# IEC 61577-3

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# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

## Radiation protection instrumentation – Radon and radon decay product measuring instruments –
## Part 3: Specific requirements for radon decay product measuring instruments

## 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

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CONTENTS



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

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

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International Standard IEC 61577-3 has been prepared by sub-committee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

This second edition of IEC 61577-3 cancels and replaces IEC 61577-3:2002 and IEC 61263:1994. This edition constitutes a technical revision.

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

– Implementation of new requirements and tests concerning radiation detection performance.

– Implementation of new requirements and tests concerning environmental performance.

– Harmonization of the requirements and tests concerning electrical and mechanical performance with other standards in the area of radiation protection instrumentation.

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

| FDIS | Report on voting |
|---|---|
| 45B/700/FDIS | 45B/716/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 the 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

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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:

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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 61577-3:2011
https://standards.iteh.ai/catalog/standards/sist/4e79d287-7482-49ed-950a-34327a3771f4/iec-61577-3-2011

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.

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## 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.

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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)*

## 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

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

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

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**3.5**

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**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 :

$$R = \frac{\nu}{\nu_c}$$

where $\nu$ is the value measured by the equipment or assembly under test and $\nu_c$ 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:

$$R_{ref} = \frac{\nu}{\nu_c}$$

where $\nu$ is the value measured by the equipment or assembly under test and $\nu_c$ 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 $x_i$ given by the following formula:

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

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

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**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

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IEC 61577-3:2011
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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.

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#### 4.2.8 Electromagnetic interference

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

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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.

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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.

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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: