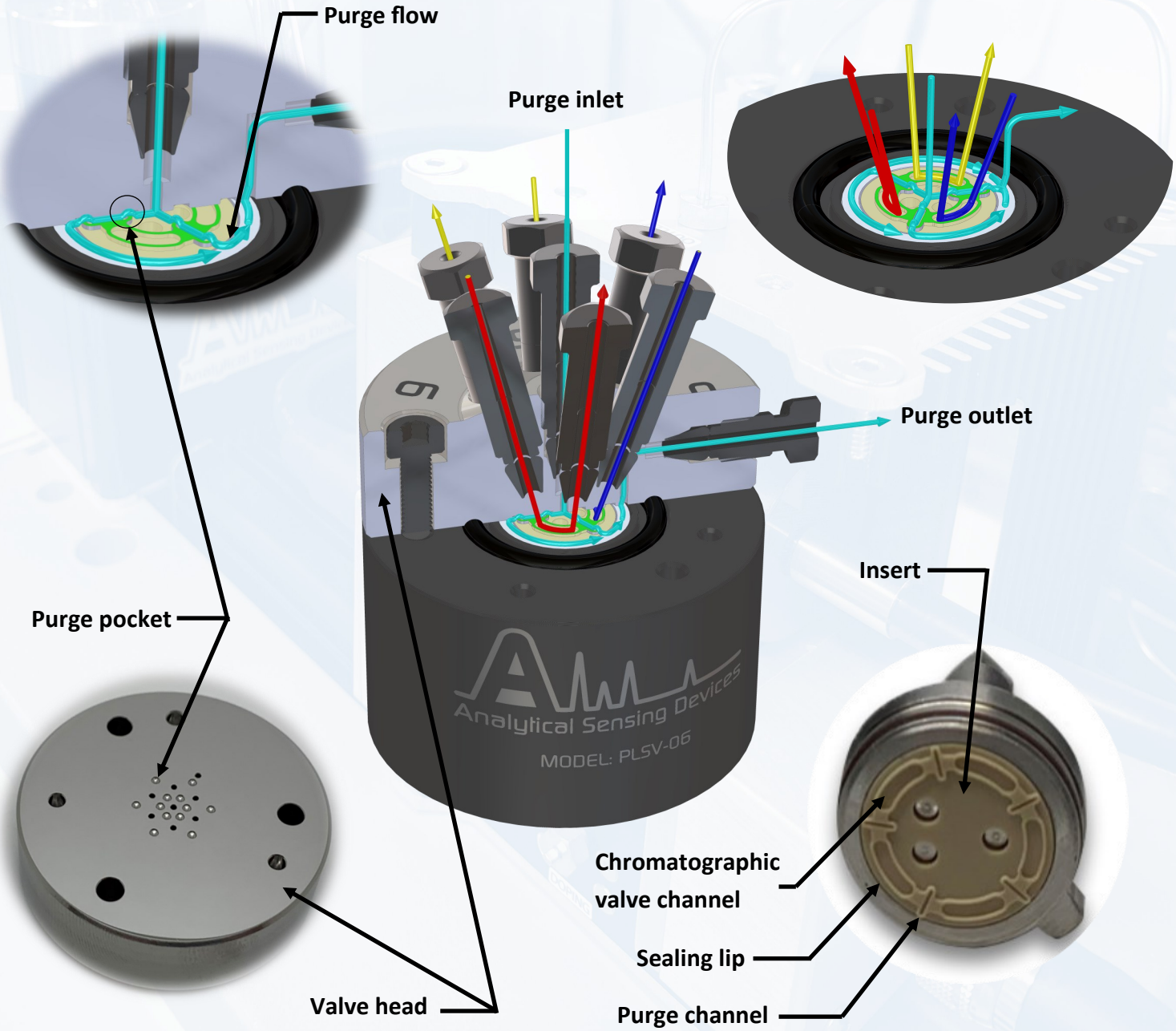
## LEAK MANAGEMENT PRINCIPLE

Our team has spent over 30 years developing gas chromatograph (GC), GC applications and servicing GCs in various fields. We have also spent the last 20 years reviewing existing valve designs and improving them. We have tested pretty much all existing GC valves (Valco, Siemens, Yokogawa, ABB, AFP). This has led us to the development of over 30 patents in that field to improve lifetime, reduce leaks, dead volume, etc. We have probably spent more time then anybody else on GC valve design.

We have spent a lot of time improving valve leak integrity of traditional conical rotary and diaphragm valve technologies. All valves leak or will leak at some point. What matters is the level of leak, leak rate. Both conical rotary and diaphragm valve technologies have design principle limitations. The ultimate challenge is, how do we design a valve with longer life-time, less wearing and that can manage inevitable leaks without impacting the chromatographic performance? For this, a completely new technology is required as well as a new way of thinking. This is the purpose of our PLSV[patent pending] technology.

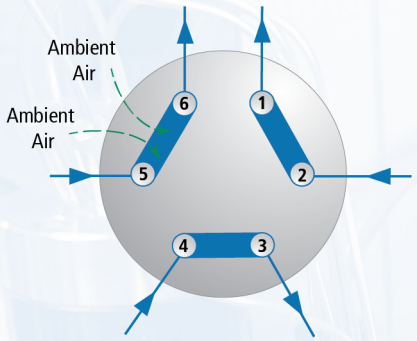


## LEAK TYPE

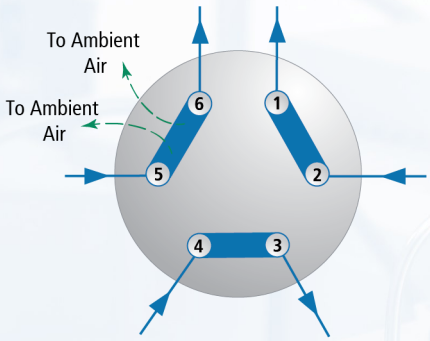
For the purpose of this document, we are considering 3 types of leaks: inboard, outboard and cross port. The most problematic one is the cross port one and it has never been well addressed in the market. This type of leak causes contamination and chromatographic performance issues.

**INBOARD**



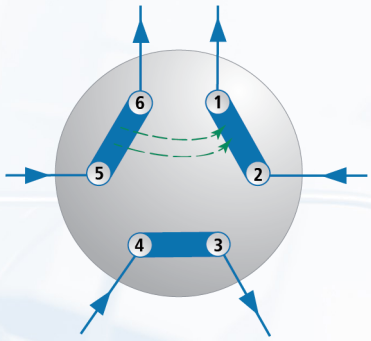

A leak that causes the gas surrounding the external body, which is mostly air, to diffuse inside the valve and pollute the carrier or sample gas.

**OUTBOARD**




A leak that flows from the valve flow path to the external valve environment. For example, hydrogen sample flowing into the surrounding atmosphere due to a leak. This may be hazardous.

**CROSS PORT**




A leak between two adjacent valve ports which are supposed to be sealed. For example, the sample flow path leaking into carrier flow path.

## LEAK RATING: WHAT DOES IT MEAN AND HOW IS IT TESTED?

All GC valves have a leak rate specification in cc-atm/min. This is rated at a specific maximum pressure. This is the number of cubic centimeters of gas that is flowing through a leak at ambient pressure. Typical GC valve leak integrity ranges between $10^{-6}$ cc-atm/sec for typical conical rotary valve to $10^{-12}$ cc-atm/sec for high end diaphragm valves [1].

| Valve type | Leak rate |
|---|---|
| Conical rotary valve | $10^{-6}$ to $10^{-7}$ |
| Diaphragm valve | $10^{-8}$ to $10^{-12}$ |
| PLSV Technology | Not possible by design, leak managememt |

This way of measuring leak integrity can be conceptualized as the time it takes for a gas flow to fill in a volume. The longer it takes, the smaller the leak. The maximum pressure rating is also important. For example, a leak rate can be specified at 50 PSIG or 300 PSIG. The higher the pressure, the more difficult it is to seal the valve. For a higher pressure, a higher sealing force is required. The result is indeed more wearing, shorter lifetime.

Low leak rate is very often achieved by increasing surface finish quality and sealing force. Increasing sealing force however has a major drawback. It reduces lifetime [1] due to increased. This is true for all valve types. For conical rotary valves, the rotational force and hence friction increases. For diaphragm valves, more force is applied on the diaphragm by the plunger. Eventually, the diaphragm is damaged.

A FID detector is not so much impacted by a small air leak but a mass spectrometer is. If particulates are introduced into the valve from the sample gas as it often happens in VOC analysis in ambient air, the valve performance may rapidly degrade.

## THERE IS NOTHING SUCH AS: HOW MANY ACTUATIONS MY VALVE WILL LAST?

A valve lifetime is influenced by chromatographic conditions: pressure, flow, temperature, detector. Asking the question: how many cycles will the valve do before breakage?, can't be answered easily.

As an example, a rotary valve will last less than 15,000 actuations for a UHP permanent gas application [2] and the same valve will last up to 200,000 for hydrocarbon measurement with FID [3]. There is consequently no answer to how many actuations will my valve do. There are just too many variables. It is like a car. If the car is used for racing, it will not last as long as the same car being used in normal driving conditions.

Valve performance is consequently well defined in its datasheet for specific conditions.

## PLSV VALVE TECHNOLOGY PATENT PENDING – MANAGING LEAK TO IMPROVE LIFETIME

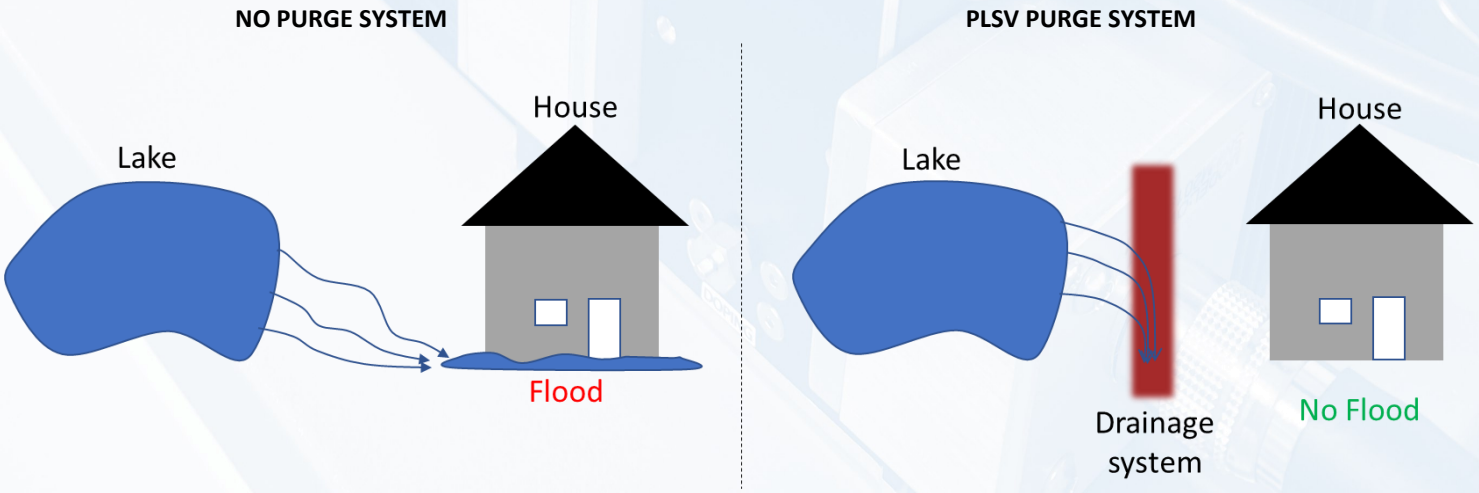
Of course, as we spent 20 years improving conical rotary and diaphragm valves, we knew it meant a completely new valve concept. A new way of doing things. This is the purpose of the Purge Leap Sealing Valve (PLSV) technology. As with any new technologies, users must understand the principle to get comfortable. Understanding the principle is key to understand the advantages.

There are two main features to the PLSV technology: purge concept and the reduced surface sealing area. They are both linked. The reduced surface sealing area reduces required sealing force and hence friction. This has a direct impact on the lifetime.

The purge concept, which is possible due to the sealing lip design, addresses leak management. Remember, all valves will leak eventually. The PLSV technology focuses on leak management to extend valve lifetime. This was the guiding principle behind this concept.

To understand the concept, let's use a house that is built in a location with high likelihood of flooding due to the clause proximity of a lake. As eventually a flood will occur, a drainage system is designed into the ground between the house and the lake to divert the water that will come out during the flood. This drainage system behaves the same way as our purge principle. It prevents water (leak in our case) to reach the house (a neighboring port). It manages water from the flood. In the case of our PLSV technology, this applies to any leak: inboard, outboard and cross port. The leak is diverted into the purge volume.

Even without a purge gas, the leak will diffuse into that path as it is the path with the least resistance. When purge gas is added, the leak will be diluted and vented away. The purge gas can be seen as the inclination of the drainage system. The inclination is what forces water to flow to a safe location. The purge gas in our design is used to vent away any leak.

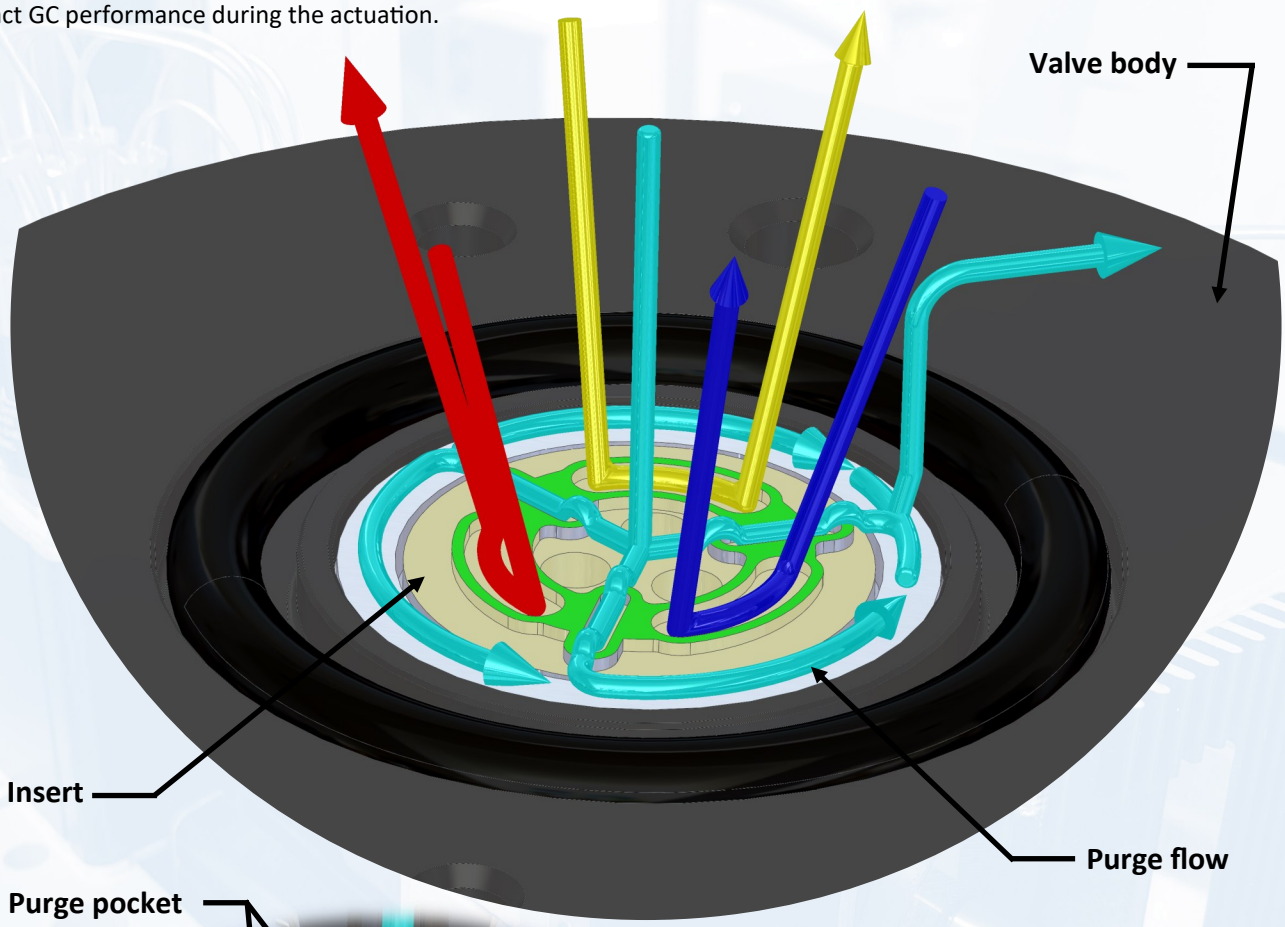


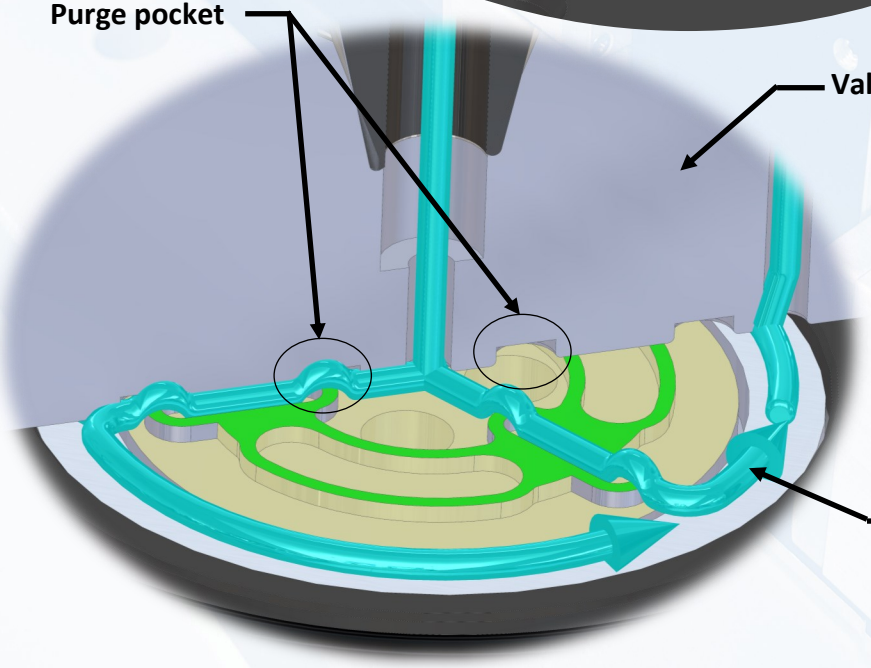

  

Purging the inside of a valve is relatively trivial. The challenge is preventing cross port leak from causing issues. This is the purpose of the purge channel in combination with the purge pocket. It also allows the purge gas to flow everywhere in the valve, including in-between valve ports.

## PURGING GROOVE – MANAGING LEAKS

The purging groove and associated purge pockets is key to our technology. Introducing purge channels in between valve port is not trivial. Purging in between ports in static mode (valve ON or OFF) is easy. The challenge was how to design a purge groove that will not impact GC performance during the actuation.



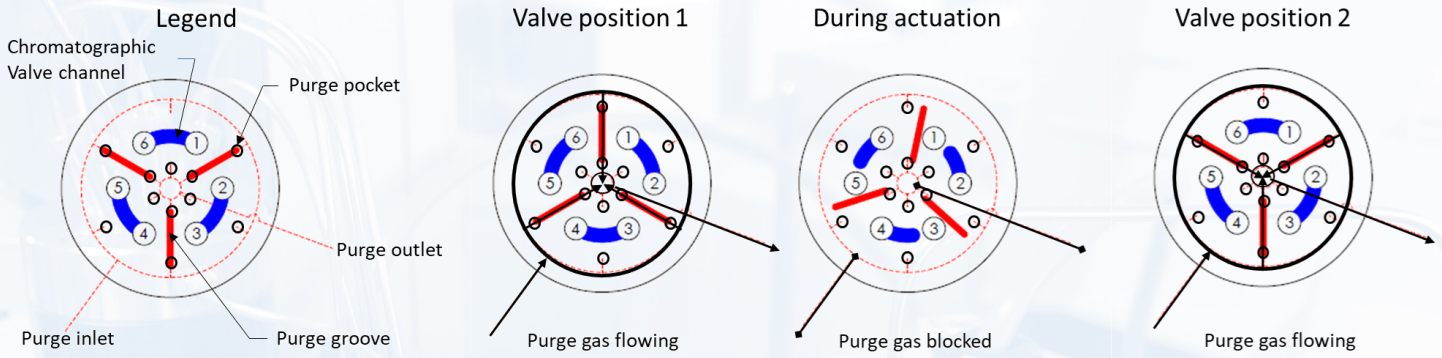



Our technology was designed and tested to make sure that the 0.11 µl groove does not impact chromatography and especially with very small sample loop (10 to 20 µl). This has been achieved by integrating purge pockets[patent pending]. During actuation, the grooves are no more connected to purge pockets. They are sealed. The purge flow is only restored at the end of an actuation.

Depending on chromatographic conditions, a small flow burst can be perceived in the purge port outlet. This flow burst is normal. Also, the higher the number of valve ports, the larger the burst due to the higher number of grooves.

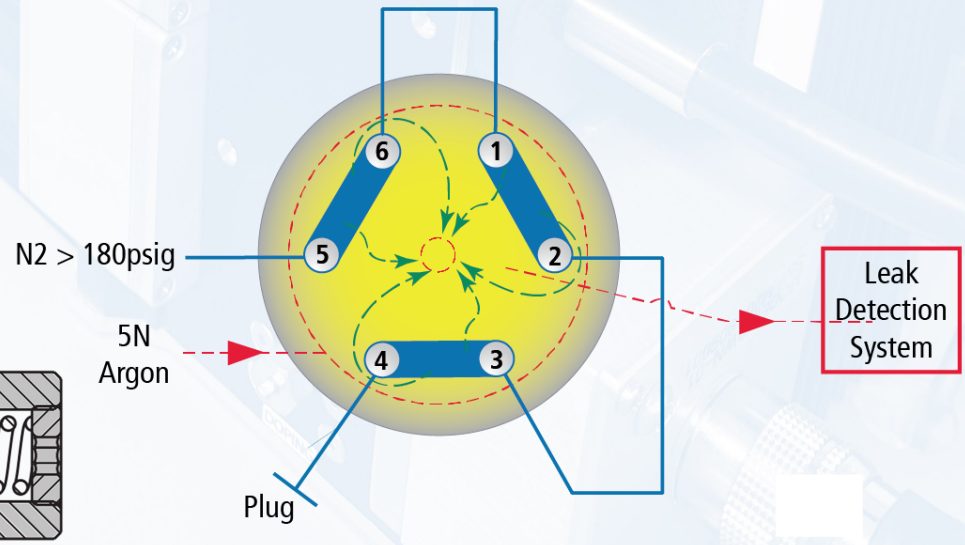
With this purge system innovation, we now have the only valve technology that manages leaks: inboard, outboard and cross-port.



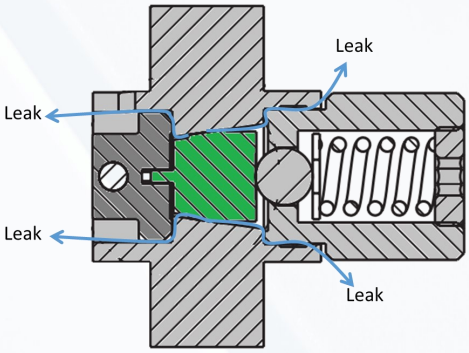

## HOW OUR VALVES ARE TESTED?

When our PLSV valve are manufactured, they are all tested for leak. 100% of them are tested. They are tested using our proven leak detection system[patent pending] . As previously mentioned, our valve can manage leaks. We still need to make sure during manufacturing that our valves are meeting our high quality requirements. This is done by pressurizing all valve ports to the specified maximum pressure and monitor the leak rate into the purge. All valves are tested to $3x10^{-12}$ cc-atm/sec. This makes sure that the valve quality is controlled in manufacturing. Such a test is impossible with other valve technologies as leaks are not captured and diverted into a purge volume. For example, on a conical rotary valve, outboard leaks are going into the atmosphere. It is consequently impossible to do such a test unless a special housing is designed around the valve!

**PLSV leak test setup**



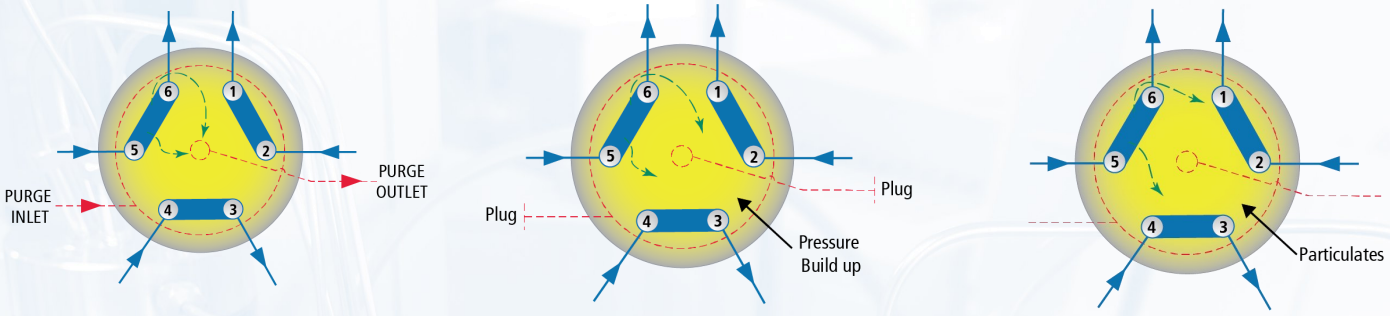

**Conical rotary valve leak flow path**



## I DON'T WANT TO USE PURGE, CAN I PLUG THEM OR LEAVE THEM OPEN?

Of course our recommendation is to use the purge. We only guarantee the performance with purge. We have designed that purge system for a very good reason based on over 30 years of experience. Purging the valve is low cost. Only low cost fittings are required and just a few ml/min of gas. Without purge flow, our design will work, but not as efficiently. Leaks with slowly diffuse into the empty purged volume which surrounds the valve ports. However, it will not be vented away. The purge vents away any leak.




The worst thing would be to plug the purge ports. This may eventually cause an internal pressurization of the valve. This pressure will push against the rotor sealing force. This will result in premature leak and potential insert damages.

If the ports are left open without purge gas, particulates may flow into the valves. The potential damage is obvious. It will generate scratches. If purge is not used, ports must at least be fitted with particulate filters. However, we only guarantee performance with purge. Again, this purge has been designed for a reason and to have better performances, different methods are required.

**REFERENCES**

[1] Leak testing, VICI, https://www.vici.com/vval/vval_leak.php
[2] Rotary valves, then and now, Yves Gamache, AFP
[3] PP! Maintenance schedule, Peak Laboratories, http://www.peaklaboratories.com/resources/