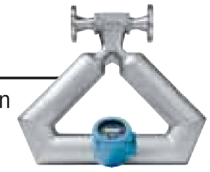


by Tim Patten

Handling Entrained Gas

New Methods for Measurement Accuracy & Minimizing Waste

Emerson Process Management has developed new technologies for its Micro Motion Coriolis range of flowmeters for improved performance in a wide range of entrained-gas conditions. According to Emerson, the new technology achieves timely, accurate, and reliable results in many applications where entrained gas previously prevented success.

Gas and liquid coexist in many processes. This mixing of dissimilar states can manifest itself in many ways and with many names — transient, two-phase, flashing, and slugs, to name a few. In a primarily liquid process, it is perhaps best known as entrained gas. By any name, entrained gas is often a troublesome challenge to accurate and reliable flow measurement.

Entrained gas is present in many liquid flow measurement applications, such as the manufacture of film emulsions, beer (wort), glucose, liquid fertilizers, soaps and lotions, hair-care products, phenols, dairy products, polyethylene, and ethylene oxide. Flow measurement performance in such environments can be unpredictable, depending upon the application, as measurement accuracy can be affected by many factors, such as the positioning of the measuring devices or the characteristics of the fluid being measured.

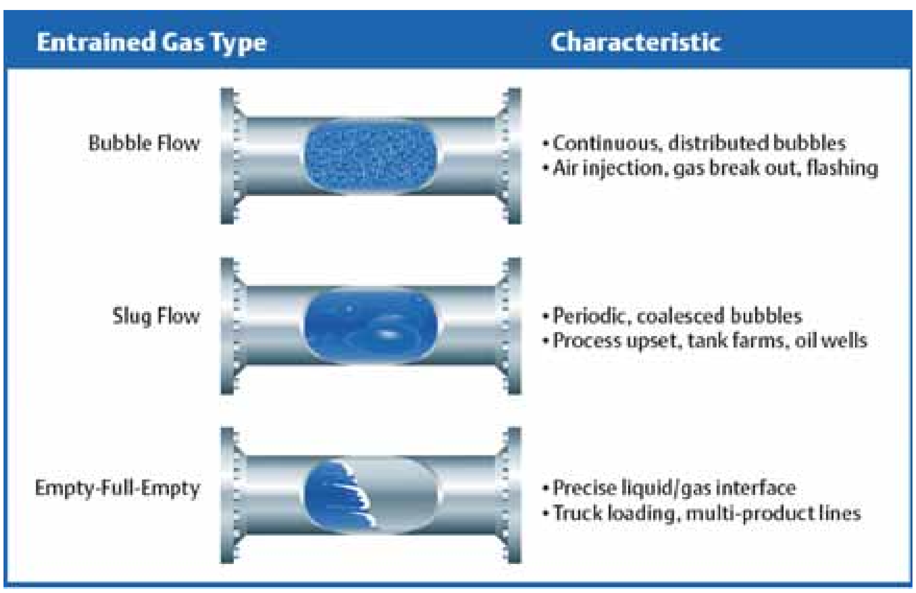


Figure 1. *Types of entrained gas*

Characterizing Entrained Gas

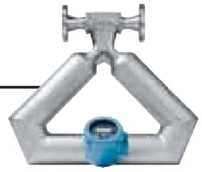
To understand how recent technologies have largely overcome problems related to entrained gas, it is important to understand the different categories of entrainment: slug flow, bubble flow, and empty-full-empty (EFE).

Slug flow is the occurrence of periodic large, coalesced gas bubbles in a liquid process. Slugs are usually not intentional and can be disruptive to flow and density measurement. Slug flow is commonly found in long-distance piping that does not fill properly. It may occur as a result of leaks in pump suction or tank agitation, allowing air to be pulled into a line.

Bubble flow is continuous distribution of gas bubbles (usually air) in a liquid process. The gas could be injected intentionally or could be caused by faulty equipment somewhere in the piping. Bubble flow is commonly found in high-viscosity liquids, such as toothpaste or peanut butter. It can also be present in products that are agitated or pumped at high speeds, as well as in environments where cavitating pumps or broken pump seals are a factor in the process. Most processes with bubble flow have less than 5 percent entrained gas, though in rare cases the value can be higher.

Empty-full-empty (EFE): In the case of EFE, piping starts empty, fills with liquid, remains full for the duration of the batch, and then empties upon completion of the batch. This batching is commonly found with railcar and tanker truck loading. Because the piping and the meter must be emptied between each fill, measurement can be a challenge when using a flowmeter that is configured for only liquid processes.

A subset of empty-full-empty batching is a condition referred to as multiphase flow — processes with multiple density phases with some degree of separation and a mixing layer between them. The width of the mixing layer, dispersion of bubbles, and pipe orientation are all large contributors to the flow structure. Multiphase flow is commonly found in gas injection and well-head testing applications where multiple fluids coexist in the pipe — namely oil, water, and gas.



The Design Challenge

The biggest design challenge for Coriolis flow measurement is that gas entrainment in a pipeline is actually a continuum offering an infinite variety of conditions. To determine how these conditions affect the performance of the meter, development engineers at Emerson Process Management (*www.emersonprocess.com*) used flowmeters with clear tubing to observe what actually occurred inside the meter. These observations, along with simplification of gas entrainment into bubble, slug, and EFE, enabled the engineers to develop a flowmeter sensor and electronics that significantly expand the meter's capabilities under entrained-gas conditions.

These investigations concluded that four key elements played a role in the entrained-gas performance for Coriolis meters — the signal processing speed, processing algorithms, sensor design, and meter stability independent of environmental changes.

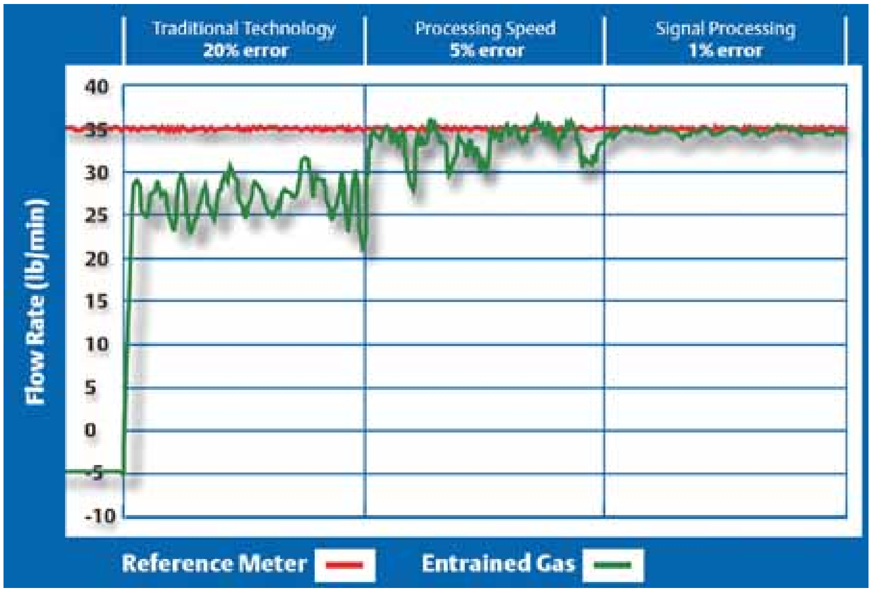


Figure 2. *Accuracy graph showing performance of new Coriolis flowmetering technology under entrained gas conditions.*

Improving Slug Flow & EFE Performance

Emerson's Micro Motion Coriolis flowmeters feature MVD (multivariable digital) technology. The accuracy and stability of the Coriolis signals are considerably improved by digitally processing the signal from the flow sensor. Digital signal processing also delivers online monitoring and diagnostics data, providing predictive process and flowmeter health information.

The characteristics of gas entrainment in slug flow and EFE batches cause frequent and large disturbances within the Coriolis meter that require the signal processing to be able to control and interpret a chaotic vibration. By increasing the processing speed in the Coriolis electronics, the meter is able to measure all these variables in synchronization with the disturbance. The improved signal processing and drive control optimize performance for transient events.

These developments have helped Micro Motion significantly reduce the flowrate error during the entrained-gas state from 20 percent with traditional technologies to just 1 percent using the company's latest-generation ELITE flowmeter with enhanced core processor.

Overcoming Bubble-Flow Conditions

Under bubble-flow conditions, the Coriolis sensor design and sensor stability dictate measurement performance. Sensor design is important because the critical bit of information is the relative difference in motion of the bubbles and fluid. Sensor stability is important because sensor vibration during bubble flow can be noisy and can cause the sensor to couple to the environment. With added stability, Coriolis flowmeters can ensure that noise introduced by bubbles causes minimal flow measurement errors.

Measurement is further compromised when bubbles change the compressibility of the fluid. As the level of gas entrainment increases, so does the measurement error. Tests show that for a given amount of entrained gas, the measurement error becomes more pronounced as the meter drive frequency is increased. By operating at lower frequencies, Coriolis flowmeters can minimize these errors.

Final Results

By addressing the four key design elements identified during its development research for entrained-gas applications — processing speed, signal processing, sensor stability, and sensor design — Micro Motion believes that many measurement applications once deemed impossible are now well within today's measurement capabilities. Regarding gas/liquid mixture applications specifically — whether the combination of gas and liquid flow is by design, by flaw, or as a consequence of day-to-day operations — Micro Motion is confident that it has developed methods that are capable of providing measurement accuracy and minimizing waste under such conditions. FC

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