United States
Environmental Protection
Agency

Environmental Sciences
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA-600/S3-84-045 Apr. 1984

EPA

Project Summary

Development and Evaluation of Dilution Probes Used for Sampling to Determine Source Signatures

Joseph D. McCain and Ashley D. Williamson

The NEA, Inc., stack sampling system was evaluated. It is designed for obtaining emission source samples in two particle size ranges (<2.5 μm and 2.5-10 μm aerodynamic diameter) corresponding to those obtained by dichotomous atmospheric samplers. The stack gas sample is drawn continuously through a nozzle and probe and is diluted with a measured flow of filtered air. A fraction of the diluted sample is drawn through collection filters in a dichotomous sampler.

The equipment was laboratory tested in a wind tunnel 10 cm in diameter. These tests used monodisperse ammonium fluorescein aerosol particles (1.3-16 μm in diameter) generated by a spinning disk. The system was judged to be reasonably well suited for defining emission source signatures. However, high losses of the larger particles due to inertial effects at the nozzle and deposition of particles in the probe and connecting Teflon hose resulted in biased particle size distributions at the filters. The losses could be partially compensated by reducing the length of the hose, using a right-angle precollector with a larger cutoff diameter (12.5 μm), and by controlled anisokinetic sampling to over-sample the larger particles. The loss in the hose of electrically-charged particles was 4 times that of charge-neutralized particles.

This Project Summary was developed by EPA's Environmental Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Atmospheric contaminants can often be apportioned to specific sources with the aid of elemental composition signatures for different source types. Such source signatures preferably are obtained by sampling techniques similar to those used for sampling the atmosphere. NEA, Inc., has developed a dilution source sampling apparatus (Figure 1) designed to obtain source samples in two particle size ranges (<2.5 μm and 2.5-10 μm aerodynamic diameter) corresponding to those obtained in ambient sampling with dichotomous sampler. In the NEA system, a sample is drawn continuously from the source (e.g., an electric power plant stack) through a nozzle and probe and is diluted with a measured flow of filtered ambient air. A portion of the diluted stream is drawn into a dichotomous sampler in which the gas flow is divided and the particles are collected on two filters designed for the desired particle size ranges.

For obtaining source signatures, this equipment has two principal advantages over conventional equipment: (1) The sample is obtained with the same filtration technique for particle size fractionation that is used in many ambient samplers, and (2) the dilution process resembles the process of cooling and dilution by entrainment of ambient air that occurs when stack gases are discharged into the atmosphere, allowing condensation of some chemical species that are in the vapor phase in the stack.

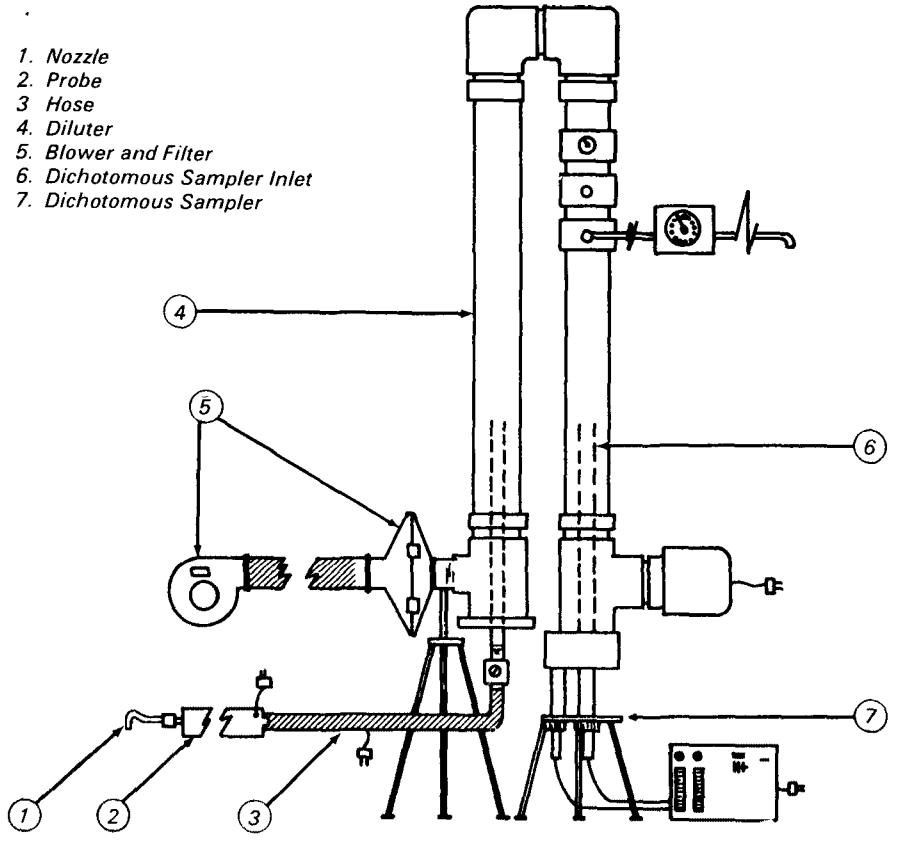

Figure 1. NEA dilution sampling system

The question of most concern in the use of this type of equipment is how nearly the particle size distribution at the collection filters resembles the original distribution at the entrance of the sampling nozzle; that is, how much of the particulate matter is lost by deposition in system components ahead of the filters. This question was addressed in the present study through laboratory testing.

Procedure

The tests were carried out in a wind tunnel 10 cm in diameter. A spinning disk aerosol generator was used to produce monodisperse ammonium fluorescein aerosol particles of 1.3 to 16 μm in diameter. The gas velocity in the tunnel could be varied over the range of 5 to 20 m/s, which is typical of the range encountered in stack sampling.

The ammonium fluorescein particles are dry and nonhygroscopic but readily soluble in dilute ammonium hydroxide, producing a solution in which the amount of the fluorescein can be measured by fluorimetry. Hence, the amounts of particles deposited in each component of the sampling system could be determined by disassembling the equipment, washing the internal surfaces of the components with dilute ammonium hydroxide, and fluorimetrically analyzing each wash.

Results

Tests with uncharged particles showed low losses within the diluter itself (e.g., 0.7% for 10-μm particles). However, losses in the nozzle and in the probe and 3-m connecting hose were unacceptably large at the high sampling rate (76 L/min) initially used. The loss in the hose alone amounted to 45% of 2-μm particles and 99% of 15-μm particles. At this sampling rate, the Reynolds number of the flow in the hose and probe was ~8000, indicating a flow in the turbulent regime, in which particle deposition rates would be expected to be high. When the sampling rate was reduced to 14 L/min, the loss in the hose declined but was still significant.

Further improvement was obtained by replacing the standard gooseneck nozzle on the NEA probe with a right-angle precollector developed by Southern Research Institute. This device was designed to have a moderately sharp and predictable cut diameter in the range of 12.5 μm at a sampling rate of 14 L/min. Using this device and a 1.64-m hose gave losses nearer to acceptable levels. For example, as shown in Figure 2, the fraction of 4-μm particles reaching the sampler inlet increased from ~30% to ~75%.

A closer approximation to an unbiased size distribution was attempted by controlled anisokinetic sampling to oversample layer particles. For 10-μm particles, a duct velocity of 15 m/s, a nozzle velocity of 4.65 m/s, a nozzle diameter of 0.794 cm, and a sampling range of 14 L/min gave a measured sampling loss that agreed within ± 10% with the value of 28% calculated from theory (Figure 2).

Paired tests using particles whose electrostatic charges had and had not been neutralized showed that charged particles were subject to ~4 times more loss in the nonconductive Teflon hose (see Figure 3). Losses in the metal probe were not appreciably sensitive to particle charge.

Conclusions and Recommendations

This study showed that the NEA system provides a reasonable method to collect samples for defining source signatures. However, the tests also showed substantial losses of (1) large particles owing to inertial effects and (2) particles of all sizes due to electrostatic charges. These losses could introduce serious bias in the particle size distribution of a sample obtained with this equipment. We found that the loss through inertial effects could be reduced by sampling modifications and partially compensated by controlled anisokinetic sampling (i.e. use of an oversize nozzle to oversample larger particles). There is no obvious way to solve the charged particle problem through a change in sampling techniques. The problem might be avoided or reduced if the components of the equipment were electrically conductive.

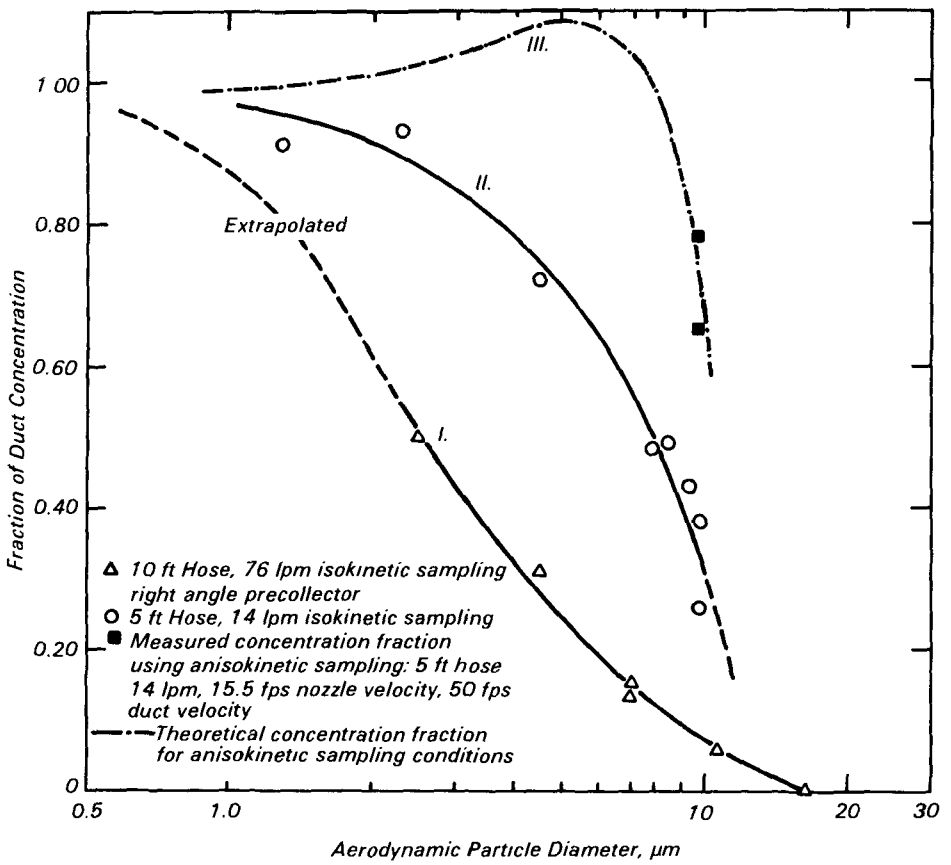

Figure 2. *Fraction of duct concentration, corrected for dilution, at dichotomous sampler inlet vs. particle size.*

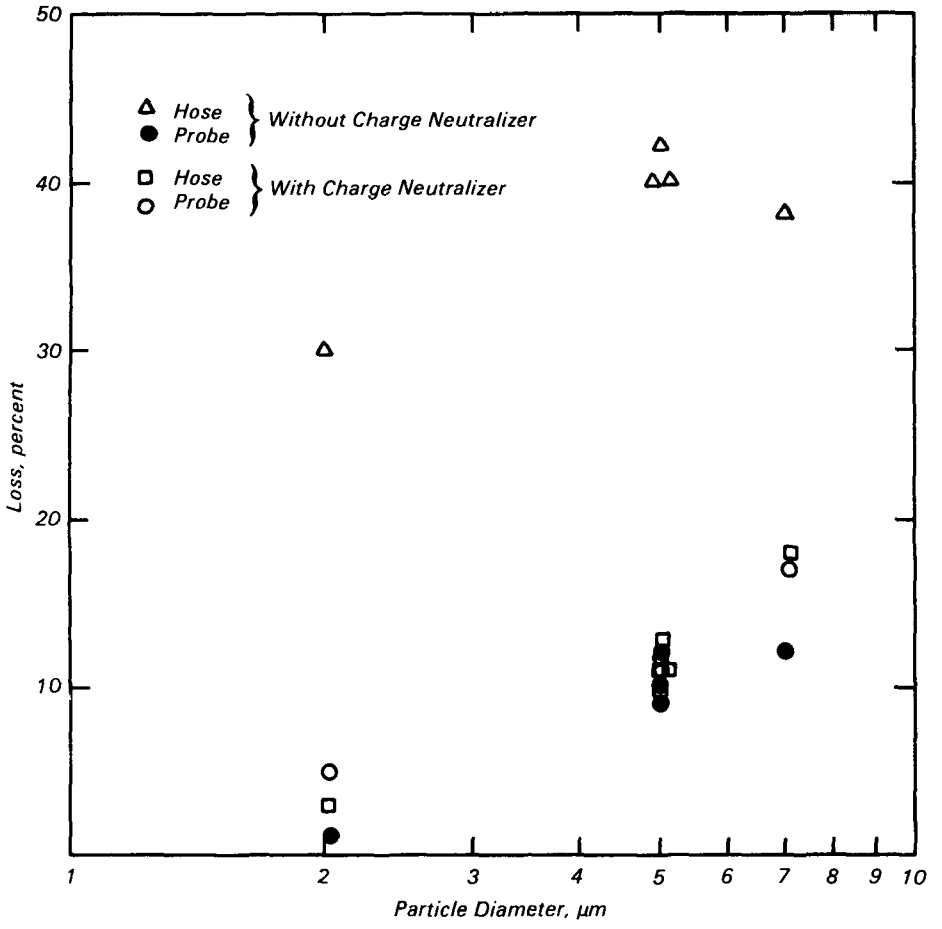

Figure 3. *Probe and hose losses by particle size for charged and neutralized particles at a sampling rate of 14 lpm.*

Joseph D. McCain and Ashley D. Williamson are with Southern Research Institute, Birmingham, AL 35255.
Roy L. Bennett *is the EPA Project Officer (see below).*
The complete report, entitled "Development and Evaluation of Dilution Probes Used for Sampling to Determine Source Signatures," (Order No. PB 84-164 284; Cost: $8.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Environmental Sciences Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Official Business
Penalty for Private Use $300

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-759-102/928