# MEASUREMENT NUTS & BOLTS

## THERE ARE THREE BASIC TYPES OF MASS FLOWMETERS: CORIOLIS, THERMAL AND MULTIVARIABLE. HOW DO THEY WORK AND WHEN SHOULD THEY BE USED?

BY DR. JESSE YODER

While the majority of flowmeters measure volumetric flow, three types measure mass flow — Coriolis, thermal and multivariable. This article discusses the reasons for measuring mass flow and then looks at the advantages and disadvantages of Coriolis, thermal and multivariable flowmeters.

Volumetric flow is measured in a number of different ways. Ultrasonic, magnetic, vortex and turbine meters use various methods for determining average speed or velocity of the flow at some point in the flow stream. They then multiply this velocity value by the cross-sectional area of the pipe to yield volumetric flow rate.

Positive displacement flowmeters measure volume directly by separating portions of the flow into small containers of known volume, and counting how many times this is done. This is a highly accurate method of flow measurement, and positive displacement flowmeters are widely used for custody transfer applications.

### Why Mass Flow is Measured

One reason to measure mass flow is to achieve greater accuracy. Because the quantity of a fluid varies with temperature and pressure, fluid flow can vary with changing temperatures and pressures. This is most notable for gases. Pressure and temperature variations have minimal effects on liquids, so these effects are often disregarded when measuring liquid flows. However, temperature and pressure have a much more pronounced effect on gases, so much of mass flow measurement is a measurement of gases.

In the process industries, it is sometimes desirable to measure mass flow for greater accuracy and to accommodate measurement standards. Chemical reactions often refer to mass rather than volume, so mass flow is often measured in the chemical industry. Some products are sold by weight rather than volume, and in these cases, it is necessary to measure mass flow. Gas flow is widely measured in the process industries.

There is a close relation between volumetric flow and mass flow measurement. If the volumetric flow of a fluid is known, multiplying this value by the density of the fluid yields mass flow. Some flowmeters, such as multivariable flowmeters, compute volumetric flow and then determine mass flow by using a calculated density value.

What percent of the total flow measurements are volumetric, as opposed to mass flow? In a recent worldwide survey conducted by Flow Research and Ducker Worldwide, 75 percent of flow measurements were volumetric and 25 percent were of mass flow. It is clear, then, that mass flow accounts for a significant percentage of total flow measurements.

### Coriolis Flowmeters

Coriolis flowmeters use fluid momentum to measure mass flow directly. The fluid enters the meter and passes through one or more vibrating tubes, and accelerates as it reaches the point of maximum vibration. As the fluid leaves this point, it decelerates. This causes a twisting motion in the tubes. The Coriolis meter measures this twisting motion, and mass flow is directly proportional to the amount of twist.

While it is natural to think that users choose Coriolis meters because of their ability to measure mass flow, user surveys show differently. In the previously mentioned user survey, respondents were asked why they are using Coriolis meters. The leading answer given was accuracy, which was mentioned by 63 percent of respondents worldwide. Reliability was the second leading reason, and was mentioned by 14 percent of respondents. Only a small percentage measure "ability to measure mass flow."

Coriolis flowmeters are among the most accurate meters. Their main limitations are line size and cost. Over 90 percent of Coriolis flowmeters are used on line sizes of two inches and less. Coriolis meters become very large and unwieldy, especially in sizes from four to six inches. Cost also increases with size. Even smaller size meters are generally more expensive than other comparable new technology flowmeters. Users who are considering Coriolis flowmeters need to balance their need for accuracy and reliability against purchase price. Some users select Coriolis meters despite their higher initial cost, because low maintenance requirements reduce their cost over the life of the meter.

## Thermal Flowmeters

While thermal flowmeters also measure mass flow, they do so very differently from Coriolis meters. Instead of using fluid momentum, thermal flowmeters make use of the thermal or heat conducting properties of fluids to determine mass flow. While the majority of thermal flowmeters are used to measure gas flow, they are also used to measure the flow of liquids.

The origins of thermal flowmeters lie in hot wire anemometers. These consist of a heated, thin wire element, and are very small and fragile. Hot wire anemometers were used in velocity profile and turbulence research. Because they are susceptible to breakage and to dirt, they are not suited to industrial environments.

There are several different thermal flowmeter technologies. Some measure the speed with which heat that is added to the flow stream disperses. Others measure the temperature difference between a heated sensor and the ambient flow stream. Thermal flowmeters typically require one or more temperature sensors to measure the fluid temperature at specific points.

Thermal flowmeters have several main advantages. One is a relatively low purchase price. Secondly, thermal flowmeters can measure the flow of some low-pressure gases that are not dense enough for Coriolis meters to measure. Both of these advantages give thermal flowmeters their own unique niche in flow measurement.

The main disadvantage of thermal flowmeters is low accuracy. While some thermal flowmeters may achieve accuracy levels of one percent, other thermal flowmeters have accuracies in the three to five percent range. It is the accuracy level of thermal flowmeters that is the main barrier to classifying them as new technology flowmeters rather than traditional technology meters. Users who are considering thermal flowmeters need to balance their accuracy needs with their cost requirements.

## Multivariable Flowmeters

Multivariable flowmeters measure mass flow by combining volumetric flow measurement with density measurement. Density is usually measured either

# TECH TRENDS:
## TWO-PHASE CORIOLIS METER


While Coriolis technology offers significant advances, a traditional drawback has been the adverse affects of two-phase flow (liquid/gas). The prevalent plague of entrained air can interrupt flow measurement and stall or shut down the flow tube, causing measurement inaccuracies, or worse yet, process interruptions. To combat this, an advanced Coriolis mass flow transmitter has been developed by the **Measurement & Instrument Division** of **Invensys Production Management**, (Foxboro, MA.)

The Foxboro CFT50 incorporates a patented dual digital processing system to improve meter control throughout all stages of void fraction operation. One processing system controls the meter drive sequence assuring uninterrupted flow tube operation. The second system processes the measurement data from the Coriolis meter, for precise fluid measurements.

Prior to this, Coriolis meters required tuned balanced flow tubes. Similar to a tuning fork, flow tubes would oscillate in concert with each other to operate properly. However, random and at times turbulent oscillation caused by multiphase flow would upset the resonance balance and interrupt metering and process operations. With digital technology, the CFT50 immediately reacts to such dramatic changes to facilitate uninterrupted flow tube control. Moreover, its signal processing allows for response times 10 times faster than traditional Coriolis transmitters, even with substantial amounts of entrained gas up to 100 percent.

By overcoming the limitations of entrained gas, it can be used in traditionally difficult to measure applications, including use with slurries and non-homogeneous fluids, as well as railcar and tank truck unloading; pharmaceutical batch applications — even starting from empty flow tubes; pulp and paper coating applications; dairy processes in cheese manufacturing and problematic fluids that foam.

All of which factors into cost of ownership, since the meter continues to operate uninterrupted, eliminating loss of production. Maintenance and operating costs are also reduced, since the transmitter can be used in applications with a wide variety of fluids without recalibrating.

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by consulting a table, or by dynamically measuring pressure and temperature. This is called an inferred method, because a formula is used to compute mass flow. The main types of multivariable flowmeters are differential pressure (DP), vortex, ultrasonic and magnetic.

One main advantage of multivariable DP flowmeters is that only one process penetration is required to get three process readings: flow, temperature and pressure. This reduces the chance of fugitive emissions, and also the number of leak points. Another advantage of multivariable DP meters is that users who are already measuring volumetric flow with a DP flowmeter can upgrade to a multivariable DP meter with a minimum of changes.

A disadvantage of multivariable flowmeters is that accuracy levels are not as high as accuracy levels of Coriolis meters. This is due to the number of variables involved, and to the fact that it is an inferred method of computing mass flow. On the other hand, the purchase price of multivariable flowmeters is substantially below that of most Coriolis meters.

## Summary

With at least three main ways to measure mass flow, users are advised to determine their accuracy requirements and their budgetary constraints before making a decision about which type of flowmeter to select. When considering cost, it is also advisable to consider the lifetime costs of a flowmeter, rather than just the purchase price. There are many high quality products available in all three categories. FC

**About the Author**

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