AITKEN NUCLEI SONDE WITH CONSTANT EXPANSION RATIO IRRESPECTIVE OF AMBIENT PRESSURE

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Abstract: A new type of Aitken nuclei sonde is reported. The sonde consists of an expansion fog chamber, which is similar in principle to the Pollak counter or the Aitken counter, as a measuring device of Aitken unclei concentration. The most important characteristics of the present fog chamber are that it is a very compact automatic one and it has a construction to keep expansion ratio constant irrespective of ambient pressure. The constant expansion ratio is an essential requirement for the measurement of Aitken nuclei concentration at different heights by a balloon or an airplane.

The variation of measured values during 50 times measurement for a same air sample is smaller than 3% of the mean. Two identical fog chambers in the present sonde give Aitken unclei concentrations which agree within 50 cm^{-3} for the concentration range covering between about 200 and about 2000 cm^{-3}.

A nuclei measuring signal is inserted into rawinsonde signal, which is transmitted to a ground station, every minute for 10 s. The total weight of a sonde is 9 kg, comprising a 5 kg fog chamber, a 3.5 kg battery and a 0.5 kg rawinsonde.

1. Introduction

For the study of global background air pollution, it is essentially important to examine the behavior of aerosols in a "clean" atmosphere which is not contaminated directly by aerosols and gases emitted from earth's surface. The Antarctic atmosphere is thought to be such a clean atmosphere. Extensive surface observations of aerosols in the Antarctic atmosphere have been made at the South Pole Station (by U.S.A. parties) and Syowa Station (by Japanese parties). From these observations, it has been revealed that in Antarctica, much of interesting phenomena relating to long-range transports of maritime background aerosols or photochemical processes resulting in production or growth of aerosol particles are observed apparently (ITO and IWAI, 1981; IWAI *et al.*, 1981; ONO *et al.*, 1981; KOIDE *et al.*, 1981; ITO *et al.*, 1981; ITO, 1982). In regions other than Antarctica, such the phenomena seem to be masked by the complex distribution of sources and sinks of aerosol particles.

In order to know properties of Antarctic aerosols furtherly, aerosol observation aloft is required. Since the observation of aerosols over Antarctica using an airplane or a balloon was very scarce (HOFMANN *et al.*, 1973, 1976a, b; HOGAN, 1979), little is known about spatial distribution of aerosols, especially of Aitken particles, over Antarctica.

In the 24th Japanese Antarctic Research Expedition, the project to make comprehensive observation of atmospheric gases and aerosols is to be undertaken. This note describes the construction and principle of an Aitken nuclei sonde to be used in the project.

2. Fog Chamber of the Sonde

The widely used method to measure concentrations of Aitken nuclei is a fog chamber method which measures concentration of Aitken nuclei in terms of the concentration of fog droplets produced on Aitken nuclei in an air sample by adiabatic expansion as the Aitken counter (AITKEN, 1923) and the Pollak counter (NOLAN and POLLAK, 1946).

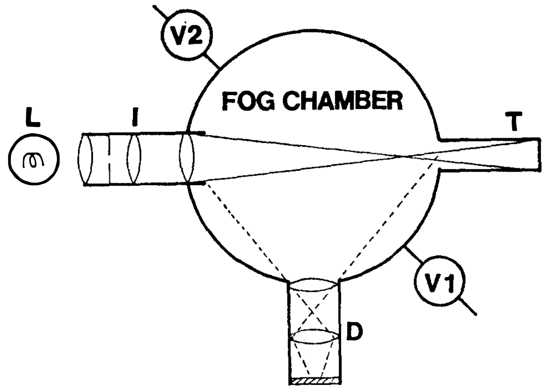

Fig. 1. Optical system of the fog chamber (top view). L, halogen lamp; I, illuminator; D, photodetector; T, light trap.

In the fog chamber of the present sonde, fog concentration is measured in terms of the maximum intensity of the light scattered laterally from a light pencil traversing fog in the chamber (see Fig. 1). The light pencil is converged into a light trap to minimize a stray light which biases photoelectric signals from fog.

The inside of the fog chamber is lined with a blackened porous synthetic leather which contains full of water. The wet lining supplies water vapor to an air sample introduced into the fog chamber.

An essential requirement for the measurement with a fog chamber is to expand an air sample adiabatically with a fixed expansion ratio during ascending or descending observation by a balloon or an aircraft. In the Aitken counter, an air sample is expanded by evacuating the air in a chamber with a cylindolical piston, whereas in the Pollak counter, expansion is done by exhausting a compressed air sample into normal pressure or exhausting an air sample in normal pressure into a low-pressure reservoir. The Aitken counter can be operated with a constant expansion ratio irrespective of ambient pressure, but it has a disadvantage in an automatic operation. In the Pollak counter, the expansion ratio varies during ascending or descending observation. In the present sonde an air sample is expanded by changing the volume of a fog chamber itself. Volume change is performed by moving a flexible ceiling of the chamber which is made of rubber film. Thus, irrespective of ambient pressure, the expansion ratio is kept at an constant value determined by a ratio of a chamber volume after expansion to that before expansion.

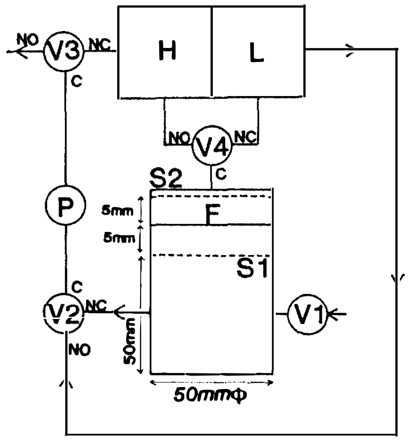

Fig. 2. Air current circuit of the fog chamber. F, rubber film; H, high-pressure reservoir; L, low-pressure reservoir; P, pump; S1, S2, stop-mesh; V1, two port solenoid valve; V2, V3, V4, three port solenoid valve (NC, normal close; NO, normal open; C, common port).

Table 1. Time schedule of automatic valve operation.

		V1	V2	V3	V4	
1	Reset	on	on	on	off	5 s
2	Sampling	on	on	off	off	30 s
3	Humidify	off	off	off	off	20 s
4	Expansion	off	off	off	on	5 s

Figure 2 shows a schematic diagram of the fog chamber and the air current circuit. Table 1 shows a time schedule of operation of solenoid valves for each measuring step in one measuring cycle.

At the 1st measuring step (reset), the rubber film (F) is forced to contact closely with a stop-mesh (S1) by pressure difference between the chamber and a high pressure reservoir. At the 2nd measuring step (sampling), the chamber is flushed with a fresh air sample. At the 3rd measuring step (humidify), the chamber is made air tight by closing solenoid valves (V1), (V2). At this step, water vapor is supplied to the air sample in the chamber from the wet-lined wall and bottom of the chamber so that air sample is conditioned at 100% relative humidity. At the 4th measuring step (expansion), the solenoid valve (V4) is operated and the rubber film (F) moves momently from the stop-mesh (S1) to the stop-mesh (S2) by pressure difference between the fog chamber and a low pressure reservoir. Thus, an air sample in a chamber is expanded adiabatically with the expansion ratio determined from the volume change. In the present chamber, the volume expansion ratio is fixed at 1.20.

The wet lining of the present chamber can contain up to 8 cm^3 of water and by this amount of water, repeating measurements during time duration up to 8 hours are possible without any water supply to the lining.

3. Calibration and Error Estimation

The intensity of scattered light in the fog chamber is measured with silicon solar cell and is amplified so that photoelectric DC output of 2 volts corresponds to the particle concentration of about 2000 cm^{-3}.

The fog chamber is calibrated against the Pollak counter of MRI type (ITO, 1976).

Figure 3 shows the results of comparison between the Pollak counter and the present fog chamber. It can be seen that DC output of the present chamber has a roughly linear relation to the concentration measured with the Pollak counter. A straight line in Fig. 3 is a least square fit of data point in the figure which covers the concentration range of 40 to 1100 cm^{-3}. The equation of that line is $Z=738V+50$, where Z is concentration (cm^{-3}) and V is DC output of the fog chamber (volt).

Coefficient of variation (standard deviation/mean) of DC output of the chamber is 2.13% for 50 times measurement of air samples drawn from a same container. The low value of coefficient of variation means that the present fog chamber has sufficient reproducibility, that is, when two consecutive measured values differ from each other more than 2.13%, the difference can be considered to be due to the effect other than instrumental one, but probably due to natural variation.

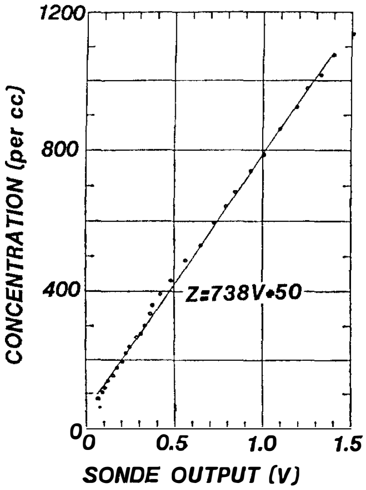

Fig. 3. Relation between DC output of fog chamber (volt) and concentration measured with Pollak counter (cm^{-3}).

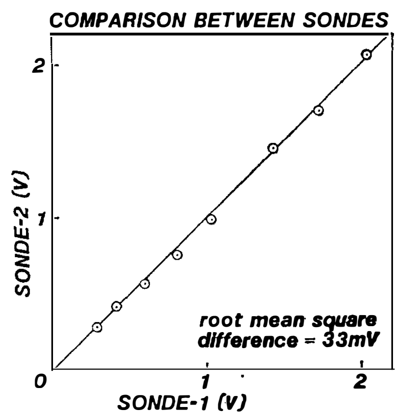

Fig. 4. Comparison between two identical fog chambers.

Figure 4 shows the results of comparison of two identical fog chambers. Fairly good agreement of two chambers can be seen. The root mean square difference between measurements of two chambers is 0.033 volts which corresponds to the concentration difference of about 50 cm^{-3}. Thus, the instrumental probable error of the chamber is about 30 cm^{-3}. This means that if the difference more than 30 cm^{-3} is seen between two ascents of the present Aitken nuclei sondes, the difference can be considered as natural one.

4. Aitken Nuclei Sonde

The voltage signal of DC output of the fog chamber is converted into frequency signal and is inserted into signals of RSII-87 type rawinsonde. The insertion is done every minute for 5 s before and after expansion. Reference signal (LR), ambient pressure (P), ambient temperature (T), and temperature of the fog chamber (CT) instead of ambient humidity are transmitted in the manner that one cycle of the order of LR, P, T, P, CT, P, T, P is 8 s.

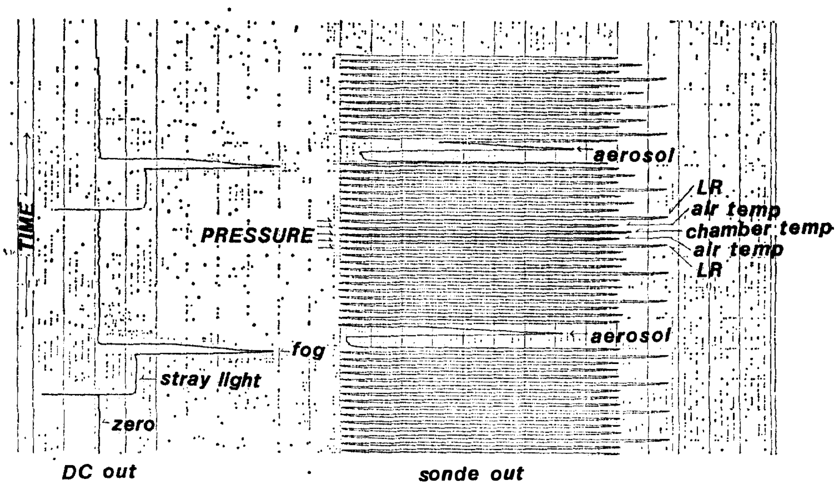

Fig. 5. An example of raw record. Left: DC output of fog chamber. Right: sonde signal.

Figure 5 represents an example of records. The left figure represents DC output of the fog chamber. Bias of 0.5 volts by stray right and signal of intensity of light which is scattered by fog in the chamber can be seen. The right figure represents an actual record of signal from the sonde. The signal of aerosol measurement inserted into the rawin signal are seen in the figure.

To keep the temperature of the chamber at normal temperature during the ascent of a sonde, waste heat from a wet chemical battery for the sonde is utilized.

Total weight of the sonde is 9 kg comprising the fog chamber and the electric circuit (5 kg), battery (3.5 kg) and rawinsonde (0.5 kg). Two sondes will be launched at Syowa Station, Antarctica in 1983. Before their launching, they are also to be used for aerosol concentration survey by airplane over Syowa Station.

References

AITKEN, J. (1923): On a simple pocket dust-counter. Collected Scientific Papers of John Aitken, ed. by C. G. KNOTT. Cambridge, Cambridge University Press, 236–246.

HOGAN, A. W. (1979): Meteorological transport of particulate material to the South Polar Plateau. J. Appl. Meteorol., **18**, 741–749.

HOFMANN, D. J., ROSEN, J. M., PEPIN, T. J. and PINNICK, R. G. (1973): Particles in the polar stratospheres. Nature, **245**, 369–371.

HOFMANN, D. J., ROSEN, J. M., KIERNAN, J. M. and LABY, J. (1976a): Stratospheric aerosol measurements IV; Global time variation of the aerosol burden and source concentration. J. Atmos. Sci., **33**, 182–187.

HOFMANN, D. J., ROSEN, J. M., KJOME, N. T. and OLSON, G. L. (1976b): Aerosols and gases in the antarctic stratosphere. Antarct. J. U. S., **11**, 99–100.

ITO, T. (1976): An automatic Pollak counter improved for routine field operation. J. Meteorol. Soc. Jpn., **54**, 81–90.

ITO, T. (1982): Nankyoku taiki-chû no sabumikuron êrozoru no ryûkei bunpu ni tsuite (On the size distribution of submicron aerosols in the antarctic atmosphere). Nankyoku Shiryô (Antarct. Rec.), **76**, 1–19.

ITO, T. and IWAI, K. (1981): On the sudden increase in the concentration of Aitken particles in the antarctic atmosphere. J. Meteorol. Soc. Jpn., **59**, 262–271.

ITO, T., ONO, A. and IWAI, K. (1981): On the origin and nature of the antarctic aerosols. Mem.

Natl Inst. Polar Res., Spec. Issue, **24**, 289–296.

IWAI, K., ONO, A. and ITO, T. (1981): On the composition of large and giant particles observed at Syowa Station, Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **19**, 131–140.

KOIDE, T., ITO, T., YANO, N. and KOBAYASHI, T. (1981): Chemical composition of large and giant aerosols at Syowa Station, Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **19**, 152–159.

NOLAN, P. J. and POLLAK, L. W. (1946): The caribration of a photoelectric nucleus counter. Proc. R. Ir. Acad., **51a**, 9–31.

ONO, A., ITO, T. and IWAI, K. (1981): A note on the origin and nature of the antarctic aerosol. Mem. Natl Inst. Polar Res., Spec. Issue, **19**, 141–151.

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