Mass appeal

Their ability to accurately measure mass flow make Coriolis meters a popular choice in process plants.

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Coriolis meters have grown in popularity during the past five years. In many process plants, users are selecting them to replace differential pressure (DP) meters. Despite their higher initial purchase price, many users find them a good investment when cost of ownership is considered.
One of the most important features of Coriolis flowmeters is that they measure mass flow. Most other flowmeters, except for thermal meters, measure volumetric flow. One way to measure volumetric flow is by collecting the fluid into small compartments and counting how many times the compartments are filled. This is how positive displacement meters work—it resembles the process of pouring milk from a large container into individual cups, and counting the cups.

A second way to measure volumetric flow is to determine the average speed or velocity of the flow as it travels down the pipe, and then multiply it by the cross-sectional area of the pipe. The other "new technology" flowmeters, including magnetic, ultrasonic and vortex meters, use this method to compute flow rate. These flowmeters use different methods to measure flow at some point in the flowstream, and use this value as a basis for determining the average flow speed.
Coriolis, magnetic, ultrasonic and vortex are classified as new technology flowmeters. This is because they have come to be widely used in the past forty years and because they use technology that differs from DP flowmeters, which are the most traditional means of measuring flow. Much of the competition today centers around DP and new technology flowmeters, such as Coriolis meters.

Why measure mass flow?
While in many cases volumetric flow is sufficient, it is also desirable at times to measure mass flow. Many products are sold by weight rather than by volume; in these cases, it is often desirable to measure mass flow. Chemical reactions are often based on mass rather than volume, so mass-flow measurement is often required in the chemical industry.

While both volumetric and mass flow apply to liquids and gases, mass flow is especially appropriate for measuring gases. That's because gases are much more affected by temperature and pressure than are liquids. Pressure has minimal effect on liquids in terms of compressibility, and is often ignored in making volumetric flow measurements. The effects of temperature on liquids often are disregarded, as well, except where high accuracy is desired.

How mass flow is measured

Mass flow can be measured in several ways. Thermal flowmeters, which are mainly used to measure gases, use a method of heat dispersion. Coriolis meters use the fluid's momentum to determine mass flow directly.

Another method, which is indirect, involves measuring volumetric flow and then using fluid density to calculate mass flow. This is possible because of the following formula:

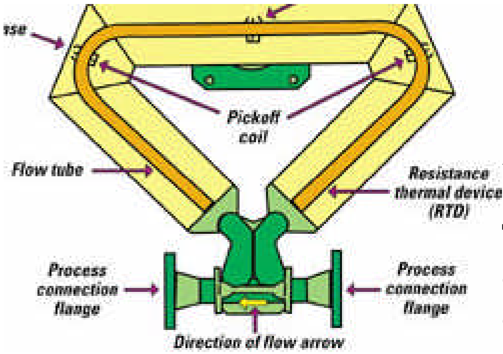
$$QM = QV *P$$

In the above equation, QM is mass flow, QV is actual volumetric flow, and "p" is the fluid density.

Once volumetric flow is known, there are several ways to determine density. It can be read off a thermodynamic chart, provided the fluid composition, pressure and temperature are known, and the density value can be used to compute mass flow. This method can be satisfactory, depending on the degree of accuracy desired. This method is not always reliable because density varies with temperature and pressure, especially for gases. So reading a density value off a chart may not provide an accurate value, if temperature and pressure are not taken into account.

Multivariable flowmeters represent another way to measure mass flow. So far, multivariable vortex meters, magnetic meters and differential pressure flowmeters have entered the market. They typically measure the temperature and pressure of the process fluid, in addition to its flow. They then use these values to determine density and the values of any other required variables that are temperature or pressure dependent. With these measurements, as well as volumetric flow, multivariable flowmeters compute mass flow.

The way multivariable flowmeters measure mass flow is considered to be indirect because it arrives at the calculation via other values, namely temperature and pressure. It is also called an inferred method, because mass flow is computed using a formula. One advantage of many multivariable flowmeters, especially DP multivariable meters, is that they only require a single process penetration to get three process readings: flow, pressure, and temperature. This reduces the number of leak points and reduces the chance of



fugitive emissions.

The limitation of multivariable flowmeters is that, because of the number of values involved in mass flow computation, accuracy is somewhat less than that of Coriolis meters. Coriolis meters measure mass flow directly, and are among the most accurate flowmeters.

Figure 1. Mass flow is directly proportional to the amount of twist.

Operating principle: the twist
Inertial force must be taken into account when describing the motion of bodies in a rotating frame of reference. For example, because of the earth's rotation, an object thrown from the North Pole toward the equator will appear to deviate from its intended path. Coriolis meters are named after Gustave Coriolis, a French mathematician who discovered the principle in 1835. The force that acts according to this phenomenon is called the Coriolis force.

Coriolis flowmeters contain one or more vibrating tubes. As the fluid to be measured passes through the tubes, it accelerates at it reaches the point of maximum vibration. It then decelerates as it leaves this point. As a result, there is a twisting motion in the tubes. Mass flow is directly proportional to the amount of twist (see Figure 1).

Paradigm case applications
Paradigm case applications for flowmeters are those for which the flowmeter type is best suited. For Coriolis flowmeters, paradigm case applications are for clean liquids and gases flowing at medium to high velocity in pipes six inches and less in diameter. Coriolis meters become quite expensive and unwieldy for larger pipe sizes. Their use to measure gas flow is a relatively recent phenomenon.

Coriolis meters can measure fluids of different densities without recalibration. Some low-pressure gases are not sufficiently dense to be measured with a Coriolis meter. While they can measure the flow of dirty liquids and slurries, it is recommended that these fluids be measured using a sensor sized for relatively low flow rates to reduce meter wear.

Accuracy: the main advantage
What really separates Coriolis flowmeters from other meters is their high accuracy. A recent survey of flowmeter users underscores this advantage. Flow

Research and Ducker Research, Bloomfield Hills, Mich., conducted a worldwide survey of flowmeter users. Users were asked why they chose Coriolis. Seventy percent of Coriolis meter users named accuracy as the chief reason. The second most-mentioned answer was reliability, which was mentioned by 15 percent of respondents.

The results of this survey are especially interesting, because Coriolis flowmeters are often perceived as mass flowmeters that also happen to be highly accurate, rather than highly accurate flowmeters that happen to measure mass flow. The survey results suggest that accuracy, rather than mass flow measurement, motivates users to purchase these meters (see Figure 2).

Figure 2. Why are you currently using Coriolis flowmeters?

Reason	Percent of Respondents
Accuracy	70.4%
Reliable	14.8%
User friendly	7.4%
Flexibility	7.4%
Dependable	7.4%
Works well with different liquids, different viscosities	7.4%
Best suited for our application	3.7%
Repeatability	3.7%
Industry standard	3.7%
Measures mass flow	3.7%
No parts to wear and replace/No moving parts	3.7%
More precision	3.7%
Other	22.2%

Note: Due to multiple responses, total exceeds 100%. Data is based on interviews with North American users.

Other advantages of Coriolis meters are low maintenance and lack of susceptibility to flow profile considerations. High purchase price is one disadvantage, although some Coriolis meters are now available in the $3,000 range. Another disadvantage is the inability of Coriolis flowmeters to measure flow in larger pipes.

Bent tube vs. straight tube

One important development in Coriolis flowmeters has been the introduction of straight tube flowmeters. The chief advantages of the straight-tube design are reduced pressure drop and easier cleaning. Some bent-tube meters can experience plugging problems. Straight-tube meters also have a more compact design. They are especially suited for sanitary applications.

A look ahead

Coriolis flowmeters are likely to maintain their rapid growth during the next several years. Thanks to lower prices, look for them to begin competing with magnetic flowmeters. Coriolis meters are more complementary to, rather than competing with, ultrasonic meters because many ultrasonic meters excel in larger pipe sizes. But look for Coriolis meters to continue to take market share away from DP flowmeters, as more users become aware of their accuracy and reliability.

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