To clamp or not to clamp—that is the question

The case for clamp-on flow meters

By Thomas Michalowski

Introduction

Flow, along with pressure and temperature, is one of the most important parameters when monitoring or controlling the fluids in pipes. Temperature and pressure are often measured alongside flow to calculate the energy flow in a pipe, but very often, especially in the water and waste sector, flow rate can be the sole parameter that is measured, either to quantify the flow for fiscal purposes or to control the flow as part of a process.

There is a wide diversity of flow meters and each type has their advantages and disadvantages. Most flow meters are inserted within the flow, often via spool pieces, to ensure the best flow through the meter itself. Sometimes it can be inconvenient to integrate a flow meter within a pipe. Or sometimes a meter provides a temporary replacement or checks on existing equipment. In these cases, the clamp-on flow meter provides a reliable and cost-effective solution.

The technologies of flow metering

Flow metering really goes back to the ancient Egyptians who devised a water clock around 1500 B.C. However, only since the industrial revolution has flow metering developed to satisfy the need to measure flows accurately for billing purposes and/or to monitor industrial processes.

The first industrial flow meters relied on fluid displacement and various designs included piston meters, paddle wheels, Pelton wheels and turbine flow meters. Today, displacement meters feature precision rotors with revolutions counted by integral electronic pulse transmitters. Flow meters based on Bernoulli's equation are still very widespread and range from simple pitot tubes to Venturi meters and orifice plates, all of which function by measuring the pressure differential at a constriction introduced into the pipe flow and then applying the Bernoulli calculation.

Over recent years a number of modern technologies have evolved. These include optical flow meters, which use laser light to detect particles entrapped within gases to obtain flow velocity; magnetic flow meters, which use Faraday's law of electro-magnetic induction; and thermal mass flow meters.

Today, major newcomers firmly establishing themselves in the flow metering portfolio include vortex meters, Coriolis meters and ultrasonic meters.

Vortex flow meters

Vortex meters rely on the detection of the frequency at which vortices are created from an obstruction placed in the fluid flow. This frequency, directly proportional to the flow rate, is converted into an electrical signal and the flow rate is calculated by the flow meter electronics. Vortex meters are inserted directly into the flow via a spool piece or directly as an insertion meter. They are used predominantly in petrochemical plants, especially for high-pressure steam lines, but also used for used natural gas allocation and for mass balancing of non-viscous fluids.

Coriolis flow meters

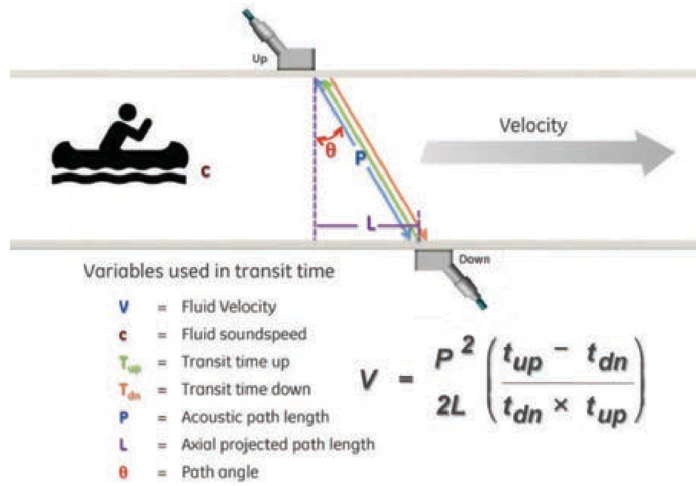
Coriolis meters use the Coriolis effect to produce a mass flow rate, rather than a volume flow rate. As two tubes oscillate, the mass flow of the fluid through the tubes will act to oppose the oscillation, causing a deflection of the tubes. This deflection is identified by the time difference between the output signals of two pick-up coils, and by processing this information the mass flow can be derived. With their wide flow, pressure and temperature range, Coriolis meters effectively measure mass flow throughout the industrial spectrum.

Ultrasonic flow meters

Ultrasonic flow meters typically use two measurement techniques: Doppler and transit-time. Doppler meters require the presence of bubbles and/or solids in the flow to reflect the transmitted ultrasonic pulses. The shift in frequency of reflected signal relative to the transmitted frequency is proportional to the velocity of the reflector, and hence, the carrying fluid.

In the transit-time technique, two ultrasonic transducers act as both signal generators and receivers and are in acoustic communication with each other. In operation, each transducer functions first as a transmitter, generating a number of acoustic pulses, and then as a receiver for an identical number of pulses. The time interval between transmission and reception of the ultrasonic signals is measured in both directions. When the fluid in the pipe is not flowing, the downstream transit time will be the same as the upstream transit time. When the fluid flow exists, the downstream transit time will be less than the upstream time, as the pulses traveling downstream will be accelerated by the flow and the pulses traveling upstream will be slowed down by the flow. The difference between the two transit times is proportional to the velocity of flow and its sign indicates the direction of flow.

Transit-time ultrasonic flow meters enjoy much wider use. They can be used for liquids and gases and offer excellent accuracy, no drift, no pressure drop, no obstruction to the flow and no routine maintenance. They can also handle bi-directional flow and a wide range of operating temperatures and offer a very high turndown ratio. By means of a thermal buffer, such as Baker Hughes Bundle Waveguide Technology, they can operate at extreme temperatures from -200°C to 600°C.



Transit time clamp-on variables

Ultrasonic transit-time flow meters offer a very important advantage over competitive technologies. Although used extensively as insertion meters with "wetted" transducers, they can also be clamped to the outside of a pipe, offering a number of advantages, including portability and reduced installation disruption.

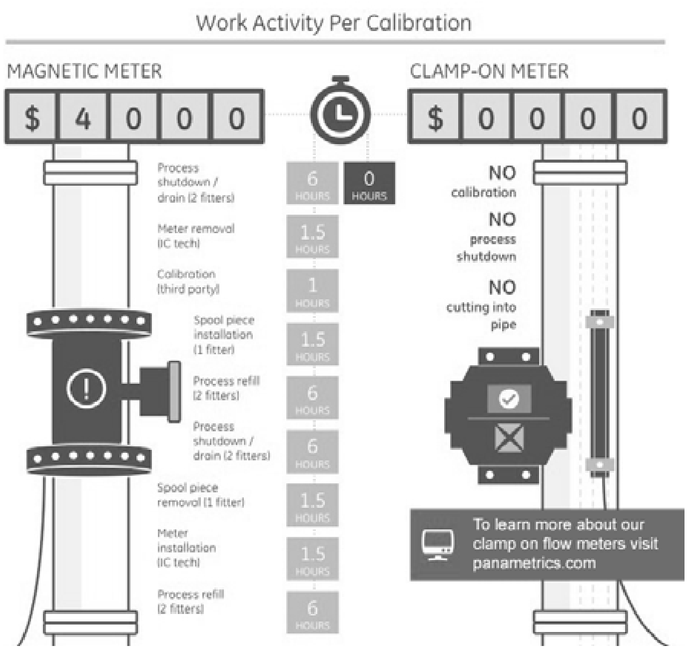
Clamp-on ultrasonic flow meters

Clamp-on ultrasonic flow meters do not achieve the accuracy of the highly accurate in-line transit-time meters used, for example, for custody transfer fiscal calculation in the oil and gas industry. This is mainly due to attenuation in the pipe wall and liner, material buildup within the pipe bore, pipe centricity and other reasons. Even so, clamp-ons can achieve accuracy better than 0.5%, although in general practice, +/- 0.5% to +/- 2.0% is the norm. They do offer excellent repeatability at around 0.2% to 0.3% and are extremely reliable.

But the major benefits of ultrasonic clamp-on flow meters are their versatility and cost-effectiveness.

- They can be used in non-conducive fluids, gases and steam.
- Being non-intrusive, they do not cause a pressure drop.
- They reduce disruption during installation because there is no need to shut down the process or cut into the pipe.
- They have no moving parts, for a long working life.
- They require no periodic calibration.
- They can measure both low and high flows. They can operate in harsh and hazardous environments.

- They are easy to use.
- Data transfer is easy, via optional outputs.
- They have a low capital cost compared with other technologies.
- One clamp-on meter can be used on a variety of pipe sizes.
- Additional analog inputs for temperature transmitters allow measurement of energy flow rate in liquids.
- Optional dual-channel/dual-path models can measure flow in two separate pipes using just one measuring unit and two sets of transducers.
- Portable versions provide easy, temporary checks of processes or of existing in-line meters.



Ultrasonic clamp-ons can save calibration time and money.

Focus on user-centered design

The development of new clamp-on flow meters puts the user at the center of the design process. Not only do new designs improve technology, but they also consider the strengths and limitations of users and anticipate how users deal with the daily realities of their jobs.

Developing new products requires observing, measuring and validating how people use those products. Baker Hughes supports this sort of research, working with industrial designers and researchers to help its engineers working on new product design understand the challenges that customers face. This research contributes to design decisions clearly rooted in people, their processes and their goals.

Applications of clamp-on ultrasonic flow meters

Clamp-on ultrasonic flow meters measure a wide range of fluids, including liquids such as:

- Ultra-pure water.
- Clean liquids.
- Sewage and wastewater.
- High viscosity liquids.
- Corrosive liquids.
- Abrasive liquids.
- Hydrocarbons, including high-temperature, high-pressure pulsating and low speed liquids.

Some gases suitable for clamp-on ultrasonic flow metering include:

- Superheated steam.
- Natural gas.
- Compressed air.
- Nitrogen and oxygen.

Clamp-ons can also differentiate between the different fluids that are sometimes carried by the same pipeline, as often happens in the petroleum industry.

Clamp-on ultrasonic flow meters have three main applications. First, as in situ or fixed installation, flow meters. Secondly, as check flow meters to evaluate the correct functioning of existing flow meters. And thirdly, as versatile multi-purpose flow meters that can be moved around a plant or installation to gather flow meter data as required. These applications apply to both liquid and gas flow metering.

Liquid flow metering

Fixed installations

In-line ultrasonic flow meters are now accepted globally as high accuracy instruments suitable for high precision tasks such as custody transfer in the oil and gas sector. Naturally much of the technology of in-line meters has migrated to clamp-on meters. While clamp-on versions at ±1% to 2% of reading do not achieve the higher accuracy of in-line ultrasonic meters with wetted transducers, they do offer other considerable benefits.

Key among the benefits, they can be easily retrofitted into an existing process without the need for a costly and inconvenient process shutdown. Such a shutdown could involve health and safety issues and associated work permits, cutting and welding work and pipeline emptying and purging plus costs of lost production, amounting to potentially thousands per hour. A clamp-on meter can be installed in less than an hour. Moreover, the capital cost of a clamp-on meter is significantly less than many competitive technologies and, as there are no moving parts, maintenance costs are reduced.

The AquaTrans* AT600 is the latest in the Panametrics line of clamp-on ultrasonic liquid flow meters. It features a user-centered design that focuses on ease of use, cost-efficiency and reliability. The AT600 is installed directly on a pipe in just minutes without shutting down the process and then left in place without maintenance and calibration. It handles a broad range of liquid flow applications like water/wastewater, industrial, HVAC, hydroelectric, and agriculture.

AquaTrans AT600 flow meter

The DigitalFlow* XMT868i represents a proven clamp-on ultrasonic flow meter. It carries the appropriate certification for installation in hazardous locations, such as those found in the petrochemical and oil and gas sectors. The XMT868i can be used to measure two separate pipes or two separate locations on the same pipe by means of a dual channel/dual path option, which receives signals from two sets of clamp-on transducers.

Portables

Portable ultrasonic flow meters are designed for short-term survey and monitoring. Typically, they are compact and lightweight and meant to be temporarily installed and moved from site to site. Portables typically include the flow electronics, external components like fixtures, transducers and cables, and accessories such as thickness gages and carrying cases. Because portables are often shared by multiple users and/or used on an irregular basis, ease of use and confidence in the measurement provide unique challenges and opportunities for clamp-on manufacturers.

Portable flow meter user

Baker Hughes Panametrics TransPort* PT878 is a proven design known for its ability to measure flow in more difficult applications. It offers the same advanced clamp-on transducers as fixed installation meters and wide range of clamping fixtures.

Suitable for a number of applications and pipe sizes, it is especially successful for water and wastewater as it measures flows from ultrapure water to extremely dirty liquids such as raw sewage and slurries.

Gas flow metering

Fixed installations

Ultrasonic clamp-on gas flow meters can measure accurately and reliably in situ a wide range of gases. For example, Baker Hughes Panametrics DigitalFlow* CTF878 can be installed on pipes from six to 30 inches in diameter, with surface temperatures from -40°C to +300°C and fluid temperatures up to 130°C. The CTF878 uses advanced transducers that produce signals five times more powerful than traditional transducers so that a very large proportion of the ultrasonic signal is actually received for measurement by the receiving transducer, after passing through the pipe wall, the gas and the opposite pipe wall.

Consequently, the signals are clean and strong with reduced background noise, even in low-density gas applications.

A particular feature of the CTF878 is its use of patented correlation tag technology, which enhances the meter's accuracy. This uses four clamp-on transducers, externally mounted on the pipe and arranged in two pairs, one upstream and one downstream. Each pair contains a transmitter and a receiver. The transmitter sends ultrasound in a continuous wave mode through the gas to its paired receiver, so that the two pairs constitute an upstream and a downstream interrogation path.

The continuous wave signal is modulated by the turbulence and local density variations characteristic of a moving gas so that both received signals contain a unique turbulence signal of the gas flow. The received signals are then demodulated and processed through a correlation algorithm. With turbulent flow conditions, a distinct correlation peak is recorded, which identifies the time taken for the unique turbulence signature to travel through the interrogation path. As this path is defined by the transducer setup, the flow velocity is simply obtained by dividing the path length by the time taken to pass through it.

Portables

Just as their liquid versions, portable ultrasonic gas flow meters are designed for short term survey and monitoring. Baker Hughes TransPort PT878GC, which handles flows up to 230°C, can provide data in terms of velocity or volumetric-totalized actual- or standard flow. Its built-in data logger has a capacity of 100,000 measurements and all flow data can be exported for remote analysis and recording.

Clamp-on flow meters in action

Clamp-on ultrasonic flow meters operate throughout the world in a variety of applications and installations.

In just one example, a semiconductor manufacturer uses a Baker Hughes portable flow meter to check and verify the performance of installed flow meters in its on-site water-treatment facility. Each department at this manufacturer's site operates its own discharge line into the water treatment facility. This amounts to over twenty discharge lines, ranging from two inches to 10 inches in diameter in a variety of materials from PVC to stainless steel. In-line flow meters are installed on each discharge line, immediately before the point where the discharge lines enter the waste treatment facility. The volumetric flow rate of each discharge line is monitored on a continuous basis. Based on these measurements, the waste treatment facility bills each department and this financial penalty motivates each department to produce as little waste as possible.

Naturally, it is vital that the accuracy and functionality of the permanently installed flow meters are verified. The company considered various portable flow meters for this task but they all proved too bulky, too costly or required an external recording device. However, they eventually tried a Panametrics portable flow meter and this proved ideal for the job. Parameters for the various discharge pipes are permanently programmed into the meter's memory, reducing setup times and the flow meter logs flow data on a continuous basis. The data is then uploaded to a PC, plotted and compared with the data generated by the relevant permanently installed meter. This has shown a correlation with 1% accuracy when compared with a correctly functioning in-line meter.

Conclusions

Clamp-on ultrasonic flow meters are now proven and accepted worldwide, with both fixed and portable meters growing in acceptance and use for many applications. The chemical and oil and gas sectors account for a large base of clamp-on users, with water and wastewater being another. The growth in water and wastewater is globally driven by population growth, migration and infrastructure improvements in developing regions where safe, potable water and effective waste treatment remain essential for economic growth.

Regardless of the industry, operations today have to maintain and improve efficiency and a key factor in this is reliable and cost-effective measurement of operating parameters, especially flow. Clamp-on flow meters are proving to be a valuable tool to help customers meet ever-growing demands while enhancing their own resources in terms of finance and personnel.

About the Author

Tom Michalowski is global product manager for clamp-on ultrasonic flow meters. He is a chemical engineer with an MBA and has been with Panametrics and Baker Hughes for 17 years.

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