THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE: **AREA/VELOCITY FLOW MONITORS**
APPLICATION: **FLOW METERING IN SMALL- AND MEDIUM (10- to 42-inch) SEWERS**
TECHNOLOGY NAME: **ADS ENVIRONMENTAL SERVICES MODEL 4000 OPEN CHANNEL FLOW METER**
TEST LOCATION: **QUEBEC CITY, QUEBEC, CANADA, AND LOGAN, UTAH**
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NSF International (NSF) manages the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. NSF evaluated the performance of the Model 4000 Open Channel Flow Meter manufactured by ADS Environmental Services. Utah Water Research Laboratory (UWRL) in Logan, Utah, and BPR of Quebec City, Canada, both NSF-qualified testing organizations, performed the laboratory and field verification testing, respectively.

EPA created the 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, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups consisting 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.

TECHNOLOGY DESCRIPTION

The following technology description is provided by the vendor and does not represent verified information.

Area/velocity flow meters are commonly used in wastewater collection, storm sewer, and combined sewer systems. The ADS 4000 flow meter utilizes a quad-redundant ultrasonic sensor that measures the time required for an ultrasonic pulse to travel from the sensor face to the surface of the water and back to the sensor. The meter converts the travel time to distance by calculating the speed of sound through air and adjusting for temperature, which is measured by two sensors inside the ultrasonic sensor head. The depth of the flow is then calculated using the pipe diameter and the range measured by the ultrasonic sensor. A pressure-depth sensor is also installed at the bottom of the pipe to measure surcharge levels and to provide a redundant depth reading when used with the ultrasonic level sensor. Doppler velocity measurements are made by transmitting an ultrasonic signal upstream using a submerged velocity sensor and measuring the frequency shift in the sound waves reflected by the moving particles in the water. The depth and velocity sensor readings are stored in the flow meter's memory until the data can be downloaded to a computer through either a voice-grade telephone line or a cellular network. The computer software calculates flow rates using the depth and velocity readings.

The ADS 4000 flow meter system includes the flow meter unit, sensors, and installation hardware. The flow meter unit is housed in a waterproof, marine-grade aluminum housing. The submersible pressure sensor, ultrasonic level sensor, and velocity sensor are attached to a circular stainless steel band installed around the inner circumference of the sewer pipe. Waterproof cables with sealed connectors convey power and signals between the flow meter unit and the sensors. The system is battery-powered, and can power the unit for about one year at a standard 15-minute measurement interval. According to vendor claims, after the unit is installed, minimal operation and maintenance (O&M) or unit calibration is required; the most common O&M procedure is cleaning the sensors.

VERIFICATION TESTING DESCRIPTION

Laboratory Test Site

The laboratory testing was completed at the Utah Water Research Laboratory (UWRL), at Utah State University in Logan, Utah. The flow meter was installed in three nominal pipe sizes: 10-inch, 20-inch, and 42-inch. The straight lengths were sized so they were at least 40 times the pipe diameter for the 10- and 20-inch pipes and at least 22 times for the 42-inch pipes. Pipe slopes were adjustable to allow the flow meter to be evaluated under different slope conditions. Sluice gates at both ends of the pipes were used to regulate appropriate flow, head, and obstruction during testing. Reference devices were directly traceable to the National Institute of Standards and Technology (NIST), and were regularly calibrated. Uncertainty for the reference devices was less than 0.25 percent.

Field Test Site

Field verification testing was conducted in a section of the Quebec Urban Community's (QUC) sewer network, located in the City of Sainte-Foy, Quebec, Canada. The ADS flow meter and reference meters were installed in a 41.7-inch diameter interceptor pipe, near the downstream of a straight run of pipe that had an average slope of 0.169 percent. The reference devices, which consisted of a bubbler for a reference level measurement, a reference flow monitor, and an Accusonic 4-path flow monitor, were installed downstream of the ADS 4000 flow meter. Upstream and downstream sluice gates were used to create the required flow conditions.

Validation of the reference flow monitor and bubbler were performed by lithium tracer dye tests. Flow rates under the upstream and downstream gates were also calculated using standard hydraulic equations for a redundant check of flow data.

Methods and Procedures

Laboratory evaluation of the flow meters consisted of collecting depth, velocity, and flow data from the ADS meter and comparing it to the depth, velocity, and flow data from the reference devices. These tests were performed under normal operating conditions of uniform flow, backwater flow, full pipe (manhole surcharged), and simulated silt. Water transmission through the pipes, as a ratio of flow depth versus the pipe diameter (d/D), ranged from 10 to 250 percent (surcharged conditions). Tests were also performed under the abnormal operating conditions of reverse flow and grease accumulation.

Field evaluation of the ADS flow meter at the Quebec site consisted of a general evaluation of the flow meter (Test A) and the performance of the meter under varying flow conditions. Testing consisted of collecting depth, velocity, and flow data at regular time intervals and comparing the data to the corresponding depth, velocity, and flow data from the reference devices. Four test scenarios were used:

1. Test B—accuracy under dry weather flow (approximately 1.71 million gallons per day [MGD]), with back-flow conditions;
2. Test C—accuracy under wet weather flow (1.71–29.7 MGD), without back-flow conditions;
3. Test D—accuracy under wet weather flow (1.71–29.7 MGD), with back flow-conditions; and,
4. Test E—accuracy under short-term (26-day) continuous operation, with various flow rates.

Three conditions were identified during testing that created an unintended challenge to the ADS flow meter:

1. The water used in the testing at UWRL did not contain the particulate concentrations of normal sewage, so small quantities of coffee creamer were added to the water on some test runs. The operating principle utilized by the ADS flow meter requires particles in the water to serve as reflectors for sound waves. The vendor maintained that the coffee creamer additive provided a level of reflectivity, but the particulate concentration in the test water did not approach that of sewage and could be a source of measurement error.

2. During each field test, a portion of the ADS flow meter data collected at one-minute intervals was not recorded. ADS personnel indicated that this happened because the flow meter was configured for maximum error checking and sensor refiring. They further indicate that the ADS 4000 flow meter can be reconfigured to collect data at one-minute intervals by reducing the level of real-time error checking.

3. The field testing results include data in which it appears that standing waves and troughs were present beneath the ADS 4000 flow meter's ultrasonic depth sensor. During portions of the testing, the depth sensor was likely affected by standing waves and troughs up to ±5 inches. The ADS flow meter measures depth with a downward-looking, narrow-beam ultrasonic sensor mounted on the top of the pipe, so depth measurements would be susceptible to influence by waves. Based on a review of the field data, it appears that waves were most prevalent at higher depths and flow rates.

No editing was allowed on the metered data during field or laboratory testing. In actual applications, the flow monitoring service provider may implement post-monitoring quality control measures to attempt to improve the accuracy of final data. According to ADS, the company typically bundles flow meter sales with post-monitoring quality control and reporting services.

VERIFICATION OF PERFORMANCE

System Operation

The testing organizations found the equipment durable and easy to use, and that it required minimal maintenance. The flow meter operation and data retrieval software programs were easy to learn. The ultrasonic sensors and stainless steel band did not promote accumulation of debris during testing.

Laboratory Testing Results

The mean deviation and the 95-percent confidence intervals under normal operating conditions (i.e., all test conditions except grease tests and reverse flow) are presented in Table 1. The width of the 95-percent confidence interval is a function of the variation in instrument deviation and of the number of test runs in each reported category. Categories with a fewer number of runs show wider confidence intervals. The calculations exclude “abnormal condition” tests, where grease was applied to the sensors or where reverse-flow conditions were created. The mean deviation for the abnormal operating conditions was 1.3 percent for the 0.5-mm grease tests, -69.5 percent for the 2.0-mm grease tests, and –62.4 percent for the reverse-flow tests.

Table 1. Deviation and 95-Percent Confidence Interval by Test Configuration for Lab Testing

Pipe size (inches)	**Deviation (percent)**	**95-percent confidence interval (percent)**
10	4.7	-6.5 – 15.8
20	-0.7	-7.9 – 6.6
42	-0.9	-10.8 – 9.0
Pipe slope (percent)		
0.1	4.7	-4.2 – 13.5
0.2	-0.9	-10.8 – 9.0
0.5	-0.8	-10.9 – 9.4
1.25	2.3	-10.8 – 15.4
2.0	0.2	-30.1 – 30.4
Percent full (d/D, percent)		
10	-0.1	-22.2 – 20.3
30	1.1	-13.5 – 15.8
50	5.4	-1.6 – 12.5
80	1.9	-7.4 – 11.2
150	-4.6	-28.8 – 19.6
250	3.3	-6.7 – 13.2
Condition		
Free flow	2.7	-4.3 – 9.7
Backwater	0.2	-7.5 – 8.0
All conditions	**1.2**	**-4.0 – 6.5**

The overall accuracy of the ADS 4000 flow meter under normal operating conditions (i.e., all test conditions except grease tests and reverse flow) is shown in Figure 1. The meter deviation is segregated into two components—bias and precision. Overall bias was 1.6 percent, as calculated by the slope of the best-fit line. Precision, as calculated with the correlation coefficient (r^2), was 0.74 percent.

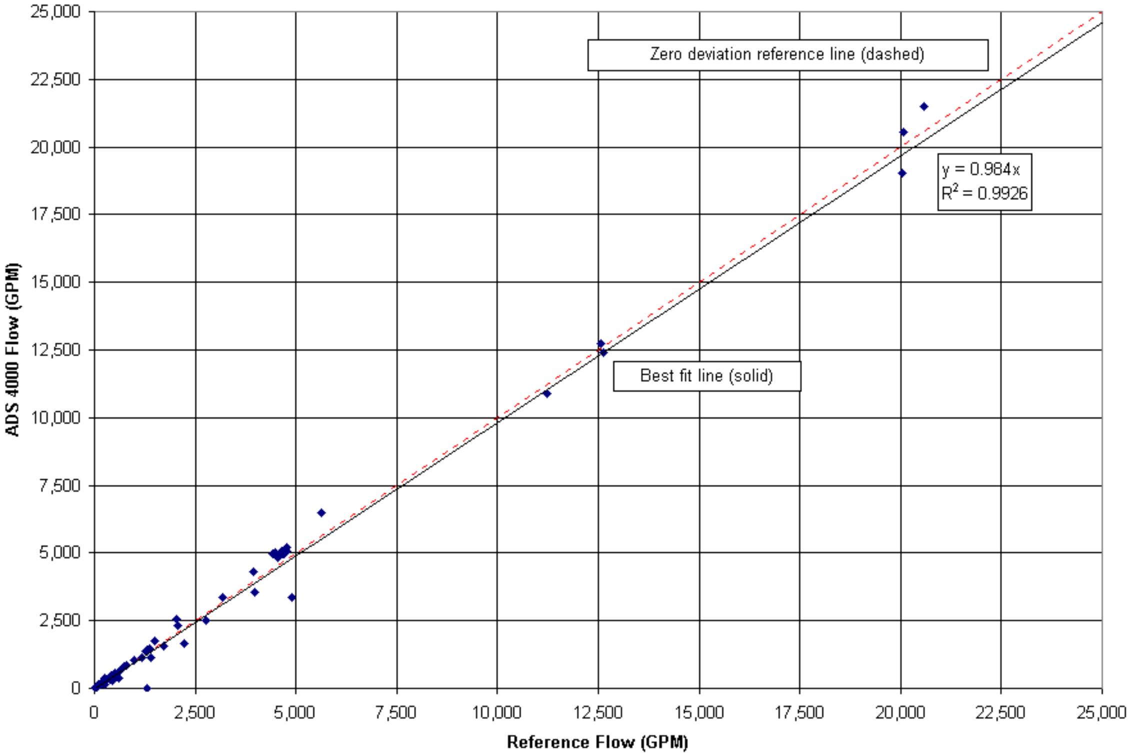

Figure 1. Laboratory-metered flow rate versus reference.

Field Testing Results

Table 2 summarizes the field testing results in two categories: mean deviation and trimmed mean deviation. The mean deviation is the arithmetic mean of all of the one-minute–interval data. The trimmed mean deviation is calculated by eliminating values greater than ±99 percent, making it less susceptible to skewing from large outliers, such as those produced when the ADS flow meter recorded zero velocity.

Table 2. Deviation from Reference Flow: Tests B, C, and D.

Flow regime	Mean deviation (percent)	Trimmed mean deviation (percent)
Test B	-14.5	-0.9
Test C	14.0	14.5
Test D	-0.8	8.3
Test B-D combined	**-0.4**	**3.8**
Simulated low flow	0.5	9.5
Simulated wet flow	-1.3	-1.0
Combined flows	**-0.4**	**3.8**

Analysis of the data collected during Test B (low flow) revealed that in nearly one-fourth of the samples the deviation was –100 percent. This occurred when the ADS 4000 flow meter recorded zero velocity and calculated the flow to be zero. This occurred most frequently when the pipe experienced back-flow conditions. The data collected during Tests C and D shows a significantly lower occurrence of data with deviations exceeding ±99 percent.

Test E (not included in Table 2) evaluated the performance of the flow meter over an extended (26-day) time period. Generally, the data collected during Test E closely correlated with the reference flow monitor data. Spikes were noted in water level measurements collected toward the end of the test, which may have been the result of accumulated condensation on the ultrasonic depth probe. No debris accumulation was observed on the equipment, and, aside from a thin film of grease on the probes, the equipment was in good condition and did not require maintenance.

QUALITY ASSURANCE/QUALITY CONTROL

A complete description of the quality assurance/quality control procedures and findings are included in the verification reports. Calibration records were maintained by the testing organizations and validation of the reference flow devices fell within control limits. NSF completed a data quality audit of at least 10 percent of the test data to ensure that the reported data represented the data generated during testing. Audits of the field and laboratory testing were conducted by NSF with no significant issues noted.

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Availability of Supporting Documents
Copies of the *Draft 4.0 – Generic Verification Protocol, Flow Monitors for Wet Weather Flows Applications in Small- and Medium-Sized Sewers, September, 2000,* the verification statement, and the verification report (NSF Report #03/13/WQPC-WWF) are available from:

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(NOTE: Appendices are not included in the verification report. Appendices are available upon request from NSF.)