PT 106
Supply pressure effect
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Explanation

Supply pressure effect (SPE) is a result of the physics of how a typical pressure regulator functions. It is a ratio of the effective area of the effective area of sensing element to the seat orifice size. It is a linear function and expressed in some pressure unit rise in outlet pressure per change in inlet pressure. It occurs as the inlet pressure varies, increasing the outlet pressure as the inlet decreases and decreasing the outlet pressure as the inlet pressure increases.

A typical pressure regulator for ultra high purity (UHP) applications is diaphragm sensed, so the focus will be on diaphragm designs. The regulator is basically a balancing act of pressures, gas pressure pushing upward on the effective area of the diaphragm opposed by downward force of the adjustment spring. If the spring force is higher than the gas pressure force, the regulator is open across the seat. If the force from the gas pressure is equal to higher, the regulator is closed across the seat. In addition to the gas pressure on the diaphragm, the poppet contributes and upward force due to a poppet spring (if not a springless design) and the gas pressure applied to the poppet.

SPE is simplistically caused by the change is gas pressure upon the poppet. The lower the gas pressure, the lower the contributing force and visa versa. The adjustment spring force is constant and offset by the combined forces from the gas pressure on the diaphragm and the poppet. If the force contributed by the poppet decreases, the force from the gas pressure on the diaphragm must increase to maintain the balance of forces with the adjustment spring. The seat orifice size impacts the force from the poppet and SPE.

Calculating SPE impact

Calculating the impact of supply pressure effect is easy. If the SPE change is expressed as 0.5 psi change in outlet pressure per 100 psi change in inlet pressure, divide the change in inlet pressure by 100 and multiply by 0.5. An example is a 2,200 psig cylinder considered empty at 200 psig. The math is 2,200-200= 2,000 ÷100= 20x0.5= 10, which means the regulator outlet pressure would increase 10 psi from a full to empty cylinder.

SPE only occurs with a change in inlet pressure which means primarily relegated to source applications for non-liquified gases as liquified gases have a constant pressure. Line / point of use (POU) regulators downstream of the source regulator have a constant inlet pressure.

SPE considerations

The value of SPE can vary significantly between regulators. The same regulator series with two seat orifice sizes will have two SPE's. Increasing the diaphragm size for a given seat and poppet will decrease the SPE. High flow regulators have a higher SPE than low flow regulators due to the ratios of diaphragm to seat orifices, the higher flow regulators have a much smaller diaphragm relative to the seat orifice. A low flow regulator SPE will typically be less than 1psi per 100 psi change, whereas a high flow regulator can be in the range of 2 to 5 psi change per 100 psi change. This translates to a potentially large outlet pressure rise for a high flow regulator rated to high inlet pressure. Using the same example again, a cylinder going from 2,200 psi to 200 psi with a SPE of 5, the change in outlet pressure becomes 100 psi.

Most regulators have pressure adjustment stops which limit the maximum outlet pressure. If the stop is set to deliver maximum of outlet rating at the maximum of inlet rating, it means that the regulator can be adjusted to deliver a higher pressure than its rating. This means a low flow regulator with a 0.5 psi SPE could deliver 13 psi more than its rating and a high flow regulator with a SPE of 5 could deliver 130 psi more than its rating if the cylinder pressure went from 2,800 to 200 psig. It is unwise to operate a regulator above its published pressure ratings which means regulators must be monitored and adjusted to compensate for SPE.

Devices and settings on the downstream side of the regulator, such as pressure measurement devices, relief valves, alarm set points, etc. must take SPE into consideration for their ratings and sizing. This is especially important for high flow regulators with higher SPE. A device should not trip or be damaged due to SPE.

SPE can be confused with an across the seat leak (outlet pressure rise due to contamination typically). One must be aware of the impact of SPE to understand whether the outlet pressure rise is an internal leakage or SPE.

A regulator adjusted to a desired outlet pressure setting with N2 purge pressure, typically 80 psig, will need readjustment if the inlet pressure is significantly different with the process gas.

Read SPE specifications carefully, as the inlet pressure increment can vary. For example, mini-regulators with small diaphragms often state a given change per 20 psi rather than the typical 100 psi.

Piston and bellows sensed regulators also have SPE, if not pressure balanced.

The regulators discussed herein are unbalanced designs. A balanced pressure regulator design can mitigate SPE. A typical balanced regulator has the bottom of the poppet exposed to outlet pressure instead of inlet pressure.