Direct-Flow Filter Sampler: An Improved Large-Volume Collector of Radioactive Stratospheric Debris[1]

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ABSTRACT

The Direct-Flow Sampler is an improved balloon-borne device designed to collect particulate matter from very large volumes of stratospheric air at altitudes between 50,000 and 100,000 ft. This equipment utilizes a high-volume blower to pull air through 1 sq ft of Institute of Paper Chemistry (IPC) #1478 filter paper at rates from 400 to 800 cfm. Laboratory tests at low pressures involving aerosols of known size and density, together with intercomparison flights with other sampling devices, indicate that the Direct-Flow Sampler is a very efficient collector of submicron particles. Several vertical profiles of radioactivity over Minneapolis, Minn., that were obtained with impactor collectors and with filter samplers are shown to be in generally good agreement. Development of this sampler was supported by the Atomic Energy Commission as part of a program aimed at achieving a better understanding of the characteristics of stratospheric dust and radioactive debris, and of the mechanisms controlling fallout from the stratosphere.

1. Introduction

Because of the pressing need for information concerning the nature, concentration and distribution of radioactive debris injected into the stratosphere during nuclear weapons tests, the Atomic Energy Commission has supported the development of large-volume particle collectors suitable for use with high-altitude balloon vehicles. The Direct-Flow Sampler shown in Fig. 1 is an outgrowth of this work.

2. The direct-flow sampling unit

This sampler has been designed for use at altitudes between 50,000 and 100,000 ft. It utilizes a 0.5-hp Torrington blower to pull air at high velocities through 1 sq ft of filter paper, and a flowmeter to measure the total volume sampled. Flow rate at 65,000 ft is approximately 700 cfm. Important features of the system are summarized in Fig. 2.

In operational use this unit is lifted to a pre-determined sampling altitude where a timer-programmer actuates the blower. The length of the sampling period set into the programmer varies from 15 minutes to 4 hours, depending upon the operating altitude, but is normally sufficient to allow the processing of a volume equivalent to 1000 cu ft at STP conditions. On completion of the sampling period the blower is turned off, dust doors close, and the sampler is cut loose from the balloon. Descent by parachute is observed by light aircraft, and ground recovery crews are directed to the impact area by radio. Filters are mailed to the New York Operations Office of the Atomic Energy Commission for analysis.

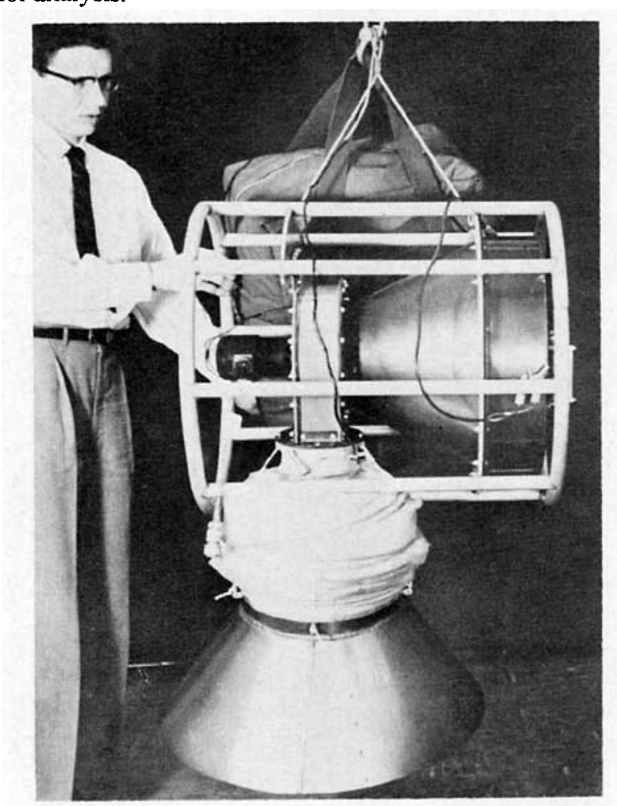

FIG. 1. Direct-flow aerosol sampler (with exhaust duct).

[1] This work was supported by the Division of Biology and Medicine of the U. S. Atomic Energy Commission.

3. Filter collector characteristics

The filter mat is a high porosity, medium background-count paper having the physical properties shown in Table 1. This material is fabricated by the institute of Paper Chemistry (IPC), Appleton, Wisconsin, the fibers being impregnated with an organic adhesive in order to improve particle-retention characteristics.

Table 1. Physical properties of the Institute of Paper Chemistry (IPC) fibrous filter mats.

Material	Viscose
Mat thickness	0.084 cm
Average fiber diameter	17 microns
Fiber density	1.49 g cm^{-3}
Bulk density	0.189 g cm^{-3}
Average pore diameter	170 microns ± 60
Porosity	90 per cent
Fiber volume	10 per cent

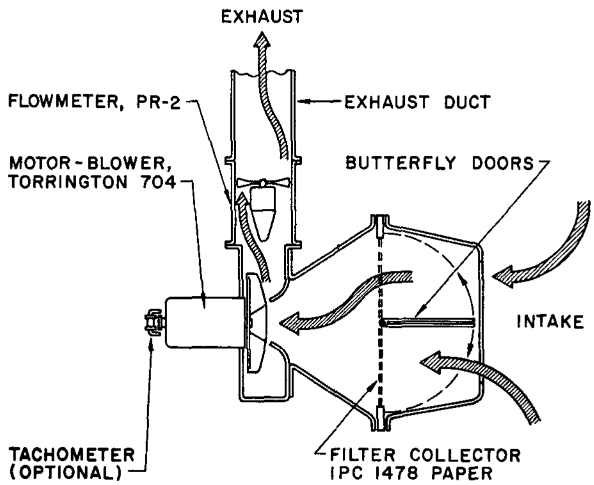

Fig. 2. AEC direct-flow particle sampler, Model DFS-2B (balloon-borne).

Figs. 3 and 4 reproduced from a report by Stern, Zeller and Schekman (1960) show the observed collection efficiency of IPC paper for spherical particles, as a function of air velocity, at ambient pressures corresponding to altitudes of 65,000 and 85,000 ft. These data show that a minimum efficiency exists for each particle size at a point on the efficiency curve where diffusion effects are at a minimum and inertial (impaction) effects are beginning to dominate the mechanism of collection. It can also be noted that for a given particle size and velocity, efficiency increases as air pressure decreases. In the Direct-Flow Sampler, high collection efficiency is achieved by operating well into the impaction regime (i.e., 700 ft min^{-1} at 65,000 ft; 500 ft min^{-1} at 85,000 ft).

4. Measurement of volumes sampled

Meaningful interpretation of data from these sampling flights has required the development of a method for determining the volume of air drawn through the filter. Isotopic activity is usually expressed in terms of disintegrations per minute per 1000 standard cubic feet.

In contrast with early, indirect methods which related volume flow to blower rpm, the Direct-Flow Sampler utilizes a low-drag propeller anemometer mounted in the blower exhaust for the measurement of volumes sampled. The meter shown in Fig. 5 was specifically designed for this work, and it has been calibrated against recognized flow standards over a range of pressures corresponding to the sampling altitudes of interest. Fig. 6, obtained from altitude chamber tests in which a calibrated gas meter (operated at atmospheric pressure) was used as the reference standard, shows that output is a linear function of volume flow, essentially independent of pressure up to 100,000 ft. Every 100 revolutions of the propeller is registered on an electromechanical counter, each count being equivalent to 9.7 ambient cu ft of air.

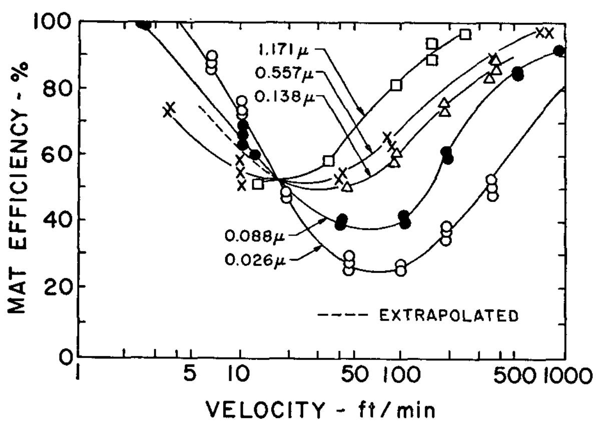

Fig. 3. Experimental collection efficiencies of the IPC filter mat for spherical polystyrene particles of density 1.05 and spherical poliomyelitic particles of density 1.23 at 65,000 ft.

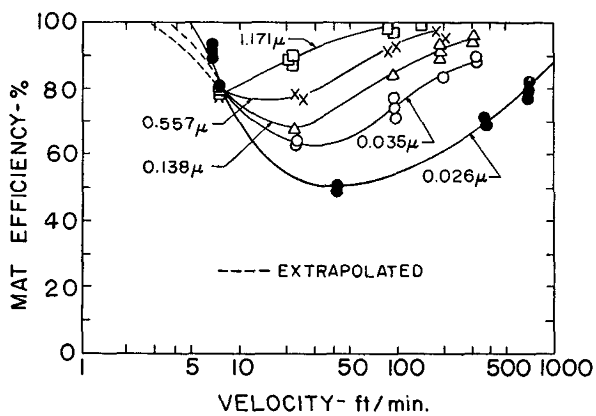

Fig. 4. Experimental collection efficiencies of the IPC filter mat for spherical polystyrene particles of density 1.05 and spherical T-3 *E. coli* phage and poliomyelitic particles of density 1.23 at 85,000 ft.

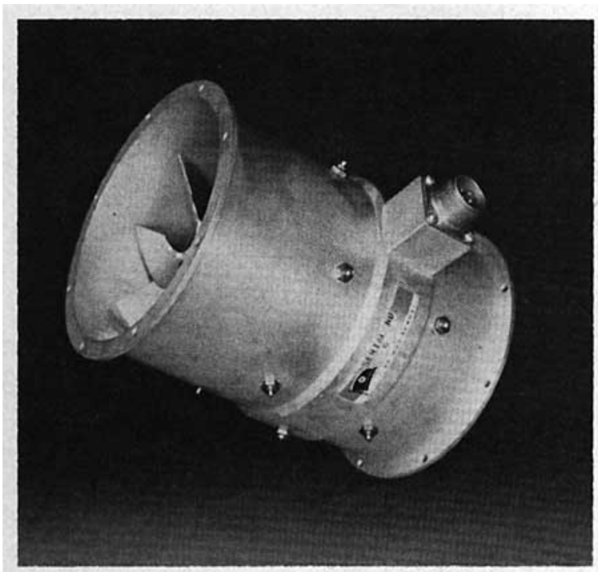

FIG. 5. PR-2 high-altitude air flowmeter.

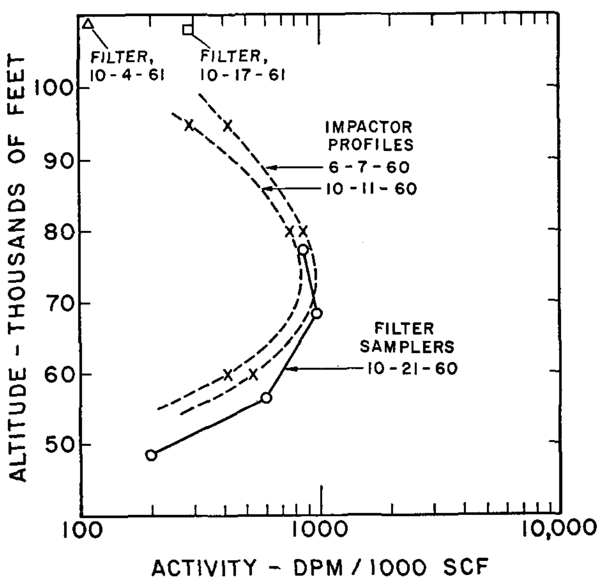

FIG. 6. High-altitude calibration of PR-2 flowmeter with precision (0.5 per cent) gas meter.

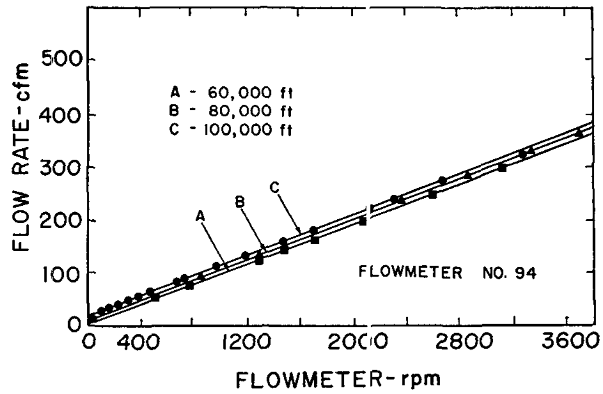

FIG. 7. Comparison of impactor and filter sampler profiles—Cerium 144.

FIG. 8. Model DFS-2B direct-flow aerosol sampler.

5. Comparison with impactor data-vertical profile step flights

A number of dual-balloon step flights have been performed at Minneapolis, Minn., since 1960 using Direct-Flow Samplers. The objective of these flights has been to obtain a vertical profile of radioactive debris in the stratosphere by sampling at four nominal altitudes: 50,000, 60,000, 70,000 and 80,000 ft.

In Fig. 7 we have plotted radioactivity data from one of the earlier filter-profile flights together with data from two impactor profile flights. It should be noted that in contrast to the filter samples which were obtained at one level, the impactor samplers operated while the balloon was rising steadily, so that each impactor point represents the average specific activity of a slice of atmosphere thousands of feet thick. The impactor data were derived from values previously reported by Drevinsky and Martell.[1] Considering the possible errors in computing sampled volumes, and the fact that samples were analyzed by different methods in different laboratories, the similarity between impactor and filter profiles is remarkably good.

[1] Drevinsky, P. Y., and E. A. Martell, 1961: Preliminary results on the size and vertical distribution of residual nuclear debris in the stratosphere, in radioactive fallout from nuclear weapons tests. Proceedings of an AEC conference, Germantown, Md., November 15–17, A. W. Klement, Ed. (TID-7632), pp. 170–187.

6. Present status of the direct-flow sampler

While retaining the general configuration introduced in 1960, the Direct-Flow Sampler has been modified from time to time in accordance with recommendations from operational field crews and experience gained from research flights. The latest version, Model DFS-2B, is shown in Fig. 8. These are presently being flown in research flights by Litton Systems, Inc., Minneapolis, Minn., and operationally by the U. S. Air Force at San Angelo, Texas, and the Australian Government at Mildura, Australia.

Acknowledgments. The original Direct-Flow Sampler was conceived and developed by Sidney C. Stern, Staff Scientist at General Mills, with the encouragement and support of Mr. J. Z. Holland and others in the Division of Biology and Medicine, U. S. Atomic Energy Commission.

REFERENCE

Stern, S. C., H. W. Zeller and A. I. Schekman, 1960: The aerosol efficiency and pressure drop of a fibrous filter at reduced pressures. *J. Colloid Sci.*, **15**, 546–562.