Understanding the Impact of the Valve Flow Coefficient (Cv) in Fluid Systems

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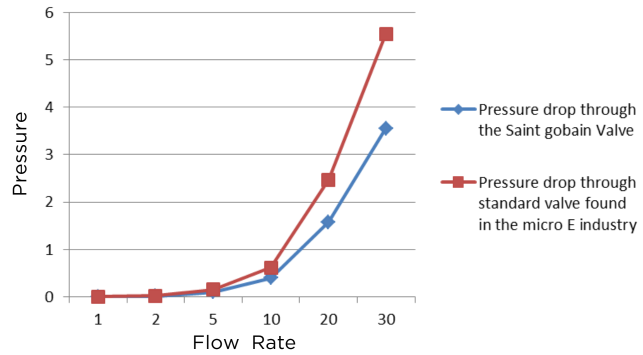
When scaling up, or down, a high-purity liquid installation many complex factors need to be considered, from ensuring the integrity of a transported product, to the cleanliness of the environment, for both the safety of the process and the operator. Oftentimes the flow coefficient Cv (flow capacity rating of valve) is a bit misunderstood. Given the Cv formula can be used for any flow component in a fluid line, most are familiar with it, yet few consider how it relates to their specific installation. Therefor this article will focus on factors that pertain to achieving a specific flow performance and specifically the flow coefficient (Cv) as it relates to valves.

Cv Empirical Explanation and More

As we know, when working on a turbulent flow the Cv formula is: $Cv = Q\sqrt{(SG/\Delta P)}$ where Q is the flow going through the valve in gallons per minute (GPM), SG is the specific gravity of the fluid and ΔP is the pressure drop in PSI through the component. In the semiconductor industry, due to the low velocity of the transported fluid the high purity chemistry and slurries are mostly in a semi–turbulent state or a laminar state. Yet you will notice there is not a single link to the viscosity of the transported product in the Cv formula. This is significant given the viscosity directly impacts the Cv value when the flow is in a semi-turbulent or laminar mode. Consider that if you calculate the pressure drop in your system with the formula above you could end up with a result that is 4 to 5 times lower. No doubt this inaccuracy can cause significant issues in your installation.

To take this further, let's analyze how pressure drop based on flow evolves through a valve by comparing Saint-Gobain's **Furon® Q-Valve** (½" inner flow path and ½" pipe connection) to a standard semiconductor industry valve of the same size. The Q-Valve, which meets the requirements of the semiconductor industry (metal free, 100% fluoropolymer flow path and so on), has a Cv of 3.5, one of the best for its dimensions. To ease the calculation we will use deionized (DI) water, which will free us of the specific gravity or impact of the viscosity if we are not in the right state.

As we can see on the following graph, at a normal flow rate used in micro-e for ½" 5 to 10 lpm; the pressure drop difference between a standard valve and a Furon valve is in the range of 0.1 to 0.3 PSI. At first glance, this does not appear to be much. However, let's factor in a viscous product and that you have a number of these lines in your flow line, now the numbers start to accumulate. By moving from a standard valve to a Furon valve, you start to see a significant difference in pressure drop, which may occur across your installation. An "easy" counter effect is to increase the pressure through put of your pump, but is at the expense of wasting energy and adding the potential for additional shearing or particle generation in your critical fluid. This would be up to a certain limit, defined by another component in your installation, such as your pump pressure capability or some more delicate



device. Now that we have reviewed, the impact of the Cv on our flow and how this could impact our installation, let's see what can potentially impact the Cv.

Design Impact on Cv and Resulting Trade-Off

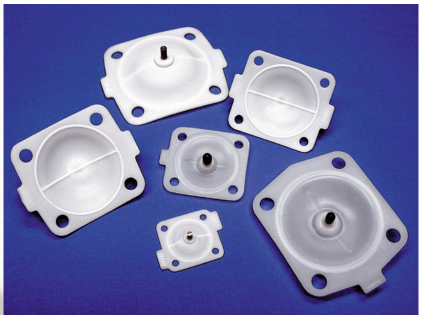
The first impact that may come to mind is a larger orifice. The size of the orifice can benefit flow through and directly relates to the volume of your valve. However there are trade-offs for this improved Cv. The first is cost increase. A higher volume requires a larger valve, which can cost up to 50% more than the initial valve due to specific material and process requirements. Additionally, by increasing the size of the component (due to the specific micro-e material requirements), you could lose pressure rating performance. When increasing the inner volume of your valve, you potentially increase volume retention as well as particle generation, given that using larger actuation systems results

Furon Q-Valves - Pneumatic & Manual

in more points of contact and creates a hub for generating particles. Another possible drawback is significant velocity loss. The critical point to be taken here is the importance of choosing the right size orifice; too small and flow can be restricted too much and too big and you may end up paying for other problems down the line.

Another potential impact to Cv is the difference in valve technology. Though there are more, we will specifically cover stopcock/ball valves, weir style valves; and diaphragm valves. Other valve technologies, such as the butterfly valve, will not be discussed because their construction materials are generally not used for fluid handling components for the semiconductor industry.

Weir Valve



Diaphragm Valves
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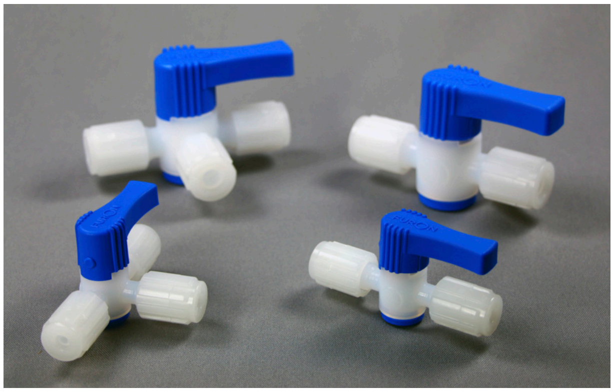
Starting with the simplest design, the stopcock/ball valve provides by far the best Cv of the three valve technologies mentioned. Considering the premium Cv achieved, you would assume they are expensive. Actually, they are generally the most inexpensive of the three values mentioned. One drawback in using stopcock valves is the need for a liquid O-ring on the fluid path, which may create compatibility issues. The exception is the **Furon Stopcock (SCM2 & SCM3) Valve** that employs a PFA on PTFE technology and allows for O-ring-free sealing. Additionally, stopcock valves can lower pressure, temperature ratings and have a tendency to generate a great deal of particles when actuated. This occurs when the key or ball is rotating inside the valve body. Both drawbacks are related to the PTFE/PFA construction materials required for the flow path by the micro-e industry.

The Weir-Type Valve, if done properly, should provide a very good Cv, perhaps not as good as a stopcock/ball valve, but still very good. And although liquid O-rings are not an issue, weir valves have other drawbacks. In a weir style valve the diaphragm is generally a sandwich structure consisting of a thin layer of PTFE that is backed by an elastomeric component in which a metal pin is embedded to connect the membrane to the valve actuating system. It is the sandwich materials that generate a number of potential issues when used on critical, high purity chemistry. Specifically, the delamination of the sandwich creates the possibility of multiple points of contamination to the liquid (metal and elastomer). In addition, the significant surface contact between the membrane and the valve seat, which is necessary to secure a full seal,



Furon Stopcock Valves - SCM2 & SCM3

generates many particles, though significantly less than a stopcock/ball valve.

The Diaphragm Valve is the most commonly used valve in the semiconductor industry as it offers a great balance in terms of the issues previously identified: potential contamination, materials and particle generation. The trade-off is that the construction of these valves is more complex and as a result, they are priced higher than the average cost of the other valves. Additionally, the Cv performance is well below a stopcock/ball valve and slightly below a weir style valve. However, by using Saint-Gobain's patented **rolling diaphragm technology**, this does not have to be an issue. In fact, with this technology, we can offer the equivalent Cv of a weir style valve in combination with premium pressure and temperature capabilities, as well as the cleanest valve technology. This allows for a system design with the lowest impact possible on the transported fluid.

As demonstrated in this document, understanding the Cv rating and the impacts that could affect that rating as it relates to valves is critical when optimizing an installation for fluid and energy efficiency. Cost aside, there are a number of issues that are unique to the semiconductor industry that ultimately guide and often restrict installation choices, such as: dead volume, particle generation, cleanliness as well as the physical and mechanical properties of appropriate polymers. Additionally, choosing the appropriate valve for your installation goes far beyond the simple notion that if "I need more flow, I will get a larger valve." Most likely the residual effect of that choice will affect the performance of the system, particularly regarding cleanliness. Instead critical adjustments to your valve actuation mechanism and valve flow path designs as well as to your valve technology may allow you to achieve the required results, even if the installation still uses the same ½" valve.