EXPERIENCE ON AIRBORNE MEASUREMENT OF THE FINE AEROSOL FRACTION BY A DIFFUSION BATTERY

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Received May 22, 1992

Some peculiarities of an airborne diffusion aerosol spectrometer (DAS) are considered. Its merits and demerits are analyzed. It is concluded that the development of the DAS based on the parallel principle of measuring the aerosol particle size spectra can be recommended.

It is well known that an aerosol is one of the major atmospheric components which attenuates the radiation propagated in the atmosphere.[1] The aerosol extinction coefficients depend strongly on the particle size, chemical composition and concentration, which are subject to wide spatiotemporal variations. Therefore the reliable data on all the basic characteristics of the atmospheric aerosol are necessary to estimate quantitatively the aerosol extinction. However, some problems arise in microphysical modeling of the aerosol optical properties. They are due to lack of data[2] on the particle size distribution in the range smaller than 0.1 μm and are caused by the difficulty of measuring such particles. More often microphysical modeling is based on the aerosol particle size spectra measured by photoelectric counters ($r \geq 0.2$ μm) while the fine fraction is approximated by any distribution function.[3] The aerosol optical characteristics calculated in this way and the measured ones often differ by an order of magnitude and more.[4] Therefore, the problem of direct measuring the fine aerosol fraction ($r \leq 0.1$ μm) is urgent as before.

The questions pertaining to the measurement of the microphysical aerosol properties have been detailed in Ref. 5 in which in particular it is noted that the diffusion battery and the electrostatic particle analyzers are most suitable for measuring the fine fraction. The comparison of these methods made in Ref. 6 showed the satisfactory agreement of the obtained data.

The problem of measuring the entire spectrum of the aerosol particle size goes back to organization of the aircraft–laboratory of the Institute of Atmospheric Optics, Siberian Branch of the Russian Academy of Sciences, Tomsk since a single photoelectric counter,[7] which registered only the particles with size greater than 0.2 μm, was used onboard the aircraft. This gives no way of correct comparison of the calculated and measured parameters describing the aerosol optical properties.[4] In order to extend the measuring range of the particle size toward smaller size, a diffusion aerosol spectrometer (DAS) was installed onboard the aircraft–laboratory in 1991. The DAS was developed at the Institute of Chemical Kinetics and Combustion, Siberian Branch of the Russian Academy of Sciences, Novosibirsk and was capable of measuring the aerosol particle size distribution in the range $r = 3–200$ nm in the eight channels.

The determination of the aerosol particle size by the DAS is based on the dependence of the rate of aerosol sedimentation on the wire on the particle size. One can judge about the particle size by the measured number of aerosol particles passed through the given number of wires. The so–called "run" is usually measured, that is, a ratio of the number of particles having passed through the given number of wires to that in the input flow.[8] Further an inverse problem is solved, and the differential particle size distribution function is constructed using the obtained readings.[9]

The DAS consists of a multiwire diffusion battery (DB), which contains eight cells placed in series. Every cell has a collection of wires and output nozzles equipped with electrically controlled valves. A condensation coarsening device (CCD) and a photoelectric particle counter (PPC) are also included in the DAS. The complex of these devices is set in CRATE–CAMAC and linked with an IBM PC. The DAS operates as follows. At the instant t_1 the valve of the eighth cell of the DAS uncovers a port. The air to be investigated passes through all the eight cells, CCD, and PPC. At the instant t_2 the valve of the eighth cell covers the port while the valve of the seventh cell uncovers it. In this case the air passes through the seven cells, DDC, and PPC. This process continues until the instant t_8 at which the air passes only through the first cell without wires and for this reason the PPC registrates only the particles being contained in the air sample under investigation.

This paper is devoted to the experience on the airborne operation of the DAS, since the peculiarities of its in–flight operation were not taken into account under development and production of this device.

An air sampler for the DAS was installed in the nose of the aircraft, as shown in Fig. 1. The air flow rate through the spectrometer was provided with a diffuser, which created a rarefaction at the output from the system. The isokinetic condition was provided with selection of an input sampling pipe. As it was shown previously, in this modification the pump was not needed and was removed whereas the isokinetic condition held under changes of the altitude and speed of the aircraft.[7,10]

The air to be investigated was conveyed to the DAS through the sampler *1* (Fig. 1). The input pipe *3* of the sampler *1* was connected with the tee *7* by the flexible pipe *5*. The outboard air was divided by the tee *7*. One flow was conveyed to the input *9* of the CCD while the other–—to the input *8* of the DB. Since the hydraulic resistances of the DDC and DB are different whereas the equal values of the volume air speeds (60 l/h) must be obtained in every pipe–line, we put the optional rotameter *6* to equalize the air flow rates. After analysis of the studied aerosol the spent air was vented overboard through the output nozzles *10* and *11*, the tee *12*, the output connecting pipe *4*, and the sampler diffuser.
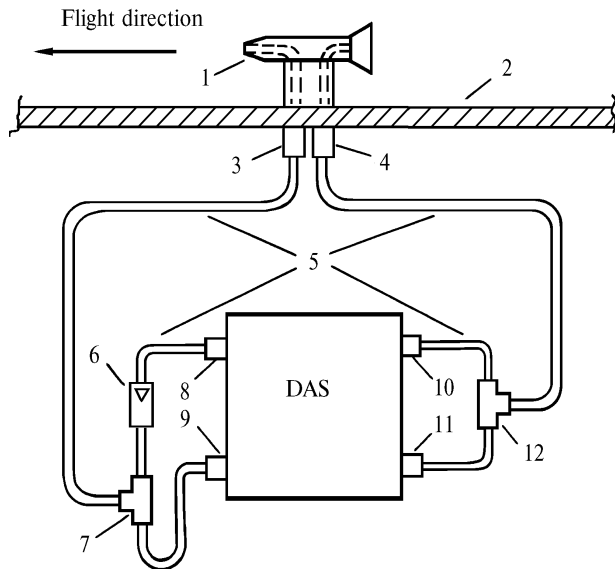
FIG. 1. The scheme of air sampling for the diffusion spectrometer. 1) Sampler, 2) aircraft board, 3) input connecting pipe, 4) output connecting pipe, 5) flexible pipes, 6) rotameter, 7 and 12) tees, 8) input nozzle of the DB, 9) input nozzle of the coarsening device, 10) output nozzle of the DB, and 11) output nozzle of the PPC.

The "OPTIK–È" AN–30 aircraft–laboratory used to perform the experiments has a hermetic cabin. This produces the difference between the pressures in the aircraft and outside it as great as 0.5 atm. Since the outboard air passed inside the DAS, the same pressure difference will be exerted on the elements of the complex.

The next problem, which appeared when starting up the DAS, was the presence of microholes in the pipe–lines and units of the complex. It resulted in the diffusion of the aerosol from the cabin into the device. This problem was solved by extra sealing of the entire air path from the input pipe to the output diffuser. After balancing the air flows inside the DAS and eliminating the microleaks, a start has been made on the routine measurements of the fine aerosol fraction.

The results of measuring the aerosol particle size spectrum carried out in September of 1991 over Baikal Lake at the altitudes of 600 and 3000 m above the underlying surface are shown in Figs. 2a and 2b, respectively.

It can be seen from Fig. 2 that the particles of the smallest size (3–30 nm) exist in the boundary layer (at an altitude of 600 m), and disappear at an altitude of 3000 m. This is due to the fact that the second altitude is far from the source (underlying surface), the aerosol–forming gases do not evaporate, and the microparticles are not formed. This is in agreement with the theory of aerosol formation set forth in Refs. 11 and 12 as well as with the data of electrostatic analyzers given in Refs. 13 and 14.

During the flights one essential demerit of the DAS was revealed. It was caused by the constructional features of the spectrometer, namely, by the consecutive mode of its operation. The reproducibility of data at the same altitude disappears when measuring in the regions with nonuniform horizontal aerosol distribution.

In our opinion, this is due to the fact that it takes about 5 min to measure the entire spectrum consecutively. During this time the aircraft passes 22–28 km in the

measurement regime, and under conditions of the nonuniform aerosol distribution, for example, over the industrial center, this makes its own contribution to the entire spectrum in every channel. The question arises in interpretation of such data as to whether the selected modes are the result of evolution of the atmospheric processes or of the entry of the aircraft into the aerosol inhomogeneity or the plume of an enterprise.
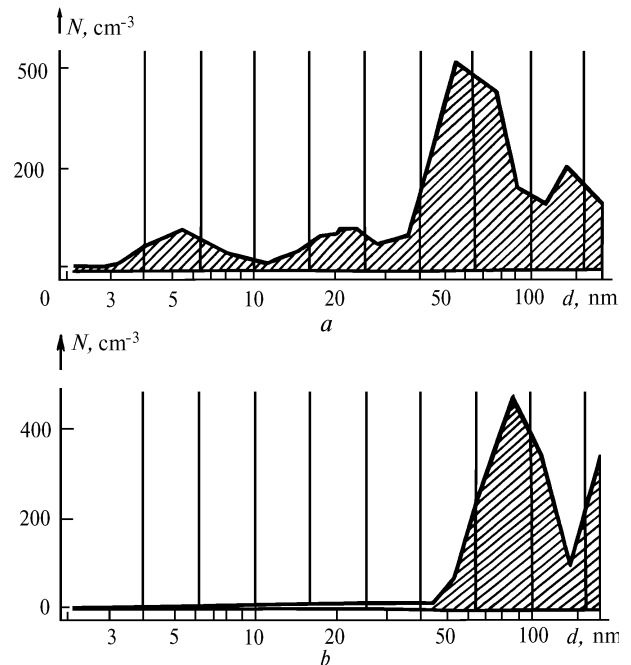

FIG. 2. Aerosol particle size distribution over Baikal Lake at altitudes of 600 (a) and 3000 m (b).

Evidently, the most optimum solution of this problem is the development of the DAS in which polling of all eight cells of the DB is carried out simultaneously. In this case the air under investigation should be pumped through all cells of the DB simultaneously. We solved the similar problem previously, when an airborne photoelectric counter was started up, and obtained excellent results.[7,15]

In conclusion we note that the extension of the range of airborne measurements of aerosol particle size simultaneously with measurements of submicron and coarse fractions qualitatively change our concept of the microphysical properties and essentially enhances the capabilities of the entire airborne complex.

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