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Edition 2.0 2014-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Radiation protection instrumentation – Radon and radon decay product measuring instruments – Part 2: Specific requirements for ^{222}Rn and ^{220}Rn measuring instruments

Instrumentation pour la radioprotection – Instruments de mesure du radon et des descendants du radon – Partie 2: Exigences spécifiques pour les instruments de mesure du ^{222}Rn et du ^{220}Rn

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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- withdrawn,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:

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

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:

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

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.