ALD6 Diaphragm Valve Technical Report

Scope

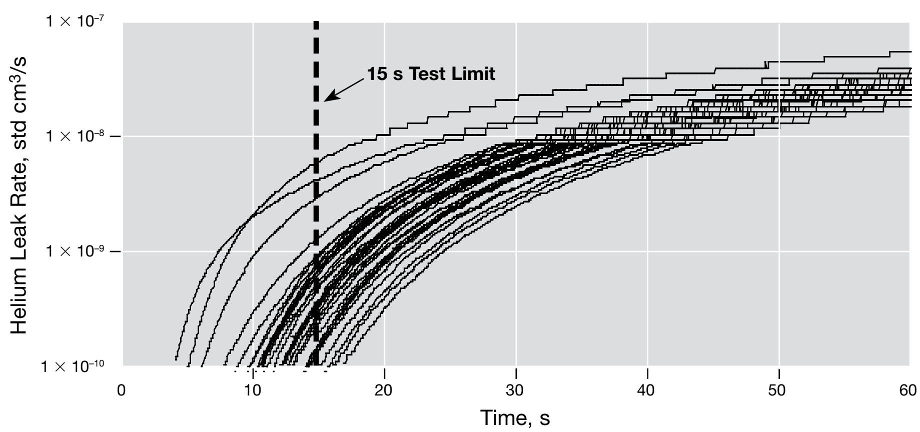
This technical report provides data on Swagelok® ALD6 normally closed diaphragm valves. The report covers:

- helium seat leak testing
- valve flow consistency analysis
- lab cycle testing
- actuator thermal isolation and valve thermal response
- particle counting
- ionic cleanliness
- surface finish
- moisture analysis
- hydrocarbon analysis
- pneumatic actuation response.

Particle counting, moisture analysis, and hydrocarbon analysis data show test results from valves cleaned with deionized (DI) water according to the techniques described in Swagelok *Ultrahigh-Purity Process Specification (SC-01),* MS-06-61.

Helium Seat Leak Testing

Swagelok ALD6 valves processed to meet Swagelok *Ultrahigh-Purity Process Specification (SC-01),* MS-06-61, were evaluated for inboard helium leak integrity of the valve seat in accordance with SEMI-F1. The 36 valves exhibited a helium permeation response that was significantly better than the 1×10^{-8} std cm^3/s leak rate at the 15 s test limit.

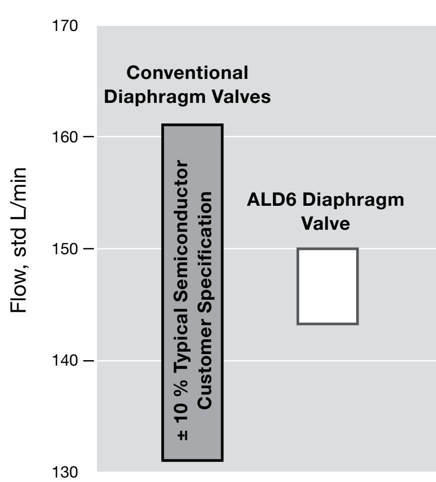


Valve Flow Consistency Analysis

Swagelok ALD6 valves are factory set to provide a consistent flow performance.

A quantity of 48 valves was tested in accordance with SEMI F32 following standard production assembly. The measured difference in flow output among the 48 valves was less than 6 %.

- 5 psig (0.34 bar) inlet pressure
- 5 psi (0.34 bar) differential pressure
- 70°F (20°C)



Lab Cycle Testing

The Swagelok ALD6 valve was evaluated to determine an estimated cycle life under controlled laboratory conditions. All valves were electronically monitored during testing for envelope seal integrity. At regular intervals the valves were removed and evaluated for seat seal integrity, envelope seal integrity, flow performance, and actuator seal performance.

These tests are not a guarantee of a minimum number of cycles in service. They indicate that in tests under these laboratory conditions the probability of early failure is low. Laboratory tests cannot duplicate the variety of actual operating conditions and cannot promise that the same results will be realized in service.

Valve Model	Standard, ALD6				Thermal, ALD6T
Quantity	16	16	16	16	16
Gas	Dry, filtered nitrogen				
External (Oven) Temperature	70°F (20°C)	70°F (20°C)	248°F (120°C)	248°F (120°C)	70°F (20°C)
Valve Temperature	70°F (20°C)	70°F (20°C)	248°F (120°C)	248°F (120°C)	392°F (200°C)
Actuator Temperature (measured while cycling)	98°F (37°C)	98°F (37°C)	260°F (127°C)	260°F (127°C)	194°F (90°C)
Valve Pressure	50 psia (2.4 bar)	Vacuum	50 psia (2.4 bar)	Vacuum	50 psia (2.4 bar)
Cycle Rate	10 cycles per second, 50 % actuation duty cycle				
Cycles Accumulated (Millions)	25 suspended	100 suspended	25 suspended	25 suspended	25 suspended
Measured Valve Flow Rate at 70°F (20°C)①	No change	No change	Change < 6 %	Change < 4 %	Change < 6 %
Envelope Leakage②③ $> 1 \times 10^{-9}$ std cm^3/s He	1 at 16 million	NONE	NONE	NONE	NONE
Seat Seal Leakage②④ $> 1 \times 10^{-7}$ std cm^3/s He	1 at 25 million	NONE	NONE	NONE	NONE
Actuator Air Leakage② > 1 L/min at 80 psig input	NONE	NONE	NONE	NONE	NONE

① No change—None of the valves in the population exhibited a measured change in flow or a change in flow greater than the defined limit.

② NONE—None of the valves in the population exhibited detectable leakage or leakage greater than the defined limit.

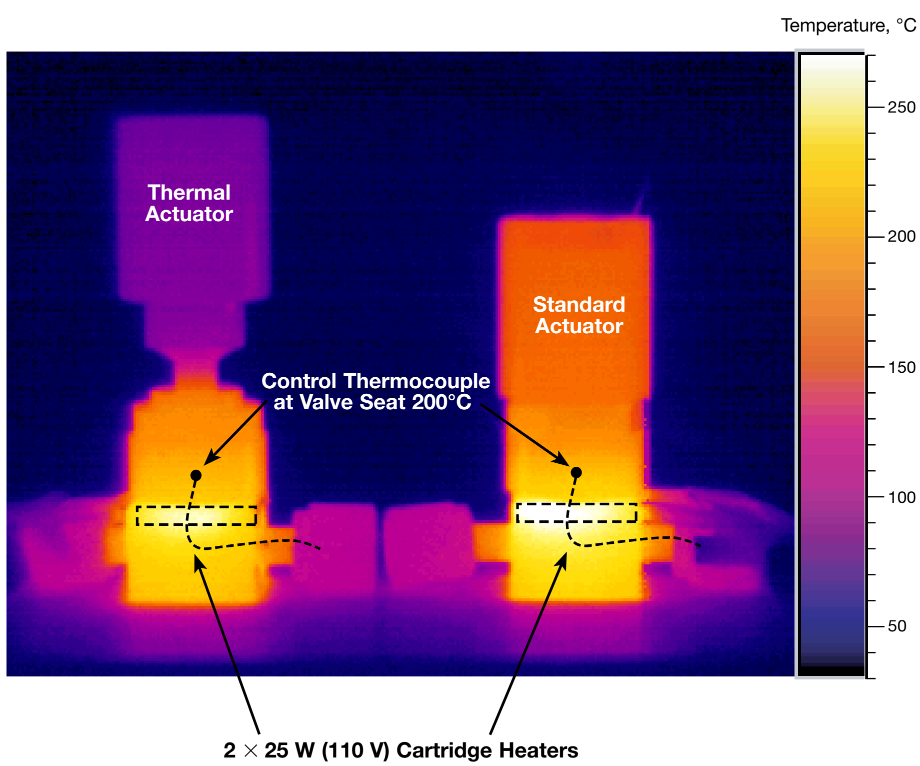
③ The valve exhibiting excessive envelope leakage occurred at 16 million cycles. According to Weibull analysis, the valve is 95 % reliable with 95 % confidence for greater than 25 million full open/close actuation cycles with nitrogen media at less than 50 psia (2.4 bar) and at temperature within a range of 68 to 72°F (20 to 22°C). The mean time to failure of 25 million is 0.6 %.

④ The valve exhibiting excessive seat seal leakage measured 3.0×10^{-7} std cm^3/s He at the 25 million cycle mark.

Actuator Thermal Isolation and Valve Thermal Response

A Swagelok ALD6 valve was evaluated for thermal response using an infrared (IR) video camera. The adjacent figure presents temperature profiles of two valves, with and without actuator thermal isolation. Heater cartridges were inserted in the valve bodies and energized using a temperature controller to maintain a valve body temperature of 200°C (392°F).

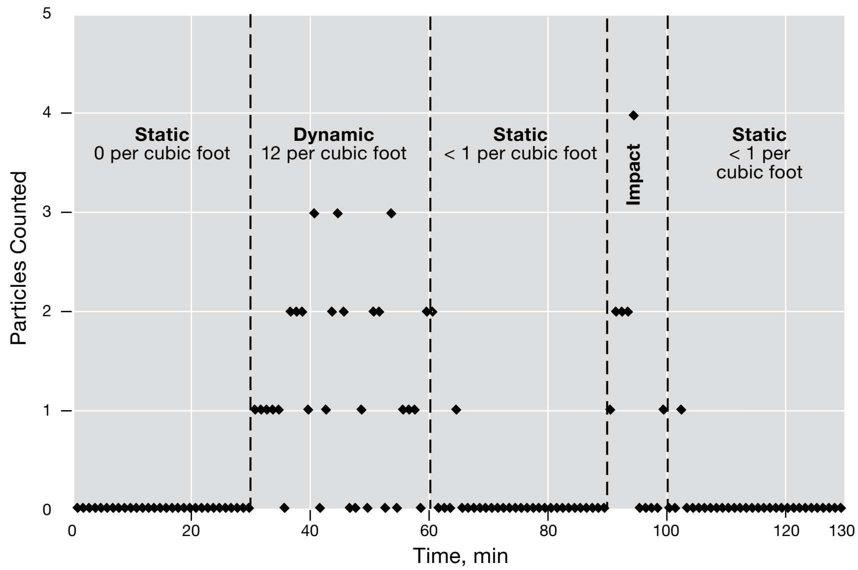
The IR image of the valves indicates a significant reduction in actuator temperature is realized when the thermal isolator is employed. The temperature profile in the valve body is also notably more uniform when the thermal isolator is used, minimizing cold or hot spots in the fluid flow path. The use of the thermal isolation coupling has the additional benefit of reducing the power required to maintain temperature when the valve body is actively heated.



Particle Counting

ASTM F1394 Particle Count Performance

Testing was performed in accordance with ASTM F1394, measuring particles greater than 0.02 µm in size. Static particle emissions from a Swagelok ALD6 valve meet the recommended performance of fewer than 20 particles per cubic foot, in accordance with SEMI E49.8.



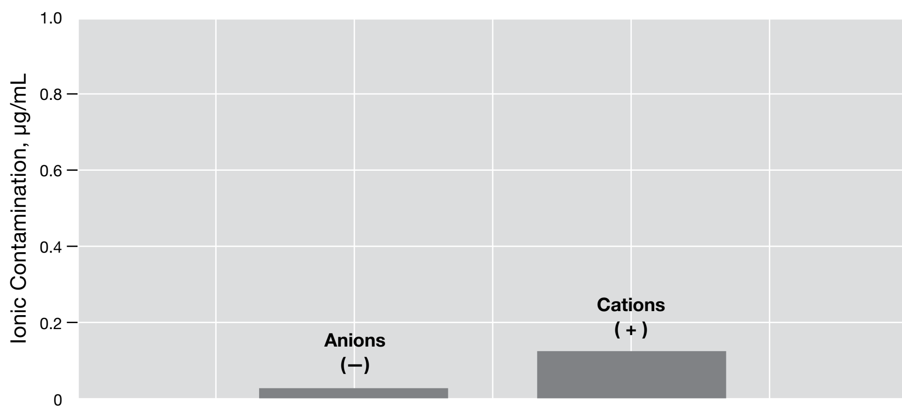
Ionic Cleanliness

Residual ionic contamination is very low (less than 1 µg/mL) for Swagelok SC-01 processed valves.

Swagelok ALD6 diaphragm valves were tested in accordance with ASTM F1374:

- Each valve was filled with deionized (DI) water.
- After 24 h, the sample was extracted and analyzed.

Anions (—)	Cations (+)
Fluoride	Lithium
Chloride	Sodium
Nitrate	Ammonium
Phosphate	Potassium
Sulfate	Magnesium
	Calcium



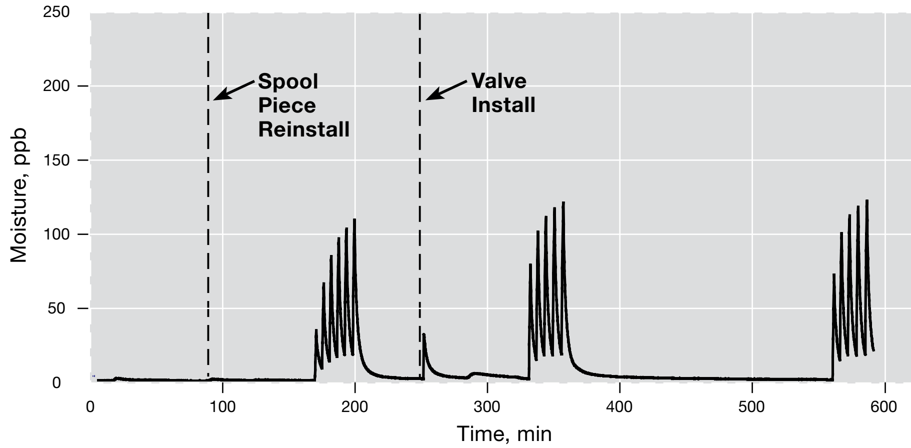
Surface Finish

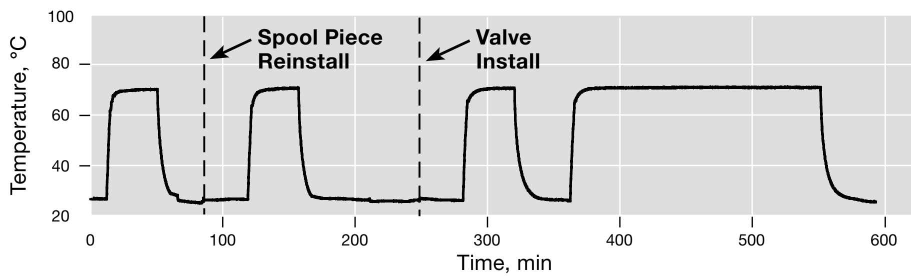
Statistical process control (SPC) allows Swagelok to provide consistent surface finishes, as described in in the Swagelok *Ultrahigh-Purity Process Specification (SC-01),* MS-06-61. The roughness average (R_a) specification established for the wetted surfaces of Swagelok ALD6 valves manufactured with a P finish is 5 µin. (0.13 µm) R_a on average.

Moisture Analysis

A Swagelok ALD6 valve recovered from a 200 ppb moisture spike in less than 10 min. This is much faster than the 1 h guideline of SEMI E49.8. Moisture analysis of Swagelok SC-01 processed products was performed in accordance with SEMASPEC 90120397B-STD guidelines.

The lower graph shows the pattern of elevated temperatures that were applied to a valve during testing to enhance the moisture sensitivity of the system.

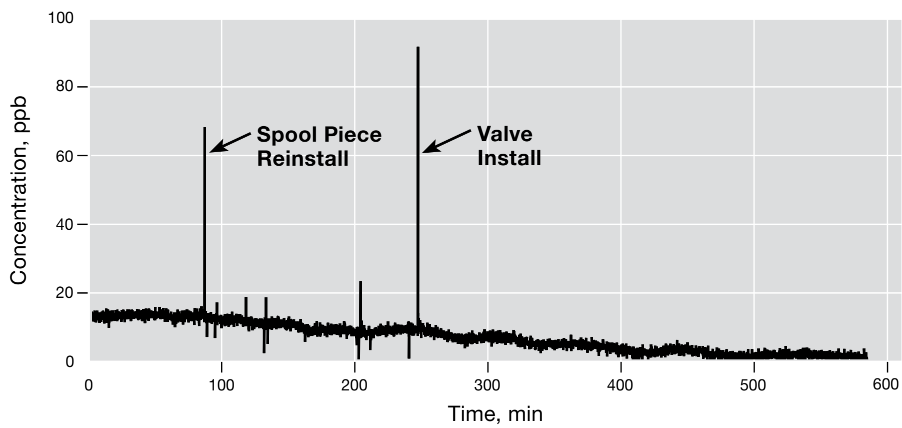


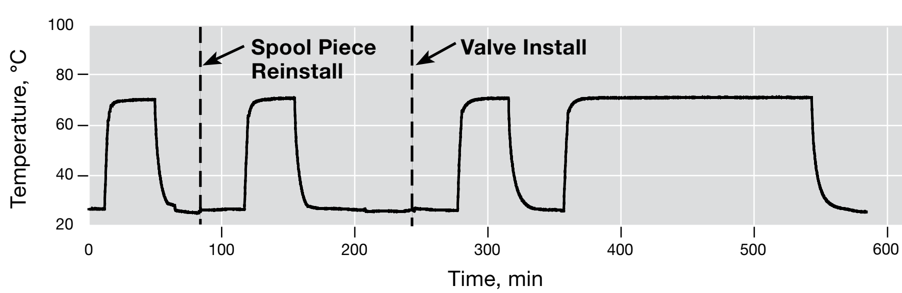


Hydrocarbon Analysis

Hydrocarbon residues in a Swagelok ALD6 valve fall within the background level produced by the test instrument. Hydrocarbon analysis of Swagelok SC-01 processed products is conducted in accordance with SEMASPEC 90120396B-STD guidelines.

The lower graph shows the pattern of elevated temperatures that were applied to a valve during testing to drive off any hydrocarbon residues in the system.

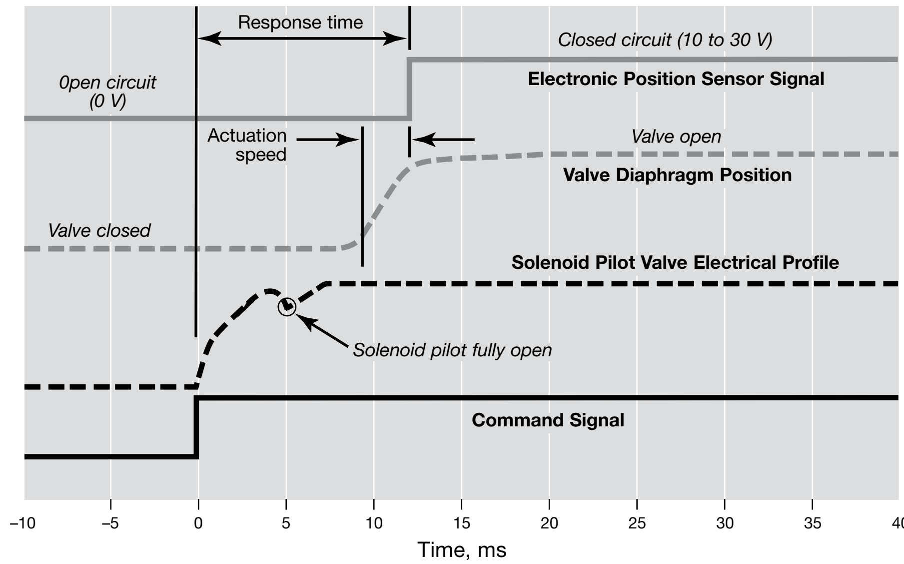




Pneumatic Actuation Speed

The actuation speed of a Swagelok ALD6 valve was electronically evaluated using an oscilloscope and a linear variable displacement transducer (LVDT) in direct contact with the valve diaphragm. The measured valve opening profile is compared to the control signal, response of the solenoid pilot valve, and signal from the optional electronic position indicator. The measured actuation speed of the ALD6 valve is less than 5 ms with a response time of less than 15 ms.

- MAC® 34B-AAA-GDFC solenoid pilot valve
- 70 psig (4.8 bar) actuation pressure
- Tubing from solenoid pilot valve to actuator: 1/8 × 0.016 ×3 in.
- Tubing to solenoid pilot valve inlet: 1/4 × 0.063 in.
- Unrestricted solenoid pilot valve exhaust port

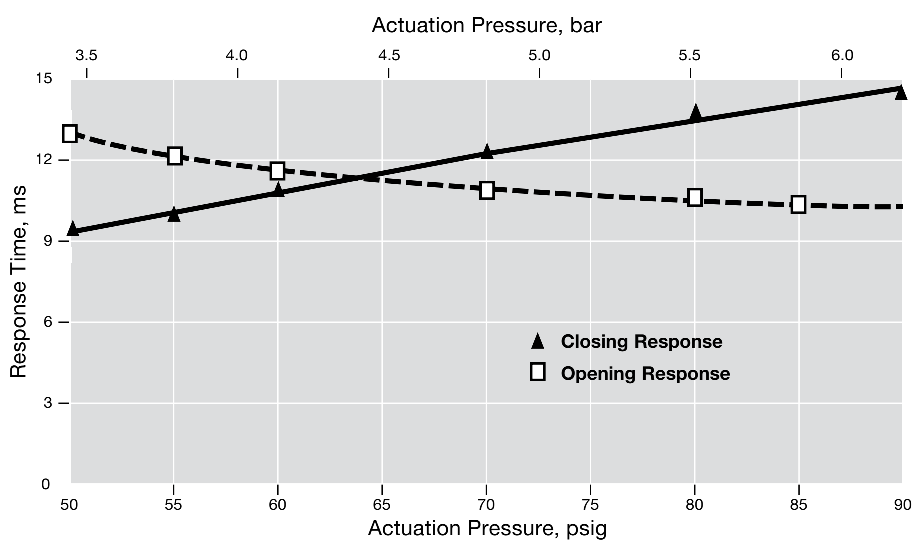


Actuation Response Versus Actuator Supply Pressure

The open response of the Swagelok ALD6 normally closed valve, with varying actuator supply pressure, was evaluated using an LVDT and oscilloscope. Over a broad range of actuation pressures, the difference in opening and closing valve response was less than 5 ms.

Increasing the pneumatic supply pressure results in a faster opening response and slower closing response. Reducing the pneumatic supply pressure has the opposite effect.

- MAC 34B-AAA-GDFC solenoid pilot valve
- Tubing to solenoid pilot valve inlet: 1/4 × 0.016 in.
- Tubing from solenoid pilot valve to actuator: 1/8 × 0.016 × 3 in.
- Unrestricted solenoid pilot valve exhaust port
- Response time recorded at half maximum diaphragm stroke



These tests do not simulate any specific application and are not a guarantee of performance in actual service. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

Referenced Documents

ASTM Standards[1]

F1374 Standard Test Method for Determination of Ionic/Organic Extractables of Internal Surfaces—IC/GC/FTIR for Gas Distribution Systems Components

F1394 Standard Test Method for Determination of Particle Contribution from Gas Distribution System Valves

SEMATECH SEMASPECs[2]

90120396B-STD Standard Test Method for Determination of Total Hydrocarbon Contribution by Gas Distribution Systems Components

90120397B-STD Standard Test Method for Determination of Moisture Contribution by Gas Distribution Systems Components

SEMI Standards[3]

F1 Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

E49.8 Guide for High-Purity and Ultrahigh-Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

F32 Test Method for Determination of Flow Coefficient for High-Purity Shutoff Valves

F70 Test Method for Determination of Particle Contribution of Gas Delivery System

Swagelok Specification

Ultrahigh-Purity Process Specification (SC-01), MS-06-61

① American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428, U.S.A.

② SEMATECH, Inc., 2706 Montopolis Dr., Austin, TX 78741, U.S.A.

③ Semiconductor Equipment and Materials International, 3081 Zanker Road, San Jose, CA 95134, U.S.A.

Safe Product Selection
When selecting products, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

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