AN-13

PLSV – Pressure drop and dead volume : PLSV against Diaphragm valve

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ABSTRACT

The PLSV valve technology was compared against an AFP ELDV-2 Diaphragm valve for the measurement of VOCs using a gas chromatograh/Mass-Spectrometer instrument. The third-party test demonstrates the benefit of the PLSV technology against the diaphragm valve in regards to pressure drop and dead volume.

INTRODUCTION

GC-MS instruments require valves with very good leak integrity as air leak can have major impacts on their performance. As a consequence, to date, diaphragm valves are the preferred technology for this type of products as conical rotary valves are known to have shorter life time and poor leak integrity. An ideal valve would combine the benefits of a conical rotary valve i.e. no dead volume and no pressure drop with the quality of a diaphragm valve i.e. long life time and better leak integrity. This test was done to confirm the claims that the ASDevices PLSV technology offers the best of both technologies.

To date, this GC application is done using a 10 ports AFP ELDV-2 diaphragm valve to measure trace VOCs. This type of valve is known for its small size, long life time and low leak rate. However, the diaphragm valve technology suffers from pressure drop during the valve actuation and internal dead volume which are inherent by design. The comparison test, conducted by FPI (Focused Photonic Inc) described in this report clearly demonstrates the benefits of the PLSV technology over the diaphragm valve technology.

TEST PURPOSE

The test consists of validating the following points:

1. PLSV valve actuation time
2. PLSV valve pressure drop and dead volume
3. Chromatographic performance

EXPERIMENTAL MATERIALS AND EQUIPMENT

1. ASDevices PLSV-10-00-SP-18-ST
2. AFP ELDV-2
3. FPI GC Platform with Mass Spectrometer

A REVIEW OF DIAPHRAGM VALVE INHERENT DESIGN ISSUES

Despite their qualities, diaphragm valves have issues by design: dead volumes and pressure drop.

The dead volume issue of the diaphragm valve is represented in Figure 1. These dead volumes are located between the plungers and the valve ports. Their impact is a double injection and an example is provided in Figure 2. The two small O_2 and N_2 peaks are caused by the re-injection of the dead volume which is not ideal, especially when dealing with small sample loops and ultra-trace level measurement. In regards to port pressure drop, this is down to the elastic nature of the valve diaphragm. When working with capillary columns, the column head pressure is very low but the gas velocity is high. In that case, any slight variation in the port pressure drop upon actuation affects the carrier gas flow velocity in the column and hence variations in peak elution time and baseline. Those two impacts are limiting the performance of this application using the GC-MS.

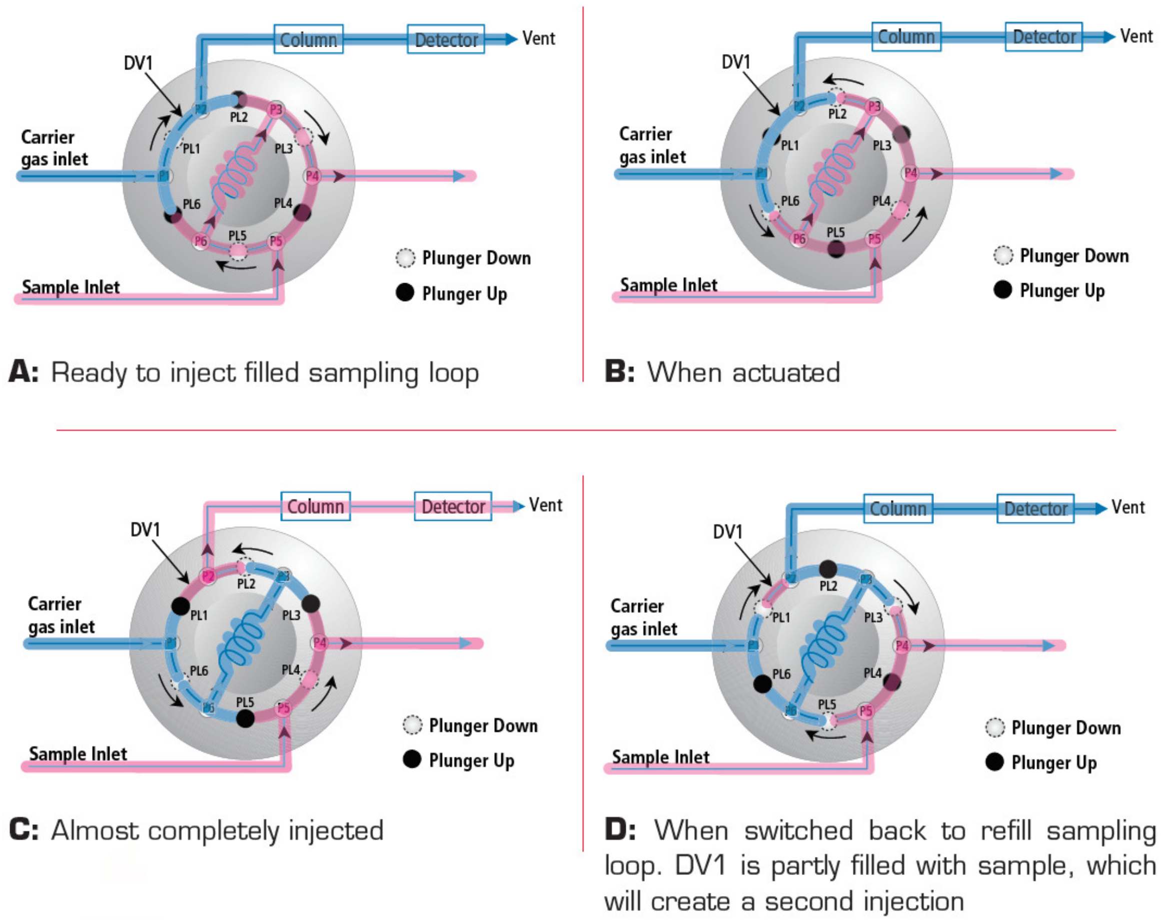

Figure 1 – Diaphragm valve dead volume issue [1]

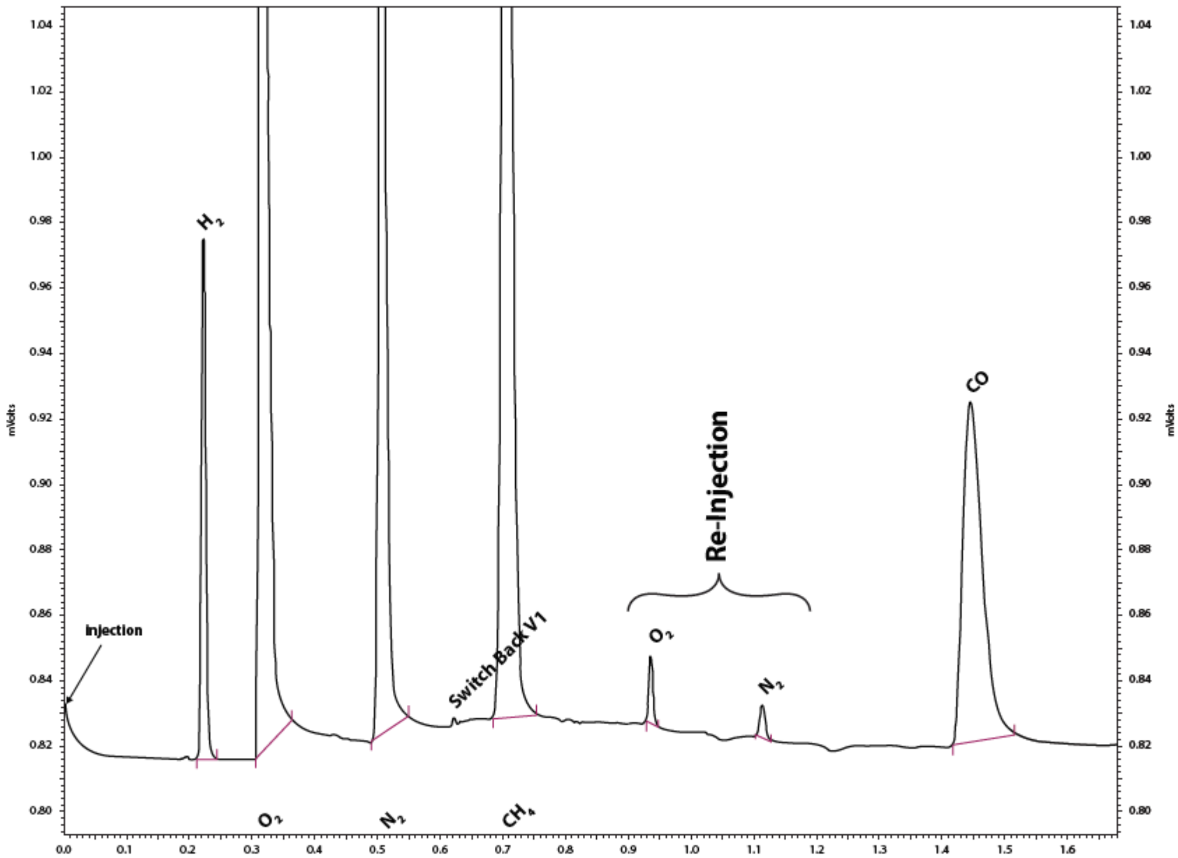

Figure 2 – Diaphragm valve dead volume re-injection issue

VALVE ACTUATION TIME

As shown in Figure 4, the AFP ELDV-2 valve was replaced by the ASDevices PLSV valve technology. The gas connections as well as actuation pressure were kept unchanged in order to do a direct comparison. The actuation pressure was set to 60 PSIG. In order to prove the actuation time, the GC-MS software impulse time was set to 0.1 sec (100 ms). This is the shortest time available on the GC platform. The duration of the pulse, which is used to drive the actuation solenoid was used to assess the actuation time. The proper actuation was confirmed by assessing the valve position after the impulse. The test demonstrated that 0.1 sec (100 ms) is sufficient to drive the valve. It was not possible to verify if a shorter actuation is possible due to the software limitation. However, 100 ms is fast enough. The actuator used for this test is ASDevices standard actuator. For faster and more compact footprint, the compact pneumatic actuator (Figure 5) could have been used.

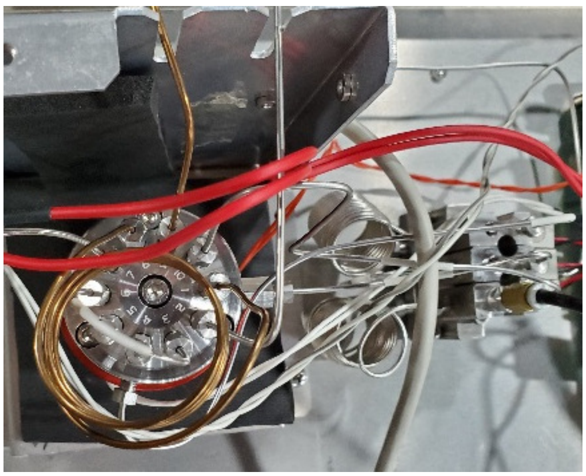

Figure 3 – AFP ELDV-2

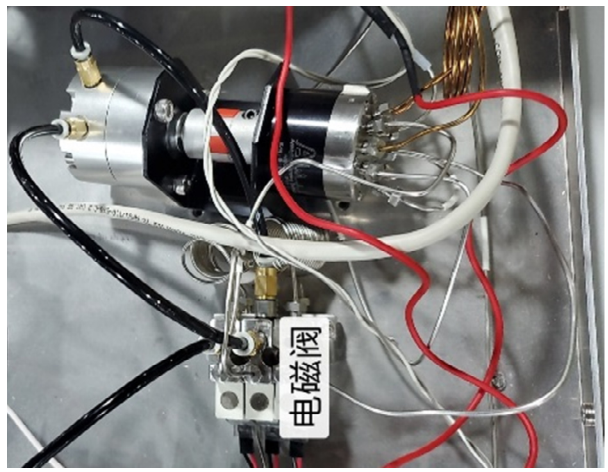

Figure 4 – ASDevices uInProve

Figure 5 – ASDevices Compact pneumatic actuator

PRESSURE DROP AND DEAD VOLUME

During this test, AFP ELDV-2 and ASDevices PLSV technologies were compared in the exact same conditions. The valves were actuated every 2 minutes (ON and OFF). A blank sample, air, was injected into the chromatographic system when the valves were activated (ON). The dead volume and pressure drop effects were assessed by looking at the chromatogram.

With these GC conditions, it was assessed that the air peak requires 1.1 minute to elute from the chromatographic column after injection (ON). In the chromatogram, the peaks at around 1.1 min and 5.1 min are due to air sample injection as injection occurs at 0 min and 4 minutes. In Figure 6, it can be seen that AFP ELDV-2 dead volume effect appears at 3.1 min and 7.1 min as the valve is deactivated (OFF) at 2 min and 6 min. This behaviour is not present on the ASDevices PLSV technology due to its design as can be seen on Figure 7. As mentioned previously, all diaphragm valves have, by design, a dead volume which is a major limiting factor and this is well represented in this test.

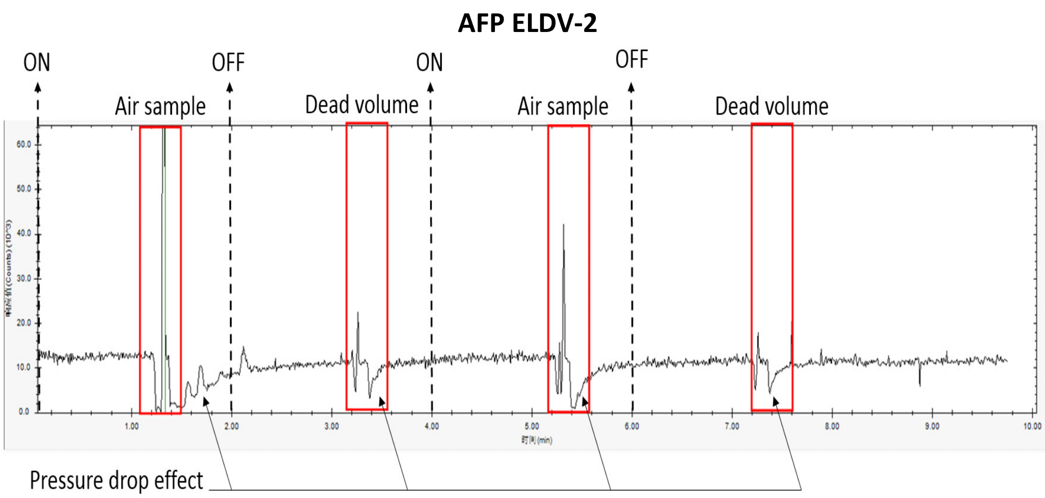

Figure 6 – AFP ELDV-2 dead volume and pressure drop performance

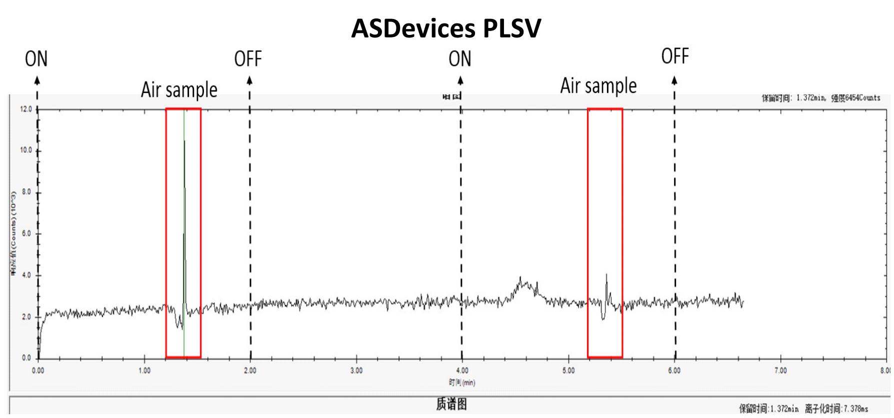

Figure 7 – ASDevices PLSV dead volume and pressure drop performance

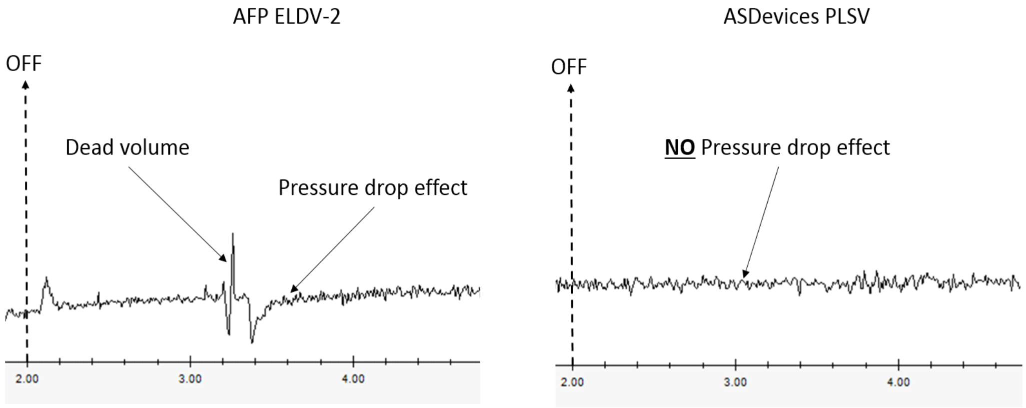

Figure 8 – Comparison between AFP ELDV-2 and ASDevices PLSV

The pressure drop effect is clearly demonstrated in Figure 8. Due to the elastic nature of the diaphragm, the pressure drop across the diaphragm valve is not the same in both positions (ON vs OFF). As a consequence, the pressure drop has an impact on the carrier flow into the column and eventually appears as a baseline fluctuation as the flow perturbation travels across the chromatographic system. This is represented in Figure 8 by the baseline sudden decrease followed by a re-stabilisation. Using the ASDevices PLSV, it can be seen that this effect does not occur as the PLSV insert is all made of solid material compared to ELDV-2 soft polymer diaphragm.

This type of baseline fluctuations is problematic in chromatography as it may interfere with chromatographic peaks and make peak measurement and detection more difficult.

It is to be noted in figure 6 and 7 that the average baseline signal is lower with the ASDevices PLSV technology due to a better leak integrity of the valve.

CHROMATOGRAPHIC PERFORMANCE

In this test, we used a quantitative sample loop and a 1 ppm TO14 mixed gas for comparison. The sample passed through silanized stainless steel tubes. Before the test, a blank was injected 3 times to ensure no residual gas was present into the system and especially into the diaphragm valve dead volume. This test did not consisted of showing the dead volume issue associated with the diaphragm valve as this was done previously, but chromatographic performance of both valve technologies. From Figures 9 and 10, it can be seen that both valves are performing well. The ASDevices PLSV valve however provided a more stable baseline during the analysis which is explained by the fact that this valve technology does not suffer from pressure drop during valve actuation.

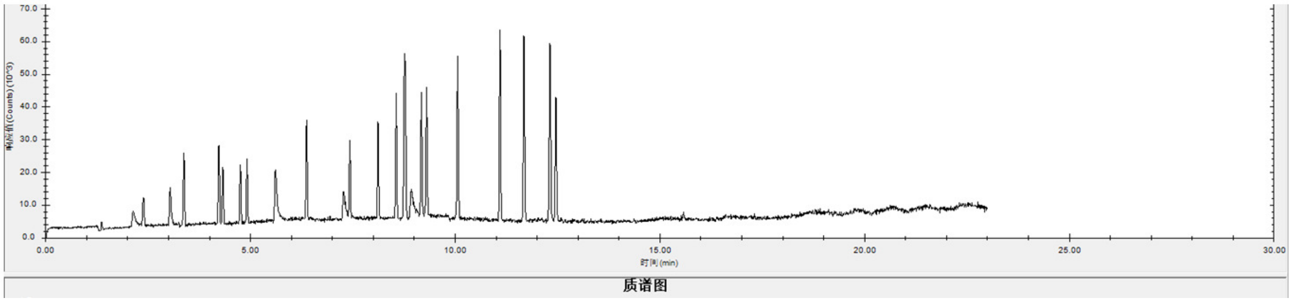

Figure 9 – Chromatographic performance with AFP ELDV-2

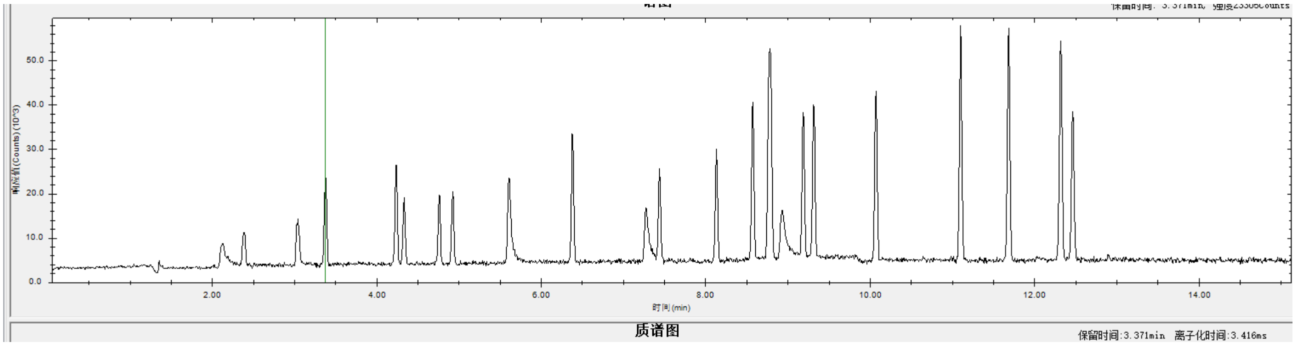

Figure 10 – Chromatographic performance with ASDevice PLSV technology

CONCLUSION

In conclusion, the ASDevices PLSV valve technology offers a better performance compared to a diaphragm valve technology. The same problematic behaviour would be observed on an AFP or VICI diaphragm as those issues are inherent by design. The tests have proven that the ASDevices PLSV technology does not suffer from pressure drop and has no dead volume which are major benefits resulting in better chromatography. The ASDevices PLSV technology also offers a better leak integrity as well as long life-time and compact integration with the compact pneumatic actuator.

REFERENCE

[1] Y. Gamache, AB-04 – Things you should know about GC Diaphragm valves, AFP Cookbook vol. 1.4

The tests and data used in this application note were independently conducted and obtained by FPI (www.fpi-inc.com), a leading provider of analytical and chromatographic solutions.