THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

U.S. Environmental Protection Agency

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ETV Joint Verification Statement

TECHNOLOGY TYPE: Continuous Ambient Mass Monitor

APPLICATION: MEASURING FINE PARTICULATE MASS IN AMBIENT AIR

TECHNOLOGY NAME: Continuous Ambient Mass Monitor

COMPANY: Thermo Andersen

ADDRESS: 500 Technology Court
Smyrna, GA 30082

PHONE: 800-241-6898
FAX: 770-319-9999

WEB SITE: http://www.AndersenInstruments.com
E-MAIL: sales@AndersenInstruments.com

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 Thermo Andersen continuous ambient mass monitor (CAMM).

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, accuracy and correlation relative to time-integrated reference methods, effect of meteorological conditions, influence of precursor gases, and short-term monitoring capabilities. The CAMM 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 system audit for Phase I and Phase II. EPA QA staff conducted an external technical systems audit during Phase II.

TECHNOLOGY DESCRIPTION

The CAMM is a continuous ambient air monitor that determines fine particulate mass by measuring the increase in pressure drop across a membrane filter during particle sampling. The CAMM reports $PM_{2.5}$ concentrations in micrograms per cubic meter of air ($\mu g/m^3$). A new section of filter tape is exposed every measurement period, allowing particles to remain in or close to equilibrium with the sample air during collection. The CAMM measures at ambient temperature to minimize losses due to volatilization and has a short sampling duration and low face velocity to reduce sampling artifacts. The CAMM consists of a conventional FRM PM_{10} inlet, a $PM_{2.5}$ Sharp Cut Cyclone, a diffusion dryer, a filter tape, a tape transfer mechanism, and a data acquisition and control unit. Fine particle monitoring is accomplished by a filter tape transport system and an array of pressure transducers. The monitoring system includes a microprocessor-controlled drive to advance the tape and a mechanism to release and reseal the filter tape during each advance. Automatic filter changes and enclosure design both support sample equilibration with ambient conditions and optimize the reduction of sampling artifacts. Sensor calibrations are stored via internal memory. Built-in diagnostic features, analog outputs, and instrument interfaces provide the user with advanced quality control features through local or remote access.

VERIFICATION OF PERFORMANCE

Inter-Unit Precision: Only one of the duplicate CAMMs provided usable data during Phase I. The second unit had a leak in the sampling system, and the collected data were invalidated. Consequently, no measure of inter-unit precision is available for Phase I. During Phase II, regression analysis showed r^2 values of 0.918 and 0.930, respectively, for the hourly data and the 24-hour averages from the duplicate monitors. The slopes of the regression lines were 0.903 (0.024 95% confidence interval) and 0.774 (0.086), respectively, for the hourly data and 24-hour averages, indicating a statistically significant difference between the duplicate CAMMs. The intercepts were 5.8 (2.8) $\mu g/m^3$ and 16.1 (9.9) $\mu g/m^3$, respectively. The calculated coefficient of variation (CV) for the hourly data was 17.2% and for the 24-hour averages, the CV was 13.8%.

Comparability/Predictability: During Phase I, comparisons of the 24-hour averages with $PM_{2.5}$ FRM results showed a slope of the regression line for Monitor 1 of 0.45 (0.26) and an intercept of 13.5 (5.4) $\mu g/m^3$. The regression results show an r^2 value of 0.386. During Phase II, comparison of the 24-hour averages with $PM_{2.5}$ FRM results showed slopes of the regression lines for Monitor 1 and Monitor 2 of 1.46 (0.30) and 1.20 (0.22), respectively, and no statistically significant intercept was observed in either case at the 95% confidence level. The regression results show r^2 values of 0.809 and 0.843 for Monitor 1 and Monitor 2, respectively.

Meteorological Effects: Multivariable analysis shows that none of the meteorological parameters measured during Phase I influenced the readings of the CAMM relative to the FRM at the 90% confidence level. Multivariable analysis showed that, during Phase II, relative humidity had a statistically significant (90% confidence) influence on the readings of one of the duplicate CAMMs. However, this effect was largely canceled out by the intercept of the regression analysis, and was of no practical significance.

Influence of Precursor Gases: None of the precursor gases had a statistically significant effect (90% confidence) on the readings of the CAMM during Phase I or Phase II.

Short-Term Monitoring: In addition to 24-hour FRM samples, short-term sampling was performed on a five-sample-per-day basis during Phase II only. The results from the duplicate CAMMs were independently averaged for each of the sampling periods and compared with the gravimetric results. Considering all of the short-term data together, linear regression showed slopes of 1.27 and 1.15, respectively, for Monitor 1 and Monitor 2. The intercepts of the regression lines were 13.1 and 15.6 $\mu g/m^3$, respectively; and the r^2 values were 0.716 and 0.666, respectively.

Other Parameters: The CAMMs required some maintenance during both phases of verification testing. During Phase I, the virtual impactors on the two CAMMs were cleaned approximately weekly. Additionally, the filter tape in each CAMM was changed several times during Phase I. Some additional troubleshooting was performed on one of the units to identify the source of problems indicated by the error codes on the display of the monitor. As noted previously, a leak in this monitor that invalidated all data. With the exception of several power outages, approximately 90% data recovery was achieved from the one CAMM that operated in Phase I. During Phase II of the verification test, the virtual impactors required cleaning approximately every one to two days as a result of the high $PM_{2.5}$ concentrations. An external timer mechanism was added to each of the CAMMs to allow data collection on a two-minute time scale rather than the default one-hour time scale.

Gabor J. Kovacs Date
Vice President
Environmental Sector
Battelle

Gary J. Foley Date
Director
National Exposure Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency