Test Report # 30011300 Rev 0

Adiabatic Compression In Nitrogen Service

Scope: This test report contains test data on the effects of adiabatic compression in nitrogen service on AP3600 diaphragm valves with Vespel, Kynar, and PFA seats.

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Introduction

Background

Heat is generated when a gas is compressed from a low pressure to a high pressure. When the pressurization occurs rapidly there is essentially no heat transfer to the surrounding environment (adiabatic process). In gas handling systems, adiabatic compression is used to refer to the heat of compression that occurs when a cylinder valve (or any high pressure isolation valve) is rapidly opened to pressurize a section of tubing such as a pigtail (flexible tube line from the cylinder to the gas source manifold) from atmospheric pressure to full cylinder pressure.

Previous adiabatic compression testing reported in Report No. 30010000 found that severe damage to PCTFE seats was possible if the test valve was partially open, but if the test valve was fully closed, then no damage resulted. The purpose of the tests described in this report was to evaluate seat materials other than PCTFE.

Test Units

Model AP3600SM 2PW FV4 FV4 manual, diaphragm valves were used for testing. Valves were assembled for testing with Vespel®, Kynar®, and PFA seats. PFA seats are not currently available in high-pressure AP Tech valves, but were evaluated because PFA has excellent oxygen compatibility properties. Figure 1 shows a sectional view of the AP3600 valve body.

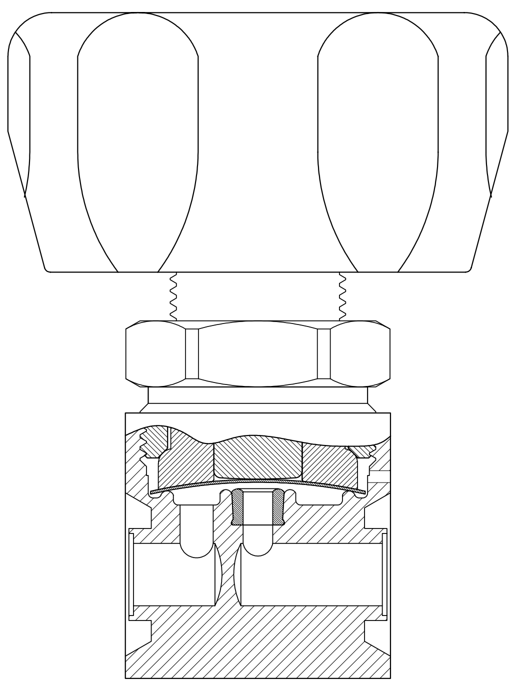

Figure 1. AP3600 Valve Sectional View

Adiabatic Compression Test

Test Setup and Protocol

The test setup is shown in Figure 2. An AP3000 air actuated, diaphragm valve (V1) was connected directly to the cylinder outlet connection and used to rapidly pressurize the tube line at the inlet to an AP3600 manual, diaphragm valve (V3). An AP3000 air-actuated, diaphragm valve (V2) with a flow restrictor in the outlet was used to vent the tube line. A 0-3000 psig (0-207 barg) range transducer was used to monitor the tube line pressure. The transducer output was recorded using a data acquisition system at 240 samples per second. The tube line was 3/8 inch nominal size tube with .305 inch (7.7 mm) inside diameter. The tube line was 5 feet (1.5 m) long and installed at the inlet to the test valve. A new seat was installed in the test valve prior to the start of each test. Testing was performed using conditions that had resulted in failure of PCTFE seats – once a seat had failed, further testing on that seat material was stopped. For the tests with an across-the-seat leak, a notch was placed in the seat to create a leak path. A wire was pressed into the seat to create the notch. The wire was removed before installation of the diaphragms and actuator.

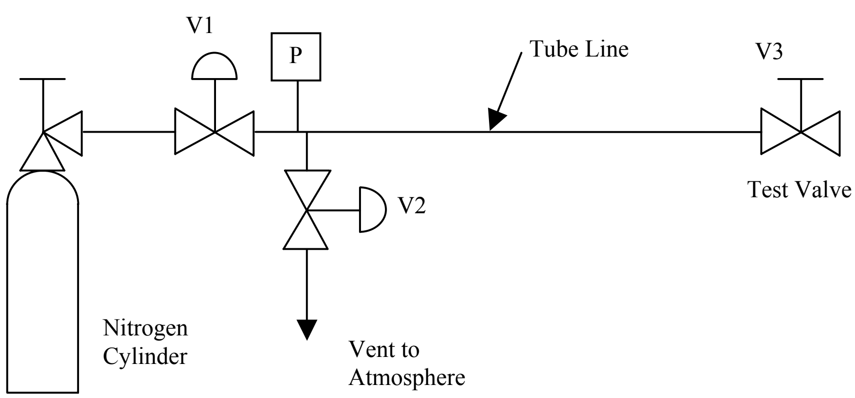

Figure 2. Adiabatic Compression Test Setup

The basic test procedure consisted of the below steps. Each seat was first evaluated with test valve V3 closed. The seat was then evaluated with test valve V3 partially open to achieve different flow rates. Finally, a notch was placed in the seat using a wire to create an across-the-seat leak in test valve V3 and the seat was evaluated with the test valve closed. Exact conditions for each test are described in the results section.

1. Close all valves.
2. If the test valve V3 is closed during the entire test, then skip to step 8.
3. Open valve V1.
4. Slowly open cylinder valve.

5. Adjust test valve V3 to obtain desired flow rate.
6. Close valve V1.
7. Open valve V2 to vent system to atmospheric pressure, then close valve V2. Skip to step 9.
8. Slowly open cylinder valve.
9. Start data acquisition system.
10. Open valve V1 to rapidly pressurize to cylinder pressure and wait approximately 2 seconds, then close.
11. Open valve V2 to vent to atmospheric pressure and wait approximately 2 seconds, then close.
12. Repeat steps 11 and 12 until valve damage is evident by increased leak rate or until the test valve inlet has been exposed to 20 pressurization cycles.
13. Close cylinder valve.
14. At the end of each test, the disassembled and inspect the seat in test valve V3.

Results

Evidence of melting or an eroded seat confirmed whether seat damage had occurred. The cylinder pressure is the pressure on the first pressurization when multiple cycles were performed. The fill time is the time from the first increase in pressure reading until 95% of full cylinder pressure. It should be noted that it was very difficult to set test valve V3 to maintain the same leak rate at each pressurization cycle. This is because diaphragm valves are not intended for throttling due to sealing geometry and coarse stem adjustment.

A summary of the test results is shown in Table 1 for the Vespel seat tests, Table 2 for the Kynar seat test, and Table 3 for the PFA seat tests. The Vespel seat was not damaged during the test. Figure 3 shows a new Vespel valve seat prior to testing. Figure 4 shows the Vespel seat after valve test #V5. The Kynar seat showed melting and erosion that was similar to damaged PCTFE seats discussed in Report No. 30010000. Figure 5 shows a new Kynar valve seat prior to testing. Figure 6 shows a damaged Kynar valve seat after valve test #K2. Figure 7 shows a new PFA valve seat prior to testing. Figure 8 shows the PFA seat after valve test #P3. PFA seats are not used in high pressure AP Tech valves for a number of reasons. During this test, high pressure caused the seat to move upward out of the seat cavity as the valve was opened, effectively shutting off the flow. This movement prevented testing of the PFA seat when the valve was partially opened.

Table 1. Vespel Seat Adiabatic Compression Test Results

Valve Test No.	Nominal Tube Size, inch	Flow Rate thru Test Valve V3 (at cylinder pressure), slm	Cylinder Pressure, psig	Cycles Performed	Fill Time, milliseconds	Seat Damage
Test valve V3 closed.						
V1	3/8	0	2414	10	117	No
Test valve V3 partially open.						
V2	3/8	60	2361	10	110	No
V3	3/8	150	2296	10	137	No
V4	3/8	350	2225	10	117	No
Test valve V3 closed but wire used to cause across-the-seat leak.						
V5	3/8	10	2130	10	125	No

Table 2. Kynar Seat Adiabatic Compression Test Results

Valve Test No.	Nominal Tube Size, inch	Flow Rate thru Test Valve V3 (at cylinder pressure), slm	Cylinder Pressure, psig	Cycles Performed	Fill Time, milliseconds	Seat Damage
Test valve V3 closed.						
K1	3/8	0	2110	10	132	No
Test valve V3 partially open.						
K2	3/8	150	2062	1	175	Yes

Table 3. PFA Seat Adiabatic Compression Test Results

Valve Test No.	Nominal Tube Size, inch	Flow Rate thru Test Valve V3 (at cylinder pressure), slm	Cylinder Pressure, psig	Cycles Performed	Fill Time, milliseconds	Seat Damage
Test valve V3 closed.						
P1	3/8	0	2043	10	132	No
Test valve V3 partially open.						
P2	3/8	150	2003	*	*	*
Test valve V3 closed but wire used to cause across-the-seat leak.						
P3	3/8	3	2000	10	108	No
P4	3/8	7	1970	10	117	No

* Flow shut off as test valve was opened to set flow rate. Test was halted and disassembly found that seat had moved upward to shut off flow.

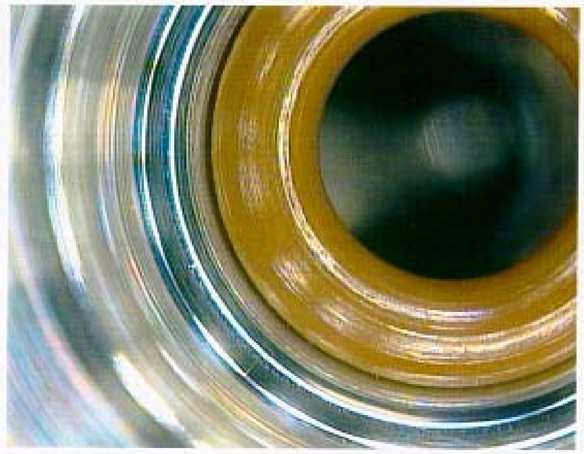

Figure 3. New Vespel seat before testing
(10X magnification)

Figure 4. Vespel seat after Test #V5 (wire used to create across-the-seat leak)
(25X magnification)

Figure 5. New Kynar seat before testing
(12X magnification)

Figure 6. Kynar seat after Test #K2
(12X magnification)

Figure 7. New PFA seat before testing
(15X magnification)

Figure 8. PFA seat after Test #P3 (wire used to create across-the-seat leak)
(30X magnification)

Summary

Adiabatic compression testing was performed in nitrogen service to determine conditions that would cause damage to the seat of an AP3600 springless, diaphragm valve when an upstream isolation valve was rapidly opened. Tests were conducted with Vespel, Kynar, and PFA seats. When the test valve was fully closed, no seat damage to the Vespel, Kynar, or PFA occurred after 10 pressurization cycles. The Kynar seat was damaged when tested with the test valve partially open in a single pressurization. The Vespel seat was not damaged under any test conditions. The PFA seat was also not damaged under any test conditions, but could not be tested with the valve partially open.

The test data demonstrates that Kynar seat diaphragm valves can be damaged due to adiabatic compression in nitrogen service. No damage was found during testing with PFA seats, but PFA is not currently acceptable for high pressure service. The test data demonstrates that Vespel can withstand heating due to adiabatic compression under a variety of test conditions. In general, AP Tech has found that compared to PCTFE, Vespel is less likely to form a leak tight seal, is not as chemically compatible especially in corrosive gas service, and has higher moisture outgassing characteristics. Therefore, Vespel is not recommended to replace PCTFE in all systems. In a specific application where PCTFE seats are being damaged due to adiabatic compression, the user should consider the use of Vespel seat valves as a possible solution.

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