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IEC 60951-3

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Centrales nucléaires de puissance – Instrumentation importante pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles –
Partie 3: Ensemble de surveillance locale en continu des rayonnements gamma à large gamme

IEC 60951-3:2009

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

Part 3: Equipment for continuous high range area gamma monitoring

FOREWORD

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

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International Standard IEC 60951-3 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 1989. This edition constitutes a technical revision.

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

- To clarify the definitions.
- To update the references to new standards published since the first issue.
- To update the units of radiation.

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

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

FDIS	Report on voting
45A/736/FDIS	45A/758/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 this 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

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. 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 60768 provides requirement for equipment for continuous in-line and on-line monitoring of radioactivity in process streams in normal and incident conditions. Finally, ISO 2889 gives guidance on gas and particulate sampling. The relationship between these various radiation monitoring standards is given in the Table 1 below.

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

For more details on the structure of the IEC SC 45A standard series, see item d) of this introduction.

c) Recommendations and limitations regarding the application of the 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 3: Equipment for continuous high range area gamma monitoring

1 Scope

This part of IEC 60951 provides general guidance on the design principles and performance criteria for equipment for continuous high range area gamma monitoring in nuclear power plants for accident and post-accident conditions.

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

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

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

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

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

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

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

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

ISO 8529 (all parts), *Reference neutron radiations*

3 Terms and definitions

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

4 Design principles

4.1 General

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

4.2 Range of measurement

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

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

4.3 Accuracy (relative error)

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

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

4.4 Location of sensors

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

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

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

4.5 Detector radiation response characteristics

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

4.6 Requirements related to accident conditions

In addition to 4.11 of IEC 60951-1, the following requirements shall apply.

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

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

5 Functional testing

5.1 General

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

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

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

5.2 Reference sources

5.2.1 General

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

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

5.2.2 Gamma

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

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

5.2.3 Beta

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

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

5.2.4 Neutron

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

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

5.3 Performance characteristics

5.3.1 Reference response

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

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

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

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

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

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

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

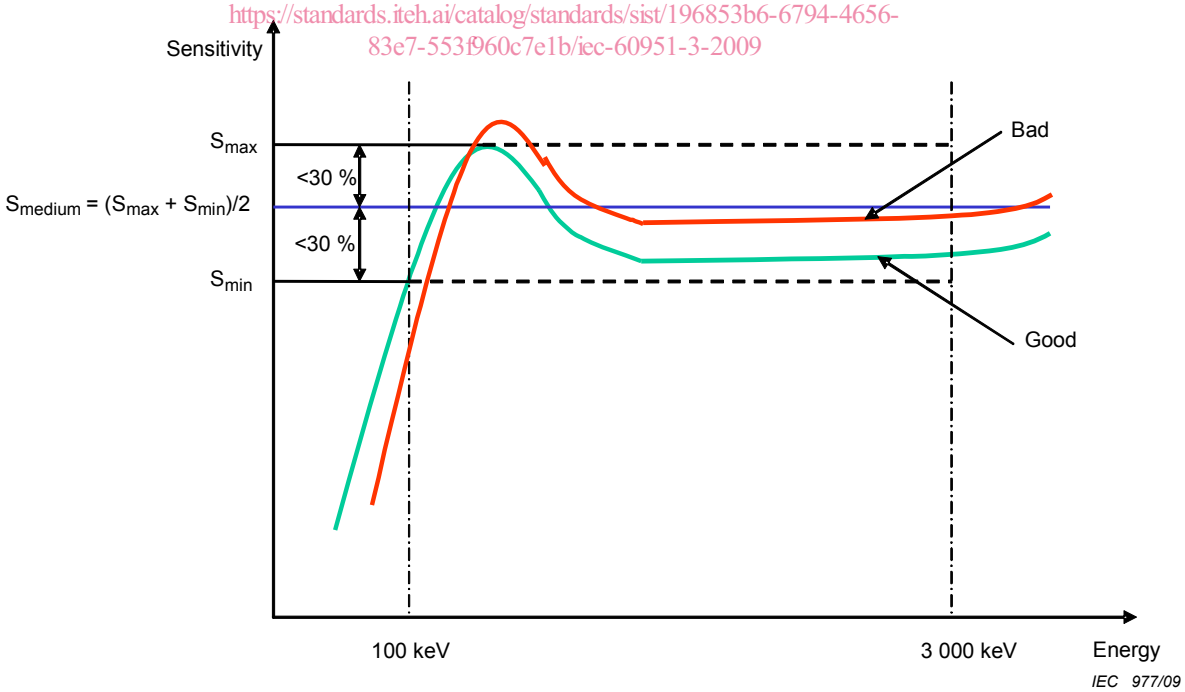

Figure 1 – Energy response

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