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THE ASPIRATION METHOD FOR THE DETERMINATION OF ATMOSPHERIC-ION SPECTRA

(Aspiratsionnyi metod izmereniya spektra aeroionov)

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The first chapter of the present monograph deals with the general theory of the aspiration method. The requirements imposed on the measuring capacitor are rendered more stringent, possibilities of measuring integral quantities with the aid of differential counters are indicated and new variants of the method of modulating the air-ion current in the measuring capacitor are suggested.

In the second chapter the systematic measurement errors are investigated and the range of application of the aspiration method determined. Empirical relationships are developed which suffice for the quantitative estimation of the essentially nonlinear edge effect. The distorting effects caused by an increase in the air-ion concentration, the asymmetry of the measuring capacitor, and the mass of air ions are calculated. A theory is developed for the resolving power of the counter which is limited by diffusion and turbulence. The last portion of the chapter deals with the adsorption of air ions at the counter inlet.

The third chapter starts with an analysis of the methods employed in measuring the air-ion current. A quantitative estimation of the counter sensitivity is carried out in order to specify the requirements for the stability of the voltage supply. The spectrum measurements under conditions of fluctuating air-ion concentrations are discussed on the basis of special observation results. Allowance is made for design calculations and the optimization of the counter parameters. The closing sections give a survey of the different designs of the aspiration counter along with a description of the SAI-TGU-66 universal aspiration counter.

INTRODUCTION

The study of ionized air and aerosols is of interest for science and technology. Ionized air and charged aerosols are employed, for example, in electrostatic precipitators, electrostatic painting, neutralization of static electricity, electrophotography, etc. The characteristics of the special air-ion distribution are studied in the physics of the atmosphere /Tverskoi,1962/. According to data of 1957 the conductivity of atmospheric air was recorded outside the USSR by 36 stations /Israël, 1957 a/. Air ions are further of significance in hygiene /Minkh, 1963/ and medicine /Portnov, 1960/.

Major emphasis is laid upon the determination of the size spectrum of the submicroscopic aerosol particles. One of the most promising methods is the measurement of the electric mobilities of the particles /Fuks, 1955; Junge, 1955, 1963; Green, Lane, 1964/. The particle size spectrum is then calculated from the mobility spectrum /Metnieks, Pollak, 1961; Fuchs, 1963; Fuks, Stechkina, 1963/.

The aspiration method is the most universal and widespread method for measuring the concentration and mobility of air ions. Other methods for measuring mobility have limited application only. For the measurement of gas-ion mobilities one often uses ac methods, which are reviewed by Loeb/Loeb, 1960/. The application of ac methods is limited to the measurement of light air ions which in most cases is effected under laboratory conditions. Ac methods proved to be suitable for the measurement of the ion mobility in the rarefied upper layers of the atmosphere /Bragin, 1962, 1963/. The mass-spectrographic measurement method of the ionic composition of gases /Istonin, 1959; Narcisi, Bailey, 1956/ is applicable under rarefied-gas conditions.

The recently developed pulse method /Fedorov, 1952; Tsvang, 1956; Tsvang, Gutman, 1958/ yields interesting data on the spectral distribution of mobilities of light ions in atmospheric air /Tsvang, Komarov, 1959; Komarov, Kuzmenko, Seredkin, 1960/. For the study of the mobility spectrum of heavy ions, however, the pulse method and the ac methods are considered to be unsuitable /Komarov, Seredkin, 1960/.

Some simplified methods for air ion concentration measurement are also known /Korsunskii, Reznik, Truten', 1962a, 1965b; Chernyavskii, 1962; Tammet, 1962a/. However, these methods provide only rough approximations and are quite limited in application.

The first ideas relating to the aspiration method were published toward the end of the last century /Giese, 1882/. The work of J. J. Thomson and coworkers /Thomson, J.J., Rutherford, 1896; McClelland, 1898; Rutherford, 1899; Zeleny, 1901/ greatly contributed to the development of the aspiration method.

Notwithstanding its long history, the theory of aspiration counters has recently experienced vital impetus resulting from modern achievements in the measurement of weak currents, thus opening new possibilities for the study of air ions. The use of artifical ionization has led to the development of measurement methods at increased space charge densities and mobilities. The extension of the measurement range allows one to deal with side-effects in the measuring capacitor, which hitherto were not accounted for and which may considerably distort the measurement results. From the above considerations it thus follows that the theory of measurement methods must be rendered more rigorous.

The known devices for the air ion spectrum measurement are unsatisfactory and their sensitivity and resolving power are inadequate for many problems. For example, the structure of the distribution spectrum of atmospheric ions has hitherto not been properly investigated. It is difficult to say to what extent this situation is due to basic limitations and to what extent to the imperfection of the instruments. To estimate the adequacy of a counter design, information is required on the dependence of the functional properties of the instrument on the design parameters. Although some success has been achieved in the study of this problem /Gubichev, 1960; Komarov, 1960a, 1960b; Seredkin 1960; Siksna, Lindsay, 1961/, the available information does not suffice for detailed counter design calculations.

The present work considers measuring methods in which the precipitation of air ions in the measuring capacitor is electrometrically recorded. However, most of the results may be applied to the recording and study of the precipitated particles with the aid of optical or electronic-optical methods /Rohmann, 1923; Lipscomb, Rubin, Sturdivant, 1947; Gillespie, Langstroth, 1952; Hinkle, Orr, Dalla Valle, 1954; Litvinov, Litvinova, 1955; Sergeeva, 1958; Gillespie, 1960; Challande, David, 1960/ or with the aid of radioactive radiation /Gerdien, 1907; Wilkening, 1952; Bergstedt, 1956; Stievstadt, Papp, 1960; Matulyavichene, 1962; Styro, Matulyavichene, 1965; Fontan, Billard, Blanc, Bricard, Huertas, Marty, 1966; Wilkening, Kawano, Lane, 1966; Styro, Pestov, 1968/. The similarity between processes taking place in aspiration devices for measuring aerosols and those in devices for the electrostatic precipitation of aerosols for clean-air maintenance /Riezler, Kern 1959/ affords certain results a wider range of application.

In attempting to present the subject matter in the most systematic manner, the author has fully covered the problems related to the considered theme with the exception of some specific problems for which references are given.

The electrostatic system of units (CGSE), which is traditionally used when describing the movement of ions and charged aerosol particles in air, has been employed throughout the book.

The author would like to take the opportunity to express his gratitude to coworkers at the Air-Ionization and Electroaerosol Laboratory of the Tartu State University for their cooperation. Particular thanks go to Ya. I. Salm for his constant attention and useful remarks.

For atmospheric ion measurements, the APi-TOF measured. directly from the ambient. parameterize the relation to m/Q.Â However, for the range of good transmission the DL is well below 1 ion/cm3. 2.3 Laboratory test setups. Two different laboratory setups were used for testing the ion transmission and concentration response of the instrument. In the rst setup the APi-TOF was connected in parallel with.Â The mass calibration of an unknown spectrum is a multi-step process, where several methods are applied before the nal solution is reached. The rst step is to get a rough mass calibration with an accuracy of at least 0.5 Th. This is often already reached when the instrument is calibrated of-ten enough in the eld and the sampling conditions are not changed.