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:	**LasIR® 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 UNISEARCH LasIR TDL Open-Path Monitor.

VERIFICATION TEST DESCRIPTION

The verification test described in this report was designed to challenge the LasIR 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 (ammonia, HF, or methane) 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 May 22 and 26, 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 LasIR. 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 effects of reducing the source intensity on the monitor's performance. Concentration linearity was investigated by challenging the monitor with each target gas at test cell concentrations ranging between 40 and 800 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 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 LasIR uses a TDL to measure concentrations of HF, HCl, CH_4, H_2, CO, CO_2 , NH_3, C_2H_2, C_2H_4, NO, and NO_2. The LasIR controller houses the laser, its temperature and current control circuits, a reference cell used to lock the absorption feature to line center, an audit cell into which a known concentration of the gas being measured may be introduced for calibration purposes, and a computer to operate the system and process and store the measurement data. The controller can be placed indoors or outdoors and is connected by a fiber optic cable to the measurement sensors, which can be located kilometers away. A number of sensors can be operated from the controller simultaneously. The response of the system for most gases is in the range of a few parts per million per meter.The light from the laser, which is mounted, with its focusing optics, in a thermoelectric cooler, is transferred by a fiber optic cable to a telescope, through the open path, onto a retroreflector, and back to the telescope. About 10% of the light is split off before entering the telescope and directed through a small internal cell containing the gas being measured and then to the reference detector. This reference signal is used to lock the laser to the selected absorption feature and may also act as a transfer calibration standard.

VERIFICATION OF PERFORMANCE

Minimum Detection Limit: The LasIR exhibited detection limits of 0.09 and 1.21 ppm*m for methane, 0.13 to 0.23 ppm*m for HF, and 1.05 to 13.7 ppm*m for ammonia. In these field tests, there was no strong trend in detection limits with either path length or integration time for the target gases.

Source Strength Linearity: The tests of the LasIR to determine the effects of source strength showed that there was no consistent degradation of the monitor's performance with a decrease in source strength of up to 72%. The LasIR showed a maximum deviation of 0.019 ppm at a path-average concentration of 0.454 ppm over 220 meters, over this range of reduction in source strength.

Concentration Linearity: The concentration linearity results showed that the LasIR had a response slope of 1.00 and an r^2 value of 1.00 for methane over a gas cell concentration range of 40 to 800 ppm; a response slope of 0.71 and an r^2 value of 0.96 for HF over a gas cell concentration of 66 to 549 ppm; and a slope of 1.17 and an r^2 value of 0.99 for ammonia over a gas cell concentration of 75 to 494 ppm.

Accuracy: The percent relative accuracy for methane ranged between 0.02 and 12.2% at a 1.5-meter path length used to minimize the effect of atmospheric methane. The HF percent relative accuracy ranged between 5.1 and 28.7%, at a path length of 220 meters. The percent relative accuracy for ammonia ranged between 3.66 and 19.7% at the 220-meter path length, and between 6.54 and 13.7% at a path length of 480 meters. These results are subject to uncertainties in the delivery and determination of the target gases. In particular, it should be noted that the HF concentration was determined by impinger sampling downstream of the optical cell, and thus is subject to significant uncertainty.

Precision: Using a path length of 220 meters for HF and ammonia and 1.5 meters for methane, the LasIR exhibited precision in repetitive measurements of 0.63% RSD for methane, 1.19% RSD for HF, and 1.84% RSD for ammonia at target gas cell concentrations of 800, 549, and 494 ppm, respectively.

Interferences: Analysis of the effects of ambient water vapor and carbon dioxide on the LasIR's measurements showed no consistent effect of these species on the accuracy of measurement for methane and HF. The MDL for HF was reduced slightly with increased levels of H_2O and CO_2 in the light path.

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