BS IEC 62534:2010

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Radiation protection instrumentation — Highly sensitive hand-held instruments for neutron detection of radioactive material

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement.

A list of organizations represented on this committee can be obtained on request to its secretary.

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ISBN 978 0 580 59410 6

ICS 13.280

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2010.

Amendments issued since publication

Amd. No.	Date	Text affected

IEC 62534

Edition 1.0 2010-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Radiation protection instrumentation – Highly sensitive hand-held instruments for neutron detection of radioactive material

Instrumentation pour la radioprotection – Instruments portables de haute sensibilité pour la détection neutronique de matières radioactives

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX
U

ICS 13.280

ISBN 978-2-88912-004-8

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIATION PROTECTION INSTRUMENTATION – HIGHLY SENSITIVE HAND-HELD INSTRUMENTS FOR NEUTRON DETECTION OF RADIOACTIVE MATERIAL

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International Standard IEC 62534 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

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

FDIS	Report on voting
45B/639/FDIS	45B/653/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- withdrawn,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.

RADIATION PROTECTION INSTRUMENTATION – HIGHLY SENSITIVE HAND-HELD INSTRUMENTS FOR NEUTRON DETECTION OF RADIOACTIVE MATERIAL

1 Scope and object

This International Standard applies to hand-held instruments used for the detection and localization of neutron emitting radioactive material. These instruments are highly sensitive meaning that they are designed to detect slight variations in the range of usual background that may be caused by illicit trafficking or inadvertent movement of radioactive material. This high sensitivity allows scanning of larger volume items such as vehicles and containers. These instruments may also be used in fixed or temporally fixed unattended mode to monitor check points or critical areas. Instruments addressed by this standard will also provide a means to detect photon radiation for personal protection.

This standard does not apply to the performance of radiation protection instrumentation which is covered in IEC 61005 and in IEC 61526.

The object of this standard is to establish performance requirements, provide examples of acceptable test methods, and to specify general characteristics, general test conditions, radiation characteristics, electrical safety, and environmental characteristics, that are used to determine if an instrument meets the requirements of this standard.

The results of tests performed provide information to government agencies and other users on the capability of radiation detection instruments for reliably detecting neutron sources.

Obtaining operating performance that meets or exceeds the specifications as stated in this standard depends upon properly establishing appropriate operating parameters, maintaining calibration, implementing a suitable response testing and maintenance program, auditing compliance with quality requirements, and providing proper training for operating personnel.

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 60050-393:2003, *International Electrotechnical Vocabulary (IEV) – 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 60529:2001, *Degrees of protection provided by enclosures (IP Code)*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61005:2003, *Radiation protection instrumentation – Neutron ambient dose equivalent (rate) meters*

IEC 61526:2005, *Radiation protection instrumentation – Measurement of personal dose equivalents Hp(10) and Hp(0,07) for X, gamma, neutron and beta radiations – Direct reading personal dose equivalent meters and monitors*

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

3 Terms and definitions

3.1 General

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

NOTE Radiation quantities and dosimetric terms are from IEC 60050-393 and IEC 60050-394.

3.2 Definitions

3.2.1
acceptance test
contractual test to prove to the customer that the instrument fulfils certain specifications

[IEV 151-16-23, modified]

[IEV 394-40-05, modified]

3.2.2
alarm
audible, visual, or other signal activated when the instrument reading exceeds a preset value or falls outside of a preset range

[IEV 393-18-03, modified]

3.2.3
background level
radiation field in which the instrument is intended to operate which includes background produced by naturally occurring radioactive material

3.2.4
conventionally true value
value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose

NOTE Conventionally true value of a quantity is sometimes called assigned value, best estimate of the value, conventional value or reference value.

[IEV 394-40-10]

3.2.5
false alarm
alarm not caused by an increase in radiation level over background conditions

3.2.6
functionality test
test performed to verify that alarms activate and that radiation detection is acceptable

3.2.7
influence quantity
quantity that may have a bearing on the result of a measurement without being the subject of the measurement

3.2.8
manufacturer
includes the designer of the equipment

3.2.9
point of measurement
place at which the conventionally true values are determined and at which the reference point of the instrument is placed for calibration or test purposes

3.2.10
purchaser
includes the user of the equipment

3.2.11
radioactive material
in this standard, radioactive material includes special nuclear material, unless otherwise specifically noted

3.2.12
reference point of an instrument
mark on the equipment at which the instrument is positioned for the purpose of calibration and testing

NOTE The point from which the distance to the source is measured.

[IEV 394-40-15, modified]

3.2.13
type test
conformity test made on one or more items representative of the production

[IEV 151-16-16]

[IEV 394-40-02]

3.3 Quantities and units

In the present standard, units of the International System (SI) are used[1]. The definitions of radiation quantities are given in IEC 60050-393, IEC 60050-394.

The following units may also be used:

- for energy: electron-volt (symbol: eV), 1 eV = $1{,}602 \times 10^{-19}$ J;
- for time: years (y), days (d), hours (h), minutes (min).

Multiples and submultiples of SI units will be used, when practicable, according to the SI system.

4 General requirements

4.1 General characteristics

Instruments addressed by this standard are used for the detection of neutron emitting radioactive material. These instruments are hand-held and battery-powered. They have a significantly higher detection capability than pocket-sized devices which allows them to be used to search around larger volume items such as vehicles and containers.

[1] The International System of Units, 8th edition, 2006.

4.2 Physical configuration

The instrument case design shall meet the requirements stated for IP code 53 (see IEC 60529).

Controls and adjustments that may affect the operation of the instrument including setting of alarms shall be designed so that access to them is limited to authorized persons.

Provisions shall be made to permit testing of visual and/or sound warning indicators without the use of radiation sources.

Alarm threshold values shall be calculated by the instrument automatically using background measurements and user definable alarm factors.

4.3 Basic information

4.3.1 Documentation supplied

The manufacturer shall provide instrument performance specifications and instructions for operation. See Clause 8 for details.

4.3.2 Radiation detector

Manufacturer provided information shall describe the radiation detector types used for neutron detection and the personal protection alarm (e.g., ^{3}He, GM). For gas-filled counter tubes the internal pressure shall be stated by the manufacturer.

The instrument's fluence response to bare and moderated ^{252}Cf shall be stated by the manufacturer.

4.3.3 Size

The dimensions of the instrument shall be specified by the manufacturer with maximum dimensions of 350 mm × 200 mm × 150 mm excluding the handle.

4.3.4 Weight

The weight or mass of the instrument shall be specified by the manufacturer and should be less than 5 kg.

4.4 Operating modes

4.4.1 Monitor mode

The instrument shall have the ability to monitor the area surrounding the instrument for changes in radiation levels that may be caused by a source passing through the area. This shall be done without actions by the user and shall work autonomously. The user shall have the ability to select whether the alarm will be silent or audible, and visual or not.

4.4.2 Search mode

The instrument shall have a search function that is activated by the user. The instrument shall provide an audible and visual indication when operated in search mode. Audible and visual indications shall be related to the magnitude of the radiation field (e.g., increasing frequency or pitch of beep tone with increasing radiation signal) for eyes-free searching and localization.

4.4.3 Integration mode

The instrument shall have the ability to integrate counts for an extended period of time. The start and end of the integration time shall be user activated with the accumulated counts displayed as the measurement proceeds. An alarm shall be provided based on the accumulated counts. The integrated mode alarm method shall be described by the manufacturer.

4.5 Maintenance/Calibration

The instrument shall have an access-controlled, menu-driven mode that will allow personnel to check and perform adjustments as needed to calibrate the instrument as well as make adjustments to factors that can control the response of the instrument.

4.6 Communication interface

The instrument shall have the ability to transfer data to another device such as a personal computer. The manufacturer shall provide a full description of the transfer data format. "XML" format based on ANSI N42.42 is recommended.

4.7 User interface

The following are considered essential or desirable:

a) the following shall be provided:
   – simple to use for non-expert users and user-friendly controls for routine operation,
   – neutron radiation alarms with visual and audible alarms,
   – display that provides a method to track radiation levels when operating in the "search" mode,
   – display that provides a real-time radiation level indication that can be viewed when operating in the "monitor" mode,
   – audible and/or visual indication that is related to the magnitude of the radiation field (e.g., increasing frequency or pitch of beep tone with increasing radiation signal) for eyes-free searching and localization,
   – readable display in all lighting conditions including darkness,
   – protection of the setting of all operational parameters, if available,
   – controls and switches that are designed in a way to minimize accidental operation,
   – diagnostic capabilities,
   – indication of battery status, and
   – the capability to operate if the user is wearing gloves.

b) the following should be provided:
   – silent alarms for covert operation such as vibration alarm and/or earphone connection with an adjustable volume to cope with the large variations in human hearing sensitivity and noise level.

4.8 Markings

4.8.1 General

All external instrument controls, displays, and adjustments shall be identified as to function. Internal controls needed for operation shall be identified through markings and identification in technical manuals. External markings shall be easily readable and permanently fixed under normal conditions of use.

4.8.2 Exterior markings

The following markings shall appear on the exterior of the instrument or each major assembly (e.g., detector probe) as appropriate:

- manufacturer and model number,

- unique serial number,
- location of the reference point, and
- function designation for controls, switches, and adjustments that are not menu or software driven.

Markings shall be easily readable and permanently fixed under normal conditions of use (including use of normal decontamination procedures).

4.9 Power supply

4.9.1 Requirements

Instruments shall be equipped with a test circuit or other visible direct indicator of battery condition for each battery circuit.

The manufacturer shall state the expected continuous operating time using the recommended batteries and the conditions (functional and environmental) used to determine this time.

The instrument shall be fully operational for a minimum of 8 h after warm-up under standard test conditions. The low-battery indication shall be no lower than the minimum voltage required for proper operation.

If operated using consumable batteries, the batteries shall be widely available, not unique to the instrument, and be field replaceable (e.g., AA) with no special tools. Battery chargers shall meet appropriate electrical standards.

4.9.2 External DC or AC power

The instrument should be capable of operating from an external DC or AC source. Adequate protection from reverse polarity, over-voltage, and electrical noise shall be provided. AC or DC power sources may include:

a) 12 V DC as would be obtained from a 12-volt vehicle electrical system.
b) A portable battery pack, such as one that can be worn, that supplies 4 V DC to 28 V DC.
c) A regulated 12 V DC power supply operating from mains power.
d) A single phase 100 V AC to 240 V AC 50 Hz – 60 Hz power supply.

Requirements are verified by observation of the instrument and review of manufacturer-provided information.

4.10 Protection of switches

Switches and other controls should be protected to minimize or prevent inadvertent deactivation or improper operation of the instrument.

4.11 Display units

Neutron indication shall be in counts per second.

4.12 Effective range of measurement

The neutron energy range shall be from thermal to fast neutrons with tests performed using moderated and unmoderated ^{252}Cf.

The manufacturer shall also state the range for neutron count rate indication.

4.13 Alarms

4.13.1 Source indication alarm

A source indication alarm shall be provided when the measured neutron field (count rate) is above the source indication alarm threshold. This alarm threshold shall be calculated by the instrument from the background measurement by adding a user-defined count rate increment or number of standard deviations (depending on instrument operating mode). The alarm shall be both audible and visual, and not be affected by slowly increasing radiation fields that could cause a slow change in the alarm threshold. It shall not be possible to switch off all alarm indications at the same time.

4.13.2 Personal protection alarm

Alarms shall be provided to alert the user when the measured neutron field (counts per second) or the photon radiation field intensity are above a user-selected threshold level (typically 100 μSv.h^{-1}). Each alarm shall be audible and visual, be different from the neutron source indication alarm, and adjustable through the restricted mode. For the personal protection photon radiation alarm, the alarm value shall be based on ^{137}Cs. For neutron, the alarm value shall be based on the spectrum from ^{252}Cf.

The personal protection alarm shall be functional over the stated range of the instrument.

4.14 Explosive atmospheres

The manufacturer shall state as to whether the instrument is certified for use in explosive atmospheres and its category. Proof of certification shall be provided when claimed.

4.15 Indication features

The instrument shall provide an indication of its operational status and alarm condition. The user shall have the ability to select the visibility of the status indication.

All alarm indicators shall automatically or manually reset as defined by the user.

5 General test procedure

5.1 Nature of test

Unless otherwise specified in the individual steps, all tests enumerated in this standard are to be considered type tests. Certain tests may be considered acceptance tests by agreement between the purchaser and the manufacturer.

When performing radiation tests as described in this standard, the reference point of the instrument shall be placed at the point of measurement and the instrument shall be oriented with respect to the direction of the radiation source as indicated by the manufacturer.

5.2 Reference conditions and standard test conditions

Reference conditions are given in Table 1. Except where otherwise specified, tests shall be carried out under the standard test conditions in accordance with Table 1. For those tests carried out under standard test conditions, the values of temperature, pressure, and relative humidity shall be stated and the appropriate corrections made to give the response under reference conditions. The values of any corrections should be stated.

5.3 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 precision to determine whether the requirements for the characteristic under test are met.

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

6 Radiation tests

6.1 Rate of false source indication alarm

6.1.1 Requirements

The false alarm rate for the source indication alarm shall be less than or equal to 1 per 1 h of continuous use when operated in a stable background environment.

6.1.2 Test method

The alarm threshold shall be the same as used in 6.2 and 6.3.

Place the instrument in an area with a stable and controlled background radiation level and switch on the instrument. Observe the instrument for a period of 8 h and note the number of alarms during that time interval. The average false alarm rate during this period shall not exceed 1 alarm in 1 h.

6.2 Alarm and response time

6.2.1 Requirements

The instrument shall indicate the presence of neutron radiation when exposed separately to both an unmoderated and moderated neutron field within a period of not more than 2 s of the exposure.

6.2.2 Test method

Neutron tests should be made in a low scatter irradiation facility (see ISO 8529-1:2001) or with the instrument placed in an area where there is open space on all sides of at least 1 m around the instrument and source. The alarm set point shall be set to the same value as that used for the false alarm test.

Expose the instrument to a neutron fluence of 0,1 n/s.cm^2 (± 20 %) from a ^{252}Cf source. Photons from the source shall be shielded with 1 cm of lead. The source to instrument distance shall be between 1 m and 2 m based on direct flux.

NOTE This fluence is approximately equivalent to an unmoderated ^{252}Cf source emitting 20 000 n/s placed 125 cm from the instrument. The distance chosen represents a point source placed in the center of a cargo container (short dimension of approximately 2,48 m). This is also based on comparison with a neutron alarm caused on a typical portal monitor.

For the test, the neutron field shall be increased to the required level within a period of not more than 2 s. The instrument shall indicate the presence of neutrons within a period of 2 s after the field increase. Reduce the field and repeat the test 60 additional times. The test result is acceptable if presence is indicated in at least 59 of 61 exposures.

The test shall be repeated with a moderated neutron field obtained by placing the ^{252}Cf source at the centre of a 30 cm diameter D_2O moderation sphere, or equivalent moderator. The use of an equivalent moderator shall be recorded.

6.3 Neutron alarm in the presence of photons

6.3.1 Requirements

The instrument should not trigger a neutron alarm when exposed to a gamma ambient dose equivalent rate of up to 0,1 mSv.h^{-1}.

The instrument shall indicate the presence of neutron radiation when exposed to a neutron source while being exposed to the increased level of photon radiation.

6.3.2 Test method

The instrument shall be exposed to photons from ^{60}Co at an ambient dose equivalent rate of 0,1 mSv.h^{-1}. Verify that that no additional neutron alarms relative to the false alarm rate are triggered within a continuous exposure time of 5 min. In order to eliminate dependence on the neutron detector geometry the distance between the ^{60}Co source and the detector should be at least 50 cm.

While the instrument is exposed to the elevated gamma field as stated above, expose the instrument to the neutron source as specified in 6.2. The instrument shall trigger a neutron alarm in 10 of 10 trials.

6.4 Over-range characteristics for neutron alarm

6.4.1 Requirements

The instrument shall indicate that an over range condition exists when the neutron radiation level is greater than the manufacturer's stated maximum.

6.4.2 Test method

Expose the instrument to a step change from ambient radiation background to at least 10 times that of the manufacturer-stated maximum. The instrument shall indicate that an over range condition exists within 3 s of the step change and shall remain in that condition for the entire exposure period (minimum of 5 min). After a minimum of 5 min exposure, reduce the radiation field to the pre-test value. The instrument shall operate normally within 5 min.

6.5 Personal protection alarm

6.5.1 Requirements

The requirements stated in 4.13.2 shall be met.

6.5.2 Test method

Expose the instrument to a step change from the ambient radiation background to an ambient radiation level that is 30 % greater than the personal protection alarm threshold. The instrument shall provide an alert indicating that the measured radiation level is greater than the personal protection alarm. The alarm shall activate within 2 s of the step change in the radiation intensity.

The alarm shall be tested separately for both gamma and neutron radiation. For gamma, the alarm shall be tested separately using ^{137}Cs and ^{60}Co. For neutron, the alarm shall be tested using moderated and unmoderated ^{252}Cf.

6.6 Warm-up time

6.6.1 Requirements

The manufacturer shall state the time required for the instrument to become fully functional. The maximum time shall be less than 2 min.

6.6.2 Test method

Switch on the instrument following the manufacturer's guidance and verify that the unit functions properly by doing an alarm test after the warm up time stated by the manufacturer or within two minutes, whichever is shorter.

7 Environmental, mechanical and electrical performance requirements

7.1 Temperature

7.1.1 Requirements

Over a temperature range from –20 °C to +50 °C, the instrument shall function correctly and alarm for an increase in neutron radiation over ambient background. As a result of the temperature change, the indication of the magnitude of the radiation field from a neutron source (^{252}Cf or ^{241}Am-Be) shall not change by more than ±15 %.

There shall be no visible external damage to the instrument, and all control functions shall be verified to be operating correctly.

If the manufacturer has stated a wider operational temperature range, the instrument's ability to perform correctly over that range shall be tested.

7.1.2 Test method

Before starting each test the instrument shall be placed in an environment with a temperature of 20 °C ± 2 °C for a period of 30 min. The relative humidity of the environment should be less than 65 % to prevent condensation during testing.

Shock and ramp temperature tests shall be performed once to the high temperature extreme of 50 °C ± 5 °C and once to the low temperature extreme of –20 °C ± 3 °C applying the following procedure:

a) Shock tests – Room temperature to high and low temperature extreme

The instrument shall be either directly placed in an environmental chamber that has equilibrated to the extreme temperature (high or low) or it shall be introduced in the chamber at 20 °C and then the temperature in the chamber shall be changed to the extreme level within 5 min. Reading changes as a function of time shall be recorded for a period of 60 min. At the end of this part of the test, the instrument shall be placed in the same manner at a temperature of 20 °C ± 2 °C for a period of 60 min and the reading of the instrument at the end of interval shall be recorded. The reading shall not change by more than ±15 % after the initial 15 min following the change. The alarm function shall be verified at each extreme temperature.

b) Temperature ramp tests – Room temperature to high and low temperature extreme

The instrument shall be placed in a test chamber at a temperature of 20 °C ± 2 °C. The temperature shall then be linearly changed to the extreme temperature (high or low) at a rate of approximately 10°C.h^{-1}. Reading changes occurring during this time period shall be recorded. The temperature of the test chamber shall be maintained at the extreme temperature level for 8 h and the reading of the instrument shall be recorded. The reading shall not change by more than ±15 %. The alarm function shall be verified at each extreme temperature.

7.2 Humidity

7.2.1 Requirements

Over the range of relative humidity from 40 % to 93 % at 35 °C, the instrument shall function correctly and alarm to an increase in neutron radiation over the ambient background radiation level. As a result of the humidity, the indication of the magnitude of the radiation field from a neutron source shall not change by more than ±15 %.

There shall be no visible external damage to the instrument, and all control functions shall be verified to be operating correctly.

7.2.2 Test method

The instrument shall be placed in an environmental chamber at a temperature of 20 °C ± 2 °C and relative humidity of approximately 65 % and allowed to stabilize for 30 min. Any reading changes occurring during this time period shall be recorded. The temperature and relative humidity shall then be linearly increased to +35 °C and 93 %, respectively, at a rate of approximately 10 % relative humidity per hour. The relative humidity and temperature in the test chamber shall be maintained for 16 h and the reading of the instrument shall be recorded. The relative humidity shall then be reduced to 40 %, at the rate given above, while maintaining the temperature at +35 °C. Reading changes occurring during this time period shall be recorded. The reading of the instrument shall not change by more than ±15 %. The alarm function shall be verified at the +35 °C and 93 % set point.

7.3 Cold temperature start-up

7.3.1 Requirements

The instrument shall be able to operate when switched on at the cold temperature limit (–20 °C). The indication of the magnitude of the radiation field from a neutron source (^{252}Cf or ^{241}Am-Be) shall not change by more than ±15 %.

7.3.2 Test method

The instrument shall be placed in a test chamber at a temperature of 20 °C ± 2 °C. Switch on the instrument and after the manufacturer‘s stated warm up time, record the response obtained from a the neutron source, then switch off the instrument.

The temperature shall then be linearly changed to the cold temperature limit of –20 °C at a rate of approximately 10 °C.h^{-1}. Allow the temperature to stabilize for a minimum of 2 h.

Switch on the instrument, and after the manufacturer’s stated warm-up time, re-expose the instrument to the same radiation field that was used prior to the test. Verify the alarm function of the instrument. The instrument shall function properly and the reading shall be within ±15 % of the reading obtained prior to the test.

7.4 Dust and moisture resistance

7.4.1 Requirements

The instrument case design shall meet the requirements stated for IP code 53 (see IEC 60529), which means that the instrument shall be protected from the ingress of dust and spraying water. For IP53, the ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the instrument or to impair safety, and water sprayed at an angle up to 60º on either side of the vertical shall have no harmful effects.

Following the dust and moisture tests, the instrument shall function correctly and alarm for an increase of the neutron radiation level over the alarm threshold. The indication of the magnitude of the radiation field from a neutron source (^{252}Cf or ^{241}Am-Be) shall not change by more than ±15 %. There shall be no visible damage to the instrument, and all control functions shall be verified to be operating correctly.

Instruments that are specified to be resistant to salt water spray shall exhibit this same performance after being subjected to a salt water spray.

7.4.2 Test method – Dust

The test shall be made using a dust chamber (IEC 60529, category 2) where the powder circulation pump may be replaced by other means suitable to maintain the talcum powder in suspension in a closed test chamber. The amount of powder to be used should be 2 kg/m^3 of the test chamber volume. The powder shall not have been used for more than 20 tests.

The instrument shall then be exposed to the dust environment for a period of 1 h. After exposure, the reading of the instrument shall not change by more than ±15 % from the pre-exposure values.

Following exposure, the alarm function shall be verified followed by an inspection to determine the extent of dust ingress. Particular attention shall be made to the battery compartment and any other easily accessed portions of the instrument. The protection is satisfactory if, on inspection, powder has not accumulated in a quantity or location such that, as with any other kind of dust, it could interfere with the correct operation of the instrument or impair safety.

7.4.3 Test method – Moisture

The test shall be made using a suitable nozzle (see IEC 60529, spray nozzle) with the water pressure adjusted to give a flow rate of 10 l.min^{-1} ± 5 %, which should be kept constant during the test. The water temperature should not differ by more than 5 °C from the temperature of the instrument under test. The test duration is 5 min.

The instrument shall be exposed to the water spray. The spray nozzle should be located approximately 2 m from the instrument. The instrument shall be positioned such that the nozzle is directly pointed at the display. During the exposure, the orientation shall be changed by +60º and –60º in two orthogonal planes. The reading of the instrument shall not change by more than ±15 % from the pre-exposure values.

Following exposure, the alarm function shall be verified followed by an inspection of the instrument including the battery compartment to ensure that moisture did not penetrate into the instrument.

For instruments that are designed for use in salt water spray environments, this test shall be conducted using salt water with a specific mass of approximately 1 025 kg.m^{-3} at 20 °C ± 5 °C.

7.5 Mechanical

The requirements in Clause 4 regarding size, mass, case construction, reference point marking and switch protection can be verified by inspection of the instrument. The following tests are intended to determine the effect of mechanical handling of the instrument on its response.

7.5.1 Drop

7.5.1.1 Requirements

The instrument shall function properly after being dropped from a height of 0,3 m onto a hardwood surface and from a height of 1 m in its shipping case.

7.5.1.2 Test method

The instrument shall be dropped from a height of 0,3 m onto a hardwood surface on each of its surfaces. The response of the instrument after the drops shall not change by more than ±15 % from the original reading before all drops. The instrument shall then be exposed to a neutron field to verify alarm functionality. There shall be no visible external damage to the instrument, and all control functions shall be verified to be operating correctly.

The drop test shall be repeated from a height of 1 m with the instrument in its shipping case.

7.5.2 Vibration

7.5.2.1 Requirements

The instrument shall withstand exposure to vibrations associated with the operation of handheld or hand-carried equipment. The physical condition and functionality of the instrument shall not be affected by the vibration exposure (e.g., solder joints shall hold, nuts and bolts shall not come loose).

7.5.2.2 Test method

Conduct a visual inspection and verify that the instrument is functioning properly. Subject the instrument to a random vibration at 0,01 $g^2.Hz^{-1}$ (spectral density) using 5 Hz and 500 Hz for the frequency endpoints for a period of 1 h in each of three orthogonal orientations. After each 1 h vibration interval, perform a functionality test including alarm activation.

After the test, inspect the instrument for mechanical damage and loose components. If internal inspection is not possible, check for loose components by gently shaking the instrument.

The instrument's response shall be unaffected (remain within ± 15 % of the pre-test values) after the vibration test.

7.6 Impact (Microphonics)

7.6.1 Requirements

The instrument's response shall be unaffected by microphonic conditions such as those that may occur from low intensity impacts from sharp contact with hard surfaces. The indication of the magnitude of the radiation field shall not change by more than ±15 %.

7.6.2 Test method

Prior to the test, perform a functionality test.

Using an appropriate test device (e.g., spring hammer), expose the instrument case to 3 impacts at an intensity of 0,2 J. The test shall be performed on each side of the instrument case while observing the response. The instrument's response shall remain within ±15 % of the pre-test values.

After the test, inspect the instrument for mechanical damage and loose components. If internal inspection is not possible, check for loose components by gently shaking the instrument.

7.7 Battery requirements

7.7.1 Requirements

a) The instrument should operate on standard rechargeable and/or non-rechargeable batteries.

b) With new or fully charged batteries of the type recommended by the manufacturer, the battery life shall be at least 8 h under no alarm conditions.

c) Under continuous alarm conditions, the battery lifetime should be greater than 30 min.

d) A low battery indicator shall be provided to inform the user that the batteries need to be replaced or recharged. The instrument shall be fully operational until the low battery indication is activated.

7.7.2 Test method

Requirement a) shall be verified through review of the technical manual and direct observation of the batteries.

To verify requirement b), ensure that the batteries are fully charged and after allowing the instrument to warm up, expose the instrument to neutron radiation and note the reading. Leave the instrument on and after a period of 8 h repeat the measurement. The average reading from the second exposure shall be within ± 15 % of the initial average reading.

To verify requirement c), ensure that the batteries are fully charged and after allowing the instrument to warm up, expose the instrument to a neutron radiation field that activates the alarm. The alarm shall remain functional for a minimum of 30 min exposure in this field.

To verify requirement d), replace the batteries with a DC power supply and appropriate series resistor to simulate a battery near the end of its life. Reduce the applied voltage to the level that activates the low-battery indication. Increase the voltage until the low-battery indicator just turns off. Verify that the instrument operates by exposing the instrument to the same neutron field as used for the verification of requirement b). The average reading at the test voltage shall be within ± 15 % of the average reading at full voltage and that the alarms function as required.

7.8 Electrostatic discharge

7.8.1 Requirements

The instrument shall function properly during and after exposure to contact discharges at intensities of up to 6 kV. The indication of the magnitude of the radiation field shall not change by more than ±15 %.

7.8.2 Test method

The “contact discharge” technique shall be used. Discharge points shall be selected based on user accessibility (see IEC 61000-4-2). There shall be ten discharges per discharge point with a one-second-recovery time between each discharge. The maximum intensity of each discharge is 6 kV. An alarm can occur at the time of discharge.

The instrument shall then be exposed to a neutron radiation field to verify that the instrument functions normally, including alarm activation. There shall be no visible external damage to the instrument, and all control functions shall be verified to be operating correctly.

7.9 Radio Frequency (RF)

7.9.1 Requirements

The instrument should not be affected when exposed to RF fields from 80 MHz to 1 000 MHz and from 1,4 GHz to 2,5 GHz at 10 $V.m^{-1}$. The indication of the magnitude of the radiation field shall not change by more than ±15 %. No alarms or other response or functional changes shall occur due to the RF exposure alone.

7.9.2 Test method

Place the instrument in an RF controlled environment and expose it in only one orientation to an RF field of 20 $V.m^{-1}$ over a frequency range from 80 MHz to 1 000 MHz and from 1,4 GHz to 2,5 GHz measured without an instrument present in the irradiation area. The test should be performed using an automated sweep at a frequency change rate not greater 1 % of the fundamental (previous) frequency for the first range and 0,1 GHz for the second range. Dwell time should be chosen based on the instrument's response time, but should not be less than 3 s. If susceptibilities are observed, the test shall be repeated over the frequencies showing susceptibility at 10 $V.m^{-1}$ in three orthogonal orientations. No alarms or other response or functional changes shall occur due to the RF exposure alone.

The instrument shall then be exposed to a neutron source while being exposed to the RF scan. The reading of the instrument shall not change by more than ±15 %. The same guidance stated previously shall be followed if susceptibilities are observed at 20 $V.m^{-1}$.

There shall be no visible external damage to the instrument, and all control functions shall be verified to be operating correctly.

7.10 Radiated emissions

7.10.1 Requirement

RF emissions from an instrument shall be less than that which can interfere with other equipment located in the area of use. RF emissions when measured at 3 m shall be less than those shown in Table 2.

7.10.2 Test method

Place the instrument in a shielded room or chamber, as appropriate. Place an antenna 3 m from the assembly. With the instrument off, collect a background spectrum using a bandwidth of 50 kHz.

Switch the instrument on and perform a RF scan. RF emissions shall be less than the limits shown in Table 2 throughout the test.

7.11 Conducted immunity

7.11.1 Requirements

The instrument should not be affected by RF fields that can be conducted onto the instrument through an external conducting cable. The indication of the magnitude of the radiation field shall not change by more than ±15 %.

Instruments that do not have at least one external conducting cable are excluded.

7.11.2 Test method

Without the addition of radiation test sources, expose the instrument to a conducted RF field over the frequency range from 150 kHz to 80 MHz at an intensity of 140 dB (µV) 80 % amplitude modulated with a 1 kHz sine wave.

The test should be performed using an automated sweep at a frequency change rate not greater 1 % of the fundamental (previous) frequency. Dwell time should be chosen based on the instrument's response time, but should not be less than 3 s.

The results are acceptable if no alarms, spurious indications, or reproducible changes in response occur that exceed ±15 % of the initial indicated value.

7.12 Magnetic fields

7.12.1 Requirements

The instrument shall be fully functional when exposed to a 1 mT (10 gauss) DC magnetic field. The indication of the magnitude of the radiation field shall not change by more than ±15 %.

7.12.2 Test method

Expose the instrument to a 1 mT DC magnetic field. The exposure shall be done in two orientations (0° and 90°) relative to the field lines. The mean reading of the instrument shall not change by more than ±15 %. No alarms or other response or functional changes shall occur due to the magnetic field alone.

The instrument shall then be exposed to a neutron source while being exposed to the magnetic field. The mean reading of the instrument shall not change by more than ±15 %.

8 Documentation

8.1 General

This section specifies the requirements for documentation.

8.2 Type test report

The manufacturer shall provide a report covering the type tests performed in accordance with the requirements of this standard.

8.3 Certificate

The manufacturer shall provide a certificate or other documentation containing at least the following information:

- Contacts for the manufacturer including name, address, telephone number, fax number, and email address
- Type of instrument (model number, serial number, and software version), detector and types of radiation the instrument is designed to measure, range of count rates the instrument is designed to indicate
- Reference point and reference orientation for radiation sources used for calibration
- Location and dimensions of the sensitive volumes of the detectors
- Warm-up time
- Response of the instrument to moderated and unmoderated ^{252}Cf
- Results of tests for accuracy, linearity and lower limit of detection
- Mass and dimensions of the instrument
- Power supply (battery) requirements
- Results of radiation tests
- Results of tests under environmental conditions

- Results of electrical and mechanical tests
- Certification of compliance with explosive atmosphere requirements, if applicable
- Declaration of conformity with respect to this standard

8.4 Operation and maintenance manual

Each instrument shall be supplied with operating instructions, maintenance, and technical documentation.

The manufacturer shall supply an operational and maintenance manual containing at least the following information for the user:

- Operating instructions and restrictions
- Orientation for use
- Spare parts list and special tool list (if required)
- Maintenance instructions and restrictions
- Troubleshooting guide

Table 1 – Reference conditions and standard test conditions

Influence quantities	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Reference gamma radiation source Reference neutron radiation source	^{137}Cs and ^{60}Co ^{252}Cf (D_2O moderated and unmoderated) [a]	^{137}Cs and ^{60}Co ^{252}Cf (D_2O moderated and unmoderated) [a] ^{241}Am-Be may be used for tests where changes in relative response are measured.
Warm-up time	1 min	≤ 1 min
Ambient temperature	20 °C	18 °C to 22 °C [b]
Background ambient dose equivalent rate – photon	0,1 μSv.h^{-1}	≤0,2 μSv.h^{-1}
Background ambient neutron fluence	~0,015 s^{-1}.cm^{-2}	0,015 s^{-1}.cm^{-2} (± 50 %)
Relative humidity	65 %	50 % to 75 % [a]
Atmospheric pressure	101,3 kPa	70 kPa to 106 kPa [a]
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to earth's magnetic field
Assembly controls	Set up for normal operation	Set up for normal operation
Contamination by radionuclides	Negligible	Negligible

a) The neutron source is encapsulated in 1 cm steel and 0,5 cm lead.

b) The values in the table are intended for tests performed in temperate climates. In other climates, the actual values of the quantities at the time of test shall be stated. Similarly a lower limit of pressure of 70 kPa may be permitted at higher altitudes.

Table 2 – Radiated RF emission limits

Emission frequency range MHz	**Field strength** μV/m
30–88	100
88–216	150
216–960	200
Above 960	500

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