ADVANCED PRESSURE TECHNOLOGY

Product Note, PN 421
Pressure Regulator Seat Abrasion

June 28, 2010

There is a failure mode in certain applications where the PCTFE seat material of a gas pressure regulator abrades, eventually causing an across the seat leak. Some material is transferred to the mating part and some material is swept into the gas flow path. The phenomenon is appropriately named ‘seat abrasion’. It occurs in applications where the mass flow controller or shut off valve cycling downstream of the regulator is closely coupled with low internal volume between the two components. Flow cycling; either on / off or changing flow; causes the seat to abrade. The degree of abrasion is a function of poppet stroke (travel), which is the distance the poppet moves due to a combination of pressures and flow, and the number of flow cycles. Increased stroke causes an increase in seat abrasion.

Seat abrasion primarily takes place in point of use applications. It is especially prone to occur in integrated gas systems (IGS) prevalent in semiconductor wafer process tools due to the IGS low internal volume. Many installations use the same regulator inside the process tool and in the distribution line upstream feeding the tool. The regulator upstream sees the same process gas, flow, and cycling as the regulator in the tool, but it is only the regulator in the tool where seat abrasion has been observed.

Investigation, Observations and Findings

AP Tech launched an extensive investigation of seat abrasion and possible remedies. Regulator designs and variations to existing designs were evaluated. Springless tied diaphragm regulators were compared to free poppet spring type regulators. Different seat materials were evaluated. Regulators were cycled at different flow rates and tested for across the seat performance. After extensive testing and evaluation some conclusions were finally drawn.

The abrasion occurs due to contact of the mating parts, the minor misalignment of the poppet to the seat, and the rapid movement of the poppet. It is impossible to produce anything that is perfectly aligned and there will always be some tolerance for the fit of mechanical parts. Though the regulator poppet aligns extremely well to the seat, both radially and axially, there is still a tolerance and therefore a misalignment.

PCTFE, PFA and PTFE seat materials were tested. It was found that PFA survived much longer than PCTFE, but that PTFE survived much longer than PFA. This is not surprising as the coefficient of friction is lowest with the PTFE material and the PTFE tends to conform to misalignment more than PCTFE or PFA.

The springless tied diaphragm design was found to survive flow cycling, passing creep testing. However, upon disassembly, it was found that seat abrasion still occurred. The tied diaphragm feature, poppet attached to the diaphragm, masked the abrasion by pulling the poppet closed as outlet pressure increased above set point, in spite of the abrasion. Please refer to PN 402 posted on the AP Tech website for an explanation of tied diaphragm regulators. Though the tied diaphragm design survived the testing, overall creep performance was not as good with increased cycles compared to PTFE seated regulators.

There is little downside to using PTFE instead of PCTFE at point of use other than permeation rate. Helium permeation is greater with PTFE (and PFA) than PCTFE. PTFE performs as well as, or better than PCTFE in all other critical aspects. Another benefit is that PTFE is also compatible with N2O, which eliminates the need for a Vespel seat for this gas service. The PTFE seat is rated for 300 psig or less maximum inlet pressure as the material can cold flow under high loads, but this should not be a factor for point of use applications.

Flow cycle test data performed by AP Tech is summarized in Table 1 for the AP 500 standard regulator. The comparison is limited to PCTFE and PTFE. PFA performs in between these two, therefore, it was not included. Flow cycle testing generally consisted of opening a pneumatic valve on the regulator outlet to initiate flow for 2 seconds and then closing the valve to stop flow for 2 seconds for one complete cycle. The regulators were periodically tested for creep after 3 minutes and after 2 hours. If the creep exceeded 2 psi in 3 minutes or 3 psi in 2 hours, then it was considered a failure. The test results show a significant improvement in flow cycle life from PCTFE to PTFE under the specified test conditions.

Seat Material	Inlet Pressure	Outlet Pressure	Flow Rate	Failure Range	
				Minimum	Maximum
PCTFE	60 psig (0.41 MPa)	30 psig (0.21 MPa)	1.0 slpm	1,600,000	2,400,000
PCTFE	60 psig (0.41 MPa)	30 psig (0.21 MPa)	5.0 slpm	800,000	2,000,000
PCTFE	60 psig (0.41 MPa)	30 psig (0.21 MPa)	15.0 slpm	10,000	300,000
PTFE	60 psig (0.41 MPa)	30 psig (0.21 MPa)	5.0 slpm	5,000,000 (test goal, no failures)	
PTFE	60 psig (0.41 MPa)	30 psig (0.21 MPa)	15.0 slpm	5,000,000 (test goal, no failures)	

Table 1. AP500 Standard Flow Cycle Test Summary

Recommendation

Flow cycle seat abrasion is a function of poppet stroke and low internal volume between the regulator and mass flow controller (or valve) being cycled downstream. It was found that PCTFE performed well to 1 slpm and the flow cycle life decreased as flow rates or stroke increased. Tied diaphragm designs mask the seat abrasion and do not perform as quite well as PTFE seated regulators. It is our recommendation to standardize on PTFE seat material for all on tool applications, even though there is not a need to use PTFE at low flow rates.