THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

U.S. Environmental Protection Agency

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ETV Joint Verification Statement

TECHNOLOGY TYPE:	**Continuous Ambient Particulate Carbon Monitor**
APPLICATION:	**MEASURING PARTICULATE CARBON IN AMBIENT AIR**
TECHNOLOGY NAME:	**Series 5400 Monitor**
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 5400 particulate carbon monitor.

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, and influence of precursor gases. The Series 5400 reports particulate organic, elemental, and total carbon concentrations (OC, EC, and TC) and was compared with particulate carbon concentrations determined by laboratory thermal/optical reflectance (TOR) analysis of filter-based reference samples. Ambient aerosol carbon levels differed markedly in the two phases of testing, with OC, EC, and TC averages of 4.6, 1.3, and 5.9 $\mu g/m^3$, respectively, in Phase I, and of 19.8, 6.1, and 25.9 $\mu g/m^3$, respectively, in Phase II. 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 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 5400 is an automatic speciation analyzer of suspended particulate matter. It measures the elemental and organic carbon contained in suspended particulate matter at averaging times as short as one hour. Its thermal CO_2 analysis technique is similar to that used in many analytical laboratories to measure carbon particulate concentration. Results from the instrument can be used to compare organic and elemental carbon particulate concentrations (in $\mu g/m^3$) with mass-based measurements such as $PM_{2.5}$, PM_{10} or PM_1 (in $\mu g/m^3$). Ambient air passes through a $PM_{2.5}$, PM_{10}, or PM_1 size-selective inlet before entering the instrument. The Series 5400 contains two cartridges located in temperature-regulated ovens to collect the sampled particulate matter. While one cartridge is being used for particle collection, the instrument performs its thermal CO_2 analysis on the previously collected particulate matter contained in the other collector. The Series 5400 differentiates between organic and elemental carbon particulate matter by oxidizing collected samples at an intermediate temperature and at a high final burn temperature. When operated at a two-hour cycle, the Series 5400 can perform up to three sample oxidations at intermediate temperatures prior to the final burn. With zero and span gas sources attached, the Series 5400 automatically audits and calibrates the CO_2 sensor at user-defined intervals. Sample oxidation during the analysis phase regenerates the Series 5400's exchangeable collection cartridges. The Series 5400 is constructed to be operated automatically and unattended for months at a time between maintenance routines. The Series 5400 makes carbon particulate data available to external devices through analog outputs and a bidirectional RS-232 interface. Data stored internally may be viewed from the monitor's display, or may be downloaded through the RS-232 port directly to a PC or by modem to a remote location. Internal diagnostics notify the user of status conditions that might affect data quality.

VERIFICATION OF PERFORMANCE

Inter-Unit Precision: Linear regression results of the hourly readings of the duplicate Series 5400 monitors indicate r^2 values of 0.94, 0.93, and 0.95, respectively, for OC, EC, and TC in Phase I. The calculated slopes of the regression lines for these data were 1.063 (0.021), 1.037 (0.022), and 1.069 (0.020), respectively where the numbers in parentheses are 95% confidence intervals. Daily 24-hour averages were calculated for OC, EC, and TC and showed similar correlation and agreement results as the hourly data. The regression results for these data indicate r^2 values of 0.97, 0.94, and 0.97, respectively. The calculated slopes of the regression lines for the

24-hour average data were 1.094 (0.081), 1.038 (0.113), and 1.098 (0.088), respectively, for OC, EC, and TC. During Phase II, linear regression results on hourly readings from the duplicate monitors indicate r^2 values of 0.94, 0.92, and 0.86, for OC, EC, and TC, respectively. The calculated slopes of the regression lines for these data were 0.971 (0.019),1.029 (0.024), and 1.074 (0.035), respectively. Daily 24-hour averages were calculated for OC, EC, and TC in Phase II and showed similar correlation and agreement results as the hourly data. The regression results for these data indicate r^2 values of > 0.97, for each carbon fraction. The calculated slopes of the regression lines for these data were 1.027 (0.072), 1.164 (0.083), and 1.090 (0.070), respectively. Without the application of a correction factor to the results of one monitor, a bias of approximately 50% was observed.

Comparability/Predictability: During Phase I, comparison of the 24-hour averages from the Series 5400 monitors to the OC, EC, and TC reference measurements showed a negative bias of the Series 5400 readings. The slopes of the regression lines for each monitor were below 0.4 for all three carbon fractions, and the r^2 values were between 0.43 and 0.52. During Phase II, comparison of the 24-hour averages to the OC, EC, and TC reference measurements again showed a negative bias of the Series 5400 readings. The slopes of the regression lines for each monitor fell between approximately 0.2 and 0.7 for Monitor 1 and 0.2 and 0.9 for Monitor 2 for all three carbon fractions, when all sampling periods were included in the analysis. However, better quantitative agreement between the Series 5400 monitors and the reference measurements was observed for some of the sampling periods relative to others. The r^2 values for the Phase II regression analyses, when all sampling periods are included, were between 0.65 and 0.90.

Meteorological Effects: During Phase I, the multivariable model ascribed to vertical and horizontal wind speed, wind direction, and ambient air temperature at 2 meters and 10 meters a significant effect on Series 5400 readings relative to the reference carbon results at 90% confidence. In general, the combined effect of these parameters was small. For example, the multivariable model predicts an average value of OC during Phase I for one of the monitors which is different from the linear regression model by ~5%. During Phase II, the multivariable model ascribed to wind speed, wind direction, the standard deviation of the wind direction, solar radiation, relative humidity, and barometric pressure a significant effect on readings relative to the reference carbon results at 90% confidence. Again, the combined effects of these parameters were small.

Influence of Precursor Gases: The multivariable model ascribed to ozone, hydrogen sulfide, and nitrogen dioxide a statistical influence on the readings of one or both monitors relative to the reference carbon results during Phase I. During Phase II, the model ascribed to nitric oxide and total nitrogen oxides a statistical influence on the readings of both Series 5400 monitors relative to the reference EC and TC results, and to nitrogen dioxide an influence on the readings of one monitor relative to the OC results at the 90% confidence level. The combined effect of the multiple parameters was typically a few percent, relative to the linear regression of Series 5400 and reference results.

Other Parameters: In general, these monitors required little maintenance and could be operated largely unattended. The monitors require 240 V power and should be installed indoors. Data recovery of approximately 90% was achieved for the two monitors over both phases of testing.

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