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:	**Water Distribution Monitoring Panel and Event Monitor™ Trigger System**	
COMPANY:	**Hach Company**	
ADDRESS:	**P.O. Box 389** **Loveland, Colorado 80538**	**PHONE: 800-227-4224** **FAX: 970-669-2932**
WEB SITE:	**www.hach.com**	
E-MAIL:	**dkroll@hach.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 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 Hach Company Water Distribution Monitoring Panel (WDMP), as well as the Hach Event Monitor™ Trigger System (EMTS), in continuously measuring total chlorine, turbidity, temperature, conductivity, pH, and total organic carbon (TOC) in drinking water. This verification statement provides a summary of the test results.

VERIFICATION TEST DESCRIPTION

The performance of the WDMP and EMTS units was assessed in terms of their accuracy, response to injected contaminants, inter-unit reproducibility, ease of use, and data acquisition. The verification test was conducted between August 9 and November 12, 2004, and consisted of four stages, each designed to evaluate a particular performance characteristic of the WDMP and EMTS units. The first three stages of the test were conducted using a recirculating pipe loop at the U.S. EPA's Test and Evaluation Facility in Cincinnati, Ohio. Stage 4 used a single-pass pipe at the same facility.

In the first stage of this verification test, the accuracy of the measurements made by the WDMP units was evaluated during eight, 4-hour periods of stable water quality conditions by comparing each WDMP 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 WDMP units to changes in water quality parameters caused 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. Grab samples were collected prior to the contaminant injections and at 3, 15, and 60 minutes after injection to confirm the response of each water quality parameter, whether it was an increase, decrease, or no change. In the first phase of Stage 3 of the verification test, the performance of the WDMP units was evaluated during 52 days of continuous operation, throughout which reference 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 WDMP to determine whether this length of operation would negatively affect results. 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 WDMP could be evaluated. Second, to evaluate the response of the WDMP 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. The fourth and final stage of the verification test involved testing whether the EMTS detected the injection of 13 contaminants (aldicarb, arsenic trioxide, colchicine, dichlorvos, dicamba, *E. coli* bacteria, glyphosate, lead nitrate, mercuric chloride, methanol, nicotine, potassium ferricyanide, and sodium fluoroacetate), as well as whether it correctly identified the contaminants. Because the Stage 4 results were qualitative, grab samples were not collected. Throughout the test, 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

This verification report provides results for the verification testing of the Hach WDMP, as well as the EMTS, which functions in concert with the WDMP. For the purposes of this report, the astroTOC online ultraviolet (UV) TOC analyzer was considered a part of the WDMP, even though the TOC analyzer is actually a stand-alone continuous monitor. Following is a description of the combined system, based on information provided by the vendor. The information provided below was not verified in this test.

The WDMP contains online monitors for free or total chlorine, pH, turbidity, electrolytic conductivity, temperature, sample pressure, and TOC. Chlorine residual is measured by a Hach CL17 chlorine analyzer. The CL17 collects a water sample every 2.5 minutes and uses the EPA-approved colorimetric diethyl-p-phenylene diamine method. The CL17 uses minimal reagents and a mixing system that operates with no moving parts, including a self-cleaning stir bar in the sample chamber. A differential pH electrode, which uses a pH buffer as a reference point, measures pH. Turbidity is measured using a Hach 1720D process turbidimeter. The sample flows continuously through a patented bubble removal system that vents entrained air from the sample, eliminating interference in low-level turbidity measurement. Incandescent light is directed from the sensor head assembly down into the turbidimeter body and is scattered by suspended particles in the sample. A sensor detects light scattered at 90 degrees from the incident beam, which is a measure of the turbidity in the water. Electrolytic conductivity is continuously measured by a two-electrode cell. Temperature is measured by the temperature-sensing element in the conductivity cell.

The astroTOC UV analyzer combines a chemical and UV oxidation technique in a low-temperature reactor to measure the TOC. A 4-20 mA analog signal carries the TOC information to the EMTS. The WDMP is fed by a single, 1/2-inch sample line. Free-flowing waste drains through a single outlet. A sample line runs from the WDMP to the astroTOC, which has a drain line from a single outlet.

The EMTS integrates the multiple sensor outputs from the WDMP and astroTOC. Once each minute, software applies an algorithm (patent pending) to the sensor measurements, calculating the site's water quality baseline. The EMTS alarms when the trigger signal exceeds a trigger threshold, indicating an "event." The EMTS may be equipped with an agent library containing profiles of various contaminants. The EMTS also contains a plant event library that has no entries when the system is first installed. If an event occurs and its signature cannot be matched to any signature in the agent library, the plant event library is searched for a match. If a match is found, the event is reported. If no match is found, the signature for the event is stored in case the event recurs. In addition to a trigger signal alarm, the EMTS can also alarm on high/low parameter excursions. It logs all input data, trigger signal values, and diagnostic data in a database that can be extracted to a memory stick. Operators can view and recall logged data for each parameter and the trigger signal using a touch-screen. The EMTS can also act as "slave" on an RS485 Modbus network to provide data whenever polled by a Modbus "master."

The combined system of the WDMP and the EMTS, designed for wall or rack mounting, is approximately 3.3 feet tall by 6.6 feet wide. The WDMP costs $12,800, the EMTS costs $8,450, and the online TOC analyzer costs $14,076 in the recommended configuration for a total cost of approximately $35,000 for the units tested. The monthly cost for consumables is approximately $260.

VERIFICATION OF PERFORMANCE

Evaluation Parameter			Total Chlorine	Turbidity	Tem-perature	Conductivity	pH	TOC
Stage 1—Accuracy	Units 1 and 2, range of %D (median)		-47.4 to 4.5 (-3.9)	-53.9 to -1.3 (-34.1)	-3.0 to 44.3 (-0.2)	-15.5 to 8.1 (2.2)	-6.6 to 3.1 (0.9)	-64.7 to 147.5 (-14.8)
Stage 2—Response to Injected Contaminants	Nicotine	Reference	–	[(a)]	NC	NC	NC	+
		WDMP	–	+	NC	NC	NC	+
	Arsenic trioxide	Reference	–	[(a)]	NC	+	+	NC
		WDMP	–	+	NC	+	+	NC
	Aldicarb	Reference	–	[(a)]	NC	NC	NC	+
		WDMP	–	+	NC	NC	NC	+
Stage 3—Accuracy During Extended Deployment	Units 1 and 2, range of %D (median)		-15.9 to 6.9 (-3.2)	-81.1 to 245.5 (-21.3)	-7.4 to 8.5 (-0.1)	-1.8 to 9.6 (4.8)	-2.7 to 0.5 (-0.9)	-47.3 to 103.0 (-6.9)
Stage 3—Accuracy After Extended Deployment	Unit 1, %D		-4.9	-5.9	-0.2	6.7	-2.2	-20.5
	Unit 2, %D		-4.9	-11.8	4.6	0.3	0.2	3.4
Stage 3—Response to Injected Contaminants	*E. coli*	Reference	–	+[(b)]	NC	+	–	+
		WDMP	–	+	NC	+	–	+
	Aldicarb	Reference	–	+[(b)]	NC	NC	–	+
		WDMP	–	+	NC	NC	–	+
Injection Summary	Total chlorine and TOC were dramatically affected by injections of nicotine, *E. coli,* and aldicarb; and turbidity, pH, and conductivity were affected by some or all of the injections, but not as consistently as total chlorine and TOC. Aldicarb altered the pH during Stage 3, but not Stage 2.							
Inter-unit Reproducibility (Unit 2 vs. Unit 1)	Slope (intercept)		0.98 (0.03)	0.97 (0.005)[(c)]	0.72 (7.68)	0.92 (4.19)	1.06 (-0.40)	0.97 (0.31)
	r^2		0.994	0.881[(c)]	0.758	0.961	0.919	0.991
	p-value		0.779	0.884[(c)]	5.5×10^{-6}	0.006	0.517	0.374
	With the exception of temperature and conductivity, both units generated similar results.							
Stage 4—Contaminant Identification	Each time a contaminant was injected, the EMTS detected a deviation in baseline conditions, causing a "trigger event." Eleven of 13 contaminants were correctly identified at some point during the injection time. Ferricyanide and lead nitrate were identified correctly 100% of the time. The rest of the injected contaminants were identified as a contaminant other than themselves at some point throughout the duration of the injection. Only nicotine and arsenic trioxide were never correctly identified.							
Ease of Use and Data Acquisition	Neither the WDMPs nor the EMTSs required daily operator attention. Hach Company staff adjusted the flows on the turbidity and total chlorine meters as needed to keep them at the required levels and rebooted the EMTS when it was not displaying data properly. The chlorine sensors and turbidimeters needed periodic cleaning, and the TOC analyzer was calibrated three times.							

[(a)] Relatively large uncertainty in the reference measurements made it difficult to detect a significant change.
[(b)] Magnitude of change different between duplicate injections.
[(c)] Outlier excluded.
+/– = Parameter measurement increased/decreased upon injection.
NC = No change in response to the contaminant injection.

Original signed by Gregory A. Mack 11/23/05
Gregory A. Mack Date
Assistant Division Manager
Energy, Transportation, and Environment Division
Battelle

Original signed by Andrew P. Avel 1/17/06
Andrew P. Avel Date
Acting Director
National Homeland Security Research Center
U.S. Environmental Protection Agency