

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Radiation protection instrumentation – Installed dose rate meters, warning assemblies and monitors – X and gamma radiation of energy between 50 keV and 7 MeV

Instrumentation pour la radioprotection – Débitmètres à poste fixe, ensembles d'alarmes et moniteurs – Rayonnements X et gamma d'énergie comprise entre 50 keV et 7 MeV



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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

X

ICS 13.280

ISBN 978-2-88912-171-7

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope and object.....	10
2 Normative references	11
3 Terms and definitions	13
4 Design requirements	15
4.1 General characteristics.....	15
4.1.1 Overview	15
4.1.2 Measurement range.....	15
4.1.3 Safety classification.....	15
4.2 Detailed characteristics	16
4.2.1 Equipment configuration	16
4.2.2 Equipment reliability	16
4.2.3 Equipment indication	17
4.2.4 Alarm/trip/interlock facilities.....	18
5 General test procedures	19
5.1 Nature of tests.....	19
5.2 Reference conditions and standard test conditions	19
5.3 Tests performed under standard test conditions	19
5.4 Tests performed with variation of influence quantities.....	19
5.5 Statistical fluctuations	20
5.6 Reference radiation	20
5.6.1 Gamma	20
5.6.2 Beta	20
5.6.3 Neutron	20
5.7 Consideration of natural background radiation.....	20
6 Radiation characteristics	20
6.1 False alarm test	20
6.1.1 Requirements	20
6.1.2 Method of test	20
6.2 Point of test.....	21
6.3 Linearity	21
6.3.1 Requirements	21
6.3.2 Test source of gamma radiation.....	21
6.4 Variation of response with photon radiation energy	22
6.4.1 Requirements	22
6.4.2 Method of test	22
6.5 Variation of response with angle of incidence	23
6.5.1 Requirements	23
6.5.2 Method of test	23
6.6 Response to beta radiation.....	24
6.6.1 Requirements	24
6.6.2 Method of test	24
6.7 Response to neutron radiation.....	24
6.7.1 Requirements	24
6.7.2 Method of test	24

6.8	Overload characteristics	25
6.8.1	Requirements	25
6.8.2	Method of test	25
6.9	Statistical fluctuations	25
6.9.1	Requirements	25
6.9.2	Method of test	26
6.10	Response time	26
6.10.1	Requirements	26
6.10.2	Method of test	26
6.11	Zero drift	27
6.11.1	Requirements	27
6.11.2	Method of test	27
6.12	Alarm requirements	27
6.12.1	Requirements	27
6.12.2	Method of test	27
6.12.3	Equipment fault alarms	27
6.13	Alarm response time and stability	28
6.13.1	Requirements	28
6.13.2	Method of test	28
6.14	Warm-up	28
6.14.1	Requirements	28
6.14.2	Method of test	28
7	Electrical, mechanical and environmental characteristics	28
7.1	Mains operation	28
7.1.1	Requirements	28
7.1.2	Method of test	29
7.2	Electromagnetic compatibility (EMC)	29
7.2.1	General	29
7.2.2	Emission of electromagnetic radiation	29
7.2.3	Electrostatic discharge	29
7.2.4	General radiated electromagnetic fields	30
7.2.5	Conducted disturbances induced by fast transients or bursts	30
7.2.6	Conducted disturbances induced by surges	31
7.2.7	Conducted disturbances induced by radio-frequencies	31
7.2.8	Ring wave immunity	31
7.2.9	50 Hz/60 Hz magnetic field	32
7.2.10	Voltage dips and short interruptions	32
7.3	Mechanical characteristics	33
7.3.1	Areas of application	33
7.3.2	Microphonics/impact	33
7.4	Environmental characteristics	33
7.4.1	Ambient temperature	33
7.4.2	Relative humidity	34
7.4.3	Sealing	34
8	Documentation	35
8.1	Type test report	35
8.2	Certificate	35
8.3	Operation and maintenance manual	35
Annex A (informative)	Monitoring of pulsed ionizing radiation	39

Bibliography.....	40
Figure 1 – Example of the rotation of the detection assembly.....	24
Table 1 – IEC SC 45A/SC 45B standards series	8
Table 2 – Emission frequency range	29
Table 3 – Reference conditions and standard test conditions	36
Table 4 – Tests performed under standard test conditions	37
Table 5 – Tests performed with variations of influence quantities.....	37
Table 6 – Maximum values of additional indications due to electromagnetic disturbances	38

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RADIATION PROTECTION INSTRUMENTATION –
INSTALLED DOSE RATE METERS, WARNING ASSEMBLIES
AND MONITORS –
X AND GAMMA RADIATION OF ENERGY BETWEEN 50 keV AND 7 MeV**

FOREWORD

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International Standard IEC 60532 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

This third edition cancels and replaces the second edition, published in 1992, and constitutes a technical revision.

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

- the document has been updated to take account of the requirements of IEC standards published since 1996.

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

FDIS	Report on voting
45B/655/FDIS	45B/670/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.

The committee has decided that the contents of this publication will remain unchanged until the stability 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 organization of the standard

This International Standard specifically focuses on radiation monitoring systems used for normal and incident conditions.

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 normal and incident 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 except as typical examples given in informative annexes.

This standard is one associated with a series of standards which cover post accident radiation monitors important to safety in nuclear power plants. The full series is comprised of the following standards:

- IEC 60951-1 – *Nuclear power plants – Instrumentation important to safety – Radiation monitoring for accident and post-accident conditions – Part 1: General requirements*
- IEC 60951-2 – *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*
- IEC 60951-3 – *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*
- IEC 60951-4 – *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 stream*

b) Situation of the current standard in the structure of the IEC SC 45A/SC 45B 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.

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 stream 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 – IEC SC 45A/SC 45B standards series

Developer	ISO	SC 45A – Process and safety monitoring		SC 45B – Radiation protection and effluents monitoring
		Accident and post accident conditions	Normal and incident conditions	
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	
Liquid with sampling (OFF LINE)	N/A	N/A	IEC 60861	
Process stream (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	
Central system	N/A	IEC 61504		IEC 61559 (all parts)

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/SC 45B standard series and relationships with other IEC standards and other bodies' documents (IAEA, ISO)

The IEC 61508 series defines the requirements for an overall safety life-cycle framework and a system life-cycle framework. The IEC 61508 series should be complied with when developing instruments with safety functions for radiation monitoring outside the nuclear power plant sector whilst complying with the requirements defined in this standard.

The top-level standard of the IEC SC 45A standard series is IEC 61513. It provides general requirements for instrumentation and control systems and equipment that are used to perform functions important to safety in nuclear power plants. IEC 61513 structures the IEC SC 45A standard series.

IEC 61513 refers directly to other IEC SC 45A standards for general topics related to the 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/SC 45B 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 45/SC 45B standard series, corresponds to the technical reports which are not normative.

IEC 61513 has adopted a presentation format similar to the basic safety publication.

The IEC 61508 series, with an overall safety life-cycle framework and a system life-cycle framework, provides an interpretation of the general requirements for the nuclear power plant sector (see IEC 61508-1, IEC 61508-2 and IEC 61508-4). Compliance with IEC 61513 will facilitate consistency with the requirements of the IEC 61508 series 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 as well as to IAEA 50-C-QA (now replaced by IAEA 50-C/SG-Q) for topics related to quality assurance (QA).

The IEC SC 45A standard series consistently implement and detail the principles and basic safety aspects provided in the IAEA code on the safety of nuclear power plants (NPPs) and in the IAEA safety series, in particular the requirements of Safety Guide NS-R-1, establishing safety requirements related to the design of nuclear power plants, and 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.

**RADIATION PROTECTION INSTRUMENTATION –
INSTALLED DOSE RATE METERS, WARNING ASSEMBLIES
AND MONITORS –
X AND GAMMA RADIATION OF ENERGY BETWEEN 50 keV AND 7 MeV**

1 Scope and object

This International Standard applies to installed dose rate meters, warning assemblies and monitors that are used to prevent or mitigate a minor radioactive release, or minor degradation of fuel, within the nuclear power plants /nuclear facility design basis, and to warn personnel or to ensure their safety during or following events that involve or result in release of radioactivity in the nuclear power plants (NPP) /nuclear facility (NF), or risk of radiation exposure. This equipment is typically classified as category “A” or “B” or “C” or “not classified” in IEC 61226.

It covers equipment intended to isotropically measure air kerma, ambient dose equivalent or other exposure quantities due to X or gamma radiation of energy between 50 keV and 7 MeV. The equipment is intended primarily for the purpose of radiological protection, and may play an auxiliary or indirect role in the achievement or maintenance of nuclear plant safety.

Instruments measuring over a more limited energy range fall within the scope of this standard provided they cover at least the range of 80 keV to 1,5 MeV.

Assemblies of this type are commonly defined as area radiation monitors. They are normally employed to determine continuously the radiological situation in working areas in which the radiation field may change with time, for example nuclear power plants, particle accelerators, high active laboratories, fuel reprocessing plants, and to provide alarms when the radiation field goes outside predetermined limits. They are also employed to act in safety related protection systems, such as personnel access control systems which allow access to areas which can be subject to radiation fields.

This standard also gives guidance applicable to equipment for use in pulsed radiation fields, for example, those emanating from pulsed radiation or particle accelerators. This guidance is important, since the operation of the majority of the equipment defined by this standard in pulsed fields will give false readings.

The assemblies considered in this standard comprise at least:

- a detector assembly (e.g. ionization chamber, Geiger-Muller tube, scintillation counters, semiconductors);
- a measuring assembly, which may be fitted into a centralized panel which, in the case of warning assemblies and monitors, provides signal outputs and contacts capable of activating alarm or trip/interlock circuits for the purpose of radiation protection.

This standard is also applicable to installed dose rate measuring assemblies designed for special applications (e.g. very high dose rates). However, some of the requirements may need to be amended or supplemented according to the particular characteristics of such assemblies.

This standard is not applicable to criticality monitors.

Assemblies designed to perform combined functions should comply with the requirements pertaining to each of these functions.

This standard specifies general characteristics, general test procedures, radiation, electrical, safety, and environmental characteristics and the identification certificate for the assemblies defined above.

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, *IEC standard voltages*

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-393:2003, *International Electrotechnical Vocabulary – Part 393: Nuclear instrumentation – Physical phenomena and basic concepts*

IEC 60050-394:2007, *International Electrotechnical Vocabulary – Part 394: Nuclear instrumentation – Instruments, systems, equipment and detectors*

IEC 60068-2-18, *Environmental testing – Part 2-18: Tests – Test R and guidance: Water*

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60529:1989, *Degrees of protection 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 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measuring techniques – Electrostatic discharge test*

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

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measuring techniques – Electrical fast transient (burst immunity) test*

IEC 61000-4-5:2005, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measuring techniques – Surge immunity test*

IEC 61000-4-6:2008, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measuring techniques – Immunity to conducted disturbances induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-12, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61187:1993, *Electrical and electronic measuring equipment – Documentation*

IEC 61226:2009, *Nuclear power plants – Instrumentation and control important to safety – Classification of instrumentation and control functions*

IEC 61504, *Nuclear power plants – Instrumentation and control systems important to safety – Plant-wide radiation monitoring*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61513:2001, *Nuclear power plants – Instrumentation and control for systems important to safety – General requirements for systems*

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, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

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

ISO 4037-1:1996, *X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods*

ISO 4037-2:1997, *X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy – Part 2: Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV*

ISO 4037-3:1999, *X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosimeters and the measurement of their response as a function of energy and angle of incidence*

ISO 4037-4:2004, *X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy – Part 4: Calibration of area and personal dosimeters in low energy X reference radiation fields*

ISO 6980-1:2006, *Nuclear energy – Reference beta-particle radiation – Part 1: Methods of production*

ISO 6980-2:2004, *Nuclear energy – Reference beta-particle radiation – Part 2: Calibration fundamentals related to basic quantities characterizing the radiation field*

ISO 6980-3:2006, *Nuclear energy – Reference beta-particle radiation – Part 3: Calibration of area and personal dosimeters and the determination of their response as a function of beta radiation energy and angle of incidence*"

ISO 8529-1:2001, *Neutron reference radiations – Part 1: Characteristics and methods of production*

ISO 8529-2:2000, *Reference neutron radiations – Part 2: Calibration of radiation protection devices related to the basic quantities characterizing the radiation field*

ISO 8529-3:1998, *Reference neutron radiations – Part 3: Calibration of area and personal dosimeters and determination of response as a function of energy and angle of incidence*

3 Terms and definitions

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

General terminology concerning detection and measurement of ionizing radiation and nuclear instrumentation is given in IEC 60050-393, IEC 60050-394, and IEC 60050-151.

NOTE Degrees of requirement: In this standard, requirements are defined as follows:

- the word "shall" signifies a mandatory requirement (where appropriate a qualifying statement is included when there may be allowable exceptions);
- the word "should" indicates requirements that are not mandatory for compliance with the standard but are strongly recommended;
- the word "may" signifies an acceptable method or an example of good practice.

3.1

manufacturer

designer and seller of the equipment

3.2

purchaser

user (operator) of the equipment

3.3

detector assembly

DA

component of the installed radiation monitor system that contains the detectors and associated electronic devices; it can also include programmable electronic circuits

3.4

processing assembly

PA

assembly (which can be associated with one or more detector assemblies) which converts the output signal from the detector assemblies into a form, generally digital, suitable for transmission down a data link to the central computer, centralizer, and/or which generates alarm outputs to the alarm units at preset signal levels

3.5

alarm assembly

AA

assembly that will initiate an audible or visible alarm normally local to the DA in the event of an alarm threshold being breached or in case of fault of the equipment

3.6

centralizer

CC

central processing computer system for the calculation, display, and storage of data from the processing assembly

3.7

monitoring assembly

MA

combination of processing, alarm, and detector assemblies

3.8

order of magnitude

range of measurement or the levels to be measured which differ by about a factor of ten for one order of magnitude, one hundred for two, a thousand for three and so on

3.9

priming source

very small radioactive source, if used, mounted in or in close proximity to the detector(s), the source being there to ensure that the low level alarm will not normally alarm unless there is a fault

3.10

conventionally true dose rate

best estimate of the true dose rate used for calibration of equipment; this value and its uncertainty to be determined from a secondary or primary standard, or by a reference instrument which has been calibrated against a secondary or primary standard

3.11

coefficient of variation

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

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

3.12

test nomenclature

3.12.1

qualification tests

tests performed on a representative sample of equipment to verify the adequacy of the design and that the equipment meets the specifications agreed upon between manufacturer and user under normal, operational conditions and anticipated operation occurrences

NOTE 1 Qualification tests are performed in order to verify that the requirements of a specification are fulfilled.

NOTE 2 Qualification tests are subdivided into type tests and routine tests.

3.12.2

type test

conformity test made on one or more items representative of the production

[IEC 60050-151:2001, 151-16-16], [IEC 60050-394:2007, 394-40-02]

3.12.3

routine test

conformity test made on each individual item during or after manufacture

[IEC 60050-151:2001, 151-16-17], [IEC 60050-394:2007, 394-40-03]

3.12.4

acceptance test

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

[IEC 60050-151:2001, 151-16-23, modified], [IEC 60050-394:2007, 394-40-05]

3.12.5

supplementary tests

tests intended to provide supplementary information on certain characteristics of the assemblies

NOTE The term “dose rate” used in this standard shall mean the quantity, e.g. air kerma, that the instrument is intended to measure. The radiation tests are defined by the manufacturer in terms of this quantity.

4 Design requirements

4.1 General characteristics

4.1.1 Overview

Equipment may be designed as a single assembly (monitoring assembly) with the detector assembly adjacent to or contained within the monitoring assembly or the detector remote from the remaining equipment.

The detector assembly (detector and associated electronics) may be located remotely from any processing assembly (electronics) and the indication and alarm assembly.

It is desirable that all these options are provided by a single common design of equipment, and for the design to allow for the use of alternative types of detectors with the same indication and alarm assemblies.

4.1.2 Measurement range

The equipment shall measure the dose rate due to X or gamma rays over an energy range of at least 80 keV to 1,5 MeV. Effective response to energies outside this range down to 50 keV and up to 7 MeV may be specified. The range of the equipment shall be at least three orders of magnitude of dose rate; five or more orders of magnitude may be required in some applications.

4.1.3 Safety classification

The equipment covered in this standard is intended primarily for the purpose of radiological protection and, as defined in 5.3 of IEC 61226:2009 may be installed in facilities such as nuclear power plants, nuclear fuel storage and processing sites, and thus may play a role in the achievement or maintenance of nuclear power plant safety.

For example, if the signals are used for initiating protective action to mitigate the consequences of malfunction or failure of structures, systems or components, then the equipment shall be considered as part of the safety-related systems or the protection system. In this case, it shall meet the requirements of the respective system.

If a safety classification applies, appropriate requirements shall apply concerning specification, design, manufacturing, installation and operation of the equipment with respect to the quality of hardware and software. The requirements shall be agreed between the manufacturer and the purchaser. In particular, the purchaser shall decide the appropriate safety standard applicable to the site in which the system will function, i.e. either IEC 61513 or in the IEC 61508 series.

Compliance with IEC 61513 is required for monitors used in nuclear power plants.

The basic safety standards that comprise IEC 61508 may apply as well as they have been interpreted for the nuclear industry, and may be selected in some specific cases by agreement between the manufacturer and the purchaser. When the IEC 61508 series is selected, the requirements of that series shall apply as appropriate to the required safety integrity level (SIL) specified for the system.

Additionally, in such safety related protection system applications, equipment shall be environmentally qualified in accordance with the requirements of IEC 60780. When applicable, equipment shall be seismically qualified in accordance with the requirements of IEC 60780.

NOTE 1 It is anticipated that the SIL for equipment intended for the purpose of general area radiological protection will be SIL 1. In cases where the equipment is intended to act as an interlock in a safety related protection system(s), such as personnel access control systems which prevent human access to areas which can be subject to very high radiation fields, it is anticipated that the SIL for equipment will be SIL 2 or 3.

NOTE 2 The final choice between IEC 61513 and the IEC 61508 series will be agreed between purchaser and manufacturer. As an indication, the following correspondence is given:

- Cat. A -> SIL 3
- Cat. B -> SIL 2
- Cat. C -> SIL 1

4.2 Detailed characteristics

4.2.1 Equipment configuration

The type of equipment defined in this standard generally comprises up to four types of assemblies, which may be interconnected in a number of configurations.

These assemblies are

- detector assembly (DA),
- processing assembly (PA),
- alarm assembly (AA),
- monitoring assembly (MA).

The design of the equipment shall take account of the practical use of assemblies, noting that they may be required to measure radiation fields incident from various angles relative to their location.

Where detector assemblies are to be used in high neutron radiation fields, the detector assembly should be constructed of materials which will minimize the effects of neutron activation.

The detector assembly should be constructed from smooth, nonporous materials to reduce the possibility of contamination and designed to facilitate decontamination.

4.2.2 Equipment reliability

The reliability shall be managed either by IEC 61513 and associated series, or by IEC 61508 according to the required SIL.

When intended being used in NPP/NF, the equipment shall comply with IEC 61513.

The required reliability of the functions shall be specified either quantitatively (mean time between failures) or qualitatively (compliance with the single failure criterion).

For any part of the equipment (including sampling assembly if any), subject to appropriate planned maintenance, the following requirements shall be reached:

- MTBF (mean time between failure): > 20 000 h (with preventive maintenance).

A failure modes and effects analysis (FMEA) shall be performed in addition to the MTBF calculation in the case of equipment classified in accordance with IEC 61226.

For particular designated safety applications, by agreement between the manufacturer and the purchaser, the equipment may be designed to meet the IEC 61508 series to the applicable SIL for the safety application. When this equipment is designed with safety functions enacted in software (firmware), the instrument can be considered as a programmable electronic system (i.e. SMART). As such, either compliance with the IEC 61508 series, IEC 60880 and IEC 62138, or evidence that the equipment meets the required SIL, shall be provided by the manufacturer.

For equipment hardware, evidence of how the manufacturer has met the requirements of either IEC 60987, or IEC 61508-2, should include assessment such as a failure modes, effects and diagnostic analysis (FMEDA), demonstration of the safe failure fraction (SFF), and statistical testing as appropriate.

This shall include evidence of how the manufacturer has met the lifecycle requirements of IEC 61508-3 to meet the required SIL.

The equipment shall be designed to be fail-safe and have a minimum safe failure fraction of 60 % for SIL 1 applications, 90 % for SIL 2, and 99 % for SIL 3.

Diagnostic facilities shall be provided to detect component and software failures which would cause loss of the safety function of the equipment. These facilities shall result in actuation of all the required trip/interlock/alarm functions.

4.2.3 Equipment indication

The processing unit shall be capable of giving a local indication and local audible and visual alarms. The visual and audible alarm requirements shall be as agreed between the manufacturer and purchaser. The equipment should have the facility to transmit indication and alarms to remote locations. The equipment performance shall be independent of any operational mode and be unaffected by failure of the remote location's equipment. Additionally, a facility to allow the connection of a local chart recorder may be provided.

For multi-monitor installations this remote location may be a centralizer. The requirements of this facility should be in accordance with the IEC 61559 series. The preferred processing unit display should be an analog logarithmic scale meter having a scale length at least 20 mm per decade with appropriate divisional marks. A digital display may be used as long as a clear indication of the scales is provided. In the case of a processing unit with linear scales, the indication ratio between adjacent scales shall not exceed a factor of 10.

The effective range of measurement of the equipment shall be as follows:

- For processing units with linear scales, the effective range shall be between 10 % and 100 % of each range.
- For processing units with logarithmic scale, the effective range shall be between 1,5 times the lowest significant dose rate marked and full scale.
- For processing units with digital indication, the effective range shall be from the start of the second least significant order of magnitude scale (i.e, two digits indicated) to the full range of indications available.

4.2.4 Alarm/trip/interlock facilities

4.2.4.1 General

Processing units which provide outputs for trip/interlock safety functions (see 4.1.3) shall be designed to be fail-safe on interruption or failure of the power supply. The outputs shall result in an actuation of all the selected alarm/trip/interlock functions.

Regarding how the outputs are activated, genuine alarm, instrument fault or power failure, these outputs will hold in the alarm/trip/interlock activated condition until the unsafe condition disappears and until specifically reset by a reset control function.

The alarm unit (AU) for equipment configured to provide area radiological protection shall produce both audible and visual alarms on interruption or failure of the power supply. However activated (genuine alarm, instrument or power failure), the alarm circuits shall be operable to hold alarm conditions until specifically reset by a reset control. The audible alarm shall be capable of being muted by push button on the alarm unit. The visual alarm will continue to operate until reset.

In all cases, an indication of power supply failure shall be provided on the processing unit.

NOTE The suggested alarm hierarchy is as follows: high alarm (4.2.4.2), low alarm (warning level) (4.2.4.3, instrument fault alarm (4.2.4.4).

4.2.4.2 High level alarms

As a minimum one high level alarm should be provided. The alarm set points may be fixed or adjustable. Each alarm shall activate within 1s of the displayed value reaching the set point. Other (alert level) alarms may be provided to operate on increasing dose rates but at a level below the alarm level.

Adjustable alarms should cover at least 10 % to 100 % of scale reading (linear scales), from 50 % of the lowest order of magnitude scale to 100 % highest order of magnitude scale (logarithmic scales) and over all but the least significant decade for digital displays.

4.2.4.3 Low level alarms

A low level alarm facility should be provided. These shall be adjustable as defined in 4.2.4.2. These are to operate on decreasing dose rate and generally act as an additional fault alarm but could be used for process control.

4.2.4.4 Instrument fault alarms

Diagnostic facilities should be provided as far as reasonably practicable to detect electronic component, inter-unit communication and processing firmware (software) failures which may cause loss of the safety function of the equipment. These facilities shall result in fault indication or alarm. Separate indication of the source of the fault is desirable.

It should be possible to set the fault alarm to a point below the minimum of the effective range of measurement such that on failure of the detector assembly this alarm will operate within 5 min of the failure.

There will generally be an interrelationship between the time for the alarm to operate, the frequency of false alarms and the margin between background level and alarm level.

The low level alarm may be set to operate above an enhanced background (priming source used to elevate existing background to ensure detection functionality) where the statistics of the measurement are such that they minimize false alarms.

4.2.4.5 Priming sources

Where radioactive sources are incorporated into the detector assembly, these sources and the labelling of the instrument shall conform to the appropriate international and national regulations with regard to radioactive materials. Generally, the activity of these sources is however below regulatory concern. The time for which any radioactive sources will be effective for its function shall be specified by the manufacturer and should normally not be less than 5 years. The need to adjust the position of the source or make other equivalent adjustments such as through data changes in the operating firmware should not be required more than once each year.

Displayed information shall take account of any priming source, so that the correct reading is given for all dose rates during the specified life of the source. Account may be taken of the allowable inaccuracy.

4.2.4.6 Interrelationship between response time and statistical fluctuations

The response time and the coefficient of variation of the statistical fluctuations are interdependent characteristics for which acceptable limits are given in 6.9 and 6.10.

For high dose rates, it is recommended that whenever possible, while conforming to the limits in this standard, the response time be reduced. Response times of less than 1 s offer little advantage and thus it is better practice to reduce the statistical fluctuations.

For very low dose rates, the manufacturer shall indicate the appropriate values of the coefficient of variation and response time which may, with agreement from the purchaser, exceed the limits given in 6.9 and 6.10.

5 General test procedures

5.1 Nature of tests

Unless otherwise specified in the individual clauses, all tests enumerated in this standard are to be considered as "type tests". Nevertheless, by agreement between the manufacturer and the purchaser, some of them may be considered as acceptance tests.

5.2 Reference conditions and standard test conditions

Reference and standard test conditions are given in Table 3. Reference conditions are those conditions to which the performance of the instrument is referred and standard test conditions indicate the necessary tolerances in practical testing. Except where otherwise specified, the tests in this standard shall be performed under the standard test conditions given in the third column of Table 3.

5.3 Tests performed under standard test conditions

Tests performed under standard test conditions are listed in Table 4, which indicates, for each characteristic under test, the requirements according to the clause where the corresponding test method is described.

5.4 Tests performed with variation of influence quantities

For those tests intended to determine the effects of variations in the influence quantities given in Table 5, and Table 6, all other influence quantities shall be maintained within the limits for the standard test conditions given in Table 3 unless otherwise specified in the test procedure concerned.

5.5 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuations of the indication arising from the random nature of radiation alone is a significant fraction of the variation of the indication permitted in the test, then sufficient readings shall be taken to ensure that the mean value of such readings may be estimated with sufficient accuracy to demonstrate compliance with the test in question.

The interval between such readings shall be sufficient to ensure that the readings are statistically independent.

5.6 Reference radiation

5.6.1 Gamma

All tests shall be conducted with ^{137}Cs unless specified otherwise. As an alternative, ^{60}Co may be used. In this case, correction shall be made for the difference in response of the detector assembly between ^{60}Co and ^{137}Cs . These radiation qualities are specified in the ISO 4037 series: Parts 1 to 4.

5.6.2 Beta

A test for the detector assembly response to gamma radiation in the presence of beta radiation shall be conducted based on agreement between the manufacturer and the purchaser. The response of the detector assembly to beta radiation from a $^{90}\text{Sr}/^{90}\text{Y}$ source shall be stated by the manufacturer. The reference beta radiation fields are specified in the ISO 6980 series: Parts 1 to 3.

5.6.3 Neutron

The response to neutron radiation shall be stated by the manufacturer at the request of the 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. ^{252}Cf or $^{241}\text{Am}/\text{Be}$ should be used for neutron tests. The reference neutron radiation fields are specified in the ISO 8529 series: Parts 1 to 3.

5.7 Consideration of natural background radiation

For the measurement of low dose equivalent rates it is necessary to take into account the contribution of natural background radiation. This is usually done by taking a significant number of readings of background radiation. The mean indicated value of these readings has to be subtracted from the indicated value of the dose rate detector assembly under test. If the detector assembly contains a priming source this shall be taken into account.

6 Radiation characteristics

6.1 False alarm test

6.1.1 Requirements

No unexplained alarms shall occur over a period of 100 h with the monitor operating in a stable background. Repeat if explained alarms occur.

6.1.2 Method of test

With the monitor operating normally in a stable background, observe the monitor to verify that no alarms occur for a period of 100 h.

6.2 Point of test

The point of test at which the gamma dose rate is to be determined shall be chosen such that the distance between the radiation source and the detection assembly shall be sufficiently large to ensure that any error due to the non-uniformity of irradiation of the detector is not more than $\pm 5\%$.

6.3 Linearity

6.3.1 Requirements

This refers to the linearity of the instrument's measurement range. The instrument error is to be established in respect of the radiation quantity which the equipment is designed to measure.

Under standard test conditions, the response linearity of the detector assembly, when exposed to either of the reference radiations shall not exceed $\pm 30\%$, over the effective measurement range.

NOTE This uncertainty is additional to the uncertainty in the value of the conventional true dose rate.

6.3.2 Test source of gamma radiation

6.3.2.1 Requirements

The test shall be performed with a source of ^{137}Cs or ^{60}Co . The use of ^{60}Co is subject to the requirements of 5.6.

The conventional true dose rate shall be known and the uncertainty stated (see NOTE in 3.12.5).

6.3.2.2 Tests to be performed

A type test shall be performed on monitoring units comprised of at least one of each type of processing, alarm, and detector assemblies.

Routine tests shall be carried out on each combination of processing units, alarm units and detector assemblies.

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

6.3.2.3 Type tests

For assemblies provided with linear scales, the type test shall be carried out on all ranges and on at least 3 points on each range, i.e. at about 25 %, 50 % and 75 % of the scale range.

For assemblies provided with single range and logarithm graduation, or for digital displays, the type test shall be carried out on all order of magnitude scales of dose rate and on at least 2 points on each order of magnitude scale. (The higher value in each decade shall be at least three times the lower and at least 70 % of the maximum of that order of magnitude.) If a detector contains a priming source this shall be taken into account.

6.3.2.4 Routine tests

For assemblies provided with linear scale, the routine test shall be carried out at one point on one value (between 50 % and 75 %) in the range in which the highest alarm is set.

For assemblies provided with single range and logarithmic graduation, or for digital displays, the test shall be carried out on one value (between 10 % and 90 %) in the range in which the highest alarm is set. If a detector contains a priming source this shall be taken into account.

For routine tests, current or pulse injection to the processing assembly is acceptable. When current or pulse injection is used it shall be based on the radiation type test results.

6.4 Variation of response with photon radiation energy

6.4.1 Requirements

The response in reference direction to photon energy between 80 keV and 1,5 MeV shall be within –25 % to +40 %.

For assemblies intended for use in energies between 50 keV and 80 keV and/or higher than 1,5 MeV, the variation shall be subject to agreement between the purchaser and manufacturer.

If the ambient dosimeter is to be used in the vicinity of nuclear power installations, the response up to 7 MeV should fulfil the above requirement by agreement between the purchaser and manufacturer.

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.

In the case of multiple detectors covering different dose rate ranges, the test should be performed for each detector at the appropriate dose rate and energy.

6.4.2 Method of test

The following energies should be used for low air kerma rates (taken from the ISO 4037 series):

- mean energy (keV): quality (tube voltage, kV);
- 83 keV(N-100) or 87 keV(L-100);
- 100 keV(N-120) or 109 keV(L-125);
- 118 keV(N-150);
- 164 keV(N-200) or 149 keV(L-170);
- 208 keV(N-250) or 211 keV(L-240);
- 662 keV(Cs-137);
- 1 250 keV (Co-60).

When the instrument is intended for use in other energies:

- 48 keV(N-60) or 48 keV(L-55);
- 65 keV(N-80) or 60 keV(L-70) or 59,5 keV(Am-241).

For 6,61 MeV the following alternatives may be used:

- 6,61 MeV (R-F); or
- 6,61 MeV (R-O); or
- verification by Monte Carlo simulation especially for this energy.

The test for this energy shall be agreed between the purchaser and manufacturer.

The results shall be expressed as a ratio of the indication per unit dose rate for each radiation source utilized to the response per unit dose rate for the reference gamma radiation (^{137}Cs).

6.5 Variation of response with angle of incidence

6.5.1 Requirements

The response with angle of incidence against the direction of calibration for more than one plane of response shall be within following variation (see Figure 1):

For the range 80 keV to 1,5 MeV:

- for 661,6 keV $0^\circ, \pm 15^\circ, \pm 30^\circ, \pm 45^\circ, \pm 60^\circ \pm 20\%$;
- for 83 keV $0^\circ, \pm 15^\circ, \pm 30^\circ, \pm 45^\circ, \pm 60^\circ$ to be defined by the manufacturer;
- for 59,5/60 keV $0^\circ, \pm 15^\circ, \pm 30^\circ, \pm 45^\circ, \pm 60^\circ \pm 30\%$ where applicable.

The manufacturer shall state the relative variation of the response for $\pm 90^\circ$.

The results should be expressed as a ratio of the response per unit dose rate for each radiation source utilized to the response per unit dose rate for zero degrees angle of incidence.

In general, detector assemblies are designed to be installed on a flat surface such as a wall. So the range of the angles to be tested are limited to $\pm 60^\circ$ from the normal to the mounting surface (see 6.5.2). If another range of the angles is required, the range of the angles to be tested shall be selected by agreement between the manufacturer and purchaser.

The necessity of additional angles to be tested for the other X-ray or gamma ray exposures shall be determined in accordance with the agreement made between the manufacturer and purchaser.

- a) The direction of radiation shall be changed in steps of 15° in a plane including the calibration direction specified by the manufacturer and the response determined throughout the range of angles specified in 6.5.1.
- b) The procedure of a) above shall be repeated for the plane perpendicular to that used in a) but still including the calibration direction.

6.5.2 Method of test

The assembly shall be mounted so as to most conveniently enable measurements to be made at the required angle.

For this test, the reference point of the detector assembly shall be placed at a point of test where the dose (rate) is known. The photon radiation qualities of the narrow spectrum series and the gamma sources ^{137}Cs and ^{241}Am specified in the ISO 4037 series should be used if possible.

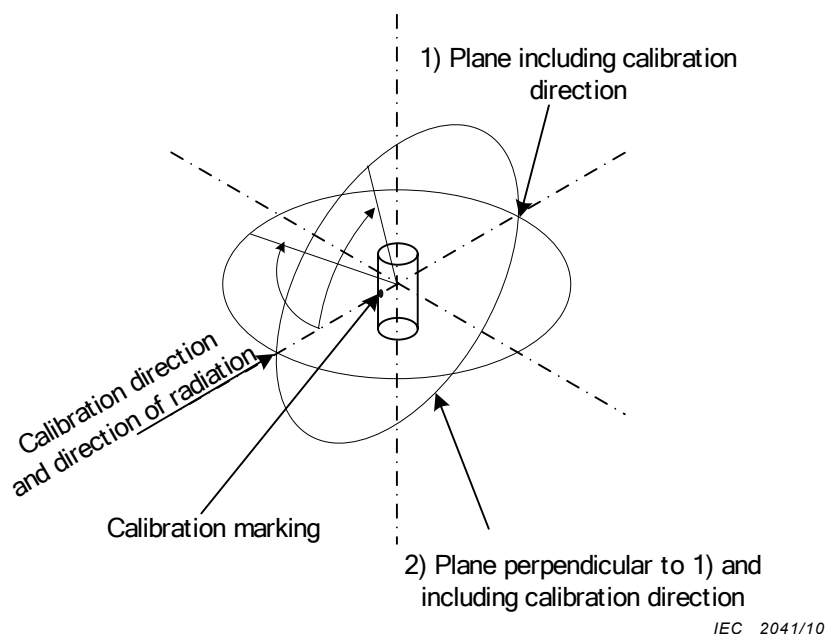


Figure 1 – Example of the rotation of the detection assembly

6.6 Response to beta radiation

6.6.1 Requirements

When the detector assembly is used for measuring dose due to gamma radiation in the presence of beta radiation, the more energetic particles may penetrate into the sensitive volume of the detector. The response of the detector assembly to beta radiation from an Sr-90/Y-90 source shall be stated by the manufacturer, if the detector assembly is intended to be used in the presence of beta radiation.

6.6.2 Method of test

Expose the detector assembly at 0° angle of radiation incidence to beta reference radiation specified in ISO 6980: Parts 1 to 3 of the following quality:

– $^{90}\text{Sr}/^{90}\text{Y}$ ($\bar{E} \approx 0,8 \text{ MeV}$);

The indicated dose rate value shall be less than 10 % of the exposed dose rate value.

6.7 Response to neutron radiation

6.7.1 Requirements

The response of the detector assembly to neutron radiation shall be stated by the manufacturer if the detector assembly is intended to be used in the presence of neutron radiation.

By agreement between the purchaser and the manufacturer, tests can be omitted if documented analysis demonstrates that the instrument is not sensitive to neutron radiation.

6.7.2 Method of test

When a test is required the following procedure is recommended.

The detector assembly shall be exposed in the reference calibration direction, to radiation from a ^{252}Cf or $^{241}\text{Am/Be}$ source such that the reading will be 70 % of the maximum of the

second most sensitive order of magnitude scale. If this is not practically achievable, a limit of 10 mSv/h should be applied.

The indication $I_{(n+\gamma)}$ from the neutron source shall be noted.

The photon dose rate $\dot{H}^*(10)\gamma$ at the detector assembly shall be determined (by calculation or use of a reference instrument) and the indication $I_{(\gamma)}$ established from this: $I_{(\gamma)} = R_{\gamma} \times \dot{H}^*(10)\gamma$ taking into account the photon response to radiation from ^{60}Co . For ^{252}Cf , the fraction of photon to neutron dose rate is usually about 0,04.

NOTE 1 The energy of photons emitted from a ^{252}Cf source is similar to the energy emitted from a ^{60}Co source (about 1,25 MeV).

Similarly the neutron dose rate, $\dot{H}^*(10)n$ shall be determined.

The neutron response shall be expressed as:

$$R_n = \frac{I_{(n+\gamma)} - I_{(\gamma)}}{H^*(10)_n}.$$

Neutron radiation qualities are specified in the ISO 8529 series: Parts 1 to 3.

NOTE 2 Encasing the ^{252}Cf source in 1 mm of lead would reduce the gamma (photon) emissions.

NOTE 3 The dose rate quantity is chosen to $\dot{H}^*(10)$ as this quantity is equivalently defined for neutron and photon radiation.

6.8 Overload characteristics

6.8.1 Requirements

For dose rates greater than that corresponding to a scale maximum, the indication of the detector assembly/monitoring unit shall be off scale at the higher end of the scale and shall remain so. This requirement shall apply to each scale range where the scale change is switchable.

6.8.2 Method of test

Prior to the overload test, reference readings shall be established. The readings shall be obtained from the each scale.

The detector assembly shall then be exposed for 5 min to a dose rate 10 times the scale maximum. The indication shall remain off scale at the higher end of the scale throughout this period.

The time taken by the monitor to return to normal after the dose rate is returned to the pre-exposure level shall not be greater than 10 min. The post test reading shall be within $\pm 10\%$ of the pre-test or reference readings.

6.9 Statistical fluctuations

6.9.1 Requirements

The coefficient of variation of the dose rate due to random fluctuations shall be less than 20 % for the most sensitive scale and 10 % for all other scales.