THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

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ETV Joint Verification Statement

TECHNOLOGY TYPE:	**TUNABLE DIODE LASER (TDL) OPEN-PATH MONITOR**		
APPLICATION:	**MONITORING AIR QUALITY**		
TECHNOLOGY NAME:	**GasFinder 2.0 TDL Open-Path Monitor**		
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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; stakeholder groups which 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 12 technology areas under ETV, is operated by Battelle in cooperation with EPA's National Exposure Research Laboratory. AMS has recently evaluated the performance of optical open-path monitors used to determine pollutants in outdoor air. This verification statement provides a summary of the test results for the Boreal GasFinder 2.0 TDL Open-Path Monitor.

VERIFICATION TEST DESCRIPTION

The verification test described in this report was designed to challenge the GasFinder 2.0 in a manner similar to that which would be experienced in field operations. An optically transparent gas cell filled with known concentrations of a target gas (methane, HF, or ammonia) was inserted into the optical path of the monitor, simulating a condition where the target gas would be present in the ambient air. The monitor was challenged with a target gas, and the resulting measurement was compared to the known concentration of the target gas. The gases were measured in a fixed sequence between April 22 and 28, 2000, at a Battelle outdoor test site near West Jefferson, Ohio.

The target gases were measured at different concentrations, path lengths, integration times, and source intensities to assess the minimum detection limit (MDL), source strength linearity, concentration linearity, accuracy, precision, and sensitivity to atmospheric interferences of the GasFinder 2.0. The MDL was calculated for each target gas by supplying pure nitrogen to the test cell in the optical path of the monitor and taking a series of 25 measurements using an integration time of either 1 or 5 minutes. Source strength linearity was investigated by measuring the effect of reducing the intensity of the light source on the monitor's performance. Concentration linearity was investigated by challenging the monitor with each target gas at concentrations ranging between 25 and 500 ppm. Accuracy and precision of the monitor relative to the gas standards were verified by introducing known concentrations of the target gas into the cell. The effects of atmospheric interfering gases were established by supplying the gas cell with a target gas and varying the distance (path length) between the source and detector.

Quality assurance (QA) oversight of verification testing was provided by Battelle and EPA. Battelle QA staff conducted a technical systems audit and a data quality audit of 10% of the test data. Battelle testing staff conducted a performance evaluation audit, which was reviewed by QA staff. EPA QA staff conducted an independent on-site technical system audit.

TECHNOLOGY DESCRIPTION

The GasFinder 2.0 measures gas concentration over an open path and consists of an integrated transmitter/receiver unit and a remote, passive retroreflector array. The remote retroreflector is initially targeted by the operator using a two-axis monitor mount, assisted by a telescopic sight and an on-board visible aiming laser. The transceiver houses the laser diode source, drive electronics, detector module, and microcomputer subsystems. The transceiver unit is in a weatherproof enclosure and has connectors for power input and data input/output. The laser light emitted from the transceiver unit propagates through the atmosphere to the retroreflector and returns, where it is focused onto a photodiode detector. Simultaneously, a portion of the laser beam is passed through an onboard gas cell to provide a continuous calibration update. These two optical signals are converted into electrical waveforms, which the microcontroller processes to determine the actual concentration of the target gas along the optical path. The computed gas concentration is then displayed on the back panel of the monitor, as well as transmitted to a central coordinating computer where the data are collected, stored, and displayed. By selecting the appropriate diode laser, the monitor can measure the concentration of methane, ammonia, carbon dioxide, hydrogen sulphide, or hydrogen fluoride in the presence of other gases. Atmospheric gases, such as water vapor, have a negligible effect on the laser system. The self-contained, automatic, self-calibrating monitor can be used as a portable tool, or it can be permanently installed with a path length up to 1,000 meters. It displays average gas concentrations either in parts per million (ppm) or, for low gas concentrations, in parts per million meters (ppm*m). The GasFinder 2.0 weighs 5 kg and measures 26 x 20 x 15 cm (LxWxH) (10.2 x 7.9 x 5.9 inches). It uses 12Vdc power and operates in the range of -30° C to +50° C.

VERIFICATION OF PERFORMANCE

Minimum Detection Limit: The GasFinder 2.0 detection limits were 0.29 to 0.56 ppm*m for methane. Because the original data were not appropriate for MDL measurements, HF and ammonia were calculated using the

alternate approach described in Section 6.1. This approach resulted in a detection limit of 0.09 ppm*m for HF and 5.32 ppm*m for ammonia at a path length of 220 meters and a 1-minute integration time.

Source Strength Linearity: There was little to no degradation of the monitor's performance with a decrease in source strength of up to 55%. The GasFinder 2.0 showed a maximum deviation from the known NH_3 concentration in the gas cell of about 1.3 ppm at 25 ppm NH_3, and 7.5 ppm at 100 ppm NH_3.

Concentration Linearity: The concentration linearity results showed that the GasFinder 2.0 had a response slope of 0.95 and an r^2 value of 0.99 for methane; a slope of 1.29 and an r^2 of 0.99 for HF; and a slope of 1.08 and an r^2 of 0.99 for ammonia.

Accuracy: The accuracy of the GasFinder 2.0 ranged from 5.2 to 11% for methane at a 220-meter path length, and at a 480-meter path, the accuracy was 34%. For HF, accuracy was 18 to 77% at path lengths of 220 and 480 meters. With a cell concentration of 25 ppm, accuracy was 18%. In all cases, HF results from the GasFinder 2.0 were higher than those determined by impinger samples. Losses on the gas cell wall (as great as 42% in one case) contribute significantly to the bias observed. For ammonia, accuracy was 1.3 to 9.8% at a 220-meter path length. With a 480-meter path length, accuracy was 18 and 37%.

Precision: Using a path length of 220 meters and cell concentrations of methane, HF, and ammonia of 500, 320, and 475 ppm, respectively, the GasFinder 2.0 exhibited precision in repetitive measurements of 1.24% RSD for methane, 1.75% RSD for HF, and 3.14% RSD for ammonia.

Interferences: Analysis of the effects of ambient water vapor and carbon dioxide showed no consistent effect of these species on the accuracy of measurement of the target gases, or on the MDLs for those gases.

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