless otherwise agreed upon between purchaser and manufacturer. If necessary, equipment shall be qualified for the environmental conditions of the application in accordance with relevant standards.

In particular, equipment shall be designed to minimize the effects of the specified environmental conditions, and the location of detectors shall be selected considering the accident and post-accident radiation background and the need for shielding to minimize its effect. As far as is practical, locations shall be selected so as to facilitate maintenance and calibration operations. The location should also take into account the possible need to locate electronic equipment in an area of lower dose rate.

Consideration shall be given to the possibility that materials used in the construction of the monitors may release poisonous or corrosive substances under adverse environmental conditions, such as fire, high temperature or high radiation. As far as practicable, the design shall minimize this by the choice of materials and appropriate containment of materials.

4.13 Reliability

The required reliability of the functions shall be specified either quantitatively (mean time between failures) or qualitatively (compliance with the single failure criterion).

For any part of the equipment (including sampling assembly, if any), subject to appropriate planned maintenance, the following requirement shall be reached:

- Mean Time Between Failure (MTBF): > 20 000 h (with preventive maintenance).

- A failure modes and effects analysis (FMEA) shall be performed in addition to the MTBF calculation in the case of equipment classified as performing a function important to safety in category A in accordance with IEC 61226.
- The manufacturer shall specify the frequency of routine maintenance, and fully describe each maintenance procedure (see 4.15.2). These maintenance requirements should be kept to a practical minimum.

4.14 User interface

4.14.1 General

The system shall provide continuous display and/or recording of activity or dose rate and, in addition, provide an alarm signal when the activity or dose rate level exceeds a preset value.

4.14.2 Display of measured value

The choice between logarithmic scales, linear scales, or numeric displays shall be appropriate to the purpose of the equipment. Logarithmic scales or numeric displays are generally preferred.

In the case of assemblies provided with linear scales, it shall be possible to change the range in such a way that the scaling factors do not exceed 10. An indication of the scale in use shall be provided.

Where the accident conditions are such as to give rise to large variations in reading, manual switching between ranges shall not be used unless specifically agreed to by the purchaser.

4.14.3 Alarms

4.14.3.1 General

The alarm and indication facilities shall be appropriate for the purpose of the equipment.

Alarm circuits shall be operable either to hold an alarm condition until specifically reset by a reset control or to automatically reset when the alarm state disappears. Alarm mode selection should be readily accomplished but allow for positive administrative controls. This may be accomplished, for example by requiring a key, password, or minor equipment modification to switch modes.

All alarm functions shall be provided with test facilities to allow checking of alarm operation. In the case of adjustable alarms, checking shall be possible over the range of adjustment with indication of the actual alarm operation point.

Alarm functions shall be agreed upon between the supplier and the manufacturer. As a minimum the following alarms shall be provided as applicable.

4.14.3.2 High-level alarm

At least one adjustable alarm setpoint shall be provided, adjustable over:

- at least 10 % to 90 % of scale reading (linear scales), from 50 % of the lowest decade to 90 % of the highest decade (logarithmic scales),
- or from 10 % of the second least significant decade to 90 % of the highest decade (digital display).

4.14.3.3 Fault alarms

As many separate alarms as practicable should be provided for electronic or mechanical fault. At least, the following should be provided when appropriate:

- Loss of detector signal.
- Loss of the sampling circuit.
- Loss of the cooling system.
- Loss of the heating system.
- Sampling circuit high pressure.
- Sampling circuit high temperature.
- Sampling circuit high humidity.
- High ambient radiation.
- Purging system failure.

4.14.4 Status indication

The following indications should be provided when appropriate:

- Power On.
- Pump On/Off.
- Flow Min/Max.
- Pressure.
- Humidity.
- Temperature.
- Detector power supply status.
- Detector heating unit On.
- Gas stream cooling device On.
- Gas stream heating device On.
- Group fault alarms are indicated.
- Purging system On.
- Occurrence of internal power supply changeover if internal supplies (e.g., batteries) are provided.

4.14.5 Local indications

Local indication and alarm units should be provided at accessible locations, close to the detector assembly, for the purpose of controlling access to high radiation areas in accident conditions or for maintenance and calibration during normal plant operation.

Where provided, the local indication and alarm units shall be qualified for the conditions appropriate to their purpose and location, in accordance with IEC/IEEE 60780-323. If the local indication and alarm units are not qualified to the same requirements as the detector it shall be demonstrated that their failure will not affect the essential function of the monitor.

4.15 System testing, maintenance facilities and ease of decontamination

4.15.1 System testing

Capability shall be provided to allow periodic checks of the satisfactory operation of the system from the detector to the measurement display, alarm functions, and system outputs. These checks should include operational checks, calibration, and verification of the measurement linearity.

The capability to check the good detector response at one representative point on the measurement scale without accessing the detector, using for example a remote-controlled check source, should be provided. Additional points should also be checked, and therefore means of access to the detector and to ensure the repeatability of the check, such as a support in which the detector is placed for checking with reference source(s), should be provided.

4.15.2 Maintenance facilities

The manufacturer shall specify the frequency of routine maintenance, and fully describe each maintenance procedure, taking into account the failure rate of each component in order to define a preventive maintenance schedule.

These maintenance requirements should be kept to a practical minimum and the design of all equipment shall be such as to facilitate ease of repair and maintenance. Interchangeability of components should be possible without requiring any adjustment and pairing. All the equipment shall be designed so as not to subject operating personnel to risks of contamination or radiation during handling or other operations.

Maintenance operations shall be able to be carried out either fully or partly when the plant is operating. The equipment should allow remote inspection and adjustment, inspection and processing of intrinsic performance drifts, self testing of values, assistance with diagnosis and indication of the anomalies on all parts. Self-diagnostic features should be available through a display.

All electronic equipment shall be provided with a sufficient number of easily accessible identified test points to facilitate adjustments and fault location. Any special maintenance tools shall be supplied.

4.15.3 Ease of decontamination

The detection assembly or the sampling and detection assembly shall be constructed in such a manner that the build-up of contamination is reduced as much as possible and shall be designed to facilitate decontamination when this becomes necessary. External surfaces shall be specially treated to permit decontamination.

4.16 Electromagnetic interference

Precautions shall be taken against the effects of electromagnetic interference either received or emitted by the equipment.

Unless otherwise agreed upon between the purchaser and the manufacturer, the following standards shall apply: IEC 61000-4-2, IEC 61000-4-3, IEC 61000-4-4, IEC 61000-4-5, IEC 61000-4-6, IEC 61000-4-8, IEC 61000-4-12 and IEC 61000-6-4.

Levels of severity are given in 5.5.4.

4.17 Power supplies

Assemblies should be designed to operate from single-phase AC supply voltage in one of the following categories in accordance with IEC 60038:

- 100 V AC 50 Hz or 60 Hz;
- 110 V AC and/or 230 V AC 50 Hz;
- 120 V and/or 240 V AC 60 Hz;
- 24 V DC.

Nominal single-phase power in the United States of America and Canada is 117 V and/or 234 V, 60 Hz. Nominal single-phase power of 110 V, 50 Hz is also used in the United Kingdom.

Upon agreement between manufacturer and purchaser, the equipment may be designed for operation from a low-voltage stand-by supply in the case of a power failure. In such cases, it would be desirable for the equipment not to malfunction or trigger an alarm as a result of the supply change over; an indication for this change-over should be provided.

By agreement between manufacturer and purchaser, three-phase supplies may be used for air pump motors.

4.18 Interfaces

The physical properties of system component interfaces shall be specified. These shall include the type of connections (pipes coupling and cable connectors), electrical properties, and interpretation of the exchanged signals (e.g., pinout). Wherever possible, these specifications should be made by reference to commonly available standards.

Where network interfaces are provided, details of network interface protocols should be provided. Typically these details include: the logical organization of data bits transmitted, the information exchanges between network nodes used to deliver data, the quality and nature of the data delivery, the organization of data sequences, and the syntax of data being transferred. In order to verify the fulfilment of requirements concerning both design and performance of an equipment linked to its network, a general functional validation shall be performed, including tests on data exchange between subsystems and with operator.

Where the equipment is part of a plant-wide radiation monitoring system, it shall fulfil the corresponding requirements of IEC 61504 ~~and/or IEC 61559-2~~, unless otherwise agreed upon between manufacturer and purchaser.

4.19 Sampling assembly

Where a sampling assembly is needed, it shall provide sampling, transport and conditioning of the air, gas, steam or liquid to be measured, together with the possibility of isolating and dismantling the detector and the sampling control system when necessary.

In general, the performance of the instrument partly depends on the design of the sampling assembly. Therefore, a study performed by the manufacturer should characterise the sampling losses that can be predicted during normal and accident conditions. These losses shall remain as low as possible. The layout and the length of the sampling circuits shall comply with the instrument response time and ensure sufficient uniformity of sampling at the point of measurement, avoiding any trapping of aerosols and dust in air, formation of air bubbles in liquid, or condensation in the sampling pipes by variation of temperature or pressure. In particular, it is recommended to take into account the nature of the construction materials, the state of the internal surface and the ease of decontamination (by taking account of electrostatic effects, chemical corrosion, possible absorption and condensation), the transit time up to the detector (flow, fluid velocity and density) and the chemical forms of the monitored radioelements.

The following characteristics shall be taken into account and shall be agreed upon between manufacturer and purchaser:

- number and optimum position of sampling probes (representativity of the samples, minimum distance between inlet and outlet to avoid recirculation, etc.);
- inside diameter of pipes;
- nature of the material used and in particular effects of chemical corrosion or erosion and static electricity;
- finish condition of internal surfaces;
- ~~curve~~ radii of curvature and changes of direction;
- length of piping, slopes;

- joining of the pipes, connection to external pipes, to the monitor;
- effect of harmful chemicals and steam;
- filtration of the suspended matter.

The components of the sampling assembly depend on the type of fluid to be sampled and the particular conditions of measurement. Its design shall take into account the guidance of ISO standards related to sampling (e.g. ISO 2889 for radioactive particulates sampling).

In addition, the following requirements shall be fulfilled:

- where necessary, the sampling device shall be designed to guarantee the integrity of the nuclear containment;
- isokinetic probe or shrouded probe shall be used if aerosols or iodine are sampled, an omnidirectional probe if sampling takes place in a room;
- where flow or pressure drop have an influence on the measured value (volumetric activity), it shall be constantly measured and controlled;
- where devices are needed for sampling and conditioning the fluid (such as pumps, filters, pressure or temperature detectors, solenoid valves, etc.), they shall be compatible with dust conditions in air or materials in suspension in liquid and be dimensioned for operation between two scheduled unit outages;
- where pumps are needed, they shall be placed downstream from the point of measurement and, where necessary, shall be equipped with pressure and temperature protections from abnormal increases of these parameters;
- where necessary, personnel protection devices shall be provided against temperature, pressure, radiation, etc.;
- it shall be possible to isolate each sampling assembly for safety reasons;
- if agreed upon between the purchaser and the manufacturer, devices for collecting samples should be provided for deferred laboratory analysis;
- the acoustic noise level generated by the equipment shall be minimized and consistent with the type of environment for which the equipment is intended.

4.20 Quality

The system and equipment shall be of high quality, developed using a structured process embodying conservative design measures and verification and validation should be used, to ensure correct requirements are developed and that these requirements are correctly implemented. Computer based hardware should be developed according to the guidance of IEC 60987. Software for category A functions shall be developed according to the guidance of IEC 60880 ~~and~~ IEC 62566. Software for category B and C functions shall be developed according to the guidance of IEC 62138 and IEC 62566-2. Principles of IEC 61513 regarding safety lifecycle shall be applied.

At the request of the purchaser, all documentation produced during design, manufacture, installation, testing and start-up shall be provided to substantiate the correct performance of the system and equipment.

4.21 Type test report and certificate

At the request of the purchaser, the manufacturer shall present a report on the type tests carried out in accordance with the requirements of this series of standards (this document and specific parts). This test report shall comply with the specifications given in 5.6 of IEC 61069-1:2016 which states that:

"The conduct and the results of the assessment shall be documented in a comprehensive assessment and/or evaluation report. The report(s) should accurately, clearly, unambiguously and objectively present the objective, the results and all relevant information of the assessment.

The reports shall include at least the following information:

- an appropriate title;
- the credentials of the institute and/or person(s) responsible for the assessment or evaluation;
- if the system has been assessed for a particular application, the characteristics of that application in terms of type of process, type and number of input/outputs, scan rate required, system mission, tasks and functions, etc., shall be included;
- a description and identification of the system assessed, including a list showing the hardware with model numbers and the software with released data;
- the objective(s) of the assessment;
- a summary of the salient points arising out of the assessment and the conclusions reached;
- an account of the procedures, methods, specifications and tests (preferably summarized in a matrix and supplemented by referenced documents), together with a summary of the reasons leading to the particular selection of assessment elements as shown in the matrix. The reasons why certain aspects are not assessed should be also recorded;
- any deviation from the assessment plan (additions or exclusions) should be recorded and commented upon;
- measurements, examinations and derived results supported by tables, graphs, drawings or photographs as appropriate;
- failures observed;
- a statement of the measurement uncertainties;
- a statement as to whether or not the system complies with the requirements against which the system was assessed.

The assessment report shall contain a title page stating the report title, a unique (serial) number, the assessment authority and the date of issue.

The format should be standardized and facilitate comparison of assessments of different systems.

Corrections or additions to the report after its issue shall be made only by a further report, referring to the original report identified by its title and number. This supplementary report shall meet the same requirements as the main report."

A certificate shall also be provided with each equipment, giving at least the following general information and the additional information specified in the relevant subsequent part of the standard:

- identification of the entity who draws up the certificate,
- identification of the manufacturer,
- identification of the product,
- type test program/procedure and report,
- purchase order related documents,
- signatory's official capacity.

5 Functional testing

5.1 General

Except where otherwise specified, tests described in this clause are to be considered as type tests, although any or all may be considered as acceptance tests by agreement between manufacturer and purchaser. The stated requirements are minimum requirements and may be extended for any particular equipment or function.

These tests do not include additional qualification tests that shall be performed if the equipment is to be qualified in accordance with IEC/IEEE 60780-323.

5.2 General test procedures

5.2.1 General

General test procedures applicable to all types of monitors are covered in this document. Detailed test procedures will vary in accordance with the particular characteristics of each type of monitor. Specialized test requirements are given in the relevant standard dealing with each type of monitor.

The tests described in this standard may be classified according to whether they are performed under standard test conditions or under other conditions.

5.2.2 Tests performed under standard test conditions

Standard test conditions are defined in Table 2. Tests performed under standard test conditions are listed in Table 3, which indicates, for each characteristic under test, the requirements according to the clause where the corresponding test method is described.

5.2.3 Tests performed with variation of influence quantities

The object of these tests is to determine the effects of variations of the influence quantities.

In order to facilitate the execution of these tests, they can be divided into three categories:

- tests relating to the measurement, alarm and indication assemblies (all types of measurements);
- tests relating to the sampling assembly (off-line measurement);
- other complementary tests relating to postulated performance in volumetric measurement (all types of measurements).

In order to check the effects of the variation of each influence quantity listed in Table 4, all the other influence quantities shall be maintained within the limits of the standard test conditions given in ~~Table 2~~ Table 3, unless there are other requirements.

In order to simplify these tests, only a single test needs to be performed for each individual influence quantity. This test shall measure the effect of the specified change of influence quantity for activity or dose rate levels of approximately 50 % of the second most sensitive range or decade.

The tests relating to the measurement, alarm and indication assemblies are shown in Table 4 with the range of variation of each influence quantity and the limits of the corresponding variations of the indication of the assembly.

The tests of the sampling assembly are shown in the different parts of this standard dealing with off-line measurement. The range of variation of each influence quantity and the limits of the corresponding variations of the parameters under test are described.

The complementary tests relating to postulated performance in volumetric measurement where real testing is impossible are described hereinafter. The calculations and numerical simulations shall take into account the specified change of influence quantity required in Table 4 for at least the same activity or dose rate levels as stated above, and, if agreed upon between the purchaser and the manufacturer, for the whole range of measurement.

Table 2 – Reference conditions and standard test conditions

Influence quantity	Reference conditions	Standard test conditions
Reference radiation sources	See specific parts of IEC 60951	See specific parts of IEC 60951
Warm-up time: (whole equipment)	30 min	≥ 30 min
Ambient temperature	20 °C	18 °C to 22 °C
Relative humidity	65 %	50 % to 75 %
Atmospheric pressure [a]	101,3 kPa	86 kPa to 106 kPa
Power supply voltage	Nominal supply voltage U_N	U_N ± 1 %
AC power supply frequency [b]	Nominal frequency	Nominal frequency ± 0,5 %
AC power supply waveform	Sinusoidal	Sinusoidal with total harmonic distortion less than 5 %
Gamma radiation background	Air kerma rate in accordance with manufacturer's specification	Air kerma rate in accordance with manufacturer's specification
Electrostatic field	Negligible	Negligible
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to the earth's magnetic field
Sampling flow-rate	Adjusted to nominal flow-rate (defined by manufacturer)	Adjusted to nominal flow-rate ±5 %
Assembly controls	Set for normal operation	Set for normal operation

[a] Where the detection technique is particularly sensitive to variation in atmospheric pressure, the conditions shall be limited to ±5 % of the reference pressure.

[b] DC power supply may be used, and in such a case no frequency is specified.

Table 3 – Tests performed under standard test conditions

Characteristics under test	Requirements	Reference (subclause)
Reference response	In accordance with the manufacturer's specification	5.3.1
Sensitivity and relative response for solid sources	< 10 % from the manufacturer's specification	5.3.2
~~Accuracy (relative error)~~ Linearity	< 20 % (between 2,5 times the lowest value and 75 % of the range of measurement) < 30 % (whole range of measurement)	5.3.3
Response to other artificial radionuclides	Variation < 20 % from the manufacturer's specification	5.3.4
Precision (or repeatability)	Coefficient of variation < 10 % for any reading exceeding 10 times the lowest value of the effective range of measurement	5.3.6
Stability of the indication	< 2 % of scale maximum angular deflection (analogue display) or of first order of magnitude of range of measurement (digital display)	5.3.7
Response time	In accordance with the manufacturer's specification	5.3.8
Overload ~~test~~ characteristics	To remain at full-scale indication (or unambiguous indication) when exposed to an activity or dose rate twice that which would give full scale deflection and perform normally when this overload is removed	5.3.9
Alarm trip range	Adjustable over 10 % to 90 % of scale reading (linear scales), from 50 % of the lowest decade to 90 % of the highest decade (logarithmic scales), or from 10 % of the second least significant decade to 90 % of the highest decade (digital display).	5.4.1
Alarm trip stability	No deviation outside the range 95 % to 105 % of the nominal alarm set level during 100 h	5.4.2
Fault alarms	As specified in design criteria	5.4.3 and 5.4.4
Warm-up ~~time~~	Variation of indication < 10 % from value under standard test conditions	5.4.5
Short circuit withstand tests	As specified in design criteria	5.4.7
Degrees of protection (IP and IK codes)	IP 65 (measurement and processing devices) or IP 44 (sampling devices) and IK 07 (all devices) for the devices installed locally IP 30 and IK 07 for the devices installed in clean and dry rooms (electrical rooms) IP 65 and IK 07 for the devices installed outside the buildings	5.5.2.1
Mechanical vibrations	As specified in design criteria	5.5.2.2

Table 4 – Tests performed with variation of influence quantities

Influence quantity	Range of values of influence quantity	Limits of variation of indication	Reference (subclause)
Response to background radiation	In accordance with the manufacturer's specifications	In accordance with the manufacturer's specifications	5.3.5
Slow supply voltage variations	Upper and lower limits of supply voltage and down to zero	In accordance with the manufacturer's specifications	5.4.6.1
Sudden supply voltage variation	< 1 % of the lower limit of supply voltage during 20 ms	As specified in design criteria	5.4.6.2
AC power supply frequency	±10 % of nominal frequency	As specified in design criteria	5.4.6.3
Dry heat storage	T = + 70 °C, t = 96 h	As specified in design criteria	5.5.1.1
Cold storage	T = – 40 °C, t = 96 h	As specified in design criteria	5.5.1.2
Variable temperature storage	5 cycles of 30 min T = – 25 °C to +70 °C	As specified in design criteria	5.5.1.3
Stability of performance with variation of temperature and humidity	Damp heat T = + 40 °C, t = 96 h Cyclic damp heat: 6 cycles T = + 25 °C to + 55 °C	Change in indication < ±10 % over the entire ranges of variation of temperature and humidity	5.5.3
Electromagnetic compatibility	As specified in relevant test	As specified in relevant test	5.5.4

NOTE 1 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.

NOTE 2 DC power may be used, and in such a case the AC power supply frequency test does not apply.

5.2.4 Calculations and/or numerical simulations

This subclause applies to in-line and on-line instruments but is also applicable to off-line instruments if agreed upon between purchaser and manufacturer.

At the request of the purchaser, wherever real testing is impossible, for example when the instrument is intended to measure the activity of a fluid in such a way that it is not feasible to reproduce the same conditions for testing or calibrating, the manufacturer shall provide calculations and/or numerical simulations to ensure that the performance required in this standard, and especially characteristics of detection tested on point sources, are guaranteed in the real conditions of use.

At the request of the purchaser, calculations reproducing the exact geometry of the “volumetric source – collimator – detector – shielding” assembly and taking into account several mono-energetic volumetric sources shall be provided by the manufacturer in order to validate performance in detection (limit of detection, sensitivity, etc.) and to be compared with real tests with single isotope point sources or based on equivalent type-tested configurations. A detailed analysis shall explain the differences and limitations between real testing and calculations.

By agreement between purchaser and manufacturer, other calculations taking into account the speed of the stream or the flow-rate, and a multi-energetic volumetric source as close as possible to the real postulated volumetric source, should be provided, as well as the corresponding detailed analysis.

The manufacturer shall provide a comprehensive documentation to substantiate that the software used in calculations and simulations correctly represent the physical phenomena in the specified range. This documentation should be composed of, for example, comparisons with other verified methods of calculations or qualified codes, analysis, including parametric analysis of sensitivity, results of trials and tests in real conditions, data and corresponding correlations from technical publications, and all other relevant methods.

5.2.5 Reference sources

5.2.5.1 General requirements

All sources involved in the reference response test (primary calibration sources) shall be traceable to the National Standardizing Laboratory of a country for Radioactivity measurements (NSLR) in the country in which the source is used.

All sources used for the rest of the type tests or routine or acceptance tests (secondary calibration sources) shall either be prepared from radioactive solutions traceable to the NSLR, or shall refer to the primary calibration, during the reference response test, in order to have a direct link with it (transfer factor).

All secondary calibration sources should be solid sources.

The type of source is specified in the specific part of IEC 60951. In order to cover the range of measurement and energy of the equipment, a number of sources are likely to be necessary, the activity of which shall be appropriate for the equipment.

The conventionally true surface emission rate or activity of the sources shall be known with an absolute uncertainty better than 10 % (k = 2), and a relative uncertainty to other sources in the test set better than 10 % (k = 2). Where the method of test uses a pre-calibrated reference instrument as an alternative to an accurately defined source strength, the calibration of this instrument shall be to a comparable standard of uncertainty.

5.2.5.2 Primary calibration (reference response)

5.2.5.2.1 Gaseous sources

For instruments with sampling, the reference sources shall be gaseous sources of a known volumetric activity of the appropriate radionuclide or radionuclide mix. The nature of the gases to be used shall be agreed upon between the manufacturer and the purchaser.

As an alternative to the use of calibrated gaseous sources, a calibrated instrument may be used to establish the correct response to an undefined source activity. If it is intended to use such an instrument, it shall be calibrated during these tests, unless it had already been calibrated.

If the use of gaseous sources leads to unacceptable source volumes or activities, an acceptable method is to simulate a large source by positioning a smaller source at different locations with respect to the detector and to use the reading as an input for calculations and numerical simulations of the detector response. The manufacturer shall demonstrate the validity of such calculations.

5.2.5.2.2 Solid sources

For instruments with sampling, the relative response to solid sources shall be determined during the type tests by cross-calibration against gaseous sources, and this relative response may then be used in conjunction with solid source tests when these are substituted for gaseous source tests.

For area monitors, all tests shall be carried out with solid sources, either primary sources or secondary sources cross-calibrated during primary calibration.

Such solid sources shall be of a physical form and of a radionuclide appropriate to the assembly under test. In particular, the location of the source relative to the detector shall be accurately fixed and repeatable.

5.2.5.3 Other types of sources

For testing with extremely high dose rates, electronic radiation sources may be used.

5.2.5.4 Electronic signal generator

In order to avoid the use of sources of too high activity for routine or acceptance tests, the measuring assembly alone may be tested by injection of an appropriate electronic signal at the normal detector input of the measuring assembly.

5.2.6 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuation of the indication arising from the random nature of radiation alone is a significant fraction of the variation of the indication permitted in the test, then sufficient readings shall be taken to ensure that the mean value of such readings may be estimated with sufficient ~~precision~~ accuracy to demonstrate compliance with the test in question.

The interval between such readings shall be at least three times the response time in order to ensure that the readings are statistically independent.

5.3 ~~Performance~~ Radiation characteristics

5.3.1 Reference response

5.3.1.1 Requirements

The manufacturer shall state the relationship between the indication given by the measuring assembly and the reference dose rate or activity when the equipment is operated under standard test conditions and set up as defined by the manufacturer. The uncertainty of the reference response shall be specified.

The test shall be carried out with a set of sources of different representative radionuclide and geometric characteristics, such as defined in 5.2.5.

5.3.1.2 Test method

The assembly shall be operated under standard test conditions and set up as defined by the manufacturer with no reference radiation source present. The background indication shall be noted.

The assembly shall then be exposed to an appropriate reference source sufficient to give a reading approximately at the mid-point of the linear scale or in the second lowest decade of logarithmic scale or digital display. The value of R_{ref} shall be computed as defined in 3.14.

5.3.2 Sensitivity and relative response for solid sources

5.3.2.1 Requirements

For instruments normally tested with gaseous sources, the relative response for solid sources shall be determined by cross-calibration against gaseous sources.

The test shall be carried out with a set of sources of different representative radionuclide and geometric characteristics, as defined in 5.2.5.

5.3.2.2 Test method

The background shall be measured in the geometry that will be used for the measurement with solid sources; for example, with the measuring cell empty, and the value shall be noted.

Solid sources, of an activity sufficient to give a reading approximately at the mid-point of the scale or decade above the lowest scale or decade, shall be placed at defined locations relative to the detector, with the gaseous source test conditions unchanged, but the gaseous source absent. The relative response to the solid source shall be noted. For subsequent tests, the instrument response to the gaseous source shall be computed, using the relative response established for the solid sources.

If such a relative response for solid sources is used in routine or acceptance tests, the possible variation in background radiation should be taken into account.

5.3.3 ~~Accuracy (relative error)~~ Linearity

5.3.3.1 Requirements

Under standard test conditions, with the calibration controls adjusted according to the manufacturer's instructions, the ~~accuracy (linearity error or relative error)~~ response linearity of the detector assembly shall not exceed 20 %, between 2,5 times the lowest value of the effective range of measurement and 75 % of this range, and shall not exceed ±30 % over the whole effective range of measurement. The uncertainty of the radioactive source is not included.

Tests can be performed in two ways:

- with gaseous or solid radioactive sources;
- with injection of an electronic signal (restricted to ranges of measurement where the use of sources is impossible).

Where sources are used, the test shall be carried out with a set of sources of the same radionuclide and geometric characteristics, such as defined in 5.2.5, except for area monitors where different kinds of sources have to be used in practice as they are available for high dose rate. In this latter case, the sources and the geometry used shall be defined.

The reference curve shall be determined from the reference response when the test is performed with gaseous sources or from the sensitivity obtained during the test of 5.3.2 when solid sources are used.

5.3.3.2 Test method

~~Type tests shall be undertaken at approximately 25 % of the most sensitive range or decade, at 50 % of the maximum of the intermediate ranges or decade, at the maximum achievable range, and at one point on each range for linearly scaled instruments and on each decade of the effective range of measurement of digitally or logarithmically scaled instruments. The ratio between two successive measurements shall be at least equal to 10.~~

For assemblies provided with linear scales, the type test shall be carried out on all ranges and on at least 3 points on each range, i.e. at about 25 %, 50 % and 75 % of the scale range.

For assemblies provided with single range and logarithm graduation, or for digital displays, the type test shall be carried out on all order of magnitude scales of dose rate and on at least 2 points on each order of magnitude scale. (The higher value in each decade shall be at least three times the lower and at least 70 % of the maximum of that order of magnitude.)

At least three of these tests shall be carried out using a radioactive source, including the upper and the lowest values.

Where electronic test signals are used, they shall be used on all ranges or decades (in addition to radioactive sources), and the manufacturer shall provide an analysis demonstrating the performance of the system from the point of the highest source test to the maximum range.

Where this test is carried out with gaseous radioactive sources, it shall be performed in accordance with the design of the monitor:

- For off-line equipment using a measuring cell: by circulating a reference source through the assembly at nominal flow rate for a sufficient time to reach the equilibrium of the reading, or by filling up the measuring cell with a volume equal to the nominal volume of a reference source.
- For off-line equipment using a concentration device: by concentrating the reference source in the normal operation condition (time of concentration, volume, etc.).
- For in-line, on-line or off-line equipment without measuring cell: by locating the detector relative to a sufficiently large volume of reference source to be equivalent to the actual operating conditions of the monitor.

In order to minimize the effects of possible contamination of the sampling assembly, all tests with gaseous sources shall proceed from low to high values of volumetric activity.

5.3.4 Response to other artificial radionuclides

5.3.4.1 Requirements

The response for radionuclides of interest shall be agreed upon between manufacturer and purchaser. The response of the assembly to radionuclides other than that of the reference shall not differ by more than 20 % from the value specified by the manufacturer.

5.3.4.2 Test method

The test method described in 5.3.1 using appropriate radionuclides shall be performed.

5.3.5 Response to background radiation

5.3.5.1 General

Because there is generally a relationship between the response to ambient gamma radiation and the decision threshold, and the requirement for both depends on the particular plant application, the response of the assembly to gamma radiation, as well as the decision threshold, shall be agreed upon between the manufacturer and the purchaser, in accordance with the expected ambient activity.

Similar test methods as agreed upon between the manufacturer and purchaser shall be used for other activities, for example neutrons and/or high energy betas, may affect the reading.

This requirement does not apply to area monitors.

5.3.5.2 Requirements

The manufacturer shall state the decision threshold and the maximum value of the reading when the detector, fitted with its ambient gamma radiation protection devices where necessary, is exposed in a reference orientation specified by the manufacturer to a step change in gamma air kerma rate from the reference background air kerma rate to 10 µGy/h from Cs-137 and Co-60.

5.3.5.3 Test method

The equipment shall be operated under standard test conditions with no radioactive source present and the background indication shall be determined.

Next, using a Cs-137 source, position the source relative to the measurement assembly (i.e. the detector with its fitted ambient gamma radiation protection devices) so that the source to measurement assembly distance is at least 2 m and the conventionally true gamma air kerma rate at the measurement assembly position, with the measurement assembly absent, is equal to 10 µGy/h ± 10 %. The reference orientation of the measurement assembly in relation to the source shall be as specified by the manufacturer.

Record the reading at 1 min intervals after the start of the exposure and continue taking readings until the reading of the assembly is stable. At least 10 readings shall be taken after the stability is achieved. Calculate the decision threshold based on the final readings.

The measurement assembly shall also be exposed in a number of source-to-detector orientations, as agreed upon between the manufacturer and the purchaser. Where the measurement assembly may be programmed with a gamma compensation factor, this shall not be changed during these tests.

The reading of the measurement assembly in each orientation shall not exceed twice the value specified by the manufacturer for the reference orientation.

Repeat the same test with a Co-60 source.

5.3.6 Precision (or repeatability)

5.3.6.1 Requirements

The coefficient of variation of the indication due to statistical fluctuations shall be less than 10 % for any reading exceeding 10 times the lowest value of the effective range of measurement.

5.3.6.2 Test method

Use suitable radioactive sources to give an indication between 10 and 50 times the lowest value of the effective range of measurement.

Take at least 10 readings at appropriate time intervals. In order to obtain independent values, calculate the mean value and the coefficient of variation of all the readings taken. The coefficient of variation shall lie within the limits required.

5.3.7 Stability of the indication

5.3.7.1 Requirements

The indication from a given source of activity, after the assembly has been in operation for 30 min, shall vary over the following 100 h by not more than:

- 2 % of scale maximum angular deflection for instruments with an analogue display;
- 2 % of the first order of magnitude of the effective range of measurement for instruments with a digital display.

5.3.7.2 Test method

Use irradiation equipment (e.g. radioactive source or electron beam) to give an indication between 10 to 20 times the lowest value of the range of measurement.

Take sufficient readings after 30 min, then further readings after 10 h and 100 h with no adjustment made to the assembly and no change of conditions. The means of the readings taken each time shall lie within the limits indicated.

Readings shall be corrected for decay of the source if necessary.

5.3.8 Response time

5.3.8.1 Requirements

The manufacturer shall specify the response time of the assembly for an activity or dose rate between 10 to 50 times the lowest value of the range of measurement and give all useful data to determine its relationship with the precision and the false alarm rate. The influence quantities, their range of values and the variation they cause to the response time shall be specified.

The test shall be carried out with sources of the same representative radionuclide and geometric characteristics. These sources may be gaseous or solid sources.

5.3.8.2 Test method

A recorder, able to record much faster than the response time being measured, shall be connected to the assembly to determine the change in indication as a function of time.

Where this test is carried out with gaseous sources, it shall be performed in accordance with the design of the monitor:

- For off-line equipment:
  - by circulating a non-radioactive gas through the assembly at nominal flow rate for a sufficient time to reach the equilibrium of the reading of the background, or by filling up the measuring cell with a volume equal to the nominal volume of a non-radioactive gas;
  - then by continuously injecting into the inlet of the monitor, at the nominal sampling flow rate, a solution of known volumetric activity of appropriate radionuclide for the time needed to reach the equilibrium.
- For in-line, on-line or off-line equipment, and especially for area monitors, when the use of a gaseous source is not possible:
  - by locating the detector relative to an empty volume, equivalent to the actual operating conditions of the monitor, for a time sufficient to reach the equilibrium of the reading of the background;
  - then by rapidly introducing a sufficiently solid source into the empty volume, for the time needed to reach the equilibrium.

NOTE In the context of this test, "rapidly" is defined as a much shorter time than the response time being tested.

The response time is the interval of time separating the initial moment where the radioactive solution or solid source is injected and the moment at which the reading reaches 90 % of the variation for the first time. For off-line equipment using a concentration device, where the measurement is an integration of the volumetric activity, the response time is a percentage of the equilibrium value of the first derivative of the output signal as a function of time.

5.3.9 Overload ~~test~~ characteristics

5.3.9.1 Requirements

The equipment shall maintain full-scale indication or an unambiguous indication when "exposed" to an appropriate activity or dose rate twice greater than that necessary to give the maximum scale reading and shall perform normally when this overload "exposure" is removed.

Unless otherwise agreed upon between manufacturer and purchaser, an overload indication shall be provided to point out that the activity or dose rate is too high for the measuring unit.

5.3.9.2 Test method

Subject the detector assembly to an appropriate form of activity to give a reading between 10 and 50 times the lowest value of the range; note the reading.

Subject the detector assembly to an appropriate form of activity about twice greater than that necessary to produce the maximum scale reading. Check the overload indication. Maintain the exposure for at least 10 min and verify that the assembly maintains a maximum reading.

Remove the overload source and “expose” the detector assembly under identical conditions to those used for the first reading. After a period to be agreed upon between manufacturer and purchaser, but generally of less than 10 min, the reading shall not differ by more than 10 % from the value previously noted.

For some applications this kind of test is impossible. In such cases, a demonstration by analysis shall be provided by the manufacturer.

5.4 Electrical ~~performance tests~~ characteristics

5.4.1 Alarm trip range

5.4.1.1 Requirements

The ranges of alarm settings shall conform to the requirements of 4.14.3. These requirements exclude the detectors.

5.4.1.2 Test method

Using an appropriate electronic signal generator, as specified by the manufacturer, the range of indication of the equipment over which the alarm trip operates shall be determined.

These tests shall be performed for the effective range of measurement.

For alarms intended to operate on increasing signals, the alarm shall be adjusted to its lowest setting and the input signal slowly increased until the alarm operates. The indication of the equipment shall be noted.

For alarms intended to operate on decreasing signals, operate as above, but slowly decrease the level of input signal.

5.4.2 Alarm trip stability

5.4.2.1 Requirements

The operating point of any alarm circuit shall not deviate outside the range 95 % X to 105 % X in the period of 100 h of operation, where X is the nominal alarm set level.

These requirements exclude the detector.

5.4.2.2 Test method

For any alarm circuit whose nominal trip setting has been determined as X.

- For a condition equivalent to 94 % X applied electronically or by software to the assembly, no trip shall occur within 100 h.
- When a condition equivalent to 106 % X is applied to the assembly, after 30 min and 100 h of operation, the alarm shall operate in less than 1 min.

5.4.3 Fault alarm

5.4.3.1 Requirements

When failure appears in one of these parts of the equipment:

- detector;
- electronic circuit;
- sampling assembly where appropriate;

an alarm shall operate and permit the identification of the failure. For the electronic circuit and the sampling assembly, a specific fault alarm shall operate within 1 min after failure. The manufacturer shall indicate the time required to obtain a detector fault alarm after failure, taking into account the background of the detector.

The equipment shall provide facilities to simulate failures.

5.4.3.2 Test method

For each part: detector, electronic circuit and sampling assembly (where appropriate), a failure shall be simulated. The specific fault alarm shall operate before the time required. No other unrelated alarm shall operate.

5.4.4 Status indication and fault alarm tests

The indication and alarm facilities described in 4.14.3 and 4.14.4 shall be functionally tested.

5.4.5 Warm-up ~~time — Detection and measuring assembly~~

5.4.5.1 Requirements

When exposed to irradiation equipment (e.g. radioactive source or electron beam), the assembly in steady state operation shall give an indication that does not differ by more than ±10 % from the value obtained under standard conditions 30 min after being switched on.

5.4.5.2 Test method

Prior to this test, the equipment shall be disconnected from the power supply for at least 1 h.

Use irradiation equipment (e.g. radioactive source or electron beam) to give approximately 10 to 50 times the lowest value of the effective range of measurement. Switch on the detection and control assemblies.

Switch on the equipment. Note values of indication of activity or dose rate every 5 min during 1 h. Ten hours after switching on, take sufficient readings and use the mean value as the "final value" of indication.

Draw a graph of activity or dose rate indication versus time, correcting for decay in activity as necessary.

The difference between the "final value" and the value read from the curve for 30 min shall lie within the limits specified.

5.4.6 Influence of supply variations

5.4.6.1 Influence of slow supply voltage variations

When several different voltage levels are required by the monitor, each supply voltage is taken as a separate influencing factor.

Firstly, verify the functional characteristics of the equipment at the upper and lower limits of its rated power supply voltage. Then, slowly drop the voltage from the latter value down to zero.

The variation of the voltage duration shall be at least 1 min.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.4.6.2 Influence of sudden supply voltage variation

Unless otherwise agreed upon between the purchaser and the manufacturer, the voltage loss duration is one period of the power source frequency. During this outage, the voltage applied shall not exceed 1 % of the lower limit of the rated supply voltage range.

Input signals shall not be disturbed. Measures shall be taken to ensure that output signals remain stable. The supply voltage is then cut-off for the specified period. Output signals shall then be observed, from just before the voltage cut-off, throughout the voltage outage and until after the voltage is re-established.

If the settings or equipment operating mode affects the output signals observed, the configuration producing the greatest variation shall be adopted.

For analogue signal outputs, the test is carried out on a stabilized output at the lower, mean and upper levels of the voltage range.

For logical (digital) outputs, the test is carried out for both states.

Upon completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.4.6.3 Influence of supply frequency variations

Functional characteristics shall be verified at ±10 % of the nominal frequency.

5.4.7 Short circuit withstand tests

The effects of external short circuits on electronic equipment functions shall be verified, particularly for circuits fed by internal power supplies.

Short-circuits shall be produced at the external interfaces of the various constituent parts, such as plug-in units inputs and outputs, and power supply units.

The functional consequences of these short-circuits shall then be observed, involving, for example:

- the emission of an erroneous output signal, especially by an equipment sharing a power supply with the faulty equipment,
- the appearance of erroneous input data,
- de-energizing of all or part of the equipment.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5 Environmental ~~performance test~~ characteristics

5.5.1 Stability of performance after storage

5.5.1.1 Dry heat storage

This test shall comply with IEC 60068-2-2 (test Bb), completed by the following:

- the assemblies shall not encounter heat radiating from the walls of the test chamber,
- the assemblies are not energised,
- TA = + 70 °C, t = 96 h, < 1 °C/min heat gradient (unless otherwise specified by the manufacturer on the maximum heat gradient accepted by the equipment).

On completion of this test, the assemblies are placed in normal atmospheric conditions for 2 h so that they reach thermal equilibrium. The performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.1.2 Cold storage

This test shall comply with IEC 60068-2-1 (test Ab), completed by the following procedures:

- the assemblies shall not encounter heat radiating from the walls of the test chamber,
- the assemblies are not energised,
- TB = – 40 °C, t = 96 h, < 1 °C/min heat gradient (unless otherwise specified by the manufacturer on the maximum heat gradient accepted by the equipment).

On completion of this test, the assemblies are placed in normal atmospheric conditions for 2 h so that they reach thermal equilibrium. The performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.1.3 Variable temperature storage

This test shall comply with IEC 60068-2-14 (test Nb), completed by the following procedures:

- the assemblies shall not encounter heat radiating from the walls of the test chamber,
- the assemblies are not energised,
- number of cycles: 5, duration of each test condition: 30 min,
- TB = – 25 °C, TA = +70 °C, < 1 °C/min heat gradient (unless otherwise specified by the manufacturer on the maximum heat gradient accepted by the equipment).

On completion of this test, the assemblies are placed in normal atmospheric conditions for 2 h so that they can reach thermal equilibrium. The performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.2 Mechanical ~~tests~~ characteristics

5.5.2.1 Degrees of protection (IP and IK codes)

The tests shall comply with IEC 60529 and IEC 62262. The equipment is not energised.

Unless otherwise agreed upon between the purchaser and the manufacturer, the protection indices of the various items of equipment should be:

- IP 65 (measurement and processing device) or IP 44 (sampling devices) and IK 07 (all devices) for assemblies installed locally,
- IP 30 and IK 07 for the assemblies installed in clean and dry rooms (electrical rooms),
- IP 65 and IK 07 for the assemblies installed outside the buildings.

5.5.2.2 Mechanical vibrations test

This test is used to check the mechanical strength of the assemblies. It does not apply to equipment whose stiffness is provided by another system (e.g.: cables, etc.).

The test shall be carried out in three tri-rectangular reference axes. It includes three successive phases for each of the three specified axes:

Phase 1: search for critical frequencies (resonance frequencies or frequencies for which defective operation of the monitor has been observed).

The frequency range is entirely swept in accordance with the procedures detailed below, except for the scanning rate which may be reduced to allow accurate determination of the critical frequencies. Eventually, this will reveal:

- an electrical discontinuity between normally closed dry contacts,
- inadvertent closing of the normally open dry contacts,
- defective operation of the monitor,
- any other resonance phenomenon.

Phase 2: Endurance by frequency sweeping. The frequency varies in accordance with the methods specified below.

Phase 3: Identical to phase 1.

These test phases are defined in IEC 60068-2-6 (test Fc). They are supplemented by the following procedures:

- The assemblies are energised during phases 1 and 3 of the test and are not energised during phase 2.
- The vibration table is fixed by a rigid part which will not distort the test results, and which receives the assembly with its usual fixing system. For the plugged-in parts, solidarity is only provided by the means to be used in normal service.
- The module is subjected to sinusoidal rectilinear vibrations which are applied to it in three tri-rectangular directions. Sweeping (through to the specified frequency band once in each direction) is continuous and its speed is logarithmic with respect to time. The frequency variation takes place at a rate of approximately one octave per minute.
- The export frequency range is from 10 Hz to 500 Hz.
- The vibrations are defined according to the following characteristics:
  – displacement: 0,15 mm peak to peak,
  – constant displacement below the transfer frequency,
  – transfer frequency: 58 Hz,
  – constant acceleration of 10 m/s^2 above the transfer frequency.

The number of cycles is equal to:

- phase 1: 1 cycle/axis,
- phase 2: 10 cycles/axis,
- phase 3: 1 cycle/axis.

A variation of the critical frequencies between phases 1 and 3 of more than 5 % leads to an inspection.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.3 Stability of performance with variation of temperature and humidity

5.5.3.1 General

Wherever the equipment or part of the equipment are submitted to variations of temperature or humidity of the medium to be measured, or of the ambient atmosphere, the influence of such variations shall be tested.

As the ranges of variation of such influence quantities may be different for testing the measurement assembly and testing the detector, these tests shall be performed in two steps if necessary:

- Test of the influence of the temperature or humidity on the measurement assembly.
- Test of the influence of the temperature or humidity on the detector being in contact with the medium to be measured, if applicable.

5.5.3.2 Requirements

The change in indication shall be less than 10 % over the entire ranges of variation of temperature and humidity.

Unless otherwise agreed upon between the manufacturer and the purchaser, the following ranges of variation of temperature and humidity shall apply.

5.5.3.3 Test method

The measurement assembly (or part of it), if necessary without its shielding, shall be exposed to suitable solid sources as defined in 5.2.5, such that the nominal reading under standard test conditions is known.

The test shall be performed following the method described in the following IEC standards:

– IEC 60068-2-78 for damp heat, steady state test, supplemented by the following procedures:
  - the assemblies are fitted in their reference position,
  - they shall not be subjected to heat radiated by the walls of the test chamber,
  - assemblies are energised,
  - duration of the test condition: 96 h
  - T = + 40 °C, 93 % relative humidity.

– IEC 60068-2-30 (test Db variant 2) for damp heat cyclic test, supplemented by the following procedures:
  - the assemblies are fitted in their reference position,
  - they shall not be subjected to heat radiated by the walls of the test chamber,
  - the assemblies are energised,
  - number of cycles: 6,
  - TA = + 25 °C, TB = + 55 °C.

Switch on the instrument, select the appropriate range and place in an environmental chamber at the reference conditions. The other characteristics of the air in the chamber shall be lower than the value that could cause damage to the equipment. This value shall be indicated by the manufacturer.

The detection assembly shall be exposed to suitable test sources in such a way that the nominal reading under standard test conditions is known.

The instrument shall be left in this condition for 30 min or until equilibrium is assured. If a set-zero control is available to the operator, this shall then be adjusted to bring the indication to a point stated by the manufacturer.

For instruments with a non-linear scale, such a control is used to bring the indication to some reference point rather than to zero. If this is the case, the control shall be set to bring the indication to the appropriate reference point.

The indication of the instrument shall be measured during the tests. On completion, the instruments are placed in normal atmospheric conditions for 2 h so that they reach thermal equilibrium. The performance of the monitors shall comply with the performance stipulated by the manufacturer.

NOTE Certain detectors are particularly sensitive to temperature variations (for instance NaI scintillator). During this test it is advisable to provide means that will allow the permissible maximum heat gradient given by the manufacturer to be checked in addition to the non-deterioration of their characteristics.

5.5.4 Electromagnetic compatibility

5.5.4.1 Oscillatory wave immunity

The test procedures previously defined in IEC 61000-4-12, and now defined in IEC 61000-4-18:

- oscillation frequency: 1 MHz + 10 %,
- service frequency between 50 Hz and 400 Hz and non-synchronized on the network frequency.

Injection takes place in common mode using the coupling/uncoupling network. If the manufacturer's specifications stipulate that an earth connection is required for one of the circuit conductors, the test of this circuit shall be performed in differential mode while applying the specified common mode severities.

The severity of the test shall be:

- circuits inside the control room: no test,
- circuits connecting the control room and the other rooms of the electrical building or between the electrical rooms: level 1,
- circuits exiting the electrical building: level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.2 Electrical transient burst immunity test

This test shall comply with IEC 61000-4-4.

The severity of the test shall be:

- for equipment installed in the control room: level 2,
- for other equipment: level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.3 Radiated radio frequency immunity test

This test shall comply with IEC 61000-4-3.

Depending on the type of measurements to be made on the monitor, one or the other of the following modes shall apply to the disturbance:

- when the measurement results are instantaneous (less than 1 s), the frequency range is swept slowly (1,5 × 10^{-3} decades/s) by maintaining the level of the electrical field constant during sweeping,
- when a disturbance may have occurred on the equipment, a more detailed search of the disturbing frequency zone and the minimum level of the electrical field required to cause the disturbance is carried out,
- when the results of measurement are obtained slowly (taking more than 1 s), the disturbance is applied after the first sweep by maintaining the level of the electrical field constant for the following fixed frequencies: 80 MHz; 100 MHz; 150 MHz; 200 MHz; 300 MHz; 500 MHz; 1 000 MHz, to which the multiple/sub-multiple frequencies of the clock frequencies of the tested sub-system are added.

The severity of the test for all the equipment shall be level 3, unless otherwise agreed upon between the purchaser and the manufacturer.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.4 Electrical discharge immunity test

This test shall comply with IEC 61000-4-2.

The discharges shall be carried out on every sensitive part of the equipment that an operator may come into contact with, i.e. each type of discontinuity (LED, display, pushbutton, switch, terminal) on the surfaces of the equipment and the outside of cabinets or boxes front or rear doors submitted to the test.

The contact test takes place on conducting surfaces, on insulating surfaces for the test in the air, and the plate test close to each side.

The severity of the test for all the equipment shall be:

- contact discharge: class 2,
- air discharge (and at the plate): class 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.5 Conducted disturbances immunity test

This test shall comply with IEC 61000-4-6. However, as nuclear power stations are not installed in the immediate vicinity of radio transmitters, the attenuation or absence of disturbances in certain frequency bands are not taken into account.

The severity of the test for all the equipment shall be level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.6 50 Hz magnetic field immunity test

This test shall be performed in compliance with IEC 61000-4-8 or the absence of components sensitive to magnetic fields shall be demonstrated.

The severity of the test for all the equipment shall be level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.7 Surge immunity test (high energy)

This test shall comply with IEC 61000-4-5.

Only the AC supply and the connections that could leave the electrical building shall be tested.

The severity of the test shall be:

- AC supply: level 3 in common mode (between phase and earth) and level 2 in differential mode (between phases),
- input or output that could be connected to an electrical building outgoing cable: level 2 in common mode.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.8 Non-aggression test: radio disturbances

This test shall comply with IEC 61000-6-4.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

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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*

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

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 60951-3~~:2009~~, *Nuclear power plants – Instrumentation systems important to safety – Radiation monitoring ~~equipment~~ for accident and post-accident conditions – Part 3: Equipment for continuous high range area gamma monitoring*

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*

IEC 60960:1988, *Functional design criteria for a safety parameter display system for nuclear power stations*

~~IEC 61000-4-11:2004, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*~~

IEC 61031:2020, *Nuclear facilities – Instrumentation and control systems – Design, location and application criteria for installed area gamma radiation dose rate monitoring equipment for use during normal operation and anticipated operational occurrences*

IEC 61250:1994, *Nuclear reactors – Instrumentation and control systems important for safety – Detection of leakage in coolant systems*

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IEC 62003:2020, *Nuclear power plants – Instrumentation, control and electrical power systems – Requirements for electromagnetic compatibility testing*

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IEC TR 63123:2017, *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 63147:2017/IEEE Std 497™, *Criteria for accident monitoring instrumentation for nuclear power generating stations*

ISO 4037-1:2019, *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods*

ISO 4037-3:2019, *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*

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IEC 60951-1

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

IEC 60951-1:2022-11(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 1: General requirements

FOREWORD

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.

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.

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.

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 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*

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*

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]

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:

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

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.

Note 2 to entry: Experimental standard deviation of the mean is sometimes incorrectly called standard error of the mean.

3.10
measuring assembly
assembly designed to measure a quantity

Note 1 to entry: In this document, the quantity is volumetric activity or dose rate, although the value may be expressed in other units.

3.11
minimum detectable (measurable) activity
radioactivity which, if present in a sample, produces a counting rate that will be detected (i.e. considered to be above background) with a certain level of confidence

Note 1 to entry: The 'certain level of confidence' is normally set at 95 %; that is, a sample containing exactly the minimum detectable activity will, as a result of random fluctuations, be taken to be free of radioactivity 5 % of the time.

Note 2 to entry: The minimum detectable activity is sometimes referred to as the detection limit or lower limit of detection.

Note 3 to entry: The counting rate from a sample containing the minimum detectable activity is termed the determination level.

Note 4 to entry: An example formulation for minimum detectable activity is calculated as follows.

$$MDA = \frac{k_1^2 + 2k_1\sqrt{R_b t_s\left(1+\frac{t_s}{t_b}\right)}}{(t_s)(E)(C)}$$

where:

k_1 is the one-sided coverage factor = 1,645 at 95 % confidence

R_b is the background count rate in s^{-1}

t_s is the sample count time in min

t_b is the background count time in min

E is the detector efficiency in counts per disintegration

C is the conversion factor from dpm to other desired activity unit, if applicable

[SOURCE: IAEA Safety Glossary, 2018 edition]

3.12
particle
aggregate of molecules, forming a solid or liquid, ranging in size from a few molecular diameters to several millimetres

[SOURCE: ISO 2889:2015, 3.55]

3.13
process streams
fluid which flows through a system intended to provide a useful purpose

Note 1 to entry: Examples of process streams are: primary coolant system, spent fuel cooling system, component cooling system, etc.

Note 2 to entry: The process streams within the scope of this document are those streams in which the level of radioactivity may significantly increase as a result of accident or post-accident conditions.

Note 3 to entry: Monitoring of these process streams for radioactivity provides information on the quality or integrity of the barrier and potential release to the environment.

3.14
reference response
response of the assembly under reference conditions to unit reference dose rate, expressed as:

$$R_{ref} = \frac{\nu - \nu_B}{\nu_c}$$

where:

ν is the value measured by the equipment or assembly under test

ν_B is the background value of the equipment without external influence

ν_c is the conventional quantity value of the reference source

Note 1 to entry: The background value may be automatically taken into account by an algorithm included in the measurement systems.

3.15
relative error
error of measurement divided by a true value of the measurand

Note 1 to entry: Since a true value cannot be determined, in practice, a conventional quantity value is used. For this standard, relative error is calculated as follows.

$$E = \frac{(\nu - \nu_B) - \nu_c}{\nu_c}$$

where:

ν is the value measured by the equipment or assembly under test,

ν_c is the conventional quantity value of the reference source,

ν_B is the background value of the equipment without external influence.

Note 2 to entry: The background value may be automatically taken into account by an algorithm included in the measurement system.

3.16
relative response
value calculated during type testing equal to the ratio between the reference response of the equipment and the sensitivity of the same equipment to the solid source of interest

Note 1 to entry: The relative response allows determination of the reference response of identical equipment that has been type tested from the measurement of the sensitivity of the solid source.

3.17
response time
period of time necessary for a component to achieve a specified output state from the time that it receives a signal requiring it to assume that output state

Note 1 to entry: For the purposes of the tests described in this document, the input signal is assumed to be a step variation and the ending output state is the point at which the output signal variation reaches 90 % of its final value for the first time.

[SOURCE: IAEA Safety Glossary, 2018 edition]

3.18
routine test
conformity test made on each individual item during or after manufacture

3.19
sampling collection efficiency
for a given quantity of radioactive material, ratio of the collected activity to the supplied activity, for a specified time interval

3.20
sensitivity <of a measuring assembly>
ratio of the variation of the observed variable to the corresponding variation of the measured quantity for a given value of the measured quantity

[SOURCE: IEC 60050-395:2014, 395-03-105]

4 Design principles

4.1 General

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).

In the case where different radiation monitoring systems for design basis accidents (DBA) and that for design extension conditions (DEC) including severe accident (SA) are required, they should be independent of each other as far as reasonably practicable.

4.2 Basic requirements related to functions

The main purpose of equipment for continuous monitoring of radioactivity in accident or post-accident conditions is to continuously measure radiation levels in appropriate areas and processes. These radiation measurements are displayed locally and/or in control rooms and/or incident control centers to keep plant operators aware of current radiological conditions. This information is used by operators to assess plant conditions, take appropriate actions in order to mitigate the consequences of a plant accident and prevent the inadvertent release of radioactive substance, and by site emergency personnel, national authorities, for actions necessary to safeguard public and plant personnel. Therefore, the equipment concerned by this document is capable of actuating alarms and providing inputs to other plant systems and processes to isolate processes at abnormal radiation levels.

The basic requirements for the design, selection, testing, calibration and functional location of equipment for continuous monitoring of radioactivity in accident or post-accident conditions are plant specific. It is typically split into three key parts, effluent and ventilation radiation monitoring, process radiation monitoring, and area radiation monitoring:

- Effluent and ventilation radiation monitors measure the specific activity in gases released into the environment in accident and post-accident conditions to ensure that the specific activity is not hazardous to the public's safety and to help in early warning and process isolations for containment or recirculation of control room heating-ventilation-air conditioning.
- Process radiation monitors measure the specific activity in a fluid (either gas, liquid or steam) and are normally used in plant process to help in early warning and process isolations, such as detecting reactor coolant pressure boundary leaks into containment and other systems. Process radiation monitors can be classified into three basic types:
  - In-line monitors: the detector is located directly in the process stream (pipe, stack, tank, duct, etc.).
  - On-line monitors: the detector is located external to and faced directly to the process stream.
  - Off-line monitors: a sample is drawn from the process stream to the detector located at some distance.

- Area radiation monitors (wide range type) are strategically located within buildings subject to high range dose rates in accident and post-accident conditions, such as the reactor building and containment vessel, and serve as post-accident monitoring devices. Area radiation monitors are wall mounted in the area or tank to be monitored. Depending on the radiation level at the detector position, the electronics part of the monitor may be located at some distance from the detector.

For the purpose of critical data collection, these monitors are usually designed to withstand adverse environmental and seismic conditions, during and after an accident.

Radiation monitoring requirements and radiation monitoring system design should be addressed early in plant design to establish effective monitoring at the appropriate sensitivity level. Thus, for maximum performance capability, the following procedure should be followed by the purchaser and the manufacturer:

- Establish the required measurement characteristics (purchaser):
  - Determine the scenarios of normal and accidental operations, and the corresponding source terms (main isotopes to be measured by the monitor), including their chemical composition.
  - Determine the essential information required by the plant operator or the control system to initiate emergency actions, the functions assigned to the equipment for continuous radiation monitoring and classify them according to IEC 61226 guidance.
  - Determine the optimum points of measurement taking into account installation conditions (location, interfaces to plant protection features, ambient conditions and qualification requirements, electrical connections through safety barriers, etc.).
  - Calculate the activity transfers (propagation through pipes or ducts and through the safety barriers), in order to determine the activity spectrums and the background at the point of measurement.
  - Determine the time profile of the postulated release and the required range of measurement and response time of the complete channel (including the sampling system, if any, and the time to send or to display the information to the plant operator or the control system).
  - Determine the gross characteristics of the detectors (type of radiation and measurement, sensitivity and range of measurement, energy response and overload performance, etc.) and of the sampling system, if any.
  - Determine the acceptable false alarm rate taking into account the plant conditions and the consequences of error in measurement (including losses in sampling), and specify the precision and linearity needed to stay under this threshold.
- Check the metrological characteristics of the chosen instrument (agreement between the purchaser and the manufacturer):
  - Calculate the response time of the instrument (measure time related to a specified linearity and time for the apparatus to provide an alarm), and the global response time of the channel (including the response time of the sampling system).
  - Calculate, at the point of measurement, geometric detection efficiency, decision threshold and minimum detectable activity, taking into account the appropriate shielding.
  - For each characteristic of the instrument, the manufacturer should specify its variations as a function of the corresponding influence quantities (or variable parameters). These influence quantities (or variable parameters) should be, at least:

    i) activity spectrum and time profile of the activity spectrum (during transient operating conditions) of the source to be measured,

    ii) activity spectrum and time profile of the activity spectrum (during transient operating conditions) of the background,

    iii) detection geometry,

    iv) confidence level (e.g. 95 %) (in order to calculate the minimum detectable activity),

  v) flow rate of the effluent to be measured,
  vi) thermodynamic conditions,
  vii) precision and time profile of the precision (in order to calculate the measurement time during steady-state as well as transient operating conditions),
  viii) measurement time and response time (during transient operating conditions).

– For the influence quantities depending on the process or the location, the purchaser should indicate their range of values. Otherwise, the manufacturer should make any useful hypothesis in order to take into account the probable conditions of use of the instrument.

NOTE The term "manufacturer" includes the designer and the seller of the equipment. The term "purchaser" includes the user.

If the signals are used for initiating protective action to mitigate the consequences of malfunction or failure of structures, systems or components, then the equipment may be part of the safety-related systems or the protection system. In this case, it shall meet the requirements of the respective system in accordance with IEC 61226.

The equipment shall be environmentally qualified in accordance with the requirements of IEC/IEEE 60780-323 (and IEC/IEEE 60980-344 for seismic testing).

4.3 Measurement range

The purchaser shall specify the required effective range of measurement. The range shall be suitable for the level of radiation during accident and post-accident conditions. The low end of the measurement range shall overlap the measurement range of monitors provided for normal plant conditions for at least one decade (logarithmic scale). The highest measurable activity or dose rate should be at least one decade over the highest activity or dose rate expected during accident and post-accident conditions.

4.4 Energy response

The detector may be selected to measure either beta or gamma radiation. The purchaser shall confirm that the energy response of the detection assembly is suitable for monitoring the potential activity.

4.5 Minimum detectable activity

The minimum detectable activity should only be considered in steady-state operating conditions. Its calculation by a formula is possible, using the measurement time, however it does not give a rigorous statement of the beginning of the range of measurement.

The required minimum detectable activity will depend on the particular application and be subject to local regulations and plant design; it shall be specified by the plant designer.

The manufacturer shall specify the minimum detectable activity for nuclides of interest, taking into account the check sources or provisions incorporated to provide an on-scale indication on the monitor, as well as all useful data needed to specify the beginning of the effective range of measurement, even in transient operating conditions. The influence quantities, their range of values and the variation they cause on the minimum detectable activity shall be specified.

4.6 Precision (or repeatability)

Precision (or repeatability) is a measure of the dispersion of the estimations around their average value. It shall be given by the manufacturer in the effective range of measurement in % of the signal value for a given confidence interval (or probability of error). Assuming that the estimations follow a Gaussian distribution, this probability should be expressed in terms of a number of standard deviations.

NOTE For example, the precision could be 20 % of the signal value within a part of the effective range of measurement with a probability of 95 % (meaning that all the estimations are within ±2σ, with σ the standard deviation), and 30 % within another part of the effective range of measurement with another probability.

Precision shall be consistent with accident analysis assumptions, operator needs, and requirements imposed by other systems that use the radiation monitoring signals. Moreover, they shall be characterized for signal values below the beginning of the effective range of measurement. The influence quantities, their range of values and the variation they cause on precision shall be specified by the manufacturer.

Typically, the precision should be within 20 % over the entire effective range of measurement, all influence quantities taken into account.

4.7 Linearity

Linearity is a measure of the deviation between the conventional quantity value and the average of the estimations. It shall be given by the manufacturer in the effective range of measurement in % of the signal value for a given confidence interval (or probability of error). Assuming that the estimations follow a Gaussian distribution, this probability should be expressed in terms of a number of standard deviations.

NOTE For example, the linearity could be 20 % of the signal value within a part of the effective range of measurement with a probability of 95 % (meaning that all the estimations are within ±2σ, with σ the standard deviation), and 30 % within another part of the effective range of measurement with another probability.

Linearity shall be consistent with accident analysis assumptions, operator needs, and requirements imposed by other systems that use the radiation monitoring signals. Moreover, they shall be characterized for signal values below the beginning of the effective range of measurement. The influence quantities, their range of values and the variation they cause on linearity shall be specified by the manufacturer.

Typically, the linearity should be within 30 % over the entire effective range of measurement, all influence quantities taken into account.

4.8 Measurement time

The measurement time is the average time during which the measurement is to be performed to obtain an estimation of the signal in stated conditions. It should only be considered in steady-state operating conditions. Its calculation by a formula is possible, however it does not take into account the processing algorithms implanted in the monitor.

The manufacturer shall specify the measurement time as well as all useful data (standard deviation or precision) necessary to know the precision of the estimations and the false alarm rate. The influence quantities, their range of values and the variation they cause on the measurement time shall be specified.

4.9 Response time

The response time is the time needed for the monitor, after a sudden variation of the measured signal (for example a step), for its output signal or indication to reach 90 % (increasing transition) or 10 % (decreasing transition) of the variation for the first time.

For integrating systems, it is a percentage of the equilibrium value of the first derivative of the output signal as a function of time that should be considered.

The response time is to be considered only in transient operating conditions. It shall take into account the processing algorithms of the monitor.

Therefore, its calculation by a formula is not relevant, and the manufacturer shall specify it by performing tests or numerical simulations and give all useful data to determine its relationship with the precision of the estimations and the false alarm rate. The influence quantities, their range of values and the variation they cause on the response time shall be specified.

4.10 Overload performance

The indicated measurement shall not decrease or fall to zero during and following exposure beyond the maximum measuring range. It shall maintain a full-scale indication or an unambiguous indication. When the exposure returns to within the maximum range, the system shall recover within the time interval specified by the purchaser.

4.11 Ambient background shielding or compensation devices

Shielding or electronic compensation shall be provided as necessary to reduce the effects of background radiation on the measurement of process radiation.

It may be agreed upon between the manufacturer and the purchaser that significant background radiation is only to be expected from defined directions or sources (vessels, pipes, etc.). In such cases, the construction of shielding may take this into account. In the absence of such an agreement, shielding shall give virtually identical radiation attenuation in all directions seen from the sensitive volume of the detector, taking into account the structural materials of the detection assembly, and the angular response of the detector.

If the equipment cannot easily be removed from the shielding, such shielding should be easily removable. The maximum mass of the elements, or the appropriate handling means, should be agreed upon between manufacturer and purchaser.

When electronic techniques incorporating additional detectors are used to reduce the effect of background radiation, these detectors shall be chosen and located to give the best practical compensation, taking into account the range of energies and the direction of the radiation.

4.12 Requirements related to accident conditions

Equipment design shall ensure that the equipment supports the necessary system functions and that the equipment will not fail due to environmental conditions experienced during normal, accident, or post-accident conditions.

The accident and post-accident time interval during which system operation is required shall be specified by the purchaser.

The local environmental conditions in which the different components of the system can operate during normal operation, accident, and post-accident conditions shall be specified by the purchaser. Specification of environmental conditions shall include, where applicable, temperature and pressure and their rate of change, vibration, humidity, aggressive or corrosive fluids, vapours, or dusts, seismic conditions, electromagnetic environment and other adverse physical conditions as well as the normal and accident radiation dose rate and the integrated radiation dose at the location of the monitoring equipment.

The manufacturer shall provide an equipment designed to operate anywhere in the environmental envelope stated above, unless otherwise agreed upon between purchaser and manufacturer. If necessary, equipment shall be qualified for the environmental conditions of the application in accordance with relevant standards.

In particular, equipment shall be designed to minimize the effects of the specified environmental conditions, and the location of detectors shall be selected considering the accident and post-accident radiation background and the need for shielding to minimize its effect. As far as is practical, locations shall be selected so as to facilitate maintenance and calibration operations. The location should also take into account the possible need to locate electronic equipment in an area of lower dose rate.

Consideration shall be given to the possibility that materials used in the construction of the monitors may release poisonous or corrosive substances under adverse environmental conditions, such as fire, high temperature or high radiation. As far as practicable, the design shall minimize this by the choice of materials and appropriate containment of materials.

4.13 Reliability

The required reliability of the functions shall be specified either quantitatively (mean time between failures) or qualitatively (compliance with the single failure criterion).

For any part of the equipment (including sampling assembly, if any), subject to appropriate planned maintenance, the following requirement shall be reached:

- Mean Time Between Failure (MTBF): > 20 000 h (with preventive maintenance).
- A failure modes and effects analysis (FMEA) shall be performed in addition to the MTBF calculation in the case of equipment classified as performing a function important to safety in category A in accordance with IEC 61226.
- The manufacturer shall specify the frequency of routine maintenance, and fully describe each maintenance procedure (see 4.15.2). These maintenance requirements should be kept to a practical minimum.

4.14 User interface

4.14.1 General

The system shall provide continuous display and/or recording of activity or dose rate and, in addition, provide an alarm signal when the activity or dose rate level exceeds a preset value.

4.14.2 Display of measured value

The choice between logarithmic scales, linear scales, or numeric displays shall be appropriate to the purpose of the equipment. Logarithmic scales or numeric displays are generally preferred.

In the case of assemblies provided with linear scales, it shall be possible to change the range in such a way that the scaling factors do not exceed 10. An indication of the scale in use shall be provided.

Where the accident conditions are such as to give rise to large variations in reading, manual switching between ranges shall not be used unless specifically agreed to by the purchaser.

4.14.3 Alarms

4.14.3.1 General

The alarm and indication facilities shall be appropriate for the purpose of the equipment.

Alarm circuits shall be operable either to hold an alarm condition until specifically reset by a reset control or to automatically reset when the alarm state disappears. Alarm mode selection should be readily accomplished but allow for positive administrative controls. This may be accomplished, for example by requiring a key, password, or minor equipment modification to switch modes.

All alarm functions shall be provided with test facilities to allow checking of alarm operation. In the case of adjustable alarms, checking shall be possible over the range of adjustment with indication of the actual alarm operation point.

Alarm functions shall be agreed upon between the supplier and the manufacturer. As a minimum the following alarms shall be provided as applicable.

4.14.3.2 High-level alarm

At least one adjustable alarm setpoint shall be provided, adjustable over:

- at least 10 % to 90 % of scale reading (linear scales), from 50 % of the lowest decade to 90 % of the highest decade (logarithmic scales),
- or from 10 % of the second least significant decade to 90 % of the highest decade (digital display).

4.14.3.3 Fault alarms

As many separate alarms as practicable should be provided for electronic or mechanical fault. At least, the following should be provided when appropriate:

- Loss of detector signal.
- Loss of the sampling circuit.
- Loss of the cooling system.
- Loss of the heating system.
- Sampling circuit high pressure.
- Sampling circuit high temperature.
- Sampling circuit high humidity.
- High ambient radiation.
- Purging system failure.

4.14.4 Status indication

The following indications should be provided when appropriate:

- Power On.
- Pump On/Off.
- Flow Min/Max.
- Pressure.
- Humidity.
- Temperature.
- Detector power supply status.
- Detector heating unit On.
- Gas stream cooling device On.
- Gas stream heating device On.
- Group fault alarms are indicated.
- Purging system On.
- Occurrence of internal power supply changeover if internal supplies (e.g., batteries) are provided.

4.14.5 Local indications

Local indication and alarm units should be provided at accessible locations, close to the detector assembly, for the purpose of controlling access to high radiation areas in accident conditions or for maintenance and calibration during normal plant operation.

Where provided, the local indication and alarm units shall be qualified for the conditions appropriate to their purpose and location, in accordance with IEC/IEEE 60780-323. If the local indication and alarm units are not qualified to the same requirements as the detector it shall be demonstrated that their failure will not affect the essential function of the monitor.

4.15 System testing, maintenance facilities and ease of decontamination

4.15.1 System testing

Capability shall be provided to allow periodic checks of the satisfactory operation of the system from the detector to the measurement display, alarm functions, and system outputs. These checks should include operational checks, calibration, and verification of the measurement linearity.

The capability to check the good detector response at one representative point on the measurement scale without accessing the detector, using for example a remote-controlled check source, should be provided. Additional points should also be checked, and therefore means of access to the detector and to ensure the repeatability of the check, such as a support in which the detector is placed for checking with reference source(s), should be provided.

4.15.2 Maintenance facilities

The manufacturer shall specify the frequency of routine maintenance, and fully describe each maintenance procedure, taking into account the failure rate of each component in order to define a preventive maintenance schedule.

These maintenance requirements should be kept to a practical minimum and the design of all equipment shall be such as to facilitate ease of repair and maintenance. Interchangeability of components should be possible without requiring any adjustment and pairing. All the equipment shall be designed so as not to subject operating personnel to risks of contamination or radiation during handling or other operations.

Maintenance operations shall be able to be carried out either fully or partly when the plant is operating. The equipment should allow remote inspection and adjustment, inspection and processing of intrinsic performance drifts, self testing of values, assistance with diagnosis and indication of the anomalies on all parts. Self-diagnostic features should be available through a display.

All electronic equipment shall be provided with a sufficient number of easily accessible identified test points to facilitate adjustments and fault location. Any special maintenance tools shall be supplied.

4.15.3 Ease of decontamination

The detection assembly or the sampling and detection assembly shall be constructed in such a manner that the build-up of contamination is reduced as much as possible and shall be designed to facilitate decontamination when this becomes necessary. External surfaces shall be specially treated to permit decontamination.

4.16 Electromagnetic interference

Precautions shall be taken against the effects of electromagnetic interference either received or emitted by the equipment.

Unless otherwise agreed upon between the purchaser and the manufacturer, the following standards shall apply: IEC 61000-4-2, IEC 61000-4-3, IEC 61000-4-4, IEC 61000-4-5, IEC 61000-4-6, IEC 61000-4-8, IEC 61000-4-12 and IEC 61000-6-4.

Levels of severity are given in 5.5.4.

4.17 Power supplies

Assemblies should be designed to operate from single-phase AC supply voltage in one of the following categories in accordance with IEC 60038:

- 100 V AC 50 Hz or 60 Hz;
- 110 V AC and/or 230 V AC 50 Hz;
- 120 V and/or 240 V AC 60 Hz;
- 24 V DC.

Nominal single-phase power in the United States of America and Canada is 117 V and/or 234 V, 60 Hz. Nominal single-phase power of 110 V, 50 Hz is also used in the United Kingdom.

Upon agreement between manufacturer and purchaser, the equipment may be designed for operation from a low-voltage stand-by supply in the case of a power failure. In such cases, it would be desirable for the equipment not to malfunction or trigger an alarm as a result of the supply change over; an indication for this change-over should be provided.

By agreement between manufacturer and purchaser, three-phase supplies may be used for air pump motors.

4.18 Interfaces

The physical properties of system component interfaces shall be specified. These shall include the type of connections (pipes coupling and cable connectors), electrical properties, and interpretation of the exchanged signals (e.g., pinout). Wherever possible, these specifications should be made by reference to commonly available standards.

Where network interfaces are provided, details of network interface protocols should be provided. Typically these details include: the logical organization of data bits transmitted, the information exchanges between network nodes used to deliver data, the quality and nature of the data delivery, the organization of data sequences, and the syntax of data being transferred. In order to verify the fulfilment of requirements concerning both design and performance of an equipment linked to its network, a general functional validation shall be performed, including tests on data exchange between subsystems and with operator.

Where the equipment is part of a plant-wide radiation monitoring system, it shall fulfil the corresponding requirements of IEC 61504, unless otherwise agreed upon between manufacturer and purchaser.

4.19 Sampling assembly

Where a sampling assembly is needed, it shall provide sampling, transport and conditioning of the air, gas, steam or liquid to be measured, together with the possibility of isolating and dismantling the detector and the sampling control system when necessary.

In general, the performance of the instrument partly depends on the design of the sampling assembly. Therefore, a study performed by the manufacturer should characterise the sampling losses that can be predicted during normal and accident conditions. These losses shall remain as low as possible. The layout and the length of the sampling circuits shall comply with the instrument response time and ensure sufficient uniformity of sampling at the point of measurement, avoiding any trapping of aerosols and dust in air, formation of air bubbles in liquid, or condensation in the sampling pipes by variation of temperature or pressure. In particular, it is recommended to take into account the nature of the construction materials, the state of the internal surface and the ease of decontamination (by taking account of electrostatic effects, chemical corrosion, possible absorption and condensation), the transit time up to the detector (flow, fluid velocity and density) and the chemical forms of the monitored radioelements.

The following characteristics shall be taken into account and shall be agreed upon between manufacturer and purchaser:

- number and optimum position of sampling probes (representativity of the samples, minimum distance between inlet and outlet to avoid recirculation, etc.);
- inside diameter of pipes;
- nature of the material used and in particular effects of chemical corrosion or erosion and static electricity;
- finish condition of internal surfaces;
- radii of curvature and changes of direction;
- length of piping, slopes;
- joining of the pipes, connection to external pipes, to the monitor;
- effect of harmful chemicals and steam;
- filtration of the suspended matter.

The components of the sampling assembly depend on the type of fluid to be sampled and the particular conditions of measurement. Its design shall take into account the guidance of ISO standards related to sampling (e.g. ISO 2889 for radioactive particulates sampling).

In addition, the following requirements shall be fulfilled:

- where necessary, the sampling device shall be designed to guarantee the integrity of the nuclear containment;
- isokinetic probe or shrouded probe shall be used if aerosols or iodine are sampled, an omnidirectional probe if sampling takes place in a room;
- where flow or pressure drop have an influence on the measured value (volumetric activity), it shall be constantly measured and controlled;
- where devices are needed for sampling and conditioning the fluid (such as pumps, filters, pressure or temperature detectors, solenoid valves, etc.), they shall be compatible with dust conditions in air or materials in suspension in liquid and be dimensioned for operation between two scheduled unit outages;
- where pumps are needed, they shall be placed downstream from the point of measurement and, where necessary, shall be equipped with pressure and temperature protections from abnormal increases of these parameters;
- where necessary, personnel protection devices shall be provided against temperature, pressure, radiation, etc.;
- it shall be possible to isolate each sampling assembly for safety reasons;
- if agreed upon between the purchaser and the manufacturer, devices for collecting samples should be provided for deferred laboratory analysis;

- the acoustic noise level generated by the equipment shall be minimized and consistent with the type of environment for which the equipment is intended.

4.20 Quality

The system and equipment shall be of high quality, developed using a structured process embodying conservative design measures and verification and validation should be used, to ensure correct requirements are developed and that these requirements are correctly implemented. Computer based hardware should be developed according to the guidance of IEC 60987. Software for category A functions shall be developed according to the guidance of IEC 60880 and IEC 62566. Software for category B and C functions shall be developed according to the guidance of IEC 62138 and IEC 62566-2. Principles of IEC 61513 regarding safety lifecycle shall be applied.

At the request of the purchaser, all documentation produced during design, manufacture, installation, testing and start-up shall be provided to substantiate the correct performance of the system and equipment.

4.21 Type test report and certificate

At the request of the purchaser, the manufacturer shall present a report on the type tests carried out in accordance with the requirements of this series of standards (this document and specific parts). This test report shall comply with the specifications given in 5.6 of IEC 61069-1:2016 which states that:

"The conduct and the results of the assessment shall be documented in a comprehensive assessment and/or evaluation report. The report(s) should accurately, clearly, unambiguously and objectively present the objective, the results and all relevant information of the assessment.

The reports shall include at least the following information:

- an appropriate title;
- the credentials of the institute and/or person(s) responsible for the assessment or evaluation;
- if the system has been assessed for a particular application, the characteristics of that application in terms of type of process, type and number of input/outputs, scan rate required, system mission, tasks and functions, etc., shall be included;
- a description and identification of the system assessed, including a list showing the hardware with model numbers and the software with released data;
- the objective(s) of the assessment;
- a summary of the salient points arising out of the assessment and the conclusions reached;
- an account of the procedures, methods, specifications and tests (preferably summarized in a matrix and supplemented by referenced documents), together with a summary of the reasons leading to the particular selection of assessment elements as shown in the matrix. The reasons why certain aspects are not assessed should be also recorded;
- any deviation from the assessment plan (additions or exclusions) should be recorded and commented upon;
- measurements, examinations and derived results supported by tables, graphs, drawings or photographs as appropriate;
- failures observed;
- a statement of the measurement uncertainties;
- a statement as to whether or not the system complies with the requirements against which the system was assessed.

The assessment report shall contain a title page stating the report title, a unique (serial) number, the assessment authority and the date of issue.

The format should be standardized and facilitate comparison of assessments of different systems.

Corrections or additions to the report after its issue shall be made only by a further report, referring to the original report identified by its title and number. This supplementary report shall meet the same requirements as the main report."

A certificate shall also be provided with each equipment, giving at least the following general information and the additional information specified in the relevant subsequent part of the standard:

- identification of the entity who draws up the certificate,
- identification of the manufacturer,
- identification of the product,
- type test program/procedure and report,
- purchase order related documents,
- signatory's official capacity.

5 Functional testing

5.1 General

Except where otherwise specified, tests described in this clause are to be considered as type tests, although any or all may be considered as acceptance tests by agreement between manufacturer and purchaser. The stated requirements are minimum requirements and may be extended for any particular equipment or function.

These tests do not include additional qualification tests that shall be performed if the equipment is to be qualified in accordance with IEC/IEEE 60780-323.

5.2 General test procedures

5.2.1 General

General test procedures applicable to all types of monitors are covered in this document. Detailed test procedures will vary in accordance with the particular characteristics of each type of monitor. Specialized test requirements are given in the relevant standard dealing with each type of monitor.

The tests described in this standard may be classified according to whether they are performed under standard test conditions or under other conditions.

5.2.2 Tests performed under standard test conditions

Standard test conditions are defined in Table 2. Tests performed under standard test conditions are listed in Table 3, which indicates, for each characteristic under test, the requirements according to the clause where the corresponding test method is described.

5.2.3 Tests performed with variation of influence quantities

The object of these tests is to determine the effects of variations of the influence quantities.

In order to facilitate the execution of these tests, they can be divided into three categories:

- tests relating to the measurement, alarm and indication assemblies (all types of measurements);

- tests relating to the sampling assembly (off-line measurement);
- other complementary tests relating to postulated performance in volumetric measurement (all types of measurements).

In order to check the effects of the variation of each influence quantity listed in Table 4, all the other influence quantities shall be maintained within the limits of the standard test conditions given in Table 3, unless there are other requirements.

In order to simplify these tests, only a single test needs to be performed for each individual influence quantity. This test shall measure the effect of the specified change of influence quantity for activity or dose rate levels of approximately 50 % of the second most sensitive range or decade.

The tests relating to the measurement, alarm and indication assemblies are shown in Table 4 with the range of variation of each influence quantity and the limits of the corresponding variations of the indication of the assembly.

The tests of the sampling assembly are shown in the different parts of this standard dealing with off-line measurement. The range of variation of each influence quantity and the limits of the corresponding variations of the parameters under test are described.

The complementary tests relating to postulated performance in volumetric measurement where real testing is impossible are described hereinafter. The calculations and numerical simulations shall take into account the specified change of influence quantity required in Table 4 for at least the same activity or dose rate levels as stated above, and, if agreed upon between the purchaser and the manufacturer, for the whole range of measurement.

Table 2 – Reference conditions and standard test conditions

Influence quantity	Reference conditions	Standard test conditions
Reference radiation sources	See specific parts of IEC 60951	See specific parts of IEC 60951
Warm-up time: (whole equipment)	30 min	≥ 30 min
Ambient temperature	20 °C	18 °C to 22 °C
Relative humidity	65 %	50 % to 75 %
Atmospheric pressure [a]	101,3 kPa	86 kPa to 106 kPa
Power supply voltage	Nominal supply voltage U_N	U_N ± 1 %
AC power supply frequency [b]	Nominal frequency	Nominal frequency ± 0,5 %
AC power supply waveform	Sinusoidal	Sinusoidal with total harmonic distortion less than 5 %
Gamma radiation background	Air kerma rate in accordance with manufacturer's specification	Air kerma rate in accordance with manufacturer's specification
Electrostatic field	Negligible	Negligible
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to the earth's magnetic field
Sampling flow-rate	Adjusted to nominal flow-rate (defined by manufacturer)	Adjusted to nominal flow-rate ±5 %
Assembly controls	Set for normal operation	Set for normal operation

[a] Where the detection technique is particularly sensitive to variation in atmospheric pressure, the conditions shall be limited to ±5 % of the reference pressure.

[b] DC power supply may be used, and in such a case no frequency is specified.

Table 3 – Tests performed under standard test conditions

Characteristics under test	Requirements	Reference (subclause)
Reference response	In accordance with the manufacturer's specification	5.3.1
Sensitivity and relative response for solid sources	< 10 % from the manufacturer's specification	5.3.2
Linearity	< 20 % (between 2,5 times the lowest value and 75 % of the range of measurement) < 30 % (whole range of measurement)	5.3.3
Response to other artificial radionuclides	Variation < 20 % from the manufacturer's specification	5.3.4
Precision (or repeatability)	Coefficient of variation < 10 % for any reading exceeding 10 times the lowest value of the effective range of measurement	5.3.6
Stability of the indication	< 2 % of scale maximum angular deflection (analogue display) or of first order of magnitude of range of measurement (digital display)	5.3.7
Response time	In accordance with the manufacturer's specification	5.3.8
Overload characteristics	To remain at full-scale indication (or unambiguous indication) when exposed to an activity or dose rate twice that which would give full scale deflection and perform normally when this overload is removed	5.3.9
Alarm trip range	Adjustable over 10 % to 90 % of scale reading (linear scales), from 50 % of the lowest decade to 90 % of the highest decade (logarithmic scales), or from 10 % of the second least significant decade to 90 % of the highest decade (digital display).	5.4.1
Alarm trip stability	No deviation outside the range 95 % to 105 % of the nominal alarm set level during 100 h	5.4.2
Fault alarms	As specified in design criteria	5.4.3 and 5.4.4
Warm-up	Variation of indication < 10 % from value under standard test conditions	5.4.5
Short circuit withstand tests	As specified in design criteria	5.4.7
Degrees of protection (IP and IK codes)	IP 65 (measurement and processing devices) or IP 44 (sampling devices) and IK 07 (all devices) for the devices installed locally IP 30 and IK 07 for the devices installed in clean and dry rooms (electrical rooms) IP 65 and IK 07 for the devices installed outside the buildings	5.5.2.1
Mechanical vibrations	As specified in design criteria	5.5.2.2

Table 4 – Tests performed with variation of influence quantities

Influence quantity	Range of values of influence quantity	Limits of variation of indication	Reference (subclause)
Response to background radiation	In accordance with the manufacturer's specifications	In accordance with the manufacturer's specifications	5.3.5
Slow supply voltage variations	Upper and lower limits of supply voltage and down to zero	In accordance with the manufacturer's specifications	5.4.6.1
Sudden supply voltage variation	< 1 % of the lower limit of supply voltage during 20 ms	As specified in design criteria	5.4.6.2
AC power supply frequency	±10 % of nominal frequency	As specified in design criteria	5.4.6.3
Dry heat storage	T = + 70 °C, t = 96 h	As specified in design criteria	5.5.1.1
Cold storage	T = – 40 °C, t = 96 h	As specified in design criteria	5.5.1.2
Variable temperature storage	5 cycles of 30 min T = – 25 °C to +70 °C	As specified in design criteria	5.5.1.3
Stability of performance with variation of temperature and humidity	Damp heat T = + 40 °C, t = 96 h Cyclic damp heat: 6 cycles T = + 25 °C to + 55 °C	Change in indication < ±10 % over the entire ranges of variation of temperature and humidity	5.5.3
Electromagnetic compatibility	As specified in relevant test	As specified in relevant test	5.5.4
NOTE 1 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. NOTE 2 DC power may be used, and in such a case the AC power supply frequency test does not apply.			

5.2.4 Calculations and/or numerical simulations

This subclause applies to in-line and on-line instruments but is also applicable to off-line instruments if agreed upon between purchaser and manufacturer.

At the request of the purchaser, wherever real testing is impossible, for example when the instrument is intended to measure the activity of a fluid in such a way that it is not feasible to reproduce the same conditions for testing or calibrating, the manufacturer shall provide calculations and/or numerical simulations to ensure that the performance required in this standard, and especially characteristics of detection tested on point sources, are guaranteed in the real conditions of use.

At the request of the purchaser, calculations reproducing the exact geometry of the "volumetric source – collimator – detector – shielding" assembly and taking into account several mono-energetic volumetric sources shall be provided by the manufacturer in order to validate performance in detection (limit of detection, sensitivity, etc.) and to be compared with real tests with single isotope point sources or based on equivalent type-tested configurations. A detailed analysis shall explain the differences and limitations between real testing and calculations.

By agreement between purchaser and manufacturer, other calculations taking into account the speed of the stream or the flow-rate, and a multi-energetic volumetric source as close as possible to the real postulated volumetric source, should be provided, as well as the corresponding detailed analysis.

The manufacturer shall provide a comprehensive documentation to substantiate that the software used in calculations and simulations correctly represent the physical phenomena in the specified range. This documentation should be composed of, for example, comparisons with other verified methods of calculations or qualified codes, analysis, including parametric analysis of sensitivity, results of trials and tests in real conditions, data and corresponding correlations from technical publications, and all other relevant methods.

5.2.5 Reference sources

5.2.5.1 General requirements

All sources involved in the reference response test (primary calibration sources) shall be traceable to the National Standardizing Laboratory of a country for Radioactivity measurements (NSLR) in the country in which the source is used.

All sources used for the rest of the type tests or routine or acceptance tests (secondary calibration sources) shall either be prepared from radioactive solutions traceable to the NSLR, or shall refer to the primary calibration, during the reference response test, in order to have a direct link with it (transfer factor).

All secondary calibration sources should be solid sources.

The type of source is specified in the specific part of IEC 60951. In order to cover the range of measurement and energy of the equipment, a number of sources are likely to be necessary, the activity of which shall be appropriate for the equipment.

The conventionally true surface emission rate or activity of the sources shall be known with an absolute uncertainty better than 10 % (k = 2), and a relative uncertainty to other sources in the test set better than 10 % (k = 2). Where the method of test uses a pre-calibrated reference instrument as an alternative to an accurately defined source strength, the calibration of this instrument shall be to a comparable standard of uncertainty.

5.2.5.2 Primary calibration (reference response)

5.2.5.2.1 Gaseous sources

For instruments with sampling, the reference sources shall be gaseous sources of a known volumetric activity of the appropriate radionuclide or radionuclide mix. The nature of the gases to be used shall be agreed upon between the manufacturer and the purchaser.

As an alternative to the use of calibrated gaseous sources, a calibrated instrument may be used to establish the correct response to an undefined source activity. If it is intended to use such an instrument, it shall be calibrated during these tests, unless it had already been calibrated.

If the use of gaseous sources leads to unacceptable source volumes or activities, an acceptable method is to simulate a large source by positioning a smaller source at different locations with respect to the detector and to use the reading as an input for calculations and numerical simulations of the detector response. The manufacturer shall demonstrate the validity of such calculations.

5.2.5.2.2 Solid sources

For instruments with sampling, the relative response to solid sources shall be determined during the type tests by cross-calibration against gaseous sources, and this relative response may then be used in conjunction with solid source tests when these are substituted for gaseous source tests.

For area monitors, all tests shall be carried out with solid sources, either primary sources or secondary sources cross-calibrated during primary calibration.

Such solid sources shall be of a physical form and of a radionuclide appropriate to the assembly under test. In particular, the location of the source relative to the detector shall be accurately fixed and repeatable.

5.2.5.3 Other types of sources

For testing with extremely high dose rates, electronic radiation sources may be used.

5.2.5.4 Electronic signal generator

In order to avoid the use of sources of too high activity for routine or acceptance tests, the measuring assembly alone may be tested by injection of an appropriate electronic signal at the normal detector input of the measuring assembly.

5.2.6 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuation of the indication arising from the random nature of radiation alone is a significant fraction of the variation of the indication permitted in the test, then sufficient readings shall be taken to ensure that the mean value of such readings may be estimated with sufficient accuracy to demonstrate compliance with the test in question.

The interval between such readings shall be at least three times the response time in order to ensure that the readings are statistically independent.

5.3 Radiation characteristics

5.3.1 Reference response

5.3.1.1 Requirements

The manufacturer shall state the relationship between the indication given by the measuring assembly and the reference dose rate or activity when the equipment is operated under standard test conditions and set up as defined by the manufacturer. The uncertainty of the reference response shall be specified.

The test shall be carried out with a set of sources of different representative radionuclide and geometric characteristics, such as defined in 5.2.5.

5.3.1.2 Test method

The assembly shall be operated under standard test conditions and set up as defined by the manufacturer with no reference radiation source present. The background indication shall be noted.

The assembly shall then be exposed to an appropriate reference source sufficient to give a reading approximately at the mid-point of the linear scale or in the second lowest decade of logarithmic scale or digital display. The value of R_{ref} shall be computed as defined in 3.14.

5.3.2 Sensitivity and relative response for solid sources

5.3.2.1 Requirements

For instruments normally tested with gaseous sources, the relative response for solid sources shall be determined by cross-calibration against gaseous sources.

The test shall be carried out with a set of sources of different representative radionuclide and geometric characteristics, as defined in 5.2.5.

5.3.2.2 Test method

The background shall be measured in the geometry that will be used for the measurement with solid sources; for example, with the measuring cell empty, and the value shall be noted.

Solid sources, of an activity sufficient to give a reading approximately at the mid-point of the scale or decade above the lowest scale or decade, shall be placed at defined locations relative to the detector, with the gaseous source test conditions unchanged, but the gaseous source absent. The relative response to the solid source shall be noted. For subsequent tests, the instrument response to the gaseous source shall be computed, using the relative response established for the solid sources.

If such a relative response for solid sources is used in routine or acceptance tests, the possible variation in background radiation should be taken into account.

5.3.3 Linearity

5.3.3.1 Requirements

Under standard test conditions, with the calibration controls adjusted according to the manufacturer's instructions, the response linearity of the detector assembly shall not exceed 20 %, between 2,5 times the lowest value of the effective range of measurement and 75 % of this range, and shall not exceed ±30 % over the whole effective range of measurement. The uncertainty of the radioactive source is not included.

Tests can be performed in two ways:

- with gaseous or solid radioactive sources;
- with injection of an electronic signal (restricted to ranges of measurement where the use of sources is impossible).

Where sources are used, the test shall be carried out with a set of sources of the same radionuclide and geometric characteristics, such as defined in 5.2.5, except for area monitors where different kinds of sources have to be used in practice as they are available for high dose rate. In this latter case, the sources and the geometry used shall be defined.

The reference curve shall be determined from the reference response when the test is performed with gaseous sources or from the sensitivity obtained during the test of 5.3.2 when solid sources are used.

5.3.3.2 Test method

For assemblies provided with linear scales, the type test shall be carried out on all ranges and on at least 3 points on each range, i.e. at about 25 %, 50 % and 75 % of the scale range.

For assemblies provided with single range and logarithm graduation, or for digital displays, the type test shall be carried out on all order of magnitude scales of dose rate and on at least 2 points on each order of magnitude scale. (The higher value in each decade shall be at least three times the lower and at least 70 % of the maximum of that order of magnitude.)

At least three of these tests shall be carried out using a radioactive source, including the upper and the lowest values.

Where electronic test signals are used, they shall be used on all ranges or decades (in addition to radioactive sources), and the manufacturer shall provide an analysis demonstrating the performance of the system from the point of the highest source test to the maximum range.

Where this test is carried out with gaseous radioactive sources, it shall be performed in accordance with the design of the monitor:

- For off-line equipment using a measuring cell: by circulating a reference source through the assembly at nominal flow rate for a sufficient time to reach the equilibrium of the reading, or by filling up the measuring cell with a volume equal to the nominal volume of a reference source.
- For off-line equipment using a concentration device: by concentrating the reference source in the normal operation condition (time of concentration, volume, etc.).
- For in-line, on-line or off-line equipment without measuring cell: by locating the detector relative to a sufficiently large volume of reference source to be equivalent to the actual operating conditions of the monitor.

In order to minimize the effects of possible contamination of the sampling assembly, all tests with gaseous sources shall proceed from low to high values of volumetric activity.

5.3.4 Response to other artificial radionuclides

5.3.4.1 Requirements

The response for radionuclides of interest shall be agreed upon between manufacturer and purchaser. The response of the assembly to radionuclides other than that of the reference shall not differ by more than 20 % from the value specified by the manufacturer.

5.3.4.2 Test method

The test method described in 5.3.1 using appropriate radionuclides shall be performed.

5.3.5 Response to background radiation

5.3.5.1 General

Because there is generally a relationship between the response to ambient gamma radiation and the decision threshold, and the requirement for both depends on the particular plant application, the response of the assembly to gamma radiation, as well as the decision threshold, shall be agreed upon between the manufacturer and the purchaser, in accordance with the expected ambient activity.

Similar test methods as agreed upon between the manufacturer and purchaser shall be used for other activities, for example neutrons and/or high energy betas, may affect the reading.

This requirement does not apply to area monitors.

5.3.5.2 Requirements

The manufacturer shall state the decision threshold and the maximum value of the reading when the detector, fitted with its ambient gamma radiation protection devices where necessary, is exposed in a reference orientation specified by the manufacturer to a step change in gamma air kerma rate from the reference background air kerma rate to 10 µGy/h from Cs-137 and Co-60.

5.3.5.3 Test method

The equipment shall be operated under standard test conditions with no radioactive source present and the background indication shall be determined.

Next, using a Cs-137 source, position the source relative to the measurement assembly (i.e. the detector with its fitted ambient gamma radiation protection devices) so that the source to measurement assembly distance is at least 2 m and the conventionally true gamma air kerma rate at the measurement assembly position, with the measurement assembly absent, is equal to 10 µGy/h ± 10 %. The reference orientation of the measurement assembly in relation to the source shall be as specified by the manufacturer.

Record the reading at 1 min intervals after the start of the exposure and continue taking readings until the reading of the assembly is stable. At least 10 readings shall be taken after the stability is achieved. Calculate the decision threshold based on the final readings.

The measurement assembly shall also be exposed in a number of source-to-detector orientations, as agreed upon between the manufacturer and the purchaser. Where the measurement assembly may be programmed with a gamma compensation factor, this shall not be changed during these tests.

The reading of the measurement assembly in each orientation shall not exceed twice the value specified by the manufacturer for the reference orientation.

Repeat the same test with a Co-60 source.

5.3.6 Precision (or repeatability)

5.3.6.1 Requirements

The coefficient of variation of the indication due to statistical fluctuations shall be less than 10 % for any reading exceeding 10 times the lowest value of the effective range of measurement.

5.3.6.2 Test method

Use suitable radioactive sources to give an indication between 10 and 50 times the lowest value of the effective range of measurement.

Take at least 10 readings at appropriate time intervals. In order to obtain independent values, calculate the mean value and the coefficient of variation of all the readings taken. The coefficient of variation shall lie within the limits required.

5.3.7 Stability of the indication

5.3.7.1 Requirements

The indication from a given source of activity, after the assembly has been in operation for 30 min, shall vary over the following 100 h by not more than:

- 2 % of scale maximum angular deflection for instruments with an analogue display;
- 2 % of the first order of magnitude of the effective range of measurement for instruments with a digital display.

5.3.7.2 Test method

Use irradiation equipment (e.g. radioactive source or electron beam) to give an indication between 10 to 20 times the lowest value of the range of measurement.

Take sufficient readings after 30 min, then further readings after 10 h and 100 h with no adjustment made to the assembly and no change of conditions. The means of the readings taken each time shall lie within the limits indicated.

Readings shall be corrected for decay of the source if necessary.

5.3.8 Response time

5.3.8.1 Requirements

The manufacturer shall specify the response time of the assembly for an activity or dose rate between 10 to 50 times the lowest value of the range of measurement and give all useful data to determine its relationship with the precision and the false alarm rate. The influence quantities, their range of values and the variation they cause to the response time shall be specified.

The test shall be carried out with sources of the same representative radionuclide and geometric characteristics. These sources may be gaseous or solid sources.

5.3.8.2 Test method

A recorder, able to record much faster than the response time being measured, shall be connected to the assembly to determine the change in indication as a function of time.

Where this test is carried out with gaseous sources, it shall be performed in accordance with the design of the monitor:

- For off-line equipment:
  - by circulating a non-radioactive gas through the assembly at nominal flow rate for a sufficient time to reach the equilibrium of the reading of the background, or by filling up the measuring cell with a volume equal to the nominal volume of a non-radioactive gas;
  - then by continuously injecting into the inlet of the monitor, at the nominal sampling flow rate, a solution of known volumetric activity of appropriate radionuclide for the time needed to reach the equilibrium.
- For in-line, on-line or off-line equipment, and especially for area monitors, when the use of a gaseous source is not possible:
  - by locating the detector relative to an empty volume, equivalent to the actual operating conditions of the monitor, for a time sufficient to reach the equilibrium of the reading of the background;
  - then by rapidly introducing a sufficiently solid source into the empty volume, for the time needed to reach the equilibrium.

NOTE In the context of this test, "rapidly" is defined as a much shorter time than the response time being tested.

The response time is the interval of time separating the initial moment where the radioactive solution or solid source is injected and the moment at which the reading reaches 90 % of the variation for the first time. For off-line equipment using a concentration device, where the measurement is an integration of the volumetric activity, the response time is a percentage of the equilibrium value of the first derivative of the output signal as a function of time.

5.3.9 Overload characteristics

5.3.9.1 Requirements

The equipment shall maintain full-scale indication or an unambiguous indication when "exposed" to an appropriate activity or dose rate twice greater than that necessary to give the maximum scale reading and shall perform normally when this overload "exposure" is removed.

Unless otherwise agreed upon between manufacturer and purchaser, an overload indication shall be provided to point out that the activity or dose rate is too high for the measuring unit.

5.3.9.2 Test method

Subject the detector assembly to an appropriate form of activity to give a reading between 10 and 50 times the lowest value of the range; note the reading.

Subject the detector assembly to an appropriate form of activity about twice greater than that necessary to produce the maximum scale reading. Check the overload indication. Maintain the exposure for at least 10 min and verify that the assembly maintains a maximum reading.

Remove the overload source and "expose" the detector assembly under identical conditions to those used for the first reading. After a period to be agreed upon between manufacturer and purchaser, but generally of less than 10 min, the reading shall not differ by more than 10 % from the value previously noted.

For some applications this kind of test is impossible. In such cases, a demonstration by analysis shall be provided by the manufacturer.

5.4 Electrical characteristics

5.4.1 Alarm trip range

5.4.1.1 Requirements

The ranges of alarm settings shall conform to the requirements of 4.14.3. These requirements exclude the detectors.

5.4.1.2 Test method

Using an appropriate electronic signal generator, as specified by the manufacturer, the range of indication of the equipment over which the alarm trip operates shall be determined.

These tests shall be performed for the effective range of measurement.

For alarms intended to operate on increasing signals, the alarm shall be adjusted to its lowest setting and the input signal slowly increased until the alarm operates. The indication of the equipment shall be noted.

For alarms intended to operate on decreasing signals, operate as above, but slowly decrease the level of input signal.

5.4.2 Alarm trip stability

5.4.2.1 Requirements

The operating point of any alarm circuit shall not deviate outside the range 95 % X to 105 % X in the period of 100 h of operation, where X is the nominal alarm set level.

These requirements exclude the detector.

5.4.2.2 Test method

For any alarm circuit whose nominal trip setting has been determined as X.

- For a condition equivalent to 94 % X applied electronically or by software to the assembly, no trip shall occur within 100 h.
- When a condition equivalent to 106 % X is applied to the assembly, after 30 min and 100 h of operation, the alarm shall operate in less than 1 min.

5.4.3 Fault alarm

5.4.3.1 Requirements

When failure appears in one of these parts of the equipment:

- detector;
- electronic circuit;
- sampling assembly where appropriate;

an alarm shall operate and permit the identification of the failure. For the electronic circuit and the sampling assembly, a specific fault alarm shall operate within 1 min after failure. The manufacturer shall indicate the time required to obtain a detector fault alarm after failure, taking into account the background of the detector.

The equipment shall provide facilities to simulate failures.

5.4.3.2 Test method

For each part: detector, electronic circuit and sampling assembly (where appropriate), a failure shall be simulated. The specific fault alarm shall operate before the time required. No other unrelated alarm shall operate.

5.4.4 Status indication and fault alarm tests

The indication and alarm facilities described in 4.14.3 and 4.14.4 shall be functionally tested.

5.4.5 Warm-up

5.4.5.1 Requirements

When exposed to irradiation equipment (e.g. radioactive source or electron beam), the assembly in steady state operation shall give an indication that does not differ by more than ±10 % from the value obtained under standard conditions 30 min after being switched on.

5.4.5.2 Test method

Prior to this test, the equipment shall be disconnected from the power supply for at least 1 h.

Use irradiation equipment (e.g. radioactive source or electron beam) to give approximately 10 to 50 times the lowest value of the effective range of measurement. Switch on the detection and control assemblies.

Switch on the equipment. Note values of indication of activity or dose rate every 5 min during 1 h. Ten hours after switching on, take sufficient readings and use the mean value as the "final value" of indication.

Draw a graph of activity or dose rate indication versus time, correcting for decay in activity as necessary.

The difference between the "final value" and the value read from the curve for 30 min shall lie within the limits specified.

5.4.6 Influence of supply variations

5.4.6.1 Influence of slow supply voltage variations

When several different voltage levels are required by the monitor, each supply voltage is taken as a separate influencing factor.

Firstly, verify the functional characteristics of the equipment at the upper and lower limits of its rated power supply voltage. Then, slowly drop the voltage from the latter value down to zero.

The variation of the voltage duration shall be at least 1 min.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.4.6.2 Influence of sudden supply voltage variation

Unless otherwise agreed upon between the purchaser and the manufacturer, the voltage loss duration is one period of the power source frequency. During this outage, the voltage applied shall not exceed 1 % of the lower limit of the rated supply voltage range.

Input signals shall not be disturbed. Measures shall be taken to ensure that output signals remain stable. The supply voltage is then cut-off for the specified period. Output signals shall then be observed, from just before the voltage cut-off, throughout the voltage outage and until after the voltage is re-established.

If the settings or equipment operating mode affects the output signals observed, the configuration producing the greatest variation shall be adopted.

For analogue signal outputs, the test is carried out on a stabilized output at the lower, mean and upper levels of the voltage range.

For logical (digital) outputs, the test is carried out for both states.

Upon completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.4.6.3 Influence of supply frequency variations

Functional characteristics shall be verified at ±10 % of the nominal frequency.

5.4.7 Short circuit withstand tests

The effects of external short circuits on electronic equipment functions shall be verified, particularly for circuits fed by internal power supplies.

Short-circuits shall be produced at the external interfaces of the various constituent parts, such as plug-in units inputs and outputs, and power supply units.

The functional consequences of these short-circuits shall then be observed, involving, for example:

- the emission of an erroneous output signal, especially by an equipment sharing a power supply with the faulty equipment,
- the appearance of erroneous input data,
- de-energizing of all or part of the equipment.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5 Environmental characteristics

5.5.1 Stability of performance after storage

5.5.1.1 Dry heat storage

This test shall comply with IEC 60068-2-2 (test Bb), completed by the following:

- the assemblies shall not encounter heat radiating from the walls of the test chamber,
- the assemblies are not energised,
- TA = + 70 °C, t = 96 h, < 1 °C/min heat gradient (unless otherwise specified by the manufacturer on the maximum heat gradient accepted by the equipment).

On completion of this test, the assemblies are placed in normal atmospheric conditions for 2 h so that they reach thermal equilibrium. The performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.1.2 Cold storage

This test shall comply with IEC 60068-2-1 (test Ab), completed by the following procedures:

- the assemblies shall not encounter heat radiating from the walls of the test chamber,
- the assemblies are not energised,
- TB = – 40 °C, t = 96 h, < 1 °C/min heat gradient (unless otherwise specified by the manufacturer on the maximum heat gradient accepted by the equipment).

On completion of this test, the assemblies are placed in normal atmospheric conditions for 2 h so that they reach thermal equilibrium. The performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.1.3 Variable temperature storage

This test shall comply with IEC 60068-2-14 (test Nb), completed by the following procedures:

- the assemblies shall not encounter heat radiating from the walls of the test chamber,
- the assemblies are not energised,
- number of cycles: 5, duration of each test condition: 30 min,
- TB = – 25 °C, TA = +70 °C, < 1 °C/min heat gradient (unless otherwise specified by the manufacturer on the maximum heat gradient accepted by the equipment).

On completion of this test, the assemblies are placed in normal atmospheric conditions for 2 h so that they can reach thermal equilibrium. The performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.2 Mechanical characteristics

5.5.2.1 Degrees of protection (IP and IK codes)

The tests shall comply with IEC 60529 and IEC 62262. The equipment is not energised.

Unless otherwise agreed upon between the purchaser and the manufacturer, the protection indices of the various items of equipment should be:

- IP 65 (measurement and processing device) or IP 44 (sampling devices) and IK 07 (all devices) for assemblies installed locally,
- IP 30 and IK 07 for the assemblies installed in clean and dry rooms (electrical rooms),
- IP 65 and IK 07 for the assemblies installed outside the buildings.

5.5.2.2 Mechanical vibrations test

This test is used to check the mechanical strength of the assemblies. It does not apply to equipment whose stiffness is provided by another system (e.g.: cables, etc.).

The test shall be carried out in three tri-rectangular reference axes. It includes three successive phases for each of the three specified axes:

Phase 1: search for critical frequencies (resonance frequencies or frequencies for which defective operation of the monitor has been observed).

The frequency range is entirely swept in accordance with the procedures detailed below, except for the scanning rate which may be reduced to allow accurate determination of the critical frequencies. Eventually, this will reveal:

- an electrical discontinuity between normally closed dry contacts,
- inadvertent closing of the normally open dry contacts,
- defective operation of the monitor,
- any other resonance phenomenon.

Phase 2: Endurance by frequency sweeping. The frequency varies in accordance with the methods specified below.

Phase 3: Identical to phase 1.

These test phases are defined in IEC 60068-2-6 (test Fc). They are supplemented by the following procedures:

- The assemblies are energised during phases 1 and 3 of the test and are not energised during phase 2.
- The vibration table is fixed by a rigid part which will not distort the test results, and which receives the assembly with its usual fixing system. For the plugged-in parts, solidarity is only provided by the means to be used in normal service.
- The module is subjected to sinusoidal rectilinear vibrations which are applied to it in three tri-rectangular directions. Sweeping (through to the specified frequency band once in each direction) is continuous and its speed is logarithmic with respect to time. The frequency variation takes place at a rate of approximately one octave per minute.
- The export frequency range is from 10 Hz to 500 Hz.
- The vibrations are defined according to the following characteristics:
  - displacement: 0,15 mm peak to peak,
  - constant displacement below the transfer frequency,
  - transfer frequency: 58 Hz,
  - constant acceleration of 10 m/s^2 above the transfer frequency.

The number of cycles is equal to:

- phase 1: 1 cycle/axis,
- phase 2: 10 cycles/axis,
- phase 3: 1 cycle/axis.

A variation of the critical frequencies between phases 1 and 3 of more than 5 % leads to an inspection.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.3 Stability of performance with variation of temperature and humidity

5.5.3.1 General

Wherever the equipment or part of the equipment are submitted to variations of temperature or humidity of the medium to be measured, or of the ambient atmosphere, the influence of such variations shall be tested.

As the ranges of variation of such influence quantities may be different for testing the measurement assembly and testing the detector, these tests shall be performed in two steps if necessary:

- Test of the influence of the temperature or humidity on the measurement assembly.
- Test of the influence of the temperature or humidity on the detector being in contact with the medium to be measured, if applicable.

5.5.3.2 Requirements

The change in indication shall be less than 10 % over the entire ranges of variation of temperature and humidity.

Unless otherwise agreed upon between the manufacturer and the purchaser, the following ranges of variation of temperature and humidity shall apply.

5.5.3.3 Test method

The measurement assembly (or part of it), if necessary without its shielding, shall be exposed to suitable solid sources as defined in 5.2.5, such that the nominal reading under standard test conditions is known.

The test shall be performed following the method described in the following IEC standards:

– IEC 60068-2-78 for damp heat, steady state test, supplemented by the following procedures:
  - the assemblies are fitted in their reference position,
  - they shall not be subjected to heat radiated by the walls of the test chamber,
  - assemblies are energised,
  - duration of the test condition: 96 h
  - T = + 40 °C, 93 % relative humidity.

– IEC 60068-2-30 (test Db variant 2) for damp heat cyclic test, supplemented by the following procedures:
  - the assemblies are fitted in their reference position,
  - they shall not be subjected to heat radiated by the walls of the test chamber,
  - the assemblies are energised,
  - number of cycles: 6,
  - TA = + 25 °C, TB = + 55 °C.

Switch on the instrument, select the appropriate range and place in an environmental chamber at the reference conditions. The other characteristics of the air in the chamber shall be lower than the value that could cause damage to the equipment. This value shall be indicated by the manufacturer.

The detection assembly shall be exposed to suitable test sources in such a way that the nominal reading under standard test conditions is known.

The instrument shall be left in this condition for 30 min or until equilibrium is assured. If a set-zero control is available to the operator, this shall then be adjusted to bring the indication to a point stated by the manufacturer.

For instruments with a non-linear scale, such a control is used to bring the indication to some reference point rather than to zero. If this is the case, the control shall be set to bring the indication to the appropriate reference point.

The indication of the instrument shall be measured during the tests. On completion, the instruments are placed in normal atmospheric conditions for 2 h so that they reach thermal equilibrium. The performance of the monitors shall comply with the performance stipulated by the manufacturer.

NOTE Certain detectors are particularly sensitive to temperature variations (for instance NaI scintillator). During this test it is advisable to provide means that will allow the permissible maximum heat gradient given by the manufacturer to be checked in addition to the non-deterioration of their characteristics.

5.5.4 Electromagnetic compatibility

5.5.4.1 Oscillatory wave immunity

The test procedures previously defined in IEC 61000-4-12, and now defined in IEC 61000-4-18:

- oscillation frequency: 1 MHz + 10 %,
- service frequency between 50 Hz and 400 Hz and non-synchronized on the network frequency.

Injection takes place in common mode using the coupling/uncoupling network. If the manufacturer's specifications stipulate that an earth connection is required for one of the circuit conductors, the test of this circuit shall be performed in differential mode while applying the specified common mode severities.

The severity of the test shall be:

- circuits inside the control room: no test,
- circuits connecting the control room and the other rooms of the electrical building or between the electrical rooms: level 1,
- circuits exiting the electrical building: level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.2 Electrical transient burst immunity test

This test shall comply with IEC 61000-4-4.

The severity of the test shall be:

- for equipment installed in the control room: level 2,
- for other equipment: level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.3 Radiated radio frequency immunity test

This test shall comply with IEC 61000-4-3.

Depending on the type of measurements to be made on the monitor, one or the other of the following modes shall apply to the disturbance:

- when the measurement results are instantaneous (less than 1 s), the frequency range is swept slowly (1,5 × 10^{-3} decades/s) by maintaining the level of the electrical field constant during sweeping,
- when a disturbance may have occurred on the equipment, a more detailed search of the disturbing frequency zone and the minimum level of the electrical field required to cause the disturbance is carried out,
- when the results of measurement are obtained slowly (taking more than 1 s), the disturbance is applied after the first sweep by maintaining the level of the electrical field constant for the following fixed frequencies: 80 MHz; 100 MHz; 150 MHz; 200 MHz; 300 MHz; 500 MHz; 1 000 MHz, to which the multiple/sub-multiple frequencies of the clock frequencies of the tested sub-system are added.

The severity of the test for all the equipment shall be level 3, unless otherwise agreed upon between the purchaser and the manufacturer.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.4 Electrical discharge immunity test

This test shall comply with IEC 61000-4-2.

The discharges shall be carried out on every sensitive part of the equipment that an operator may come into contact with, i.e. each type of discontinuity (LED, display, pushbutton, switch, terminal) on the surfaces of the equipment and the outside of cabinets or boxes front or rear doors submitted to the test.

The contact test takes place on conducting surfaces, on insulating surfaces for the test in the air, and the plate test close to each side.

The severity of the test for all the equipment shall be:

- contact discharge: class 2,
- air discharge (and at the plate): class 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.5 Conducted disturbances immunity test

This test shall comply with IEC 61000-4-6. However, as nuclear power stations are not installed in the immediate vicinity of radio transmitters, the attenuation or absence of disturbances in certain frequency bands are not taken into account.

The severity of the test for all the equipment shall be level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.6 50 Hz magnetic field immunity test

This test shall be performed in compliance with IEC 61000-4-8 or the absence of components sensitive to magnetic fields shall be demonstrated.

The severity of the test for all the equipment shall be level 3.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.7 Surge immunity test (high energy)

This test shall comply with IEC 61000-4-5.

Only the AC supply and the connections that could leave the electrical building shall be tested.

The severity of the test shall be:

- AC supply: level 3 in common mode (between phase and earth) and level 2 in differential mode (between phases),
- input or output that could be connected to an electrical building outgoing cable: level 2 in common mode.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

5.5.4.8 Non-aggression test: radio disturbances

This test shall comply with IEC 61000-6-4.

On completion of this test, the performance of the monitor shall comply with the performance stipulated by the manufacturer.

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IAEA Safety Glossary: 2018

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 1: Exigences générales

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L'IEC 60951-1 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.

Le texte de cette norme est issu des documents suivants:

Projet	Rapport de vote
45A/1440/FDIS	45A/1449/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.

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.

Ce 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.

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- reconduit,
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- 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 Condition*), 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 (fonctionnement normal)**	**Fonctionne-ment normal, IFP**	**DBA**	**DEC**	**Fonctionne-ment 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 1: Exigences générales

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 des matériels utilisés pour mesurer les rayonnements et la radioactivité des fluides (effluents gazeux ou liquides) dans les installations nucléaires pendant et après les accidents de dimensionnement (DBA) et les conditions additionnelles de dimensionnement (DEC), incluant les accidents graves (SA). Le présent document ne couvre que les matériels de surveillance en continu de la radioactivité utilisés lors d'accidents de dimensionnement (DBA), en conditions additionnelles de dimensionnement (DEC), incluant les accidents graves (SA), et en conditions post-accidentelles.

Le présent document a pour objet d'établir les exigences générales et de fournir des exemples de méthodes acceptables pour les matériels de surveillance en continu de la radioactivité utilisés dans les installations nucléaires pendant et après les accidents de dimensionnement (DBA) et les conditions additionnelles de dimensionnement (DEC), incluant les accidents graves (SA).

Elle spécifie, pour les matériels décrits ci-dessus, les caractéristiques générales, les procédures d'essai générales, les caractéristiques des rayonnements, les caractéristiques électriques, les caractéristiques de sûreté et d'environnement, ainsi que l'identification et la certification du matériel. Si ce matériel fait partie d'un système centralisé de surveillance en continu des rayonnements d'une installation nucléaire, des exigences supplémentaires peuvent être définies dans d'autres normes applicables à ce système.

La réalisation de prélèvements et les analyses en laboratoire, essentielles pour avoir un programme complet de surveillance des effluents, ne relèvent pas du domaine d'application du présent document.

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 60038:2009, *Tensions normales de l'IEC*

IEC 60068-2-1:2007, *Essais d'environnement – Partie 2-1: Essais – Essai A: Froid*

IEC 60068-2-2:2007, *Essais d'environnement – Partie 2-2: Essais – Essai B: Chaleur sèche*

IEC 60068-2-6:2007, *Essais d'environnement – Partie 2-6: Essais – Essai Fc: Vibrations (sinusoïdales)*

IEC 60068-2-14:2009, *Essais d'environnement – Partie 2-14 – Essai N: Variations de température*

IEC 60068-2-30:2005, *Essais d'environnement – Partie 2-30: Essais – Essai Db: Essai cyclique de chaleur humide (cycle de 12 h + 12 h)*

IEC 60068-2-78:2012, *Essais d'environnement – Partie 2-78: Essais – Essai Cab: Chaleur humide, essai continu*

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC/IEEE 60780-323:2016, *Installations nucléaires – Equipements électriques importants pour la sûreté – Qualification*

IEC 60880, *Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Aspects logiciels des systèmes programmés réalisant des fonctions de catégorie A*

IEC/IEEE 60980-344, *Nuclear facilities – Equipment important to safety – Seismic qualification* (disponible en anglais seulement)

IEC 60987, *Centrales nucléaires de puissance – Systèmes d'instrumentation et de contrôle-commande importants pour la sûreté – Exigences applicables au matériel*

IEC 61000-4-2:2008, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3:2020, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*

IEC 61000-4-4:2012, *Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61000-4-5:2014, *Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc*

IEC 61000-4-6:2013, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques*

IEC 61000-4-8:2009, *Compatibilité électromagnétique (CEM) – Partie 4-8: Techniques d'essai et de mesure – Essai d'immunité au champ magnétique à la fréquence du réseau*

IEC 61000-4-12:2017, *Compatibilité électromagnétique (CEM) – Partie 4-12: Techniques d'essai et de mesure – Essai d'immunité à l'onde sinusoïdale fortement amortie*

IEC 61000-4-18:2019, *Compatibilité électromagnétique (CEM) – Partie 4-18: Techniques d'essai et de mesure – Essai d'immunité à l'onde oscillatoire amortie*

IEC 61000-6-4:2018, *Compatibilité électromagnétique (CEM) – Partie 6-4: Normes génériques – Norme sur l'émission pour les environnements industriels*

IEC 61069-1:2016, *Mesure, commande et automation dans les processus industriels – Appréciation des propriétés d'un système en vue de son évaluation – Partie 1: Terminologie et principes de base*

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 61504:2017, *Installations nucléaires – Systèmes d'instrumentation et de contrôle-commande importants pour la sûreté – Systèmes centralisés pour la surveillance en continu des rayonnements et/ou des niveaux de radioactivité*

IEC 61513:2011, *Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Exigences générales pour les systèmes*

IEC 62138, *Centrales nucléaires – Systèmes d'instrumentation et de contrôle-commande importants pour la sûreté – Aspects logiciels des systèmes informatisés réalisant des fonctions de catégorie B ou C*

IEC 62262:2002, *Degrés de protection procurés par les enveloppes de matériels électriques contre les impacts mécaniques externes (Code IK)*

IEC 62566:2012, *Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Développement des circuits intégrés programmés en HDL pour les systèmes réalisant des fonctions de catégorie A*

IEC 62566-2:2020, *Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Développement des circuits intégrés programmés en HDL – Partie 2: Circuits intégrés programmés en HDL pour les systèmes réalisant des fonctions de catégorie B ou C*

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

ISO 2889:2015, *Echantillonnage des substances radioactives en suspension dans l'air dans les émissaires de rejet et les conduits des installations nucléaires*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1
erreur de mesure absolue
différence entre la valeur mesurée et la valeur conventionnelle de grandeur du mesurande

3.2
essai de réception (essai d'acceptation)
essai contractuel destiné à prouver au client que le dispositif satisfait à des spécifications données

3.3
diamètre aérodynamique équivalent
diamètre d'une sphère de densité 1 ayant la même vitesse de sédimentation que la particule étudiée

Note 1 à l'article: Le diamètre aérodynamique équivalent concerne les particules de diamètre est compris entre 0,1 µm et 2 mm.

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

3.4
coefficient de variation
rapport de l'écart-type s à la moyenne arithmétique $\bar{x}$ d'une série de n mesures x_i, donné par la formule suivante:

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

3.5
rendement de collection
pourcentage du nombre total de particules contenues au départ dans un volume d'air connu qui traversent un filtre et qui ont été retenues par celui-ci

3.6
valeur conventionnelle d'une grandeur
valeur fixée par accord attribuée à une grandeur pour un usage donné

Note 1 à l'article: L'expression "valeur conventionnelle vraie d'une grandeur" est parfois utilisée pour ce concept, même si son utilisation est déconseillée.

Note 2 à l'article: Parfois, la valeur conventionnelle d'une grandeur est une estimation de la valeur vraie de cette grandeur.

Note 3 à l'article: Il est généralement admis que la valeur conventionnelle d'une grandeur est associée à une incertitude de mesure suffisamment faible, qui peut être égale à zéro.

3.7
étendue de mesure effective
valeur absolue de la différence entre deux limites d'une plage nominale

Note 1 à l'article: Sur la plage nominale, les performances d'un matériel ou d'un ensemble satisfont aux exigences de ses spécifications.

3.8
faisceau électronique
flux d'électrons émis à partir d'une source et se déplaçant le long de trajectoires déterminées avec exactitude à de très grandes vitesses

Note 1 à l'article: Un tel faisceau dirigé vers un détecteur produit des débits de dose extrêmement élevés.

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

3.9
écart-type expérimental
pour une série de n mesurages du même mesurande, grandeur s qui caractérise la dispersion des résultats, donnée par la formule:

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

x_i étant le résultat du i^e mesurage et $\bar{x}$ la moyenne arithmétique des n résultats pris en compte

Note 1 à l'article: L'expression $s/\sqrt{n}$ est une estimation de l'écart-type de la distribution de x et est appelée écart-type expérimental de la moyenne.

Note 2 à l'article: L'écart-type expérimental de la moyenne est parfois appelé, de façon incorrecte, erreur type de la moyenne.

3.10
ensemble de mesure
ensemble destiné à mesurer une grandeur

Note 1 à l'article: Dans le présent document, la grandeur est l'activité volumique ou le débit de dose, même si cette valeur peut être exprimée dans d'autres unités.

3.11
activité minimale détectable
radioactivité dans un échantillon qui produit un taux de comptage qui sera détecté (c'est-à-dire supérieur au rayonnement de fond) avec un certain niveau de confiance

Note 1 à l'article: Le "niveau de confiance" est généralement fixé à 95 %, c'est-à-dire qu'un échantillon qui contient exactement l'activité minimale détectable sera, du fait de fluctuations aléatoires, considéré comme ne présentant pas de radioactivité dans 5 % des cas.

Note 2 à l'article: On parle parfois de seuil de détection {detection limit, lower limit of detection}.

Note 3 à l'article: Le taux de comptage pour un échantillon contenant l'activité minimale détectable est appelé niveau de détermination {determination level}.

Note 4 à l'article: Un exemple de formulation pour le calcul de l'activité minimale détectable est donné ci-après.

$$MDA = \frac{k_1^2 + 2k_1\sqrt{R_b t_s\left(1 + \frac{t_s}{t_b}\right)}}{(t_s)(E)(C)}$$

où:

k_1 est le facteur d'élargissement unilatéral égal à 1 645 pour un niveau de confiance de 95 %

R_b est le taux de comptage du bruit de fond en s^{-1}

t_s est le temps de comptage de l'échantillon en min

t_b est le temps de comptage du bruit de fond en min

E est l'efficacité du détecteur en comptages par désintégration

C est le taux de conversion du dpm en une autre unité d'activité souhaitée, le cas échéant

[SOURCE: Glossaire de sûreté de l'AIEA, édition 2018]

3.12
particule
agrégat de molécules, constituant un solide ou un liquide, dont les dimensions varient de quelques diamètres moléculaires à plusieurs millimètres

[SOURCE: ISO 2889:2015, 3.55]

3.13
flux de procédé
fluide qui circule dans un système mis en œuvre pour assurer une mission dans un but utile

Note 1 à l'article: Le système de réfrigérant primaire, le système de refroidissement des combustibles usés, le système de refroidissement d'un composant, etc. sont des exemples de flux de procédé.

Note 2 à l'article: Les flux de procédé couverts par le présent document sont ceux dont le niveau de radioactivité peut significativement augmenter en raison de conditions accidentelles ou post-accidentelles.

Note 3 à l'article: La surveillance de la radioactivité de ces flux de procédé fournit des informations sur la qualité ou l'intégrité de la barrière, ainsi que sur les rejets potentiels dans l'environnement.

3.14
réponse de référence
réponse d'un ensemble dans des conditions de référence vis-à-vis d'un débit de dose de référence, exprimée par:

$$R_{\text{ref}} = \frac{\nu - \nu_{\text{B}}}{\nu_{\text{c}}}$$

où:

ν est la valeur mesurée par le matériel ou l'ensemble en essai

ν_{B} est la valeur qui correspond au bruit de fond du matériel sans influence externe

ν_{c} est la valeur conventionnelle de grandeur de la source de référence

Note 1 à l'article: La valeur du bruit de fond peut être automatiquement prise en compte par un algorithme inclus dans les systèmes de mesure.

3.15
erreur relative
rapport de l'erreur de mesure à une valeur vraie du mesurande

Note 1 à l'article: En pratique, une valeur conventionnelle de grandeur est utilisée étant donné qu'aucune valeur vraie ne peut être déterminée. Pour la présente norme, l'erreur relative est calculée comme suit.

$$E = \frac{(\nu - \nu_{\text{B}}) - \nu_{\text{c}}}{\nu_{\text{c}}}$$

où:

ν est la valeur mesurée par le matériel ou l'ensemble en essai,

ν_{c} est la valeur conventionnelle de grandeur de la source de référence,

ν_{B} est la valeur qui correspond au bruit de fond du matériel sans influence externe.

Note 2 à l'article: La valeur du bruit de fond peut être automatiquement prise en compte par un algorithme inclus dans le système de mesure.

3.16
réponse relative
valeur calculée durant les essais de type égale au rapport entre la réponse de référence du matériel et la sensibilité du même matériel par rapport à la source solide de référence

Note 1 à l'article: La réponse relative permet de déterminer la réponse de référence de matériels identiques qui ont été soumis à des essais de type à partir de la mesure de la sensibilité de la source solide.

3.17
temps de réponse
temps mis par un composant pour atteindre un état de sortie donné à compter du moment où il reçoit un signal lui imposant de prendre cet état de sortie

Note 1 à l'article: Pour les besoins des essais décrits dans le présent document, il est admis par hypothèse que le signal d'entrée correspond à une variation d'échelon, et l'état de sortie de fin correspond au point auquel la variation du signal de sortie atteint pour la première fois 90 % de sa valeur finale.

[SOURCE: Glossaire de sûreté de l'AIEA, édition 2018]

3.18
essai individuel de série
essai de conformité effectué sur chaque entité en cours ou en fin de fabrication

3.19
efficacité de prélèvement
pour une quantité de matière radioactive donnée, rapport de la radioactivité collectée par la radioactivité fournie pour un intervalle de temps donné

3.20
sensibilité <d'un ensemble de mesure>
pour une valeur donnée de la grandeur mesurée, quotient de la variation de la variable observée par la variation correspondante de la grandeur mesurée

[SOURCE: IEC 60050-395:2014, 395-03-105]

4 Principes de conception

4.1 Généralités

Le moniteur de rayonnement classé pour les fonctions importantes pour la sûreté doit satisfaire aux exigences de l'IEC 62705 relatives aux caractéristiques et au cycle de vie, ainsi qu'aux normes citées dans l'IEC 62705 (l'IEC 61226, par exemple).

Lorsque des systèmes de surveillance des rayonnements différents sont exigés pour les accidents de dimensionnement (DBA) et les conditions additionnelles de dimensionnement (DEC), incluant les accidents graves (SA), il convient que ceux-ci soient, dans la mesure du possible, indépendants les uns des autres.

4.2 Exigences de base liées aux fonctions

Le principal objectif du matériel de surveillance en continu de la radioactivité en conditions accidentelles ou post-accidentelles est de mesurer de façon continue les niveaux de rayonnement pour les procédés et les zones appropriées. Ces mesures de rayonnements sont affichées localement et/ou dans les salles de commande et/ou les locaux de crise afin d'informer les opérateurs des conditions radiologiques en cours. Ces informations sont utilisées par les opérateurs afin d'évaluer les conditions de la centrale, d'engager les actions appropriées pour limiter les conséquences d'un accident dans la centrale et d'empêcher que des produits radioactifs ne soient rejetés par inadvertance, ainsi que par le personnel des services d'urgence et les autorités nationales afin d'engager les actions nécessaires à la protection du public et du personnel de la centrale. En conséquence, le matériel couvert par le présent document est capable de déclencher des alarmes et de fournir des entrées à d'autres systèmes et procédés de la centrale afin d'isoler les procédés présentant des niveaux de rayonnement anormaux.

Les exigences de base pour la conception, le choix, les essais, l'étalonnage et la localisation fonctionnelle du matériel de surveillance en continu de la radioactivité en conditions accidentelles ou post-accidentelles sont spécifiques à la centrale. En général, celles-ci sont classées en trois catégories: surveillance des rayonnements dans les effluents et les systèmes de ventilation, surveillance des rayonnements de procédé et surveillance des rayonnements de zone.

- Les moniteurs de rayonnement dans les effluents et les systèmes de ventilation mesurent l'activité spécifique présente dans les gaz rejetés dans l'environnement en conditions accidentelles et post-accidentelles afin de s'assurer que cette activité spécifique n'est pas dangereuse pour la sécurité du public et d'accélérer l'alerte et l'isolement des procédés à des fins de confinement ou de recirculation de l'air conditionné de la salle de commande.
- Les moniteurs de rayonnement de procédé mesurent l'activité spécifique dans un fluide (gaz, liquide ou vapeur) et sont normalement utilisés dans un procédé de centrale pour permettre au plus tôt l'alerte et l'isolement des procédés, par exemple la détection de fuites dans l'enveloppe sous pression du fluide réfrigérant dans l'enceinte et d'autres systèmes. Les moniteurs de rayonnement de procédé peuvent être classés suivant trois types de base:

  - Les moniteurs internes: le détecteur est placé directement dans le flux du procédé (tuyau, émissaire de rejet, réservoir, conduit, etc.).
  - Les moniteurs externes: le détecteur est situé à l'extérieur du flux de procédé, directement face au flux.
  - Les moniteurs avec prélèvements: un échantillon est prélevé dans le flux du procédé et dirigé vers le détecteur placé à distance.
- Les moniteurs de rayonnement de zone (de type à large gamme) sont situés stratégiquement dans les bâtiments exposés à des débits de dose élevés en conditions accidentelles et post-accidentelles, comme le bâtiment du réacteur et la cuve, et servent de systèmes de surveillance post-accidentelle. Les moniteurs de rayonnement de zone sont fixés sur les murs de la zone ou sur les parois du réservoir à surveiller. Selon le niveau de rayonnement présent à l'endroit d'installation du détecteur, la partie électronique du moniteur peut être déportée à une certaine distance du détecteur.

Pour les besoins de la collecte de données critiques, ces moniteurs sont généralement conçus pour résister à des conditions d'environnement hostiles et à des conditions sismiques, pendant et après un accident.

Il convient de prendre en considération les exigences de surveillance des rayonnements et la conception du système de surveillance des rayonnements dès les premières phases de conception de la centrale afin de mettre en place une surveillance efficace par rapport au niveau de sensibilité recherché. Ainsi, pour optimiser les performances, il convient que l'acheteur et le fabricant suivent la procédure suivante:

- Établir les caractéristiques de mesure exigées (acheteur):
  - Déterminer les scénarii de fonctionnement normal et accidentel ainsi que les termes sources correspondants (les isotopes prépondérants qui doivent être mesurés par le moniteur), y compris leurs compositions chimiques.
  - Déterminer les informations essentielles exigées par l'opérateur de la centrale ou le système de contrôle-commande pour déclencher les actions d'urgence, les fonctions assignées aux matériels pour la surveillance en continu des rayonnements et pour les classer conformément aux recommandations de l'IEC 61226.
  - Déterminer les points de mesure optimaux en prenant en compte les conditions d'installation (localisation, interfaces avec les fonctions de protection de la centrale, conditions ambiantes et exigences de qualification, branchements électriques au travers des barrières de confinement, etc.).
  - Calculer les transferts d'activité (propagation par les tuyaux ou conduits et au travers des barrières de confinement), afin de déterminer les spectres d'activité et le bruit de fond au point de mesure.
  - Déterminer le profil de temps associé au rejet postulé et l'étendue de mesure et le temps de réponse exigés de l'ensemble de la chaîne (y compris le système de prélèvement, le cas échéant, et le temps nécessaire pour envoyer ou afficher les informations à destination de l'opérateur de la centrale ou du système de contrôle-commande).
  - Déterminer les caractéristiques de base des détecteurs (type de rayonnement et de mesure, sensibilité et étendue de mesure, réponse en énergie et performance en saturation, etc.) et du système de prélèvement, le cas échéant.
  - Déterminer le taux de fausses alarmes tolérable en tenant compte des conditions de la centrale et de l'incidence des erreurs de mesure (y compris les pertes dans l'échantillonnage), et spécifier la précision et la linéarité nécessaires pour maintenir le taux au-dessous de ce seuil.
- Vérifier les caractéristiques métrologiques des instruments retenus (accord entre l'acheteur et le fabricant):
  - Calculer le temps de réponse de l'instrument (temps de mesure par rapport à une linéarité spécifiée et temps nécessaire à l'appareil pour déclencher une alarme) et le temps de réponse global de la chaîne (y compris le temps de réponse du système d'échantillonnage).

- Calculer, au point de mesure, l'efficacité de détection dans la géométrie donnée, le seuil de décision et l'activité minimale détectable, en tenant compte du blindage approprié.
- Pour chaque caractéristique de l'instrument, il convient que le fabricant spécifie les écarts liés aux grandeurs d'influence (ou paramètres variables) correspondantes. Il convient de prendre en compte au moins les grandeurs d'influence (ou paramètres variables) suivantes:
  - i) spectre d'activité et profil de temps du spectre d'activité (pendant les conditions de fonctionnement transitoire) de la source à mesurer,
  - ii) spectre d'activité et profil de temps du spectre d'activité (pendant les conditions de fonctionnement transitoire) du bruit de fond,
  - iii) géométrie de détection,
  - iv) niveau de confiance (par exemple, 95 %) (afin de calculer l'activité minimale détectable),
  - v) débit des effluents à mesurer,
  - vi) conditions thermodynamiques,
  - vii) précision et profil de temps lié à la précision (afin de calculer le temps de mesure en régime établi et en conditions de fonctionnement transitoire),
  - viii) temps de mesure et temps de réponse (en conditions de fonctionnement transitoire).
- Pour les grandeurs d'influence qui dépendent du procédé ou de la situation, il convient que l'acheteur indique leurs plages de valeurs. Sinon, il convient que le fabricant établisse les hypothèses nécessaires afin de prendre en compte les conditions probables d'utilisation de l'instrument.

NOTE Le terme "fabricant" couvre le concepteur et le vendeur du matériel. Le terme "acheteur" comprend l'utilisateur.

Si les signaux sont utilisés pour déclencher les actions de protection afin de limiter les conséquences de dysfonctionnements ou de défaillances de structures, de systèmes ou de composants, alors les matériels peuvent faire partie des systèmes liés à la sûreté ou du système de protection. Dans ce cas, ils doivent satisfaire aux exigences relatives à ces systèmes conformément à l'IEC 61226.

Les matériels doivent faire l'objet d'une qualification environnementale conformément aux exigences de l'IEC/IEEE 60780-323 (et à celles de l'IEC/IEEE 60980-344 pour les essais sismiques).

4.3 Etendue de mesure

L'acheteur doit spécifier l'étendue de mesure effective exigée. L'étendue doit être compatible avec le niveau des rayonnements en conditions accidentelles et post-accidentelles. La limite inférieure de l'étendue de mesure doit chevaucher d'au moins une décade (échelle logarithmique) l'étendue de mesure du moniteur utilisé pour les conditions de fonctionnement normal de la centrale. Il convient que l'activité maximale ou le débit de dose maximal mesurable soit supérieur d'au moins une décade à l'activité la plus importante ou au débit de dose le plus élevé prévu en conditions accidentelles et post-accidentelles.

4.4 Réponse en énergie

Le détecteur peut être choisi pour mesurer les rayonnements bêta ou gamma. L'acheteur doit confirmer que la réponse en énergie de l'ensemble de détection est adaptée à la surveillance de la potentielle activité.

4.5 Activité minimale détectable

Il convient de mesurer l'activité minimale détectable en régime établi uniquement. Celle-ci peut être calculée à l'aide d'une formule en utilisant le temps de mesure. Cependant, cela ne permet pas une évaluation rigoureuse du début de l'étendue de mesure.

L'activité minimale détectable exigée dépend de l'application particulière et varie en fonction des réglementations locales ainsi que de la conception de la centrale. Elle doit être spécifiée par le concepteur de la centrale.

Le fabricant doit spécifier l'activité minimale détectable pour les nucléides d'intérêt, en prenant en compte les tests-sources ou les dispositions prises afin de fournir une indication à l'échelle sur le moniteur, ainsi que toutes les données utiles nécessaires pour préciser le début de l'étendue de mesure effective, et ceci même en conditions de fonctionnement transitoires. Les grandeurs d'influence, ainsi que leurs plages de valeurs et les variations induites sur l'activité minimale détectable doivent être spécifiées.

4.6 Précision (ou répétabilité)

La précision (ou répétabilité) est une mesure de la dispersion des estimations autour de leur valeur moyenne. Elle doit être fournie par le fabricant dans l'étendue de mesure effective en % de la valeur du signal pour un intervalle de confiance donné (ou une probabilité d'erreur donnée). En prenant pour hypothèse que les estimations suivent une distribution gaussienne, il convient d'exprimer cette probabilité par un nombre d'écarts-types.

NOTE Par exemple, la précision peut être de 20 % de la valeur du signal dans une partie de l'étendue de mesure effective avec une probabilité de 95 % (ce qui signifie que toutes les estimations se situent à $\pm 2\sigma$, σ étant l'écart-type) et de 30 % dans une autre partie de l'étendue de mesure effective avec une autre probabilité.

La précision doit être cohérente avec les hypothèses retenues pour les analyses d'accidents, les besoins des opérateurs, et les exigences imposées par les autres systèmes qui utilisent les signaux de surveillance de rayonnements. De plus, elle doit être caractérisée pour les valeurs de signaux inférieures au début de l'étendue de mesure effective. Les grandeurs d'influence, ainsi que leurs plages de valeurs et les variations induites doivent être spécifiées par le fabricant.

En général, il convient que la précision soit de l'ordre de 20 % sur la totalité de l'étendue de mesure effective, toutes grandeurs d'influence prises en compte.

4.7 Linéarité

La linéarité est une mesure de l'écart entre la valeur conventionnelle d'une grandeur et la moyenne des estimations. Elle doit être fournie par le fabricant dans l'étendue de mesure effective en % de la valeur du signal pour un intervalle de confiance donné (ou une probabilité d'erreur donnée). En prenant pour hypothèse que les estimations suivent une distribution gaussienne, il convient d'exprimer cette probabilité par un nombre d'écarts-types.

NOTE Par exemple, la linéarité peut être de 20 % de la valeur du signal dans une partie de l'étendue de mesure effective avec une probabilité de 95 % (ce qui signifie que toutes les estimations se situent à $\pm 2\sigma$, σ étant l'écart-type) et de 30 % dans une autre partie de l'étendue de mesure effective avec une autre probabilité.

La linéarité doit être cohérente avec les hypothèses retenues pour les analyses d'accidents, les besoins des opérateurs, et les exigences imposées par les autres systèmes qui utilisent les signaux de surveillance de rayonnements. De plus, elle doit être caractérisée pour les valeurs de signaux inférieures au début de l'étendue de mesure effective. Les grandeurs d'influence, ainsi que leurs plages de valeurs et les variations induites sur la linéarité doivent être spécifiées par le fabricant.

En général, il convient que la linéarité soit de l'ordre de 30 % sur la totalité de l'étendue de mesure effective, toutes grandeurs d'influence prises en compte.

4.8 Temps de mesure

Le temps de mesure est le temps moyen durant lequel le mesurage doit être réalisé pour obtenir une estimation du signal dans des conditions données. Il convient de le mesurer uniquement en régime établi. Celui-ci peut être calculé à l'aide d'une formule. Cependant, cela ne prend pas en compte les algorithmes de traitement mis en œuvre dans le moniteur.

Le fabricant doit spécifier le temps de mesure ainsi que toutes les données utiles (écart-type ou précision) nécessaires pour connaître la précision des estimations et le taux de fausses alarmes. Les grandeurs d'influence, ainsi que leurs plages de valeurs et les variations induites sur le temps de mesure doivent être spécifiées.

4.9 Temps de réponse

Le temps de réponse est le temps nécessaire au moniteur, après une variation brutale du signal mesuré (par exemple, un échelon) pour que son signal de sortie ou son indication atteigne pour la première fois 90 % (dans le cas d'une augmentation) ou 10 % (dans le cas d'une diminution) de la variation.

Pour des systèmes intégrateurs, il s'agit d'un pourcentage de la valeur d'équilibre de la dérivée première du signal de sortie en fonction du temps qu'il convient de prendre en compte.

Le temps de réponse ne doit être pris en compte qu'en conditions de fonctionnement transitoire. Les algorithmes de traitement du moniteur doivent être pris en compte.

Par conséquent, son calcul au moyen d'une formule n'est pas pertinent, et le fabricant doit le spécifier en réalisant des essais ou des simulations numériques et doit fournir l'ensemble des données utiles pour déterminer sa relation avec la précision des estimations et le taux de fausses alarmes. Les grandeurs d'influence, ainsi que leurs plages de valeurs et les variations induites sur le temps de réponse doivent être spécifiées.

4.10 Performance en saturation

La mesure indiquée ne doit pas diminuer ou tomber à zéro pendant et après une exposition qui entraîne un dépassement de la valeur maximale de l'étendue de mesure. Le matériel doit maintenir l'indication de la valeur maximale de l'étendue de mesure ou une indication non ambiguë. Lorsque l'exposition repasse au-dessous de la valeur maximale de l'étendue de mesure, le système doit récupérer dans l'intervalle de temps spécifié par l'acheteur.

4.11 Protection contre le bruit de fond ou mécanismes de compensation

Une protection ou une compensation électronique doit être mise en œuvre autant que nécessaire pour réduire les effets des rayonnements de bruit de fond sur la mesure des rayonnements de procédé.

Un accord peut être établi entre le fabricant et l'acheteur sur le fait que les rayonnements de bruit de fond significatifs proviennent uniquement de directions ou de sources définies (cuves, tuyaux, etc.). Ceci peut être pris en compte dans la réalisation de la protection. En l'absence d'accord, la protection doit assurer pour la partie sensible du détecteur une atténuation des rayonnements dans toutes les directions virtuellement identiques, compte tenu de la structure matérielle de l'ensemble de détection et de la réponse angulaire du détecteur.

Si le matériel ne peut être facilement retiré de la protection, il convient que cette protection soit aisément démontable. Il convient que le fabricant et l'acheteur fixent par accord la masse maximale des éléments ou les moyens de manutention appropriés.

Lorsque des techniques électroniques qui intègrent des détecteurs supplémentaires sont utilisées pour réduire les effets des rayonnements de bruit de fond, ces détecteurs doivent être choisis et placés de manière à assurer la meilleure compensation possible, compte tenu des plages d'énergies et de la direction des rayonnements.

4.12 Exigences liées aux conditions accidentelles

La conception du matériel doit assurer la prise en charge des fonctions système nécessaires et l'absence de défaillances dues aux conditions d'environnement rencontrées en conditions de fonctionnement normal et en conditions accidentelles ou post-accidentelles.

L'intervalle de temps entre les conditions accidentelles et post-accidentelles, pendant lequel le fonctionnement du système est exigé, doit être spécifié par l'acheteur.

Les conditions d'environnement locales dans lesquelles les différents composants du système peuvent fonctionner, en conditions de fonctionnement normal, accidentelles et post-accidentelles, doivent être spécifiées par l'acheteur. La spécification des conditions d'environnement doit comprendre, lorsque cela est pertinent, la température et la pression ainsi que leur taux de variation, les vibrations, l'humidité, les fluides agressifs ou corrosifs, les vapeurs ou les poussières, les conditions sismiques, l'environnement électromagnétique et toutes autres conditions physiques hostiles, comme les débits de dose de rayonnement en conditions de fonctionnement normal et en conditions accidentelles, ainsi que les doses de rayonnement intégrées à l'endroit d'installation du matériel de surveillance.

Le fabricant doit fournir un matériel conçu pour fonctionner en tous points du domaine d'environnement décrit ci-dessus, sauf accord contraire entre l'acheteur et le fabricant. Si nécessaire, le matériel doit être qualifié pour les conditions d'environnement relatives à l'application conformément aux normes applicables.

Plus particulièrement, le matériel doit être conçu de manière à réduire le plus possible les effets induits par les conditions d'environnement spécifiées, et l'emplacement des détecteurs doit être choisi en fonction du bruit de fond en conditions accidentelles et post-accidentelles ainsi que des besoins en matière de blindage pour réduire le plus possible les effets du bruit de fond. Dans la mesure du possible, les endroits d'installation doivent être choisis de manière à faciliter les opérations de maintenance et d'étalonnage. Lors du choix de l'endroit d'installation, il convient également de prendre en compte la nécessité éventuelle d'installer des équipements électroniques dans des zones de débit de dose plus faible.

L'éventualité que des matériaux de construction du moniteur puissent rejeter des substances toxiques ou corrosives dans des conditions d'environnement hostiles, par exemple durant un incendie, en présence de températures élevées ou de rayonnements importants, doit également être prise en compte. La conception doit réduire autant que possible cette éventualité en choisissant des matériaux adaptés et en les isolant de façon appropriée.

4.13 Fiabilité

La fiabilité exigée pour les fonctions doit être spécifiée de façon quantitative (temps moyen entre défaillances) ou qualitative (conformité au critère de défaillance unique).

Les exigences suivantes doivent être remplies pour tous les composants de l'équipement (y compris l'ensemble de prélèvement le cas échéant), qui font l'objet d'une maintenance planifiée adaptée:

- Temps moyen entre défaillances: > 20 000 h (avec une maintenance préventive).
- Une analyse des modes de défaillance et de leurs effets (AMDE) doit être réalisée en plus du calcul du temps moyen entre défaillances dans le cas d'un matériel classé comme réalisant une fonction importante pour la sûreté de catégorie A conformément à l'IEC 61226.
- Le fabricant doit spécifier la fréquence des opérations de maintenance courante et décrire chaque procédure de maintenance de manière exhaustive (voir 4.15.2). Il convient de limiter ces exigences de maintenance au minimum pratique.

4.14 Interface utilisateur

4.14.1 Généralités

Le système doit afficher et/ou enregistrer l'activité ou le débit de dose en continu. En outre, il doit émettre un signal d'alarme lorsque le niveau d'activité ou du débit de dose dépasse une valeur prédéterminée.

4.14.2 Affichage des valeurs mesurées

Le choix entre les échelles logarithmiques, les échelles linéaires ou les affichages numériques doit être adapté aux objectifs du matériel. Les échelles logarithmiques ou les affichages numériques sont généralement privilégiés.

Pour les ensembles fournis avec des échelles linéaires, il doit être possible de changer de plage pour que les facteurs d'échelle ne dépassent pas 10. Une indication de l'échelle utilisée doit être fournie.

Lorsque les conditions accidentelles produisent d'importantes variations au niveau des valeurs affichées, le basculement manuel entre les plages ne doit pas être utilisé, sauf accord contraire spécifique de l'acheteur.

4.14.3 Alarmes

4.14.3.1 Généralités

Les dispositifs d'alarme et d'affichage doivent être adaptés aux objectifs du matériel.

Les circuits d'alarme doivent être capables de maintenir une condition d'alarme tant que celle-ci n'a pas été réinitialisée par une commande ou de réinitialiser automatiquement le système lorsque l'état à l'origine de l'alarme disparaît. Il convient que la sélection du mode d'alarme soit aisée, mais contrôlable. Le changement de mode peut être effectué au moyen d'une clef, d'un mot de passe ou en effectuant une légère reconfiguration matérielle.

Toutes les fonctions d'alarme doivent être fournies avec des dispositifs d'essai qui permettent de vérifier le fonctionnement des alarmes. En cas d'alarmes réglables, la vérification doit être possible pour l'ensemble de la plage de réglages avec un indicateur du point réel d'activation de l'alarme.

Les fonctions d'alarme doivent faire l'objet d'un accord entre le fabricant et l'acheteur. Au minimum et lorsque cela est pertinent, les alarmes suivantes doivent être fournies.

4.14.3.2 Alarme de haute activité

Au moins une alarme à point de consigne réglable doit être disponible, le réglage allant:

- au moins de 10 % à 90 % de la plage de lecture (échelle linéaire), de 50 % de la plus petite décade à 90 % de la plus grande décade (échelle logarithmique),
- ou de 10 % de la deuxième plus petite décade à 90 % de la plus grande décade (affichage numérique).

4.14.3.3 Alarmes de défaut

Il convient de fournir autant d'alarmes distinctes que possible pour les défauts mécaniques ou électroniques. Il convient de disposer au moins des alarmes suivantes lorsque celles-ci sont pertinentes:

- Perte de signal du détecteur.
- Pertes dans le circuit de prélèvement.