**THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM**

U.S. Environmental Protection Agency

# ETV Joint Verification Statement

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| **TECHNOLOGY TYPE:** | **ON-LINE TURBIDIMETER** | |
| **APPLICATION:** | **MEASURING LOW TURBIDITY LEVELS** | |
| **TECHNOLOGY NAME:** | **Series 4670** | |
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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) Center, one of six technology centers under ETV, is operated by Battelle in cooperation with EPA's National Exposure Research Laboratory. The AMS Center 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 ABB Series 4670 on-line turbidimeter.

## VERIFICATION TEST DESCRIPTION

The verification test described in this report was conducted by Battelle between March 2 and April 16, 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 turbidimeter 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., 0.3 to 4 nephelometric turbidity units (NTUs)]. No attempt was made to determine the ultimate detection limits of the turbidimeter tested, which the vendor literature indicates can be as low as 0.01 NTU.

In the off-line phase of testing, the linearity, accuracy, and precision of the ABB Series 4670 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 ABB Series 4670 turbidimeter was determined. In the on-line phase, a sample stream from a municipal water plant was continuously monitored by the ABB Series 4670 turbidimeter for approximately 4 weeks. Results from this phase of testing were used to determine the accuracy in measuring real-world samples and the drift characteristics of the ABB Series 4670. 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 ABB Series 4670 turbidimeter is designed to conform to ISO 7027 requirements, and thus comparison of ABB Series 4670 turbidimeter 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 ABB Series 4670 turbidimeter (i.e., visible rather than infrared), and thus is not a directly equivalent method. However, the EPA Method 180.1 method is widely recognized in the United States, by virtue of its status as one of the required methods for drinking water compliance measurements. Consequently, comparisons of the ABB Series 4670 turbidimeter results to Method 180.1 results were also made, and are presented as a secondary illustration of performance.

## TECHNOLOGY DESCRIPTION

The ABB Series 4670 turbidimeter comprising a wall-mounted analyzer and a sensor, is manufactured by ABB Instrumentation and conforms to ISO 7027. The on-line analyzer requires continuous sample flow. The flow-through system of nephelometric design uses the 90-degree scattered light principle and operates over the 0- to 30-nephelometric turbidity unit (NTU) range with a minimum range of 0 to 1 NTU. Ultralow back scatter enables true zero setting, ensuring accurate and reliable results below 0.1 NTU. The system's process connections use a 12-mm internal dimension (I.D.) tube inlet and 6-mm I.D. tube outlet.

Automatic cleaning and on-line diagnostics are standard features. The automatic cleaning eliminates optical fouling and maintains performance for up to 6 months without manual intervention. The entire sensing loop is regularly self-monitored to ensure that the light source is operating with specifications. The integral wiper cleaning system is programmable to operational frequencies of every 0.25 hour, 0.5 hour, 0.75 hour, or in multiples of 1 hour up to 24 hours. The wiper module is continuously validated by the processor to assure correct performance of the cleaning function.

The system is calibrated upon start-up using a dry secondary calibration standard, supplied for zero and span verification, or formazine standard solution. The dry standard simplifies routine calibration and eliminates the need

to produce formazine standard, which is a major safety factor.

The ABB Series 4670 turbidimeter is designed to be operated at temperatures between 0 and 50ºC, at flow rates between 0.5 and 1.5 liters per minute, and at pressures up to 3 bar. Its response time varies with flow rate, but typically exhibits a 90 percent step change in less than 45 seconds at 1 liter per minute.

## VERIFICATION OF PERFORMANCE

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

### Off-Line Testing

**Linearity:** The ABB Series 4670 turbidimeter provided linear response over the tested range of approximately 0.05 to 5 NTU. The slope of the response curve from approximately 0.05 to 5 NTU for the ABB Series 4670 turbidimeter relative to the ISO 7027 reference turbidimeter was 0.926 at the beginning of this test, with an intercept of 0.013 NTU and $r^2 > 0.999$.

**Accuracy:** In measuring standard formazin solutions in the range of 0.3 to 5 NTU, the ABB Series 4670 turbidimeter and the ISO 7027 reference turbidimeter agreed within 7.2% or less, which was comparable to the observed differences in the daily calibration checks of the reference turbidimeter.

**Precision:** The precision in the measurements of the ABB Series 4670 turbidimeter ranged from approximately 0.2% to 3% RSD at turbidities of 0.5 to 5 NTU. These results were approximately the same as for the reference turbidimeter throughout this range of turbidity.

**Water Temperature Effect:** Water temperature had a negligible effect on the response of the ABB Series 4670 turbidimeter relative to the ISO 7027 method at low turbidity (0.3 NTU) or at higher turbidity (5 NTU).

**Flow Rate:** In the narrow range of flow rates tested for the ABB Series 4670 turbidimeter (0.1 to 0.4 gpm), there was no statistically significant effect on the turbidity readings as a function of sample flow rate at 5 NTU. At 0.3 NTU, flow rate showed an effect only at 0.4 gpm. At that flow rate, turbidity readings were about 20% higher than at 0.1 or 0.26 gpm.

**Color:** Color had no effect on readings at low (~0.1 NTU) or high turbidity (5 NTU).

### On-Line Testing

**Accuracy:** In reading the turbidity of treated, unfiltered water from a municipal drinking water plant with a turbidity range of 0.3 to 4 NTU, the ABB Series 4670 turbidimeter usually showed a negative bias of up to 0.8 NTU relative to the reference turbidimeter, corresponding to a percent bias of up to 30%. On average, a bias of -18.8% relative to the ISO 7027 reference turbidimeter was found. Calibration checks of the ABB Series 4670 turbidimeter using a nominal 0.5 NTU formazin solution showed a bias of +1 to -20% with respect to the ISO 7027 reference turbidimeter, with an average bias of -8.3%, indicating a difference in response between the formazin and plant water streams.

**Drift:** A change of approximately 9% in the slopes of the ABB Series 4670 turbidimeter response curves between the beginning and end of the verification test was observed; however, this change is within the combined experimental uncertainty of the reference measurements over this time period and does not definitively indicate a calibration drift. A change of 0.002 NTU was observed in the values of the intercepts calculated from the initial and final linearity checks. This degree of change is well within the experimental uncertainty of the reference measurements. Furthermore, no apparent drift was observed in the calibration of the ABB Series 4670 turbidimeter throughout the on-line testing on the plant water stream.

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