High-precision liquid flow processes demand full fluidic control

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One of the most challenging aspects of achieving high precision in any type of fluid flow process is to maintain meticulous control of the delivered volumes per time unit. Often this requires high-frequency supervision of the liquid stream to ensure that dissolved gases do not out-gas to form bubbles. This article discusses how to address these requirements with a set of powerful tools to monitor liquid flow rate on the millisecond timescale, and to remove dissolved gases well before they cause system pressure instability.

The solubility of gases in liquids is a fundamental topic. For instance, life in the ocean is entirely dependent on this phenomenon, and many people enjoy consuming sparkling beverages. In other situations, dissolved gases may cause us troubles by outgassing causing the formation of microbubbles or by the reactivity of the gases. Just as oxygen dissolved in water forms the basis of life in the sea, it also makes the water a corrosive environment through its oxidation potential. The dissolution of gases is inherently a dynamic process and there is no such thing as a bottle of fully degassed liquid. The solubility of gases depends on the type of gas and type of liquid, as well as most importantly the temperature and pressure of the system. In general, gas solubility in liquids decreases as the temperature increases, and when the pressure decreases. The influence of temperature and pressure on the solubility of air in water is shown in *Figure 1*.

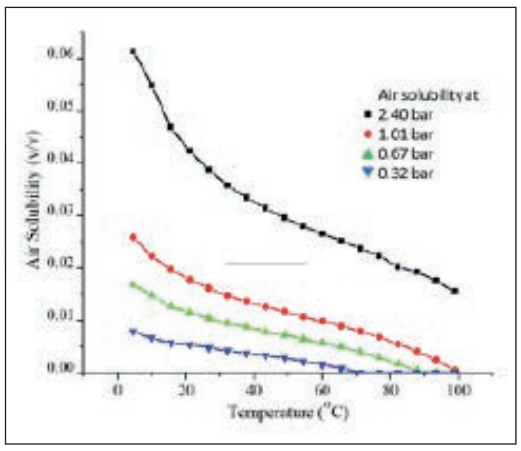

Figure 1. Solubility of air in water at different pressures as a function of temperature. The solubility of air decreases by approximately 40% on warming up a refrigerated solution to room temperature. Reduced pressure or negative pressure transients, frequently produced by pumps, reduces the solubility even further, resulting in outgassing and dispensing errors.

In industry and laboratory applications, dissolved gases can cause problems either by bubble formation, compromising the flow stability, or by the nature of the gas in question. Bubble formation by out-gassing occurs when the solubility limit of the gas is exceeded. This is a quick and dynamic process which often makes it difficult to detect as the bubbles formed can re-dissolve when the solubility increases again. Formation of microbubbles frequently occur at negative pressure transients, especially in pressurised systems, and at local hot spots. Blending solvents may also cause outgassing since the gas solubility in the mixture commonly is lower than in the individual solvents. One such example is the mixing of methanol and water that is well-known to result in outgassing. The release of energy from the formation of water-methanol hydrogen bonds in this mixture further accelerates the outgassing by increasing the solution temperature.

Widely used in industrial and laboratory applications to solve issues with outgassing and bubble formation, the DEGASi® line of highly efficient in-line degassers has been proven to continuously reduce the dissolved gases well beyond the levels where formation of microbubble can occur. These degassers have been designed to meet the very stringent requirement of chemical compatibility with negligible material leakage and stable degassing performance, which is essential within chemical analysis such as HPLC. The action of gas permeable Teflon™ AF membranes in these degassers is illustrated in *Figure 2*.

Secondary uptake of gases into a degassed liquid flow is sometimes overlooked even though this may have a significant impact on overall degassing efficiency. It is therefore also important to consider the choice of materials in your fluidic system after the degassing step. To eliminate secondary gas uptake through the flow lines, gas permeable materials like silicone and PTFE must be avoided. This becomes even more important with longer system tubing. The recommended polymeric tubing materials to minimise secondary gas uptake are Fluorinated Ethylene Polypropylene (FEP), or even better, Tefzel® EFTE, combined with suitable fittings. By choosing the proper polymer-based tubing material, metal tubing can often be completely avoided, making fluidic system assembly and future service very much easier.

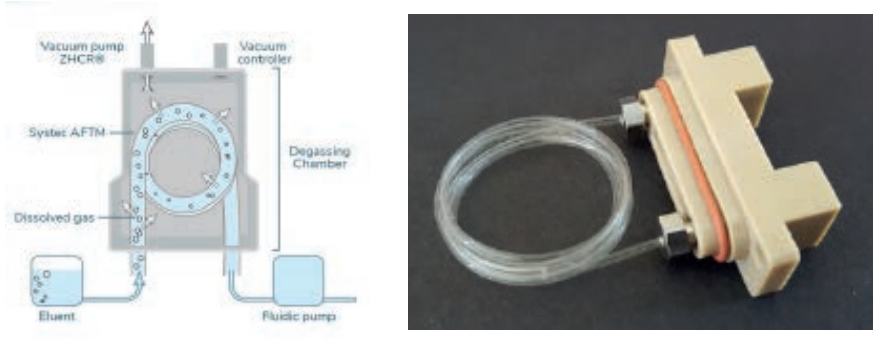

Figure 2: Schematic of the gas permeable membrane within a degassing chamber connected to vacuum pump and controller (left), and a photo of the internal construction of an in-line vacuum degasser based on Teflon™ AF membrane (right). The well-controlled vacuum in the degassing chamber provides the driving force for the dissolved gas to pass through the degassing membrane.

In flow process applications, especially with several parallel or merging liquid flows, keeping flow rates accurate is critical to achieve the required high-precision results. Even using the best quality pumps, actual process flow rates may not be as reliably consistent as some pump suppliers might claim. Variation in delivered flow can arise because pumps are often calibrated under ideal conditions with pure solvents, while flow processing often involves quite concentrated solutions where viscosity may differ. Pump pulsation is also known to significantly contribute to deviations in the fluidic profile and net process outcome.

The Biotech Liquid Flow Meter offers a solution to this issue by enabling monitoring of liquid flow rates with a resolution on the millisecond timescale. This convenient device is available in several varieties optimised for different flow rate ranges (from 10 nL/min up to 650 mL/min), all based on a sampling speed up to 13 Hz (78 ms). Its continuous read-out and computer-saved data can be used as feedback to fine-tune pump settings. This device, much like the degassers, is built to be entirely compatible with the fundamental principles of almost any chemistry. This ability to perform high-precision measurements of liquid flow rates at millisecond time resolution is creating a new understanding of how fluidic systems work. This new high performance flow monitoring technology offers a lower priced alternative to Coriolis flowmeter technology or manual approaches, which lack time resolution and absorb large amounts of technician time.

Summary

To ensure the high-precision liquid flow required by many analytical scientific instruments and fluidic processing applications a new generation of high-performance degassers and real time liquid flowmeters is necessary.

In-line degassers have been proven to continuously reduce the dissolved gases well beyond the levels where formation of microbubble can occur. Today, in-line degassers are available that meet the stringent requirement of chemical compatibility with negligible material leakage and stable degassing performance, which is essential with widely used techniques such as HPLC.

In liquid chromatography and fluidic processes, maintaining flow rate accuracy is critical to achieving high-precision results. Significant variation in delivered liquid flow from pumps can arise due to effects such as gas bubbles, dissolved gases, and pulsation.

A new generation of thermal flowmeters offering the ability to perform high-precision measurement of liquid flow rates at millisecond time resolution is creating a new understanding of how fluidic systems work. This new high performance flow monitoring technology offers a lower priced alternative to Coriolis flowmeter technology or manual approaches, which lack time resolution and absorb large amounts of technician time.