EXPERIMENTAL STUDY OF THE ELECTRICAL CHARGING OF RADIOACTIVE AEROSOLS

F. GENSDARMES[1,2], D. BOULAUD[1], A. RENOUX[2]

[1] Institut de Protection et de Sûreté Nucléaire, Département de Prévention et d'Etude des Accidents,
Service d'Etudes et de Recherches en Aérocontamination et en Confinement.CEA/Saclay, Bat 389, 91191 Gif-sur-Yvette cedex, France.

[2] Université Paris XII, Laboratoire de Physique des Aérosols et de Transfert des Contaminations.
Av. du Général de Gaulle, 94010 Créteil cedex, France.

KEYWORDS

Electric charge; Radioactive aerosol, Ionisation.

INTRODUCTION

In case of an accident within a nuclear power plant, radioactive aerosols are generally the main source of contamination. In such case, the knowledge of the aerosol charge distribution is necessary to modelling aerosol transport and deposition in the containment.

The electrical charging of radioactive aerosols is different from the charging of a non-radioactive aerosol. The experiments carried out by Yeh *et al.* (1976) showed that one can observe a positive self-charging of the radioactive aerosol, which is due to the emission of the charged particles (α or β). Several theories exist to predict the charge distribution of a radioactive aerosol (Yeh, 1976; Clement and Harrison, 1992). These theories show that the aerosol mean charge increase both, when the aerosol specific activity increase or when the ionisation rate decrease. However very few experimental data are available, making the validation of the existing theories not reliable.

The aim of this work is to carry out experimental measurements on the radioactive aerosol charge distribution. For this purpose, we have designed and realised an experimental device allowing to generate a standard radioactive aerosol of ^{137}Cs and to analyse its electric charge distribution in a stationary state.

EXPERIMENTAL DEVICE

Our experimental device represented in figure 1 allows to produce a monodispersed radioactive aerosol with a Vibrating Orifice Aerosol Generator (Berglund and Liu, 1973). The specific activity of the aerosol is controlled by using a ^{137}Cs standard radioactive solution. The aerosol is then introduced in a tank which is made of two parts. In the upper part (tank volume), the sizes of the tank are greater than the mean path of the beta electron, so the ionisation rate is maximum.

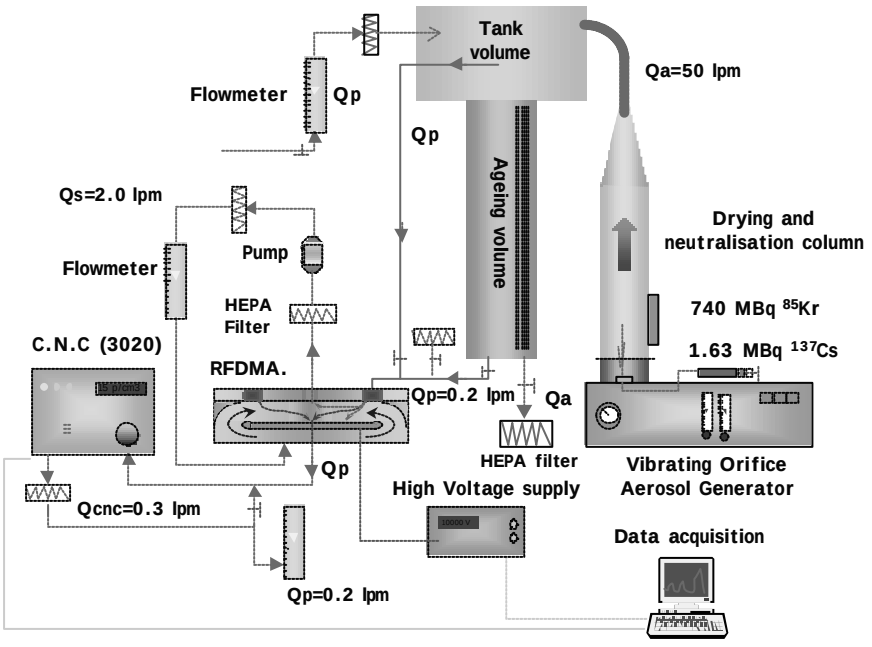

Figure 1 : experimental device.

In the lower part (ageing volume) we have an assembly of tubes of 6 mm diameters, which makes possible to reduce the path of the electrons, and thus to decrease the ionisation rate. The residence time of the aerosol is checked by the sampling flow-rate in the volume. The charge distribution of monodisperse aerosol is determined with a Radial Flow Differential Mobility Analyser (RFDMA), describe by Mesbah (1994) and a Condensation Nucleus Counter (CNC 3020). For safety reasons, due to manipulation of radioactive aerosols, our experimental device is confined in a glove box.

RESULTS

Figure 2 represents the charge distribution of a ^{137}Cs aerosol in the upper volume. The particle diameter is 0.82 µm, the specific activity is $\eta=1.28\times E^{-2}$ Bq/particle. In this part of the volume, the number of ion pairs produced per decay is about ≅4870. We also represent in this figure the models of Clement and Harrison (1992), both for the radioactive and for the non-radioactive aerosol. In these models, we use the ion asymmetry parameter determined in inactive experiments, using a method described by Gensdarmes *et al.* (1999). From the theoretical curves, we notice, that the specific activity is too weak to obtain a significant self-charging of the aerosol. However the theoretical curves are in good agreement with our experimental results. Figure 3 represents the charge distribution of the same ^{137}Cs aerosol in the lower part of the volume. In that case, the ionisation rate is reduced: we estimate the number of ion pairs produced per decay at approximately ≅100. We also represent the Clement and Harrison model for the inactive aerosol together with the radioactive model calculated for the reduced ionisation rate. In that case, the radioactive and the non-radioactive models are quite different. Our experimental data show a shift of the charge distribution toward positive values. By comparing experimental results represented in figures 2 and 3, we notice that the charge distributions of the aerosols change sign.

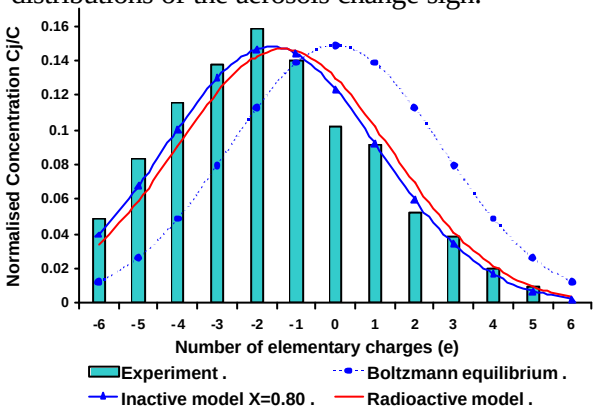

Figure 2: aerosol charge distribution in the tank volume (dp=0.82 µm; $\eta=1.28\times E^{-2}$ Bq/part.).

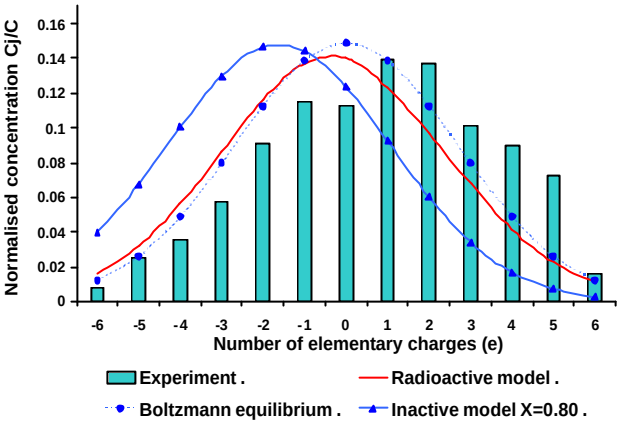

Figure 3: aerosol charge distribution in the ageing volume (dp=0.82 µm; $\eta=1.28\times E^{-2}$ Bq/part.).

CONCLUSIONS

We have designed an experimental device able to generate standard radioactive aerosol, to control the aerosol parameters and its ageing in different volumes, and to measure the resulting charge distributions. In our experiments, we have studied the influence of a geometry parameter which determines the ionisation rate of radioactive aerosols, especially in a confined space.

Our experimental results show that the variation of the charge distribution agree qualitatively with the predictions of the Clement and Harrison model, the aerosol mean charge increase when the ionisation rate decrease. Some other experiments carried out by varying the specific activity of the aerosol, confirm such a conclusion: the experiments show an increase of the aerosol mean charge when the specific activity of the particles increase.

However, our results demonstrate that the modelling of Clement and Harrison underestimates the aerosol charge distribution when the sampling geometry is confined. This effect can be explained by an increase of the ion losses by diffusion onto the walls, which leads to a reduction of the ion concentrations. Moreover, our experiments show that the study of radioactive aerosol properties remains intricate, since some parameters like the geometry of the ageing volume could strongly affect the charge distribution even for a low active aerosol.

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