BS IEC 60951-4:2009

BSI British Standards

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

National foreword

This British Standard is the UK implementation of IEC 60951-4:2009.

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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 – 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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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.

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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

<table>
<tr><td>Developer</td><td>ISO</td><td colspan="2">SC 45A – Process and safety monitoring</td><td>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><td></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 Scope	ISO Sampling circuits and methods	SC 45A – Process and safety monitoring Accident and post-accident conditions	 Normal and incident conditions	SC 45B – Radiation protection and effluents monitoring
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.

Developer Scope	ISO Sampling circuits and methods	SC 45A – Process and safety monitoring Accident and post-accident conditions	 Normal and incident conditions	SC 45B – Radiation protection and effluents monitoring
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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. 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 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;

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.

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d) auxiliary or additional equipment;

e) chemical composition: according to manufacturer's standard specification or with specimen per melt;

– 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,
  – the assemblies are energised,
  – test duration: 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 most sensitive 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 measured value of the instrument shall be recorded during the tests. On completion, the instruments are placed in normal atmospheric conditions for 2 h so that they reach thermal equilibrium. The performances of the monitors shall comply with the performances 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.

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

5.2.1.2.1 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 of IEC 60951-1.
– 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.

5.2.1.2.2 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 of IEC 60951-1, 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.

Table 2 – Additional tests to complement the general tests required in IEC 60951-1

Tests	Tests conditions	Limits of variation of indication	Reference (subclause)
Stability of performances with variation of ambient temperature or humidity (on-line measurement)	Damp heat T = + 40 °C, t = 96 h Cyclic damp heat T = + 25 °C to + 55 °C	Change in indication <±10 % over the entire ranges of variation of temperature and humidity	5.2.1.1
Stability of performances with variation of stream temperature, pressure or flow-rate (in-line measurement)	As specified in relevant test	As specified in relevant test	5.2.1.2

NOTE 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.

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