THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

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ETV Joint Verification Statement

TECHNOLOGY TYPE:	**FOURIER TRANSFORM INFRARED (FTIR) OPEN-PATH MONITOR**
APPLICATION:	**MONITORING AIR QUALITY**
TECHNOLOGY NAME:	**Model RAM 2000 FTIR Open-Path Monitor**
COMPANY:	**AIL Systems, Inc.**
ADDRESS:	**455 Commack Road Deer Park, NY 11729** — **PHONE: 770-781-8901**
WEB SITE:	**http://www.ail.com**
E-MAIL:	**r.kagann@worldnet.att.net**

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 AIL RAM 2000 FTIR Optical Open Path Monitor.

VERIFICATION TEST DESCRIPTION

The verification test described in this report was designed to challenge the RAM 2000 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 (ethylene, cyclohexane, or tetrachloroethylene) was inserted into the optical path of the monitor, simulating a condition where the target gas would be present in the ambient air. Optical path lengths of 2, 200, and 910 meters were used in these tests. The monitor was challenged with the 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 March 13 and 17, 2000, at the AIL outdoor test site at Deer Park on Long Island, New York.

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 RAM 2000. The MDL was calculated for each target gas supplying pure nitrogen to the test cell in the optical path of the monitor and taking a series of 26 single-beam spectra using an integration time of either 1 or 5 minutes. The single-beam spectra were then used to create absorption spectra, using each single-beam spectrum as the background for the next spectrum. The resulting 25 absorption spectra were then analyzed for the target gas. Source strength linearity was investigated by challenging the monitor with ethylene concentrations of 5 ppm*m and 25 ppm*m at a path length of 200 meters, while reducing the intensity of the light source. Concentration linearity was investigated by challenging the monitor with each target gas at concentrations ranging between 5 ppm*m and 50 ppm*m. 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. 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 also conducted an independent technical systems audit of the verification procedures.

TECHNOLOGY DESCRIPTION

The RAM 2000 detects and identifies the presence of more than 250 chemical species in the local atmosphere. It automatically determines the concentration and significance of each chemical detected and provides real-time results. The RAM 2000's active open-path FTIR technology uses light from a silicon carbide glower within the monitor to project a modulated infrared light beam to a retroreflector. The retroreflector directs the modulated beam back to a mercury cadmium telluride detector within the monitor. The projected infrared beam is modulated by a Michelson interferometer, which allows the detection electronics to be ac coupled and insensitive to dc contributions from any stray background source of infrared light. The return signal is analyzed for absorbed frequencies that act as fingerprints for any chemical species present.

VERIFICATION OF PERFORMANCE

Minimum Detection Limit: The RAM 2000 detection limits for the three gases tested ranged between 0.19 and 0.32 ppm*m for ethylene, between 0.04 and 0.19 ppm*m for cyclohexane, and between 0.08 and 0.19 ppm*m for tetrachloroethylene. There was no consistent trend of detection limits with either path length or integration time.

Source Strength Linearity: There was no significant degradation of monitor performance with reductions in source strength of up to 54%. The monitor showed a maximum difference from the actual gas concentration of 1 ppm*m at concentrations of both 5 ppm*m and 25 ppm*m.

Concentration Linearity: The RAM 2000 had a regression slope of 0.99 and an r^2 value of 0.99 for ethylene; a slope of 0.94 and an r^2 value of 0.99 for cyclohexane; and a slope of 1.08 and an r^2 value of 0.99 for tetrachloroethylene; each over a range of 5 to 50 ppm*m.

Accuracy: The relative accuracy of the RAM 2000 was 1.6, 7.0, and 4.9% for 50 ppm*m of ethylene, cyclohexane, and tetrachloroethylene respectively. At lower concentrations of 5 to 25 ppm*m, the relative accuracy of the RAM 2000 ranged from 0.2 to 7.0% for ethylene. Non-equilibrium conditions probably caused the measured relative accuracies at lower concentrations of cyclohexane and tetrachloroethylene to reach 20.8 and 29% respectively. The monitor performed equally well at 1- and 5-minute integration times and at 200 and 910-meter path lengths.

Precision: At a concentration of 50 ppm*m, a path length of 200 meters, and a 1-minute integration time, ethylene data had an RSD of 0.53%, cyclohexane data had an RSD of 0.51%, and tetrachloroethylene data had an RSD of 0.66%.

Interferences: Analysis of the effects of the interferences of water and carbon dioxide showed that neither the accuracy nor the MDL were affected consistently by the changing concentrations of water and carbon dioxide in the light path.

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