THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

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ETV Joint Verification Statement

TECHNOLOGY TYPE:	**PORTABLE EMISSION ANALYZER**		
APPLICATION:	**DETERMINING COMBUSTION EMISSIONS**		
TECHNOLOGY NAME:	**Model 350 Portable Multigas Emission Analyzer**		
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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 (consisting of buyers, vendor organizations, and permitters), and with 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 (QA) 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 areas under ETV, is operated by Battelle in cooperation with EPA's National Exposure Research Laboratory. The AMS Center has recently evaluated the performance of portable multigas monitors used to determine emissions from combustion sources. This verification statement provides a summary of the test results for the Testo Model 350 portable multigas emission analyzer.

VERIFICATION TEST DESCRIPTION

The verification test was conducted at the Bourns College of Engineering Center for Environmental Research and Technology at the University of California-Riverside. Emissions were sampled from a commercial gas-fired cooktop and a small diesel-fueled engine driving an electrical generator. The reference method for NO, NO_2, and NO_x determination was the chemiluminescence method that forms the basis of EPA Method 7E. Measurements were made using a Thermo Environmental Instruments Model 10 source-level NO_x monitor. The reference method for O_2 determination was an instrumental, paramagnetic pressure sensor method that is consistent with EPA Method 3A. The measurements were made using a Horiba Model CMA-331A Gas Emission Analyzer System. The reference method for CO determination was the cross-modulation non-dispersive infrared method that forms the basis of California Air Resources Board Method 10. The measurements were made using a Horiba Model CMA-331A Gas Emission Analyzer System. The reference method for SO_2 determination was the ultraviolet fluorescence method that forms the basis of EPA Method 6C. The measurements were made using an API Model 100AH analyzer. All reference method analyzers were located near the combustion sources and were configured to sample from a common intake line, downstream of a sample conditioning system.

Four Model 350s were tested in this verification. Two analyzers were configured to measure O_2, CO, NO, and NO_2 with low range sensors for CO and NO. Two analyzers were configured to measure O_2, CO, SO_2, NO, and NO_2 with high range sensors for CO and NO. The low range analyzers did not have SO_2 sensors, and the O_2 and NO_2 sensors in all four analyzers were the same. Initial tests were performed in the laboratory with prepared gas mixtures, then combustion source tests were conducted. Five test days were devoted to laboratory testing and three to source emission testing. Laboratory tests included the linearity of response of each Model 350 analyzer over a range of gas concentrations for each of the analyte gases. The response time of the analyzers was established by monitoring the rise and fall of the Model 350 responses during the linearity tests. Data from zero gas and from additional low gas concentrations were used to establish the detection limits for each Model 350 measurement. Interrupted sampling was assessed after the zero and span checks at the end of the linearity tests, when the electrical power to each Model 350 was turned off for a period of at least 12 hours. The Model 350 analyzers were then powered up, the same zero gas and span concentrations were introduced, and the analyzers' responses were recorded. The effect of potential interferences was tested by delivering test gases containing potential interferants at known concentrations to the Model 350s and monitoring their responses. The ambient temperature test quantified the zero and span drift that occurred as the analyzers were subjected to different temperatures during operation. The pressure sensitivity test quantified the variation in analyzer response and sample flow with changes in pressure in the sample gas source. Combustion source tests included tests for accuracy relative to reference method results, zero and span drift, and measurement stability.

QA oversight of verification testing was provided by Battelle. Battelle QA staff conducted a technical systems audit, a performance evaluation audit, and a data quality audit of 10% of the test data.

TECHNOLOGY DESCRIPTION

The following description of the Model 350 analyzer was provided by the vendor, and does not represent verified information.

The Model 350 is a self-contained emission analyzer system capable of measuring O_2, CO, NO, NO_2, SO_2, H_2S, and hydrocarbons in combustion emission sources, while capturing data on pressure, temperature, and flow. Low NO_x and low CO resolutions are 0.1 part per million (ppm) throughout the range. The Model 350 uses electro-chemical sensors that are temperature-controlled to operate over an ambient temperature range of 20ºF to 115ºF and can be calibrated, exchanged, and upgraded in the field without hand tools. An optional CO dilution system permits sample range expansion to over 40:1. The Model 350 weighs less than nine pounds and has an automatic sample conditioning system that includes a Peltier cooler, moisture removal pump, and patented non-heated sample line to provide representative samples from engines, turbines, boilers, burners, and other combustion sources.

The entire system operates independently on nickel metal hydride batteries, or can be connected to AC power (90 to 260 volts, 50 to 60 Hertz). A handheld control unit can operate the analyzer "docked" in the base unit or hundreds to thousands of feet from the base unit. The control unit provides the user with a simple interface and communications. Pulldown menu selections, user-defined function buttons, and/or a computer interface provide access to all operations of the system. Automatic programs for unattended operation facilitate remote, event-driven, and/or long-term (weeks) testing. An onboard printer provides documentation of test results, while internal data logging of up to 256,000 data points can be programmed. Data retrieval options include an onboard menu system and a computer download procedure; data sets can be stored in files and converted to standard spreadsheets and charts. Internal calculations are performed automatically. The unit provides onscreen information such as O_2 reference corrections (freely selectable), CO_2, combustion efficiency, excess air, flow, mass-emissions (pounds per hour, etc.), and flue gas loss. The system can be expanded to provide additional measurements for moisture, velocity, temperatures, 4- to 20-milliampere signals, and a variety of other inputs, including simultaneous multibox monitoring.

VERIFICATION OF PERFORMANCE

Linearity: The Model 350 analyzers provided a linear response for all the target gases over their full measurement ranges.

Response time: Response times ranged from 10 to 20 seconds for NO and 30 to 32 seconds for CO, but were consistently 18 seconds for NO_2, 20 seconds for O_2, and 27 seconds for SO_2.

Detection limit: Detection limits estimated from the laboratory testing for the high range analyzers (based on the upper end of the 3-sigma, 95% confidence level) were 1.22 ppm for CO, 1.57 to 1.66 ppm for NO, 0.26 to 0.41 ppm for NO_2, and 1.24 ppm for SO_2. Detection limits estimated from the laboratory testing for the low range analyzers were 0.25 ppm for CO and 0.25 to 0.45 ppm for NO. (No detection limit was calculated for O_2, since the Model 350 analyzers always read 0.0% when sampling nitrogen zero gas.)

Interference: A variety of selected interferants generally produced no response on the Model 350 analyzers, and no interferant produced a response as much as 1% of that from an equal concentration of target analyte. Responses to 394 ppm NO were 2.3 to 4.8% low when 400 ppm SO_2 also was present.

Ambient temperature effect: Ambient temperature over the range of 47ºF to 105ºF had a minimal (< 2% of span concentration) effect on the zero and span readings of the Model 350 analyzers.

Interrupted sampling: Zero and span differences caused by interruption of operation were less than 1.0% of the respective span concentrations.

Pressure sensitivity: Over the tested range of –10 to +10 inches of water (relative to ambient pressure), the sample gas pressure had no significant effect on the zero or span readings of the Model 350 analyzers.

Accuracy: The relative accuracy (RA) of the Model 350 analyzers was usually within 10% for CO, NO, NO_x, and SO_2, and within 1% for O_2, with the sources tested (two range burner sources, three diesel engine sources). The only exceptions were those conditions where CO and NO_2 concentrations were below 6 ppm, and in NO_2 measurements from the diesel engine exhaust when NO_2 was less than 7% of total NO_x. For the low concentration conditions, the CO and NO_2 analyzers were accurate to within about 1 ppm. For the NO_2 measurements from the diesel engine exhaust, RAs ranged from 8% to 55%, and the direct measurement of NO_2 by the Model 350 analyzers produced more consistent readings than did the determination of NO_2 by difference with the chemi-luminescent reference method. Total NO_x RAs for the diesel engine tests were all within 7%.

Zero/span drift: Zero/span drift ranged between –1.68% and 3.36% of the span concentration, considering zero and span data from all the tests.

Measurement stability: The significant measurement stability trends, over an hour of continuous sampling of diesel exhaust, were as follows: Both high range Model 350 analyzers showed a statistically significant decrease in SO_2 concentrations over time compared with the reference analyzer. The average downward trend of 1.3 ppm/hr represented a decrease of 6% of the mean measured concentration over one hour of sampling. An upward trend of 3 ppm/hr in the NO_x measurement in one of the units represented an increase of 3% of the mean measured concentration over one hour of sampling. Both Model 350 low range analyzers showed a statistically significant increase in NO_x concentrations over time compared with the reference analyzer. For NO_x, the average upward trend of 2.34 ppm/hr represented an increase of 2% of the mean measured concentration over one hour of sampling.

Inter-Unit repeatability: During the verification tests, duplicate Model 350 analyzers showed close unit-to-unit agreement, i.e., within 1% for almost all cases.

Other factors: The Model 350 is rugged and readily portable, and setup time was minimal. The rapid sensor response times and measurement stability allowed verification testing to proceed smoothly. The Model 350 design incorporates a sample probe and sample conditioning system, making it adaptable to a wide range of measurement applications. The cost of a Model 350 analyzer system, as tested, is $8,000.

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