# Part II: The Role of Oil & Natural Gas

## Digging down on the pros and cons of each and every possible solution

By Jesse Yoder, Ph.D.

The world's search for energy has placed a new emphasis on gas flow measurement. In the rapidly evolving area of gas measurement, particularly custody transfer, increasingly demanding requirements are driving changes in flowmeter technology. As a result, the flowmeter market for custody-transfer of natural gas has become the fastest growing niche in the flowmeter industry, with the possible exception of multiphase flow measurement.

Producers are pushing the frontiers to extract gas from harder-to-reach places—offshore, under shale, and in sand, even from landfills and dairy farms as biogas. They are striving to conform to evolving standards for hazardous and other conditions. They are constantly seeking to optimize efficiency and maximize profits with greater accuracy, more soundly verified readings, and an ever-clearer picture of what is happening at any given moment.

In addition, there are many types of gases, including natural gas, atmospheric gas, fuel gas, compressed natural gas, and others. Air is a mixture of gases, including nitrogen, oxygen, argon, etc. Individual gases that are especially important include oxygen, hydrogen, and nitrogen. Natural gas is much discussed in flow measurement because it plays such a critical role in supplying energy. Like air, natural gas is a mixture of gases. These include methane, ethane, butane, propane, and other alkanes. Like petroleum, natural gas is a fossil fuel and is found in the ground. It is extracted and refined into fuels that supply a substantial portion of the world's energy.

Each flowmeter type has its own application strengths and weaknesses in measuring oil flow and gas flow. As is the case in the broader flowmeter market, new-technology flowmeters, such as ultrasonic and Coriolis, are replacing the traditional technologies of differential-pressure (DP), turbine, and positive displacement. Some traditional flowmeter suppliers are responding to this trend through innovation—with new, more durable materials, added electronics, and new product introductions, such as the relatively new turbine meter from Elster (*www.elster.com*) that offers bi-directional flow, self-lubrication, and significantly reduced pressure drop. These innovations are helping traditional suppliers hold onto their market shares and enabling them to continue to compete in a changing marketplace. Even though gas flow can be a difficult measurement to make, flowmeter suppliers are continually identifying novel solutions for this task.

### Gas Flow Measurement

The main types of flowmeters used for gas flow measurement include:

- Ultrasonic
- Coriolis
- Vortex
- Thermal
- Differential Pressure
- Positive Displacement
- Turbine

#### Ultrasonic

There are three main types of ultrasonic flowmeters: inline, clamp-on, and insertion. Inline meters, also called spoolpiece, are mounted inline with the pipe. They come in both wafer and flanged versions. The transducers for ultrasonic inline flowmeters are mounted in the body of the meter. In clamp-on models, the transducers are mounted outside the pipe. Though the accuracy of clamp-on models is typically not as high as that of the inline versions, their ability to measure flow without pipe penetration makes them valuable for check metering and temporary flow measurement. However, clamp-on meters have had limited success in measuring gas flow.

Insertion ultrasonic meters are widely used for flare and stack gas applications. There is a growing need for this measurement worldwide, due to environmental considerations. However, ultrasonic meters compete with thermal meters and differential-pressure (DP) flowmeters with averaging Pitot tubes for these applications. Ultrasonic meters for flare and stack gas applications often sell in the $20,000 price range.

Insertion meters are also used in process pipes where they are installed by drilling a hole in the pipe and inserting ultrasonic transducers. While this form of measurement often does not achieve the same accuracy level as an inline or "spoolpiece" meter, it does have a cost advantage since the cost of the meter body is avoided. Insertion meters also have an advantage over clamp-on meters since their signal does not have to go through a pipe wall. This eliminates uncertainties that sometimes bedevil clamp-on meters involving wall thickness or the material of construction of the pipe wall.

Inline ultrasonic flowmeters are one of three main types of flowmeters used for custody-transfer of natural gas. In this area, they compete against differential-pressure and turbine flowmeters. In 1998, ultrasonic flowmeters received the approval of the American Gas Association (AGA, *www.aga.org*) for use in custody-transfer applications. Ultrasonic flowmeters used for custody-transfer of natural gas must have at least three paths due to the high accuracy required. Some now have as many as 18 paths. Suppliers of multipath flowmeters include Emerson Daniel (*www.daniel.com*), Elster Instromet (*www.elster-instromet.com*), SICK (*www.sick.com*), FMC Technologies (*www.fmctechnologies.com*), and KROHNE (*www.krohne.com*).

**Coriolis**

Coriolis flowmeters are used to measure gas flows, but they have some limitations. Coriolis meters have an easier time measuring liquids than gases, because liquids are denser than gases. Coriolis flowmeters also become expensive and unwieldy in line sizes above 4 inches. However, in the past several years, a number of suppliers have begun producing Coriolis flowmeters in line sizes above 6 inches. While many of these are aimed at the petroleum liquids market, some are also being used for custody transfer of gas.

**Vortex**

Vortex flowmeters are among the most versatile of flowmeters and can readily measure gas, steam, and liquid flows. In some cases, straightening vanes or a specified length of straight upstream pipe to reduce swirl and distorted flow patterns. The accuracy of vortex flowmeters is medium to high, depending on manufacturer and model. Vortex flowmeters can be used to measure liquid, gas, and steam flow. They are especially suited to measuring steam flow.

**Thermal**

Thermal flowmeters are used almost exclusively to measure gas flow. Thermal flowmeters typically inject heat into the flowstream and then measure how quickly this heat dissipates. This value is proportional to mass flow. Two different technologies for thermal measurement are constant power and constant temperature. One main application for thermal flowmeters is measuring stack gas flows. In the early 1990s, U.S. Environmental Protection Agency (EPA) requirements created a need to measure sulfur dioxide ($SO_2$), nitrous oxide ($NO_x$), and other industrial pollutants being emitted from smoke stacks. Due to the large size of these stacks, multiple measuring points were necessary for accurate measurement. Multipoint thermal flowmeters were developed in response to this requirement. Today, a broader need to measure greenhouse gas emission is generating added momentum in the thermal flowmeter market.

**Differential Pressure**

The use of differential-pressure (DP) flowmeters in custody-transfer of natural gas is governed by Report 3 from the American Gas Association. DP flowmeters have been used for many years for custody transfer of natural gas. Today, however, there is a trend toward ultrasonic flowmeters for this purpose. One reason is that ultrasonic flowmeters cause very little pressure drop, while the orifice plate or other primary elements used with DP flowmeters have to create reduced pressure for the flow measurement to occur. Ultrasonic flowmeters are also not subject to the type of wear that can occur with an orifice plate. The long-term reliability of ultrasonic flowmeters is typically greater than that of DP flowmeters.

Another application for DP flowmeters is in stack gas flow measurement. Flowmeters used in stack flow measurement are often accompanied with analytical equipment that is used to analyze the composition of the gases flowing through the stack. Much of the need for this type of analysis stems from EPA regulations. Because of the large size of most stacks, DP flowmeters use multiple measuring points. DP flowmeters typically use Pitot tubes for this purpose. Other flowmeters used for stack gas measurement include ultrasonic and thermal.

**Positive Displacement**

Positive-displacement flowmeters work by capturing the flow in small compartments and then counting how often this is done. Flowrate is calculated based on the number of times these compartments are filled and emptied. The main types of positive-displacement flowmeters are oval gear, rotary, piston, nutating disc, diaphragm, and helical. Positive-displacement meters are suited for residential, commercial, and industrial applications. They are widely used in utility gas flow measurement. Here they face competition from turbine flowmeters. However, positive-displacement meters excel at measuring low flowrates, and they do best in line sizes of 10 inches or less. Both diaphragm and rotary meters are widely used for gas flow measurement. While new-technology flowmeters, such as Coriolis, are beginning to make an impact on the gas utility market, in many cases they do not yet have the necessary industry approvals to allow them to be widely used for these applications.

**Turbine**

Turbine flowmeters are the third main type of flowmeter used for custody transfer of natural gas. In 1996, the AGA issued Report 7, which lays out criteria for using turbine flowmeters for custody transfer of natural gas. Turbine flowmeters, when calibrated properly, can achieve accuracies that rival those of multipath ultrasonic flowmeters. While some companies using turbine flowmeters for custody transfer of natural gas are buying replacement turbine meters, many are making the switch to ultrasonic flowmeters for new applications. The reason for this is that ultrasonic flowmeters are non-intrusive, and they do not rely on a mechanical rotor to make the measurement. Ultrasonic flowmeters can also handle impurities in the flow better than turbine meters.

In addition to custody-transfer, turbine flowmeters are used as billing meters to measure the amount of gas used at commercial buildings and industrial plants. Here they compete with positive-displacement flowmeters. As noted earlier, PD meters are generally favored for low-velocity applications with line sizes between 1.5 inches and 10 inches. Turbine flowmeters, however, are better suited for line sizes above 10 inches.

## Oil Flow Measurement

The following flowmeter types are used for oil flow measurement:

- Coriolis
- Ultrasonic
- Vortex
- Differential Pressure
- Positive Displacement
- Turbine

**Coriolis**

While Coriolis meters have many advantages, line size has always been a limitation. Due to their operating principle, Coriolis meters get unwieldy and expensive in sizes 4 inches and up. For many years, only Rheonik (now a part of GE Measurement, *www.ge-mcs.com*), made Coriolis meters in sizes above 6 inches. However, in the past several years, three more companies have entered the large line size Coriolis market. These include Micro Motion (*www.micromotion.com*), KROHNE, and Endress+Hauser (*www.us.endress.com*). These companies have produced Coriolis meters for line sizes from 8

to 16 inches. They are aimed at the fast-growing market for oil and gas flow measurement, including custody transfer.

Suppliers have not yet solved the problem of designing Coriolis meters for large line sizes that are small and compact. Many of these meters are as tall as a person, and are also very heavy. KROHNE has a straight-tube meter for large line sizes that offers some advantages. While this meter is quite long, it is not as tall as its bent tube counterparts. These meters are also expensive, and some of them sell in the $75,000 range.

Despite the size and cost disadvantages of these large line size Coriolis meters, they have begun making their presence felt in the market. With crude oil selling in the range of $90 per barrel, and prices likely to increase in the long-term, some end-users are willing to pay the higher price of these Coriolis flowmeters. In return, they get high accuracy, long-term reliability, and reduced lifecycle costs. Look for suppliers to continue to push the limits on the sizes of Coriolis meters.

**Ultrasonic**

Inline transit-time flowmeters are the most accurate type of ultrasonic meter. They come in single, dual, and multipath designs. Multipath designs measure flow at multiple locations, thereby enhancing measurement accuracy. Suppliers have made many types of multipath meters, including three-path, four-path, five-path, six-path, eight-path, and 18-path designs, among others. Since the publication of AGA-9 in 1998, the American Petroleum Institute (API, *www.api.org*) has also approved the use of ultrasonic flowmeters for custody transfer of petroleum liquids.

Inline ultrasonic flowmeters are also used for measurement of crude oil and petroleum liquids. Some of the main suppliers to this market include Caldon (now owned by Cameron, *www.c-a-m.com*), KROHNE, and Faure Herman (a unit of IDEX Corporation). Consistently high crude oil prices have made measurement of the flow of petroleum liquids increasingly important. Look for more products to be developed to address this growing application.

**Vortex**

In January 2007, an API committee approved a draft standard for the use of vortex flowmeters for custody transfer of liquid and gas. Companies such as Invensys Foxboro (*www.foxboro.com*) and Emerson Process Management (*www.emersonprocess.com*) have been active in working with the API on the development and approval of this standard. The standard was updated in 2010. While initial evidence is that so far this standard has had a limited impact on the vortex flowmeter market, end-users figure to begin selecting vortex flowmeters more frequently for custody-transfer applications in the years to come. So far, however, vortex meters have not been able to penetrate the market for custody transfer of petroleum liquids, which is still dominated by ultrasonic, DP, and PD meters. However, vortex flowmeters have found a place in the fast-growing market for measuring liquefied natural gas (LNG).

**Differential Pressure**

Differential-pressure flow technology has been around for more than 100 years. DP flowmeters require the presence of a constriction in the line to create a difference in upstream and downstream pressures. The device that creates this constriction is called a primary element. There are many types of primary elements, and each is suited for particular applications.

The most popular type of primary element is an orifice plate, which is a round metal plate with one or more holes in it. Other types of primary elements include Venturi tubes, Pitot tubes, flow nozzles, and wedge elements. Just as ultrasonic flowmeter suppliers have developed multipath ultrasonic flowmeters for custody-transfer applications, DP flowmeter suppliers have developed single- and dual-chamber orifice fittings for custody-transfer. Dual-chamber orifices are designed to allow the inspection or replacement of the orifice plate without shutting down a process line. Emerson Process Management, Daniel Division, is the leading supplier of single- and dual-chamber orifice fittings.

**Positive Displacement**

Positive-displacement flowmeters are widely used in downstream distribution of petroleum liquids. They are used to measure the amount of petroleum liquids loaded onto tanker trucks, planes, and ships, and for delivery of hydrocarbons to businesses and industrial plants. PD meters have approvals for these applications, and they are well entrenched there.

Even so, PD meters face a stiff challenge from Coriolis meters for these types of billing and custody-transfer applications. Because oil is a high-value product, end-users are more willing to pay the higher prices of Coriolis meters to measure its flow. PD meters are widely used to measure the flow of hydrocarbon products both upstream and downstream of refineries at custody transfer points. However, Coriolis meters are making inroads into this market due to their high accuracy and reliability.

**Turbine**

Like DP flowmeters, turbine flowmeters have been around for many years. Turbine flowmeters rely on a spinning rotor that rotates in proportion to flowrate. They are widely used for liquid and gas flow measurement, including measurement of petroleum liquids, but cannot be used to measure steam flow. Turbine flowmeters excel at measuring clean, steady, medium-to-high speed flows of low-viscosity fluids.

Turbine meter suppliers are making technology improvements to make turbine meters more reliable. Many of these involve making the moving parts more reliable. By making the ball bearings out of more durable material, such as ceramic and sapphire, turbine suppliers have been able to add significantly to the life of the bearings. This is important, since some customers select new-technology meters over turbine meters because turbine meters have moving parts. Other recently introduced improvements include bi-directional flow, self-lubrication, and significantly reduced pressure drop.

There are several reasons why turbine meters will continue to maintain their wide usage for oil flow applications. One is that turbine meters have a significant cost advantage over ultrasonic meters, especially in the larger pipe sizes. Their price may also compare favorably to DP flowmeters, especially in cases where one turbine meter can replace several DP meters. Users who are already familiar with turbine technology and don't want to spend the extra money required to invest in a new technology are likely to stay with turbine meters.

## A Look Ahead

As is the case for many flow applications, new-technology flowmeters are displacing traditional meters in the oil and gas flow measurement market. Coriolis and ultrasonic flowmeters typically offer higher accuracy and greater reliability than positive displacement and turbine meters. There is also more research and development work being done on new-technology meters than traditional meters, resulting in more new features and products. On the other hand, DP, positive displacement, and turbine meters have a large installed base, which will keep them in use for many years to come. Considering the world's expanding need for energy, and the increased need to measure oil and gas, competition among metering technologies is likely to remain intense. FC

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*This article is Part II of a two-part series on oil & gas flow measurement. Part I of this series can be found in the January issue of Flow Control (pages 26-31) or in the issue archives at FlowControlNetwork.com.*

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