THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**MULTI-PARAMETER WATER MONITORS FOR DISTRIBUTION SYSTEMS**		
APPLICATION:	**MONITORING DRINKING WATER QUALITY**		
TECHNOLOGY NAME:	**Sentinal™ 500 Series**		
COMPANY:	**Clarion Sensing Systems, Inc.**		
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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 six technology areas under ETV, is operated by Battelle in cooperation with EPA's National Exposure Research Laboratory. The AMS Center evaluated the performance of the Clarion Sensing Systems, Inc., Sentinal™ 500 Series in continuously measuring free chlorine, temperature, conductivity, pH, and oxidation-reduction potential (ORP) in drinking water. This verification statement provides a summary of the test results.

VERIFICATION TEST DESCRIPTION

The performance of the Sentinal™ 500 was assessed in terms of its accuracy, response to injected contaminants, inter-unit reproducibility, ease of use, and data acquisition. The verification test was conducted between August 9 and October 28, 2004, and consisted of three stages, each designed to evaluate a particular performance characteristic of the Sentinal™ 500. All three stages of the test were conducted using a recirculating pipe loop at the U.S. EPA's Test and Evaluation (T&E) Facility in Cincinnati, Ohio.

In the first stage of this verification test, the accuracy of the measurements made by the Sentinal™ 500 units was evaluated during nine, 4-hour periods of stable water quality conditions by comparing each Sentinal™ 500 unit measurement to a grab sample result generated each hour using a standard laboratory reference method and then calculating the percent difference (%D). The second stage of the verification test involved evaluating the response of the Sentinal™ 500 units to changes in water quality parameters by injecting contaminants (nicotine, arsenic trioxide, and aldicarb) into the pipe loop. Two injections of three contaminants were made into the recirculating pipe loop containing finished Cincinnati drinking water. The response of each water quality parameter, whether it was an increase, decrease, or no change, was documented and is reported here. In the first phase of Stage 3 of the verification test, the performance of the Sentinal™ 500 units was evaluated during 52 days of continuous operation, throughout which references samples were collected once daily. The final phase of Stage 3 (which immediately followed the first phase of Stage 3 and lasted approximately one week) consisted of a two-step evaluation of the Sentinal™ 500 performance to determine whether this length of operation would negatively impact the results from the Sentinal™ 500. First, as during Stage 1, a reference grab sample was collected every hour during a 4-hour analysis period and analyzed using the standard reference methods. Again, this was done to define a formal time period of stable water quality conditions over which the accuracy of the Sentinal™ 500 could be evaluated. Second, to evaluate the response of the Sentinal™ 500 to contaminant injection after the extended deployment, the duplicate injection of aldicarb, which was also included in the Stage 2 testing, was repeated. In addition, a pure *E. coli* culture, including the *E. coli* and the growth medium, was included as a second injected contaminant during Stage 3. Inter-unit reproducibility was assessed by comparing the results of two identical units operating simultaneously. Ease of use was documented by technicians who operated and maintained the units, as well as the Battelle Verification Test Coordinator.

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 Sentinal™ 500 unit was provided by the vendor and does not represent verified information.

The Sentinal™ 500 is designed to remotely monitor and report drinking water quality. The Sentinal™ 500 uses a sensor array to acquire information about drinking water quality on site in near-real time by analyzing the water quality and comparing it to its normal baseline values and notifies utility/security personnel if water quality changes significantly from its baseline. The Sentinal™ 500 used in this verification test measured free chlorine, temperature, conductivity, pH, and ORP in drinking water. The sensors measured these parameters by potentiometric, amperometric, and conductance methods.

The Sentinal™ 500 consists of sensors and their respective meters with digital displays; a data acquisition, analysis, and management microprocessor; a communications link such as radio, cellular networks, satellite networks, wireless Ethernet or LANs (as configured during this test), and a receiving station where the data are presented and alarms are distributed. The systems can serve up their own Web pages to the network, and other monitoring sites can be accessed through each site. The system could be configured to actuate valves and pumps to shut off or divert water for on-site treatment.

For this verification test, the continuous data were stored on the on-board computer and downloaded daily by plugging an Ethernet cable into a laptop and entering an IP address into Microsoft Explorer. A Web page was called up, and the data could be easily downloaded as an Excel spreadsheet. System software (the Sentinal™ Data Acquisition and Management Device) could be configured to average all of the data over time to determine site-specific normal baselines. The software also can be programmed to recognize when deviations (threshold set by the user) from the baseline occur and either triggers “alerts” or “alarms,” depending on the degree of deviation. All aspects of the data acquisition could be configured for remote observation and data collection.

The Sentinal™ 500 is 30 inches by 36 inches and weighs about 30 pounds. Prices for Sentinal™ systems range from $12,600 to $24,500. The cost of the system as configured for the verification test is $17,000. Other costs include $800 annually for replacement chlorine sensor gel caps and electrolyte gel and a one-time purchase of a calibration kit for $540.

VERIFICATION OF PERFORMANCE

Evaluation Parameter			Free Chlorine	Temperature	Conductivity	pH	ORP
Stage 1—Accuracy	Units 1 and 2, range of %D (median)		3.4 to 117.1 (26.2)	-18.4 to 2.7 (-3.7)	-26.8 to -22.4 (-24.6)	-6.1 to 0.5 (-1.9)	[a]
Stage 2—Response to Injected Contaminants	Nicotine	Reference	–	NC	NC	NC	–
		Sentinal™ 500	–	NC	NC	NC	–
	Arsenic trioxide	Reference	–	NC	+	+	–
		Sentinal™ 500	–	NC	+	+	–
	Aldicarb	Reference	–	NC	NC	NC	–
		Sentinal™ 500	–	NC	NC	NC	–
Stage 3—Accuracy During Extended Deployment	Units 1 and 2, range of %D (median)		-54.8 to 50.0 (-21.5)	-7.8 to 2.7 (-2.7)	-0.8 to 5.5 (2.1)	-7.2 to 1.6 (0.3)	[a]
Stage 3—Accuracy After Extended Deployment	Unit 1, %D		-10.9	-0.5	2.5	0.0	[a]
	Unit 2, %D		-18.5	-3.1	0.3	1.2	[a]
Stage 3—Response to Injected Contaminants	*E. coli*	Reference	–	NC	+	–	–
		Sentinal™ 500	–	NC	+	–	–
	Aldicarb	Reference	–	NC	NC	–	–
		Sentinal™ 500	–	NC	NC	–	–
Injection Summary	For a reason that is not clear, aldicarb altered the pH, as measured by the reference method, during the Stage 3 injections, but not during the Stage 2 injections.						
Inter-unit Reproducibility (Unit 2 vs. Unit 1)	Slope (intercept)		0.86 (0.10)	0.98 (-0.04)	1.01 (-4.13)	1.05 (-0.3)	0.89 (72)
	r^2		0.87	1.00	0.98	0.95	0.98
	p-value		0.92	0.23	0.74	0.17	0.87
	All sensors generated results that were similar according to the results of the t-test. However, the slopes of the ORP and free chlorine sensor data plotted against one another suggest that the results from each unit were somewhat different from one another.						
Ease of Use and Data Acquisition	Based on the performance of the free chlorine sensors, they may have to be adjusted periodically to maintain the accuracy of the measurements. The memory module in Unit 1 had to be replaced and, twice, each unit had to be rebooted before data could be downloaded.						

[a] ORP was not included in the accuracy evaluation because of the lack of an appropriate reference method.
+/– = Parameter measurement increased/decreased upon injection.
NC = No obvious change was noted through a visual inspection of the data.

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