IEC 60951-1

Edition 2.0 2009-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**Centrales nucléaires de puissance – Instrumentation importante pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles –
Partie 1: Exigences générales**

IEC 60951-1:2009

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

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Part 1: General requirements

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60951-1 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 1988. This edition constitutes a technical revision.

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

- To clarify the definitions.
- To up-date the references 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/734/FDIS	45A/756/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.

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

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 the standard

This IEC standard specifically focuses on radiation monitoring systems used for accident and post-accident 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 accident 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.

This standard is one in a series of standards covering post-accident radiation monitors important to safety. The full series is comprised of the following standards.

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

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

The IEC 60951 series of standards are at the third level in the hierarchy of SC 45A standards. They provide guidance on the design and testing of radiation monitoring equipment used for accident and post-accident conditions. Other standards developed by SC 45A and SC 45B provide guidance on instruments used for monitoring radiation as part of normal operations. The IEC 60761 series provides requirements for equipment for continuous off-line monitoring of radioactivity in gaseous effluents in normal conditions. IEC 60861 provides requirements for equipment for continuous off-line monitoring of radioactivity in liquid effluents in normal conditions. IEC 60768 provides requirements for equipment for continuous in-line and on-line monitoring of radioactivity in process streams in normal and incident conditions. Finally, ISO 2889 gives guidance on gas and particulate sampling. The relationship between these various radiation monitoring standards is given in Table 1.

Table 1 – Overview of the standards covering the domain of radiation monitoring

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

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	
Central system	N/A	IEC 61504		IEC 61559 series

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 and other bodies documents (IAEA, ISO)

The top-level document of the IEC SC 45A standard series is IEC 61513. It provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 61513 structures the IEC SC 45A standard series.

IEC 61513 refers directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation of systems, defence against common cause failure, software aspects of computer-based systems, hardware aspects of computer-based systems, and control room design. The standards referenced directly at this second level should be considered together with IEC 61513 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 are standards related to specific equipment, technical methods, or specific activities. Usually these documents, which make reference to second-level documents for general topics, can be used on their own.

A fourth level extending the IEC SC 45A standard series, corresponds to the Technical Reports which are not normative.

IEC 61513 has adopted a presentation format similar to the basic safety publication IEC 61508 with an overall safety life-cycle framework and a system life-cycle framework and provides an interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. Compliance with IEC 61513 will facilitate consistency with the requirements of IEC 61508 as they have been interpreted for the nuclear industry. In this framework IEC 60880 and IEC 62138 correspond to IEC 61508-3 for the nuclear application sector.

IEC 61513 refers to ISO standards as well as to IAEA 50-C-QA (now replaced by IAEA GS-R-3) for topics related to quality assurance (QA).

The IEC SC 45A standards series consistently implements and details the principles and basic safety aspects provided in the IAEA code on the safety of NPPs and in the IAEA safety series, in particular the Requirements NS-R-1, establishing safety requirements related to the design of Nuclear Power Plants, and the Safety Guide NS-G-1.3 dealing with instrumentation and control systems important to safety in Nuclear Power Plants. The terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

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

Part 1: General requirements

1 Scope

This part of IEC 60951 provides general guidance on the design principles and performance criteria for equipment to measure radiation and fluid (gaseous effluents or liquids) radioactivity levels at nuclear power plants during and after an accident. This standard is limited to equipment for continuous monitoring of radioactivity in accident and post-accident conditions.

The object of this standard is to lay down mandatory general requirements and give examples of acceptable methods for equipment for continuous monitoring of radioactivity within the plant during and after accident conditions in nuclear power plants using light water reactors.

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

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

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 60038:2002, *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: *Degrees of protections provided by enclosures – IP code*

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

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

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

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

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

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

IEC 61000-4-4:2004, *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 61000-4-8:2001, *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 61000-6-4:2006, *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, *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 61559-2:2002, *Radiation in nuclear facilities – Centralized systems for continuous monitoring of radiation and/or levels of radioactivity – Part 2: Requirements for discharge, environmental, accident, or post-accident monitoring functions*

IEC 62138, *Nuclear power plants – Instrumentation and control 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)*

ISO 2889:2009, *Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
acceptance test
contractual test to prove to the customer that the device fulfils certain specifications

[IEV 394-40-05]

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

[IAEA Safety Glossary, 2007 edition]

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

[IEV 393-11-41]

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

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

[IAEA Safety Glossary, 2007 edition]

3.5
coefficient of variation
ratio of the standard deviation s to the arithmetic mean $\bar{x}$ of a set of n measurements x_i given by the following formula:

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

[IEV 394-40-14]

3.6
collection efficiency
percentage retained by the filter of the total amount of particles initially in a known volume of air passed through the filter

[ISO 2889]

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

[IEV 394-40-10]

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

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

[IEC 60761-1,3.9]

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

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

[IAEA Safety Glossary, 2007 edition]

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

[IEC 60761-1,3.10]

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

3.11
effective range of measurement

absolute value of the difference between the two limits of a nominal range

[IEV 394-40-16]

NOTE In the nominal range the performance of a piece of equipment or an assembly meets the requirements of its specifications.

3.12
electron beam
electron flux emitted from one source and moving along the exactly determined tracks with very great velocities

[IEV 841-30-01]

NOTE Such beam routed to a detector causes extremely high dose rates.

3.13
experimental standard deviation
for a series of n measurements of the same measurand, the quantity s characterizes the dispersion of the results and is given by the equation:

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

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

[IEV 394-40-40]

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

NOTE 2 Experimental standard deviation of the mean is sometimes incorrectly called standard error of the mean.

3.14
measuring assembly
assembly designed to measure a quantity

NOTE In this standard, the quantity is volumetric activity or dose rate, although the value may be expressed in other units.

3.15
minimum detectable (measurable) activity
quantity of radioactivity giving a count which, in the presence of a specified background noise, has a 95 % probability not to be caused by that of background noise alone

[IEV 394-40-25]

3.16
particle
aggregate of molecules forming a solid or liquid of size ranging from a few molecular diameters to some tenths of a milimeter (several hundred micrometers)

[ISO 2889]

3.17
process streams
fluid which flows through a system intended to provide a useful purpose.

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

NOTE 2 The process streams within the scope of this standard are those streams in which the level of radioactivity may significantly increase as a result of accident or post-accident conditions.

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

3.18
reference response
response of the assembly under reference conditions to unit reference dose rate, expressed as:

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

where:

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

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

v_{c} is the conventionally true value of the reference source

[IEV 394-40-22]

NOTE The background value may be automatically taken into account by an algorithm included in the measurement systems.

3.19
relative error
error of measurement divided by a true value of the measurand

[IEV 394-40-11]

NOTE 1 Since a true value cannot be determined, in practice, a conventionally true value is used. For this standard, relative error is calculated as follows.

$$E = \frac{(v - v_B) - v_c}{v_c}$$

where:

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

v_c is the conventionally true value of the reference source,

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

NOTE 2 The background value may be automatically taken into account by an algorithm included in the measurement system.

3.20
relative response
value calculated during type testing equal to the ratio between the reference response of the equipment and the sensitivity of the same equipment to the solid source of interest

NOTE The relative response allows determination of the reference response of identical equipment that has been type tested from the measurement of the sensitivity of the solid source.

3.21
response time
the period of time necessary for a component to achieve a specified output state from the time that it receives a signal requiring it to assume that output state

[IAEA Safety Glossary, 2007 edition]

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

3.22
routine test
conformity test made on each individual item during or after manufacture

[IEV 394-40-03]

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

3.24
sampling collection efficiency
for a given quantity of radioactive material, ratio of the collected activity to the supplied activity, for a specified time interval

[IEV 394-39-45]

3.25
sensitivity (of a measuring assembly)
for a given value of the measured quantity, ratio of the variation of the observed variable to the corresponding variation of the measured quantity

[IEV 394-39-07]