Swagelok

ALD Diaphragm Valve Technical Report

Scope

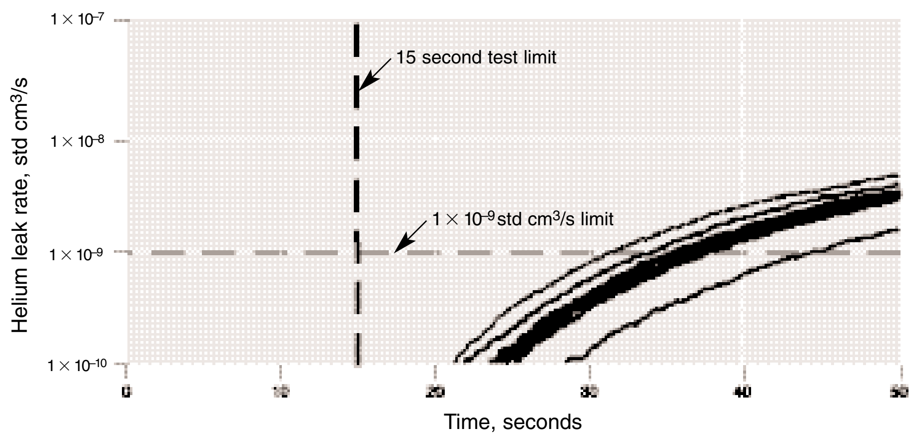
This technical report provides data on Swagelok® ALD normally closed diaphragm valves. The report covers:

- helium seat leak testing
- valve flow consistency analysis
- lab cycle testing
- actuator thermal isolation and valve thermal response
- particle counting
- 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 Specification SC-01.

Helium Seat Leak Testing

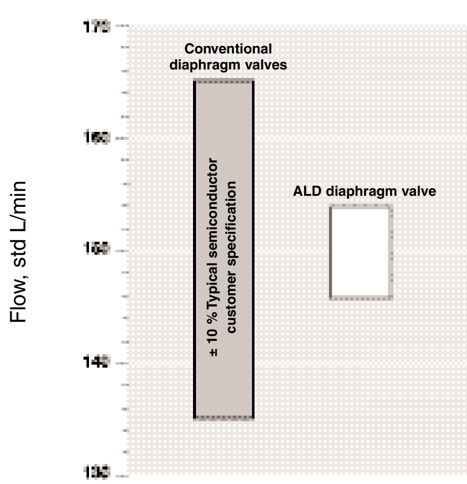
Swagelok ALD valves processed to Swagelok SC-01 were evaluated for inboard helium leak integrity of the valve seat according to SEMI-F1. The 10 valves exhibited a helium permeation response that was significantly better than the 1×10^{-9} std cm³/s leak rate at the 15 second test limit.



Valve Flow Consistency Analysis

Swagelok ALD valves are factory set to provide a consistent flow performance. A quantity of 30 valves was tested according to SEMI F32 following standard production assembly. The measured difference in flow output among the 30 valves was less than 6 %.

- 30 psig (2.0 bar) inlet pressure
- 10 psi (0.68 bar) differential pressure
- 70°F (21°C)



Lab Cycle Testing

The Swagelok ALD 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, ALD				Thermal, ALDT		
Quantity	16	15	13	16	16	8	8
Gas	Dry, filtered nitrogen						
External (Oven) Temperature	70°F (21°C)	70°F (21°C)	248°F (120°C)	248°F (120°C)	70°F (21°C)	70°F (21°C)	70°F (21°C)
Valve Temperature	71°F (21°C)	70°F (21°C)	248°F (120°C)	248°F (120°C)	392°F (200°C)	392°F (200°C)	392°F (200°C)
Actuator Temperature (measured while cycling)	95°F (35°C)	95°F (35°C)	275°F (135°C)	275°F (135°C)	194°F (90°C)	194°F (90°C)	194°F (90°C)
Valve Pressure	50 psia (2.4 bar)	< 50 Torr	50 psia (2.4 bar)	< 50 Torr	50 psia (2.4 bar)	50 psia (2.4 bar)	50 psia (2.4 bar)
Cycle Rate	10 cycles per second, 50 % actuation duty cycle						
Cycles Accumulated (millions of cycles)	50 suspended	50 suspended	29 suspended	50 suspended	22 suspended	27 suspended	30 suspended
Measured Valve Flow Rate①	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Envelope Leakage② > 1×10^{-9} std cm^3/s He	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Seat Seal Leakage > 1×10^{-9} std cm^3/s He	NONE	NONE	NONE	NONE	NONE	NONE	NONE
Actuator Air Leakage②③ > 1 L/min at 80 psig input	NONE	NONE	1 at > 15 million	3 at > 15 million	NONE	NONE	1 at > 25 million

① No Change—No measured change in valve performance during flow testing performed at approximately 5 million cycle intervals.

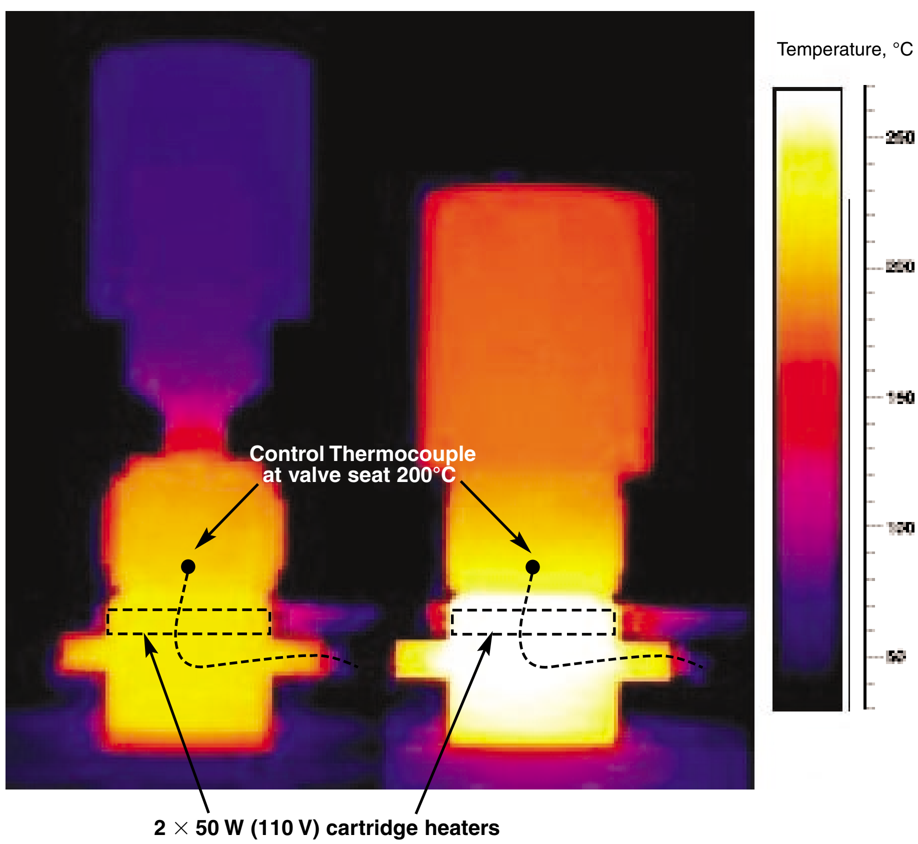
② NONE—All valves in the population exhibited no detectable leakage or leakage within the defined limit.

③ Valves exhibiting actuator air leakage of 1 liter per minute remained fully functional and continued to be cycled to the level indicated in the corresponding Cycles Accumulated box. These valves exhibited no significant change in the actuation response or flow performance. Air leaking from actuator enters the surrounding environment and does not enter the process fluid stream.

Actuator Thermal Isolation and Valve Thermal Response

A Swagelok ALD 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).

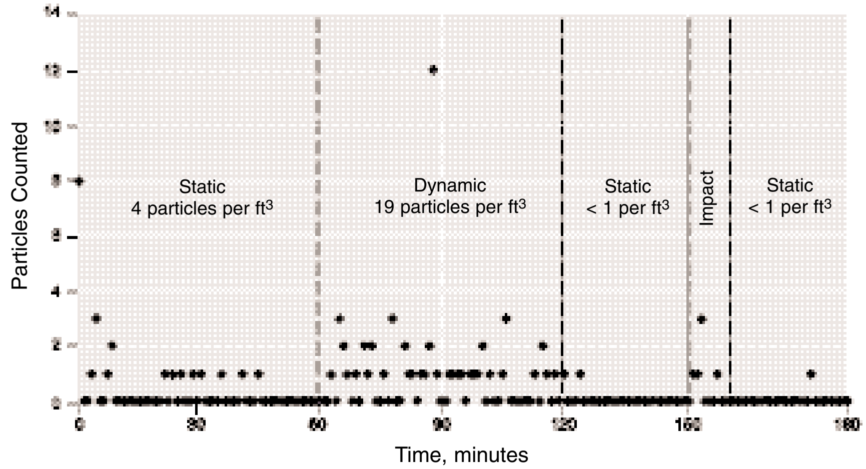
The IR image of the valves indicates a significant reduction in actuator temperature is realized when the thermal isolator is employed. The temperature profile in the valve body is also notably more uniform when the thermal isolator is used, minimizing cold or hot spots in the fluid flow path. The use 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

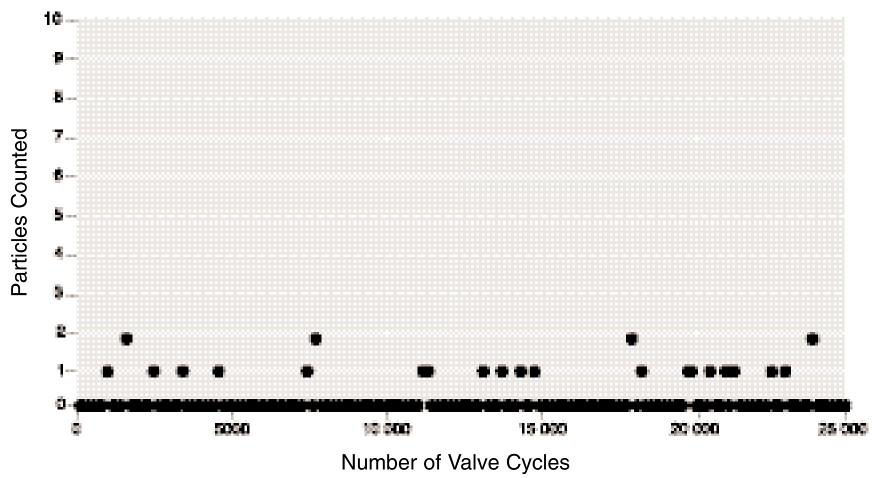
ASTM F1394 Particle Count Performance

Testing was performed according to ASTM F1394 measuring particles greater than 0.02 micrometer in size. Static particle emissions from a Swagelok ALD valve meet the recommended performance of fewer than 20 particles per ft^3 according to SEMI E49.8.



Dynamic Particle Count Performance

Particle shedding performance of a Swagelok ALD valve was assessed under test conditions according to SEMI F70 and ASTM F1394. Fewer than 30 particles greater than 0.1 micrometer in size were counted over a 14-hour dynamic cycle test (25 000 dynamic valve cycles), or approximately 1 particle every 1000 valve cycles (0.001 particle per cycle).



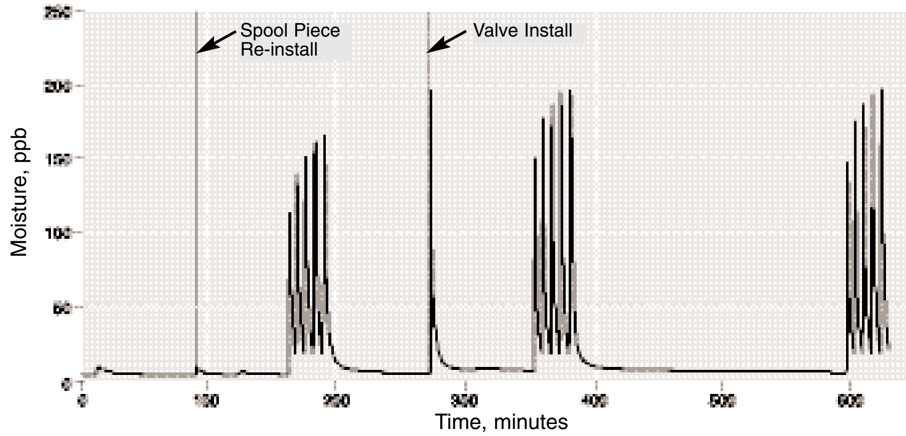
Surface Finish

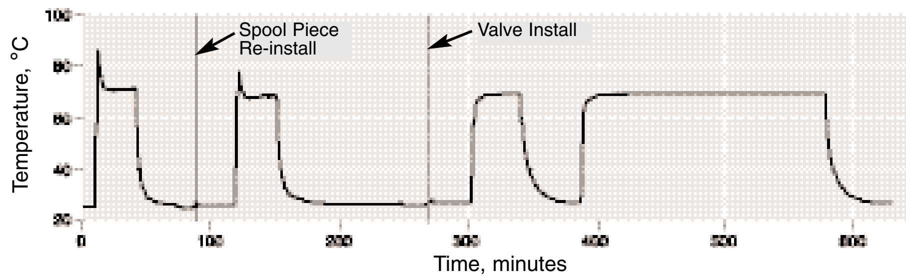
Statistical process control (SPC) allows Swagelok to provide consistent surface finishes, as described in Specification SC-01. The roughness average (R_a) specification established for the wetted surfaces of Swagelok ALD valves manufactured with a P finish is 5 µin. (0.13 µm) R_a on average.

Moisture Analysis

A Swagelok ALD valve recovered from a 200 ppb moisture spike in less than 10 minutes. This is much faster than the 1 hour 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.

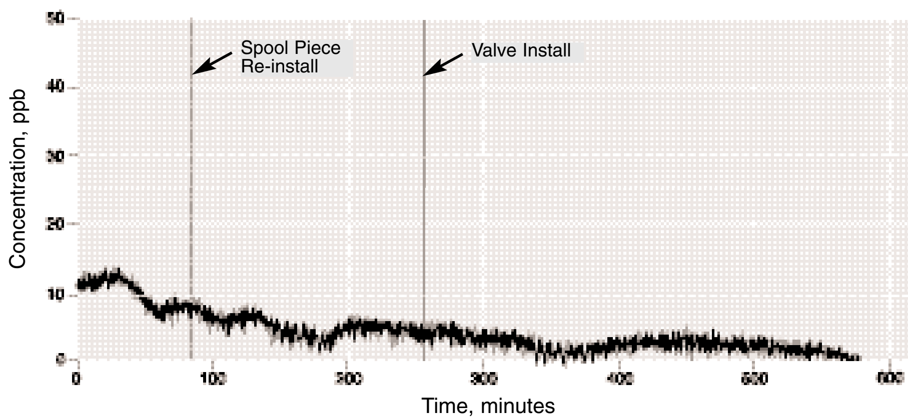


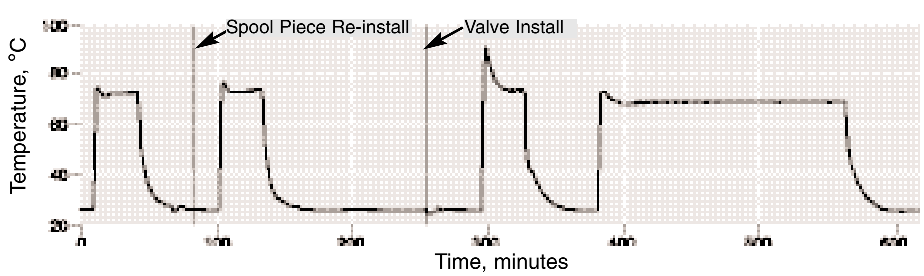


Hydrocarbon Analysis

Hydrocarbon residues in a Swagelok ALD 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.

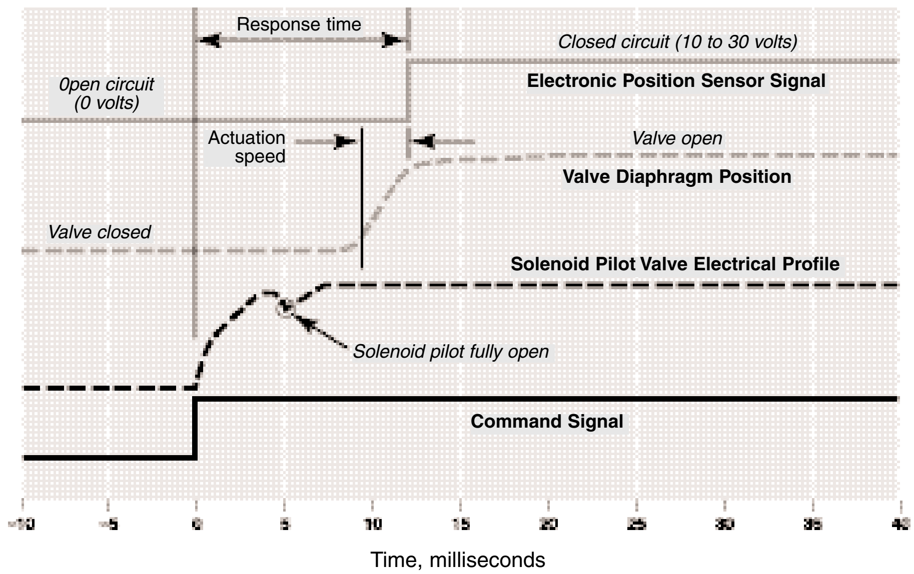




Pneumatic Actuation Speed

The actuation speed of a Swagelok ALD 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 ALD valve is less than 5 milliseconds with a response time of less than 15 milliseconds.

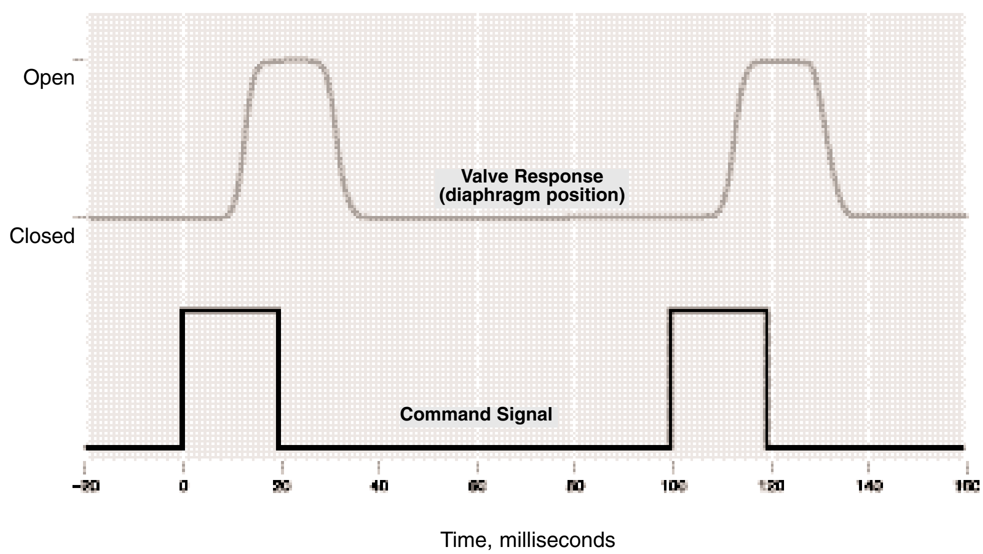
- ■ MAC® 34B-AAA-GDFC solenoid pilot valve
- ■ 70 psig (4.8 bar) actuation pressure
- ■ Tubing from solenoid pilot valve to actuator: 1/8 × 0.016 × 3 in.
- ■ Tubing to solenoid pilot valve inlet: 1/4 × 0.063 in.
- ■ Unrestricted solenoid pilot valve exhaust port



Valve Fast-Pulse Response

The short pulse response of a Swagelok ALD valve was measured using an LVDT and oscilloscope. Even at pulse widths as short as 20 milliseconds the ALD valve can provide a precise and repeatable pulse.

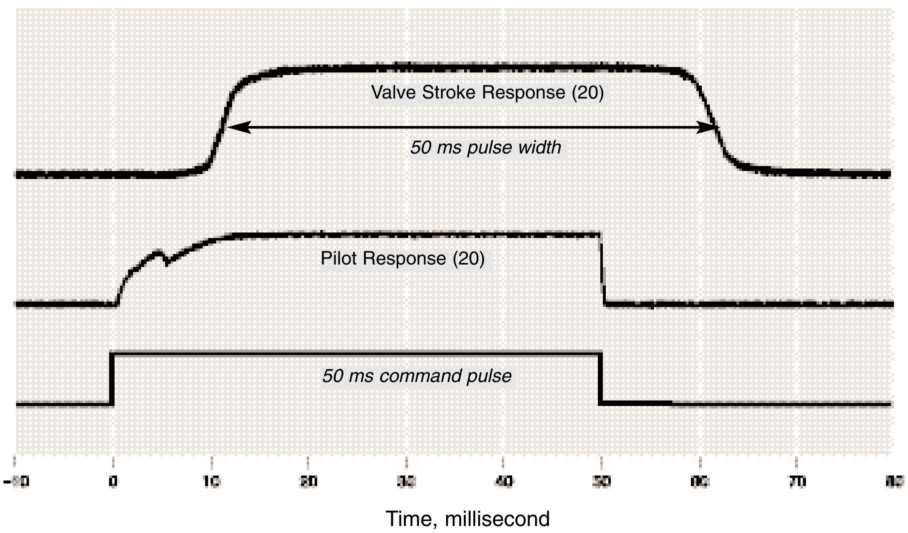
- ■ MAC 34B-AAA-GDFC solenoid pilot valve
- ■ 70 psig (4.8 bar) actuation pressure
- ■ Tubing from solenoid pilot valve to actuator: 1/8 × 0.016 × 3 in.
- ■ Tubing from air trunk line to solenoid pilot valve inlet: 1/8 × 0.016 × 6 in.
- ■ Tubing from solenoid pilot valve exhaust to exhaust trunk line: 1/8 × 0.016 × 2 in.



Actuation Repeatability

The pulse repeatability of a Swagelok ALD valve was evaluated using an LVDT and oscilloscope to track the diaphragm stroke during actuation. Twenty individual pulses were randomly collected over the course of 2 hours from a valve cycling at 5 cycles per second. All 20 of the valve stroke profiles and solenoid pilot valve coil-current profiles are superimposed in the adjacent figure. The measured valve actuation response and pulse width was repeatable to better than 1 millisecond.

- 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



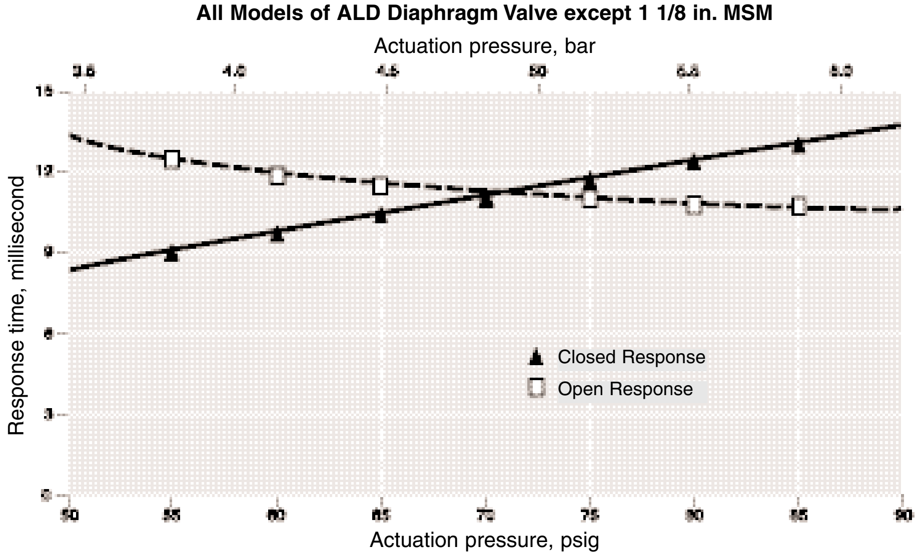
Actuation Response Versus Actuator Supply Pressure

The open response of the Swagelok ALD valve, with varying 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 milliseconds.

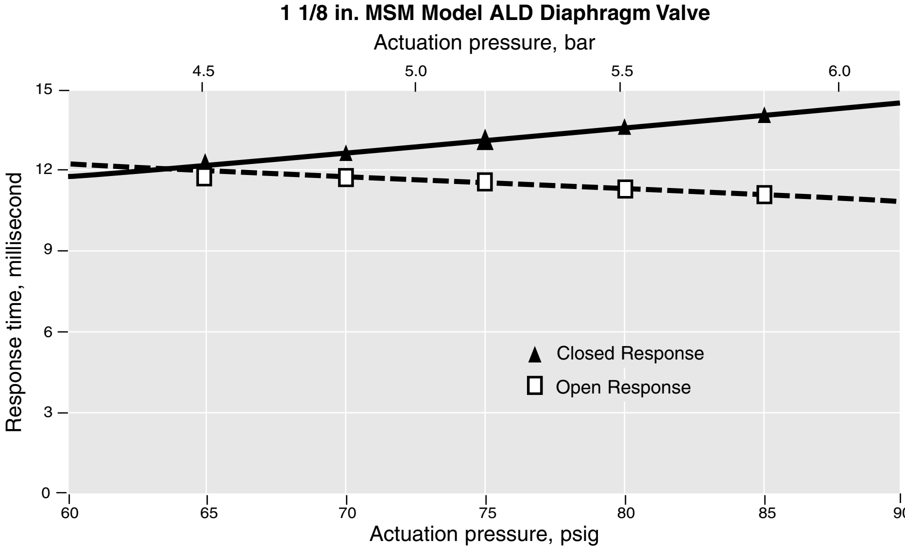
Increasing the pneumatic supply pressure results in a faster opening response and slower closing response. Reducing the pneumatic supply pressure has the opposite effect.

- 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 max diaphragm stroke

All Models of ALD Diaphragm Valve except 1 1/8 in. MSM



1 1/8 in. MSM Model ALD Diaphragm Valve

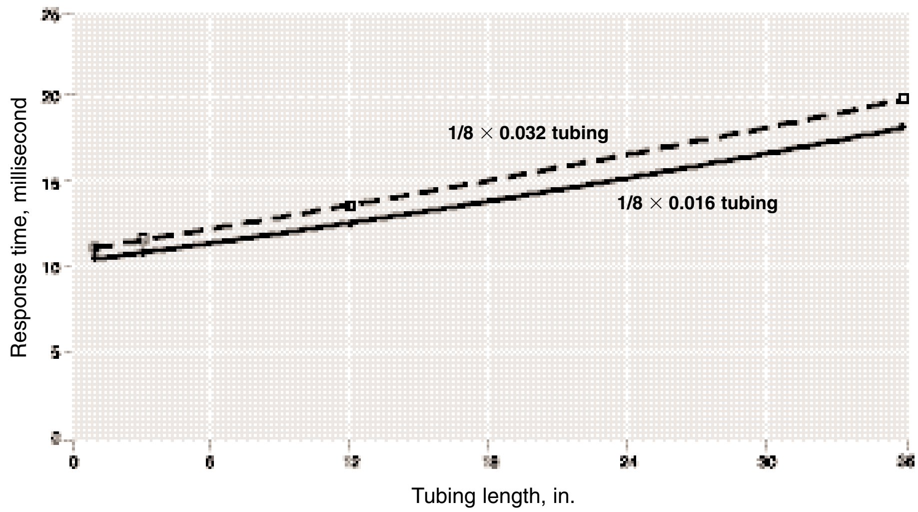


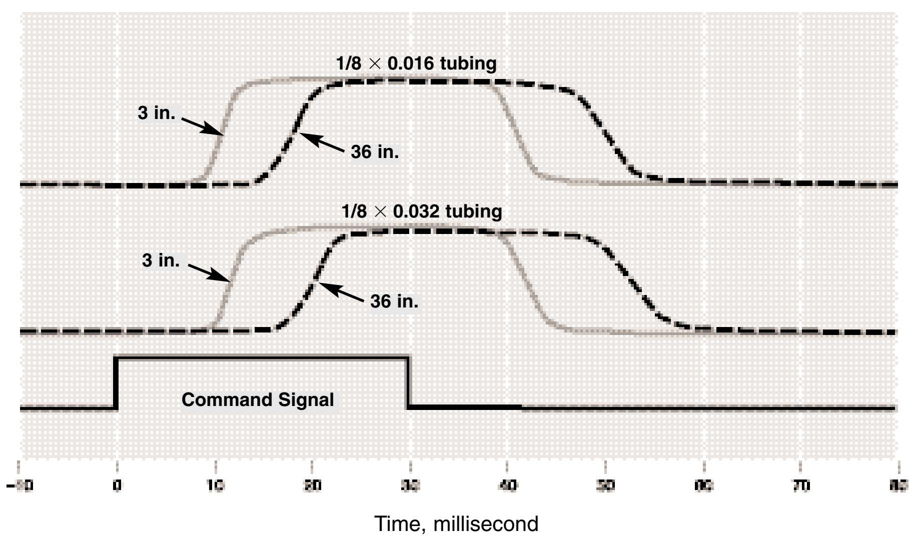
Actuation Response Versus Actuator Supply Tubing Length and Diameter

The response of a Swagelok ALD valve with various length of tubing connecting the solenoid pilot valve and actuator was evaluated using an LVDT and oscilloscope.

Increasing the length of tubing between solenoid pilot and actuator increases the valve response time. Response times of less than 20 milliseconds can be achieved even when a distance of 36 inches separates the solenoid pilot and valve actuator. In addition to tubing length, the inner diameter of the tubing can also affect the actuation response.

- MAC 34B-AAA-GDFC solenoid pilot valve
- 70 psig (4.8 bar) actuation pressure
- Tubing to solenoid pilot valve inlet: 1/4 × 0.063 in.
- Unrestricted solenoid pilot valve exhaust port
- Response time recorded at half max diaphragm stroke

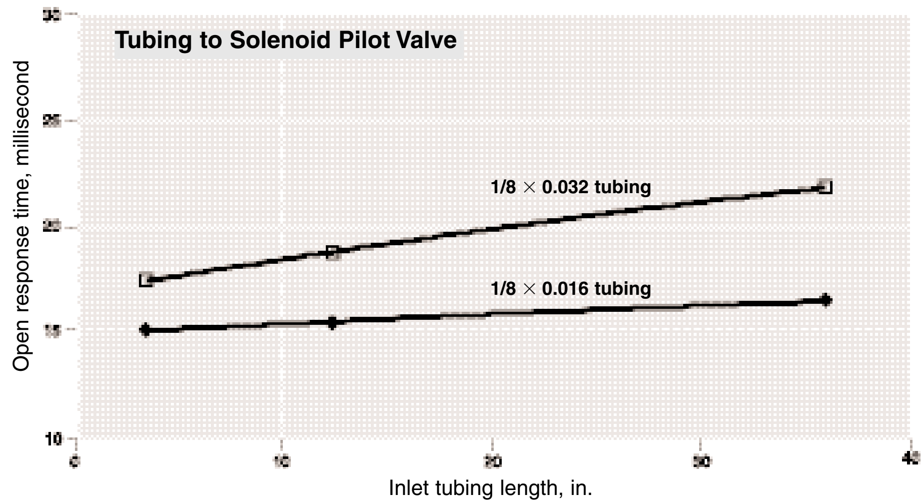


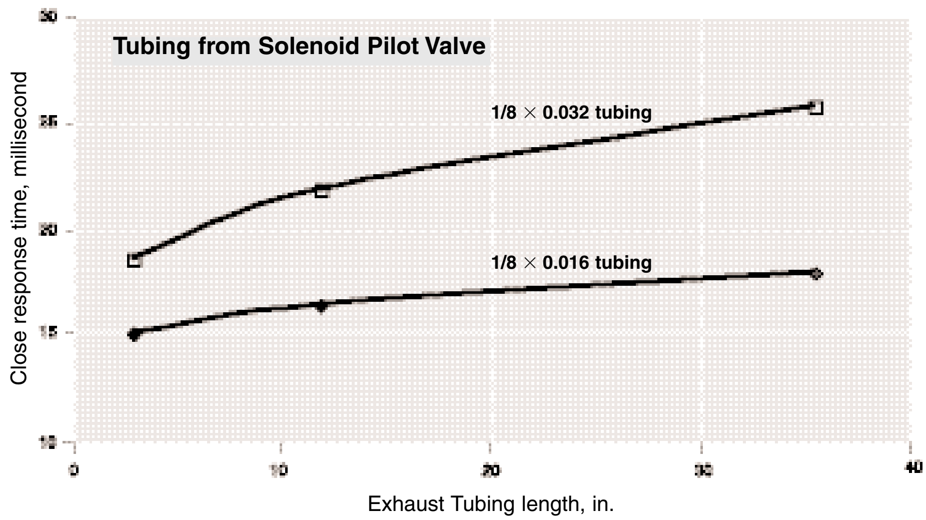


Actuation Response Versus Solenoid Pilot Valve Supply and Exhaust Tubing Parameters

The response of a Swagelok ALD valve with various lengths of solenoid valve supply and exhaust tubing was analyzed using an LVDT and oscilloscope. In general, it is advantageous to maximize the airflow to and from the solenoid pilot valve for fastest actuation response. The use of 1/4 × 0.063 in. tubing for solenoid pilot valve supply and exhaust provided ample air flow and little dependence on tubing length. When supply and exhaust tubing with smaller inner diameters was tested, the length of tubing had some influence on the actuation response, as illustrated in the adjacent figure.

- MAC 34B-AAA-GDFC solenoid pilot
- 70 psig (4.8 bar) actuation pressure
- Tubing from solenoid pilot valve to actuator: 1/8 × 0.016 × 3 in.
- Response time recorded at half max 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 Standards①

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 SEMASPEC②

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 Standard③

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

SC-01 Ultrahigh-Purity Surface Finish and Cleanliness

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 Material International, 3081 Zanker Road, San Jose, CA 95134, U.S.A.

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

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