



BSI Standards Publication

Measurement of radioactivity in the environment – Air: radon-222

Part 12: Determination of the diffusion coefficient in waterproof materials:
membrane one-side activity concentration measurement method

National foreword

This Published Document is the UK implementation of CEN ISO/TS 11665-12:2021. It is identical to ISO/TS 11665-12:2018. It supersedes PD ISO/TS 11665-12:2018, which is withdrawn.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 committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

This publication is not to be regarded as a British Standard.

© The British Standards Institution 2021
Published by BSI Standards Limited 2021

ISBN 978 0 539 14659 2

ICS 13.040.01; 17.240

Compliance with a Published Document cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 October 2018.

Amendments/corrigenda issued since publication

Date	Text affected
30 April 2021	This corrigendum renumbers PD ISO/TS 11665-12:2018 as PD CEN ISO/TS 11665-12:2021

English Version

Measurement of radioactivity in the environment - Air:
radon-222 - Part 12: Determination of the diffusion
coefficient in waterproof materials: membrane one-side
activity concentration measurement method (ISO/TS
11665-12:2018)

Mesurage de la radioactivité dans l'environnement -
Air : radon 222 - Partie 12: Détermination du
coefficient de diffusion des matériaux imperméables:
méthode de mesure de l'activité volumique d'un côté
de la membrane (ISO/TS 11665-12:2018)

This Technical Specification (CEN/TS) was approved by CEN on 12 April 2021 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

CEN members are required to announce the existence of this CEN/TS in the same way as for an EN and to make the CEN/TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the CEN/TS) until the final decision about the possible conversion of the CEN/TS into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of ISO/TS 11665-12:2018 has been prepared by Technical Committee ISO/TC 85 "Nuclear energy, nuclear technologies, and radiological protection" of the International Organization for Standardization (ISO) and has been taken over as CEN ISO/TS 11665-12:2021 by Technical Committee CEN/TC 430 "Nuclear energy, nuclear technologies, and radiological protection" the secretariat of which is held by AFNOR.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO/TS 11665-12:2018 has been approved by CEN as CEN ISO/TS 11665-12:2021 without any modification.

Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms, definitions and symbols	1
3.1 Terms and definitions	1
3.2 Symbols	2
4 Principle	3
5 Equipment	5
6 Sample preparation	6
6.1 General consideration	6
6.2 Fixing the sample in the holder	7
6.3 Connection of the holder (cap) with the chamber	7
7 Control measurements	8
7.1 Verification of radon-tightness	8
7.2 Calibration	9
7.3 Detector background	9
7.4 Instrument statistical fluctuation	9
8 Measurement of radon activity concentration	10
9 Processing and expression of the results for the sample	11
9.1 Determination of the radon diffusion coefficient in the sample	11
9.2 Characteristics of measurement limits	11
9.3 Estimation of confidence interval and uncertainty	13
9.4 Expression of the results	13
10 Requirements for the test	14
11 Influencing factors	15
12 Expression of the results and assessment of the standard uncertainty for the material	16
13 Quality management and calibration of the test device	17
14 Test report	17
14.1 The test report for material	17
14.2 The test report for each sample	18
14.3 Archived material	18
Annex A (informative) Determination of the radon diffusion coefficient of the sample	19
Bibliography	27

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

A list of all parts in the ISO 11665 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Radon isotopes 222, 219 and 220 are radioactive gases produced by the disintegration of radium isotopes 226, 223 and 224, which are decay products of uranium-238, uranium-235 and thorium-232 respectively, and are all found in the earth's crust. Solid elements, also radioactive, followed by stable lead are produced by radon disintegration^[4].

When disintegrating, radon emits alpha particles and generates solid decay products, which are also radioactive (polonium, bismuth, lead, etc.). The potential effects on human health of radon lie in its solid decay products rather than the gas itself. Whether or not they are attached to atmospheric aerosols, radon decay products can be inhaled and deposited in the bronchopulmonary tree to varying depths according to their size.

Radon is today considered to be the main source of human exposure to natural radiation. UNSCEAR^[5] suggests that, at the worldwide level, radon accounts for around 52 % of global average exposure to natural radiation. The radiological impact of isotope 222 (48 %) is far more significant than isotope 220 (4 %), while isotope 219 is considered negligible. For this reason, references to radon in this document refer only to radon-222.

Radon activity concentration can vary from one to more orders of magnitude over time and space. Exposure to radon and its decay products varies tremendously from one area to another, as it depends on the amount of radon emitted by the soil, weather conditions, and on the degree of containment in the areas where individuals are exposed.

As radon tends to concentrate in enclosed spaces like houses, the main part of the population exposure is due to indoor radon. Soil gas is recognized as the most important source of residential radon through infiltration pathways. Other sources are described in other parts of ISO 11665 and ISO 13164 series for water^[2].

Radon enters into buildings via a diffusion mechanism caused by the all-time existing difference between radon activity concentrations in the underlying soil and inside the building, and via a convection mechanism inconstantly generated by a difference in pressure between the air in the building and the air contained in the underlying soil. Indoor radon activity concentration depends on radon activity concentration in the underlying soil, the building structure, the equipment (chimney, ventilation systems, among others), the environmental parameters of the building (temperature, pressure, etc.) and the occupants' lifestyle.

To limit the risk to individuals, a national reference level of 100 Bq·m⁻³ is recommended by the World Health Organization^[6]. Wherever this is not possible, this reference level should not exceed 300 Bq·m⁻³. This recommendation that was endorsed by the European community member states establishes national reference levels for indoor radon activity concentrations. The reference levels for the annual average activity concentration in air cannot be higher than 300 Bq·m⁻³^[8].

To reduce the risk to the overall population, building codes which require radon prevention measures in buildings under construction and radon mitigating measures in existing buildings should be implemented. Radon measurements are needed because building codes alone cannot guarantee that radon concentrations are below the reference level.

When a building requires protection against radon from the soil, radon-proof insulation (based on membranes, coatings or paints) placed between the soil and the indoors may be used as a stand-alone radon prevention/remediation strategy or in combination with other techniques such as passive or active soil depressurization. Radon-proof insulation functions at the same time as the waterproof insulation.

The radon diffusion coefficient is a parameter that determines the barrier properties of waterproof materials against the diffusive transport of radon. Applicability of the radon diffusion coefficient for radon-proof insulation can be prescribed by national building standards and codes. Requirements for radon-proof insulation as regards the durability, mechanical and physical properties and the maximum

design of value of the radon diffusion coefficient can also be prescribed by national building standards and codes.

As no reference standards and no reference materials are currently available for these types of materials, and related values of the radon diffusion coefficient, the metrological requirement regarding the determination of the performance of the different methods described in ISO/TS 11665-13 and in this document, as required by ISO 17025[3], cannot be directly met.

NOTE The origin of radon-222 and its short-lived decay products in the atmospheric environment and the measurement methods are described in ISO 11665-1.

Measurement of radioactivity in the environment — Air: radon-222 —

Part 12:

Determination of the diffusion coefficient in waterproof materials: membrane one-side activity concentration measurement method

1 Scope

This document specifies the method intended for assessing the radon diffusion coefficient in waterproofing materials such as bitumen or polymeric membranes, coatings or paints, as well as assumptions and boundary conditions which will be met during the test.

The test method described in this document allows to estimate the radon diffusion coefficient in the range of 10^{-5} m²/s to 10^{-12} m²/s [8][9] with an associated uncertainty from 10 % to 40 %.

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.

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*

ISO 80000-10, *Quantities and units — Part 10: Atomic and nuclear physics*

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

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11665-1, ISO 80000-10 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1.1 material

material produced according to certain technical specifications which is the object of the test

3.1.2 sample

certain amount of *material* (3.1.1) chosen from the production batch for determination of the *radon diffusion coefficient* (3.1.3)

3.1.3

radon diffusion coefficient

D

<bulk> radon activity permeating due to molecular diffusion through unit area of a monolayer material of unit thickness per unit time at unit radon activity concentration gradient on the boundaries of this material (3.1.1)

[SOURCE: ISO/TS 11665-13:2017, 3.1.3, modified — “<bulk>” has been added as the domain of the definition.]

3.1.4

decisive measurements

measurement results used to calculate the *radon diffusion coefficient* (3.1.3)

3.1.5

decisive volume of the chamber

volume of the chamber used to calculate the *radon diffusion coefficient* (3.1.3)

3.1.6

decisive area of the sample

material (3.1.1) sample (3.1.2) area used to calculate the *radon diffusion coefficient* (3.1.3)

3.1.7

radon transfer coefficient

radon transport in thin boundary layer of air near the surface of the *sample* (3.1.2)

Note 1 to entry: The default value of the radon transfer coefficient is 0,001 m/s to 0,1 m/s.

[SOURCE: ISO/TS 11665-13:2017, 3.1.15, modified — Note 1 to entry has been removed. Note 2 to entry has become Note 1 to entry and has been slightly rephrased.]

3.2 Symbols

For the purposes of this document, the symbols given in ISO 11665-1 and the following apply.

D	Radon diffusion coefficient of the sample, in square metre per second
$D^<$	Lower limit of the confidence interval of the radon diffusion coefficient of the sample, in square metre per second
$D^>$	Upper limit of the confidence interval of the radon diffusion coefficient of the sample, in square metre per second
D_M	Radon diffusion coefficient of the material, in square metre per second
λ	Radon decay constant, in per second
λ_L	Radon leakage rate, in per second
$\hat{\lambda}_L$	Best estimate of the radon leakage rate, in per second
C	Radon activity concentration in the sample, in becquerel per cubic metre
C_{sd}	Radon activity concentration in a source-detect chamber, in becquerel per cubic metre
C_0	Radon activity concentration in a source-detect chamber at the initial time after injection of radon, in becquerel per cubic metre
C_{amb}	Radon activity concentration in the ambient air, in becquerel per cubic metre

C_m	Measured radon activity concentration in a source-detect chamber, in becquerel per cubic metre
d	Thickness of the sample, in metre
S_s	Decisive area of the sample, in square metre
V_{sd}	Decisive volume of the source-detect chamber, in cubic metre
h	Radon transfer coefficient, in metre per second
t	Time, in second
τ_i	Time of start of i measurement period, in second (or hour)
r_g	Gross count rate, in counts per second
r_g^α	Gross count rate from alpha-source, in counts per second
r_0	Background count rate, in counts per second
R_m	Measured rate of decrease of radon activity concentration in the chamber (of pulse count rate)
R_c	Calculated rate of decrease of radon activity concentration in the chamber
R_L	Calculated rate of decrease of radon activity concentration in the chamber at verification of radon-tightness
R_{min}	Function of the minimum measured rate of decrease in the chamber
R_{max}	Function of the maximum measured rate of decrease in the chamber
$u(y)$	Standard uncertainty of the value of y
$s(y)$	Standard deviation of the value of y
$u_{rel}(D)$	Relative uncertainty of the radon diffusion coefficient in the sample
k	Coverage factor
N	Number of samples of the test material

4 Principle

The one-side method is based on the measurement of the decrease over time of the radon activity concentration in a source-detect chamber in contact with one side of the tested membrane. The test is performed in a non-stationary mode. This test method can be used for single-layer waterproof materials when testing results are needed rapidly. They are not applicable for multi-layer waterproof materials that do not meet the requirements of [Figure 7](#).

A sample of the tested material is installed in the sealed end of the cylindrical chamber ([Figure 1](#)). The detector of radon activity is located at the other end of the chamber.

In the beginning of the test, a highly active portion of radon is injected into the chamber through a special valve. Since then, radon activity concentration in the chamber begins to decline because of

- a) diffusion of radon through the sample towards the ambient air,
- b) radon decay, and
- c) leakage of radon from the chamber.