HIGH-ACCURACY, SEWER FLOW MONITORING FOR REAL-TIME SYSTEM CONTROL

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- Real-time flow monitoring
- Multi-path transit-time flowmeter
- Ultrasonic transit-time flowmeter

INTRODUCTION

This paper discusses applications and configurations for multiple-path ultrasonic transit-time flowmeters under various hydraulic regimes commonly encountered in wastewater collection systems. The meters provide continuous, real-time flow data, which can be used to maximize collection system storage as an alternative to adding plant capacity or building new facilities to handle wet-weather flows. Centralized flow data acquisition from multiple remote sewer monitoring locations utilizing telephone or wireless communications can be readily implemented, allowing automated data gathering and archiving for use collection system control programs and performance evaluations, as well as serving as a standard basis for community cost allocation.

DISCUSSION

The acoustic transit-time technique is based on the principle that an acoustic pulse traveling at an angle across a pipe will be accelerated in the downstream direction by the water flowing through the pipe and will arrive at a receiving transducer in less time than an acoustic pulse traveling in the upstream direction. By mounting transducers to define a path crossing the pipe or channel at an angle to the flow axis and measuring the difference in acoustic transit times in the upstream and downstream directions, an average flow velocity at the level of the acoustic path is calculated according to the following formula:

$$V = \frac{Tup - Tdn}{Tup * Tdn} * \frac{L}{2\cos\theta}$$

where:

V = average flow velocity at the level of the path,
T_1 = acoustic transit time in the upstream direction,
T_2 = acoustic transit time in the downstream direction,
L = acoustic path length between transducers, and
θ = acoustic path angle relative to flow axis.

Because accuracy in measuring velocity requires knowledge of the acoustic path length and the angle the path makes with respect to the meter centerline, transit-time transducers are typically permanently installed, and the meter is “dry” calibrated, based on careful measurements of these values and of the meter cross-section taken at the time of transducer installation. Since these values do not change, transit-time meters do not require any periodic re-calibration over time.

With the multiple-parallel-path method, average velocity is measured simultaneously at more than one elevation in the flow. These velocity measurements define a velocity profile for the flow cross-section and are used to calculate an integrated flowrate.

Three- or four-path transit-time flowmeters were installed in seven CSO lines as part of the Quebec Urban Community (QUC) Real-Time Control Project. Line sizes of the round concrete pipes range from 900-mm- (30-in-) to 2286-mm (7.5-ft-) diameter. Acoustic path lengths, angles, and site cross-section parameters were carefully measured during transducer installation and were entered as parameters into the flowmeter electronics. The electronics initiates measurement on each submerged acoustic path, measures acoustic travel times, calculates a velocity for each path, and integrates all measured velocities over the cross-sectional area of flow, as determined from simultaneous data provided by a water level sensor. Flow, level, and velocity data from each site is output by the flowmeter every two seconds to a local RTU.

Because these meters are to be used for real-time control of the CUQ system, meter accuracy under widely varying flow conditions was a critical factor in choosing a metering technology. Flowmeter accuracy under both dry and wet-weather conditions was maximized at these sites by placing two paths below the typical dry weather water level, wherever possible, with a third path placed to provide additional velocity data during small wet-weather events. In the larger lines and at sites with widely varying water levels, a fourth acoustic path was placed higher in the pipeline, to provide a fourth velocity during large wet-weather events. Level sensors (provided by others) provide a 4-20 mA input into the Accusonic consoles, for use in calculating the flow cross-section and for turning acoustic paths on and off as they become submerged or exposed.

The use of multiple acoustic paths at increasing elevations in the flow makes the meter responsive to changing flow profiles associated with quickly changing conditions, which can go from nearly dry to surcharged within minutes during a rain event at some of these sites. Because the flow velocity profile is directly measured, there is no requirement for flow profile calibrations that are required for other measurement methods commonly used in collection system applications.

Transit-time flowmeters are inherently bi-directional flow measurement devices, which can be important at sites where backflows can be caused by downstream hydraulic or operational conditions. This feature has been important in several CSO projects on the East Coast, where negative velocities have indicated leaking tide gates.

Multi-path transit-time flowmeters installed for the City of Saginaw have also been useful in understanding the collection system hydraulics during rain events, which activate its CSO basins. For example, the City's Weiss Street CSO facility receives flow through three sewer lines. Two of these are gravity lines; the third is from a pump station, which feeds into the facility's vortex separator. Multi-path transit-time flowmeters are installed on the two gravity lines, with pump curves being used to determine flow into the vortex separator. A transit-time flowmeter was not used on this line because of air entrainment caused by flow through the separator. Readings from the transit-time flowmeter in one of the gravity lines would sometimes indicate a reverse-flow condition when the pump station was activated. What was initially considered a flowmeter error was actually indicating a condition where pumped flow increased the hydraulic grade line at the inlet of the basin. This caused the gravity line to flow backwards or upstream into the gravity sewer. Flow in the gravity line would reverse once pumping stopped. This type of back-flow condition is very difficult for system modelers to predict and quantify without real-time, reliable flow data.

Four-path transit-time flowmeters were installed in twelve interceptors throughout the Detroit, Michigan area as part of the Greater Detroit Regional Sewer System (GRDSS) Phase IV evaluation. Site characteristics range from a 1.9-m- (6.25-ft-) diameter round concrete pipe to a 7.3-m x 5.3-m (24-ft x 17.5-ft) arch sewer. The average size for the meters in the Detroit system is fourteen feet, and many of the sites have irregular cross-sections, which were carefully surveyed during meter installation. Prior to installation of these multi-path meters, Detroit had to calculate flow through their interceptor system. Because these meters are to be used to calibrate and confirm a regional model, meter accuracy under widely varying flow conditions was a critical factor in choosing a metering technology.

An 8-path transit-time flowmeter using a crossed-plane configuration was installed two years ago for billing purposes in a vertical section of interceptor pipe in Wayne County, Michigan. This meter replaced a 1.7-

m-diameter (66-inch) magnetic meter located just downstream of a 90° elbow. The crossed-plane configuration is used to maintain flowmeter accuracy downstream of elbows and other hydraulic conditions which cause cross-flow through the metering section. Because access to the pipe exterior was available here, fully removable penetrating transducers were being used, which allows for maintenance without dewatering the pipe or entering the line.

CONCLUSION

Multi-path transit-time flowmeters are being used in seven CSO lines for the QUC Real-Time Control Project, in addition to numerous widely varying collection system sites throughout the United States, to provide continuous, high-accuracy data during dry- and wet-weather conditions. The data is used by project engineers for real-time control of collection systems, developing and verifying system flow models, cost allocation, and documentation of CSO events. Because of the flexibility in configuring multi-path transit-time flowmeters, the technology offers a good solution for many difficult-to-monitor sites where reliable flow data is required.

REFERENCES

ISO 6416:1992 Part 3E - Liquid Flow Measurement in Open Channels--Measurement of Discharge by the Ultrasonic (Acoustic) Method.