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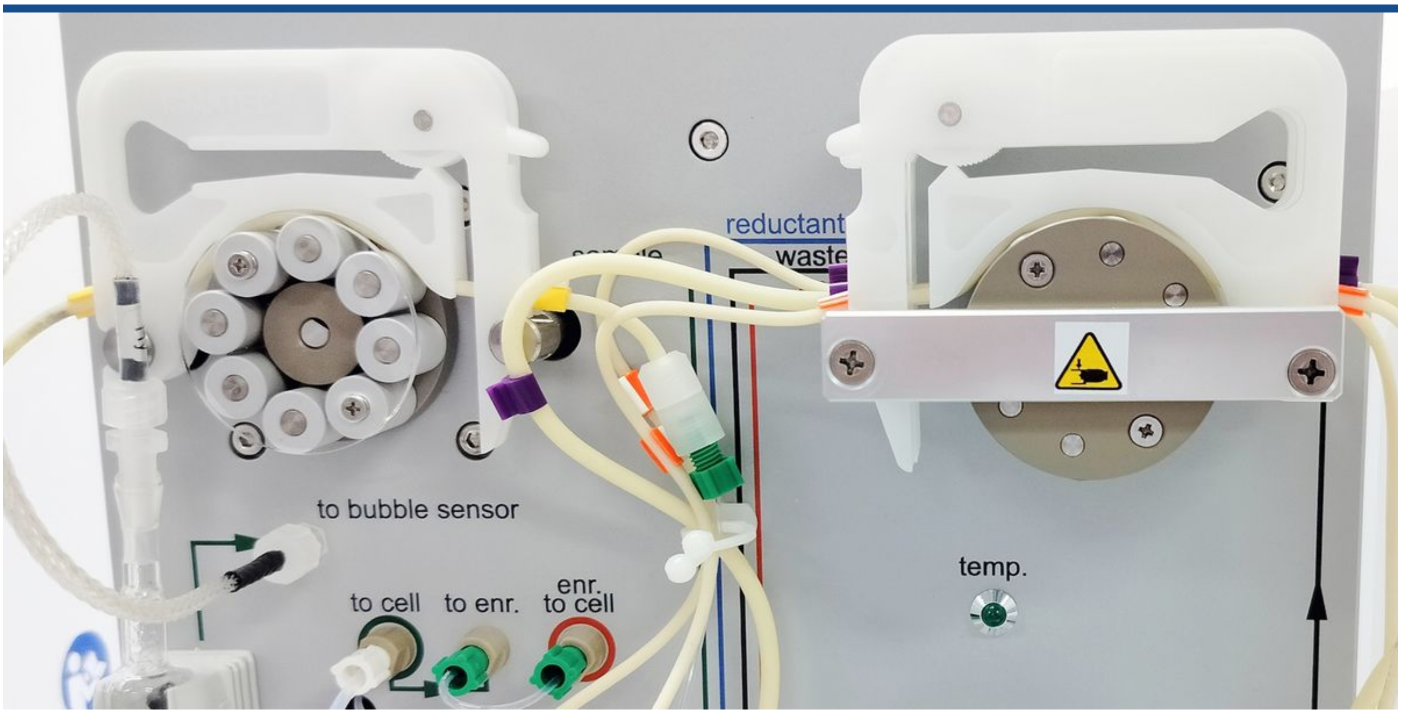

Studying the Impact of Dissolved and Undissolved Gas on the Performance of Peristaltic Pumps

A set of experiments illustrating how dissolved gas can affect peristaltic pumps in chromatography processes

Jul 27, 2023 Carlo Dessy

Peristaltic pumps are fluid delivery tools widely used in laboratory techniques including high-performance liquid chromatography (HPLC), gel permeation chromatography/size-exclusion chromatography, flow chemistry and liquid dosing. It is widely acknowledged that dissolved gas can have an impact on the performance of peristaltic pumps. A common solution to address this problem with these systems is to utilize a vacuum degasser on the inlet side of the pump.

A vacuum degasser is a chamber kept under vacuum pressure that contains a length of gas-permeable tubing leading the solvent to the pump. Any gas dissolved in the solvent will be extracted in the vacuum chamber before it can reach the pump. Vacuum degassers have been shown to be very efficient at removing dissolved gas; however, they fail completely if any undissolved gas bubbles are transported along the tubing. In this scenario, undissolved gas bubbles pass the degassing device largely unaffected by the vacuum and will reach the HPLC pump, leading to unreliability and affecting analytical results. This led to the question as to what effect dissolved gas might have on the performance of peristaltic pumps.

In this study, we first investigated whether dissolved gas might also have an impact on peristaltic pumps and be the source of inequalities seen in the performance of dual-cartridge systems.[1] In further investigations, we demonstrate the effect of undissolved gas bubbles on pump performance and introduce a novel solvent line monitoring device that provides a simple way of eliminating the problems resulting from this effect.

Experiment #1

In this study, we used a dual-cartridge peristaltic pump equipped with two new lengths of Tygon tubing with a nominal inner diameter of 0.76mm designed to deliver flow rates between 0.1 and 5 mL/min. Flow rate was measured using two liquid chromatography flowmeters, which precisely measure real-time flow rates from 0.01 to 5 mL/min. Deionized water was used as the test liquid for our experiments.

After conditioning the peristaltic pump at a nominal flow rate of 1 mL/min for several minutes, we started a ramp experiment with incremental increases in steps of 0.5 mL/min from 0.5 mL/min to 5.0 mL/min nominal flow rate. Data was acquired on each step for about 120 seconds. Between steps, the flow rate was set to zero gain to ensure the same conditions for the whole ramping experiment.

Our experiments were designed to investigate the different impact of dissolved gases and undissolved gas bubbles associated with dual-channel peristaltic pumping of a liquid to a flow chemistry system or similar applications.

Our first experiment investigated the comparative flow from the two channels of the peristaltic pump at different flow rates (see Figure 1) below.

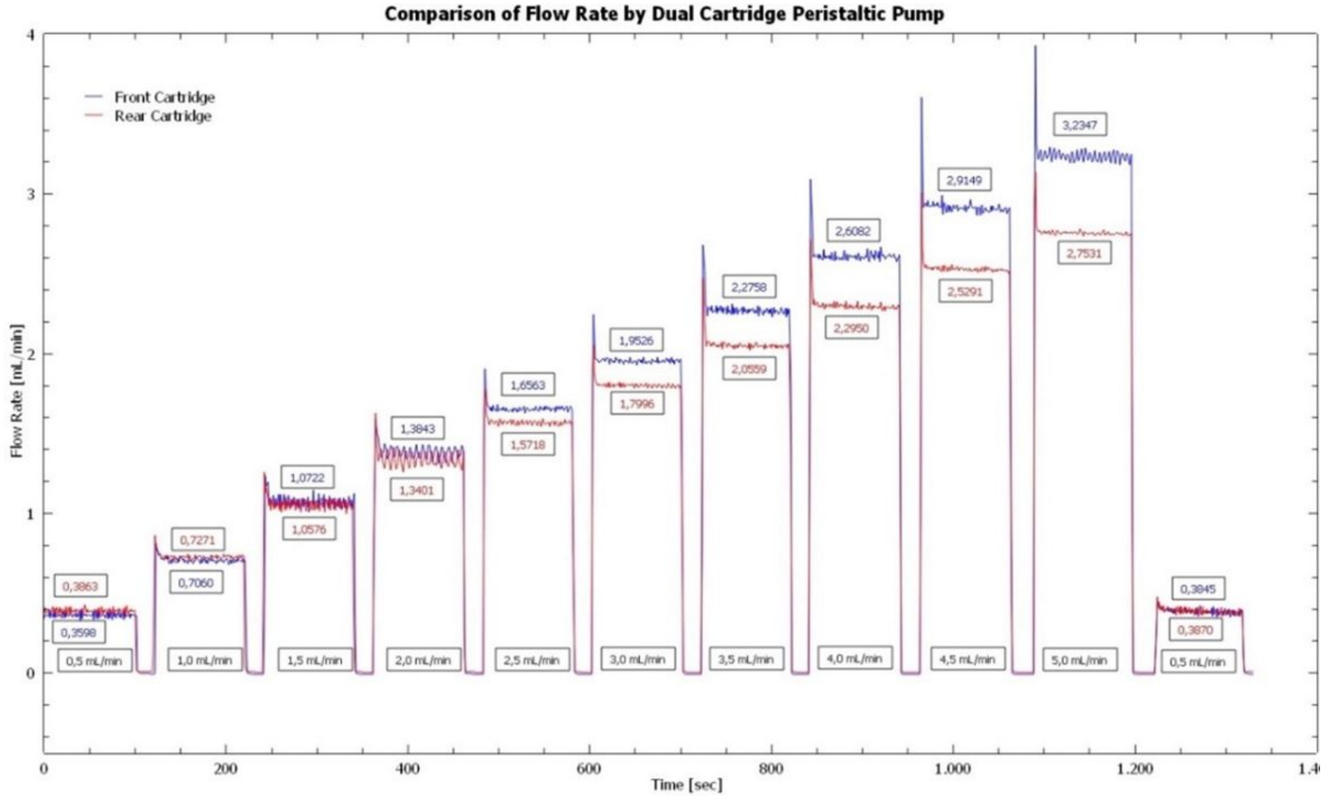

Figure 1: Comparing flow rate in the 2 channels of a dual-cartridge peristaltic pump

The results from our first experiment revealed that the two peristaltic pump channels, thought to be identical as they are driven by a common shaft and equipped with the exact same length of tubing, performed quite differently with a notable increasing difference of real flow between the two channels.

Experiment #2

In our second experiment, we investigated the effect of connecting a dual-channel vacuum degasser on the inlet lines, between the solvent reservoir and pump. This is a set-up commonly used in many liquid chromatography applications to remove dissolved gases.

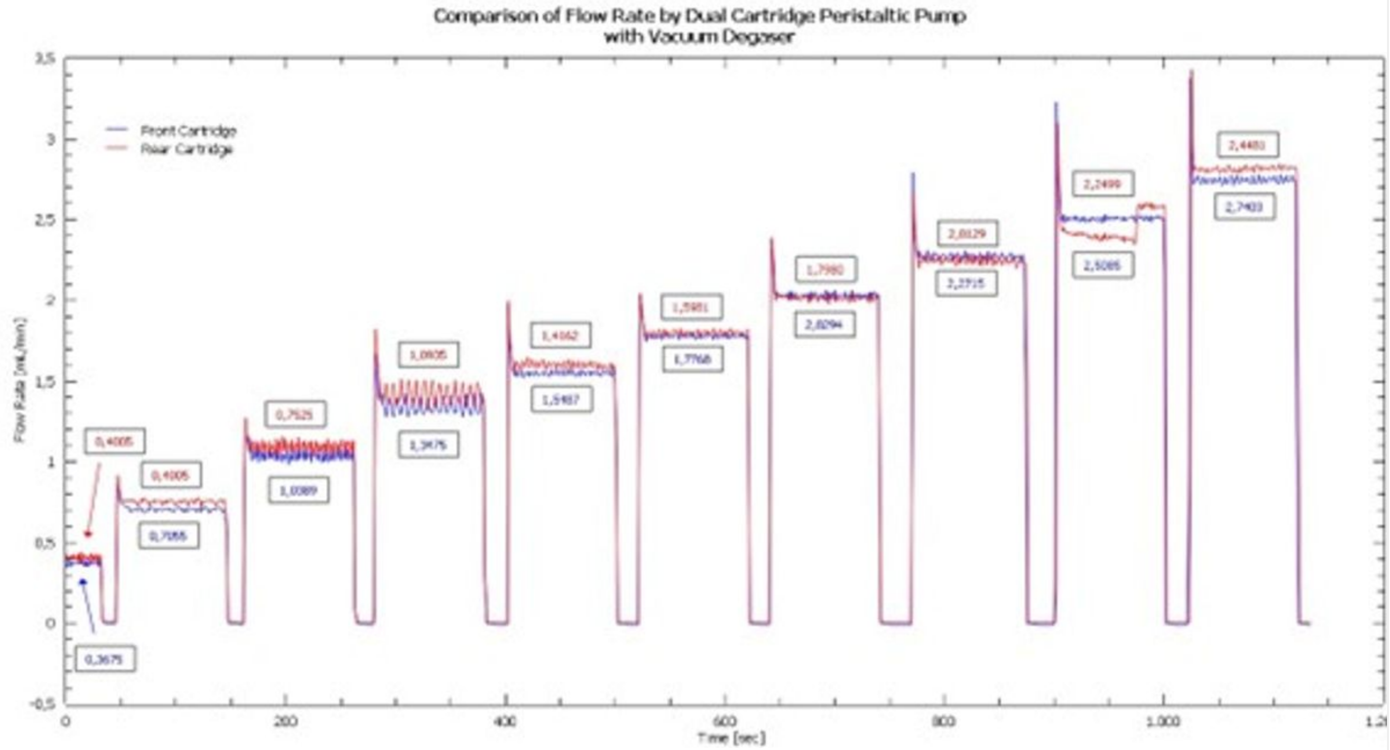

Figure 2: Comparing the flow rate in the two channels of a dual-cartridge peristaltic pump with a vacuum degasser on the inlet lines.

As shown in Figure 2, the measured flow results are now very similar for both channels—a completely different result from the first experiment.

The above demonstrates the value of using a degasser with a peristaltic pump feeding solvent to a liquid chromatograph or flow chemistry system. Undoubtedly the degasser has done its job of removing dissolved gases, improving overall performance of the peristaltic pump.

Experiment #3

In our third experiment, we investigated the effect of an undissolved gas bubble on the flow rate of liquids delivered by a peristaltic pump.

To demonstrate the effect of undissolved gas, we introduced a small gas bubble into the inlet line of one of the peristaltic pump channels while monitoring the flow rate (see Figure 3).

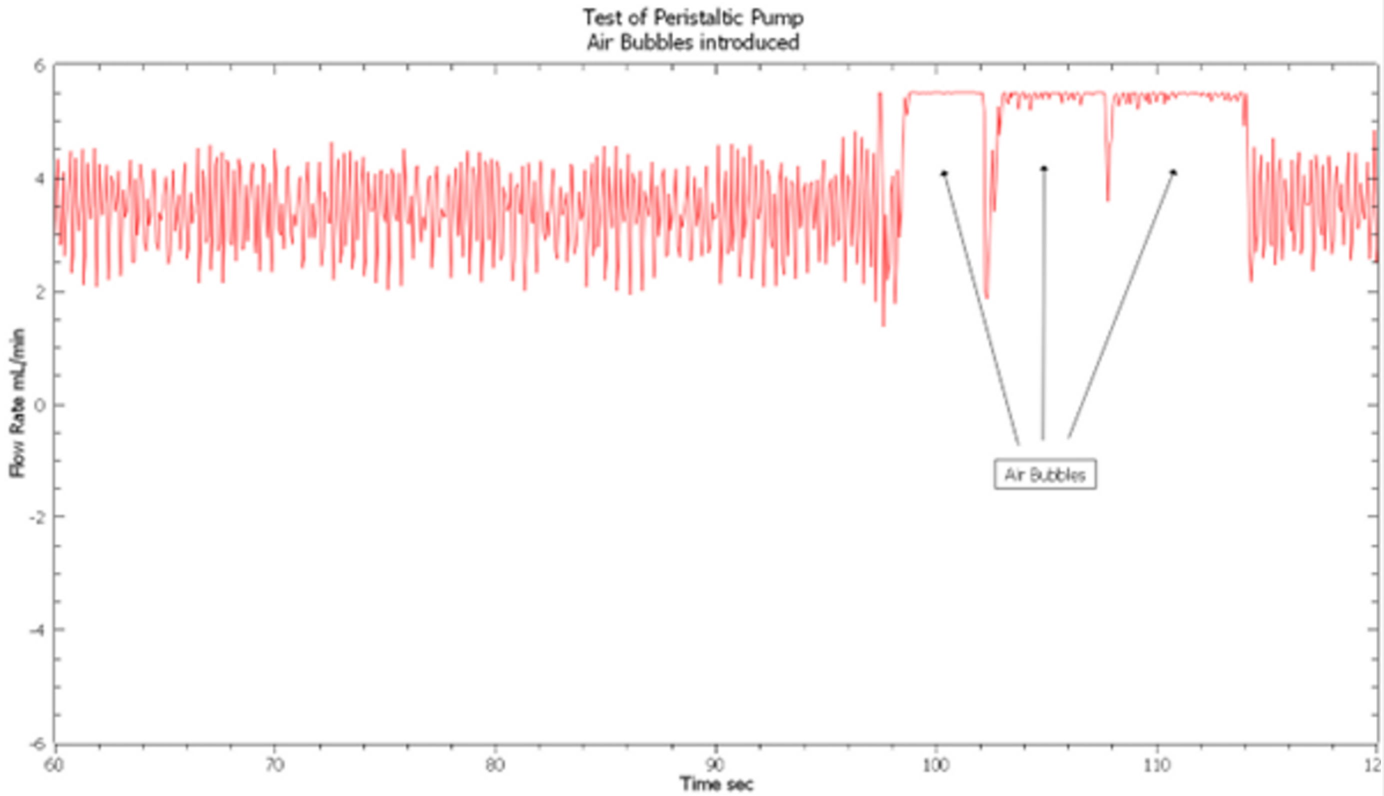

Figure 3: How undissolved gas bubbles affect peristaltic pump flow measurement.

The data above shows that the undissolved gas bubbles passed the vacuum degasser unperturbed. This caused the peristaltic pump to cavitate, which is shown as periods of very high flow rate on the connected flowmeter.

This effect happens when an undissolved gas bubble is compressed in the pump and, upon exiting the driven part of the tubing, expands, accelerating the liquid and creating a high flow rate period.

Figure 3 demonstrates that peristaltic pumps are prone to undissolved gas bubbles even when using degassers, producing erroneous results from any connected liquid system without any indication of a problem with the pumping system.

Experiment #4

Our fourth and final experiment was designed to investigate the behavior of a peristaltic pump if solvent in the feeding reservoir flask runs dry. This was simulated by temporarily pulling the inlet tube out of the flask while the peristaltic pump was running. Results of this experiment can be seen below in Figure 4.

As expected, the measured flow rate dropped to zero quickly. The spikes of apparent flow shown are due to small droplets of residual solvent being pumped through the system.

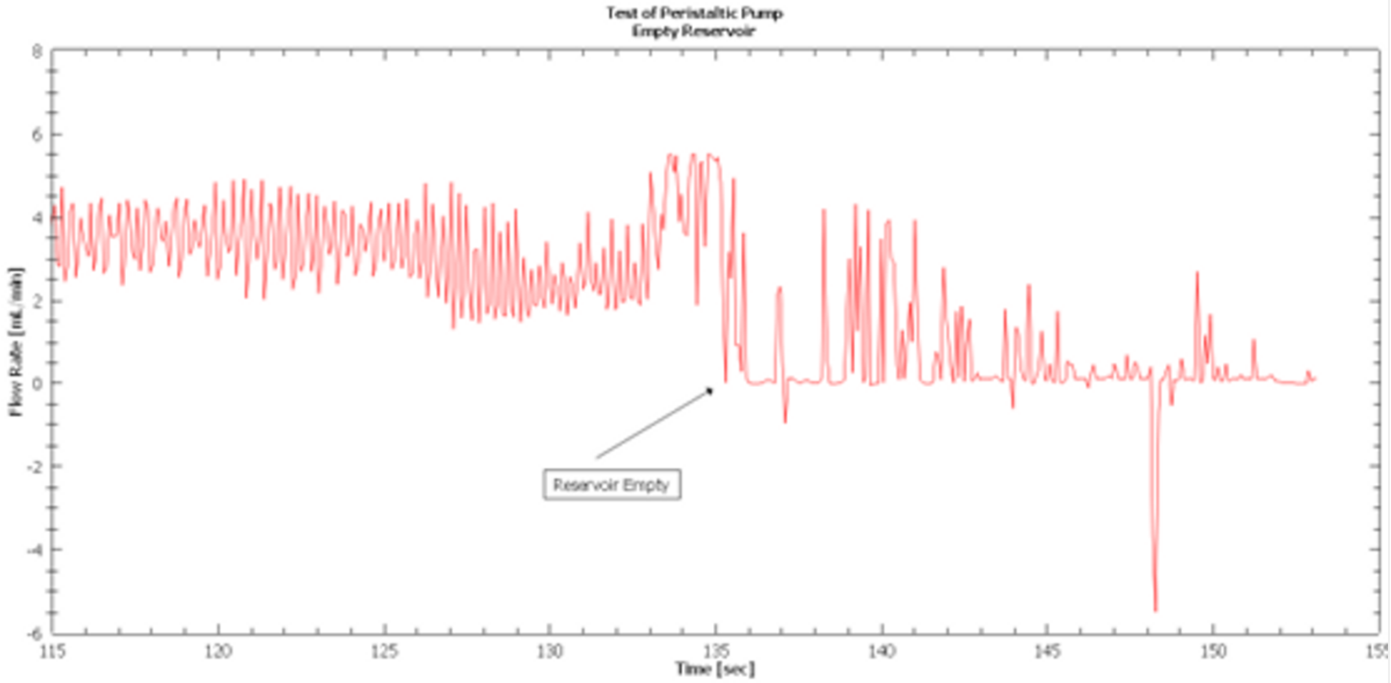

Figure 4: Impact of peristaltic pump feed reservoir running dry on measured flow rate.

Experiments 3 and 4 demonstrate that even a vacuum degasser is powerless when bubbles of undissolved gas travel are present in the solvent feed lines coming from your peristaltic pump.

To address the problem of undissolved gas bubbles in solvent feed to liquid chromatography and flow chemistry systems, the solvent lines would benefit from detecting any undissolved gas bubbles within a length of translucent tubing.

Figure 5: A mechanism to alert for undissolved gas bubbles

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Having a system to alert the bench scientist to the presence of undissolved gas bubbles can safeguard your laboratory against the above-described problem or running out of solvent in critical applications. Actively monitoring the tubing eliminates incorrect analytical results, system downtime, or even extensive equipment maintenance. An ideal system could even automatically trigger shutdown of a pump or a switching valve when a solvent flow line becomes empty or contains too many micro bubbles.

Conclusion

It is widely acknowledged that peristaltic pumps with multiple channels are of great value in many liquid chromatography, flow chemistry, and dosing applications. However, pump performance can be easily affected by dissolved gases. Using a vacuum degasser has been shown to be highly effective at addressing this problem.

We have also shown that detection of undissolved gas bubbles, which are not removed by vacuum degassers, is crucial for safe and unperturbed operation of any liquid pump system. Monitoring solvent lines can safeguard your HPLC, flow chemistry, or liquid dosing system from the many problems caused by undissolved gas bubbles.

To get reliable results, we recommend using a non-invasive flowmeter to accurately measure the effective flow rate of each channel from dual-channel pumps in real time and to continuously monitor the flow from single-pump channels.