IEC 61577-4

Edition 1.0 2009-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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)

Instrumentation pour la radioprotection – Instruments de mesure du radon et des descendants du radon –
Partie 4: Dispositif pour la réalisation d'atmosphères de référence contenant des isotopes du radon et leurs descendants (STAR)

IEC 61577-4:2009

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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)

FOREWORD

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International Standard IEC 61577-4 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

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

FDIS	Report on voting
45B/598/FDIS	45B/606/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 maintenance result 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- withdrawn,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 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.

NOTE In normal conditions, due to the very short half-life of ^{219}Rn, its activity and the activity of its RnDP[1] 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, for instance in underground mines, spas and waterworks, the workers are exposed to very significant levels of RnDP. These radionuclides are present in variable quantities in the air, in a gaseous form for the radon isotopes, and as very fine particles for the 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 the very particular 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.

Remark:

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

IEC 61577-1: This emphasizes the terminology and units of the specific field of radon and radon decay products (RnDP) measurement techniques and presents 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: Details how a STAR is constructed and how it can be used for testing.

[1] RnDP is the acronym of Radon Decay Products and it is equivalent to Radon Progeny (see [1] in the Bibliography).

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)

1 Scope and object

The IEC 61577 series covers the general features concerning test and calibration of radon and radon decay products measuring instruments. It is also intended to help define type tests, which have to be conducted in order to qualify these instruments. These type tests are described in IEC 61577-2 and IEC 61577-3. This standard addresses only the instruments and associated methods for measuring isotopes 220 and 222 of radon and their subsequent short-lived decay products in gases.

IEC 61577-4 concerns the System for Test Atmospheres with Radon (STAR) needed for testing, in a reference atmosphere, the instruments measuring radon and RnDP. The clauses that follow do neither claim to solve all the problems involved in the production of equipment for setting up reference atmospheres for radon and its decay products, nor to describe all the methods for doing so. They do however set out to be a guide enabling those faced with such problems to choose the best methods for adoption in full knowledge of the facts.

2 Normative references

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

IEC 60050-111:1996, *International Electrotechnical Vocabulary (IEV) – Chapter 111: Physics and chemistry*

IEC 60050-393:2003, *International Electrotechnical Vocabulary (IEV) – Part 393: Nuclear instrumentation – Physical phenomena and basic concepts*

IEC 60050-394:2007, *International Electrotechnical Vocabulary (IEV) – Part 394: Nuclear instrumentation – Instruments, systems, equipment and detectors*

IEC 61577 (all parts), *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures*

ISO/IEC Guide 99:2007, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ICRP 32: *Annals of the ICRP, Publication N° 32, Limits for inhalation of Radon Daughters by Workers, Vol. 6, N°1, 1981, Pergamon Press*

ICRP 38: *Annals of the ICRP, Publication N° 38, Radionuclides transformations, Energy and Intensity of Emissions, Vol. 11 - 13, 1983, Pergamon Press*

ICRP 65: *Annals of the ICRP, Publication N° 65, ICRP Publication 65: Protection Against Radon-222 at Home and at Work, Vol. 23/2,* 1994, Pergamon Press

3 Terms, definitions and units

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

Throughout the whole standard, the term RADON is used to denote all the radon isotopes, which are covered by this standard. When a particular isotope is to be referred to, it will be indicated by its chemical symbol preceded by its mass number (e.g. ^{220}Rn, ^{222}Rn). For historical reasons, ^{220}Rn is also called thoron.

The term RADON DECAY PRODUCTS or its abbreviation (RnDP) denotes the whole set of short-lived decay products, which are concerned by 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 (^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po), (^{216}Po, ^{212}Pb, ^{212}Bi, ^{212}Po, ^{208}Tl).

All the nuclear data used in this standard refers to ICRP 38, as this standard applies mainly to instruments used for radiation protection purposes.

3.1 General terms and definitions

3.1.1
activity
A

quotient, for an amount of radionuclide in a particular energy state at a given time, of dN by dt, where dN is the expectation value of the number of spontaneous nuclear transitions from this energy state in the time interval of duration dt:

$$A = \frac{\mathrm{d}N}{\mathrm{d}t}$$

NOTE This quantity is expressed in becquerels (Bq).

[IEV 393-14-12]

3.1.2
volumic activity
activity concentration
C_A
quotient of the activity by the total volume of the sample

NOTE 1 For a gas, it is necessary to indicate the temperature and pressure conditions for which the volumic activity, expressed in becquerel per cubic metre, is measured, for example standard temperature and pressure (STP).

NOTE 2 This quantity is expressed in becquerels per cubic metre (Bq·m^{-3}).

[IEV 393-14-16]

3.1.3
primary standard
standard that is designed or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quantity

NOTE The concept of primary standard is equally valid for base quantities and derived quantities.

[VIM, 5.4, modified]

3.1.4
secondary standard
standard whose value is assigned by comparison with a primary standard of the same quantity

[VIM, 5.5, modified]

3.1.5
reference standard
standard generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived

[VIM, 5.6, modified]

3.1.6
mass flow rate
($kg \cdot s^{-1}$)
mass of a gas flowing in a conduit during a unit time

3.1.7
volume flow rate
($m^3 \cdot s^{-1}$)
volume of gas flowing in a conduit during a unit time

3.1.8
aerosol
set of solid or liquid particles in suspension in a gaseous medium

NOTE The range of particle diameter is generally from a few nanometres up to 10 µm.

[IEV 393-11-37]

3.1.9
homogeneous
qualifies a physical medium in which the relevant properties are independent of the position in the medium

[IEV 111-13-08]

3.1.10
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 "Conventionally true value of a quantity" is sometimes called assigned value, best estimate of the value, conventional value or reference value.

[IEV 394-40-10]

3.2 Specific terms and definitions

3.2.1
Potential Alpha Energy
PAE or ε_p
total alpha energy emitted during the decay of RnDP atoms along the decay chain through to ^{210}Pb or ^{208}Pb respectively for the decay chains of the ^{222}Rn and ^{220}Rn

$$\varepsilon_{p\ 222} = [(6{,}003 + 7{,}687) \times N_{218Po} + 7{,}687 \times (N_{214Pb} + N_{214Bi}) + 7{,}687 \times N_{214Po}] \times 1{,}602 \times 10^{-13} \quad \text{(J)}$$

$$\varepsilon_{p\ 220} = [(6{,}779 + 7{,}804) \times N_{216Po} + 7{,}804 \times (N_{212Pb} + N_{212Bi}) + 8{,}785 \times N_{212Po}] \times 1{,}602 \times 10^{-13} \quad \text{(J)}$$

where N is the number of atoms

NOTE 1 The 7,804 MeV alpha energy corresponds to a virtual alpha emission due to the branching ratio of ^{212}Bi.

NOTE 2 Annual Limits of Intake (ALI) can be expressed in the term of PAE_{222} and PAE_{220}. For this reason, PAE_{222} and PAE_{220} are used as health risk indicator.

[ICRP 32]

3.2.2
Potential Alpha Energy Concentration
PAEC or c_p
concentration of any mixture of short-lived radon decay products in air in terms of the alpha energy released during decay through ^{210}Pb or ^{208}Pb

NOTE This quantity is expressed in the SI unit J·m^{-3}.

[ICRP 32]

3.2.3
Potential alpha energy exposure
$P_p(T)$
time integral of the potential alpha energy concentration in air, c_p, to which an individual is exposed over a given time period T, e.g. one year

$$P_p(T) = \int_T c_p(t).dt$$

NOTE This quantity is expressed in the SI unit J·m^{-3}·h.

[ICRP 65]

3.2.4
equilibrium equivalent concentration
c_{eq}
activity concentration of radon, in radioactive equilibrium with its short-lived decay products that has the same potential alpha energy concentration as the non-equilibrium mixture to which the c_{eq} refers

NOTE This quantity is expressed in the SI unit Bq·m^{-3}.

[ICRP 32]

3.2.5
equilibrium factor
F
ratio of equilibrium equivalent concentration to the radon gas concentration

$$F = \frac{c_{eq}}{C_{Rn}}$$

[ICRP 65]

3.2.6
emanating power (or emanation coefficient)
ratio between the number of radon atoms (n) transferred to the pore space of the material and the number (N) of radon atoms present in the material itself, including the pores' space

$$\tau = \frac{n}{N}$$

3.2.7
emanation rate
value of the activity of radon atoms leaving a material per unit mass per unit time

NOTE This is expressed in $Bq \cdot kg^{-1} \cdot s^{-1}$.

3.2.8
deconvolution
mathematical treatment of a set of data resulting from a measurement (i.e. counted events) allowing, through the use of a particular set of equations, to get the value of the original quantity to be measured

3.2.9
Activity Median Aerodynamic Diameter
AMAD [2][2]
median of the activity distribution of diameters of the unit density ($kg \cdot m^{-3}$) spheres that have the same settling velocity as the aerosol particle concerned

3.2.10
Activity Median Thermodynamic Diameter
AMTD
median of the activity distribution of diameters of the unit density ($kg \cdot m^{-3}$) spheres that have the same thermodynamic properties as the aerosol particle concerned

3.2.11
unattached fraction of *PAEC*
fraction of the potential alpha energy concentration of short-lived RnDP that is not attached to the ambient aerosol

NOTE The particle size concerned is in the order of magnitude of nm.

[ICRP 65]

3.2.12
attached fraction
fraction of the potential alpha energy concentration of short-lived RnDP that is attached to the ambient aerosol.

NOTE The sizes of the carrier aerosol, to which most of RnDP are attached, are generally in the 0,1 μm to 0,3 μm range.

3.2.13
grab sampling
collection of a sample (e.g. of air containing radon or aerosol particles) during a period considered short compared with the fluctuations of the quantity under study (e.g. volumic activity of the air)

3.2.14
continuous method
method which ensures a continuous recording of the parameter to be measured, over a defined period of time, and with a time resolution adapted to the phenomenon to be studied

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2 Numbers in brackets refer to the bibliography.

3.2.15
integrating method
method that relies on the measurement of the integral over a defined sampling and measurement time of the quantity under study

3.2.16
passive sampling
sampling that applies to instruments using no active device like pumps for sampling the atmosphere

NOTE In this case, the sampling is in most instruments mainly made by diffusion.

3.2.17
active sampling
sampling applies to instruments using active devices like pumps for sampling the atmosphere

3.2.18
reference source
radioactive secondary standard source for use in the calibration of the measuring instrument

[IEV 394-40-19]

3.2.19
reference atmosphere
radioactive atmosphere in which the influencing parameters (aerosols, radioactivity, climatic conditions, etc.) are sufficiently well-known or controlled to allow its use in a testing procedure for radon or RnDP measuring instruments. The parameter values concerned are traceable to recognized standards

3.2.20
System for Test Atmospheres with Radon
STAR
system that designates the equipment needed for the creation and the use of a reference atmosphere

3.2.21
High Efficiency Particulate Air filters (HEPA filters)
filters used for the aerosol collection, with a minimum efficiency of 99,97 % for particle size of 0,3 µm

3.3 Units and conversion factors

This standard uses the International System of Units (SI).

NOTE The following "non-standard" units are still sometimes used:

Curie (Ci), a unit of activity:	1 Ci = $3{,}7 \times 10^{10}$ Bq
MeV·l^{-1}, a unit of potential alpha energy concentration	1 MeV·l^{-1} = $1{,}6 \times 10^{-4}$ µJ·m^{-3}

The following conversion factors are given for information:

Working Level (WL), a quantity of volume potential alpha energy	1 WL = 20,8 µJ·m^{-3}
Working Level Month (WLM), a quantity of exposure to potential alpha energy	1 WLM = 3,6 mJ·h·m^{-3}

- A ^{222}Rn activity concentration of 1 Bq·m^{-3} in equilibrium with its $RnDP_{222}$, is equivalent to a Potential Alpha Energy,Concentration, $PAEC_{222}$ of $5{,}62 \times 10^{-9}$ J·m^{-3} .

- A ^{220}Rn activity concentration of 1 Bq.m^{-3} in equilibrium with its $RnDP_{220}$, is equivalent to a Potential Alpha Energy,Concentration, $PAEC_{220}$ of $75{,}8 \times 10^{-9}$ J·m^{-3} .

4 General description of a System for Test Atmospheres with Radon (STAR)

4.1 General

The need for a reference atmosphere arises from the necessity for a complete and standardized testing, under controlled conditions, of the measuring instruments concerned.

The various examples illustrated indicate a need for a test facility related directly to the elements to be measured. Such a facility will consist of four inseparable parts:

– the equipment for producing the atmosphere;
– the equipment for containing the atmosphere;
– the reference atmosphere thus created;
– the equipment and methods for monitoring this atmosphere.

Equipment used to characterise the atmosphere shall be traceable to a primary standard.

In order to simplify the text of this standard, such a system is referred to as a "STAR" (an acronym for System for Test Atmospheres with Radon).

The Figure 1 shows the general components of a complete STAR.

It is also called “Radon Chamber”; however, this term does not imply the same integrated concept.

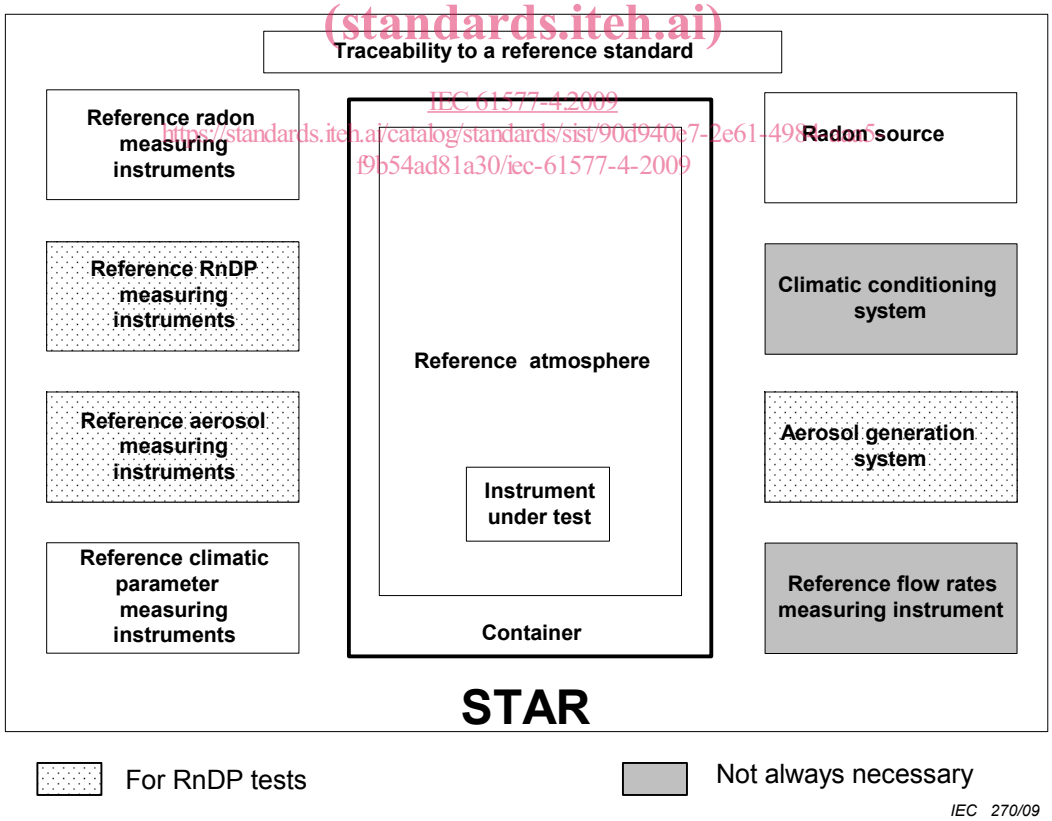

Figure 1 – Components of a STAR: general case

In some cases, a STAR may comprise only parts of the complete scheme. As an example, STAR used only for testing radon instruments, which are not affected by aerosols and RnDP in the atmosphere, do not need special equipment for controlling quantities relating to these effects. Figure 2 illustrates this minimum configuration.