KNOWLEDGE

Explaining how two-phase flow affects mass flowmeters

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Overview

This article discusses the effects of two-phase flows on Coriolis meters in general and Micro Motion meters in particular. Two-phase flow is defined here as a gas/liquid mixture moving through the pipeline (and mass flowmeter.)

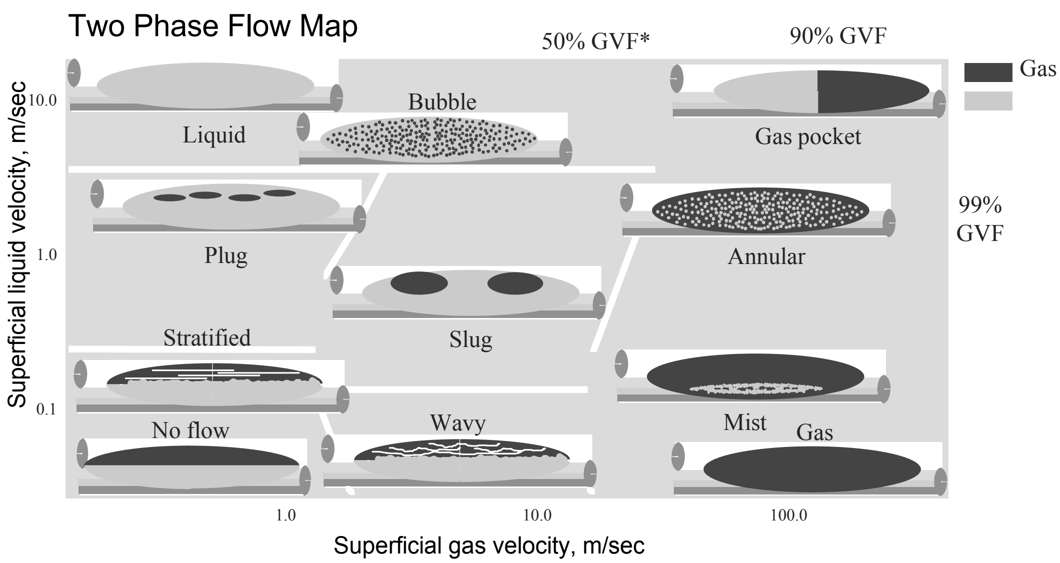
The following Mandhane flow map (based on an article in the Oil & Gas Journal, April 1995) represents the typical distribution of liquid and gas across and along a pipe. With changing flow rates and gas/liquid content the distribution of the two-phases can change considerably and various (liquid) flow patterns can be identified. Please note that this map typically represents the behaviour of liquids with viscosity up to approximately 10 cP. Higher viscosity can change the physical distribution and interaction of the two phases considerably.

How much (% volume) gas can be measured in liquid is one of the most difficult questions that can be asked about Coriolis meters, as a lot of parameters (like distribution of the gas, operating pressure, viscosity and installation etc.) have direct influence on the capability to do so. Next to this there is always a practical consideration: the user will (nearly) never know for sure how much the gas percentage is in the pipeline, so s/he will make a guess. Immediately the danger lurks how to quantify this guess - for some people 5% gas content is a lot, for others 25% gas content is a "small" amount. Basically the safest answer is no gas, but under certain well defined conditions it's very well possible to measure liquids with gas content.

We will try to quantify and explain this in more detail. By comparison, some Coriolis meter suppliers have made some wild claims concerning the amount of gas that can be measured in the past (and probably also in the future), clearly showing that they are not aware what is happening in the unit under operating conditions.

Let's look first at why the Coriolis meter will generally not be able to measure two-phase flows. The best way to explain it is that the Coriolis meter is attempting to accelerate the total mass (the liquid and the gas) when it is travelling through the measuring tubes. If the meter can accelerate the gas (bubbles) with the liquid, normally due to the inertia (viscosity), it will operate mostly without problems. But if the meter cannot do this (for example the gas content is too high, or the viscosity too low) , the liquid will "slosh" around and the measuring tubes will be dampened out and stop vibrating. This situation is called "saturation" of the meter.

A good analogy is a basketball: filled up and pressurized with 100% air or water, it will bounce from the ground (interestingly enough at different frequencies - due to the density change - the same operational principle as our meter!) But if it's half full with liquid and water and hits the ground, the energy will be immediately dissipated by the "sloshing" around and it will not bounce, however hard you try.



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Flow patterns and the use of aIr eliminators

Slug flow condition: The most common two-phase flow regime is called slug flow, in which the pipe cross section is filled alternatively with gas and liquid. Voids in the liquid will degrade the meter performance due to the above mentioned saturation of the measuring tubes. However, the big advantage of a Coriolis meter in these kind of applications is that it cannot be damaged in comparison to mechanical flow meters. Further the measurement will continue when the situation in the tubes has stabilized.

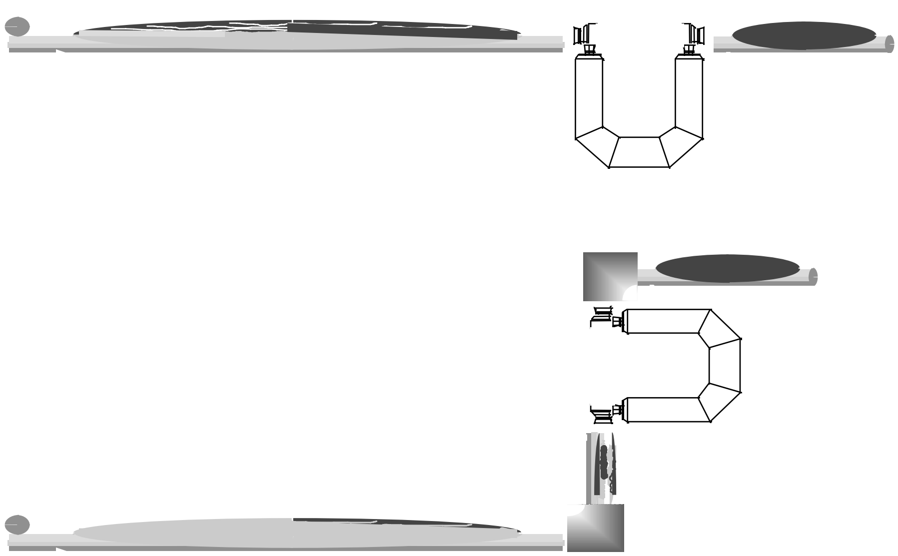
If this "slugging" is a continuous process, Coriolis meters cannot be used directly and an air eliminator has to be installed to separate the gas to ensure a good measurement. This is standard practice for traditional volumetric flowmeters.

If, however, this slugging happens in the beginning and at the end of a batch (for example starting and stopping batches with an empty meter) it might be possible to use a mass flowmeter directly without an air eliminator.

For this Micro Motion has incorporated the "slugflow" option in the electronics. This is a function wherein a minimum/maximum density "window" is set in which the meter is allowed to operate. When the meter detects densities outside this window, control outputs might be activated in order to adapt the operation of the process properly. Further the pulse outputs might be driven to zero to avoid counting.

Sensor mounting position

Especially with slug flow condition, the installation can be very important. Mounting the sensor in a so-called "flag" position brings the advantage that the liquid is forced to collect before going through the sensor, thus greatly reducing the liquid/gas transition times.



Stratified and wavy patterns: If there are large void fractions low (gas/liquid) velocities can result in what is called stratified and wavy patterns. These regimes can have two separate layers, one liquid and one gas. In these conditions the sensor will always be in saturation, therefore an air eliminator has to be used.

Plug condition: Small void fractions and high liquid velocity can produce the plug pattern. In some cases meter can work (with very noisy flow signals), but in general we do not advise to use it in this regime. Again, use an air eliminator or change the process to avoid this regime.

Bubble and annular patterns: In the bubble and annular patterns, gas - well-mixed and up to certain contents - can be very well measured depending on the viscosity and the design of the meter (for example, straight tube meters have much more problems with gas than U-shaped tubes). In a major comparison testing done by NEL (National Engineering Laboratory 1993, UK) on eight different mass flowmeters, it was found that when air was injected into water up to approx 5% volume, Coriolis meters can work; however, five meters failed due to stopped operation or unacceptable errors.

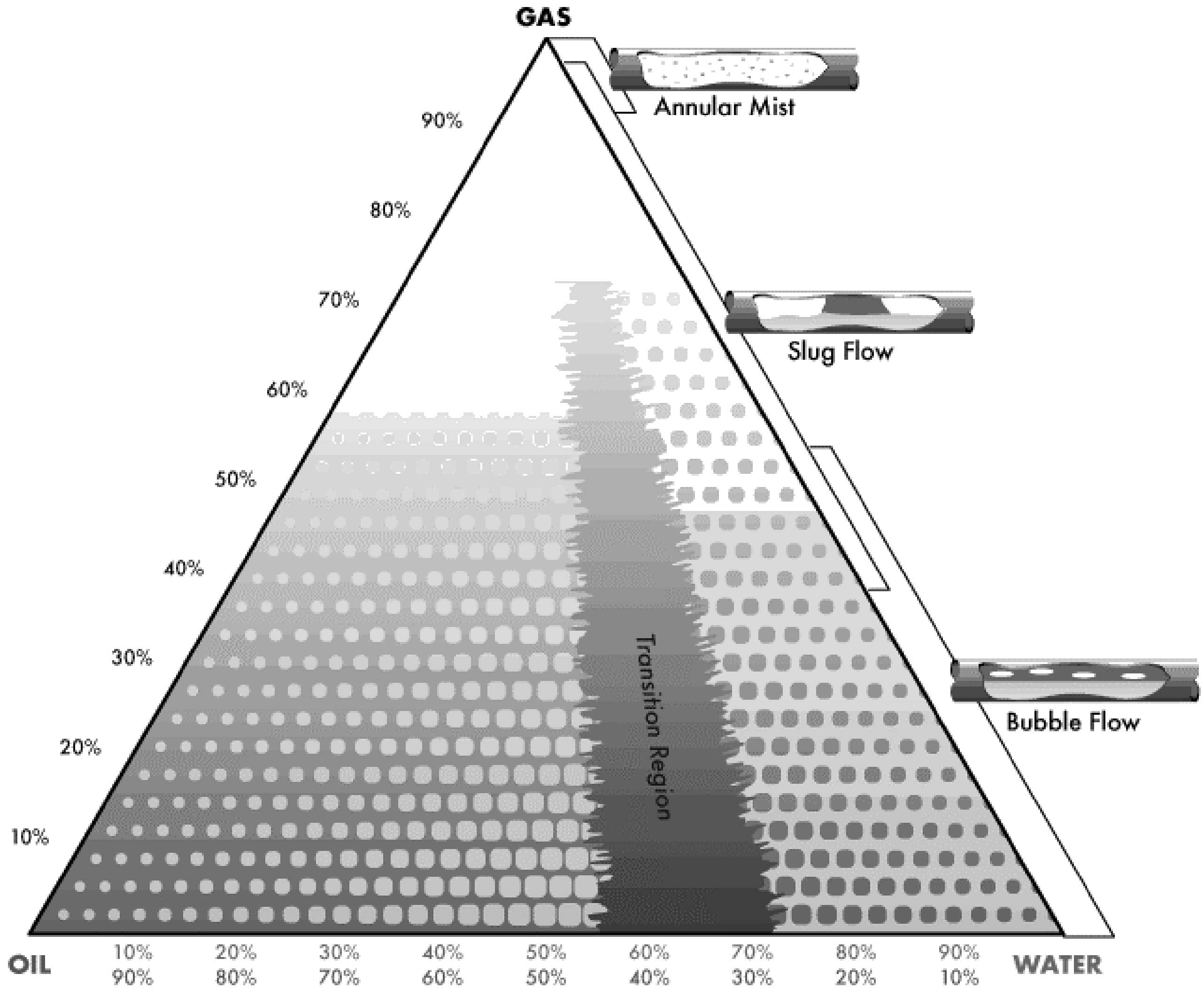
Interestingly, one of the manufacturers who now claims in their specification sheets that 20% gas entrainment is measurable, came out as one of the worst. Emerson participated with a Micro Motion D100 sensor. We can assume that the Micro Motion ELITE product line can cope with even more percent gas volume as the older Micro Motion D meter could.

Conclusion

Again, many factors can influence the ability to measure entrained gas, but especially viscosity is important. To give you some guidelines, the following limits have been seen at some applications in the field with Micro Motion sensors:

Product	Viscosity	Max. gas content
LPG	0.1 cp	0.5%
Water	1 cp	5%
Latex	5000 cp	50%

It is advisable to consult Emerson flow experts for help in situations when you are not completely confident whether entrained gas protection will be needed or not, and what kind of method should be applied for optimal efficiency.


GAS
Annular Mist
Slug Flow
Bubble Flow
Transition Region
90%
80%
70%
60%
50%
40%
30%
20%
10%
OIL
WATER
10% 90%
20% 80%
30% 70%
40% 60%
50% 50%
60% 40%
70% 30%
80% 20%
90% 10%

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Micro Motion, Inc. USA
Worldwide Headquarters
7070 Winchester Circle
Boulder, Colorado 80301
T (303) 530-8400
(800) 522-6277
F (303) 530-8459
www.micromotion.com

Micro Motion Europe
Emerson Process Management
Wiltonstraat 30
3905 KW Veenendaal
The Netherlands
T +31 (0) 318 549 549
F +31 (0) 318 549 559

Micro Motion Japan
Emerson Process Management
Shinagawa NF Bldg. 5F
1-2-5, Higashi Shinagawa
Shinagawa-ku
Tokyo 140-0002 Japan
T (81) 3 5769-6803
F (81) 3 5769-6843

Micro Motion Asia
Emerson Process Management
1 Pandan Crescent
Singapore 128461
Republic of Singapore
T (65) 6 777-8211
F (65) 6 770-8003

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