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THE QA-PROGRAMME FOR THE MEASUREMENT OF RADON AND SHORT-LIVED RADON DECAY PRODUCTS AT THE FEDERAL OFFICE FOR RADIATION PROTECTION (BFS)

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INTRODUCTION

The measurement of the concentration of radon in air, and the concentration of radon decay products, or the level of the potential alpha energy concentration (PAEC) of the short-lived radon daughters represents an important task, relevant within a wide-ranging field, including the areas of science, administration, economy and other areas, and has a wide variety of legal, scientific, social and financial aspects. Moreover, these measurements are difficult to carry out, because of their statistical character, and the importance of a number of mostly not well defined influencing parameters resulting in distinctive variations, these sometimes ranging over orders of magnitude, and generally not being well reproducible.

These particularities make it especially important to guarantee at least the quality and accuracy of the readings from measuring devices, and to reduce uncertainties as much as possible, this depending of course, on the aim of the measurement. One way of obtaining reliable and correct results from the measuring devices, is the calibration of the instruments on the basis of an accepted standard, which should be traceable back to the national standards, these being the standards with the highest level of accuracy.

In Germany, the Federal Office for Radiation Protection (BfS), in its role as a coordinating office for problems relating to radioactivity monitoring issues, assumes, within the framework of its administrative and scientific tasks, also responsibilities regarding problems arising in relation to natural radiation exposure and, consequently, also with respect to the measurement of radon and the PAEC.

In this regard, the BfS has to contribute towards obtaining a high level of accuracy in the field of the measurement of radon and its decay products, by providing expert advice, information and support to administrative authorities, measuring institutions, and other bodies involved in this area of activity. The checking and calibration of measuring systems and devices, represents one of the important tasks to be carried out in this regard.

In order to enable fulfilment of these tasks, the BfS had a set of calibration chambers and containers installed in its laboratories and was subsequently accredited as a German Calibration Service (DKD) Calibration Laboratory. The laboratory is comprised of the following elements:

- The laboratory for the measuring quantity "Radon-222 Concentration in Air"
- The laboratory for the measuring quantity "Potential Alpha Energy Concentration (PAEC)"
- Physics laboratories
- Supporting technical equipment
- A nuclide storage room

THE RADON-222 CALIBRATION LABORATORY

The equipment of the radon calibration laboratory consists of an 8m³ chamber and six 0.4 m³ containers all made of stainless steel, and of supplementary technical devices. Openings and various connections make it possible to put into the containers devices and instruments to be calibrated, or to monitor the interior atmosphere. Part of the equipment consists of a closed pipe
loop with an airtight pump, controlling the internal circulation of gases, this including a radium-226 source with an activity of 100 kBq, and a high emanation factor within the circuit (Fig. 1).

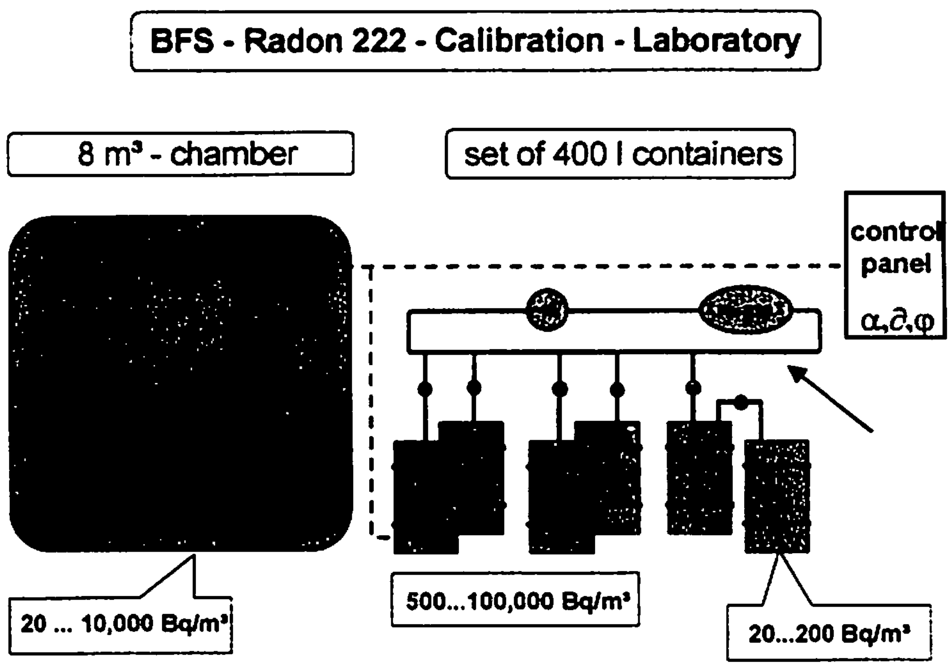

Figure 1: Scheme of the Radon-222-Calibration Laboratory

Every unit, i.e. the chamber and the 6 containers, is equipped with sensors for the measuring of the quantities radon concentration, temperature and humidity. For the purposes of measuring the radon concen-tration, a semi-conductor sensor with negatively charged detector surface for the accumulation of the radon daughters is put into application. The values from these on-line measurements are displayed on the screen of the control panel and, in addition, continuously registered. Within the chamber, a concentration range of 20 to 10,000 Bq/m³ can be applied, this range being, in the containers, 500 to 100,000 Bq/m³.

A container aligned with a further container, is applied for the range 5 to 200 Bq/m³. To achieve the required radon concentration within the units, a radon sample is taken from another dry specific Ra-226 source using a syringe. The gamma-activity of the contents of the syringe is firstly measured, and then the amount necessary to achieve the concentration, is fed volumetrically dosed into the chamber or container.

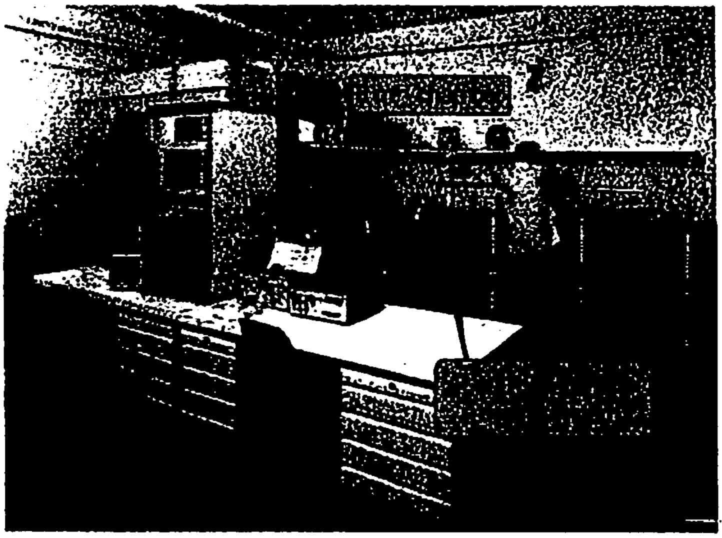

Figure 2: View of the radon laboratory

The loss in radon activity due to natural decay, is subsequently compensated over the calibration period via the circuit loop, using a dosing system fitted with dosing pumps specially designed for the transferring of the very small amounts of gas.

The chamber and the containers are best used for the calibration of active and passive radon dosemeters, and of radon measuring devices, taking into account the respective conditions of their application.

QUALITY ASSURANCE FOR THE RADON CALIBRATION LABORATORY

The radon calibration laboratory is part of the DKD radon/radon decay products calibration laboratory and has to fulfil the specific requirements relating to the uncertainties affecting the measurements. For this reason, the calibration chamber and the containers are regularly recalibrated. External recalibrations are carried out on the basis of standards, which can be traced back to the National Standards of the Physikalisch-Technische Bundesanstalt, using a radon transfer standard as the reference standard, and occasionally also the certified gas standards of the PTB. For the transfer standard, a commercial radon measuring instrument specifically reserved for this task is used.

The routine measurement of the radon concentration in the chamber or, respectively in the containers, is carried out using a set of scintillation chambers (Lucas cells, working standard 1) which have proved to remain constant in their effectivity over periods of more than 20 years, and, in addition, with diffusion chambers containing electronic detectors (working standard 2), the latter being located in the containers themselves. The third method involves the use of a particular measuring device (working standard 3) of the same type as the reference standard. The procedure, starting with the National Standard of the PTB, and ending with the instrument to undergo routine calibration, is shown in Fig. 3.

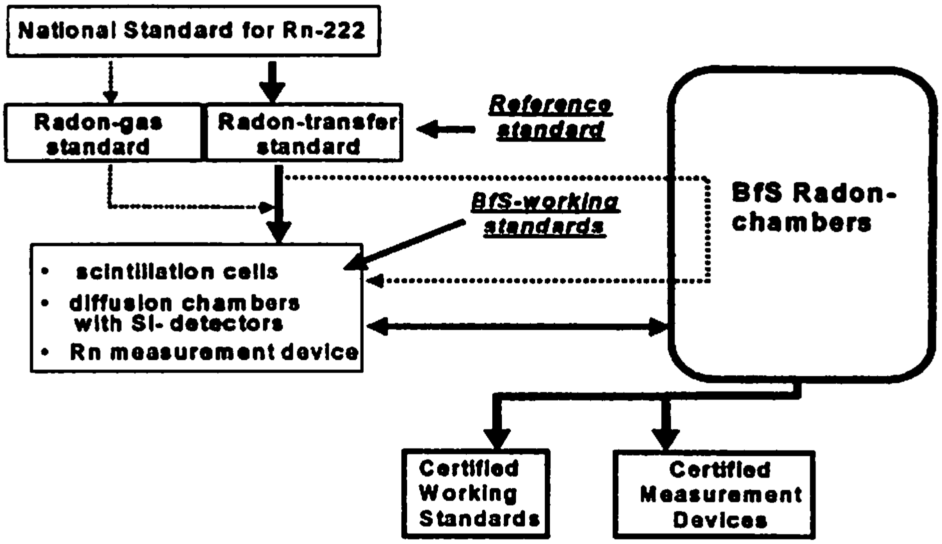

Figure 3: Calibration/Recalibration Procedure for the Measuring Quantity "Radon-222-Concentration

The uncertainties for the estimation of the value for the radon concentration within the calibration volumes which are expressed as "expanded measuring uncertainty" are divided up into three ranges as follows:

measurement area	radon concentration	uncertainty		
(SC scintillation chamber, DC Lukas cell, AS active standard device)		SC	DC	AS
Living /workplace area I	50 ... 1000 Bq/m³	24%	42%	14%
workplace area I	1000 ... 10,000 Bq/m³	8%	10 %	8%
workplace area II	10,000 ... 100,000 Bq/m³	8 %	8%	8%

(relative expanded uncertainty-coverage factor 2)

The 36 m³ chamber is located in a separate room, used especially for the calibration of instruments for the measurement PAEC, or both radon and daughter nuclides simultaneously. Another important field of application is research work and specific investigations on radon and radon decay products. For the purpose of these tasks, a chamber with thermally insulated walls has been constructed, with a large range of openings, doors, windows and orifices for cables and hoses. Measuring systems and settings for data capture and processing and for process management are also fitted into the equipment, along with several supporting devices (Fig. 4).

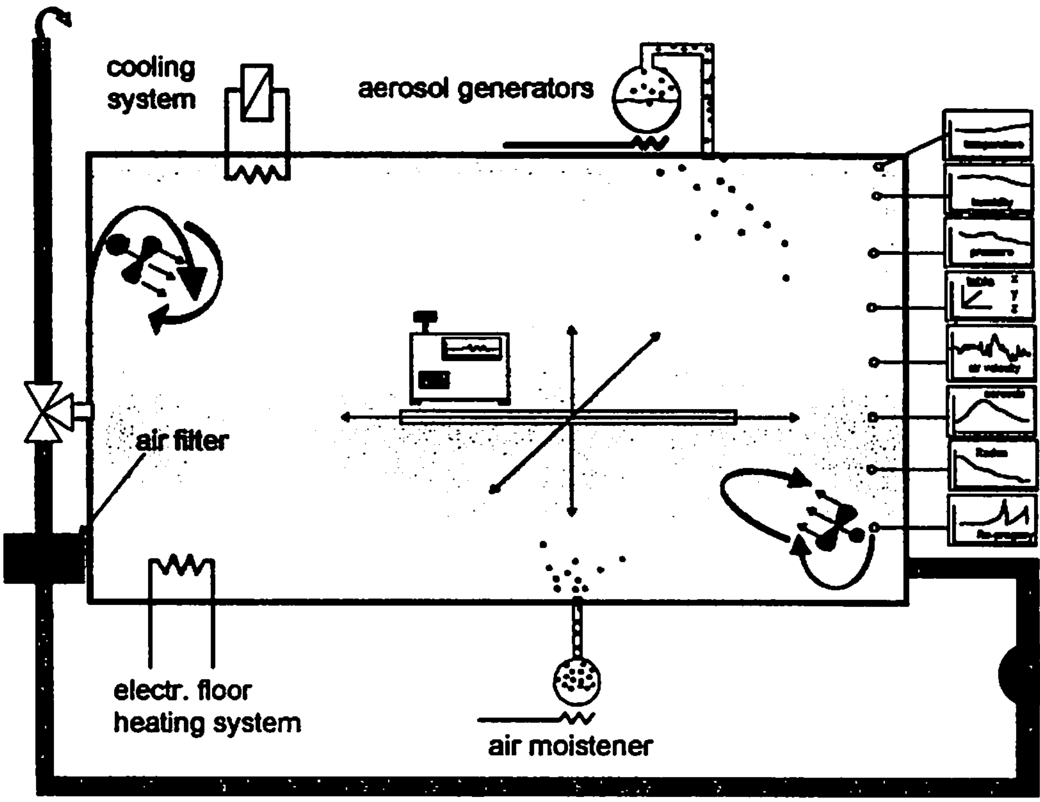

Figure 4: Scheme of the radon decay products chamber

The following parameters are recorded using sensors integrated into the chamber, or sampling instruments and external detectors and measuring devices:

- The potential alpha-energy concentration both for attached and unattached, short-lived radon decay products (PAEC)
- The activity concentration of the short-lived radon decay products
- The activity concentration of radon-222
- The equilibrium factor for radon and its decay products
- Aerosol parameters (particle concentration and particle distribution)
- Air temperature, relative humidity and atmospheric air pressure or subpressure within the chamber
- Air motion and turbulence

The most important parameters with regard to calibration of measurement devices for radon decay products are the aerosol concentration, aerosol particle size distribution, and also electrical charges. In order to be able to adjust a specific aerosol atmosphere within the chamber, the following technical provision for controlling the aerosol parameters is available:

Aerosol generators
- Condensation aerosol generator for carnauba wax
- La Mer aerosol generator for different substances
- Atomizer for salt solutions

Aerosol measuring instruments
- Electrostatic classifier SMPS
- Laser aerosol spectrometer LASX
- 8-stage graded screen array

Using the SMPS or the LASX device the aerosol concentration and the particle size distribution can be monitored on-line, along with the parameters which exercise a significant influence on the aerosol characteristics, e.g. humidity.

Generally parameters can be adjusted within the chamber as followes:

• radon-concentration	50 ... 100,000 Bq/m^3
• temperature	0 ... 45 °C
• humidity	10 ... 95 %
• pressure/pressure difference	slight subpressure or balanced to room atmosphere
• air velocity (turbulence)	0 ... 2 m/s
• aerosols (polydisperse)	200 ... 300,000 p/m^3
• PAEC	2 ... 4000 MeV/cm^3
• F (equilibrium factor)	0.2 ... 0.9
• f (unattached fraction)	1 ... 30 %
• sensor-/table position	cartesian co-ordinates

In order to be able to decrease the aerosol concentration within the chamber, the chamber is fitted with an external air circulation loop, comprised of a fan, a high efficiency particulate air filter and several valves. Depending on the position in which the valve is set, the air is either fed back, after the filtering out of aerosols, into the chamber, or released into the atmosphere above the roof, in order to decrease the radon concentration within the chamber. In the latter case, the volume of exhaust air is replaced with air subsequently let into the chamber, as a result of the subpressure produced by the air released.

The equipment fitted inside the chamber, also comprises a special transportation system which operates on the basis of cartesian coordinates. A table on which, e.g. devices to be investigated or calibrated can be set up in defined positions inside the chamber. It is also possible to keep the device in continuous motion on tracks, directed by the chamber control system.

The inhomogeneities in the aerosol concentrations, and, in particular, in the unattached fraction of the radon daughters near surfaces or the chamber walls can, in this way, be taken into consideration, both for the purposes of targeted investigations, as well as with regard to their influence on the results of measurements. In this regard the possibility to control the air motion and the air turbulence within the chamber with the use of two fans, installed at opposite corners inside the chamber and to be turned in two directions each, are of high importance. To compensate for more significant changes in the atmospheric air pressure within the chamber, which could have significant negative effects on the air-tight chamber, in particular as a result of implosive effects, a pressure compensation system has been installed, which provides the possibility of carrying out controlled exchange of air volumes, between the chamber and a 2 m^3 pressure tank.

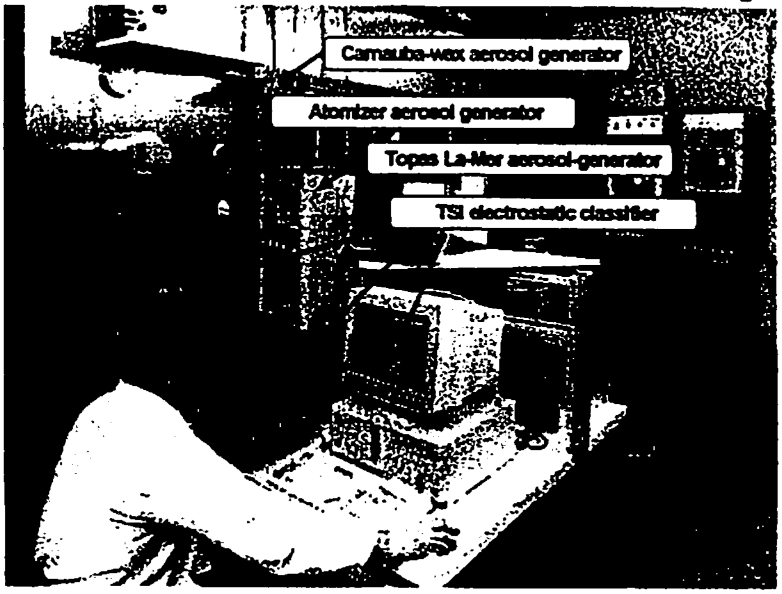

Figure 5: View of the radon decay product chamber

QUALITY ASSURANCE FOR THE RADON/RADON DECAY PRODUCTS CALIBRATION LABORATORY

As the concentrations of the short-lived radon decay products applied within the radon/radon decay products calibration chamber represent the most important single element for the DKD laboratory, these are traceable back to the National Standard of the "Physikalisch-Technische Bundesanstalt (PTB)", using an Ra-226 reference standard, produced and certified by the PTB. This standard is designed as a surface source, containing the Ra-226 activity in equilibrium with its short-lived decay products.

The standard source is used to calibrate a γ-measuring system for the measurement of Bi-214. The system is used in the subsequent calibration of a double α-spectro-meter which is applied as a working standard in routine work.

More precisely, this means the monitoring of the chamber atmosphere in relation to the PAEC, and the calibration of instruments for the measuring of both the PAEC, and the combination of radon and its decay products, in the same device. The relevant surface area of the standard source is of about the same diameter as the filters commonly used for the determination of the PAEC within the chamber, by means of the collecting of the unattached radon daughters on a wire screen, and of the fraction attached to aerosols, on high efficiency filters. Both samples are subsequently measured in the double α-spectrometer, after allowing time for the decay of Po-218

A schematic diagram showing the different calibration processes is presented in Fig. 6.

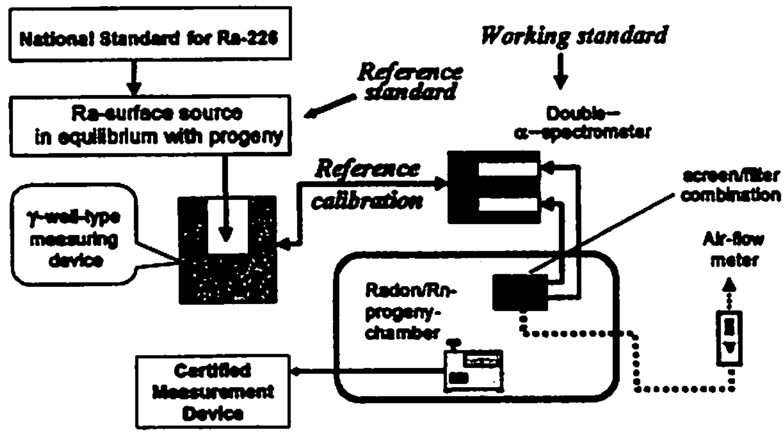

Figure 6: Calibration/Recalibration Procedure for the Measuring Quantity PAEC

The uncertainties for the estimation of the value for the PAEC are divided up into three ranges as follows:

measurement area	PAEC	uncertainty
Living area/workplace I	2...40 MeV/cm³	< 14 %
workplace area I	40...400 MeV/cm³	< 12 %
workplace area II	400...4000 MeV/cm³	< 12 %

(relative expanded uncertainty-coverage factor 2)

In order to guarantee constantly the high level of accuracy and to meet the requirements for a secundary reference laboratory for the quantities radon and radon decay products, the participation in intercomparisons regularly between four institutions including the PTB is planned.

The most important task is the calibration of measuring instruments owned by the BfS, and also of other such devices operated by other authorities and, on application, of those operated by private institutions and companies as well. Another important use of the chambers is their application in scientific investigations in the field of the measurement of radon and its decay products, in particular regarding the improvement of the quality assurance. In this respect, the equipment is also made available to guest scientists, within the framework of national and international scientific co-operation.