

Dynamic Calibration of an Aerosol Monitor with Natural and Artificial Alpha-Emitters

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Abstract

Measurement of airborne artificial α -activity concentrations in the presence of naturally occurring radionuclides requires reliable subtraction of the natural contribution and precise calibration. Therefore, the commercially available aerosol monitor LB150D-R was calibrated dynamically at the IPSN/CEA in Saclay, France. Aerosols with activity median aerodynamic diameters of 0.4 μm and 4 μm labelled with ^{239}Pu were generated and isokinetically sampled by the aerosol monitor. The response to ^{239}Pu activity concentrations and detection limits in the presence of radon progeny were determined. The retention of aerosols and their distribution on the filter was investigated using fluoresceine labelled aerosols.

I. INTRODUCTION

In nuclear technology there are α -emitting nuclides which are man-made or artificial like for instance ^{239}Pu or ^{241}Am . The allowed limits of intakes for these radionuclides are extremely low. Therefore aerosol monitors with very low detection limits are required for the measurement of aerosol-bound activity concentrations in air. This can be done by sampling the aerosols on a filter and measuring the filter activity with radiation detectors. An additional problem in the detection of artificial α -emitting radionuclides is, that there are usually large contributions from naturally occurring α -emitters like radon, thoron and their daughters which must be compensated for. Retention of aerosols on internal surfaces of the instrument reduces the collected fraction on the filter.

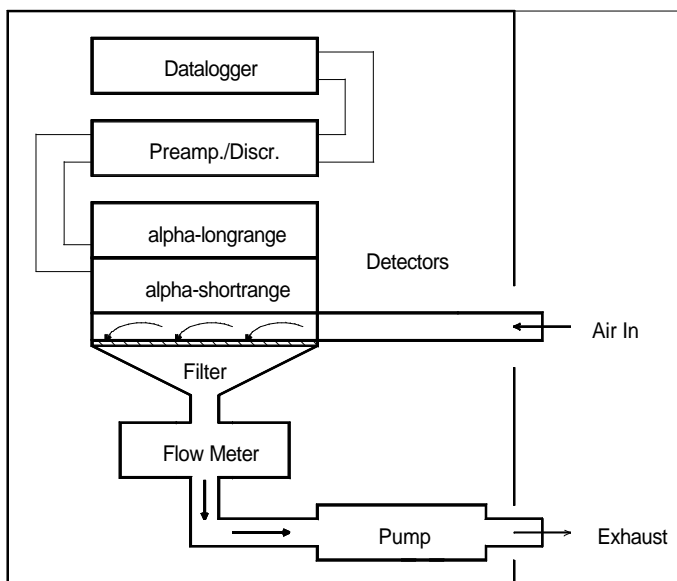


Figure 1: Schematic diagram of aerosol monitor LB150D-R

From these considerations it is very clear, that a dynamic calibration of an aerosol monitor using real aerosols is essential. The LB150D-R was therefore calibrated dynamically at the ICARE facility of the IPSN/CEA in Saclay [1].

II. DESCRIPTION OF AEROSOL MONITOR LB150D-R

The aerosol monitor LB150D-R is manufactured by EG&G Berthold [2]. The monitor samples aerosols on a fibreglas filter with diameter $\varnothing 200$ mm at an air flow rate of typically 40 m^3/h . A gas proportional detector system with two (α detection) or three counter tubes (α , β and guard detector to reject cosmic rays) is assembled above the filter. In the following we discuss only the α -system with two detectors which is shown in Figure 1.

It has two sandwiched proportional counters with thin entrance windows to the filter and between each other. The counters are operated in the α -plateau with counting gas P10. The first counter above the filter detects short range α -particles with energies below ≈ 6 MeV. The second counter detects long range α -particles with energies above ≈ 6 MeV. Artificial radionuclides have α -decay energies below 6 MeV and radon and thoron daughters have α -energies above 6 MeV. Therefore α -particles with long ranges are identified as natural, while short range α 's are considered to be artificial. A certain fraction of the natural component is detected among the short range α 's because of energy loss on the filter or track inclination.

The processor of the aerosol monitor subtracts rate " α -long range", weighted with a compensation factor, from rate " α -short range" to calculate the rate " α -artificial". The compensation factor is determined experimentally and depends on the geometrical details of the detectors and the filter unit.

III. RESPONSE TO ^{239}Pu LABELLED AEROSOLS

The air flow meter was calibrated and the detector response to α -particles was determined using a solid ^{239}Pu source. The detection efficiency of counter " α -short range"

Table 1
Results of ^{239}Pu calibration

Activity concentration [Bq/m ³]	AMAD [μm]	Relative response [%]
16.1 ± 0.5	0.4	76 ± 3
41.8 ± 1.6	4	59 ± 10

was found to be 27.6%. CsCl aerosols with activity median aerodynamic diameters (AMAD) of 0.4 μm and 4 μm were generated in an ultrasonic nebulizer at the ICARE testbench of IPSN/CEA [3]. The aerosols were labelled with ^{239}Pu . After injection into the wind tunnel, they were isokinetically sampled by the aerosol monitor under calibration. The activity concentration in the wind tunnel was monitored using reference filters which were periodically changed and analyzed. The aerosol monitor LB150D-R recorded counting rates from the proportional counters and measured the air flow rate. Measured artificial activity concentrations were calculated using this data. The results are given in Table 1. The relative response was reduced compared to the calibration with solid sources. The effect was more pronounced for aerosols with larger activity median aerodynamic diameter. The weighted mean of the relative response to ^{239}Pu is 74.6% with the inverse variances of the datapoints at AMAD 0.4 μm and 4 μm used as weights.

IV. DETECTION LIMITS WITH RADON BACKGROUND

The quality of the compensation for natural α -contributions directly influences detection limits. Therefore, the response to artificial α -emitters was measured in the presence of radon daughters. Radon daughters were generated at the ICARE test-bench of the CEA in Saclay, France [3]. The activity concentrations of the radon daughters ^{218}Po , ^{214}Pb , ^{214}Bi and ^{214}Po , the equilibrium factor and the attached fraction were determined by the calibrating laboratory. The detection limits at confidence level 95% for the detection of ^{239}Pu in the presence of radon progeny were calculated [1]. The results are summarized in Table 2.

Table 2
Detection limits for ^{239}Pu in the presence of radon progeny

Radon activity concentration [Bq/m ³]	Measuring time [min]	Detection limit [mBq/m ³]
172	60	386
60	60	220
37	60	176
37	150	62

V. RETENTION OF AEROSOLS

The mechanisms of aerosol deposition on surfaces are determined by Brownian and turbulent diffusion, thermal precipitation and by gravitational, centrifugal and electric forces [4]. To investigate the details of transport and deposition of aerosols through the aerosol monitor LB150D-R fluoresceine labelled aerosols of different sizes, charged and uncharged were generated at VEGA testbench of the IPSN/CEA [1]. After sampling by the LB150D-R, the aerosols were carefully washed down from internal surfaces and from cut pieces of the filter into a solution. The total

Table 3
Aerosol retention and distribution on the filter

Electrical charge /particle	Aerodynamic diameter [μm]	Collected fraction [%]	Homogeneity on the filter
neutral	2	94	0.91
3000 u+	2	83	0.86
neutral	4	88	0.89
neutral	10	66	0.84

deposited aerosol mass on any of the segments was determined by measuring the fluorescent light yield from the collected solution attached to those segments. The losses of aerosols on all internal surfaces of the instrument and their distribution on the filter were determined for different aerosol diameters and electrical charge states. The total collected fraction on the filter was calculated and is given in Table 3. The retention in the aerosol monitor LB150D-R is more important for larger aerosols. The collected fraction on the filter is lower for electrically charged aerosols. The homogeneity on the filter was characterized by a partition coefficient which is 1 for ideal homogeneity. Smaller aerosols are more homogeneously distributed than larger aerosols. These observations qualitatively agree with the results found with ^{239}Pu labelled aerosols, where the detection efficiency for smaller aerosols was higher. Thus, by combining both experimental methods, an improved and consistent understanding of the transport and deposition mechanisms could be obtained.

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