THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**AMBIENT AMMONIA MONITOR**
APPLICATION:	**MEASURING AMMONIA EMISSIONS AT ANIMAL FEEDING OPERATIONS**
TECHNOLOGY NAME:	**Nitrolux™ 1000 Ammonia Analyzer**
COMPANY:	**Pranalytica, Inc.**
ADDRESS:	**1101 Colorado Avenue Santa Monica, California 90401** **PHONE:310-458-3345 FAX: 310-458-0171**
WEB SITE:	**www.pranalytica.com/**
E-MAIL:	**webber@pranalytica.com**

The U.S. Environmental Protection Agency (EPA) supports 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 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. Information and ETV documents are available at www.epa.gov/etv.

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 seven technology areas under ETV, is operated by Battelle in cooperation with EPA's National Exposure Research Laboratory. In collaboration with the U.S. Department of Agriculture, the AMS Center has recently evaluated the performance of ambient ammonia (NH_3) monitors to measure NH_3 emissions. This verification statement provides a summary of the test results for the Pranalytica Nitrolux 1000 NH_3 analyzer.

VERIFICATION TEST DESCRIPTION

The objective of this verification test was to evaluate the Nitrolux 1000's performance in measuring gaseous NH_3 in ambient air at two animal feeding operations. The verification test was conducted in two phases, each at separate animal feeding operations. The first phase of testing was conducted between September 8 and October 3, 2003, at a swine finishing farm near Ames, Iowa. The second phase was conducted between October 20 and November 14, 2003, at a cattle feedlot in Carroll, Iowa. These sites were selected to provide realistic testing conditions and were expected to exhibit a wide range of NH_3 concentrations during the test periods. The verification test was designed to evaluate relative accuracy (RA), linearity, precision, response time, calibration and zero drift, interference effects, comparability, ease of use, and data completeness.

During Weeks 1 and 4 of each phase of the verification test, the Nitrolux 1000 response to a series of NH_3 gas standards of known concentration was used to quantify RA, linearity, precision, and calibration/zero drift. Ammonia gas standards ranging from 0 to 10,000 parts per billion (ppb) NH_3 and 0 to 2,000 ppb NH_3 were delivered during Phases I and II, respectively. The Nitrolux 1000 response time, the time to reach 95% of the change in the stable signal, was also assessed during the delivery of the gas standards. During the second phase, interference effects were quantified from the Nitrolux 1000 response to various chemical species that may be present at animal feeding operations; the potential interferent gases were delivered both in the presence and absence of NH_3. The Nitrolux 1000 continuous response to ambient air also was evaluated during both phases as the comparability to simultaneous determinations by a time-integrated ambient NH_3 reference method (acid-coated denuders). Comparisons were made with reference samples that were collected on a five-per-day schedule for periods of between 2 to 12 hours for approximately 10 days during each phase, based on procedures in EPA Method IO-4.2.

QA oversight of verification testing was provided by Battelle and EPA. Battelle QA staff conducted a technical systems audit, a performance evaluation audit, and a data quality audit of 10% of the test data. This verification statement, the full report on which it is based, and the test/QA plan for this verification test are all available at www.epa.gov/etv/centers/center1.html.

TECHNOLOGY DESCRIPTION

The following description of the Nitrolux 1000 was provided by the vendor and does not represent verified information.

The Nitrolux 1000 is an ambient NH_3 analyzer that uses resonant photoacoustic spectroscopy and a line-tunable carbon dioxide (CO_2) laser to provide continuous or on-demand measurements. A CO_2 laser is useful to excite NH_3 because one of its laser lines is nearly coincident with one of NH_3's strongest spectral features. The excited NH_3 molecules undergo collisional deactivation, which converts the absorbed energy into periodic local heating at the modulation frequency of the laser. The resulting acoustic waves are detected with a low-noise microphone to quantify NH_3 with minimal interferences from carbon monoxide, hydrogen sulfide, methane, sulfur oxides, nitrogen oxides, ozone, and other contributors at their typical concentrations in a non-polluted atmosphere.

The Nitrolux 1000 is sensitive to NH_3 concentrations of 1 ppb and has a range of 0 to 2,000 ppb with full-scale ranges of 20 to 2,000 ppb by automatic or manual switching. The Nitrolux 1000 consists of a sealed-off radiofrequency-excited $^{13}CO_2$ laser, whose operating wavelength can be line-switched by using an intracavity grating, a flow-through analysis cell, a laser power meter, a signal processor, and a single-board computer for controlling all internal operations and analyzing the signals to produce concentration readings in real time. Optional analysis cells allow for simultaneous measurement of two to 16 input streams. Samples are extracted in a continuous mode at approximately 400 to 500 standard cubic centimeters (cm) per minute and pass through a 40-micrometer in-line filter to remove particulate matter. Time-stamped NH_3 concentration measurements are stored on an internal hard disk.

Power requirements of the Nitrolux 1000 are 150 Watts at 110 volts, 60 Hertz alternating current. It comes with a rack-mountable foldout 15-inch flat-panel display, including keyboard and mouse. The rack mount is 40.3 cm (19 inches) wide, 61.0 cm (24 inches) deep, and 25.4 cm (10 inches) high. It weighs 29.5 kilograms (65 pounds). The approximate cost of the Nitrolux 1000 with rack mount display is $24,000. Additional particulate filters cost $250 each, and mounting rails for installation are $150 per pair.

VERIFICATION OF PERFORMANCE

The performance of the Nitrolux 1000 was evaluated in two phases in this verification test. During both phases of the verification test, the Nitrolux 1000 was installed inside a temperature-regulated instrument trailer, with a Teflon tube used to draw the outside air into the Nitrolux 1000 inlet. The following presents a summary of the performance of the Nitrolux 1000 during this verification test. The values presented in this table are based on discrete measurements taken every 60 seconds and recorded by the Nitrolux 1000. Values in parentheses are 95% confidence intervals.

Performance Summary of the Nitrolux 1000

Parameter	Results					
	Phase I			Phase II		
		Week 1	Week 4		Week 1	Week 4
Relative accuracy[a][b]	Average RA %D[c] range	27% 20 to 34%	10% −21 to -7%	Average RA %D range	44% −48 to −41%	40% −54 to −28%
Linearity[a]	Range Slope Intercept r^2	0 to 5,000 ppb 1.25 (±0.02) 13.2 ppb (±34.1) 0.9997	0 to 10,000 ppb 0.798 (±0.071)[d] 167 ppb (±310) 0.9940	Range Slope Intercept r^2	0 to 2,000 ppb 0.586 (±0.022) −12.2 ppb (±24.9) 0.9993	0 to 2,000 ppb 0.716 (±0.121) −58.5 ppb (±137) 0.9854
Precision[a]	Average RSD[e] Range	0.2% 0.1 to 0.5%	0.6% 0.2 to 1.3%	Average RSD Range	1.0% 0.3 to 2.3%	1.3% 1.2 to 1.5%
Response time	Rise time = 54 to 1,893 seconds Fall time = 54 to 214 seconds			Rise time = 108 to 1,808 seconds Fall time = 108 to 231 seconds		
Calibration/ zero drift	▪ No apparent drift in response to zero air during Week 1 or Week 4. ▪ Apparent drift of approximately 44% in response to 1,000 ppb NH_3 observed during Week 1. No apparent drift observed during Week 4.			▪ No apparent drift in response to zero air during Week 1 or Week 4. ▪ Apparent drift of approximately 13% in response to 1,000 ppb NH_3 between Week 1 and Week 4.		
Interference effects[f]	Interference check conducted during Phase II.			Hydrogen sulfide (285 ppb): no apparent effect Nitrogen dioxide (95 ppb): no apparent effect 1,3-Butadiene (95 ppb): no apparent effect Diethylamine (96 ppb): ~19% response in zero air, no apparent effect in 500 ppb NH_3[g]		
Comparability		Raw Data[a]	Corrected Data[h]		Raw Data[a]	Corrected Data[h]
	Slope Intercept r^2	1.83 (±0.07) 4.77 (±34.01) 0.9842	1.46 (±0.06) -6.7 (±27.2) 0.9842	Slope Intercept r^2	0.646 (±0.03) 0.43 (±4.1) 0.9794	1.10 (±0.06) 21.6 (±7.0) 0.9794
Ease of use	▪ Daily checks were simple and quick ▪ Little skill required to operate ▪ No maintenance required ▪ User-friendly software					
Data completeness	99%			99%		

(a) Results are based on Nitrolux 1000 factory calibration, since on-site calibration was not performed. On-site calibration is generally included in Nitrolux 1000 installation procedures, but an independent NH_3 standard was not available during the verification test.
(b) Relative accuracy is expressed as an average absolute value of the percent difference from NH_3 gas standards.
(c) %D = Percent difference.
(d) Including only data from 0 to 5,000 ppb, the slope was 0.924 (±0.006), with an intercept of -12.8 (±34.4), and an r^2 of 0.9998. The linear range for the Nitrolux 1000 is reported to be 0 to 2,000 ppb by the manufacturer.
(e) RSD = Relative standard deviation.
(f) Calculated as the change in signal divided by the interferent gas concentration, expressed as a percentage.
(g) The presence of an NH_3 impurity in the diethylamine gas standard or the release of NH_3 from the sample lines during delivery could not be ruled out.
(h) Results of Week 1 linearity check were used to apply a calibration correction to the Nitrolux 1000 ambient data.

Original signed by Gabor J. Kovacs 7/16/04
Gabor J. Kovacs Date
Vice President
Energy and Environment Division
Battelle

Original signed by Gary J. Foley 9/13/04
Gary J. Foley Date
Director
National Exposure Research Laboratory
Office of Research and Development
U.S.Environmental Protection Agency

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