IEC 60768

Edition 2.0 2009-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

IEC 60768:2009

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 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 ±2σ, with σ the standard deviation), and 30 % within another part of the effective range of measurement with another probability.

Precision shall be consistent with 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 ±2σ, 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.