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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Instrumentation important to safety – Radiation monitoring for accident and post-accident conditions – Part 2: Equipment for continuous off-line monitoring of radioactivity in gaseous effluents and ventilation air

Centrales nucléaires de puissance – Instrumentation importante pour la sûreté – Surveillance des rayonnements pour les conditions accidentelles et post-accidentelles – Partie 2: Matériels pour la surveillance des rayonnements en continu avec prélèvements dans les effluents gazeux et l'air de ventilation

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

Part 2: Equipment for continuous off-line monitoring of radioactivity in gaseous effluents and ventilation air

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 60951-2 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, as well as IEC 60951-5, published in 1994. This edition 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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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/735/FDIS	45A/757/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 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 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
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 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	

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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 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.

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

Part 2: Equipment for continuous off-line monitoring of radioactivity in gaseous effluents and ventilation air

1 Scope

This part of IEC 60951 provides general guidance on the design principles and performance criteria for equipment for continuous off-line monitoring of radioactivity in gaseous effluents and ventilation air used 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:

- noble gas activity monitors intended to measure the volumetric activity of radioactive noble gases in gaseous effluents at the discharge point and the variation of volumetric activity with time during accident and post-accident conditions. The monitor may also be used for the determination of the total discharge of noble gas activity over a given period;
- noble gas, aerosol and specific nuclide (commonly iodine, in its different forms: inorganic iodine, organic iodine and iodine sticking on dust) monitors intended to measure the volumetric activity in air or gas systems (control room ventilation, reactor leakage collection, drywell ventilation exhaust, fuel handling building ventilation exhaust, reactor building ventilation purge exhaust) and detect any significant increase of radioactivity during or after an accident.

This standard is only applicable to continuous off-line measurement, i.e. monitors whose detector measures a representative proportion of the main effluent or ventilation stream at some remote location (sampling assembly). It does not apply to monitors with the detector positioned in or adjacent to the effluent or ventilation stream, which are within the scope of IEC 60951-4.

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

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

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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 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 Basic requirements related to functions

The equipment will typically measure levels of activity in engineered gaseous discharge routes, such as reactor or fuel handling buildings, and ventilation ducts and stacks. It is intended to provide, depending on the required function, a measure of activity discharged to the environment or detection and quantification of leakage in containment barriers, and any useful information on the behaviour of the plant, which causes or allows the activity release.

The measurement of activity discharge to the environment should ideally be comprehensive, but since measurement of halogen and particulate activity released in effluents during an accident is more complex, it is often judged that monitoring only noble gases will be sufficient. Therefore, monitors should be capable of detecting and measuring gaseous effluent radioactivity with compositions ranging from fresh equilibrium noble gas fission product mixtures to 10 days old mixtures. Multiple instruments may be needed to cover the effective range of measurements required.

Since the measurement is continuously carried out on a sample of effluent or ventilation transferred to a remote location, the detection and measurement assembly shall be installed in an accessible location and in an environment which is compatible with the equipment design limits specified in this standard. This shall be also applicable to the active parts of the sampling assembly (pumps, flow control instruments) requiring maintenance.

The other part of the sampling assembly (sampling probe, pipework) may be designed for and located in a harsh environment. In this case, if the monitor is classified according to the guidance of IEC 61226, it should be classified at the same level as the monitor. If qualification is needed, the part of the sampling assembly located in the harsh environment should be environmentally qualified to these specific ambient conditions.

If necessary, the system shall indicate a value related to the measured volumetric activity under the conditions of temperature and pressure at the sampling location, agreed upon between the manufacturer and purchaser. They shall also agree on how to correct the expression of measurement if the conditions inside the measuring assembly are different from the calibration conditions.

4.3 Sampling assembly

4.3.1 General

The design of the sampling assembly shall take into account the guidance of ISO 2889 and shall comply with the general requirements of IEC 60951-1.

The sampling assembly typically includes one or more of the following assemblies and functional units:

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- Sampling and exhaust pipes.
- Gas conditioning device (e.g. gas cooling device with condensate removing device or gas reheating device to prevent condensation inside the measuring chamber, inlet and outlet connection for an external purging system to remove the remaining gas in the collecting device, etc).
- Measuring chamber.
- Airborne particles collecting devices:
  - aerosol filter unit (filter tape or fixed filter) for aerosol monitors;
  - inlet dust filter only for iodine and noble gas monitors;
  - iodine molecular filter unit or charcoal filter or cartridge unit (filter changing device or fixed filter) for iodine monitors.
- Ambient gamma radiation protection device and/or compensation device.
- Individual air pump or centralized pumping station.
- Air flow-rate measurement and/or control devices.
- When appropriate (depending on sampling conditions): pressure, temperature or humidity measurement and/or control device.

4.3.2 Measurement technique requirements

Depending on the radionuclides to be monitored, the air or gas shall be filtered to remove radioactive particulates and iodine or passed in a container of known constant volume; in the latter case, the measuring cell shall be of the flow-through type, its volume and operating pressure shall be specified, and the detector shall be easily removable for service or replacement with a detector mounting ensuring a repeatable geometrical location.

Where the measurement technique is sensitive to pressure, a pressure measurement shall be provided. The calibration shall take into account the actual conditions of service by appropriate corrections; the acceptable pressure and variation of pressure in the sampling assembly shall be specified by the manufacturer. Care shall be taken to ensure that the pressure in the measuring volume is only slightly affected by the variation of pressure drop across the inlet filter.

Where the measurement technique is sensitive to flow rate, a flow-rate measuring device shall be provided. The calibration shall take into account the actual pressure and temperature of service by appropriate corrections. The influence of gas stream conditioning devices upon the volume measurement shall be considered. A flow-rate control device should also be provided which has a flow-rate adjustment range sufficient to allow for variation in the intrinsic characteristics of the air pump and any filters used. A correction of the measurement for the effects of different flow-rates should also be provided.

If necessary, a humidity measurement of the atmosphere to be monitored may be provided to control the conditioning device in order to avoid any condensation in the pipes and the monitors; alarms should be provided to signal when the relative humidity exceeds a value specified by the manufacturer.

If necessary, a temperature measurement of the sample in front of and close to the measuring device may be provided. In this case, alarms should be provided to signal when the temperature is close to the maximum allowed temperature for the detector.

4.3.3 Requirements on filters and collecting devices

If required, filters or other trapping devices shall be placed in holders at the sampling assembly inlet to remove any dust, aerosols or volatiles from the air or gas. They shall therefore be designed not to trap or retain noble gases or iodine (except iodine sticking onto

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dust); if this is not possible, they shall be monitored separately. The manufacturer of such filters shall specify their retention characteristics for several chemical forms of iodine.

Collecting filters (e.g. glass fibre filter plate, glass fibre filter tape, charcoal filter cartridges) shall be designed to ensure an as uniform as possible deposition of particles. The manufacturer of such filters shall state the retention characteristics of the filters for several chemical forms of radioactive particles, their lifetime, and the collection efficiency of the collecting filter for particles over a range of at least 0,1 µm to 10,0 µm aerodynamic equivalent diameter or to values agreed upon by the manufacturer and the purchaser. The efficiency of the filters should be more than 98 % for dust apart from iodine and more than 99 % for iodine.

The presence of radioactive gases (for example ^{41}Ar, ^{85}Kr, ^{133}Xe or ^{222}Rn) in the air being monitored has an effect on the monitoring of particles; this is especially true for non-selective detectors; to reduce the effects of these radionuclides, the air space in the vicinity of the detector and inside the filters shall be kept to the minimum. If necessary, and if practicable, a purging capability could be provided, to reduce unwanted and disturbing influence of radioactive noble gasses on the measurement of the particle activity.

Collecting filters or trapping devices shall be accessible during normal and post-accident conditions; the pressure drop in the filter as well as its contamination should be controlled, and it should be possible to replace it by an easy and quick disconnection of the filter unit from the pipes.

For the collecting filters introducing an important pressure drop, a differential pressure measurement should be provided to indicate a clogged or pierced collector. In this case, alarms shall be provided for warning of any excessive variation of this differential pressure.

4.3.4 Requirements on sampling circuit and materials

Where a pump is an integral part of any assembly, its nominal flow rate shall be stated by the manufacturer. The sampling assembly design shall provide simple access to the pump and its replaceable parts. Care shall be taken to prevent radioactive gases from leaking into the breathing zone of workers. The acceptable leakage rate depends on the emergency conditions and shall be agreed upon between the manufacturer and the purchaser.

Prevention against condensation in the pipe by variation of temperature or pressure shall be taken. If a gas stream cooling device is used, the condensate flow of the cooling device shall be removed automatically.

Leakage of air or gas in the sampling system (between inlet and outlet of the monitor) shall be less than 5 %.

Losses of particulates and iodine shall be maintained as low as possible by taking into account piping circuit and constructional material in order to estimate and minimize electrostatic effects, adsorption, condensation and plate-out; the level of such losses, and the ways to reduce it, shall be agreed upon between the manufacturer and the purchaser. In any case, the roughness of the surfaces in contact with the gas stream should be less than 0,4 µm.

Delay time to detector shall be maintained as low as possible by optimising the pipe length and diameter, flow rate, etc.

Where the measured sample may contain an explosive mixture of gases (e.g. H_2), the assembly shall be designed to prevent the possibility of ignition of the sample by the instrumentation.

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