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Project Summary

Design, Fabrication and Testing of Ambient Aerosol Sampler Inlets

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Data are presented on the wind tunnel performances of two prototype Inhalable Particulate Matter (IPM) inlets designed for use with a dichotomous sampler. One inlet was developed by the Aerosol Science Laboratory (ASL) of Colorado State University, and the other was developed in a joint effort between the University of Minnesota (UM) and Lawrence Berkeley Laboratory (LBL). The ASL inlet is based on a unique omnidirectional cyclone fractionator, which is described in detail. Over the range of 0.5 to 24 km/h wind speeds, its measured 50% cutpoint was virtually invariant, 14.4 to 13.7 μm—well within the presently proposed IPM 50% cutpoint requirement. Testing of the UMLBL inlet indicated near compliance with the IPM performance envelope, but some small differences remain in the data generated by UM and ASL personnel. Enrichment is apparent for both inlets in the 1 to 10 μm particle size range at the highest wind speed. A redesign is underway to eliminate this and another problem related to unfavorable particle deposition patterns on the ASL inlet cyclone. As this report was being completed, a change in D_{50} for IPM from 15 to 10 μm was under serious consideration. Although the inlets discussed would then no longer be appropriate, alterations of their design may allow adaptation to a new cutpoint choice.

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

The effective sampling of aerosols in the ambient atmosphere has received increasing attention over the past five years. To obtain a representative measurement of the particulate matter present, a sample must be drawn through an inlet device onto a suitable sampling substrate, which is then weighed or otherwise analyzed. To provide meaningful data, the inlet must allow all particles of interest to be collected with the same shape of the collection effectiveness curve (effectiveness vs. particle size) independent of sampling conditions. These conditions include ambient wind velocity (magnitude and three-dimensional direction), turbulence scale and intensity, and the presence of extraneous airborne matter (e.g., rain, snow, insects). The Hi-Vol sampler is the principal instrument used in the United States to measure ambient aerosol concentration. This sampler measures total suspended particulate (TSP) and operates at a flow rate of 1.41

m³/min (50 cfm). The collection effectiveness of this sampler, however, was found strongly dependent on particle size, approach flow wind speed, and sampler orientation.

Growing recognition of the deficiencies in both the TSP standard and the Hi-Vol sampler by which the standard has been implemented has led the U.S. Environmental Protection Agency (EPA) to consider a new category of ambient aerosol referred to as Inhalable Particulate Matter (IPM). Currently, IPM is defined as those particles having aerodynamic diameters $\leq 15\,\mu m$. Ideally the inlet of an IPM sampler would transmit 100% of all particles smaller than 15 μm, independent of the ambient wind speed which carried the particles toward the inlet, and would not transmit the larger particles. An infinitely sharp cutpoint and strict independence of wind speed cannot be achieved in practice, however. Instead, the 15 μm cutpoint is taken to be the particle size at which the collection effectiveness is 50%, and the collection effectiveness for all particle sizes must fall within a prescribed IPM performance envelope over a specified range of wind speeds (2 to 24 km/h).

The project report describes an inlet developed at Colorado State University intended for IPM sampling, and provides data from the wind tunnel testing of the resulting inlet. Additionally, measurements are reported on the wind tunnel testing of a second candidate IPM inlet developed in a joint effort between the University of Minnesota (UM) and Lawrence Berkeley Laboratory (LBL). Both inlets operate at a flow rate of 16.7 L/min and thus are suitable as replacement inlets for existing dichotomous samplers.

Inlet Descriptions

Figure 1 shows the inlet developed at the Aerosol Science Laboratory, Colorado State University (ASL/Wedding inlet). The housing for the inlet is similar to that of the current commercial inlet for the dichotomous sampler. The particle size fractionator component of the cyclone receives an angular impetus as it follows a channel defined by two adjacent curved directional vanes, and accelerates toward the outer radius of the cyclone R_2. When the particle arrives at R_2 with velocity U_o, it begins its upward ascension with velocity U_v. If the particle is not removed, it will travel the distance l, negotiate the turn at the top of the cyclone R_1 and travel downward to the exit plane of the inlet. Particles that are removed are intended to deposit on the inside collector surface, as shown in Figure 1.

Figure 2 shows the inlet developed jointly by UM and LBL. The fractionator component of the inlet is an impaction stem and cup.

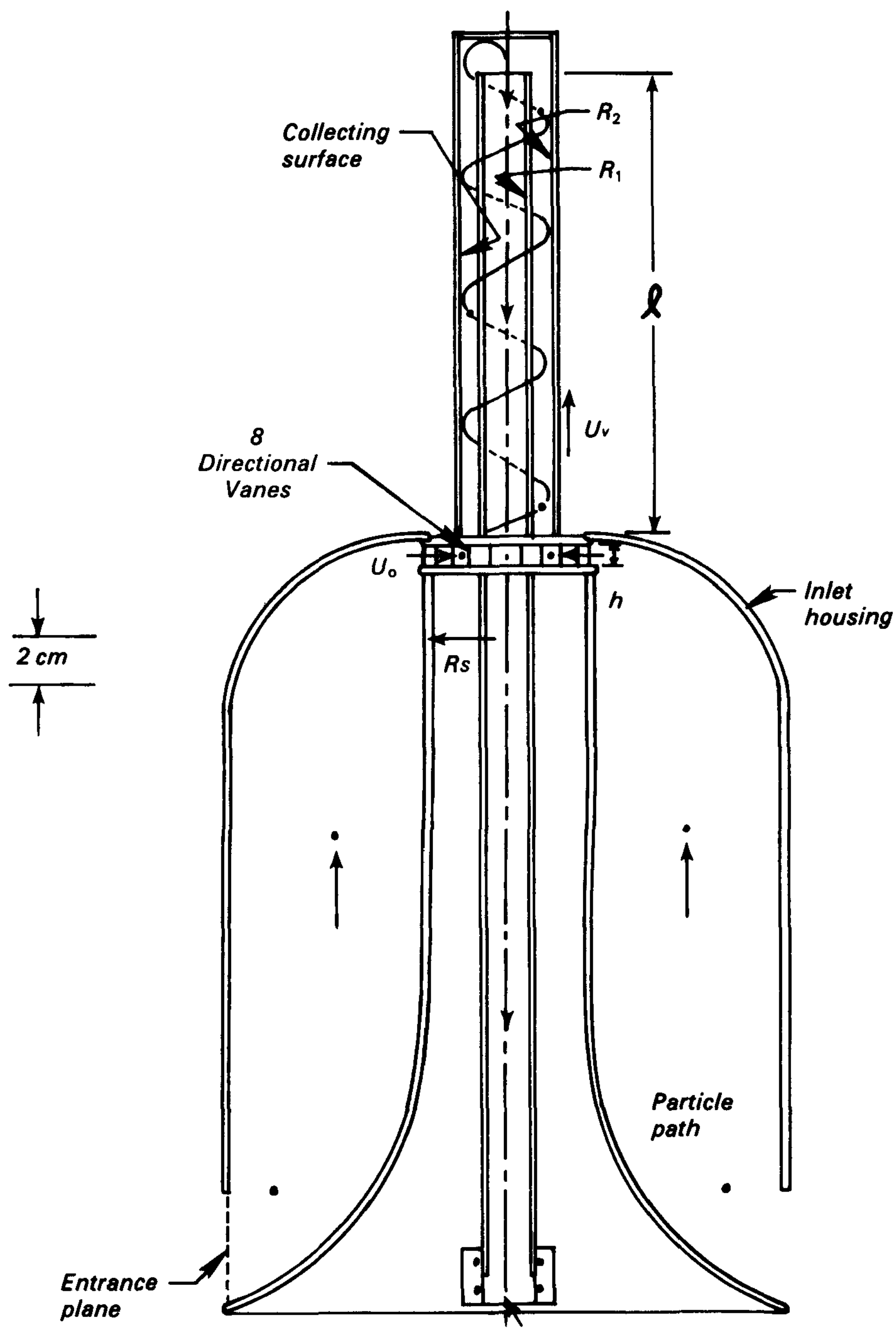

Figure 1. Wedding IPM inlet.

Results

The two inlets were tested in the closed-loop ASL Wind Tunnel. The tunnel has a cross-sectional dimension of 1.22 m square at the test section. Monodisperse aerosol supplied to the tunnel is generated by a vibrating orifice atomizer operated in an inverted manner. Particles employed in the study were made from an oleic acid-ethanol mixture tagged with uranine.

Results from the wind tunnel tests on the sampling effectiveness of the Wedding inlet are shown in Figure 3. Each plotted point represents the average value of at least eight data points taken on different days. Tests are quickly and reproducibly performed for speeds of 2 to 24 km/h (and greater). For the 0.5 and 2 km/h tests, fluid energy is insufficient to mix adequately the injected aerosol—thus the greater error potential must be noted. Except for an enrichment condition below 10 μm at 24 km/h the measurements shown in Figure 3 for the Wedding inlet fall within the IPM performance envelope. The D_{50} values at 0.5, 2, 8, and 24 km/h are 14.4, 14.0, 14.2, and 13.7 μm, respectively. (D_{50} is the particle diameter for which the sampling effectiveness is 50%.)

The UMLBL inlet results are given in Figure 4. Within experimental error the measurements fall within the IPM performance envelope, except for the 5 μm points at 2 and 24 km/h. Independent measurements performed at UM showed a virtually identical enrichment at 24 km/h, but all measurements at 1 km/h were within the limits of the IPM performance envelope. The differences between the two sets of measurements, although small, are unresolved at present.

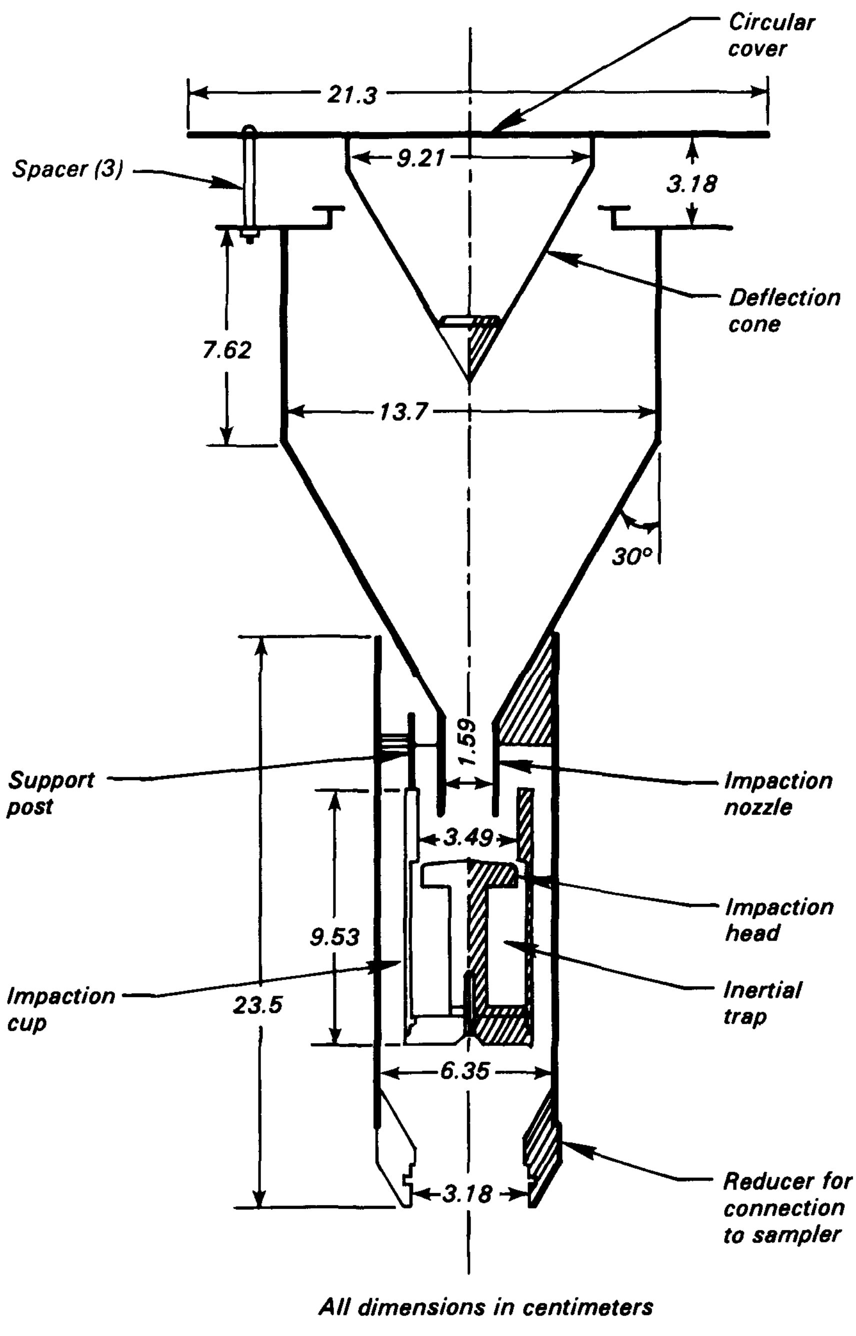

Figure 2. *UMLBL IPM inlet.*

Conclusions and Recommendations

A candidate IPM inlet was designed, fabricated, and tested in a wind tunnel. On the basis of the tests it is recommended as a reasonable interim choice for use on EPA's IPM dichotomous sampler network. A new completely revised fractionator and inlet housing concept are presently being designed and tested specifically to eliminate an enrichment condition exhibited by the inlet, to make the unit more compact and versatile, and to improve performance characteristics of the cyclone fractionator. The fractionator should cause the mass to deposit in more favorable locations. The redesign was initiated in July 1980 under a different project and is currently underway.

Wind tunnel testing was performed on a second inlet provided by the UM and LBL. While the tests showed UMLBL inlet to be in near compliance with the presently proposed IPM performance envelope, independent measurements at the UM have shown a slightly better performance. The differences between the two sets of measurements, although small, remain unresolved and may indicate the degree of uncertainty in such measurements at the present time.

The technology represented by each of these inlets does not purport to be the ultimate answer to IPM sampling needs. As health effects and other environmental factors and national/scientific needs dictate monitoring strategy changes (e.g., D_{50}, flow rates), other inlet systems will need to be developed. As this report was being completed, a change in D_{50} for IPM from 15 to 10 μm is under serious consideration. Although the inlets discussed in this report would then no longer be appropriate, the principles of their design are adaptable to a new cutpoint choice.

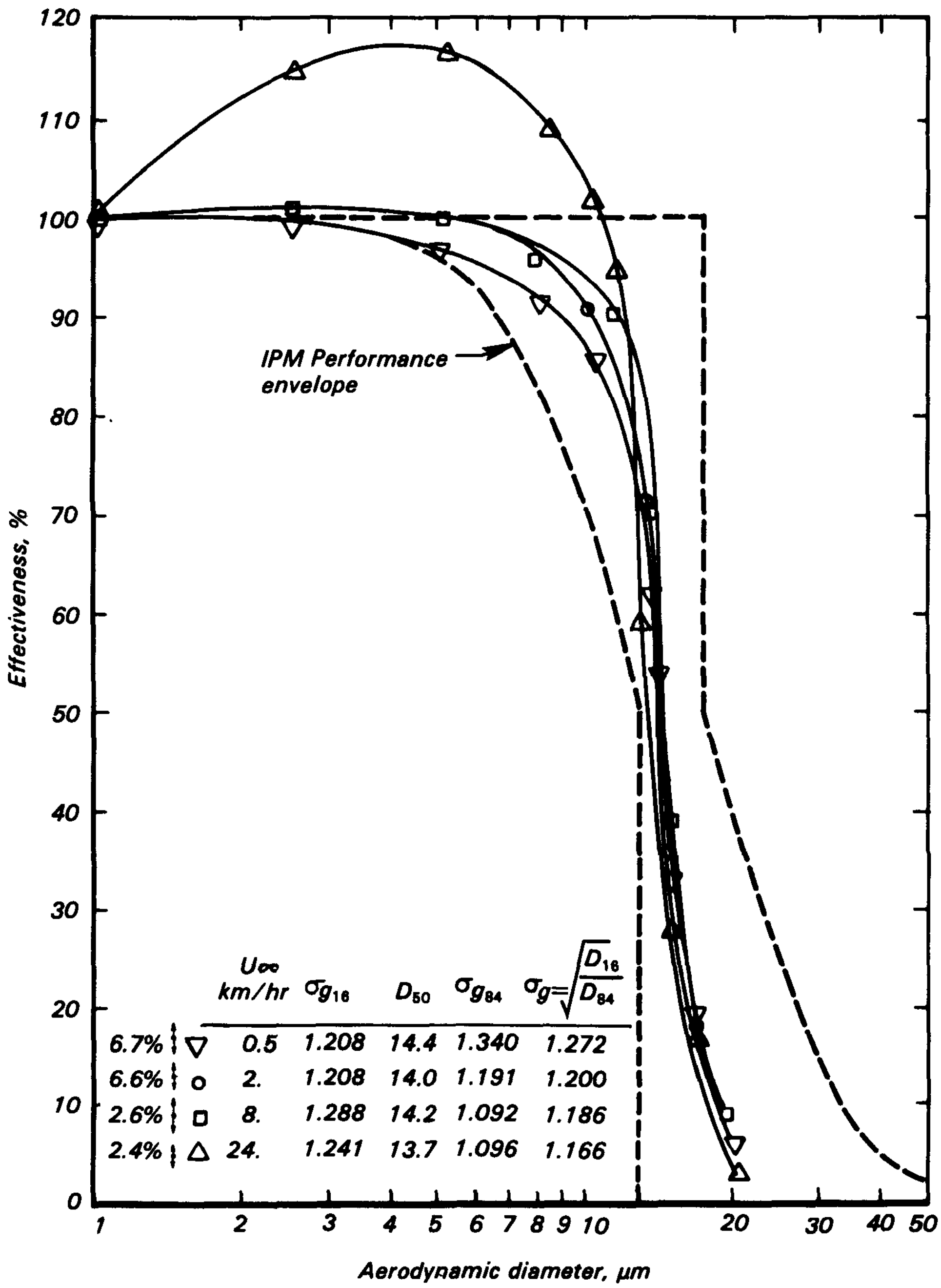

Figure 3. Sampling effectiveness for Wedding inlet.

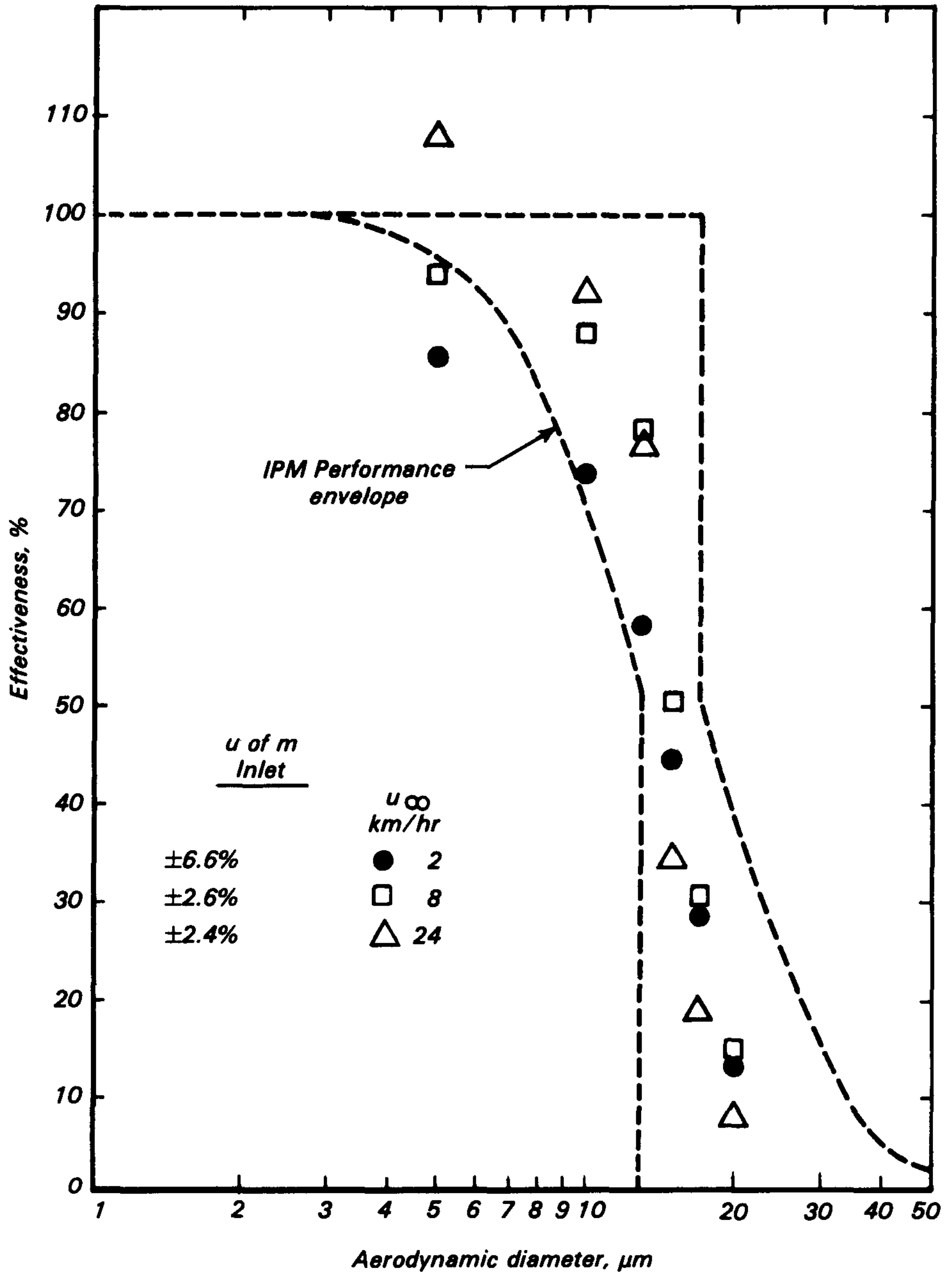

Figure 4. Sampling effectiveness for UMLBL inlet.

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***Charles W. Lewis** is the EPA Project Officer (see below).*
The complete report, entitled "Design, Fabrication and Testing of Ambient Aerosol Sampler Inlets," (Order No. PB 82-198 417; Cost: $7.50, subject to change) will be available only from:
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