DESIGN AND CHARACTERIZATION OF A DOUBLE GERDIEN ION COUNTER

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INTRODUCTION

Nanoaerosol formation in the boundary layer is a frequent phenomenon (Kulmala et al. 2004). Binary homogeneous nucleation by Sulphuric acid and water (Weber et al. 1996) and ternary homogeneous nucleation including ammonia have been identified as a plausible candidate to participate in the initial nucleation. Ion-Induced Nucleation (IIN) is, as well, one of the possible pathways for new particle formation in the atmosphere (Yu and Turco, 2000) but it is still unclear how much is the contribution of ions with respect to neutral pathways.

Ions are ubiquitous in the atmosphere, they are part of the aerosol spectrum, in the troposphere they are formed by natural radioactive sources (such as Radon decay, gamma radiation from the soil and Galactic Cosmic Rays -GCR-). Being able to measure the ion concentration in several independent ways is very important to understand and try to quantify ion-induced nucleation processes and dynamics.

METHODS

The instrument described in this work was designed to operate in the CLOUD chamber at CERN (Kirkby, 2007; Duplissy et al., 2010). The main characteristic that makes this instrument different respect with a Gerdien counter made for outdoor measurements is the low sample flow rate. Using a high inlet flow rate is helpful to increase the sensitivity of the instrument, since the core of the instrument is an electrometer and the measured quantity is an electronic current, with the consequence that, at the same ion concentration, increasing the flow rate will increase the signal. The need to lower the flow rate is related to the exigence to minimize the dilution flow in the aerosol chamber in order to maintain the conditions of the chamber as constant as possible.

In a Gerdien counter, an electric potential difference is applied between two coaxial cylindrical electrodes, with air drawn between the cylinders. Ions with the same polarity as the outer electrode are moved toward the central electrode, and the ion density is inferred from a voltage relaxation measurement. Using two Gerdien condensers it is possible to measure both positive and negative ions simultaneously. The ion currents are generally of the order of 10 fA, requiring a sensitive electrometer and a careful design in order to avoid losses of ions (due to diffusion or to plastic insulators in the line). For a given ion concentration $n$ the current in the central electrode is:

$$I = e n v d A$$

Where $e$ is the elementary charge, $v_d$ is the drift velocity of the ions, $A$ is the surface area of the internal electrode.

The second key quantity for the design of a Gerdien condenser is the critical mobility $\mu_c$ defined as (Nicoll and Harrison, 2008):

$$\mu_c = \frac{(b^2 - a^2) \ln \left( \frac{b}{d} \right) \nu}{2 \nu L}$$
Where \( v \) is the flow velocity, \( b \) and \( a \) respectively the radii of outer and inner electrodes, \( V \) the voltage applied to the two electrodes and \( L \) the length of the condenser.

Gerdien condensers have been previously used to measure ion concentration either directly by current measurement, or as with the original Gerdien method, through using the rate of change in electrode voltage to infer the ion current flowing (Aplin and Harrison 2000). A disadvantage of the current measurement mode for a disposable atmospheric instrument is that it requires expensive high value \( 10^{12} \Omega \) resistors, which may have appreciable temperature coefficients. The instrument described therefore uses the voltage relaxation method to avoid the need for a high value resistor. The approach used is to reset the central electrode voltage to a known value and determine the rate of change in voltage.

The dimensions chosen for the instrument presented in this work are: \( a=1.25 \text{ cm} \), \( b=2.54 \text{ cm} \), \( L=48 \text{ cm} \), the chosen bias voltage \( V \) is 30 Volts for a corresponding critical mobility of \( 7\times10^{-7} \text{ m}^2\text{s}^{-1}\text{V}^{-1} \).

![Figure 1. Sketch of a single column of the Gerdien counter.](image)

The instrument was designed as described above and calibrated in concentration using a radioactive source as source of ions. The polarity of the ions was selected with a Differential Mobility Analyser and their concentration measured with an aerosol electrometer (TSI 3068B).

### RESULTS

![Figure 2. In this figure is shown the result of the calibration of the two polarity of a the Gerdien condenser using a TSI electrometer (model 3036) as a reference instrument.](image)

The calibration was performed at an inlet flow rate of 4 l/min. Figure 2 shows a good signal to noise ratio up to 1500 ions cm\(^{-3}\), value close to outdoor concentration of ions. The parameters of the fitting equations provide the calibration factors for the negative and positive column allowing us to use the instrument as an absolute ion counter.
CONCLUSIONS

The response of the instrument is found to be linear with the signal of the reference instrument, as expected, meaning that the instrument is working properly. Fluctuations when the ion concentration is close to zero suggest that the signal-electrical noise is becoming smaller, for this reason the instrument is still not able to perform an outdoor measurement where ion concentration is of the order of $10^3$ cm$^{-3}$ or smaller, but its characteristics are already sufficient to perform in the CLOUD aerosol chamber, where high concentrations of ions will be created artificially.

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