



Behind the scenes:

The DigitalFlow™ GC868 Clamp-On Ultrasonic Flowmeter for Gas discussed in this article is a winner in this year's *Flow Control* magazine's Innovation Awards. This is the first in a look behind the technology of the winning products.

Figure 1

This two-channel configuration measures gas flow on two separate pipes.

Field testing a new technology.



A Clamp-On Ultrasonic Flowmeter for Gases

By Michael J. Scelzo

Despite the industrial success of clamp-on ultrasonic flowmeters for liquid measurement, it has long been accepted as if it were a fundamental limit imposed by nature, that this technology could not be used to measure the flow of gases in metal pipes.

The incorrect conclusion, that clamp-on gas flow metering is impossible, developed because the acoustic impedance of gases, even at pressure, is much less than the acoustic impedance of metals. This fact, reinforced with the knowledge that attenuation in most gases is much greater than in common liquids at

the same frequency, led to a belief that virtually no useful amount of ultrasonic energy can be transmitted from the pipe into the gas, and then back out of the gas through the metal pipe and into the receiving transducer. Along with this assessment of what was thought to be a negligible amount of sound intensity surviving to the receiver, is the further problem of a relatively strong coherent interfering wave traveling through the pipe wall into the receiver.

Together, these factors led many to conclude that the signal-to-noise ratio would be so low as to be useless, especially if it is



Figure 2
A short section of solid, straight 6-inch Inconel pipe approximately 12 inches long was found on this natural gas transmission pipeline to provide a site for the transducer installation.

understood that for a transit-time flowmeter to succeed, not only must the signal be detectable, it must be timed to a few nanoseconds or a few microseconds, in order to compute the flow velocity to high accuracy.

Even if it is correctly recognized that since the signal-to-noise ratio, while very small, is nevertheless greater than zero, it is another matter to figure out how to detect the gas borne signal and time its arrival accurately in both upstream and downstream directions.

Existing technical methods could not overcome these obstacles. A multiyear program to develop a clamp-on ultrasonic flowmeter that could be used to measure gas flows at high and low pressure in metal pipes resulted in the Panametrics DigitalFlow™ GC868 flowmeter. The solutions to the above mentioned problems involved developing new patent-pending hardware and software (preventing at this time, unfortunately, a detailed discussion of how it works).

The new flowmeter system (see Figure 1) consists of an electronics console, clamp-on ultrasonic transducers, connecting cables, and a clamping fixture to hold the transducers solidly in place on the pipe. A couplant is applied to the transducer faces to couple them acoustically to the outside pipe wall.

Field Testing

A prototype flowmeter was built and tested in August 2000 at a major petrochemical production facility in the Neth-

erlands. These initial field tests were performed on air flowing in a large number of steel pipes ranging in size from 3-inch to 8-inch at pressure from 6 to 12 bar. The customer needed a measurement survey to determine compressed air usage throughout the facility. Nearly 100 measurements were successfully made in total on different pipes.

This early trial provided results to show the viability of the technology in an uncontrolled field environment. The facility was rather old, and the pipes were in relatively poor condition and at lower than expected pressure. Despite the difficult conditions, the prototype meter worked as desired, and an estimation of the accuracy of the meter was above expectations and well within the customer's requirements.

Another test was performed in November 2000 on a natural gas transmission pipeline at a customer location in the western United States (see Figure 2). The sour natural gas in this case, containing 12 percent H₂S, was corrosive enough to require an Inconel liner inside the 10-inch, Schedule 40 carbon steel pipeline. The Inconel liner posed a problem because it was not mechanically bonded to the carbon steel pipe wall. The interface between the carbon steel pipe and the Inconel liner was too acoustically reflective to pass the ultrasonic signals through.

Located near a well head were an expansion loop and a short section of solid, straight 6-inch Inconel pipe, approximately 12 inches long. The straight pipe sec-

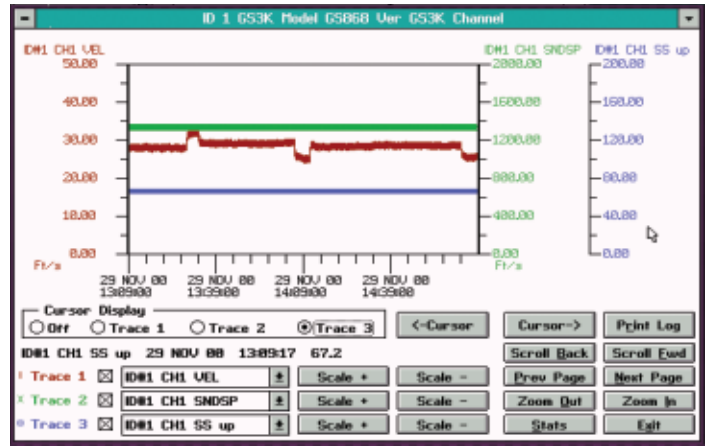


Figure 3
The clamp-on meter's tracking compared to that of a field orifice meter in a natural gas pipeline.

tion was long enough to mount the transducers and clamp, but the amount of straight pipe run was much less than needed for the flow profile to develop fully for best measurement accuracy. Once installed and adjusted for super-compressibility at a pipeline pressure of 1,300 psi, however, the clamp-on flowmeter closely tracked the field meter reading of approximately 34 MMSCF/D. Later, the clamp-on meter's stability was monitored for one-and-one-half hours, and then the flow rate was varied to test the clamp-on meter's response. In all tests, the clamp-on meter closely tracked the field orifice meter (see Figure 3).

At another major petrochemical production facility in the southern United States, the clamp-on ultrasonic flowmeter was tested from November 2000 to February 2001 on a 6-inch, carbon steel nitrogen pipeline at 400 psig, with a flow range up to 5,300 standard cubic feet per minute (see Figure 4). Flow rate data was compared with data from an orifice meter located downstream. Over the duration of the test, the average correlation of the ultrasonic meter with the orifice meter was better than ± 2 percent of reading.

Calibrating the Meter

To determine the accuracy of the device compared to that of a reference meter, a calibration of two DigitalFlow GC868 flowmeters was scheduled at the GTI Metering Research Facility at the Southwest Research Institute (SwRI) for the week of May 21, 2001. The two me-



Figure 4

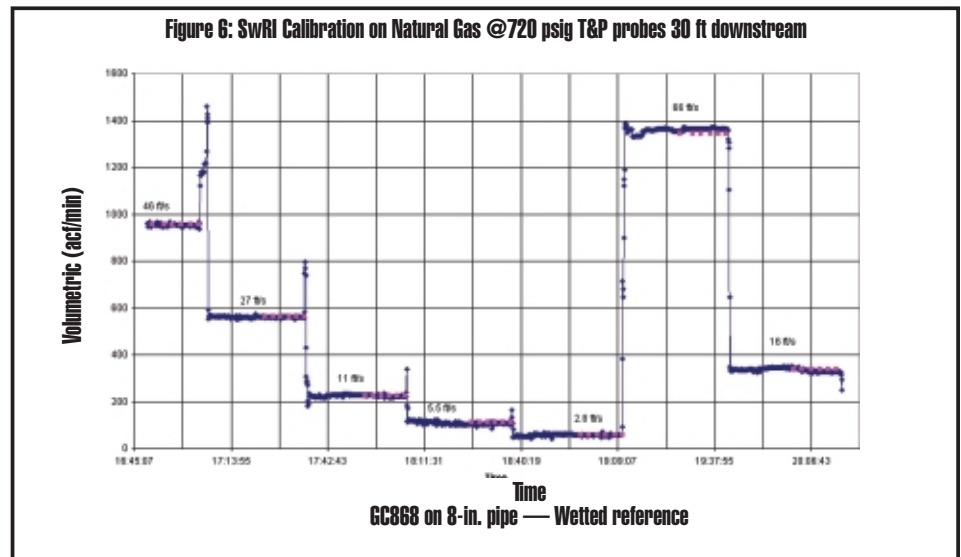
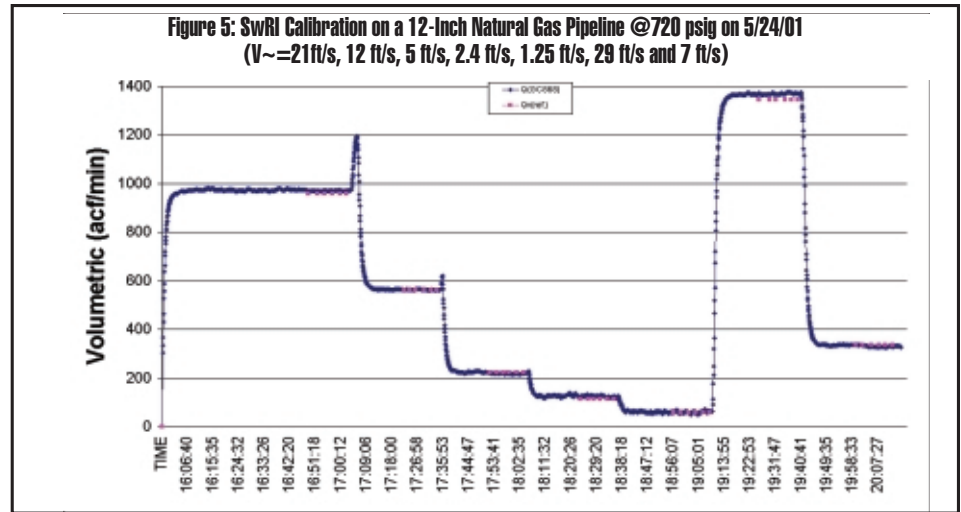
This test at a petrochemical production facility was on a 6-inch, carbon steel nitrogen pipeline at 400 psig with a flow range up to 5,300 SCFM.

ters were calibrated simultaneously on 8-inch and 12-inch, Schedule 40 pipe sections, both containing natural gas. The installation point of the meter on the 8-inch pipe section was 40 feet downstream of an elbow and a reducer. The installation point of the meter on the 12-inch section was 10 feet upstream of an elbow. The pressure and temperature taps were another 30 feet downstream. To establish thermal equilibrium, natural gas was allowed to flow through the pipeline calibration section for about 30 minutes before data collection began.

Two calibration runs were performed on May 24, one in the morning at 500 psig and one in the afternoon at 700 psig. As neither meter had any initial calibration prior to arrival at the site, the first calibration run was used to determine the meter factor. Data for the second run was obtained at the GTI Metering Research Facility at SwRI, and is presented in Figures 5 and 6. The range of flow was 50 to 1,380 actual cubic feet per minute. The data shows the correlation between the DigitalFlow GC868 flowmeters and the reference meter.

Performance Specifications

Performance specifications have been derived from data obtained during beta testing and calibration runs. The stated accuracy specification of the meter is: above 5.5 feet per second velocity, ± 2 percent of volumetric flow reading for single-path installations and ± 1.4 percent



of volumetric flow reading for two-path installations, with a time averaged accuracy of ± 1 percent of reading. The repeatability specification is ± 0.2 to ± 0.5 percent of reading. Minimum required gas pressure depends on pipe size and fluid density. For example, 90 psig is the minimum pressure requirement for instrument air in a 6-inch carbon steel pipeline. The meter will operate on unlined pipes of all metal and plastic materials, from 3- to 36-inches in diameter. The temperature range for the transducers is -40° to 300° F. Tests are now underway at up to 450° F.

Acknowledgments

The work reported here includes important contributions from Dr. Shirley Ao, Dr. Scott Li, Lawrence Lynnworth and Peter Kucmas. For more details, see www.panametrix.com, PCI or PCI R&D pages, *Ultrasonic Report UR-252* or *UR-*

252FC, Panametrix, from which this paper is excerpted.

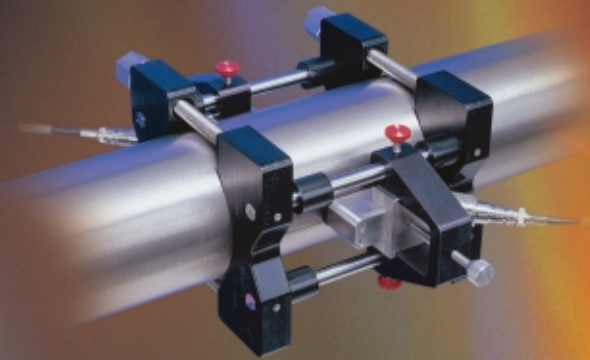
About the Author

Michael J. Scelzo received his B.S. ChE from WPI in 1969, and his M.B.A. from the Southern New Hampshire University in 1988. At Panametrix since 1973, he worked in the applications engineering, sales and marketing departments of the PCI Division. He is currently the Vice President of Marketing for the PCI Division.

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