BS EN 61577-3:2014

BSI Standards Publication

# Radiation protection instrumentation — Radon and radon decay product measuring instruments

Part 3: Specific requirements for radon decay product measuring instruments

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**National foreword**

This British Standard is the UK implementation of EN 61577-3:2014. It is derived from IEC 61577-3:2011. It supersedes BS IEC 61577-3:2012, which is withdrawn.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags [C〉 〈C].

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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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# Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 3: Specific requirements for radon decay product measuring instruments (IEC 61577-3:2011 , modified)

Instrumentation pour la radioprotection - Instruments de mesure du radon et des descendants du radon - Partie 3: Exigences spécifiques concernant les instruments de mesure des descendants du radon (CEI 61577-3:2011 , modifiée)

Strahlenschutz-Messgeräte - Geräte für die Messung von Radon und Radon-Folgeprodukten - Teil 3: Besondere Anforderungen an Messgeräte für Radonfolgeprodukte (IEC 61577-3:2011 , modifiziert)

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Comité Européen de Normalisation Electrotechnique
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## Foreword

This document (EN 61577-3:2014) consists of the text of IEC 61577-3:2011 prepared by IEC/SC 45B "Radiation protection instrumentation" of IEC/TC 45 "Nuclear instrumentation", together with the common modifications prepared by CLC/TC 45B "Radiation protection instrumentation".

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2015-11-17
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2017-11-17

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# Annex ZA
(normative)

## Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| IEC 60050-394 | - | International Electrotechnical Vocabulary (IEV) - Part 394: Nuclear instrumentation - Instruments, systems, equipment and detectors | - | - |
| IEC 60068-2-27 | - | Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock | EN 60068-2-27 | - |
| IEC 61000-6-4 | - | Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments | EN 61000-6-4 | - |
| IEC 61140 | - | Protection against electric shock - Common aspects for installation and equipment | EN 61140 | - |
| IEC 61187 | - | Electrical and electronic measuring equipment - Documentation | EN 61187 | - |
| IEC 61577-1 | - | Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 1: General principles | - | - |
| IEC 61577-4 | - | Radiation protection instrumentation - Radon and radon decay product measuring instruments - Part 4: Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR) | EN 61577-4 | - |
| ISO/IEC Guide 98-3 | 2008 | Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) | - | - |

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# INTRODUCTION

Radon is a radioactive trace gas produced by the decay of $^{226}$Ra, $^{223}$Ra and $^{224}$Ra, respectively decay products of $^{238}$U, $^{235}$U and $^{232}$Th which are present in the earth's crust. By decay, radon isotopes (i.e., $^{222}$Rn, $^{219}$Rn, $^{220}$Rn) produce three decay chains, each ending in a stable lead isotope. The radon isotope $^{220}$Rn generally is called thoron[1].

NOTE In normal conditions, due to the very short half-life of $^{219}$Rn, its activity and the activity of its RnDP[2] are considered negligible compared to the activity of the two other series. Its health effects are therefore not important. Thus in this standard $^{219}$Rn and its decay products are not considered.

Radon isotopes and their corresponding short-lived Radon Decay Products (RnDP) (i.e., $^{218}$Po, $^{214}$Pb, $^{214}$Bi, $^{214}$Po for $^{222}$Rn, and $^{216}$Po, $^{212}$Pb, $^{212}$Bi, $^{212}$Po, $^{208}$Tl for $^{220}$Rn) are of considerable importance, as they constitute the major part of the radiological exposure to natural radioactivity for the general public and workers. In some workplaces such as underground mines, spas and waterworks, the workers are exposed to very significant levels of RnDP. Various quantities of these radionuclides are airborne in a gaseous form for the radon isotopes and as particulates for the radon decay products. It is worthwhile for health physicists to be able to measure with a great accuracy the level of this kind of natural radioactivity in the atmosphere. Because of the unique behaviour of these radioactive elements in the atmosphere and in the corresponding measuring instruments, it is necessary to formalize the way such instruments could be tested.

The standard series IEC 61577 covers specific requirements concerning test and calibration of radon and radon decay product measuring instruments. In order to facilitate its use, the IEC 61577 series is divided into the following different parts:

IEC 61577-1 (Normative): This part deals with the terminology and units used in the specific area of radon and radon decay products (RnDP) measurements and describes briefly the System for Test Atmospheres with Radon (STAR) used for test and calibration of radon and RnDP measuring devices.

IEC 61577-2 (Normative): This part is dedicated to the test of $^{222}$Rn and $^{220}$Rn measuring instruments.

IEC 61577-3 (Normative): This part is dedicated to the test of $RnDP_{222}$ and $RnDP_{220}$ measuring instruments.

IEC 61577-4 (Normative): This part describes the construction of a STAR and its use for testing.

IEC 61577-5 (Informative): This is a technical guide concerning special features of radon and radon decay products as well as their measurement.

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1 The term *thoron* is not used in this standard. Instead, the term *radon* is used to denote the radionuclides $^{220}$Rn and $^{222}$Rn. In the case of only one radionuclide being explicitely specified, the atomic mass number and the chemical symbol will be given.

2 RnDP is the acronym of Radon Decay Products which are sometimes denoted as radon progeny. The term *Radon Decay Product* or its abbreviation (RnDP) denotes the whole set of short-lived decay products that are the focus of this standard. A particular isotope is indicated by its chemical symbol preceded by its mass number. The subscripts $_{222}$, $_{220}$ added to the symbol RnDP refer to the whole set of short-lived decay products of the corresponding radon isotope ($RnDP_{222}$: $^{218}$Po, $^{214}$Pb, $^{214}$Bi, $^{214}$Po, and $RnDP_{220}$: $^{216}$Po, $^{212}$Pb, $^{212}$Bi, $^{212}$Po, $^{208}$Tl).

# RADIATION PROTECTION INSTRUMENTATION – RADON AND RADON DECAY PRODUCT MEASURING INSTRUMENTS –

## Part 3: Specific requirements for radon decay product measuring instruments

## 1 Scope

This part of IEC 61577 describes the specific requirements for instruments measuring the volumetric activity of airborne short-lived radon decay products and/or their ambient potential alpha-energy concentration outdoors, in dwellings, and in workplaces including underground mines.

This standard applies practically to all types of electronic instruments that are based on grab sampling, continuous sampling technique and electronic integrating measurement methods. The measurement of activity retained by a sampling device, for example a filtering device, can be performed both during sampling or after the completion of a collection cycle.

The different types of instrumentation used for measurements are stated in IEC 61577-1.

## 2 Normative references

The following references are indispensable in applying this document. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

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

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

〚C〉 IEC 61577-1, *Radiation protection instrumentation. Radon and radon decay product measuring instruments – Part 1: General principles*

IEC 61577-4, *Radon and radon decay product measuring instruments. Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR)* 〈C〛

## 3 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 60050-394 apply as well as the following:

**3.1**
**conventionally true value of a quantity**
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.

[IEC 60050-394:2007, 394-40-10]

**3.2**
**rated range**
range of a quantity to be measured, observed, supplied, or set, assigned to the instrument

[IEC 60050-394:2007, 394-39-42]

**3.3**
**error (of measurement)**
result of a measurement minus a true value of the measurand

NOTE 1 Since a true value cannot be determined, in practice a conventionally true value is used.

NOTE 2 When it is necessary to distinguish "error" from "relative error", the former is sometimes called “absolute error of measurement”. This should not be confused with “absolute value of error”, which is the modulus of the error.

[IEC 60050-394:2007, 394-40-13]

**3.4**
**relative error**
error of measurement divided by a true value of the measurand

NOTE Since a true value cannot be determined, in practice a conventionally true value is used.

[IEC 60050-394:2007, 394-40-11]

**3.5**
**intrinsic error**
error of a measuring instrument, determined under reference conditions

[IEC 60050-394:2007, 394-40-12]

**3.6**
**response (of a radiation measuring assembly)**
ratio, under specified conditions, given by the relation :

$$R = \frac{v}{v_c}$$

where $v$ is the value measured by the equipment or assembly under test and $v_c$ is the conventionally true value of this quantity.

NOTE 1 The input signal to a measuring system may be called the stimulus; the output signal may be called the response (IVM).

NOTE 2 Response can have several definitions. As an example, the definition of the response of a radiation measuring assembly is given.

[IEC 60050-394:2007, 394-40-21]

**3.7**
**reference response**
response of the assembly under reference conditions to a reference dose rate or activity expressed as:

$$R_{\text{ref}} = \frac{\nu}{\nu_{\text{c}}}$$

where $\nu$ is the value measured by the equipment or assembly under test and $\nu_{\text{c}}$ is the conventionally true value of the reference source

NOTE The background value may be automatically taken in account by an algorithm included in the measurement system.

[IEC 60050-394:2007, 394-40-22]

**3.8**
**cross-interference**
ratio of the response of the instrument to the radiation from an interfering radionuclide to the response of the radiation from the radionuclide of interest

NOTE In the context of this standard the term cross-interference is used to characterize the falsification of $RnDP_{220}$ on the indication of instruments measuring quantities of $RnDP_{222}$, and vice versa.

**3.9**
**coefficient of variation**
ratio of the standard deviation *s* to the arithmetic mean $\bar{x}$ of a set of *n* measurements $x_{\text{i}}$ given by the following formula:

$$V = \frac{s}{\bar{x}} = \frac{1}{\bar{x}}\sqrt{\frac{\sum (x_{\text{i}} - \bar{x})^2}{n-1}}$$

[IEC 60050-394:2007, 394-40-14]

**3.10**
**response time (of a measuring assembly)**
duration between the instant of a step change in the measured quantity and the instant when the output signal reaches for the first time a specified percentage of its final value, with that percentage being usually taken as 90 %

[IEC 60050-394:2007, 394-39-09]

## 4 General design considerations

### 4.1 Design considerations for the measurements

#### 4.1.1 Deposition of radon decay products on surfaces

After the decay of radon, the freshly generated radon decay products form clusters (particulate diameters in the order of magnitude of nm) some of which are attached to the ambient aerosol, and the fraction of attached clusters are referred to as attached fraction of radon decay products. The part of free clusters denotes the unattached fraction. The unattached fraction of decay products has a high mobility and deposits preferably on surfaces.

The deposition of radon decay products on surfaces results in a depletion in the vicinity of the instrument and can cause distortion of the measurements. In order to minimize these effects an open face air sampling is preferred.

In cases where open face air sampling is not applicable, the manufacturer shall specify the relative error in relation to the unattached fraction of the radon decay products.

NOTE Freshly formed radon decay products appear to be mainly positive in the atmosphere, their size increases rapidly by clustering with surrounding molecules in the air (water, trace gases). These ultrafine particles with

thermodynamic diameters in the conventional range of less than 5 nm are called the unattached fraction. Wire screens are commonly used for the measurement of the unattached fraction.

#### 4.1.2 Airflow system

Instruments operating with air sampling shall be appropriately designed and constructed to avert recirculation between the air inlet and the air exhaust. The minimum distance between air inlet and outlet shall be agreed upon between manufacturer and purchaser.

The design of the air sampling system should avoid turbulences. The impact of flow-rate and pressure drop on the measurement shall be agreed upon between manufacturer and purchaser.

### 4.2 Design considerations for handling and maintenance

#### 4.2.1 Portability

The instrument shall be designed to be easily carried by hand in order to perform in-situ measurements. This requires, in particular, robustness against mechanical shock.

#### 4.2.2 Application under heavy environmental conditions

If the instrument is applied under heavy environmental conditions occurring mostly outdoors or at workplaces, in particular in mines, the instrument shall be of rugged construction. Where applicable appropriate measures shall be met to protect the instrument and its components against external influences or conditions such as

a) mechanical impacts;
b) corrosion and corrosive solvents;
c) fungus;
d) vermin;
e) solar radiation;
f) ice formation;
g) moisture and spraying water;
h) explosive atmospheres.

In cases where the impact of external influences cannot be eliminated totally, the influences shall not affect the satisfactory operation of the instrument or compromise safety. Spray water shall have no harmful effects.

The manufacturer shall specify the minimum ranges of environmental conditions or external influences within which satisfactory operation of the instrument is ensured. The manufacturer shall state influences or conditions that significantly reduce the measurement capability of the instrument.

The manufacturer shall explicitly state whether the instrument can be used in explosive atmospheres (e.g., in mines) or not.

#### 4.2.3 Automatic operation

The instrument shall be such that the measurement cycle can be carried out either manually or with programming so that automatic operation can be achievable.

#### 4.2.4 Reliability

The instrument shall be designed to provide reliable performance with failures kept to a minimum.

#### 4.2.5 Capability for operational testing

Capability should be provided to allow the purchaser to carry out periodic checks of the operation of the instrument.

These checks shall be carried out using one or more suitable radioactive sources as necessary.

#### 4.2.6 Adjustment and maintenance facilities

All electronic components shall be provided with a sufficient numbers of accessible and identifiable test points to facilitate adjustments and fault location. Any special maintenance tools and appropriate maintenance manuals shall be supplied.

The design of all components shall be such as to facilitate ease of repair and maintenance.

#### 4.2.7 Acoustic noise level

Acoustic noise level of the instrument shall arise mainly from the sampling assembly and its resultant vibration.

The manufacturer should select the components and design the instrument so that the noise level is minimized. In particular, for instruments that are used indoors, the reduction of acoustic noise level shall be taken into consideration.

#### 4.2.8 Electromagnetic interference

All necessary precautions shall be taken against detrimental effects of electromagnetic interference on or by the instrument.

The manufacturer shall quantify the electromagnetic emission of the equipment. The emission limits applicable to the instrument covered by this standard are given in IEC 61000-6-4. Moreover, the manufacturer shall state the influence of cellular phones and walkie-talkies on the instrument at a given distance and give appropriate warning.

#### 4.2.9 Storage

The instrument shall remain operable within the specified requirements of this standard after storage without batteries and transportation in the manufacturer’s packaging at any temperature between –25 °C and +60 °C. In some cases, more severe requirements may be stated such as capability to withstand air transportation at low atmospheric pressure.

## 5 Technical components

### 5.1 Sampling assembly

The sampling assembly can include the following components and functional units:

a) sampling and exhaust pipes;

b) air sampling inlet;

c) aerosol retention device;

d) air pump;

e) flow-rate control and measurement system.

An open face sampling inlet is recommended. The sampling device shall be designed to minimize particle losses.

In the case where an air filter is applied for aerosol retention and sampling of airborne radionuclides, a high-efficiency particle filter (HEPA) should be applied. The manufacturer shall state the type of the filter.

Access to the filter shall be designed so as to permit fast and easy removal. Attention shall be given to the air seal around the filter so as to minimize leakage between the filter and the filter holder. Warning shall be given that the pressure drop is such that a filter change is necessary. The design shall enable the filter to be changed easily without damage.

The air pump shall be placed downstream from a filter or any other sampling unit, and shall be able to withstand the variations of pressure induced by operation conditions, filter types, and atmospheric dust-mass blockage. The pump shall be capable of continuous operation between scheduled maintenance operations.

The range of acceptable flow-rates shall be stated by the manufacturer. If the measurements are influenced by flow-rate, a flow-rate control device shall be provided that has a flow-rate adjustment range sufficient to allow for variation in the intrinsic characteristics of the air pump and any filters used. If the flow-rate is to be measured and indicated, the pressure and the temperature at which the flow-rate meter is calibrated and at which the flow-rate is expressed shall be provided.

### 5.2 Radiation detection assembly

The radiation detection assembly produces an electrical signal related to the radiation emitted by the sampled radon decay products incident on the detector. The efficiency of detection shall be optimized.

Contamination of the detector may increase the background. Precautions shall be taken for the protection against contamination, when the instrument is not in use. Wherever possible, the radiation-detector window should be protected by a removable thin screen, or a rugged solid-state detector should be used.

NOTE The contamination can be caused by:

– deposition of airborne decay products;

– recoil of sampled decay products.

### 5.3 Data processing and recording

This assembly comprises functional units for acquiring and processing signals supplied by the detector.

The manufacturer shall publish the relevant measurement principles and procedures used to produce the measurement result and its uncertainties. The detail of information shall facilitate the verification of measurement results by the purchaser.

The electronic data recording system shall have the capacity sufficient for recording all measurement data, including the spectrometry data generated during a long autonomous data-acquisition period. The data shall be retained on a media that ensures the protection and availability of the data, especially in the event of malfunction and interruption of operation or failure of power supply. The manufacturer shall specify the capacity of the data recording system.

### 5.4 Measurement display

The display shall be easily readable in different ambient conditions. The measurement units shall be clearly marked on the display. If needed by the measurement method, the indication of the flow-rate, the atmospheric air pressure and the ambient temperature shall be provided.

The display shall show one or more of the following quantities:

– the activity concentration of radon decay products;
– the potential alpha energy concentration or exposure;
– the equilibrium equivalent radon concentration.

The quantities shall be given in combined SI-units. Appropriate submultiples should be used. The display should show the uncertainty of the measurement.

The result of a measurement shall contain both the measured value of the measurand and the uncertainty associated with that measured value. The uncertainty given should be based on the requirements of the ISO/IEC Guide 98-3 to the expression of uncertainty in measurement.

Data outputs should be provided permitting remote indications and the use of one or more of the following devices:

– display;
– data recorder;
– printer;
– computer;
– or other devices via data port.

The instrument should be equipped with a preset threshold level to give a warning that the relevant radiation quantity (e.g., the activity concentration of radon decay products or the potential alpha energy concentration) exceeds a predetermined value. The preset threshold level should be adjustable.

### 5.5 Power supply

The power supply assembly shall fulfil the requirements on the protection of persons against electric shock as specified in IEC 61140.

Some instruments may be equipped with batteries. The batteries may be connected in any desired manner and shall be individually replaceable. The correct polarity shall be clearly indicated. The manufacturer shall specify the type(s) of batteries.

Rechargeable batteries shall be fully charged by line power within 16 h. A device that turns off the charger upon complete charging of a battery should be provided. A minimum load indication shall be clearly displayed before the display malfunctions.

## 6 Test conditions

### 6.1 General

General test procedures covered in this part of IEC 61577 concern instruments with different technical characteristics. Except where otherwise specified, these are considered type tests. The stated requirements are minimum requirements and may be extended for any particular equipment or functional unit. Certain tests may be considered acceptance tests by agreement between manufacturer and purchaser.

Unless specified otherwise, the manufacturer shall specify at least one of the following quantities as a test quantity:

a) the activity concentration of one or more short-lived radon decay products;
b) the potential alpha energy concentration (PAEC) or exposure (PAEE) of short-lived radon decay products;
c) the equilibrium equivalent concentration.

A test quantity is one with which the metrological characteristics of the instrument are tested. The specification of the test quantity can also be agreed upon between the manufacturer and the purchaser.

### 6.2 Standard test conditions

Unless otherwise specified, the tests described in this standard shall be executed under standard test conditions which are established in a radon reference atmosphere.

The standard test conditions listed in Table 1 shall be kept constant within the specified limits during a test.

### 6.3 Execution of tests

The radon decay product concentration in the test atmosphere shall induce an indication within the rated range. Unless otherwise specified the indication shall lie within the lower third of the rated range.

Statistical fluctuation of the measurements caused by the random nature of radioactivity shall be minimized by taking a sufficient number of measurements to guarantee that the average value is sufficiently precise to assess the conformity as to the relevant requirement.

In order to test the instrument for a specific influence quantity, this quantity shall be varied over the range specified in Table 3 while the other influence quantities shall be kept constant within the tolerances of the standard test conditions specified in Table 2. The relative error in the instrument indication under reference conditions shall be calculated.

NOTE When the instrument being tested is deployed under special ambient conditions, the range of influence quantities can be agreed upon between the manufacturer and the purchaser.

### 6.4 Test sources

#### 6.4.1 Solid sources

Tests of instruments for measuring radon decay products and/or potential alpha energy are often carried out using solid reference sources consisting of well-defined radionuclides whose activity is accurately known. Such sources make it possible to check the correct operation of the electronic circuits used for analysis starting with the detector through to the indicating device.

According to the principle of measurement, reference alpha or beta sources shall be used.

NOTE As a rule alpha or beta planar sources are used. Typical alpha emitting radionuclides are $^{244}$Cm, $^{241}$Am or $^{238}$Pu; typical beta emitting nuclides are $^{137}$Cs, $^{99}$Tc, $^{36}$Cl, $^{90}$Sr/$^{90}$Y.

The dimensions of the active surface of the sources should be the same as the area of the active deposit on the filter. When solid sources of the same dimensions as the active deposit collected on the filter are not available, the manufacturer shall state the source dimensions and methods to be used to correct the different sizes if this is necessary for the tests.

#### 6.4.2 Reference atmospheres

The potential alpha-energy concentration of short-lived decay products of radon-222 (or radon-220) established in a real atmosphere depends on the specific climatic and aerosol-specific physical parameters. Tests shall assess the measurement capabilities of the instrument for the intended use and, therefore, test atmospheres shall be established to simulate real measurement conditions. These test atmospheres shall be generated in radon reference chambers using a STAR.

NOTE 1 The components and operation of a STAR as well as the generation of radon reference atmospheres for testing of instruments are described in IEC 61577-4.

STAR commonly operates with artificial test aerosols. A polydisperse aerosol distribution shall be used for standard testings. The activity median aerodynamic diameter of the aerosol particle, AMAD, should lie within the range between 〚C〉 100 nm 〈C〛 and 500 nm and the geometric standard deviation, GSD, between 1,5 and 2,5.

NOTE 2 Monodisperse aerosols with a geometric standard deviation below 1,5 should be used for extended performance studies and investigations of fundamental aerosol behaviour.

## 7 Requirements and tests concerning radiation detection performance

### 7.1 Reference response to a test source

#### 7.1.1 Requirements

The manufacturer shall state the nominal indication of the instrument and its approved tolerance to a test source provided.

NOTE This test is only mandatory when the manufacturer provides an appropriate test source.

#### 7.1.2 Test method

The instrument shall operate under standard test conditions and in standard operation mode with no reference radiation present. The background indication of the instrument shall be noted.

The test source shall induce an indication within the rated range. The source shall be in a position specified by the manufacturer in place of the sampling medium (e.g., filter).

After the warm-up time of the instrument, the indication as to the test source reduced by the background shall be within the tolerances of the nominal indication given by the manufacturer.

### 7.2 Cross-interference to other radon isotopes

#### 7.2.1 Requirements

The cross-interference to $RnDP_{222}$ of an instrument made for $RnDP_{220}$ shall not be more than 20 %.

The cross-interference to $RnDP_{220}$ of an instrument made for $RnDP_{222}$ shall not be more than 20 %.

#### 7.2.2 Test method

The test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions.

Concerning the cross-interference to $RnDP_{220}$ the following is applied:

The instrument shall be prepared to measure quantities relevant to short-lived decay products of $^{222}Rn$. Instead of $^{222}Rn$, an amount of $^{220}Rn$ sufficient for establishing a volumetric activity of 1 000 $Bq \cdot m^{-3}$ shall be injected into the reference atmosphere and kept constant for more than 50 h. The activity concentration of $^{222}Rn$ in the reference atmosphere shall be negligible. After at least 50 h after injection, the instrument shall acquire measurement data for at least 1 h. The ratio of the average value of indication during the data acquisition time to the average value of the corresponding quantity for $RnDP_{220}$ shall be calculated and given in percent.

Concerning the cross-interference to $RnDP_{222}$ the following is applied:

The instrument shall be prepared to measure quantities relevant to short-lived decay products of $^{220}$Rn. Instead of $^{220}$Rn, an amount of $^{222}$Rn sufficient for establishing a volumetric activity of 1 000 Bq·m$^{-3}$ shall be injected into the reference atmosphere and kept constant during at least 4 h. The activity concentration of $^{220}$Rn in the reference atmosphere shall be negligible. After at least 3 h after injection, the instrument shall acquire measurement data for at least 1 h. The ratio of the average value of indication during the data acquisition time to the average value of the corresponding quantity for $RnDP_{222}$ shall be calculated and given in percent.

### 7.3 Linearity of indication

#### 7.3.1 Requirements

The linearity shall be assessed by the linearity error which is the deviation from a straight line of the curve representing the output quantity as a function of the input quantity. The linearity error will be described by the parameter $Q$

$$Q = \left| \frac{R_{max} - R_{min}}{R_{max} + R_{min}} \right|,$$

where $R_{max}$ is the response of the instrument when the input induce an output above 90 % of the rated range and $R_{min}$ is the response of the instrument when the input induce an output below 10 % of the rated range.

The parameter of the linearity $Q$ shall be below 0,15. If the instrument has different working ranges the parameter of the linearity $Q$ shall be below 0,15 for each working range.

The linearity shall be tested over the rated range of the instrument.

#### 7.3.2 Test method

The test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions. The standard test conditions shall be kept constant during the test.

The conventionally true value of the test quantity shall be such as to induce an output above 90 % of the rated range. $R_{max}$ shall be determined from the ratio of the input and output. The procedure is to be repeated to yield a value below 10 % of the rated range to determine $R_{min}$. Then, the parameter of the linearity $Q$ shall be calculated.

If the instrument has different working ranges the procedure is to be repeated for each.

### 7.4 Instrument statistical fluctuation

#### 7.4.1 Requirements

The results of successive measurements of the same radiation quantity shall be repeatable. The coefficient of variation attributed to the sampling and signal processing of the instrument shall not exceed 10 %. Statistical fluctuations from radioactive decay shall be disregarded.

NOTE Statistical fluctuations are caused by the random nature of radiation and radioactivity, and by the sampling procedure and the signal processing of the instrument. The test for instrument statistical fluctuations in order to prove the repeatability of measurements does not include the statistical fluctuations caused by radioactive decay.

#### 7.4.2 Test method

The test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions. The standard test conditions shall be kept constant during the test. The test shall be performed in the upper half of the rated range. The time of sampling and

measurement shall be such as to limit the statistical fluctuations from radioactive decay to below 5 %.

A minimum of 10 independent measurements shall be taken. The mean value and the coefficient of variation $V$ of all readings registered shall be determined. The coefficient of variation $V_i$ attributed to the sampling and signal processing of the instrument is calculated by

$$V_i = \sqrt{V^2 - V_{Rad}^2} ,$$

where $V_{Rad}$ is the coefficient of variation caused by the statistical fluctuation from radioactive decay.

NOTE In the case of counting measurements, the coefficient of variation $V_{Rad}$ caused by the statistical fluctuation from radioactive decay is calculated by

$$V_{Rad} = \sqrt{\frac{\frac{R_b}{t_b} + \frac{R_0}{t_0}}{(R_b - R_0)^2}} ,$$

with $R_b$ as gross counting rate, $R_0$ as counting rate of the background, $t_b$ as time of measurement of the sample and $t_0$ as time of measurement of the background. When $R_b >> R_0$ , the equation simplifies to

$$V_{Rad} = \sqrt{\frac{1}{t_b R_b}} .$$

### 7.5 Response time

#### 7.5.1 Requirements

The manufacturer shall specify the response time of the assembly.

NOTE This test is not relevant for instruments based on grab sampling or other short-term sampling methods.

#### 7.5.2 Test method

The test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions. When the activity concentration of the short-lived radon decay products is in equilibrium, the instrument shall be suddenly exposed to the test quantity established inside the STAR in order to achieve a step change.

The duration between the instant of a step change and the instant when the output signal reaches for the first time 90 % of its final value shall be measured and given as response time.

NOTE 1 A step change in the test quantity can be achieved by putting the instrument, which is already in operation, into the test atmosphere, or by turning on the sampling unit.

NOTE 2 A recorder should be connected to the instrument to determine the change in the indication as a function of time.

### 7.6 Signal accumulation

#### 7.6.1 Requirements

An integrating instrument shall be capable of accumulating and summing time consecutive or simultaneous effects of the phenomenon and storing the quantity to be measured permanently or for at least the total of measurement. The integration can be performed electronically by the signal processing system or passively by a measuring sensor, that is directly affected by the phenomenon.

EXAMPLE In the case of a signal processing system, the integration can be exemplarily performed by the summation of pulses registered during the time of measurement. In contrast a passive measuring sensor could be a nuclear track detector whose property is being changed by accumulation of latent tracks while exposing to radiation. The measuring quantity is ascertained by processing the sensor.

The integrated value indicated by the instrument related to the conventionally true integrated value shall lie within the nominal tolerances given by the manufacturer.

#### 7.6.2 Test method

The test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions. The standard test conditions shall be kept constant during the test. The test shall be performed in the upper half of the rated range. The time period of accumulation and integration shall be agreed upon between the manufacturer and the purchaser.

## 8 Requirements and tests concerning air circuit performance

### 8.1 General

These tests shall be applied to all instruments where the response depends on a known flow-rate through the sampling and detection assemblies. When it is demonstrated that one or more tests are not needed to assess the conformity with performance requirements, those tests can be excluded. The decision on exclusion of tests shall be agreed upon between the manufacturer and the purchaser.

### 8.2 Flow-rate stability

#### 8.2.1 Requirements

The manufacturer shall specify the nominal air flow-rate. After the nominal warm-up time of the instrument, the relative error of the sampling flow-rate shall not vary by more than 10 % for the subsequent 20 h of operation.

#### 8.2.2 Test method

The test shall be carried out with dust-free air in order to avoid any variation of the pressure drop of the sampling device during the test.

An air flow meter calibrated under measuring conditions shall be incorporated in the air circuit in order to measure the flow-rate after 30 min, 5 h and 20 h of operation.

### 8.3 Accuracy of the flow-rate measurement

#### 8.3.1 Requirements

The manufacturer shall specify the accuracy of the flow-rate measurement of the air. The relative error of the flow-rate measurement shall not be more than 10 %.

#### 8.3.2 Test method

A flow-rate measurement device calibrated under measuring conditions shall be incorporated in the air circuit. Filtered, dust-free air shall flow through the air circuit under standard operating conditions of the instrument. The relative error of the air flow-rate measured after 30 min with respect to the air flow-rate specified by the manufacturer is to be calculated.

### 8.4 Effect of filter pressure drop

#### 8.4.1 Requirements

An increasing pressure drop of 10 % from the nominal pressure drop shall not cause a relative error regarding the indication of the instrument of more than 10 % under standard test conditions. The relative error shall be determined with respect to a relevant radiation quantity indicated by the instrument.

#### 8.4.2 Test method

In order to identify the effect on the whole measurement chain, the test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions. The standard test conditions shall be kept constant during the test. The test quantity shall induce an indication within the rated range.

Before starting the test, the instrument is to be fitted with a clean sampling filter. A valve shall be inserted downstream to the air inlet. A calibrated pressure sensor relative to the atmospheric pressure shall be fitted to measure the pressure drop across the air inlet and the valve.

EXAMPLE A U-tube or a differential manometer can be used as a pressure sensor.

The nominal pressure drop through the filter shall be measured by the pressure sensor; the indication of the instrument shall be registered.

NOTE If the valve considerably affects the air flow, the nominal pressure drop shall measured without the valve in the air circuit.

Then the valve shall be adjusted to obtain a pressure drop through the filter of 10 % above the nominal pressure drop. The indication of the instrument at this pressure drop is to be registered and the relative error regarding the indication at nominal pressure drop is to be determined.

### 8.5 Low sampling flow-rate indication

#### 8.5.1 Requirements

The system shall indicate an alarm when the indication of the sampling flow-rate goes below an acceptable level.

#### 8.5.2 Test method

The system shall operate normally at the beginning of the test. The air sampling flow-rate shall be reduced to a level below the preset air sampling flow-rate alarm level. An alarm shall be activated.

## 9 Requirements and tests concerning environmental performance

### 9.1 Response to ambient gamma radiation

#### 9.1.1 Requirements

The instrument shall be designed in such a way that the influence of external gamma radiation on the measurement result is minimized. The manufacturer shall state the differential change of the indicated value caused by an ambient dose equivalent rate of 1 $\mu Sv \cdot h^{-1}$ in relation to the indicated value at the lowest and highest limit of the rated range under standard test conditions.

#### 9.1.2 Test method

The gamma radiation test field shall be produced by a $^{137}Cs$ source. At the reference point the test field shall have an ambient dose equivalent rate of (1,0 ± 0,1) $\mu Sv \cdot h^{-1}$ uniform over a plane area greater than the detector. The source shall be placed at a distance to achieve this.

The ambient dose equivalent rate of the external gamma radiation at the reference point shall be measured by a calibrated dose rate meter.

During the test, the instrument to be tested shall be positioned with the detector at the reference point.

### 9.2 Number concentration of aerosols

#### 9.2.1 Requirements

The relative error due to variations of the number concentration of aerosol particles in the sampled atmosphere shall be within the limits specified in Table 3.

#### 9.2.2 Test method

The test shall be performed in a radon reference atmosphere established in a STAR under standard test conditions. The standard test conditions shall be kept constant during the test. The test quantity shall give an indication within the upper half of the rated range.

By means of an aerosol generator, the number concentration of aerosols in the reference atmosphere shall be [C] adjusted to about $10^8$ $m^{-3}$ [C].The characteristics of the test aerosol are described in 6.4.2. After reaching a steady state, the indication of the instrument is to be registered.

This procedure shall be repeated for number densities of [C] about $10^{10}$ $m^{-3}$ [C] (standard test condition) and [C] about $10^{12}$ $m^{-3}$ [C]. The maximum relative error with respect to standard test conditions shall be calculated.

### 9.3 Ambient temperature

#### 9.3.1 Requirements

Over the ranges of temperature specified in Table 3, the relative error regarding the indication of the instrument shall remain within the limits specified in that table.

#### 9.3.2 Test method

This test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions for environmental characteristics except ambient temperature.

The measurement shall begin after a thermal steady state has been reached and should last for a duration depending on the instrument characteristics.

The temperature shall be maintained at each of its extreme values for at least 1 h, and the indication of the instrument measured during the last 30 min of this period shall be compared with the corresponding reading under standard test conditions.

### 9.4 Relative humidity and condensed moisture

#### 9.4.1 Requirements

The relative error regarding the indication of the instrument caused by humidity and condensed moisture shall be within the limits specified in Table 3. The test for condensed

moisture shall only be carried out if the manufacturer has not explicitly excluded the use of the instrument under such conditions.

#### 9.4.2 Test method

This test shall be executed in a radon reference atmosphere established in a STAR under standard test conditions for environmental characteristics except ambient temperature and relative humidity. The relative humidity shall be 90 % at an ambient temperature of 30 °C. The test shall be carried out at a thermal steady state.

The test conditions shall be maintained for at least 1 h and the indication of the instrument measured during the last 30 min of this period shall be compared with the corresponding reading under standard test conditions.

Then the temperature shall be reduced below the dew point in order to create moisture precipitation (condensed moisture). The test conditions shall be maintained for at least 1 h and the indication of the instrument measured during the last 30 min of this period shall be compared with the corresponding reading under standard test conditions.

### 9.5 Atmospheric pressure

The influence of the atmospheric pressure is significant only for some types of instruments. In this case the atmospheric pressure at which tests are carried out and the effects of variation in atmospheric pressure shall be stated by the manufacturer.

## 10 Requirements and tests concerning electrical performance

### 10.1 Warm-up time

#### 10.1.1 Requirements

Ten minutes after being switched on and when exposed to a radioactive source, the instrument shall give an indication that does not differ by more than ± 10 % from the value obtained under standard conditions (see Table 1).

#### 10.1.2 Test method

Prior to this test, the instrument shall be disconnected from the power supply for at least 1 h. An appropriate radioactive source shall be used in order to yield an indication within the rated range.

During the first hour, the value indicated shall be recorded periodically in a time interval appropriate for the test. One hour after switch-on, sufficient readings shall be taken and the mean value shall be used as the “final value” of indication.

The difference between the “final value” and the value from the graph for 10 min shall be within the limits specified.

### 10.2 Power supply variations

#### 10.2.1 Requirements

The instrument shall be capable of operating from the mains with a supply voltage tolerance of ± 10 % and supply frequencies of 47 Hz to 52 Hz (57 Hz to 62 Hz in countries where the nominal frequency is 60 Hz) without the indication varying by more than 10 % from the indication under standard test conditions.

#### 10.2.2 Test method

The test shall be carried out in a radon reference atmosphere provided by a STAR. The volumetric activity of radon decay products shall be adequate for the instrument to generate an indication within the rated range. With the power supply voltage and frequency at their nominal values, the mean of a sufficient number of readings shall be taken.

a) Voltage test:

   The mean of sufficient consecutive readings shall be taken with the supply operating at a nominal frequency and at a voltage 10 % above the nominal value. Repeat the procedure at a voltage 10 % below the nominal value.

   These two mean values shall not differ from that obtained with the nominal supply voltage by more than ± 10 %.

b) Frequency test:

   The mean of sufficient consecutive readings shall be taken with the supply operating at a nominal voltage and at a frequency of 47 Hz or 57 Hz in countries where the nominal frequency is 50 Hz or 60 Hz respectively. The procedure shall be repeated at a frequency of 52 Hz or 62 Hz in countries where the nominal frequency is 50 Hz or 60 Hz respectively.

   These two mean values shall not differ from that obtained with the nominal frequency by more than ± 10 %.

### 10.3 Battery test

#### 10.3.1 Requirements

The capacity of the battery (including secondary battery) shall be such that, after 8 h of continuous use, the indication of the assembly shall not differ from the initial indication by more than ± 10 %.

#### 10.3.2 Test method

An appropriate radioactive source shall be used in order to induce an indication within the rated range.

The initial response shall be registered. After continuous operation for 8 h, the response shall be compared with the response at the beginning of the test.

## 11 Requirements and tests concerning mechanical performance

### 11.1 Requirements

The instrument shall be designed to withstand mechanical shock without degradation of performance. The manufacturer shall specify the performance of the instrument with mechanical shock.

The instrument shall withstand mechanical shocks from three mutually perpendicular directions involving an acceleration up to 300 $m \cdot s^{-2}$ for a time interval of 18 ms, the shape of the shock pulse being semi-sinusoidal. The instrument shall not be damaged and remain operable according to the requirements of technical standards (see IEC 60068-2-27) or this standard .

### 11.2 Test method

The test methods for the mechanical types of shock are defined in IEC 60068-2-27.

## 12 Operation and maintenance manual

Each instrument shall be supplied with an appropriate manual in accordance with IEC 61187.

The manual shall include the following information:

a) manufacturer name or registered trade mark;
b) relevant design characteristics of the instrument type;
c) measurement quantities and units;
d) type and dimension of aerosol filter;
e) type of detector;
f) instructions for use of the instrument;
g) effective range of measurement;
h) warm-up time;
i) nominal air flow-rate;
j) explosion proof qualification;
k) nominal power supply voltage and current consumption;
l) environmental conditions under which the instrument operates in compliance with this standard:
   – ambient gamma radiation;
   – ranges of temperature, relative humidity, atmospheric air pressure;
   – dust and other adverse conditions that affect the measurements;
   – external electromagnetic radiation and electrostatic discharge;
   – mechanical shock.

The documentation shall provide information on the expected operational lifetime of critical and replaceable components such as air pump, detector, flow-rate measuring device, batteries, etc., according to their technical characteristics.

The manual shall provide information on how to check the instrument's performance and how to identify technical malfunctions. A full description of the maintenance procedure shall be given. The maintenance requirements should be kept to a practical minimum.

NOTE The operational and maintenance manual may be issued as hard copy or by electronic data transfer.

## 13 Type test report and certificate

The results of performance tests shall be reported accurately, clearly, unambiguously and objectively.

The results shall be published in a test report, and shall include all the required information as requested by the customer for the proper implementation of test method used and the proper interpretation of test results.

Each test report shall include at least the following information:

a) the name and address of the laboratory, and the location where the tests were carried out;
b) the manufacturer's name of the instrument tested;
c) relevant design characteristics of the instrument type;
d) type and serial number of the instrument tested;

e) year of manufacture of the instrument;

f) a description of the test methods and the specific test conditions;

g) test results with the proper units of measurement;

h) a statement of compliance/non-compliance with the requirements of this standard;

i) the name(s), function(s) and signature(s) or equivalent identification of person(s) authorizing the test report.

NOTE 1 Test reports are sometimes called test certificates.

NOTE 2 The test reports may be issued as hard copy or by electronic data transfer.

**Table 1 – Reference conditions and standard test conditions (unless otherwise indicated by the manufacturer)**

| | Quantity | Reference conditions | Standard test conditions |
|---|---|---|---|
| | Warm-up time | 10 min | ≥ 10 min |
| | Activity concentration of $^{222}Rn$[b] | < 10 Bq· m$^{-3}$ | < 10 Bq· m$^{-3}$ |
| | Activity concentration of $^{220}Rn$[c] | < 10 Bq· m$^{-3}$ | < 10 Bq· m$^{-3}$ |
| C | Ambient temperature | 20 °C | 18 °C to 24 °C C |
| C | Relative humidity | 65 % | 40 % to 75 % C |
| | Atmospheric pressure | 101,3 kPa | 90 kPa to 106 kPa[a] |
| | Number concentration of aerosols | $10^{10}$ m$^{-3}$ | $10^{9}$ m$^{-3}$ to $10^{11}$ m$^{-3}$ |
| | Air flow velocity | < 2 m·s$^{-1}$ (quiescent or slow moving air) | < 2 m·s$^{-1}$ |
| | Power supply voltage | Nominal supply voltage $U_N$ | Nominal supply voltage $U_N$ ± 0,5 % |
| | AC power supply frequency | Nominal frequency | Nominal frequency ± 0,5 % |
| | AC power supply waveform | Sinusoidal | Sinusoidal with a total harmonic distortion less than 5 % |
| C | Ambient dose equivalent rate | Negligible | < 0,25 μSv·h$^{-1}$ C |
| | Electromagnetic field of external origin | Negligible | Negligible |
| | Magnetic induction of external origin | Negligible | Negligible |
| | Radio frequency | Negligible | Less than the lowest value that causes interference |
| | Sampling flow-rate | Nominal flow-rate | Nominal flow-rate ± 0,5 % |

a Where the detection technique is particularly sensitive to variation in atmospheric pressure, the conditions shall be limited to ± 0,5 % of the reference pressure.

b Only for instruments measuring short-lived decay products of $^{220}Rn$.

c Only for instruments measuring short-lived decay products of $^{222}Rn$.

**Table 2 – Tests of the radiation detection performance**

| Characteristics under test | Requirement | Subclause |
|---|---|---|
| Cross-interference to $RnDP_{222}$[a] | Response to $RnDP_{222} \leq 20$ % | 7.2 |
| Cross-interference to $RnDP_{220}$[b] | Response to $RnDP_{220} \leq 20$ % | 7.2 |
| Linearity of indication | Test parameter for linearity $Q < 0{,}15$ | 7.3 |
| Instrument statistical fluctuation | Coefficient of variation less than ± 10 % | 7.4 |
| Response time | In accordance with the manufacturers specifications | 7.5 |

a Only for instruments measuring short-lived decay products of $^{220}Rn$.

b Only for instruments measuring short-lived decay products of $^{222}Rn$.

**Table 3 – Tests performed with variation of influence quantities**

| Influence quantity | Range of value | Limits of variation[a] | Subclause |
|---|---|---|---|
| Ambient dose equivalent rate | ≤ 1 $\mu Sv \cdot h^{-1}$ | In accordance with manufacturer's specification | 9.1 |
| Number concentration of aerosols | $10^8$ $m^{-3}$ to $10^{12}$ $m^{-3}$ | ± 25 % | 9.2 |
| Ambient temperature | –5 °C to 45 °C | ± 10 % | 9.3 |
| Relative humidity | 90 % at 30 °C | ± 10 % | 9.4 |
| Moisture[b] | Condensed | ± 50 % | 9.4 |
| Atmospheric pressure | 90 kPa to 106 kPa | In accordance with manufacturer's specification | 9.5 |
| Warm-up time | 10 min | ± 10 % | 10.1 |
| AC power supply voltage | From 90 % $U_N$ to 110 % $U_N$ | ± 10 % | 10.2 |
| AC power supply frequency | From 47 Hz to 52 Hz (From 57 Hz to 62 Hz)[c] | ± 10 % | 10.2 |
| Battery capacity | After 8 h of continuous operation | ± 10 % | 10.3 |
| Mechanical shock | As defined by the manufacturer | As defined by the manufacturer | 11 |

a Referring to reference conditions.

b Only if not explicitly excluded by the manufacturer.

c Only in countries where the nominal frequency is 60 Hz.

**Table 4 – Tests of the air circuit**

| Characteristics under test | Requirement | Subclause |
|---|---|---|
| Flow-rate stability | Variation less than ± 10 % in 20 h (operating hours) | 8.2 |
| Accuracy of air flow-rate | Relative error regarding the indication of the instrument less than ± 10 % | 8.3 |
| Filter pressure drop | Relative error regarding the indication of the instrument less than 10 % at an increasing pressure drop up to 10 % | 8.4 |
| Loss of sampling circuit | Indicate a fault when flow-rate goes below an acceptable level. | 8.5 |

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