

## Entrained Gas Handling in Micro Motion® Coriolis Flowmeters

### Introduction

This white paper discusses the measurement problems caused by process fluids that contain bubbles of air or other gas, and describes how Micro Motion® sensor and transmitter technology can be used to overcome those problems. This white paper also presents suggestions for minimizing measurement problems by improving application design.

Although the most common term applied to this problem is “entrained air,” in fact the bubbles may contain any gas. This white paper uses the term “entrained gas” rather than “entrained air” in order to address the broader topic. Other frequently used terms include “two-phase flow” and “slug flow.”

### Historical perspective

Micro Motion products were originally developed for the chemical industry, where most applications contain very little entrained gas, and Micro Motion's product vision focused on high measurement accuracy in clean fluids. As Coriolis technology has moved into other applications and other industries, the issue of entrained gas has become more significant. While, in fact, more than 95% of applications do not have a problem with entrained gas, entrained gas handling is critical for those few applications that do.

### The entrained gas problem

Micro Motion's Coriolis sensor technology produces direct measurements of mass, density, and temperature. When gas is present in a liquid stream, it occupies volume. It is important to understand that entrained gas does not cause primary measurement errors in mass flow measurement: Coriolis technology measures any fluid mixture in the tubes. However, because the density measurement is a ratio of mass to volume, if some of the volume is occupied by gas, which is less dense than liquid, then the overall density of the mixture must decrease. Because most applications need to know the density of the liquid only

(the liquid fraction) rather than the density of the mixture, the density value reported by the meter *will not be incorrect, but will be low for application purposes*. Until Coriolis meters can reach beyond measuring “just what is in the tubes” and distinguish fluid phases, this deviation will not be correctable.<sup>1</sup>

### Micro Motion technology

Existing Micro Motion technology can be used with good results in applications that contain entrained gas, if the correct products are used and configured appropriately. In addition, certain application characteristics can improve measurement. These application characteristics are discussed in the section entitled “Application recommendations.”

#### *Sensor technology*

For two-phase flow, the best measurement is provided by dual-tube sensors with a low tube frequency. If a sensor with high tube frequency is used, the two-phase fluid does not vibrate with the tube, resulting in large measurement errors for flow. Micro Motion's ELITE® sensors are recommended for applications with entrained gas. F-Series and R-Series sensors meet application requirements in certain situations. Because the single-tube T-Series sensors have a high operating frequency, they are not recommended for applications with entrained gas.

#### *Transmitter technology*

In general, analog signal processing, as used by Micro Motion's RFT9739 and earlier transmitters, is not flexible enough to measure two-phase flow. There is no way to change or optimize the signal processing chain for a specific application.

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1. Because Coriolis meters use density data to calculate volumetric flow, the density deviation will cause a proportional error in the volumetric flow indication.



Micro Motion's MVD™ technology employs digital signal processing (DSP). This allows the transmitter software to apply algorithms to the raw sensor data to compensate for specific conditions. In the case of entrained gas, the transmitter must remove or “look through” the noise imposed by the two-phase flow, and report only the “real” flow measurement of the liquid. The DSP algorithms in the MVD electronics very effectively filter the noise and provide an excellent measurement.

### Transmitter configuration

For two-phase flow, two transmitter configuration parameters are central:

- “Special mode” is used to increase the rate at which sensor data is reported to the transmitter. This allows the transmitter to filter, process, and report compensated density data almost instantaneously.
- “Fault action” is used to control the behavior of transmitter outputs under certain process conditions such as two-phase flow. The factory default setting for fault action is to drive outputs to fault levels, which means that they no longer report process data. When fault action is set to “none,” outputs continue to report process data during two-phase flow conditions.

In current Micro Motion products, these parameters are set by activating the “Entrained Gas” option. In the next generation of Micro Motion products, special mode will be activated automatically and alarm handling has been changed to allow user configuration of fault severity levels. When two-phase flow alarms are set to a lower severity level, outputs will report process data during conditions of two-phase flow, but will still report all alarms configured for higher severity levels. The transmitter can optionally log the two-phase flow alarms.

### Transmitter zero

Unstable fluid conditions (e.g., air separation from the liquid at low or zero flow) can cause significant measurement errors. For this reason, performing an auto-zero under unstable fluid conditions is highly discouraged. If the field zero is suspect, return the meter to the factory zero or the prior zero. Depending on your product, either or both of these is saved in transmitter memory.

## Application recommendations

The most important application factor in improving two-phase flow measurement is bubble distribution. For best measurement results, the gas bubbles in the process fluid should be distributed as evenly as possible between the

two sensor tubes, and should move through the tubes at the same rate that they entered the tubes. The following factors contribute to even bubble distribution:

- *Straight pipe runs.* The swirl imposed by elbows in the piping can cause gas to enter the sensor tubes unevenly, causing measurement errors.
- *Higher flow rates.* If flow rate is sufficiently high, bubbles move through the sensor tubes at approximately the same rate at which they entered the tubes, counteracting the effects of bubble buoyancy (produced by gravity) and low-viscosity fluids as discussed below. When it is known that entrained air is present, Micro Motion recommends a flow rate no lower than 1/5 (one fifth) of full scale.
- *Vertical pipe runs with upward flow.* Especially at lower flow rates, bubble buoyancy tends to result in bubble collection at high spots in the sensor tubes (see Figure 1a). In Figure 1b, bubble buoyancy works with the flow to move bubbles through the tubes.
- *Viscosity.* High-viscosity fluids tend to hold the bubbles in suspension better than low-viscosity fluids, maintaining their original position and distribution and therefore moving them through the sensor with the liquid. Also, in high-viscosity fluids bubbles are more likely to stay dispersed, while in low-viscosity fluids small bubbles may coalesce into large bubbles that are more likely to collect.

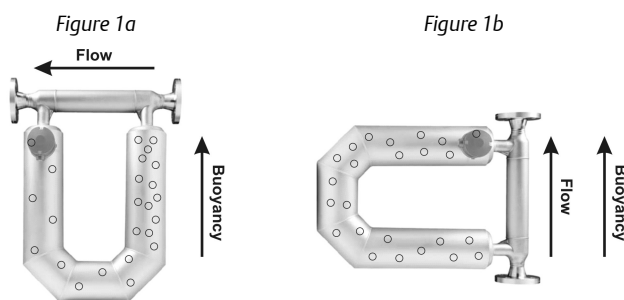


Figure 1. Effects of sensor orientation on bubble distribution

A mixer can be used to help distribute bubbles. If a mixer is used, it should not swirl the flow.

To address the boundary problems of Empty-Full-Empty batching, batch duration and meter fill time can be checked. In laboratory testing, batches with a duration of one minute or longer tended to be immune to the transient errors caused by gas remaining in the sensor tubes. As shown in Figure 2, repeatability improves as batch duration increases. Field experience has demonstrated that if the meter fill time is less than 0.1 seconds and the batch time is greater than 2-3 seconds, good Empty-Full-Empty batching

performance can be expected with mass repeatability well below 0.1%. Meter fill time is a function of meter size and flow rate.

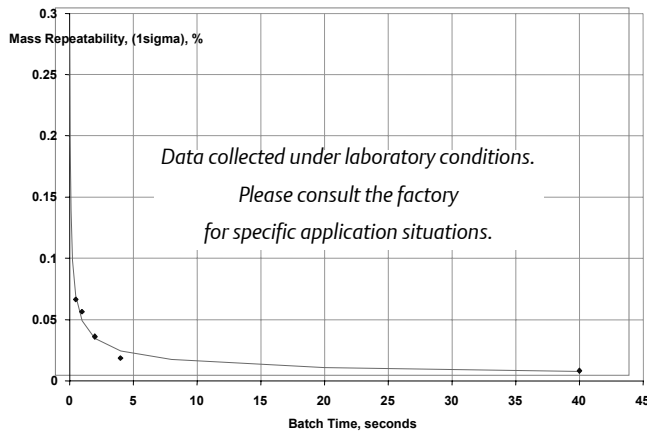


Figure 2. Effects of batch duration on repeatability

**Summary**

With appropriate product selection, installation, and configuration, Micro Motion's dual-tube Coriolis sensors paired with MVD technology minimize or overcome the measurement problems caused by entrained gas. As a result, the benefits of Micro Motion's Coriolis technology are available to an expanded set of applications in a broader range of industries, providing highly accurate measurement of mass flow, density, and volume flow with a single low-maintenance low-installed-cost device.

**About the author**

Tim Patten has been with Micro Motion, Inc. since 1989, in various engineering and marketing roles. He holds an M.S. in Mechanical Engineering from Worcester Polytechnic Institute in Massachusetts. He is currently the Measurement Director.

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