

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Instrumentation important to safety – Radiation monitoring for accident and post-accident conditions – Part 4: Equipment for continuous in-line or on-line monitoring of radioactivity in process streams

[IEC 60951-4:2009](#)

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Centrales nucléaires de puissance – Instrumentation importante pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles –

Partie 4: Equipement pour la surveillance en continu des rayonnements internes ou externes aux flux de procédé



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Partie 4: Equipement pour la surveillance en continu des rayonnements internes ou externes aux flux de procédé

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**NUCLEAR POWER PLANTS –
INSTRUMENTATION IMPORTANT TO SAFETY –
RADIATION MONITORING FOR ACCIDENT
AND POST-ACCIDENT CONDITIONS –****Part 4: Equipment for continuous in-line or on-line monitoring
of radioactivity in process streams**

FOREWORD

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International Standard IEC 60951-4 has been prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

This second edition of IEC 60951-4 cancels and replaces the first edition issued in 1991. It constitutes a technical revision.

The main technical changes with regard to the previous edition are as 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/737/FDIS	45A/759/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.

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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 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 below:

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

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

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 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 4: Equipment for continuous in-line or on-line monitoring of radioactivity in process streams

1 Scope

This part of IEC 60951 provides general guidance on the design principles and performance criteria for equipment for continuous in-line or on-line monitoring of radioactivity in process stream 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.

IEC 60951-4 is only applicable to continuous in-line or on-line measurement, i.e. monitors for which the detector measures radioactivity by being positioned in the process stream (i.e. immersed in) or adjacent to the process stream (i.e. viewing straight through a pipe or tank). It does not apply to monitors for which the detector measures a representative proportion of the stream at some remote location (sampling assembly), which are within the scope of IEC 60951-2.

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

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

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

Except where otherwise specified, all the requirements specified in Clause 4 of IEC 60951-1 shall be carried out, unless otherwise stated.

4.2 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 appropriate pipes or tanks, either by being positioned in them (i.e. immersed 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 in order 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, tank, duct),
- 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.

In addition to the basic requirements of IEC 60951-1, the specification procedure should include the following:

- Establish the required measurement characteristics (purchaser): 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.

4.3 Range of measurement

In addition to 4.2 of IEC 60951-1, the following requirements shall apply:

The effective range of measurement should be at least six decades.

4.4 In-line detectors mechanical features

4.4.1 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.

4.4.2 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.

4.4.3 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.

4.4.4 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.

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 2.

5.2 Environmental performance test

5.2.1 Stability of performances with variation of ambient and stream conditions

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

5.2.1.1.1 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 % for each test 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.

5.2.1.1.2 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 of IEC 60951-1, 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: