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Research and Development

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Project Summary

The Tapered Element Oscillating Microbalance: A Monitor for Short-Term Measurement of Fine Aerosol Mass Concentration

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A new detector, based on a device called the Tapered Element Oscillating Microbalance (TEOM), has recently been developed for short-term monitoring of ambient aerosol fine mass concentration. The main element of the detector is a tapered hollow tube (the TEOM) fixed at the wide end and holding an exchangeable filter cartridge at the narrow end. Air is drawn through the filter cartridge and down the hollow tube. As air is pumped into the tube, particulates deposit on the filter cartridge. The tapered tube oscillates continuously in a clamped-free mode with the frequency accurately monitored. As particulates load onto the filter cartridge, the frequency changes in relation to the mass added. A microprocessor-based electronics system connected to the detector then collects and processes the data.

Output is printed in a format consisting of time and aerosol concentration level in $\mu g/m^3$. The time resolution of the instrument, that is, the time required to measure an air pollution level of 10 $\mu g/m^3$ with an accuracy of 10%, is 30 minutes. The inlet is equipped with a cyclone preseparator that has a cutpoint of 2.5 μm (aerodynamic diameter). This results in a system which provides a fully automated direct measurement of the fine mass concentration of ambient aerosol.

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

Ambient aerosol mass concentration has been measured by a number of widely varying techniques. The most common method used has been gravimetric determination of aerosol mass collected by filtration of an aerosol stream through a filter substrate. The Hi-Vol and Dichotomous Samplers are examples of this traditional approach. This approach, however, is ill-suited to real-time measurement, since several hours are required for the sample collection step, and the filter samples then must generally be transported to a central facility for the gravimetric determination.

Until recently, only two alternative methods for short-term measurement of aerosol mass concentration were available: beta-attenuation and quartz crystal microbalance (QCM). Although neither can be strictly regarded as having a real-time capability, each has the potential for performing aerosol mass measurements with a time resolution ranging from several minutes (QCM) to several hours (beta-attenuation). The beta-attenuation method is based on the decrease in the number of electrons reaching an electron counter when a thin layer of material (aerosol collected on a filter) is interposed between the counter and a radioactive source of electrons. The QCM method utilizes the piezoelectric effect, with which the mass of aerosol deposited on an oscillating quartz crystal is inferred from the measured frequency change of the crystal. Both the beta-attenuation and QCM approaches have been employed in commercially available instruments.

As a result of recent work supported by the U.S. Environmental Protection Agency and summarized here, a new instrument is now commercially available (Rupprecht and Patashnick Co., Englewood, CO) for the short-term monitoring of fine aerosol mass concentration. The instrument is based on the newly developed Tapered Element Oscillating Microbalance (TEOM), which has been assigned U.S. Patent No. 3,926,271. As in the QCM method, mass is determined through measurement of frequency change. In nearly all other respects, however, the TEOM is distinctly different from the QCM and is intended to avoid well-documented difficulties of the latter.

Description

Figure 1 shows the operation of the TEOM in simplified terms. The TEOM is a tube constructed of material with a high mechanical quality factor, and it has a special taper. The tube is firmly mounted at the wide end, while the other end supports a filter cartridge. The tube is hollow, so that a pump will cause aerosol to be deposited on the filter cartridge while the remaining clean air passes through the tube. The free end of the tube is set into transverse oscillation and the natural frequency changes in relation to the mass deposited on the filter. The tapered element is kept in oscillation by a feed-back system: the oscillation of the element is converted into an electrical signal by a light emitting diode(LED)-phototransistor combination, the output of the phototransistor being modulated by the light

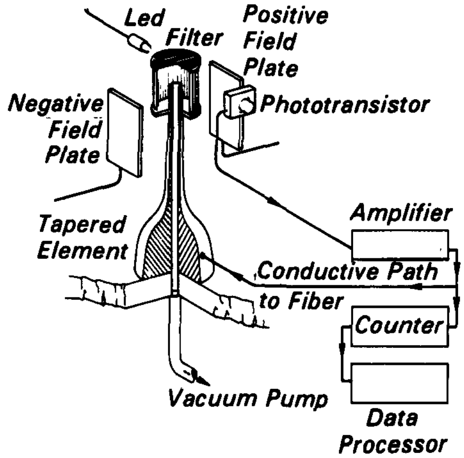

Figure 1. *The TEOM in schematic form.*

blocking effect of the vibrating element. The modulated voltage is amplified and applied to a conductive coating on the vibrating element. Interaction between the latter signal and a steady external electric field in which the vibrating element moves is the driving force which maintains the oscillation.

Figure 2 shows the TEOM in its packaged field instrument form. The system includes two modules — the detector and supporting electronics. A third component, not shown, is the external vacuum pump which moves the aerosol through the detector module. The detector module consists of the TEOM filter unit, cyclone preseparator, air heater, flow controller, and air buffer. The electronics module consists of a feed-back amplifier, frequency counter, control circuits, microprocessor, LED display, and printer. The cyclone preseparator removes aerosol particles larger than 2.5 μm in aerodynamic diameter, so that the detector responds only to the ambient fine particle mass concentration. The air heater maintains the temperature of the incoming aerosol to a narrow range near 60°C. This temperature is required for frequency stability and minimization of humidity effects on the aerosol measurements. The flow controller maintains the flow rate at 7.1 l/min. Once set into operation the printer gives automatic outputs (on a ½ to 1 h schedule) of the time of day and fine particle mass concentration, in $\mu g/m^3$. The sensitivity is such that a fine mass concentration of 10 $\mu g/m^3$ can be measured with a precision of 10% in a 30 min sampling interval.

Conclusions

The TEOM is a new and unique instrument capable of short-term aerosol fine mass concentration meas-

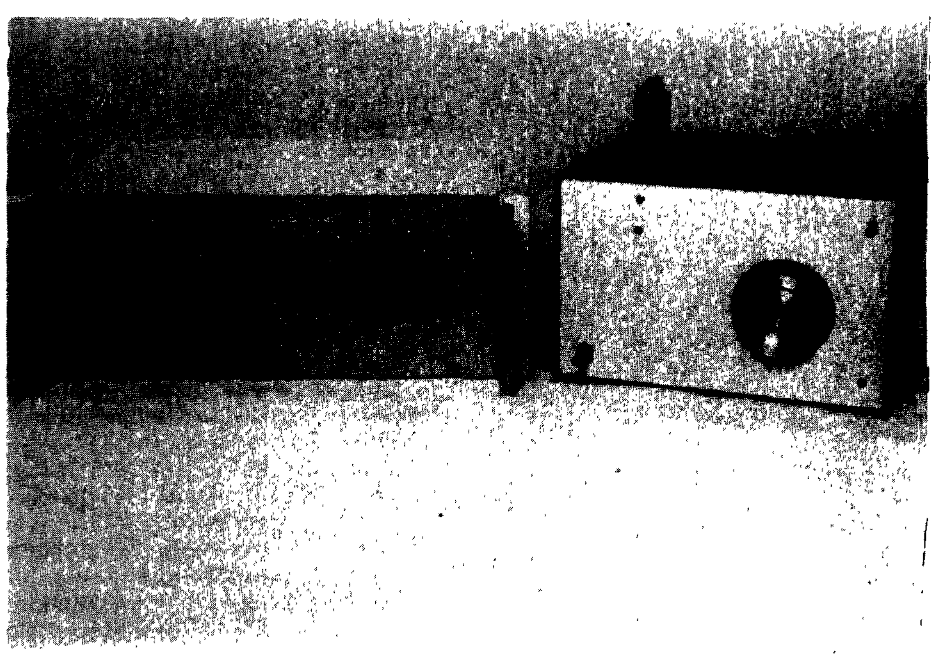

Figure 2. *The TEOM field instrument.*

urements. The TEOM measures the mass of collected particulates, independent of their composition, atomic number, optical properties, shapes, or other properties. It is potentially a strong competitor for existing beta-attenuation and QCM methods for measuring short-term ambient aerosol trends.

Recommendations

Although the detector appears very promising, extensive field testing needs to be conducted with the TEOM to confirm its expected usefulness in ambient air monitoring. This testing should include intercomparisons with existing short-term monitors such as beta-attenuation and QCM devices, integrating nephelometers, and conventional long-term samplers such as the dichotomous sampler.

The EPA author of this Project Summary is ***Charles W. Lewis*** *(also the EPA Project Officer, see below), who is with the Environmental Sciences Research Laboratory, Research Triangle Park, NC 27711.*

The complete report, entitled "The Tapered Element Oscillating Microbalance: A Monitor for Short-Term Measurement of Fine Aerosol Mass Concentration," was authored by Harvey Patashnick and Georg Rupprecht of Rupprecht and Patashnick Co., Englewood, CO 80111 (Order No. PB 81-245 219; Cost: $6.50, 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:

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