FEATURE

Miniature Proportional Solenoid Valves: A "Hot" Topic

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An overview of valve choices regarding orifice sizes and flow capability, how to evaluate and determine valve flow, and design features that promote consistent flow

Introduction

Proportional solenoid valves are widely used in conjunction with sensors and closed loop controls, replacing manual functions. Eliminating tedious physical manipulation, these valves improve the ease-of-use and reliability of results in medical devices and analytical instrumentation. In gas chromatographs, for example, proportional valves automate and control the flow of clean carrier gases and the pressure at the head of a column used to precisely separate samples and detect components at levels upwards of parts per billion. Proportional valves must maintain repeatable performance over a wide variety of operating parameters, the most critical of these being temperature (Figure 1).

Selecting a valve with a higher spring rate is not necessarily the best solution.

Heat's the Culprit

Engineers often design valves with higher operating pressures than required. They do this to maximize application use and minimize business risk; but the physical size constraints of the valve result in a trade-off at higher pressure with other performance parameters such as power consumption and leak integrity.

A valve that operates with an "over the seat" configuration allows gas to flow past its seal down through the metering orifice. This design typically enables high pressure to assist the valve when closing and incorporates weak springs to minimize the power needed to open it. In comparison, a valve with an "under the seat" configuration enables gas to flow up through the metering orifice and past the seal. Applied pressure assists the valve in opening, but a stronger spring is needed to prevent the valve from leaking due to the high pressure pushing the seal off the seat. In this case, the pressure offsets some of the force applied by the spring.

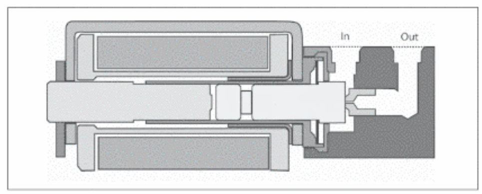

Figure 1: Proportional valve cross section (patented thermal compensation feature not shown)

Even when power consumption is not a concern, selecting a valve with a higher spring rate is not necessarily the best solution. A higher spring rate means greater forces are applied to the sealing surfaces, which can adversely affect the overall life of the valve. In addition to valve wear, more power to the solenoid results in more heat generation. The applied magnetic power to the poppet is a function of the current going though the solenoid multiplied by the number of windings. As a solenoid builds heat, the resistance in the wire increases. Increased resistance reduces the available amp turns and if this remains uncorrected, it will reduce flow in the proportional valve. In a digital valve, if heat generation is left uncorrected, the force available to keep the valve open can drop below the force of the spring, causing the valve to unexpectedly change state.

Temperature changes resulting from self-heating of the solenoid as well as changes in required flow rates of the gas directly affect the performance, repeatability and stability of the valve. Valve components such as seals and magnetic gaps are negatively impacted by temperature fluctuations such as those caused by thermal expansion. A powered solenoid valve with a low differential pressure producing relatively low flow will have a greater internal temperature rise than the same valve with a higher pressure differential and higher flow. The larger resultant flow rates actually cool the internal components of the valve. At a given power setting, seals in a valve without internal thermal compensation will expand over time and as temperature increases. As the seal expands, flow is reduced as the cylindrical area above the orifice decreases (Figures 2 and 3).

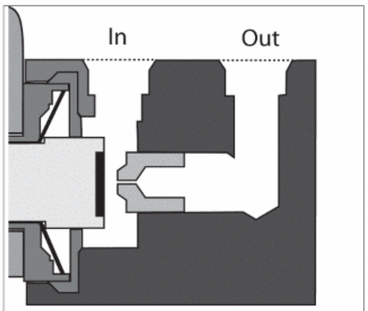

Figure 2. Valve in open state

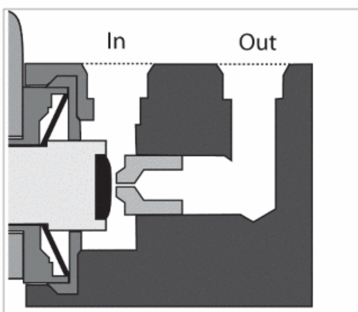

Figure 3. Heat swollen elastomer reducing flow

Internal Thermal Compensation a Must

Internal thermal compensation should be a foremost requirement when selecting proportional solenoid valves. In typical "spider spring" poppet-style proportional valves born of digital valve heritage, published repeatability and hysteresis numbers are often incorrectly related to the accuracy of the machined orifice. Engineers must realize that the orifice is subject to thermal expansion that will affect performance.

Flow is proportional to the cylindrical area above the orifice (= Π x d x h). This area is referred to as the effective metering orifice, and flow stays proportional until the cylindrical area becomes greater than the machined orifice or other limiting restriction. Valves that incorporate thermal compensation features can reduce seal expansion and control the area above the orifice, maintaining repeatability and minimizing hysteresis.

Closed Loop Feedback Does Not Solve All Ills

Even in a closed loop system, the thermal expansion of the valve can be greater than the ability of the control circuit to correct for it.

In a miniature valve with a relatively large orifice, such as 0.065 inches, thermal expansion comprises a small percentage of the total flow. Compensation is usually unnecessary in this instance. In small orifice valves, however, such as in the 0.003 to 0.030 inch range, the amount of thermal expansion can be significant, affecting a larger percentage of the actual operating stroke of the poppet.

For example, the full stroke of a proportional valve with an effective orifice of 0.003 inches can be 75 ten thousandths of an inch (0.000075 inches) while the effective stroke of a valve with an 0.065 inch orifice may be 0.0162 inches. A thermal expansion totaling only half a thousandths of an inch (.0005) would reduce the stroke of the larger valve by only 3 percent, but it would completely close the orifice of the smaller valve. A closed loop feedback circuit would attempt to increase the amount of voltage or current to the valve to correct this problem, but merely add more heat to the equation.

A properly designed thermally compensated valve uses materials that reduce the effect of elastomer swell due to permeation by gases such as helium and hydrogen at high pressure. Trace gases such as chlorine that cause fluoroelastomers to swell are also adjusted for within certain parameters.

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Conclusion

Regardless of ambient operating conditions, as soon as voltage is applied to a valve, heat becomes a factor for any critical application. By selecting a valve with well-designed thermal compensation features as well as a vendor with many years of experience in applying proportional valves in critical fluidic applications, engineers can get the highest performance and reliable results for their projects. G&I

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