THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

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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:	**Series 1400a TEOM Particle Monitor with Sample Equilibration System**	
COMPANY:	**Rupprecht & Patashnick, Co.**	
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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 Rupprecht & Patashnick, Co. Series 1400a TEOM particle monitor with sample equilibration system (SES).

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 Series 1400a SES TEOM 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 Series 1400a TEOM monitor can be configured with appropriate separation devices to measure ambient particulate mass concentrations in real time of any of the following: PM_{10}, $PM_{2.5}$, PM_1, or TSP (total suspended particulates). For this verification test, the Series 1400a TEOM monitor was configured with a PM_{10} head and a $PM_{2.5}$ sharp cut cyclone (SCC). A tapered element oscillating microbalance, which is a patented inertial mass measurement technique, directly measures particle mass collected on a filter. The Series 1400a TEOM has exposed collection filters that can be analyzed for heavy metals using standard laboratory techniques. Active volumetric flow control maintains a constant volumetric flow rate by using density-adjusted mass flow control that incorporates ambient pressure and temperature sensors. The Series 1400a TEOM monitor is a gravimetric instrument that draws ambient air through a filter at a constant flow rate, continuously weighing the filter and calculating rolling 10-minute smoothed mass concentrations. The Series 1400a TEOM computes the total mass accumulation on the collection filter, as well as 30-minute, one-hour, eight-hour, and 24-hour averages of the mass concentration. Hydrophobic filter material and sample collection at above-ambient temperature eliminates the necessity for humidity equlibration. Both analog and RS-232 outputs are available. Input/output capabilities include a menu-driven user interface, seven analog input channels for receiving external data with conversion to engineering units, vector-based averaging for wind speed and direction, internal data logging of system and external information, three user-defined analog output channels, two contact closure alarm circuits, and advanced RS-232 support for the retrieval of current and logged information. The Series 1400a TEOM monitor is 35.56 cm (14 in.) wide, approximately 99.36 cm (39.12 in.) high, and 27.94 cm (11 in.) deep. The Sample Equilibration System (SES) uses Nafion® dryer technology to condition the main and bypass sample streams to low humidity and temperature levels. The SES is designed to permit particulate matter mass measurements to be performed in a manner that minimizes the possibility of particulate matter concentrations being overestimated due to the affinity of some types of particles for moisture. When installed on the Series 1400a monitor, the SES allows the mass collected on the filter to equilibrate more rapidly than when in the presence of high humidity levels. The SES enables the monitor to operate at standardized temperatures as low as 30 °C to gain representative short-term particulate matter data at a low standardized temperature.

VERIFICATION OF PERFORMANCE

Inter-Unit Precision: During Phase I, regression analysis of the hourly data from the duplicate Series 1400a SES TEOM monitors, and the 24-hour averages, showed r^2 values of 0.948 and 0.987, respectively. The slopes of the regression lines were 0.949 (0.016) and 0.991 (0.045), respectively, for the hourly data and 24-hour averages, where the values in parentheses are 95% confidence intervals (with Monitor 1 as independent variable). An intercept of 1.87 (0.38) $\mu g/m^3$ for the hourly data, and an intercept of 1.04 (1.00) $\mu g/m^3$ for the 24-hour data, were observed. The calculated CV for the hourly data was 9.3%; and, for the 24-hour data, the CV was 4.3%. During Phase II, regression analysis showed r^2 values of 0.973 and 0.999, respectively, for the hourly data and the 24-hour averages. The slopes of the regression lines were 1.005 (0.012) and 1.053 (0.016), respectively, for the hourly data and 24-hour averages; the intercepts were -1.19 (0.97) $\mu g/m^3$ and -3.52 (1.05) $\mu g/m^3$, respectively. The calculated CV for the hourly data was 23.2%; and, for the 24-hour data, the CV was 1.8%.

Comparability/Predictability: During Phase I, the comparisons of the 24-hour averages with $PM_{2.5}$ FRM results showed slopes of the regression lines for Monitor 1 and Monitor 2 of 0.964 (0.082) and 0.927 (0.074), respectively; and these slopes were not significantly different from unity at the 95% confidence level. The regression results show r^2 values of 0.959 and 0.964 for Monitor 1 and Monitor 2, respectively. The intercepts of the regression lines were 3.62 (1.67) and 4.95 (1.50) $\mu g/m^3$, respectively, for Monitor 1 and Monitor 2, and were statistically different from zero. For Phase II, the slopes of the regression lines for Monitor 1 and Monitor 2 were 0.933 (0.087) and 0.978 (0.100), respectively, for the hourly and 24-hour averages, and not statistically different from unity at 95% confidence. The intercepts of these regression lines were -18.4 (7.6) and -22.6 (8.7) $\mu g/m^3$, respectively, for Monitor 1 and Monitor 2 and statistically different than zero. The r^2 values were 0.953 and 0.944, respectively.

Meteorological Effects: Multivariable model analysis of the 24-hour average data during Phase I ascribed to each of wind direction and the standard deviation of the wind direction a statistically significant influence on the readings of one of the monitors relative to the FRM values at a 90% confidence level. Under typical conditions during Phase II, these parameters had a combined effect of ~3% on Monitor 1 and ~13% on Monitor 2. The model analysis of the 24-hour average data during Phase II ascribed to relative humidity and solar radiation a statistically significant influence on the results of both monitors at the 90% confidence level. However, in a practical sense, the total combined effect of these parameters on the instrumental readings was negligible (~0.4%) under typical conditions during Phase II.

Influence of Precursor Gases: A similar multivariable analysis of the 24-hour average data during Phase I ascribed to hydrogen sulfide and sulfur dioxide an influence on the readings of one monitor relative to the FRM, at a 90% confidence level. Under typical conditions during Phase I, these gases had a combined effect of ~12% on Monitor 1. Multivariable analysis of the 24-hour average data during Phase II showed no statistically significant influence of the measured precursor gases on the Series 1400a SES TEOM readings.

Short-Term Monitoring: In addition to 24-hour FRM samples, short-term monitoring (3-, 5-, and 8-hour intervals) was performed on a five-sample-per-day basis in Phase II. The Series 1400a SES TEOM results were averaged for each of the sampling periods and compared with the gravimetric-based reference results. Linear regression of these data, considering all short-term intervals together, showed slopes of 0.97 and 1.02, respectively, for Monitor 1 and Monitor 2. The intercepts of the regression lines were -16.7 and -20.8 $\mu g/m^3$, respectively; and the r^2 values were 0.914 and 0.920, respectively.

Other Parameters: No operating problems arose, and no maintenance was performed on either monitor during testing.

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