Available online at www.sciencedirect.com

SCIENCE DIRECT®

Nuclear Instruments and Methods in Physics Research A 537 (2005) 672–682

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

Effect of air on gas amplification characteristics in argon–propane (1%)-based proportional counters for airborne radon monitoring

G. Curzio, D. Mazed*, R. Ciolini, A. Del Gratta, A. Gentili

Dipartimento di Ingegneria Meccanica, Nucleare e Della Produzione (DIMNP), Università di Pisa, Via Diotisalvi 2, I-56126 Pisa, Italy

Received 12 January 2004; received in revised form 2 June 2004; accepted 17 July 2004
Available online 11 September 2004

Abstract

Aiming for the development of a new technique of on-line airborne radon activity concentration measurement, the effect of air on some detection properties of argon–propane (1%)-based proportional counters is investigated when a fraction of 2%, 6% and 10% of it is successively and intentionally admixed to the counting gas in a single-wire proportional counter. The influence of the electron attachment, principally due to oxygen component, on the ionization saturation plateau and the gas amplification process is particularly examined. The previously developed semi-microscopic gas gain formula is found to describe well the gas gain data obtained in each of the gas mixtures analyzed, thus allowing a consistent examination of the air effect on the relevant gas constants. Finally, the possibility to use such air-mixed counting gases in specially designed gas-flow proportional counters intended for new on-line measurement methods of airborne radon (^{222}Rn) activity concentration appeared quite viable.

PACS: 29.30.h; 29.40.C

Keywords: Radon activity concentration; Proportional counters; Air-mixed counting gases; Gas-gain; Electron attachment

1. Introduction

Radon (^{222}Rn) is estimated to be responsible for about 30% of the whole human radiation exposure. This radiation exposure is predominantly caused by the deposition on the respiratory tract and lungs of radon progenies through the aerosols taken in through respirations [1]. Radon also presents very particular properties: it is a radioactive noble gas and diffuses easily out of soils or building materials, spreading out in the environment. Consequently, different concentrations of

*Corresponding author. Tel.: +39050836649; fax: +39050836665.
E-mail address: dahmane.mazed@studenti.ing.unipi.it (D. Mazed).

0168-9002/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2004.07.287

radon and of its progenies can be found everywhere around us. For this reason radon is an inescapable radiation exposure source both at home and at work. Since it is an inert gas, ^{222}Rn does not react chemically with other atoms or molecules, making its chemical separation impossible and its physical trapping also difficult. Because of these facts, several detection systems and various measurement methods were developed in the past aiming for an accurate assessment of its activity concentration in air [2]. However, most of those methods present some practical limitations and generally they are not able to measure radon activity concentration on-line and/or are often affected by low detection efficiencies. Therefore, they do not provide the performance required in practice for an on-line measurement of medium radon activity concentrations ($1\,\mathrm{kBq\,m^{-3}}$–$10\,\mathrm{kBq\,m^{-3}}$). This feature is in fact of fundamental relevance for the study of the time variation of radon airborne activity concentrations and its equilibrium factors, especially when a correlation with environmental parameters is sought.

For this purpose, a design study of a new gas-flow proportional counter suited for such measurements was undertaken in our laboratory. In order to check the possibility to use air-mixed counting gases, we have investigated three typical air-mixed argon–propane (1%) gas mixtures. We report in this paper the preliminary results obtained.

2. The use of gas-filled detectors for radon monitoring in ambient air

Few laboratories worldwide are focusing their research activity on the use of gas-flow proportional counters for the continuous monitoring of radon concentration in air. In fact, it is rather difficult to perform α spectroscopy in open air, due to the presence of oxygen, water vapor and other electronegative gas traces. Nevertheless, some research groups have already made significant progress in this direction [3–9] and some results are briefly reviewed below.

In 1992, Baltzer et al. [3] reported about a wire arrangement pulse-counting ionization chamber for measuring radon concentration in atmospheric air. Their device was based on both positive and negative ion collection (due to electron attachment) and it is severely limited by the excessively long collection times involved. The authors have also noticed the existence of an important microphonic noise, which could be generated by the wire structure vibrations. Klein et al. [4] mentioned the possibility of using proportional counters for in situ radon level characterization, but gave no more details. Zikovsky [5] tried to measure radon concentrations in air by performing alpha counting of the ^{218}Po and ^{214}Po products deposited on the inner walls of the counter. He first filled a proportional counter with an air sample and then evacuated the counter after periods of time between 30 and 216 min, immediately introduced P-10 gas, a standard counting gas (argon–methane (90–10%)), to detect the alphas emitted by the radon decay products. Unfortunately, in addition to the fact that this method cannot provide on-line measurements, it has also a major drawback of fundamental importance: the equilibrium factors are not exactly known [6]. In order to make on-line medium-level measurements of radon activity, Rottger et al. [7] also used a multi-wire pulse ionization chamber, similar to the one described by Baltzer. Their device was designed to permit adequately large volumes (from 5 to 13 l) and presented a special electrode configuration (Archimedean spiral layout). However, the device is still based on ion collection and, since the electrons are captured by electronegative gases, e.g., oxygen, only positive and negative ions are suitable for collection in pulses. This results in very low amplitude and long-current pulses of about 1 fA in 30 ms [8]. Therefore, this multi-wire pulse ionization chamber is naturally subjected to some limitations such as long collection times and residual microphonics noise.

Recently, Busch et al. [9] reported on the first use of a gas-flow proportional counter for performing direct radon activity concentration measurements. However, the gas-flow proportional counter used does not carry out radon measurement in ambient air, but uses the P-10 gas