THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

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ETV Joint Verification Statement

TECHNOLOGY TYPE: **Continuous Ambient Fine Particle Monitor**

APPLICATION: **MEASURING FINE PARTICULATE MASS IN AMBIENT AIR**

TECHNOLOGY NAME: **Model 3320 Aerodynamic Particle Sizer (APS$^{\text{SM}}$)**

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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; with stakeholder groups that consist of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Advanced Monitoring Systems (AMS) Center, one of six technology centers under ETV, is operated by Battelle in cooperation with EPA's National Exposure Research Laboratory. The AMS Center has recently evaluated the performance of continuous monitors used to measure fine particulate mass and species in ambient air. This verification statement provides a summary of the test results for the TSI Incorporated Model 3320 Aerodynamic Particle Sizer (APS).

VERIFICATION TEST DESCRIPTION

The objective of this verification test is to provide quantitative performance data on continuous fine particle monitors under a range of realistic operating conditions. To meet this objective, field testing was conducted in two phases in geographically distinct regions of the United States during different seasons of the year. The first phase of field testing was conducted at the ambient air monitoring station on the Department of Energy's National Energy Technology Laboratory campus in Pittsburgh, PA, from August 1 to September 1, 2000. The second phase of testing was performed at the California Air Resources Board's ambient air monitoring station in Fresno, CA, from December 18, 2000, to January 17, 2001. Specific performance characteristics verified in this test include inter-unit precision, agreement with and correlation to time-integrated reference methods, effect of meteorological conditions, influence of precursor gases, and short-term monitoring capabilities. The Model 3320 APS reports measurement results in terms of $PM_{2.5}$ mass and, therefore, was compared with the federal reference method (FRM) for $PM_{2.5}$ mass determination. Additionally, comparisons with a variety of supplemental measurements were made to establish specific performance characteristics.

Quality assurance (QA) oversight of verification testing was provided by Battelle and EPA. Battelle QA staff conducted a data quality audit of 10% of the test data, and performance evaluation audits were conducted on the FRM samplers used in the verification test. Battelle QA staff conducted an internal technical systems audit for Phase I and Phase II. EPA QA staff conducted an external technical systems audit during Phase II.

TECHNOLOGY DESCRIPTION

The Model 3320 APS is a general-purpose particle spectrometer that measures aerodynamic diameter and light-scattering intensity. It provides high-resolution, real-time aerodynamic size measurements in the range of 0.5 to 20 μm. It also measures light-scattering intensity in the equivalent optical size range of 0.37 to 20 μm. A patented, double-crest optical system detects the occurrence of particle coincidence and minimizes the effects of poor signals near the lower detection threshold. The Model 3320 APS accelerates aerosol sample flow through an accelerating orifice. The aerodynamic size of a particle determines its rate of acceleration, with larger particles accelerating more slowly as a result of increased inertia. As particles exit the nozzle, they cross through two partially overlapping laser beams in the detection area. Light is scattered as each particle crosses through the overlapping beams. An elliptical mirror, placed at 90 degrees to the laser beam axis, collects the light and focuses it onto an avalanche photodetector. The avalanche photodetector then converts the light pulses into electrical pulses. Two partially overlapping laser beams allow each particle to generate a single two-crested signal. Peak-to-peak time-of-flight is measured with 4-nanosecond resolution for aerodynamic sizing. The amplitude of the signal is logged for light-scattering intensity. Small particles that may have only one detectable crest are binned separately. Particles with more than two crests, indicative of coincidence, also are binned separately, but are not used to build aerodynamic-size or light-scattering distributions. The Model 3320 APS also features a control knob, built-in display, microprocessor-controlled volumetric flow control, barometric pressure correction, and separate pumps for sheath and total flows. It includes the Aerosol Instrument Manager® software, a 32-bit, Windows-based platform with advanced data management capabilities. The Model 3320 APS aerosol inlet has a 3/4-in. outside diameter; and the sensor is 15 in. (38 cm) long, 12 in. (30 cm) wide, and 7 in. (18 cm) high. It weighs 22 pounds. In this verification test, no size selective inlet was used. Average particle size distributions were determined every 15 minutes. The distributions were converted to $PM_{2.5}$ mass concentrations using vendor-supplied software. This software makes assumptions about particle density, particle volume, etc., to estimate mass from the size distributions. (Note: This model is being discontinued in September 2001, at which point a new model will be introduced. The results of this verification test are not applicable to the new model.)

VERIFICATION OF PERFORMANCE

Inter-Unit Precision: During Phase I, regression analysis showed $r^2 = 0.983$ for the 15-minute data and $r^2 = 0.972$ for the 24-hour averages from the duplicate monitors. The slopes of the regression lines were 0.670 (0.005) and 0.627 (0.081), respectively, for the 15-minute data and 24-hour averages, indicating a substantial bias between the two monitors. The intercept of the regression line was 0.33 (0.07) for the 15-minute data and 0.80 (0.96) for the 24-hour data. The calculated coefficient of variation (CV) for the 15-minute data was 25.2%; and, for the 24-hour averages, the CV was 25.6%. Much of these CV values may be attributed to the bias between the monitors rather than to random differences in the readings. During Phase II, regression analysis showed r^2 values of 0.973 and 0.998, respectively, for 15-minute and 24-hour average data. The slopes of the regression lines were 1.234 (0.010) and 1.280 (0.040), respectively, for the 15-minute data and 24-hour averages, indicating a significant bias between the two monitors. An intercept of 1.23 (0.34) $\mu g/m^3$ was observed for the 15-minute data and an intercept of -9.2 (13.6) $\mu g/m^3$ for the 24-hour averages. The calculated CV for the 15-minute data was 21.5%; and, for the 24-hour averages, the CV was 18.8%.

Comparability/Predictability: During Phase I, comparisons of the 24-hour averages with $PM_{2.5}$ FRM results showed r^2 values of 0.100 and 0.093, respectively for Monitor 1 and Monitor 2. The slopes of the regression lines were 0.204 (0.433) and 0.118 (0.301), respectively, for Monitor 1 and Monitor 2. During Phase II, the regression results show r^2 values of 0.803 and 0.762 for Monitor 1 and Monitor 2, respectively, with slopes of the regression lines for Monitor 1 and Monitor 2 of 0.578 (0.121) and 0.555 (0.195), respectively. These results from both phases indicate a substantial negative bias of the Model 3320 APS monitors relative to the FRM.

Meteorological Effects: Multivariable model analysis of the 24-hour average data during Phase I showed no conclusive influence of meteorology on the readings of the two monitors relative to the FRM. Multivariable analysis of the 24-hour average data during Phase II ascribed to wind speed a statistically significant influence on the readings of one of the monitors relative to the FRM values at a 90% confidence level. However, under typical conditions during Phase II, the effect of this parameter on the instrument readings was only about 0.2% relative to the simple linear regression against FRM results.

Influence of Precursor Gases: Multivariable analysis of the 24-hour average data during Phase I showed no conclusive influence of the ambient precursor gases on the readings of the two monitors relative to the FRM values at the 90% confidence level. Multivariable analysis of the 24-hour average data during Phase II showed that none of the ambient precursor gases measured had a statistically significant influence on one of the Model 3320 APS monitors, but that both carbon monoxide and nitric oxide had an effect on the other monitor. The combined effects of these gases on the readings of Monitor 1 under typical conditions during Phase II were less than 2% compared to the simple linear regression against FRM results.

Short-Term Monitoring: In addition to 24-hour FRM samples, short-term sampling was performed on a five-sample-per-day basis in Phase II. The Model 3320 APS results were averaged for each of the sampling periods and compared with the gravimetric results. Linear regression of these data showed slopes of 0.489 and 0.556, respectively, for Monitor 1 and Monitor 2, consistent with the negative bias seen relative to the 24-hour FRM results. For the individual sampling periods, both correlation and slope relative to the FRM were best during periods with the lowest $PM_{2.5}$ concentrations.

Other Parameters: The two monitors required little maintenance during either phase of testing, with the exception of recalibration of the sample flow rates of one monitor during Phase I. Substantial difficulties associated with data collection resulted in the loss of a considerable amount of data during the two phases of testing. During Phase I, delays in instrument installation and losses from the data system resulted in capture of only about 10 days of data from one monitor and 12 days from the other. During Phase II, data completeness was approximately 90% for one monitor and 50% for the other.

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