BS IEC 60768:2009

BSI British Standards

Nuclear power plants — Instrumentation important to safety — Equipment for continuous in-line or on-line monitoring of radioactivity in process streams for normal and incident conditions

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British Standards

National foreword

This British Standard is the UK implementation of IEC 60768:2009.

The UK participation in its preparation was entrusted to Technical Committee NCE/8, Reactor instrumentation.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Centrales nucléaires de puissance – Instrumentation importante pour la sûreté – Matériels pour la surveillance des rayonnements en continu, interne et externe, au niveau des fluides de procédés pour les conditions de fonctionnement normal et incidentel

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CONTENTS

FOREWORD....4
INTRODUCTION....6
1 Scope....8
2 Normative references....8
3 Terms and definitions....10
4 Design principles....10
4.1 Basic requirements related to functions....10
4.2 Measurement range....11
4.3 Energy response....11
4.4 Minimum detectable activity (or detection limit)....12
4.5 Precision (or repeatability)....12
4.6 Accuracy (or relative error)....12
4.7 Measurement time....13
4.8 Response time....13
4.9 Overload performance....13
4.10 Ambient background shielding or compensation devices....13
4.11 Requirements related to incident conditions....14
4.12 Reliability....14
4.13 User interface....14
4.13.1 General....14
4.13.2 Display of measured value....15
4.13.3 Alarms....15
4.13.4 Status indication....15
4.13.5 Local indications....16
4.14 System testing, maintenance facilities and ease of decontamination....16
4.14.1 System testing....16
4.14.2 Maintenance facilities....16
4.14.3 Ease of decontamination....17
4.15 Electromagnetic interference....17
4.16 Power supplies....17
4.17 Interfaces....17
4.18 In-line detectors mechanical features....18
4.18.1 General requirements....18
4.18.2 Pressure-containing parts....18
4.18.3 Materials....18
4.18.4 Verification of material processing....19
4.19 Quality....19
4.20 Type test report and certificate....19
5 Functional testing....20
5.1 General....20
5.2 General test procedures....21
5.2.1 General....21
5.2.2 Tests performed under standard test conditions....21
5.2.3 Tests performed with variation of influence quantities....21
5.2.4 Calculations and/or numerical simulations....21
5.2.5 Reference sources....22

5.2.6 Statistical fluctuations ... 22
5.3 Performance characteristics ... 23
5.3.1 Reference response ... 23
5.3.2 Accuracy (relative error) ... 23
5.3.3 Response to other artificial radionuclides ... 24
5.3.4 Response to background radiation ... 24
5.3.5 Precision (or repeatability) ... 25
5.3.6 Stability of the indication ... 25
5.3.7 Response time ... 25
5.3.8 Overload test ... 26
5.4 Electrical performance tests ... 26
5.4.1 Alarm trip range ... 26
5.4.2 Alarm trip stability ... 27
5.4.3 Fault alarm ... 27
5.4.4 Status indication and fault alarm tests ... 27
5.4.5 Warm-up time – Detection and measuring assembly ... 27
5.4.6 Influence of supply variations ... 28
5.4.7 Short circuit withstand tests ... 29
5.5 Environmental performance test ... 29
5.5.1 Stability of performance after storage ... 29
5.5.2 Mechanical tests ... 30
5.5.3 Stability of performance with variation of ambient and stream conditions ... 31
5.5.4 Electromagnetic compatibility ... 33
Bibliography ... 39

Table 1 – Reference conditions and standard test conditions ... 36
Table 2 – Tests performed under standard test conditions ... 37
Table 3 – Tests performed with variation of influence quantities ... 38

INTERNATIONAL ELECTROTECHNICAL COMMISSION

NUCLEAR POWER PLANTS – INSTRUMENTATION IMPORTANT TO SAFETY – EQUIPMENT FOR CONTINUOUS IN-LINE OR ON-LINE MONITORING OF RADIOACTIVITY IN PROCESS STREAMS FOR NORMAL AND INCIDENT CONDITIONS

FOREWORD

International Standard IEC 60768 has been prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition published in 1983. This edition constitutes a technical revision.

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

- to clarify the definitions.
- to up-date the reference to new standards published since the first issue.
- to update the units of radiation.

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

FDIS	Report on voting
45A/729/FDIS	45A/741/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This International Standard is to be read in conjunction with IEC 60951:2009.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

a) Technical background, main issues and organisation of this Standard

This IEC standard specifically focuses on process streams radiation monitoring systems used for normal and incident operations.

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 characteristics when developing systems for normal and incident monitoring conditions. Some specific instrument characteristics such as measurement range, required energy response, and ambient environment requirements will depend upon the specific application. In such cases guidance is provided on determining the specific requirements, but specific requirements themselves are not stated.

b) Situation of this Standard in the structure of the IEC SC 45A standards series

IEC 60768 is at the third level in the hierarchy of SC 45A standards. It provides guidance on the design and testing of process streams radiation monitoring equipment used for normal and incident conditions. Other standards developed by SC 45A and SC 45B provide guidance on instruments used for monitoring radiation as part of normal operations and also for accident and post accident conditions. IEC 60761 series provide 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 60951 standard series establishes requirements for equipment for radiation monitoring for accident and post accident conditions.

Finally, ISO standard 2889 gives guidance on gas and particulate sampling. The relationship between these various radiation monitoring standards is given in the table below:

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 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 4	IEC 60768	N/A
Area monitoring	N/A	IEC 60951-1 and 3	IEC 60532	
Central System	N/A	IEC 61504		IEC 61559

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.

d) Description of the structure of the IEC SC 45A standard series and relationships with other IEC documents, IAEA and 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 45 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 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.

NUCLEAR POWER PLANTS – INSTRUMENTATION IMPORTANT TO SAFETY – EQUIPMENT FOR CONTINUOUS IN-LINE OR ON-LINE MONITORING OF RADIOACTIVITY IN PROCESS STREAMS FOR NORMAL AND INCIDENT CONDITIONS

1 Scope

Information regarding the levels of radioactive materials in defined process streams of nuclear power plants is necessary to evaluate plant performance, to provide at an early stage information on possible radioactive releases, and to allow plant operators to take actions to control these releases.

This International Standard provides criteria for the design, selection, testing, calibration and functional location of equipment for the monitoring of radioactive substances within plant-process streams during normal operation conditions and anticipated operational occurrences.

IEC 60768 is only applicable to continuous in-line or on-line measurement, i.e. monitors of which the detector measures radioactivity by being positioned in the process stream (i.e. immerged in) or adjacent to the process stream (i.e. viewing straight through a pipe or tank). It does not apply to monitors of which the detector measures a representative proportion of the stream at some remote location (sampling assembly), which are within the scope of IEC 60861.

IEC 60768 is only applicable to monitors for normal and incident conditions. Process stream radiation monitoring equipment for accident and post-accident conditions are within the scope of IEC 60951-4.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60038:1983, *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, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60780:1998, *Nuclear power plants – Electrical equipment of the safety system – Qualification*

IEC 60880:2006, *Nuclear power plants – Instrumentation and control systems important to safety – Software aspects for computer-based systems performing category A functions*

IEC 60951-1:2009, *Nuclear power plants – Instrumentation important to safety – Radiation monitoring for accident and post accident conditions – Part 1: General requirements*[1]

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

IEC 60987:2007, *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, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:2007, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

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

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

IEC 61000-4-8:1993, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-12:2006, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61000-4-18:2006, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

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

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

IEC 61226:2005, *Nuclear power plants – Instrumentation and control systems important to safety – Classification of instrumentation and control functions*

IEC 61504:2000, *Nuclear power plants – Instrumentation and control systems important to safety – Plant-wide radiation monitoring*

IEC 62138:2004, *Nuclear power plants – Instrumentation and control important for 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)*

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[1] To be published.

3 Terms and definitions

The terms and definitions given in IEC 60951-1:2009 apply.

4 Design principles

4.1 Basic requirements related to functions

The main purpose of equipment for continuous in-line or on-line monitoring of radioactivity in process streams is to continuously measure radiation levels in appropriated pipes or tanks, either by being positioned in them (i.e. immerged in the process stream) or adjacent to them (i.e. viewing straight through the process stream). These radiation measurements are displayed locally and/or in control rooms to keep plant operators aware of current radiological conditions. This information is used for control purposes and/or initiation of protective actions. Therefore, the equipment concerned by this standard 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 in-line and on-line monitoring of radioactivity in process streams are plant specific.

Process radiation monitors within the scope of this standard can be classified into two basic types:

– in-line monitors: the detector is located directly in the process stream (pipe, stack, tank, duct, etc.),
– on-line monitors: the detector faces directly the process stream.

For the purpose of critical data collection, these monitors may be 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 conditions and anticipated operational occurrences, and the corresponding source terms (preponderant 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 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)
  – Determine the stream characteristics (physical, chemical and dynamic characteristics of the stream to be monitored) such as: type of fluid, thermodynamic state, temperature range and rate of change, pressure range and rate of change, radiochemical properties, etc.
  – If necessary, 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 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)
  - Determine the acceptable false alarm rate taking into account the plant conditions and the consequences of error in measurement, and specify the precision and accuracy 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 + time for the apparatus to provide an alarm)
  - Calculate, at the point of measurement, geometric detection efficiency, decision threshold and minimum detectable activity (or detection limit), 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:
    - activity spectrum and time profile of the activity spectrum (during transient operating conditions) of the source to be measured
    - activity spectrum and time profile of the activity spectrum (during transient operating conditions) of the background
    - detection geometry
    - number of standard deviations (in order to calculate the minimum detectable activity or detection limit)
    - flow rate of the stream to be measured
    - thermodynamic conditions
    - precision and time profile of the precision (in order to calculate the measurement time during steady-state as well as transient operating conditions)
    - 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.

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 60780 (and IEC 60980 for seismic testing).

4.2 Measurement range

The purchaser shall specify the required effective range of measurement. The range shall be suitable for the level of radiation during normal and incident conditions. A minimum of four decades of measurement is required.

4.3 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.

4.4 Minimum detectable activity (or detection limit)

The minimum detectable activity (or detection limit) 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. It 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 detection limit) 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 detection limit) 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 detection limit) shall be specified.

4.5 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 term 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 incident 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 10 % over the entire effective range of measurement, all influence quantities taken into account.

4.6 Accuracy (or relative error)

Accuracy (or relative intrinsic error) is a measure of the deviation between the conventionally true 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 term of a number of standard deviations.

NOTE For example, the accuracy 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 shall be consistent with incident 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 shall be specified by the manufacturer.

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

4.7 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) needed 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.

4.8 Response time

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

NOTE For integrating systems, it is a percentage of the equilibrium value of the first derivative of the output signal in 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.

4.9 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.

4.10 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 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 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 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 practicable compensation, taking account of the range of energies and the direction of the radiation.

4.11 Requirements related to incident conditions

Equipment design shall assure that the equipment supports the necessary system functions and that the equipment will not fail due to environmental conditions experienced during normal and incident conditions.

The incident 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 and incident 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 incident 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 incident 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 account of 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.

4.12 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 requirements shall be reached:

– MTBF (Mean Time Between Failure): > 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 4.14.2). These maintenance requirements should be kept to a practical minimum.

4.13 User interface

4.13.1 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.

4.13.2 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 incident 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.

4.13.3 Alarms

4.13.3.1 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 between the purchaser and the manufacturer. As a minimum the following alarms shall be provided as applicable.

4.13.3.2 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).

4.13.3.3 Fault alarms

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

- loss of detector signal;
- loss of the cooling system;
- loss of the heating system;
- high ambient radiation.

4.13.4 Status indication

The following indications should be provided when appropriate:

- power On;
- 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;
– occurrence of internal power supply changeover if internal supplies (e.g., batteries) are provided.

4.13.5 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 incident 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 60780. 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.

4.14 System testing, maintenance facilities and ease of decontamination

4.14.1 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.

4.14.2 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. Interchange ability 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.

4.14.3 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.

4.15 Electromagnetic interference

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

Unless otherwise agreed 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.

4.16 Power supplies

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

- 110 V a.c. and/or 230 V a.c 50 Hz.;
- 120 V and/or 240 V a.c. 60 Hz
- 24 V d.c.

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.

4.17 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 the 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 between manufacturer and purchaser.

4.18 In-line detectors mechanical features

4.18.1 General requirements

Whenever in-line detectors are located in a sleeve or a piping system implanted as part of a pipe or tank under pressure or carrying hot or corrosive fluid, specific requirements shall apply to ensure thermodynamical and mechanical conditions are taken into account.

When specified, the sleeve or piping system, including all accessories, shall be supplied by the detector manufacturer and fully assembled on the main pipe or tank when possible.

The sleeve or piping system shall be designed and arranged to permit an easy removal of the detector for maintenance and cleaning. The detector shall be adequately installed in the sleeve or piping system to prevent damage due to vibration under normal operation and maintenance activities.

The mechanical features of piping and its connections, including bolting and sealing, shall be agreed between the purchaser and manufacturer, and shall conform to relevant standards.

4.18.2 Pressure-containing parts

The maximum allowable working pressure of the detector at the most severe operating conditions shall be clearly defined by the manufacturer. In no case shall the maximum allowable working pressure of the detector and the sleeve exceed that of the sleeve flanges.

Pressure casings including the detector housing shall be of such thickness as will be suitable for containing pressure and limiting distortion under the maximum allowable pressure at the operating temperature.

The casing shall also be suitable for the hydrostatic test pressure at ambient temperature.

The pressure-containing parts shall be made of non corrosive materials, to be agreed upon between the purchaser and the manufacturer.

The bolting selected (property class) shall be adequate for the maximum allowable working pressure of the detector sleeve and for normal tightening procedures. If at some point it is necessary to use a fastener of special quality, interchangeable fasteners for other joints shall be of the same quality.

4.18.3 Materials

The materials used for pressure-containing parts shall be suitable for the fluid to be monitored. In particular, they shall resist corrosion caused by the liquid handled and by environmental conditions.

Materials are selected by the purchaser. If the detector manufacturer considers other materials to be more suitable, these should be offered as alternatives by the manufacturer according to the operating conditions specified on the data sheet.

For hazardous liquids, the manufacturer shall propose suitable materials for agreement by the purchaser.

For high or low temperature applications, the detector manufacturer shall give due consideration to mechanical design.

Chemical composition, mechanical properties, heat treatment and welding procedures shall be in accordance with the relevant material standards.

4.18.4 Verification of material processing

When tests and certificates for the above-mentioned properties are required, the procedures shall conform to relevant standards and be agreed between the purchaser and manufacturer. All certificates shall be issued by the manufacturer's quality control.

Any or all of the following inspections may be requested by the purchaser:

a) examination of components before assembling;
b) internal examination of the casing after running of test;
c) installation dimensions;
d) auxiliary or additional equipment;
e) chemical composition: according to manufacturer's standard specification or with specimen per melt;
f) mechanical properties: according to manufacturer's standard specification or with specimen per melt and heat treatment;
g) susceptibility to intergranular attack (where applicable);
h) non-destructive tests (leakage, ultrasonic, dye penetrant, magnetic particle, radiographic, spectroscopic identification, etc.).

All pressurised parts, including their fasteners, shall meet the same mechanical performances as the pipe or tank on which they are installed. The means of verification shall be agreed upon between the purchaser and the manufacturer.

4.19 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. Software for category B and C functions shall be developed according to the guidance of IEC 62138.

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.

4.20 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 standard (part 1 and specific part). This test report shall comply with the specifications given in 5.6 of standard IEC 61069-1 (1991) 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 used 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 section 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 qualification tests that shall be performed in addition if the equipment is to be qualified in accordance with IEC 60780.

5.2 General test procedures

5.2.1 General

General test procedures applicable to all types of monitors are covered in this standard. Detailed test procedures will vary in accordance with the particular characteristics of 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 1. Tests performed under standard test conditions are listed in Table 2, 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 two categories:

- tests relating to the measurement, alarm and indication assemblies;
- tests relating to postulated performance in volumetric measurement.

In order to check the effects of the variation of each influence quantity listed in Table 3, all the other influence quantities shall be maintained within the limits of the standard test conditions given in Table 1, 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 3 with the range of variation of each influence quantity and the limits of the corresponding variations of the indication of the assembly.

The complementary tests relating to postulated performance in volumetric measurement where real testing is impossible are described hereafter. The calculations and numerical simulations shall take into account the specified change of influence quantity required in Table 3 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.

5.2.4 Calculations and/or numerical simulations

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 (detection limit, 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 comprehensive documentation to substantiate that the software used in calculations and simulations correctly represents 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 test 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).

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.

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 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 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 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 3.18 of IEC 60951-1:2009.

5.3.2 Accuracy (relative error)

5.3.2.1 Requirements

Under standard test conditions, with the calibration controls adjusted according to the manufacturer's instructions, the accuracy (linearity error or relative error) shall not exceed 10 %, between 2,5 times the lowest value of the effective range of measurement and 75 % of this range, and shall not exceed ±20 % over the whole effective range of measurement. The uncertainty of the radioactive source is not included.

Tests can be performed in two ways:

- with 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.

5.3.2.2 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.

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.

5.3.3 Response to other artificial radionuclides

5.3.3.1 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.

5.3.3.2 Test method

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

5.3.4 Response to background radiation

5.3.4.1 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 between the manufacturer and purchaser shall be used for other activities, for example neutrons and/or high energy betas may affect the reading.

5.3.4.2 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.

5.3.4.3 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 measuring 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 test with a Co-60 source.

5.3.5 Precision (or repeatability)

5.3.5.1 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.

5.3.5.2 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.

5.3.6 Stability of the indication

5.3.6.1 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.

5.3.6.2 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 at each time shall lie within the limits indicated.

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

5.3.7 Response time

5.3.7.1 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 on the response time shall be specified.

The test shall be carried out with sources of the same representative radionuclide and geometric characteristics.

5.3.7.2 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.

The test is carried out in two steps:

– by locating the detector relative to an empty volume, equivalent to the actual operating conditions of the monitor, for a sufficient time 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 solid source is introduced and the moment at which the reading reaches for the first time 90 % of the variation.

5.3.8 Overload test

5.3.8.1 Requirements

The equipment shall maintain full-scale indication or an unambiguous indication when “exposed” to an appropriate activity or dose rate two times 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.

5.3.8.2 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 two times greater than that necessary to produce the maximum scale reading. 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

5.4.1 Alarm trip range

5.4.1.1 Requirement

The ranges of alarm settings shall conform to the requirements of 4.13.3. 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;

an alarm shall operate and permit the identification of the failure. For the electronic circuit, a specific fault alarm shall operate within 1 min after failure. The manufacturer shall indicate the time required to obtain 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 and electronic circuit, 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 4.13.3 and 4.13.4 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 of the two states.

On 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,
– the de-energizing of all or part of the equipment.

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

5.5 Environmental performance test

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

5.5.2.1 Degrees of protection (IP and IK codes)

This tests is applicable to on-line monitors and outside parts of in-line monitors. For in-line detectors located in sleeves or piping systems and submitted to the physical and chemical conditions of the stream to be monitored, mechanical features and tests shall be agreed upon between the purchaser and the manufacturer, and shall conform to relevant standards (see 4.18).

The tests shall comply with standards 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 and IK 07 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 (eg: 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 standard 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 ambient and stream conditions

5.5.3.1 On-line measurement – Stability of performances with variation of ambient temperature or humidity

5.5.3.1.1 Requirements

Wherever the equipment or part of the equipment are submitted to variations of temperature or humidity 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.

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.

5.5.3.1.2 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 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 noted 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.

5.5.3.2 In-line measurement – Stability of performances with variation of stream temperature, pressure or flow-rate

5.5.3.2.1 Requirements

For in-line measurement, detectors are submitted to variations of temperature, pressure and flow-rate of the stream to be measured, the outside part of the monitor (not in contact with the stream) being submitted to the influence of ambient temperature or humidity.

As it is obvious that such influence quantities and their ranges of variation are different for testing the measurement assembly and testing the detector, these tests shall be performed in two steps:

– test of the influence of the ambient temperature and humidity on the measurement assembly as described in 5.5.3.1,

– test of the influence of the temperature, pressure and flow-rate on the detector being in contact with the medium to be measured.

For all parts of the monitor, the change in indication shall be less than 10 % over the entire ranges of variation of temperature, pressure, humidity or flow-rate.

5.5.3.2.2 Test method

The test procedure shall be agreed upon between the purchaser and the manufacturer. The following method may be used so far as it is applicable.

The detector should be exposed to suitable solid sources as defined in 5.2.5, such that the nominal reading under standard test conditions is known. The indication should be monitored during the test.

The part of the measurement assembly designed to operate in-line, including the detector, should be completely immerged in water in a pressurized chamber, mounted in position of industrial use, and submitted to the specified variation of temperature, pressure and/or flow-rate for the duration prescribed in the relevant specification. The severities shall be agreed upon between the purchaser and the manufacturer, in accordance with the postulated stream characteristics. Relevant measurements shall be carried out to ensure that the water temperature, pressure and/or flow-rate shall not differ by more than values agreed upon.

5.5.4 Electromagnetic compatibility

5.5.4.1 Oscillatory wave immunity

The test procedures previously defined in IEC 61000-4-12 are now defined in IEC 61000-4-18, with the following details concerning the dampened oscillatory wave:

– 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 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 ($1{,}5\times10^{-3}$ 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; 100; 150; 200; 300; 500; 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 between the purchaser and the manufacturer.

In order to take into account the perturbations related to wireless communications, the 1 800 MHz to 3 000 MHz frequency range shall be tested for level 3.

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 a.c. supply and the connections that could leave the electrical building shall be tested.

The severity of the test shall be:

– a.c. 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.

Table 1 – 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[1]	101,3 kPa	86 kPa to 106 kPa
Power supply voltage	Nominal supply voltage U_N	U_N ± 1 %
AC power supply frequency[2]	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

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

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

Table 2 – Tests performed under standard test conditions

Characteristics under test	Requirements	Reference (subclause)
Reference response	In accordance with the manufacturer's specification	5.3.1
Accuracy (relative error)	< 10 % (between 2,5 times the lowest value and 75 % of the range of measurement) < 20 % (whole range of measurement)	5.3.2
Response to other artificial radionuclides	Variation < 20 % from the manufacturer's specification	5.3.3
Precision (or repeatability)	Coefficient of variation < 10% for any reading exceeding 10 times the lowest value of the effective range of measurement	5.3.5
Stability of the indication	< 2 % of scale maximum angular deflection (analogue display) or of first order of magnitude of range of measurement (digital display)	5.3.6
Response time	In accordance with the manufacturer's specification	5.3.7
Overload test	To remain at full-scale indication (or unambiguous indication) when exposed to an activity or dose rate two times that which would give full scale deflection and perform normally when this overload is removed	5.3.8
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 3 – 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	5.3.4
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 performances with variation of ambient temperature or humidity (on-line measurement)	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	5.5.3.1
Stability of performances with variation of stream temperature, pressure or flow-rate (in-line measurement)	As specified in relevant test	Change in indication <±10 % over the entire ranges of variation of stream temperature, pressure or flow-rate	5.5.3.2
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 case the a.c. power supply frequency test does not apply.

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