THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

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ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ON-LINE TURBIDIMETER**
APPLICATION:	**MEASURING LOW TURBIDITY LEVELS**
TECHNOLOGY NAME:	**CUS 31-W On-Line Turbidimeter**
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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; 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) program, 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 on-line turbidimeters for use in water treatment facilities. This verification statement provides a summary of the test results for the Liquisys CUS 31-W on-line turbidimeter.

VERIFICATION TEST DESCRIPTION

The verification test described in this report was conducted by Battelle in the fall of 1999 on commercial on-line turbidimeters at the City of Columbus Water Division's Dublin Road Water Plant in Columbus, Ohio. The

verification test was conducted in two phases. An off-line phase challenged the turbidimeters with a series of prepared standards and other test solutions under controlled conditions, whereas an on-line phase assessed long-term performance under realistic conditions by monitoring a sample stream in a municipal water treatment plant. The on-line phase was intended to evaluate performance in continuous unattended monitoring over a low range of turbidity [i.e., 0.1 to 1 nephelometric turbidity unit (NTU)]. No attempt was made to determine the ultimate detection limits of the turbidimeters tested, which other studies have shown can be as low as 0.01 NTU.

In the off-line phase of testing, the linearity, accuracy, and precision of the Liquisys CUS 31-W turbidimeter were determined by comparing turbidity measurements on formazin solutions to reference measurements of the same solutions. By intentionally varying the water temperature, flow rate, and color of the sample solution, the effect of these parameters on the response of the Liquisys CUS 31-W turbidimeter was determined. In the on-line phase, a sample stream from a municipal water plant was continuously monitored by the Liquisys CUS 31-W turbidimeter for approximately four weeks. Results from this phase of testing were used to determine the accuracy in measuring real-world samples and the drift characteristics of the Liquisys CUS 31-W. Quality assurance (QA) oversight of verification testing was provided by independent Battelle QA staff, who conducted a technical systems audit, and a data audit on 10 percent of the test data.

The verification test relied upon two reference methods: ISO 7027, "Water Quality—Determination of Turbidity," and EPA Method 180.1, "Determination of Turbidity by Nephelometry." The Liquisys CUS 31-W turbidimeter is designed to conform to ISO 7027 requirements, and thus comparison of Liquisys CUS 31-W results to those from the ISO 7027 reference method was the primary means of verification. EPA Method 180.1 uses a different wavelength of light than the CUS 31-W (i.e., visible rather than infrared), and thus is not a directly equivalent method. However, EPA Method 180.1 is widely recognized in the U.S. by virtue of its status as one of the required methods for drinking water compliance measurements. Consequently, comparisons of the CUS 31-W results to Method 180.1 results were also made, and are presented as a secondary illustration of performance.

A cautionary note is in order regarding the verification test results. The Liquisys CUS 31-W turbidimeter was supplied for testing without a transformer to allow operation on 110V AC power. A commercial transformer was purchased instead for use in the verification testing. However, during the verification test, that transformer was found to cause substantial noise in the output signal of the Liquisys CUS 31-W (i.e., a periodic oscillation with a peak-to-peak amplitude of about 0.07 NTU and a period of about 2.5 minutes). Unfortunately, the proper transformer was not available until the verification tests were nearly completed, and it was not feasible to repeat the entire verification test. As a result, the Liquisys CUS 31-W operated throughout this verification test with a less-than-optimal power supply system. The exact impact of this occurrence on verification results is unclear, but it is reasonable to view the performance reported here as being a worst-case result for the Liquisys CUS 31-W.

TECHNOLOGY DESCRIPTION

The basic Liquisys CUS 31-W on-line turbidimeter, manufactured by Endress + Hauser, has a four-wire transmitter that provides measuring and alarm signaling functions in water/waste water applications. The sensor and transmitter are separate devices. The transmitter can be equipped with additional software and hardware modules for specific applications. The Liquisys CUS 31-W sensor uses the 90-degree scattered light method in the near-infrared range to measure turbidity. The sensor wiper has an adjustable cycle time from 1 to 999 seconds, and an adjustable interval time from 1 to 7,200 minutes, as well as an OFF state. The nominal operating temperature range is -5 to +50°C. In addition to turbidity, a temperature measurement signal is detected and transmitted. The Liquisys CUS 31-W turbidity range is 0 to 9999 NTU. Selectable units also include ppm, g/L, %, or % SS. The control unit has a two-line display that indicates the measured value and temperature at the same time. The Liquisys CUS 31-W turbidimeter's measuring wavelength is 880 nm, and the unit comes in a field or panel-mounted housing. The sensor is factory calibrated, and an alarm indicates calibration errors. An on-site recalibration of the zero point based on a reference measurement can also be performed. Cleaning is automatically initiated in case of an alarm or limit violation. Up to four contacts can be used as limit contacts.

VERIFICATION OF PERFORMANCE

The following are summaries of key performance characteristics of the Liquisys CUS 31-W as verified by comparison to the ISO 7027 reference method. Secondary illustrations of performance relative to the EPA 180.1 method are also shown in the body of the report, and generally showed similar performance to that found in the verification comparisons.

As described above under Verification Test Description, the power transformer used with the CUS 31-W caused a periodic fluctuation in the output signal, with an amplitude of about 0.07 NTU. Thus these verification results were obtained under less than optimal conditions for operation of the CUS 31-W and should be considered worst-case results.

Off-Line Testing

Linearity: The Liquisys CUS 31-W responded linearly to turbidity in the tested range from 0.3 to 5 NTU. The slope of the response line for the Liquisys CUS 31-W turbidimeter was 1.06 relative to the ISO 7027 reference turbidimeter, with an r^2 value of 0.9996, and an intercept of 0.09 NTU.

Accuracy: In measuring standard formazin solutions, the Liquisys CUS 31-W turbidimeter showed a positive bias relative to the ISO 7027 reference turbidimeter throughout the range from 0.3 to 5 NTU. The bias ranged from about 30% at 0.3 NTU to 7.6% at 5 NTU.

Precision: The Liquisys CUS 31-W exhibited comparable precision to that of the ISO 7027 reference turbidimeter over the turbidity range of 0.3 to 5 NTU measured in this verification test. The CUS 31-W precision ranged from 4.7% relative standard deviation (RSD) at 0.3 NTU to 0.7% RSD at 5 NTU.

Water Temperature Effects: At 0.3 NTU, increasing water temperature produced a decrease in CUS 31-W turbidity readings of 1.7% per degree C, relative to the ISO 7027 reference measurement. At 5 NTU, there was no statistically significant relation between turbidity readings and water temperature.

Flow Rate: The Liquisys CUS 31-W turbidimeter exhibited a decrease in turbidity readings with increasing flow rate of 9.1% per gpm, in the flow range of 0.45 to 1.8 gpm.

Color: At 5 NTU color had no significant effect on the response of the Liquisys CUS 31-W turbidimeter. At ~0.1 NTU, increasing color intensity caused an increase in the turbidity reading of ~0.5% per CU, relative to the reference turbidimeter.

On-Line Testing

Accuracy: In reading the turbidity of treated, unfiltered water from a municipal drinking water plant, the Liquisys CUS 31-W turbidimeter consistently read higher than the ISO 7027 reference turbidimeter. The difference was observed over much of the four weeks of measurement of the water plant sample stream and was typically between 0.1 and 0.3 NTU. (A similar positive bias was observed with all the turbidimeters tested, possibly indicating a systematic bias in the reference turbidimeter readings on the plant water stream.). Calibration checks of the Liquisys CUS 31-W turbidimeter performed throughout the four weeks of on-line testing also indicated a positive bias with respect to the reference turbidimeter in reading a 0.5 NTU formazin solution. This bias ranged from 0.06 to 0.19 NTU, equivalent to about 12 to 35% of the corresponding reference turbidimeter readings.

Drift: Linearity data from the start and end of the verification test showed no significant drift in CUS 31-W calibration over the 6-week duration of the test. Cleaning the CUS 31-W generally reduced the bias relative to the reference measurements, suggesting a positive drift resulting from system contamination.

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