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BSI Standards Publication

Radiation protection instrumentation — Radon and radon decay product measuring instruments

Part 2: Specific requirements for ^{222}Rn and ^{220}Rn measuring instruments

National foreword

This British Standard is the UK implementation of IEC 61577-2:2014. It supersedes BS IEC 61577-2:2000 which is withdrawn.

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 2: Specific requirements for ^{222}Rn and ^{220}Rn measuring instruments

FOREWORD

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International Standard IEC 61577-2 has been prepared by sub-committee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition issued in 2000. This edition constitutes a technical revision.

This second edition includes the following significant technical changes with respect to the previous edition:

a) Addition of new requirements and tests concerning radiation detection performance.
b) Addition of new requirements and tests concerning environmental performance.

c) Harmonization of the requirements and tests concerning electrical and mechanical performance with other standards in the area of radon and radon decay product instrumentation.

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

FDIS	Report on voting
45B/793/FDIS	45B/798/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 61577 series, under the general title *Radiation protection instrumentation – Radon and radon decay product measuring instruments*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

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 is generally known as 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 other two series. Its health effects are therefore not important. Thus in this standard ^{219}Rn and its decay products are not considered.

In order to facilitate its use, the IEC 61577 series is divided into the following different parts:

IEC 61577-1: This part emphasizes the terminology and units used in the specific field of radon and radon decay products (RnDP) measurement techniques and describes briefly the concept of System for Test Atmospheres with Radon (STAR) used for test and calibration of radon and RnDP measuring devices.

IEC 61577-2: This part is dedicated to the tests of ^{222}Rn and ^{220}Rn measuring instruments.

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

IEC 61577-4: This part is dedicated to the construction of a STAR and its use for testing.

IEC/TR 61577-5 (informative): This is a technical report (to be developed) concerning special features of radon and/or RnDP 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 that one of these radionuclides is to be explicitly specified, the atomic mass number and the chemical symbol are given.

2 RnDP is the acronym for Radon Decay Products, which are sometimes called radon progeny. The term *Radon Decay Products* or its abbreviation (RnDP) denotes the whole set of short-lived decay products that becomes 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 2: Specific requirements for ^{222}Rn and ^{220}Rn measuring instruments

1 Scope

This part of IEC 61577 describes the specific requirements for instruments measuring the activity concentration of airborne ^{222}Rn and ^{220}Rn outdoors, in dwellings, and in workplaces including underground mines.

This standard applies practically to all types of electronic measuring instruments that are based on either spot or continuous measurements. The activity concentration can be measured by pumping or by diffusing the air containing ^{222}Rn and/or ^{220}Rn into the sensitive volume of the detection unit or at a particular moment by taking an air sample (grab sampling).

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

The standard does not apply to instruments using charcoal adsorption, electrets or solid state nuclear track detectors.

2 Normative references

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.

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*

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

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

ISO 11665-1, *Measurement of radioactivity in the environment – Air: radon-222 – Part 1: Origins of radon and its short-lived decay products and associated measurement methods*

3 Terms and definitions

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

3.1
conventionally true value of a quantity
v_c
value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose

Note 1 to entry: "Conventionally true value of a quantity" is sometimes called assigned value, best estimate of the value, conventional value or reference value.

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

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

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

3.3
error
error of measurement
result of a measurement minus a true value of the measurand

Note 1 to entry: Since a true value cannot be determined, a conventional true value is used in practice.

Note 2 to entry: 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.

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

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

Note 1 to entry: Since a true value cannot be determined, in practice a conventional true value is used.

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

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

[SOURCE: 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 to entry: The input signal to a measuring system may be called the stimulus; the output signal may be called the response (IVM).

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

[SOURCE: 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:

$$R_{\mathrm{ref}} = \frac{v}{v_{\mathrm{c}}},$$

where v is the value measured by the equipment or assembly under test and v_{c} is the conventionally true value of the reference source

Note 1 to entry: The background value may be automatically taken in account by an algorithm included in the measurement system.

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

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

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

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

Note 1 to entry: The coefficient of variation can be expressed in percent (%) of the arithmetic mean.

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

3.10
response time
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, usually 90 %, of its final value

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

4 General design considerations

4.1 Design considerations for the measurements

4.1.1 General

To measure the activity concentration of ^{222}Rn/^{220}Rn, several methods of measurement can be used. General aspects of the physical principles involved and the performance of the instruments have been summarized in IEC 61577-1 and ISO 11665-1.

The air sample shall be filtered to remove $^{222}Rn/^{220}Rn$ decay products before entering the sensitive volume of the detection unit. For the determination of ^{220}Rn volumetric activity, its very short half life shall be taken into account.

For spot measurement of the activity concentration of $^{222}Rn/^{220}Rn$, grab sampling methods are used. A sample of the air to be measured may be collected by filling a container, either a previously evacuated or flow-through type one, and sealing the container afterwards.

To measure the variation of the activity concentration of $^{222}Rn/^{220}Rn$, continuous measurement methods are used. There are two sampling methods: flow-through and diffusion sampling.

The air humidity may also affect the efficiency of some detectors and the instruments can be provided with air drying systems.

Instrumentation that is intended to be used in field monitoring shall be portable and protected against hostile environmental conditions.

The response time of the instrument shall be adequate for the variability of the phenomenon measured.

4.1.2 Effects caused by physical properties of ^{222}Rn and ^{220}Rn

There is a large difference in the half lives of ^{222}Rn (3,8 d) and ^{220}Rn (55,4 s). Special attention shall be paid to the half life of ^{220}Rn when air samples are taken and measurements are made.

In the case of the simultaneous determination for ^{222}Rn and ^{220}Rn activity concentration, separation techniques using their different physical properties such as their half lives, the alpha-particle energies emitted, and their decay products shall be introduced.

The determination of the activity concentration for $^{222}Rn/^{220}Rn$ may be affected by changes in the flow-rate. In particular the influence on ^{220}Rn measurement is significant because of its very short half life. The flow-rate shall be measured when the activity concentration of ^{220}Rn is being determined.

4.2 Design considerations for handling and maintenance

4.2.1 Portability

The instrument shall be portable in order to perform in-situ measurements. This requires, in particular, robustness against mechanical shock.

4.2.2 Application under harsh environmental conditions

If the instrument is applied under harsh 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) solar radiation;

d) ice formation;

e) moisture and spraying water;

f) 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 will be achievable.

4.2.4 Reliability

The instrument shall be designed to provide reliable performance with unrevealed 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 on 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

The instrument shall be provided with a sufficient number 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 the instrument 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 shall select the components and design the instrument so that the noise level is not excessive. In particular, for instruments which are used indoors, the reduction of the 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 comply with current registration on 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 but is not limited by the following components and functional units:

a) air pump;

b) aerosol retention device;

c) air-drying device;

d) flow-rate control and measurement system.

The air pump circuit shall provide a total air flow adequate for the measurement method. The air pump shall be capable of withstanding the variations of pressure induced by operating conditions, sampling time, filter types, and atmospheric dust-mass blockage. Pipes and connections shall be sufficiently tight to maintain a stable flow rate and prevent leaks. Where an air pump is an integral part of the assembly it is recommended that the air pump shall be capable of continuous operation between scheduled maintenance operations. The flow-rate should be stabilized or measured.

Most instruments use a filter to prevent $^{222}Rn/^{220}Rn$ decay products from entering the detector active volume. The manufacturer shall state the type of filter.

If the response is dependent on the humidity of the sampled air, the instrument may be equipped with an air-drying device (for example chemical drying agents or electrically operated Peltier-elements). Care should be taken to choose a drying agent which does not adsorb $^{222}Rn/^{220}Rn$. When chemical drying agents are used, the life-time of the drying agent shall be clearly stated.

If the measurements are influenced by flow-rate, particularly in the determination of ^{220}Rn activity concentration, 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, shall be provided.

5.2 Radiation detection assembly

The radiation detection assembly transforms the radiation emitted by the sampled ^{222}Rn, ^{220}Rn and their decay products into an electronic signal. In this case, the response shall be optimized.

Contamination of the detector may increase the background. Precautions should be taken for the protection against airborne contamination, when the instrument is not in use.

NOTE The contamination can be caused by:

– deposition of air-borne decay products;

– radioactive materials inside the relevant components of the instrument.

5.3 Data processing and recording

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

The manufacturer shall publish the measurement principles and procedures for yielding a 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 a capacity sufficient for recording all measurement data generated during a long automatic data-acquisition period. The data shall be retained on a medium that ensures 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, flow-rate indication shall be provided.

The display shall show the activity concentration of ^{222}Rn/^{220}Rn.

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 the measurement shall comprise both the value attributed to the quantity to be measured and the uncertainty of the measurement associated with that value when possible. The uncertainty given should be based on the requirements of 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:

a) display;

b) data recorder;

c) printer;

d) computer;

e) or other devices via data port.

The instrument should be equipped with a preset threshold level to give a warning that relevant radiation quantity (e.g., the activity concentration of ^{222}Rn/^{220}Rn) exceeds a predetermined value. The preset threshold level should be adjustable.

5.5 Power supply

The power supply subassembly 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 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 function unit. Certain tests may be considered acceptance tests by agreement between manufacturer and purchaser.

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 $^{222}Rn/^{220}Rn$ 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 activity concentration of $^{222}Rn/^{220}Rn$ 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 yield a sufficiently precise average value in the assessment of the instrument conformity against relevant requirements.

In order to test the instrument for a specific influence quantity, this quantity shall be varied over the range specified in Table 4 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.

6.4 Reference atmospheres

Test and calibration of $^{222}Rn/^{220}Rn$ measuring instrument shall be performed, using a STAR.

Besides appropriate gas standards, emanation standards based on ^{226}Ra- or ^{228}Th- sources can be used alternatively. These sources are available as solid matrixes or liquid solutions.

The activity concentration of $^{222}Rn/^{220}Rn$ established in a real atmosphere depends on the specific climatic parameters. Tests shall assess the measurement capabilities of the instrument for the intended use and, therefore, it is recommended that test atmospheres simulate measurement conditions. These test atmospheres shall be generated in $^{222}Rn/^{220}Rn$ reference chambers performed by the STAR.

NOTE The components and operation of a STAR as well as the generation of $^{222}Rn/^{220}Rn$ reference atmospheres for testing of instruments are described in IEC 61577-4.

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.

7.1.2 Test method

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

After the warm-up time of the instrument, the indication induced by the test source minus the background shall be within the tolerance of the nominal indication given by the manufacturer.

7.2 Cross-interference to other radon isotopes

7.2.1 Requirements

The cross-interference of ^{222}Rn for an instrument made for ^{220}Rn shall be less than 20 %.

The cross-interference of ^{220}Rn for an instrument made for ^{222}Rn shall be less than 20 %.

7.2.2 Test method

The test shall be executed in a ^{222}Rn/^{220}Rn reference atmosphere established in a STAR under standard test conditions.

Concerning the cross-interference of ^{220}Rn, the following paragraph applies.

The instrument shall be prepared to measure quantities relevant to ^{222}Rn. Instead of ^{222}Rn, an amount of ^{220}Rn sufficient for establishing a activity concentration of 1 000 Bq·m^{-3} shall be injected into the reference atmosphere and kept constant for at least 4 h. The activity concentration of ^{222}Rn in the reference atmosphere shall be negligible. After at least 4 h, 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 ^{220}Rn shall be calculated and expressed as a percentage.

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 is given 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 induces an output above 90 % of the rated range;

R_{min} is the response of the instrument when the input induces an output below 10 % of the rated range.

The parameter of linearity Q shall be below 0,15. If the instrument has different working ranges the parameter of linearity 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 indication of the instrument above 90 % of the rated range. R_{max} shall be determined according to the definition given in 3.6. The procedure is to be repeated to yield a value below 10 % of the rated range to determine R_{min}. Hereinafter, 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 $^{222}Rn/^{220}Rn$ 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

$$V_{\mathrm{Rad}} = \sqrt{\frac{1}{t_{\mathrm{b}}\, R_{\mathrm{b}}}}\ .$$

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 ^{222}Rn/^{220}Rn is constant, 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 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.

7.6 Signal accumulation

7.6.1 Requirements

An integrating instrument shall be capable of accumulating and summing consecutive or simultaneous effects and storing the measured values permanently or for at least the duration of measurement. The integration can be performed electronically by the signal processing system or passively by a measuring sensor that can accumulate the signals.

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 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 (see Table 3). 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 air flow-rate when the airflow system is used. After the 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 air 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 referring 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 pressure drop through the filter shall be measured by the pressure sensor; the indication of the instrument shall be registered.

Then the valve shall be adjusted to yield a pressure drop across 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 Indication of low sampling flow-rate

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 level 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 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 $(1{,}0 \pm 0{,}1)$ $\mu Sv \cdot h^{-1}$ uniform over a plane area of 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 Ambient temperature

9.2.1 Requirements

Over the ranges of temperature specified in Table 4, the relative error shall remain within the limits specified in that table.

9.2.2 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.

9.3 Relative humidity and condensed moisture

9.3.1 Requirements

The relative error regarding the indication of the instrument caused by humidity and condensed moisture shall be within the limits specified in Table 4. 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.

9.3.2 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 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 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.

9.4 Atmospheric pressure

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

10 Requirements and tests concerning electrical performance

10.1 Power supply variations

10.1.1 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.

10.1.2 Test method

The test shall be carried out in a $^{222}Rn/^{220}Rn$ reference atmosphere provided by a STAR. The activity concentration of $^{222}Rn/^{220}Rn$ shall be adequate for the instrument to generate an indication within the rated range.

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. The procedure shall be repeated 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 nominal

supply voltage and 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 %.

10.2 Battery test

10.2.1 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 %.

10.2.2 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 norms (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's 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 (if needed);
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 pressure;
   – 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.

13 Type test report and certificate

The results of performance tests shall be reported 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 Test reports are sometimes called test certificates.

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}
Ambient temperature	20 °C	18 °C to 22 °C
Relative humidity	65 %	50 % to 75 %
Atmospheric pressure	101,3 kPa	90 kPa to 106 kPa[a]
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 %
Ambient dose equivalent rate	< 0,20 μSv·h^{-1}	< 0,20 μSv·h^{-1}
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 of ^{220}Rn.

[c] Only for instruments measuring of ^{222}Rn.

Table 2 – Tests of the radiation detection performance

Characteristics under test	Requirement	Subclause
Cross-interference to ^{222}Rn[a]	Response to ^{222}Rn ≤ 20 %	7.2
Cross-interference to ^{220}Rn[b]	Response to ^{220}Rn ≤ 20 %	7.2
Linearity of indication	Test parameter for linearity Q < 0,15	7.3
Statistical fluctuation	Coefficient of variation less than ± 10 %	7.4
Response time	In accordance with the manufacturer's specifications	7.5

[a] Only for instruments measuring ^{220}Rn.

[b] Only for instruments measuring ^{222}Rn.

Table 3 – Tests of the air circuit performance

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

Table 4 – Tests performed with variation of influence quantities

Influence quantity	Range of values	Limits of variation[a]	Subclause
Ambient dose equivalent rate	≤ 1 μSv·h^{-1}	In accordance with manufacturer's specification	9.1
Ambient temperature	–5 °C to +45 °C	± 10 %	9.2
Relative humidity	90 % at 30 °C	± 10 %	9.3
Moisture[b]	Condensed	± 50 %	9.3
Atmospheric pressure	90 kPa to 106 kPa	In accordance with manufacturer's specification	9.4
AC power supply voltage	From 90 % U_N to 110 % U_N	± 10 %	10.1
AC power supply frequency	From 47 Hz to 52 Hz (From 57 Hz to 62 Hz)[c]	± 10 %	10.1
Battery capacity	After 8 h of continuous operation	± 10 %	10.2
Mechanical shock	As defined by the manufacturer	As defined by the manufacturer	11

[a] Referring to reference conditions.

[b] Only if not exclusively excluded by the manufacturer.

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

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