White Paper

Select the Right Flow Meter for Natural Gas Pipeline Custody Applications



EMERSON

In this White Paper

The need for high accuracy under non-ideal conditions makes natural gas custody metering applications quite challenging—but ultrasonic flow meters address these and other issues.

Global demand for natural gas is increasing. Gas producers must transport their product to customers, which invariably involves multiple transportation and measurement steps. From production through processing and delivery, natural gas often changes hands several times. Each transfer between entities constitutes a custody transfer, and both parties must agree on the quantity and quality of the gas being exchanged.

For typical gas flow measurement applications, an accuracy of 0.25% may be considered acceptable; however, for natural gas custody transfer, an accuracy of 0.1% is standard. Any measurement error results in financial discrepancies, and in large, high-volume metering stations, these discrepancies can accumulate rapidly.

This white paper focuses on flow meter selection for this highly demanding application. It explains the latest technological advancements that have significantly improved natural gas flow measurement accuracy and outlines the various flow meter design options.

Natural Gas Distribution Network

Natural gas is primarily produced from underground reservoirs. Pipelines of various sizes, typically referred to as gathering lines, connect these wells to a processing plant, where hydrogen sulfide, water, and other contaminants are removed (figure 1).

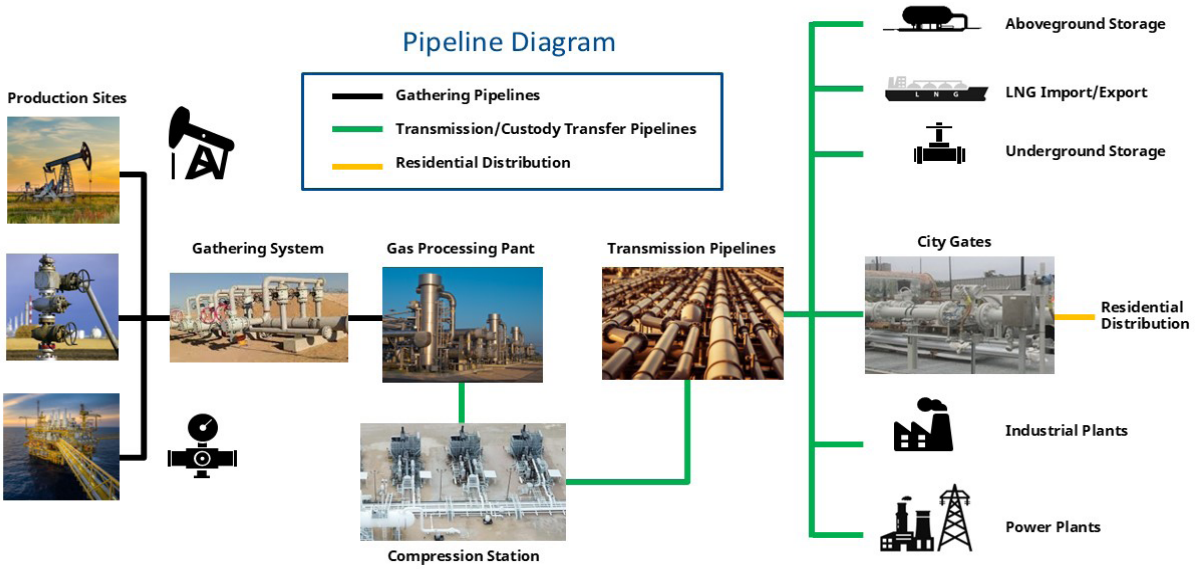


Figure 1. The natural gas network consists of gathering lines moving gas from production to processing plants, transmission lines moving gas to major users, and low-pressure distribution lines distributing gas to various customers.

Once purified at the processing plant, the saleable natural gas is transported through much larger, high-pressure transmission lines to supply major users. These users may include other pipeline networks, LNG plants for export, or gas distribution companies serving large cities. In large cities, the gas is typically odorized at the city gate, and the pressure is significantly reduced before it enters the distribution network to supply smaller end users.

Pipeline networks are vast. For example, the United States alone has approximately 320,000 miles of onshore and offshore gas gathering and transmission pipelines, as well as about 2,170,000 miles of natural gas distribution mains and service lines. While each type of natural gas pipeline presents its own challenges, this paper focuses on the metering of natural gas within the transmission network.

Gas transmission pipelines differ from other types of gas distribution lines in several ways. The pipes are typically large, with diameters of up to 42 inches. They also operate at elevated flow rates and pressures, typically ranging from 200 to 1500 psi. Due to these high flow rates and long distances, compressor stations are required every 50 to 100 miles along the network to maintain gas movement.

Accurate metering is critical throughout the network. Flow meters installed around compressor stations are necessary to monitor compressor performance, while custody transfer meters are required whenever gas ownership changes. A typical gas network may include custody transfer metering at the processing plant where gas enters the pipeline, at compressor stations, and at major end users such as public utilities, LNG facilities, and other pipeline operators.

Natural Gas Metering

Metering natural gas presents several challenges, and these difficulties are amplified in custody transfer applications. Pipelines tend to be quite large, which limits metering options. Pressure drop is also a major concern, as every pound of pressure lost increases compression costs. In addition, both flow rates and pressures can vary seasonally, creating changing conditions that push flow meters to their limits.

Large pipelines also experience variability in flow profiles. In smaller pipes, the flow profile stabilizes more quickly, allowing most meters to perform well with a reasonable length of straight pipe upstream. This length is typically defined in terms of pipe diameters, so achieving 20 or even 50 diameters of straight pipe ahead of a flow meter is relatively easy for a 2-inch pipe.

However, 50 diameters of a 36-inch pipe equate to approximately 150 feet of very expensive piping, which is not easily accommodated. Most flow meters require a standard flow profile to convert measured values into accurate flow rates, making a stable flow profile essential. Unfortunately, non-standard flow profiles are common in natural gas pipelines (figure 2), which can lead to significant measurement errors.

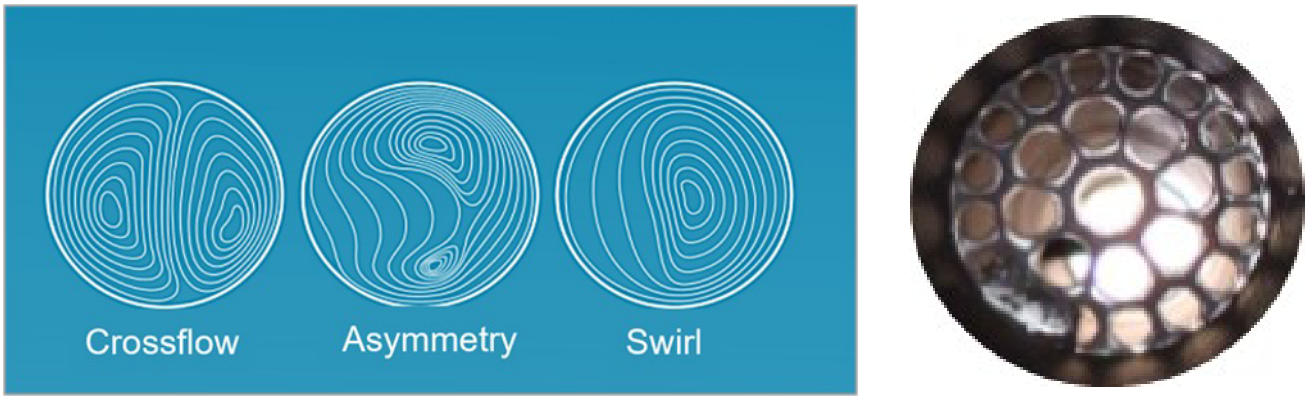


Figure 2. Abnormal flow profiles are common in large, natural gas transmission pipelines. Flow conditioners alleviate this problem but tend to trap materials and block flow (right).

A typical solution is to install a flow conditioner upstream of the flow meter to create a more consistent flow profile entering the meter. These flow conditioners are usually perforated plates with small holes designed to eliminate swirl and flow distortions caused by pipe bends, valves, or reductions. However, flow conditioners are expensive and introduce additional pressure drop into the system. They also require maintenance, as solid particles or debris found in pipelines—such as rubber fragments or gasket material—can accumulate and become trapped in front of the conditioner.

Natural gas custody transfer applications face all of these measurement challenges, while also placing a premium on measurement accuracy. In a single medium-sized metering station transporting 200 MMSCFD, a 0.25% measurement error can result in nearly $500,000 USD in annual financial impact (at $3/MSCF). Even small errors, therefore, can have significant financial consequences. When parties disagree on custody transfer measurements, resolving disputes can require considerable time, legal resources, and expense.

To minimize confusion, disputes, and legal complications, organizations such as AGA, ISO, and OIML have worked to standardize the measurement devices and procedures used in trade (figure 3). Natural gas custody transfer meters are typically required to achieve 0.1% accuracy, although total installed accuracy may vary depending on organizational standards and classification requirements.

	OIML R137 Class 1.0	AGA 9	ISO 17089 Class 1.0	OIML R137 Class 0.5
Typically, after Flow calibration	± 0.1%	± 0.1%	± 0.1%	± 0.1%
Installation disturbances	± 0.33%	± 0.3%	± 0.3%	± 0.167%
Total $\sqrt{(A2)^2+(B2)^2}$	± 0.345%	± 0.32%	± 0.32%	± 0.20%

OIML Class 1 vs Class 0.5
+/- 0.16% added uncertainty
$175,000 (1 year additional uncertainty value)

Figure 3. Custody transfer organizations require 0.1% accuracy for the flow measurement, plus some limited error associated with the installation. An OIML Class 0.5 meter can reduce uncertainty by $175,000/yr in a typical application.

Several technologies are commonly used to measure natural gas flow:

- Coriolis
- Turbine
- Differential Pressure (DP)
- Ultrasonic

All of these technologies can measure natural gas accurately in certain applications—Coriolis meters are exceptionally accurate. However, the largest Coriolis meters are limited in size and tend to create a high pressure drop.

Turbine meters can be installed in larger pipelines and offer good accuracy and turndown. However, the meter itself introduces some pressure drop, which is further increased when a flow conditioner is required. In addition, turbine meters contain a rotating measurement component that can wear over time, potentially leading to reduced accuracy.

Differential pressure (DP) meters have historically been widely used in gas custody transfer applications. Like turbine meters, they require either a stable, straight flow profile or a flow conditioner. They also tend to create significant pressure drop across both the meter and the flow conditioning elements. Unlike turbine meters, DP meters have no moving parts; however, the orifice plate can wear over time and must be periodically inspected. In addition, DP meters typically have limited turndown (approximately 10:1), so significant flow variation may require replacement of the orifice plate.

Ultrasonic meters offer several advantages over other metering technologies. They use pairs of ultrasonic transducers positioned at angles across the pipe (figure 4). These transducers alternately transmit pulses upstream and downstream, measuring the transit time (time of flight) to determine flow velocity.pulses of ultrasonic signals upstream and downstream and measure the time of flight.

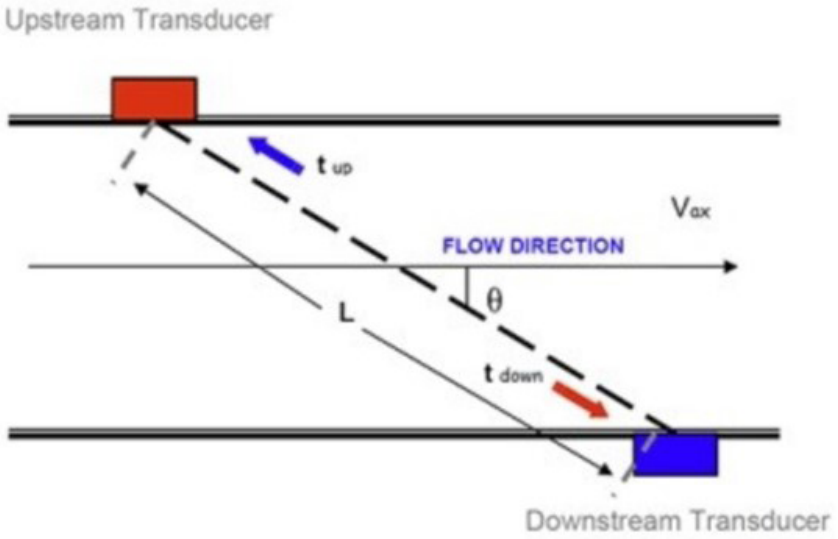


Figure 4. An ultrasonic flow meter employs pairs of transducers, each pair sending pulses of ultrasonic signals back and forth through the pipe. Pulse transit time is altered by gas flow, and this transit time is proportional to the fluid velocity.

Upstream pulses are delayed, while downstream pulses are accelerated by an amount proportional to the flow velocity. By measuring and averaging these transit time differences, the fluid velocity can be determined. The measured velocity is then multiplied by the internal cross-sectional area of the meter to calculate volumetric flow rate under process conditions, which is subsequently converted to standard conditions using gas composition, pressure, and temperature.

The full-bore design of the ultrasonic flow meter eliminates pressure drop. In addition, the meter can be applied to very large pipe sizes and is capable of measuring flow in either direction. The technology also offers a turndown ratio of up to 100:1, allowing the meter to operate accurately across a wide range of flow conditions.

Ultrasonic Flow Meter Designs

A single pair of transducers can provide relatively accurate flow measurement, provided the pipe has a consistent flow profile. Adding additional pairs of transducers enables ultrasonic flow meters to achieve higher accuracy and perform a variety of redundant and diagnostic measurements (figure 5).

A four-path meter, such as the Rosemount™ SeniorSonic 3414 Four-Path Gas Ultrasonic Flow Meter, uses four pairs of transducers, each taking chordal measurements across the pipe. This meter can achieve 0.1% accuracy and is widely used in custody transfer applications; however, it typically requires a flow conditioner to meet OIML Class 0.5 accuracy requirements.

By adding additional transducer pairs, the meter can perform enhanced flow verification and diagnostics. The Rosemount 3415 4+1 Dual-Configuration Gas Ultrasonic Flow Meter includes a fifth pair of reflective transducers to detect product buildup on the pipe walls and/or changes in gas composition. This additional pair also provides a check measurement to verify flow measurement performance.

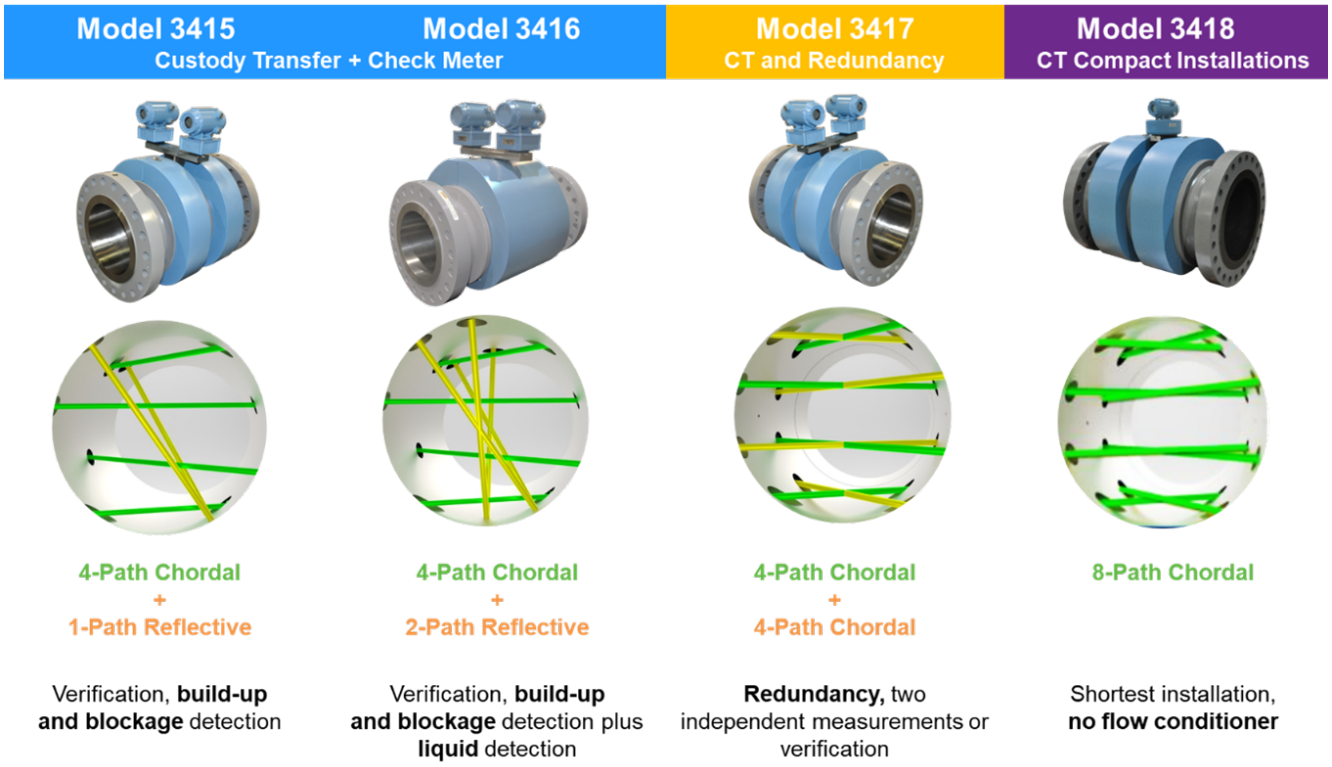
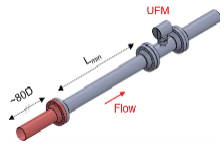
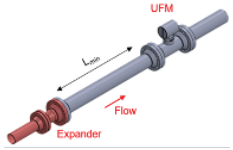
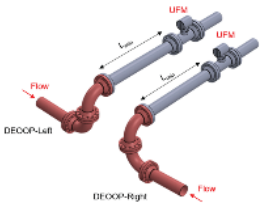
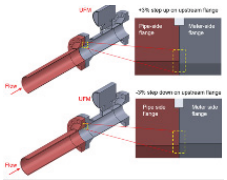
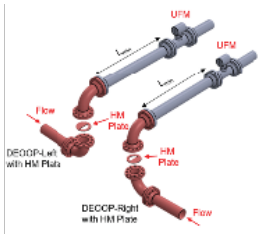
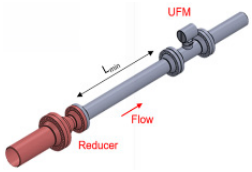
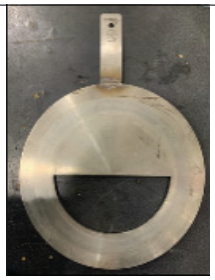


Figure 5. Adding additional transducer pairs to the custody transfer-rated Emerson 3414 flow meter provides improved diagnostic and redundant flow measurements. The Rosemount™ 3418 8-Path Gas Ultrasonic Flow Meter doesn't need a flow conditioner.

Adding a second reflective transducer pair, which reflects off the bottom of the pipe, allows the Rosemount 3416 4+2 Dual-Configuration Gas Ultrasonic Flow Meter to detect contamination and/or the presence of liquids moving along the bottom of the pipe. The Rosemount 3417 4+4 Dual-Configuration Gas Ultrasonic Flow Meter utilizes two sets of four transducer pairs, effectively providing two completely independent custody transfer meters within a single meter body.

The most advanced ultrasonic flow meter designs, such as the Rosemount 3418 8-Path Gas Ultrasonic Flow Meter, use eight pairs of chordal transducers to produce a single flow measurement. Each measurement cycle occurs every two milliseconds, with the meter performing 16 measurements to calculate flow values. By combining high-speed measurements across multiple paths and angles, this type of meter can detect and compensate for irregular flow profiles, enabling it to achieve OIML Class 0.5 accuracy without requiring a flow conditioner.

Piping Layout	Test Description	Piping Layout	Test Description
	Baseline with 80D of straight upstream pipe		One step of pipe diameter expansion before meter assembly
	Single elbow in plane		Double elbows out of plane left and right turn entry
	Plus 3% and minus 3% step change before meter		Double elbows out of plane left and right entry with half moon plate
	One step of pipe diameter reduction before meter assembly		Half moon plate

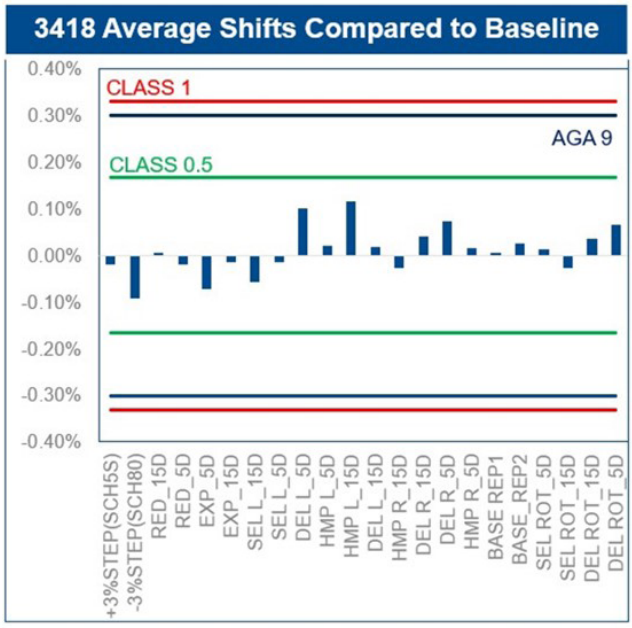


Figure 6. The top diagram shows a variety of challenging pipe installation arrangements to which the 8-path Model 3418 is subjected. Despite these sub-optimal conditions, the meter achieved OIML Class 0.5 accuracy with no flow conditioner required.

Eliminating flow conditioning can yield significant cost savings in gas transmission applications. Flow conditioners themselves are expensive—particularly for larger line sizes—and require substantial installation space, which can complicate implementation. In addition, they require ongoing maintenance to remove trapped particles and introduce pressure drop, increasing operating costs.

For a typical 12-inch pipeline, eliminating a flow conditioner can result in approximately $25,000 in avoided installation costs, $20,000 in annual compression costs, and $30,000 for each maintenance outage required to service the equipment. These savings can be significantly higher for offshore installations, larger pipelines, or under other demanding operating conditions.

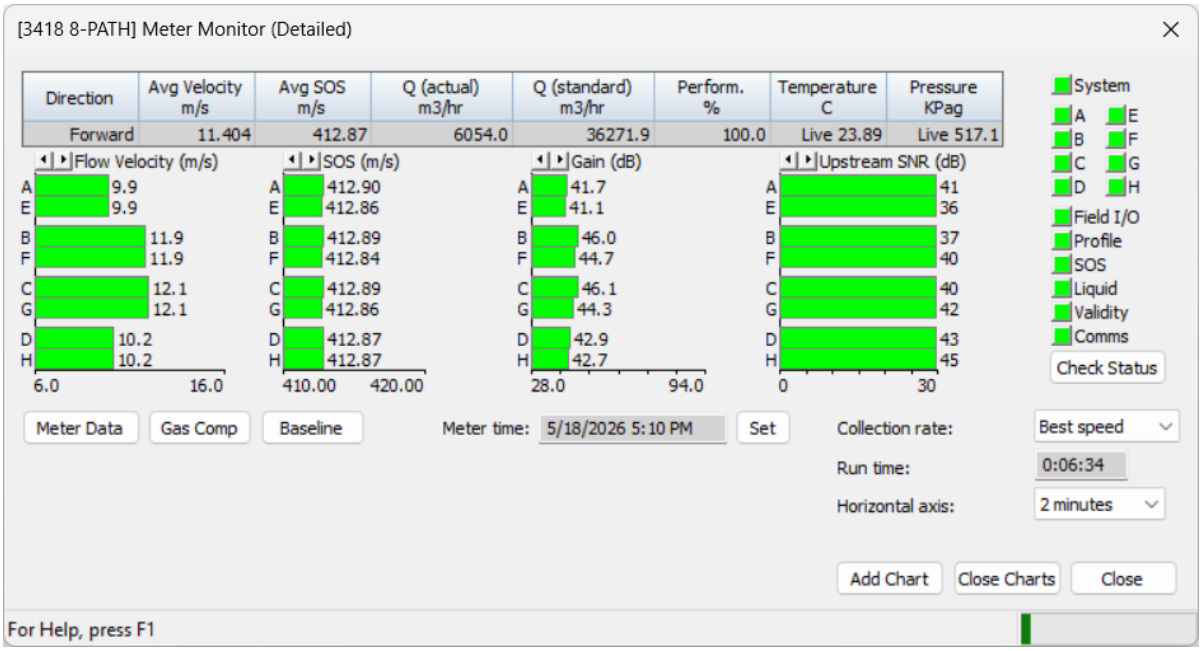
Meter Selection

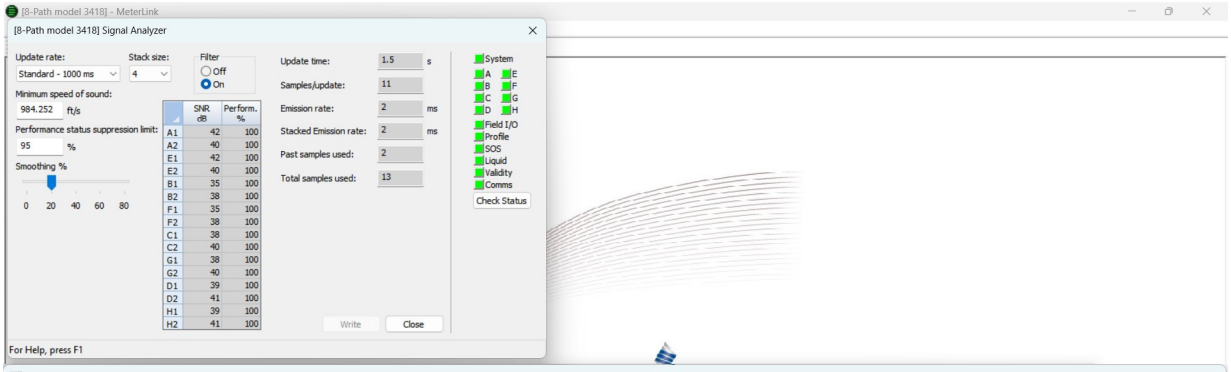
8-path meters certainly have their place in critical custody transfer applications where the profile is less than ideal, but more cost-effective designs may be a better choice, depending on the particular installation and accuracy requirements.

In each case, the most cost-effective option should be carefully evaluated, which may require consultation with an Emerson expert. For example, if a flow conditioner is already in place and no additional measurements are required, the Model 3414 may be an excellent choice, as it can achieve OIML Class 0.5 accuracy.

Ultrasonic Metering Software

Regardless of the model selected, a single software solution supports the commissioning, operation, and maintenance of our ultrasonic meters. This software provides valuable insight into meter performance by monitoring key parameters, such as swirl angle, flow profile deviations, and individual transducer performance.





Meter Name	Description	Direction	Flow Velocity (ft/s)	Uncorrected flow rate (ft3/day)	Last Scheduled SMV Result		Meter Status	Meter Time	
FIT-001A	FIT-001A, Station #1	Forward	50.43	3305796.3	Pass	12/21/25	OK	6:26:40 PM	Connect
FIT-001B	FIT-001B, Station #1	Forward	0.00	0.00	Pass	12/31/25	OK	6:26:40 PM	Connect
FIT-200	FIT-002, Rio Grand Inlet	Forward	66.67	2110988.1	Fail	11/30/25	Check Status	5:26:21 PM	Connect
FIT-400	FIT-400, Rio Grand Outlet	Forward	75.66	2110745.5	Warning	11/30/25	Check Status	5:26:21 PM	Connect
FIT-826	Compressor Discharge	Forward	0.00	0.00	N/A		Offline		Connect
FIT-827	Compressor Discharge	Forward	0.00	08082.7	Warning		Check Status	5:26:33 PM	Connect
FIT-331A	Outlet V-331 to MPLX	Forward	0.00	0.00			Offline		Connect
FIT-331B	Outlet V-331 to KM-001	Forward	0.00	0.00			Offline		Connect
FT-AA102	N/A	Bidirectional	0.00	0.00			Offline		Connect

Figure 8. A software offered with Emerson ultrasonic meters help monitor meter performance, allow signal analysis of the transducers, and manage all of the meters on a common platform.

The software also offers advanced diagnostic capabilities, enabling users to visualize individual transducer waveforms and detect pipeline issues, such as wall buildup, liquids accumulating at the bottom of the pipe, and blockages in upstream flow conditioners. When multiple flow meters are installed, Emerson's MeterLink™ Diagnostics Software allows users to access and monitor all meters from a single platform.

Case Studies

One application involved three compressors feeding a single header (figure 9, left). Initial flow modeling suggested that this configuration would create between two and five degrees of swirl in the pipeline as compressors were cycled in and out of service. However, during commissioning, the measured swirl exceeded 30% (figure 9, right), making accurate flow measurement particularly challenging.

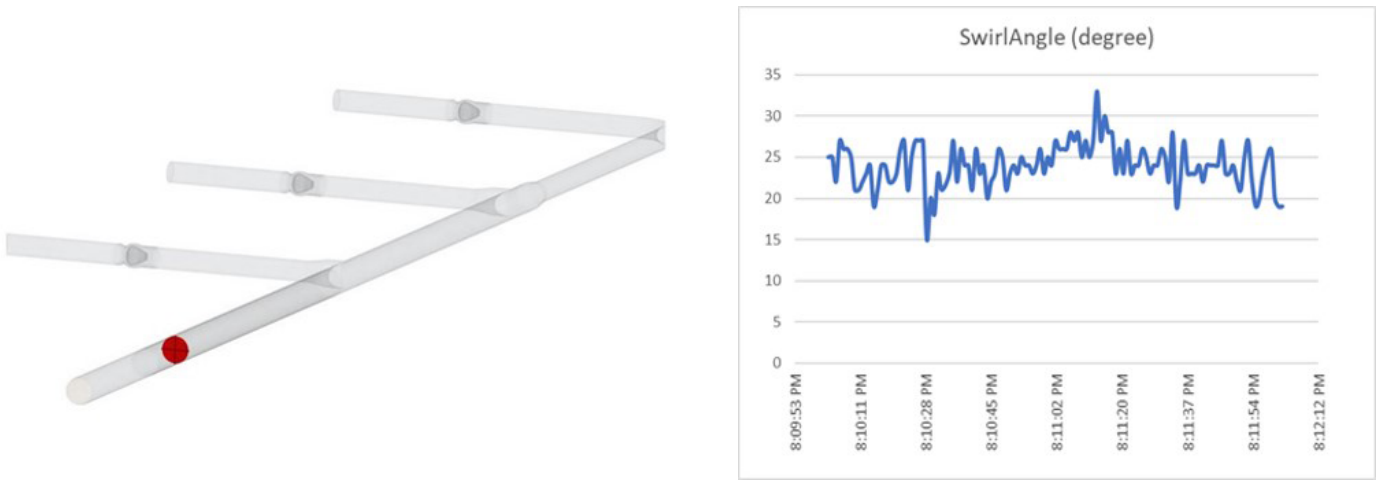


Figure 9. One application involved metering a common header coming off three compressors (red dot shows meter location). Modeling suggested a potential of 2-5% swirl at the meter location, but commissioning showed the actual value to be over 30%.

An Emerson Model 3418 8-path meter was selected for this application (Figure 10). Despite the absence of flow conditioning and the presence of a highly distorted flow profile, the meter measures natural gas flow with high accuracy and delivers reliable performance.



Figure 10. This Rosemount 3418 8-Path Gas Ultrasonic Flow Meter is installed on a common header fed by three compressors. Despite an extreme swirl profile, the meter provides a highly accurate flow measurement due to its 8-path design.

In another new pipeline design, Model 3418 8-path flow meters were selected as the primary custody transfer meters at an end-of-line LNG facility. These meters reduced upfront installation costs and are expected to deliver ongoing operational cost savings over their service life.

Conclusion

Ultrasonic flow meters are often the best choice for natural gas transmission applications. They introduce no pressure drop, offer very high turndown, support bidirectional measurement, are available in a wide range of large pipe sizes, and deliver high levels of accuracy. A variety of meter configurations are available to meet different application requirements. For example, four-path meters are well suited for custody transfer applications where flow conditioning is already in place. For more demanding applications—particularly new custody transfer installations that require high accuracy without flow conditioning—8-path meters provide an optimal solution.

In addition to these configurations, a range of ultrasonic flow meter designs offers advanced diagnostics, flow verification capabilities, and even full redundancy within a single meter body. When faced with challenging natural gas metering applications, end users should consider consulting with Emerson experts to select the most appropriate meter based on service conditions, application requirements, and budget.

For additional information, visit:
Emerson/RosemountUltrasonic

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