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

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Peristaltic pumps are fluid delivery tools widely used in laboratory techniques including HPLC, GPC/SEC, 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 HPLC systems, is to utilise a vacuum degasser on the inlet side of the pump. A vacuum degasser is fundamentally a chamber kept under vacuum pressure that contains a length of gas-permeable tubing leading the solvent to the pump. Using this technology, 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 for removing dissolved gas, they do however 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 unfortunately reach your HPLC pump leading to unreliability and the consequent errors in 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.

Experimental

In this study, we used a dual cartridge peristaltic pump (Ismatec, Germany) equipped with two new lengths of Tygon tubing with a nominal ID of 0.76mm designed to deliver flow rates between 0.1 and 5 mL/min. Flow rate was measured using two Liquid Chromatography Flowmeters (Testa Analytical, Germany) to precisely measure real-time flow rates of 0.01 to 5 mL/min. Deionised water was used as the experimental 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 *(Figure 1)*.

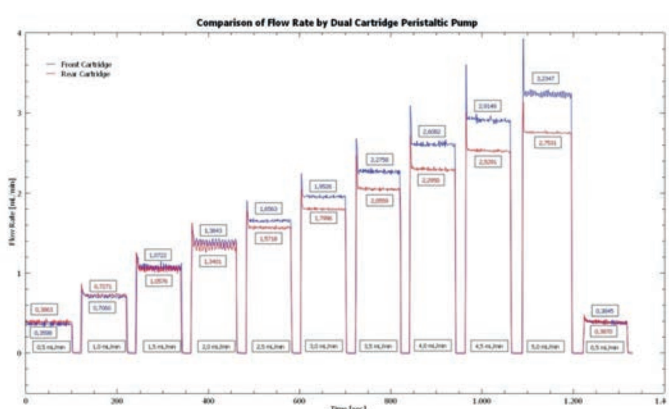

Figure 1. Comparison of flow rate by dual cartridge peristaltic pump.

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 2 channels.

In our second experiment we investigated the effect of connecting a dual channel Degasi vacuum degasser (Biotech AB, Sweden) 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.

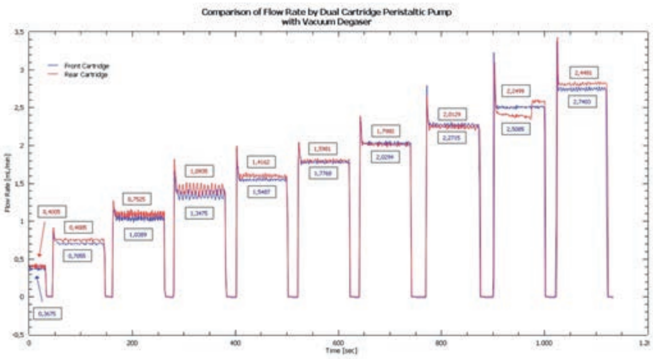

Figure 2. Comparison of flow rate by dual cartridge peristaltic pump with vacuum degasser.

As is clearly shown in *Figure 2*, the measured flow results are now very similar for both channels, a completely different result from experiment 1.

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, removing dissolved gases, thereby improving overall performance of the peristaltic pump.

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 *(Figure 3)*.

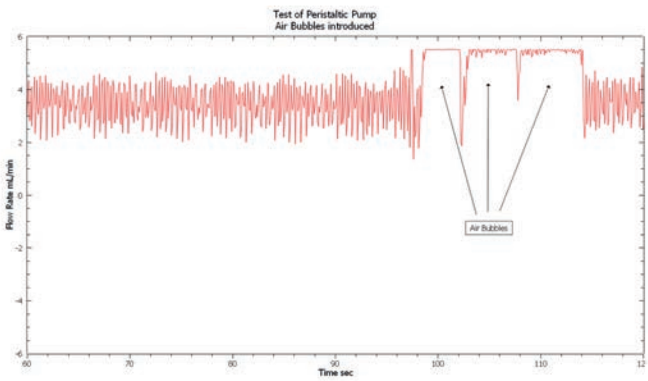

Figure 3. Test of peristaltic pump air bubbles introduced.

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.

The reason for this effect is that an undissolved gas bubble will be compressed in the pump and once exiting the driven part of the tubing, it will expand thus accelerating the liquid creating a high flow rate period.

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

Our fourth and final experiment was designed to investigate the behaviour 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, and flow was monitored. Results of this experiment can be seen below in *Figure 4*.

As would be 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.

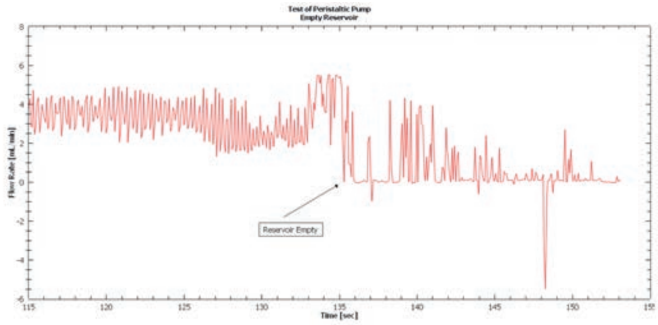

Figure 4. Test of peristaltic pump empty reservoir.

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, Testa Analytical has developed the Solvent Line Monitor *(Figure 5)*. The Solvent Line Monitor is a device designed to detect in real time undissolved gas bubbles within a length of translucent tubing.

Figure 5: Solvent Line Monitor. (courtesy: Testa Analytical)

The Solvent Line Monitor is a small stand-alone device that provides real-time detection of undissolved gas bubbles in solvent flow lines. This unique device is designed to safeguard your laboratory against the above described problem of undissolved gas bubbles in your pumped liquid feed or running out of solvent in critical applications.

By addressing these problems – the Solvent Line Monitor eliminates incorrect analytical results, system downtime, or even extensive equipment maintenance. Set up to automatically trigger shutdown of a pump or a switching valve, when a solvent flow line becomes empty or contains too many micro bubbles, the Solvent Line Monitor represents a valuable new safeguarding device that can be applied to any type of pump (peristaltic, syringe or membrane) serving HPLC, flow chemistry or liquid dosing system.

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, operation of these pumps 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. The Solvent Line Monitor is a valuable new monitoring device capable of safeguarding your HPLC, flow chemistry or liquid dosing system from the many problems caused by undissolved gas bubbles.

To get reliable optimised 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.

References

1. The importance of understanding pump flow, International Labmate, July 2022, C.Dessy et al. (see https://www.labmate-online.com/article/chromatography/1/testa-analytical-solutions-ek/the-importance-of-understanding-pump-flow/3163)