

TECHNICAL REPORT



**Radiation protection instrumentation – Radon and radon decay product measuring instruments –
Part 5: General properties of radon and radon decay products and their measurement methods**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 13.280

ISBN 978-2-8322-7123-0

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references	7
3 Symbols, quantities and units	8
3.1 Symbols.....	8
3.2 Quantities and units	9
4 Radon in the environment.....	9
4.1 Origin, genesis and decay.....	9
4.2 Radon in the rocks and soils and its transport towards the atmosphere.....	10
4.3 Radon concentration in the outdoor air.....	11
4.4 Radon concentration in houses and at workplaces	11
5 Radon decay products in the atmosphere	12
5.1 Physical processes of decay products in gaseous media	12
5.2 Aerosol characteristics and ventilation	13
6 Physical and chemical properties of radon and radon decay products.....	14
6.1 Physical and chemical properties	14
6.2 Solubility of radon in liquids	14
6.3 Radiological properties and radioactive equilibrium.....	15
6.4 Interaction of alpha particles with matter and energy deposition.....	17
7 Measurement of ^{222}Rn and ^{220}Rn and their decay products	18
7.1 Relevant measurement quantities and units	18
7.1.1 Activity concentration (C).....	18
7.1.2 Equilibrium equivalent activity concentration (EEC , C_{eq}).....	18
7.1.3 Equilibrium factor (F)	19
7.1.4 Exposure to radon (P_{Rn})	19
7.1.5 Potential alpha energy (ε_p).....	20
7.1.6 Potential alpha energy concentration (C_p)	20
7.1.7 Potential alpha energy exposure (P_p)	22
7.1.8 The unattached and attached fraction of potential alpha energy concentration.....	22
7.2 Instruments measuring airborne radon activity concentration	22
7.3 Measurement of radon decay products.....	23
7.3.1 General overview of instruments.....	23
7.3.2 Sampling of the unattached radon decay products	24
7.3.3 Counting methods for the measurement of the activity concentrations and the potential alpha-energy concentration.....	25
8 Quality assurance.....	30
8.1 Definition and purpose	30
8.2 Quality control	31
8.3 Validation and traceability of measurements	31
8.3.1 Validation of methods	31
8.3.2 Type test of radon instruments	31
8.3.3 Interlaboratory comparison	31
8.3.4 Measurement traceability and calibration	32
9 Determination of the measurement uncertainty, detection threshold, detection limit.....	32
9.1 General.....	32

9.2	Procedure for the determination	33
Annex A (informative)	Tables and Figures	35
Annex B (informative)	Radioactive decay formulae	40
B.1	General	40
B.2	Symbols	40
B.3	Preliminary considerations and assumptions	40
B.4	Build-up of filter activity during sampling	41
B.5	Decay of the filter activity after cessation of sampling	43
B.6	Number of alpha disintegrations registered after sampling	44
Annex C (informative)	Uncertainty analysis for the method of multiple successive countings to determine the activity concentrations of radon and thoron decay products	46
C.1	Symbols	46
C.2	Uncertainties of the parameter of the model function	46
C.3	Decision threshold	50
C.4	Detection limit	51
C.5	Confidence limits	51
C.6	Best estimate and its uncertainty	52
Bibliography	53
Figure 1	– Diurnal variations of the radon activity concentration in the cellar, 1 st and 2 nd floor of a detached house measured over 12 days	12
Figure 2	– Decay of ²²² Rn after injection of 1 000 Bq at the start time and generation of decay products	16
Figure 3	– Decay of ²²⁰ Rn (Thoron) after injection of 1 000 Bq at the start time and generation of decay products	16
Figure 4	– Activity build-up of ²²² Rn and its decay products for a continuous supply of ²²² Rn with a rate of 1 Bq/s (in the absence of initial activities)	16
Figure 5	– Activity build-up of ²²⁰ Rn (Thoron) and its decay products for a continuous supply of ²²⁰ Rn with a rate of 1 Bq/s (in the absence of initial activities)	16
Figure 6	– Total stopping power of alpha particles penetrating different materials, the graphs use data from [38]	17
Figure 7	– Contributions of the deposition processes to the total efficiency (calculated exemplarily for a wire screen)	24
Figure 8	– Variation of deposition efficiency of a wire screen in dependence on air flow velocity (calculated exemplarily for a wire screen)	24
Figure 9	– Measurement error of the method of MARKOV given in percent for different ratios of decay products in the air sampled	27
Figure 10	– Method of multiple successive countings	28
Figure A.1	– Sampling and measurement procedures commonly used for radon instruments	35
Figure A.2	– Sampling and measurement procedures commonly used for radon progeny instruments	35
Figure B.1	– Scheme for sampling and counting	44
Table 1	– Coefficients for the calculation of the equilibrium equivalent concentration from measured activity concentrations of radon progeny	19
Table 2	– Potential alpha energy per atom for ²²² Rn progeny including standard uncertainty	21

Table 3 – Potential alpha energy per atom for ^{220}Rn progeny including standard uncertainty 21

Table 4 – Time scheme for the method of Thomas [57] 26

Table 5 – Time scheme for the method of MARKOV [63] 27

Table A.1 – Physical and chemical characteristics [29] 36

Table A.2 – ^{226}Ra , ^{222}Rn and radionuclides of the ^{222}Rn decay chain [37] 36

Table A.3 – ^{224}Ra , ^{220}Rn and radionuclides of the ^{220}Rn decay chain [37] 37

Table A.4 – CSDA-Range of alpha particles emitted by Radon-222 and Radon-220 decay products in different materials [38] 37

Table A.5 – Solubility of radon in organic components [31] 38

Table A.6 – Diffusion coefficients and diffusion lengths for radon in different materials [79] 38

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 5: General properties of radon and radon decay products and their measurement methods

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 61577-5, which is a Technical Report, has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
45B/912/DTR	45B/926/RVDTR

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

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

A list of all parts in the IEC 61577 series, published 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 document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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

Part 5: General properties of radon and radon decay products and their measurement methods

1 Scope

This part of IEC 61577 provides basic data and technical information in order to support the design of instruments and their practical application for the measurement. The document covers ^{222}Rn as well as ^{220}Rn and the short-lived decay products of both. It is an accompanying document for the application of the technical standards series IEC 61577, and provides physical and technical fundamentals of the measurements methods. For more information, reference is made to the Bibliography.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 61577-1, *Radiation protection instrumentation – Radon and radon decay product measuring instruments – Part 1: General principles*

IEC 61577-2, *Radiation protection instrumentation – Radon and radon decay product measuring instruments – Part 2: Specific requirements for ^{222}Rn and ^{220}Rn measuring instruments*

IEC 61577-3, *Radiation protection instrumentation – Radon and radon decay product measuring instruments – Part 3: Specific requirements for radon decay product measuring instruments*

IEC 61577-4, *Radiation protection instrumentation – Radon and radon decay product measuring instruments – Part 4: Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR)*

IEC TR 62461:2015, *Radiation protection instruments – Determination of uncertainty in measurement*