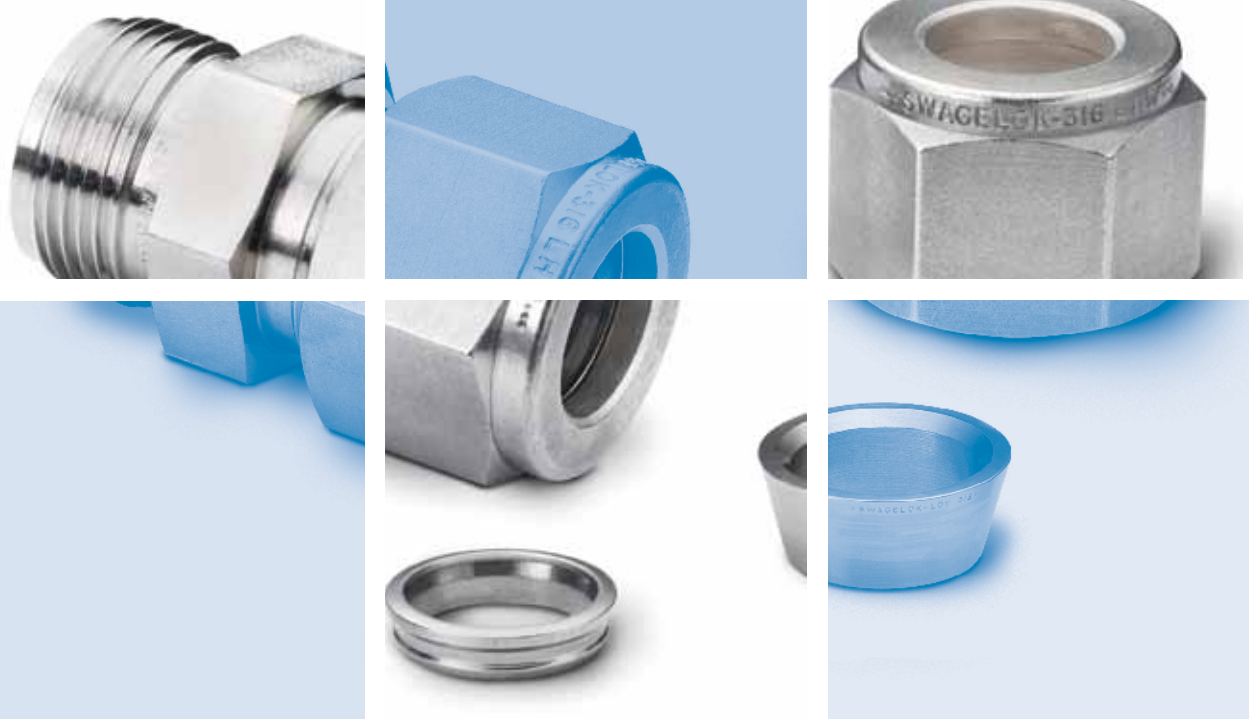


Tube Fitting Performance
Product Test Reports PTRs



and Third-Party Product Approvals and Registrations

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Tube fitting performance can be evaluated using three specific types of test criteria. These tests allow a tube fitting to be evaluated under varying dynamic conditions. The following Product Test Reports (PTRs), for Swagelok® tube fittings, are available upon request.

Tube Grip

The main function of a tube fitting is to grip the tubing sufficiently to contain system fluid. The tubing and fitting must remain connected without leakage at maximum working pressure. When overpressure occurs, such as in proof testing or when pressure spikes occur outside normal operating conditions, the fitting must also maintain both grip and seal on the tubing. Harder, heavier-walled tubing presents greater challenges for ferrule gripping action because it can be taken to higher pressure and is more resistant to the ferrule swaging or indentation. This gripping challenge on heavier-walled tubing may be severely compromised when fittings are under-tightened and/or not properly bottomed in the fitting body prior to installation. A high-quality tube fitting is designed to be more tolerant of these conditions.

- PTR-3220** Hydrostatic Pressure Test—Heavy-Wall Tubing / Continuous Production Performance Testing—316 Stainless Steel—1/4 to 1 in. and 6 to 25 mm
- PTR-387** Tensile Pull Test—Heavy-Wall Tubing—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm
- PTR-1193** Tensile Pull Test—316 Stainless Steel—5/8 to 1 in. and 6 to 25 mm
- PTR-385** Hydrostatic Pressure Test—Extra-Hard Tubing / Tubing Bottomed and Not Bottomed—316 Stainless Steel—1/4 to 1/2 in., 10 and 12 mm
- PTR-390** Hydrostatic Pressure Test—Under-Tightened Fittings / Tubing Bottomed and Not Bottomed—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm
- PTR-391** Hydrostatic Pressure Test—Extra-Heavy-Wall Tubing—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm
- PTR-394** Hydrostatic Pressure Test—Under-Tightened Fittings / Extra-Heavy-Wall Tubing / Nominal to Extra-Hard—316 Stainless Steel—1/4 to 1/2 in. and 8 to 12 mm
- PTR-393** Fire (Burn) Test with Water Quench (Reference API-607)—316 Stainless Steel—1/4 and 1/2 in.



Gas Seal

Evaluating small molecule gas applications is important when determining if a tube fitting is reliable. Performance of a fitting in high-pressure gas applications must be evaluated under the conditions of initial assembly and repeated reassembly of the components. Repeatable seal integrity in high-pressure gas testing after reassembly is the true test of a fitting design. Another challenge in gas seal applications pertains to thin-wall tubing, since it offers the least swaging resistance to provide for the coining action of the ferrules. In most applications, heavier-wall tubing provides a more reliable gas seal because it allows for ferrules to coin or reduce small defects on the tubing surface that could contribute to gas leakage.

- PTR-3221** Nitrogen Gas Pressure Test—Thin-Wall Tubing / Continuous Production Performance Testing—316 Stainless Steel—1/4 to 1 in. and 6 to 25 mm
- PTR-1192** Nitrogen Gas Pressure / Repeated Reassembly Test—Thin-Wall Tubing / Continuous Production Performance Testing—316 Stainless Steel—5/8 to 1 in. and 14 to 25 mm
- PTR-383** Helium Proof / Nitrogen Gas Pressure / Repeated Reassembly Test—Heavy-Wall Tubing—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm
- PTR-395** Nitrogen Gas Pressure / Repeated Reassembly Test—Thin-Wall Tubing—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm
- PTR-386** Thermal Cycle Test—Repeated 537°C (1000°F) / Cool Down—316 Stainless Steel—1/4 to 1/2 in.
- PTR-392** Steam Cycle / Thermal Shock Test—Repeated 192°C (377°F) Quench—316 Stainless Steel—1/4 and 1/2 in.
- PTR-1369** Cryogenic Temperature Leak Test—Inboard Helium Leak Test—Thin-Wall Tubing—316 Stainless Steel—1/4 and 1 in.
- PTR-1388** Cryogenic Temperature Leak Test—Outboard Helium Leak Test—Thin-Wall Tubing—316 Stainless Steel—1/4 and 1 in.



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Vibration Resistance

Any system may experience vibration during operation. Rotary equipment, such as pumps or compressors, can impart alternating stress vibration on the tubing runs. Because tube fittings grip the surface of the tubing, creating potential stress risers on the tube surface, the tubing can be exposed to amplified alternating stress and fatigue fracture. A good tube fitting, with hinging-colleting ferrule design, reliably collets or isolates the tubing outboard of the potential stress riser. This colleting action will minimize the effects of vibration stress at the ferrule grip location.

- PTR-3222** Rotary Flex Test—Thin-Wall Tubing—316 Stainless Steel
— 1/4 to 1 in. and 6 to 25 mm
- PTR-976** Shaker Table Vibration Test—316 Stainless Steel—1/4 to 1 in.
- PTR-3216** Seismic Intensity Analysis—316 Stainless Steel
— 1/4 to 1 1/2 in. and 10 to 28 mm



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Alloys

The following Tube Grip, Gas Seal and Vibration Resistance Product Test Reports (PTRs), are available for the listed alloys.

Alloy 625 Swagelok Tube Fittings with Alloy 625 Tubing

Tube Grip

PTR-1433 Tensile Pull Test—1/4 to 1/2 in. and 6 to 12 mm

PTR-1434 Hydrostatic Pressure Test—1/4 to 1/2 in. and 6 to 12 mm

Gas Seal

PTR-1432 Nitrogen Gas Pressure / Repeated Reassembly Test
—1/4 to 1/2 in. and 6 to 12 mm

Vibration Resistance

PTR-1435 Rotary Flex Test—1/4 to 1/2 in. and 6 to 12 mm

Alloy 825 Swagelok Tube Fittings with Alloy 625 Tubing

Tube Grip

PTR-864 Hydrostatic Pressure Test—1/4 to 1/2 in. and 6 to 12 mm

PTR-867 Tensile Pull Test—1/4 to 1/2 in. and 6 to 12 mm

Gas Seal

PTR-865 Nitrogen Gas Pressure / Repeated Reassembly Test
—1/4 to 1/2 in. and 6 to 12 mm

Vibration Resistance

PTR-866 Rotary Flex Test—1/4 to 1/2 in. and 6 to 12 mm

316 SS Swagelok Tube Fittings with 254 SMO® (6-Moly) SS Tubing

Tube Grip

PTR-2834 Tensile Pull Test—1/4 to 1/2 in.

PTR-2849 Impulse and Hydrostatic Proof Test—1/4 to 1/2 in.

PTR-2852 Hydrostatic Pressure Test—1/4 to 1/2 in.

Gas Seal

PTR-2835 High-Temperature Thermal Cycling and Hydrostatic Proof Test
—1/4 to 1/2 in.

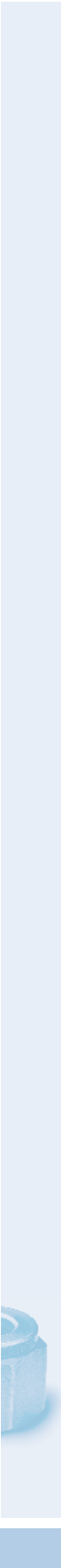
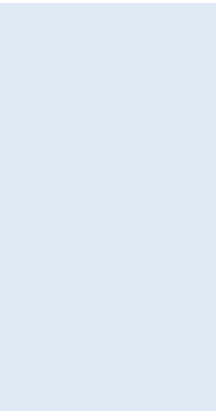
PTR-2836 Low-Temperature Thermal Cycling and Hydrostatic Proof Test
—1/4 to 1/2 in.

PTR-2853 Nitrogen Gas Pressure / Repeated Reassembly Test—1/4 to 1/2 in.

Vibration Resistance

PTR-2841 Rotary Flex Test—1/4 to 1/2 in.





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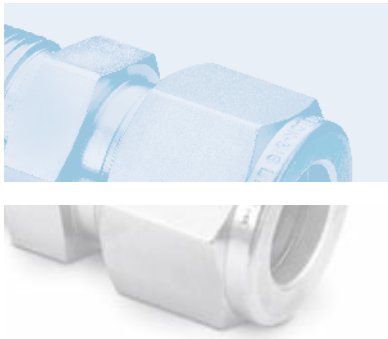
Third Party

The following documents are related to third party approvals and registrations of Swagelok tube fittings.

- Summary of Third Party Product Approvals and Registrations
- ASTM F1387 Testing of Swagelok Tube Fittings Witnessed and Approved by the United States Department of the Navy



Tube Grip



Hydrostatic Pressure Test—Heavy-Wall Tubing / Continuous
Production Performance Testing—316 Stainless Steel **PTR-3220**
—1/4 to 1 in. and 6 to 25 mm

Tensile Pull Test—Heavy-Wall Tubing—316 Stainless Steel **PTR-387**
—1/4 to 1/2 in. and 6 to 12 mm

Tensile Pull Test—316 Stainless Steel **PTR-1193**
—5/8 to 1 in. and 6 to 25 mm

Hydrostatic Pressure Test—Extra-Hard Tubing / Tubing Bottomed
and Not Bottomed—316 Stainless Steel **PTR-385**
—1/4 to 1/2 in., 10 and 12 mm

Hydrostatic Pressure Test—Under-Tightened Fittings on Normal to
Extra-Hard Tubing / Tubing Bottomed and Not Bottomed **PTR-390**
—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm

Hydrostatic Pressure Test—Extra-Heavy-Wall Tubing **PTR-391**
—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm

Hydrostatic Pressure Test—Under-Tightened Fittings / Extra-Heavy-
Wall Tubing / Nominal to Extra-Hard—316 Stainless Steel **PTR-394**
—1/4 to 1/2 in. and 8 to 12 mm

Fire (Burn) Test with Water Quench (Reference API-607) **PTR-393**
—316 Stainless Steel—1/4 and 1/2 in.





Product Test Report

PTR-3220

Swagelok Company
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Solon, Ohio 44139 U.S.A.

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September 2012
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TITLE

Hydrostatic Pressure Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Heavy-Wall Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested.

Fractional

Ordering Number	Form	Tubing Size in.	Tubing Hardness HRB
SS-400-1-4	Bar stock	1/4 × 0.065	76 to 87
SS-400-9	Forging		
SS-600-1-4	Bar stock	3/8 × 0.083	76 to 88
SS-600-9	Forging		
SS-810-1-4	Bar stock	1/2 × 0.083	70 to 88
SS-810-9	Forging		
SS-1010-1-8	Bar stock	5/8 × 0.095	80 to 85
SS-1010-9	Forging		
SS-1210-1-8	Bar stock	3/4 × 0.109	70 to 84
SS-1210-9	Forging		
SS-1410-1-8	Bar stock	7/8 × 0.109	73 to 82
SS-1410-9	Forging		
SS-1610-1-8	Bar stock	1 × 0.120	70 to 74
SS-1610-9	Forging		



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Metric

Ordering Number	Form	Tubing Size mm	Tubing Hardness HRB
SS-6M0-1-4	Bar stock	6 × 1.5	80 to 94
SS-6M0-9	Forging		
SS-8M0-1-4	Bar stock	8 × 1.5	78 to 86
SS-8M0-9	Forging		
SS-10M0-1-4	Bar stock	10 × 2.0	80 to 87
SS-10M0-9	Forging		
SS-12M0-1-4	Bar stock	12 × 2.0	82 to 88
SS-12M0-9	Forging		
SS-14M0-1-8	Bar stock	14 × 2.2	74 to 85
SS-14M0-9	Forging		
SS-15M0-1-8	Bar stock	15 × 2.2	77 to 78
SS-15M0-9	Forging		
SS-16M0-1-8	Bar stock	16 × 2.5	82 to 88
SS-16M0-9	Forging		
SS-18M0-1-8	Bar stock	18 × 2.5	74 to 78
SS-18M0-9	Forging		
SS-20M0-1-8	Bar stock	20 × 2.8	74 to 80
SS-20M0-9	Forging		
SS-22M0-1-8	Bar stock	22 × 2.8	72 to 80
SS-22M0-9	Forging		
SS-25M0-1-8	Bar stock	25 × 3.0	73 to 81
SS-25M0-9	Forging		

PURPOSE

The assemblies were tested to observe the tube grip performance of 316 stainless steel Swagelok tube fittings with advanced geometry back ferrules using heavy-wall tubing under laboratory conditions.

TEST CONDITIONS

Each sample tested consisted of one heavy-wall tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions. Testing was conducted at ambient room temperature.



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TEST METHOD

The fittings were tested as follows:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks thereby forcing a failure at the fitting-to-tubing engagement.
3. The pressure was gradually increased and pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.

TEST RESULTS

The following data sets include product tested 2010 through 2012 year to date.

Fractional

Tubing Size in.	Working Pressure (WP) psig (bar)	Samples Attaining a Minimum of $\eta \times WP$ Without Tube Slip		
		Target Performance Factor, η ^①	Samples Tested	Samples Passed
1/4 x 0.065	10 200 (702)	4.0	540	540
3/8 x 0.083	7 500 (516)	4.0	370	370
1/2 x 0.083	6 700 (461)	4.0	372	372
5/8 x 0.095	6 000 (413)	4.0	98	98
3/4 x 0.109	5 800 (399)	4.0	164	164
7/8 x 0.109	4 800 (330)	4.0	16	16
1 x 0.120	4 700 (323)	3.5	312	312

① Target performance factors listed in the table are based on the use of the maximum working pressure tubing wall thickness, according to Swagelok Tubing Data (MS-01-107), and annealed body material (e.g. forged shapes) .



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Metric

Tubing Size mm	Working Pressure (WP) bar (psig)	Samples Attaining a Minimum of $\eta \times WP$ Without Tube Slip		
		Target Performance Factor, η ^①	Samples Tested	Samples Passed
6 × 1.5	710 (10 304)	4.0	156	156
8 × 1.5	520 (7 547)	4.0	120	120
10 × 2.0	580 (8 417)	4.0	84	84
12 × 2.0	470 (6 821)	4.0	120	120
14 × 2.2	430 (6 240)	4.0	48	48
15 × 2.2	400 (5 805)	4.0	60	60
16 × 2.5	400 (5 805)	4.0	72	72
18 × 2.5	370 (5 370)	4.0	60	60
20 × 2.8	380 (5 515)	4.0	52	52
22 × 2.8	340 (4 934)	4.0	20	20
25 × 3.0	320 (4 644)	3.5	68	68

① Target performance factors listed in the table are based on the use of the maximum working pressure tubing wall thickness, according to Swagelok Tubing Data (MS-01-107), and annealed body material (e.g. forged shapes) .

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

PTR-387

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

Rev. E
August 2010
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TITLE

Tensile Pull Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested.

Ordering Number	Part Form	Tubing Size in.	Tubing Hardness HRB
Fractional, in.			
SS-400-3	Forging	1/4 × 0.065	80 to 82
SS-400-6	Bar stock		
SS-400-1-4	Bar stock		
SS-600-6	Bar stock	3/8 × 0.065	83 to 86
SS-600-3	Forging		
SS-600-1-4	Bar stock		
SS-810-3	Forging	1/2 × 0.083	85 to 87
SS-810-6	Bar stock		
SS-810-1-4	Bar stock		
SS-810-1-6	Bar stock		
Metric, mm			
SS-6M0-6	Bar stock	6 × 1.5	75
SS-6M0-3	Forging		
SS-8M0-6	Bar stock	8 × 1.5	87
SS-8M0-3	Forging		
SS-10M0-6	Bar stock	10 × 2.0	84
SS-10M0-3	Forging		
SS-12M0-6	Bar stock	12 × 2.0	85 to 87
SS-12M0-3	Forging		

PURPOSE

These assemblies were tested to observe the tensile pull performance of Swagelok tube fittings with advanced geometry back ferrules when installed on heavy-wall tubing under laboratory conditions.

TEST CONDITIONS

Tube preparation:

Tubing samples were cut to length using a tube cutter for 1/2 in. diameter and under. The samples were a minimum of three diameter lengths between fittings after assembly.

Fitting assembly:

The test fittings and tubing were assembled 1 1/4 turns past finger-tight according to Swagelok tube fitting installation instructions.



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PTR-387

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TEST METHOD

The fittings were tested using the following controlled laboratory conditions:

1. Each sample was attached in turn to a tensile test stand.
2. Samples were tensile pulled at a rate of 1/2 in. (13 mm) per minute.
3. The peak loads were measured.
4. Samples passed this test if the measured pull out or tube shear load exceeded the force exerted on the tube by the system fluid at four times working pressure as calculated by the following equations:

$$\text{Tube Calculated Burst Pressure} = \text{Working Pressure} \times 4.0$$

$$\text{Minimum Allowable Force} = \text{Tube Calculated Burst Pressure} \times \text{Tubing Cross-Sectional Area}$$

TEST RESULTS

Fractional

Size in.	Sample Size	Max / Min Peak Tensile Load lbf	Average Peak Tensile Load lbf	Minimum Allowable Force lbf
1/4 x 0.065	24	3 150 / 2 570	3 000	2 000
3/8 x 0.065	24	4 500 / 3 630	4 050	2 870
1/2 x 0.083	20	8 330 / 6 020	7 240	5 260

Metric

Size mm	Sample Size	Max / Min Peak Tensile Load kN	Average Peak Tensile Load kN	Minimum Allowable Force kN
6 x 1.5	4	11.2 / 10.5	10.8	8.0
8 x 1.5	16	16.9 / 14.6	15.6	10.5
10 x 2.0	4	22.1 / 21.5	21.8	18.2
12 x 2.0	4	27.8 / 21.9	26.0	21.3

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

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Rev. C
September 2012
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TITLE

Tensile Pull Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Tubing

PRODUCT TESTED

The following bar stock body Swagelok tube fittings were tested:

Ordering Number	Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-1010-1-8	Bar stock	5/8 × 0.095	79
SS-1210-1-8	Bar stock	3/4 × 0.109	83 to 86
SS-1410-1-8	Bar stock	7/8 × 0.109	76 to 83
SS-1610-1-8	Bar stock	1 × 0.120	81 to 85
Metric, mm			
SS-14M0-1-8	Bar stock	14 × 2.2	86
SS-15M0-1-8	Bar stock	15 × 2.2	84
SS-16M0-1-8	Bar stock	16 × 2.5	82
SS-18M0-1-8	Bar stock	18 × 2.5	82
SS-20M0-1-8	Bar stock	20 × 2.8	90
SS-22M0-1-8	Bar stock	22 × 2.8	76
SS-25M0-1-8	Bar stock	25 × 3.0	78

PURPOSE

The assemblies were tested to observe the tensile pull performance of the 316 stainless steel Swagelok tube fitting with advanced geometry back ferrules under laboratory conditions.

TEST CONDITIONS

Each non-pressurized sample tested consisted of one tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions. Testing was conducted at ambient room temperature.

TEST METHOD

1. Each sample was attached in turn to a tensile test stand.
2. Samples were tensile pulled at a rate of 3/8 in. (9.5 mm) per minute until either the tube pulled out of the fitting or the tube fractured.
3. The judgment criterion is taken from ASTM F1387, Annex A7.

$$\text{Calculated tensile load} = A_p \times S_y$$

where:

A_p = cross-section area of the tube based on wall thickness

S_y = minimum specified yield strength of tube.

4. The test result should exceed the calculated tensile load.



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TEST RESULTS

Tubing Size	Samples Tested	ASTM F1387 Calculated Tensile Load lb (kg)	Samples Attaining ASTM F1387 Calculated Tensile Load
Fractional, in.			
5/8 × 0.095	12	4 745 (2 152)	12 / 12
3/4 × 0.109	12	6 585 (2 986)	12 / 12
7/8 × 0.109	12	7 869 (3 569)	12 / 12
1 × 0.120	12	9 130 (4 141)	12 / 12
Metric, mm			
14 × 2.2	6	3 792 (1 720)	6 / 6
15 × 2.2	6	4 114 (1 866)	6 / 6
16 × 2.5	6	4 930 (2 236)	6 / 6
18 × 2.5	6	5 661 (2 567)	6 / 6
20 × 2.8	6	7 035 (3 191)	6 / 6
22 × 2.8	6	7 854 (3 562)	6 / 6
25 × 3.0	6	10 236 (4 642)	6 / 6

The stainless steel Swagelok tube fitting achieved a tensile load in excess of the calculated load under laboratory conditions.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.



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SAFE PRODUCT SELECTION

When selecting a product, 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.

Referenced Documents

ASTM F1387-99, *Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings*, American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428



Product Test Report

PTR-385

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

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September 2012
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TITLE

Hydrostatic Pressure Test of Swagelok® Tube Fittings on Hard to Extra-Hard Tubing with Tubing Bottomed and Not Bottomed

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings with advanced geometry back ferrules were tested with 316 seamless stainless steel tubing.

Ordering Number	Part Form	Tubing Size OD x wall	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 x 0.065	100+
SS-400-9	Forging		
SS-600-1-4	Bar stock	3/8 x 0.065	100+
SS-600-9	Forging		
SS-810-1-4	Bar stock	1/2 x 0.083	100+
SS-810-9	Forging		
Metric, mm			
SS-10M0-1-4	Bar stock	10 x 2.0	90
SS-10M0-9	Forging		
SS-12M0-1-4	Bar stock	12 x 2.0	100+
SS-12M0-9	Forging		

PURPOSE

These assemblies were tested under laboratory conditions to observe the performance of Swagelok tube fittings with advanced geometry back ferrules when used on hard to extra-hard tubing under hydrostatic pressure when assembled with tubing both bottomed and not bottomed on the tube shoulder of the fitting body.

This testing evaluates the tube gripping ability of assembled tube fittings to sustain hydraulic over pressure, attaining up to 3.5 x working pressure without hydraulic leakage and up to 4.0 x working pressure without fitting material rupture or tube slippage.

TEST CONDITIONS

Tube preparation:

Tubing lengths were cut using a tube cutter for 1/2 in. diameter and under. Each tube length assured a minimum of three diameter lengths between fittings after assembly.

Fitting assembly:

- Each sample tested consisted of one tube length and two test fittings, one bar stock and one forged body, assembled 1 1/4 turns past finger-tight according to Swagelok tube fitting installation instructions.
- Prior to pull up, assemblies with tubing not bottomed had the tubing withdrawn from the tube shoulder by 1/16 to 1/8 in. (1.6 to 3.2 mm).



Product Test Report

PTR-385

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TEST METHOD

The fittings were leak tested using the following controlled laboratory conditions:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks thereby forcing a failure at the fitting-to-tubing engagement.
3. Pressure was gradually increased and the pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.

TEST RESULTS

Swagelok Tube Fittings, Extra-Hard Tubing, Tubing Bottomed

Fractional

Tube Size in.	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) psig (bar)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
1/4 × 0.065	100+	48	10 200 (702)	48 / 48	43 / 48	42 / 48
3/8 × 0.065	100+	32	6500 (447)	32 / 32	31 / 32	30 / 32
1/2 × 0.083	100+	76	6700 (461)	76 / 76	73 / 76	67 / 76

Metric

Tube Size mm	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) bar (psig)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
12 × 2.0	100+	12	470 (6 821)	12 / 12	12 / 12	12 / 12



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Swagelok Tube Fittings, Hard to Extra-Hard Tubing, Tubing Not Bottomed

Fractional

Tube Size in.	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) psig (bar)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
1/4 × 0.065	100+	16	10 200 (702)	13 [ⓐ] / 16	12 / 16	12 / 16
3/8 × 0.065	100+	16	6 500 (447)	16 / 16	16 / 16	14 / 16
1/2 × 0.083	100+	16	6 700 (461)	16 / 16	13 / 16	10 / 16

ⓐ Lowest observed was 2.7 × WP.

Metric

Tube Size mm	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) bar (psig)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
10 × 2.0	90	16	580 (8 417)	16 / 16	16 / 16	16 / 16
12 × 2.0	100+	8	470 (6 821)	8 / 8	6 / 8	5 / 8

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

Swagelok Company
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Solon, Ohio 44139 U.S.A.

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TITLE

Hydrostatic Pressure Test of Swagelok® Tube Fittings with 1 Turn and 3/4 Turn of Fitting Nut Assembly on Normal to Extra-Hard Tubing with Tubing Bottomed and Not Bottomed

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested with 316 stainless steel seamless tubing.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.065 in.	81 to 82
SS-400-9	Forging		100+
SS-600-1-4	Bar stock	3/8 × 0.065 in.	83 to 88
SS-600-9	Forging		100+
SS-600-1-4	Bar stock	3/8 × 0.083 in.	78 to 80
SS-600-9	Forging		100+
SS-810-1-4	Bar stock	1/2 × 0.083 in.	86 to 88
SS-810-9	Forging		98, 100+
Metric, mm			
SS-6M0-1-4	Bar stock	6 × 1.5 mm	93
SS-6M0-9	Forging		
SS-8M0-1-4	Bar stock	8 × 1.5 mm	88
SS-8M0-9	Forging		
SS-10M0-1-4	Bar stock	10 × 2.0 mm	90
SS-10M0-9	Forging		
SS-12M0-1-4	Bar stock	12 × 2.0 mm	100+
SS-12M0-9	Forging		

PURPOSE

These assemblies were tested to observe the performance of Swagelok tube fittings with advanced geometry back ferrules when installed at 1 turn and 3/4 turn past finger-tight on normal to extra-hard tubing under hydrostatic pressure when assembled with tubing both bottomed and not bottomed on the tube shoulder of the fitting body.

This testing evaluates the tube gripping ability of assembled tube fittings to sustain hydraulic over pressure, attaining up to 3.5 × working pressure without hydraulic leakage and up to 4.0 × working pressure without fitting material rupture or tube slippage.

TEST CONDITIONS

Tube preparation:

Tubing lengths were cut using a tube cutter for 1/2 in. diameter and under. Each tube length assured a minimum of three diameter lengths between fittings after assembly.



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Fitting assembly:

- Each sample tested consisted of one tube length and two test fittings, one bar stock and one forged body, assembled 1 turn and 3/4 turn past finger-tight.
- Prior to pull-up, assemblies with tubing not bottomed had the tubing withdrawn from the tube shoulder by 1/16 to 1/8 in. (1.6 to 3.2 mm).

TEST METHOD

The fittings were leak tested using the following controlled laboratory conditions:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks thereby forcing a failure at the fitting-to-tubing engagement.
3. Pressure was gradually increased and the pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.

TEST RESULTS

Swagelok Tube Fittings, 1 Turn Assembly, Normal to Extra-Hard Tubing, Tubing Bottomed

Fractional

Tubing Size in.	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) psig (bar)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
1/4 × 0.065	81 to 82	16	10 200 (702)	16 / 16	16 / 16	16 / 16
	100+	6	10 200 (702)	5 ^① / 6	5 / 6	5 / 6
3/8 × 0.065	83 to 88	16	6 500 (447)	16 / 16	16 / 16	16 / 16
	100+	6	6 500 (447)	6 / 6	6 / 6	5 / 6
3/8 × 0.083	78 to 80	24	7 500 (516)	24 / 24	24 / 24	24 / 24
	100+	4	7 500 (516)	4 / 4	4 / 4	4 / 4
1/2 × 0.083	86 to 88	24	6 700 (461)	24 / 24	24 / 24	24 / 24
	98	34	6 700 (461)	34 / 34	34 / 34	34 / 34
	100+	18	6 700 (461)	18 / 18	17 / 18	16 / 18

① Lowest observed was 2.6 × W.P.



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TEST RESULTS

Swagelok Tube Fittings, 1 Turn Assembly, Normal to Extra-Hard Tubing, Tubing Bottomed Metric

Tubing Size mm	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) bar (psig)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
6 × 1.5	93	6	710 (10 304)	6 / 6	6 / 6	6 / 6
8 × 1.5	88	8	520 (7 547)	8 / 8	8 / 8	8 / 8
10 × 2.0	90	31	580 (8 417)	31 / 31	31 / 31	30 / 30
12 × 2.0	100+	16	470 (6 821)	16 / 16	16 / 16	15 / 16

Swagelok Tube Fittings, 3/4 Turn Assembly, Normal to Extra-Hard Tubing, Tubing Bottomed Fractional

Tubing Size in.	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) psig (bar)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
1/4 × 0.065	82	4	10 200 (702)	4 / 4	4 / 4	4 / 4
	100+	4	10 200 (702)	4 / 4	4 / 4	4 / 4
3/8 × 0.065	83	4	6 500 (447)	4 / 4	4 / 4	4 / 4
	100+	4	6 500 (447)	4 / 4	4 / 4	3 / 4
1/2 × 0.083	88	4	6 700 (461)	4 / 4	4 / 4	4 / 4
	98	4	6 700 (461)	4 / 4	4 / 4	4 / 4



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Swagelok Tube Fittings, 1 Turn Assembly, Normal to Extra-Hard Tubing, Tubing Not Bottomed

Fractional

Tubing Size in.	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) psig (bar)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Tube Slip
1/4 × 0.065	81 to 82	12	10 200 (702)	12 / 12	12 / 12	12 / 12
3/8 × 0.065	86 to 88	12	6 500 (447)	12 / 12	12 / 12	12 / 12
3/8 × 0.083	100+	4	7 500 (516)	2 ^⓪ / 4	2 / 4	2 / 4
1/2 × 0.083	86 to 87	20	6 700 (461)	20 / 20	20 / 20	19 / 19
	100+	4	6 700 (461)	4 / 4	3 / 4	3 / 4

⓪ Lowest observed was 2.8 × W.P.

Metric

Tubing Size mm	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) bar (psig)	Samples Attaining 3.0 × WP Without Leakage	Samples Attaining 3.5 × WP Without Leakage	Samples Attaining 4 × WP Without Leakage
6 × 1.5	93	4	710 (10 304)	4 / 4	4 / 4	4 / 4
10 × 2.0	90	15	580 (8 417)	15 / 15	15 / 15	15 / 15

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

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SAFE PRODUCT SELECTION

When selecting a product, 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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TITLE

Hydrostatic Pressure Test of 316 Stainless Steel Swagelok® Tube Fittings on Extra Heavy-Wall Stainless Steel Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested with 316 stainless steel seamless tubing.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.083	82
SS-400-9	Forging		
SS-400-1-4	Bar stock	1/4 × 0.083	82
SS-400-C	Forging		
SS-500-1-4	Bar stock	5/16 × 0.083	80
SS-500-9	Forging		
SS-500-1-4	Bar stock	5/16 × 0.083	80
SS-500-C	Forging		
SS-810-1-4	Bar stock	1/2 × 0.095	77
SS-810-9	Forging		
SS-810-1-4	Bar stock	1/2 × 0.095	77
SS-810-C	Forging		
Metric, mm			
SS-6M0-1-4	Bar stock	6 × 1.8	85
SS-400-C	Forging		
SS-10M0-1-4	Bar stock	10 × 2.2	72
SS-10M0-9	Forging		
SS-10M0-1-4	Bar stock	10 × 2.2	72
SS-10M0-C	Forging		
SS-12M0-1-4	Bar stock	12 × 2.5	85
SS-12M0-C	Forging		

PURPOSE

These assemblies were tested under laboratory conditions to observe the performance of Swagelok tube fittings with advanced geometry back ferrules when installed on extra heavy-wall under hydrostatic pressure.

This testing evaluates the tube gripping ability of assembled tube fittings to sustain hydraulic over pressure, attaining up to 3.5 × working pressure without hydraulic leakage and up to 4.0 × working pressure without fitting material rupture or tube slippage.



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TEST CONDITIONS

Tube preparation:

Tubing lengths were cut using a tube cutter for 1/2 in. diameter and under. Each tube length assured a minimum of three diameter lengths between fittings after assembly.

Fitting assembly

Each sample tested consisted of one tube length and two test fittings, one bar stock and one forged body (except samples with bar stock bodies only), assembled 1 1/4 turns past finger-tight according to Swagelok tube fitting installation instructions.

TEST METHOD

The fittings were leak tested using the following controlled laboratory conditions:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks thereby forcing a failure at the fitting-to-tubing engagement.
3. Pressure was gradually increased and the pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.

TEST RESULTS

Swagelok Tube Fittings, Extra Heavy Wall Tubing

Fractional

Tube Size in.	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) psig (bar)	Samples Attaining 3.0 x WP Without Leakage	Samples Attaining 3.5 x WP Without Leakage	Samples Attaining 4 x WP Without Tube Slip
1/4 x 0.083	82	8	12 000 (826)	8 / 8	8 / 8	8 / 8
1/4 x 0.083 ^①	82	8	12 000 (826)	8 / 8	8 / 8	8 / 8
5/16 x 0.083	80	4	10 500 (723)	4 / 4	4 / 4	0 / 0
5/16 x 0.083 ^①	80	4	10 500 (723)	4 / 4	4 / 4	4 / 4
1/2 x 0.095	77	8	7 800 (537)	8 / 8	8 / 8	7 / 7
1/2 x 0.095 ^①	77	8	7 800 (537)	8 / 8	8 / 8	8 / 8

Metric

Tube Size mm	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) bar (psig)	Samples Attaining 3.0 x WP Without Leakage	Samples Attaining 3.5 x WP Without Leakage	Samples Attaining 4 x WP Without Tube Slip
6 x 1.8 ^①	85	8	830 (12 046)	8 / 8	8 / 8	8 / 8
10 x 2.2	72	4	620 (8 998)	4 / 4	4 / 4	0 / 0
10 x 2.2 ^①	72	8	620 (8 998)	8 / 8	8 / 8	7 / 7
12 x 2.5 ^①	85	8	590 (8 563)	8 / 8	8 / 8	8 / 8

① Bar stock bodies only



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The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

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SAFE PRODUCT SELECTION

When selecting a product, 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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TITLE

Hydrostatic Pressure Test of 316 Stainless Steel Swagelok® Tube Fittings with 1 Turn of Fitting Nut Assembly on Extra Heavy-Wall, Normal to Extra-Hard Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested 316 stainless steel seamless tubing.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.083	82
SS-400-9	Forging		95
SS-500-1-4	Bar stock	5/16 × 0.083	80
SS-500-9	Forging		
SS-810-1-4	Bar stock	1/2 × 0.095	77
SS-810-9	Forging		99
SS-810-1-4	Bar stock	1/2 × 0.095	77
SS-810-C	Forging		
Metric, mm			
SS-8M0-1-4	Bar stock	8 × 1.8	100+
SS-8M0-9	Forging		
SS-8M0-1-4	Bar stock	8 × 2.0	80
SS-8M0-9	Forging		
SS-10M0-1-4	Bar stock	10 × 2.2	72
SS-10M0-C	Forging		98
SS-12M0-1-4	Bar stock	12 × 2.5	100+
SS-12M0-C	Forging		

PURPOSE

These assemblies were tested under laboratory conditions to observe the performance of Swagelok tube fittings with advanced geometry back ferrules at 1 turn past finger tight assembly when used on extra heavy-wall, normal to extra-hard tubing under hydrostatic pressure.

This testing evaluates the tube gripping ability of assembled tube fittings to sustain hydraulic over pressure, attaining up to 3.5 × working pressure without hydraulic leakage and up to 4.0 × working pressure without fitting material rupture or tube slippage.

TEST CONDITIONS

Tube preparation:

Tubing lengths were cut using a tube cutter for 1/2 in. diameter and under. Each tube length assured a minimum of three diameter lengths between fittings after assembly.



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Fitting assembly:

Each sample tested consisted of one tube length and two test fittings, one bar stock and one forged body (except samples with bar stock bodies only), assembled 1 turn past finger-tight.

TEST METHOD

The fittings were leak tested using the following controlled laboratory conditions:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks thereby forcing a failure at the fitting-to-tubing engagement.
3. Pressure was gradually increased and the pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.

TEST RESULTS

Swagelok Tube Fittings, 1 Turn Assembly, Extra Heavy-Wall, Normal to Extra-Hard Tubing

Fractional

Tubing Size in.	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) psig (bar)	Samples Attaining 3.0 x WP Without Leakage	Samples Attaining 3.5 x WP Without Leakage	Samples Attaining 4 x WP Without Tube Slip
1/4 x 0.083	82	24	12 000 (826)	24 / 24	24 / 24	21 / 21
1/4 x 0.083	95	24	12 000 (826)	24 / 24	16 / 24	8 / 8
5/16 x 0.083	80	12	10 500 (723)	12 / 12	6 / 12	2 / 3
1/2 x 0.095	77	24	7 800 (537)	24 / 24	24 / 24	3 / 3
1/2 x 0.095 ^①	77	17	7 800 (537)	17 / 17	17 / 17	17 / 17
1/2 x 0.095	99	16	7 800 (537)	16 / 16	15 / 16	5 / 16

Metric

Tubing Size mm	Tubing Hardness HRB	Samples Tested	Working Pressure (WP) bar (psig)	Samples Attaining 3.0 x WP Without Leakage	Samples Attaining 3.5 x WP Without Leakage	Samples Attaining 4 x WP Without Tube Slip
8 x 1.8	100+	8	650 (9 433)	8 / 8	8 / 8	6 / 8
8 x 2.0	80	8	720 (10 449)	8 / 8	3 / 8	1 / 1
10 x 2.2	72	16	620 (8 998)	16 / 16	5 / 16	0 / 0
10 x 2.2	98	16	620 (8 998)	16 / 16	16 / 16	11 / 14
12 x 2.5	100+	32	590 (8 563)	32 / 32	32 / 32	4 / 24

① Bar stock bodies only



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The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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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TITLE

Fire (Burn) Test with Water Quench (Reference API 607) of Stainless Steel Swagelok® Tube Fittings

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested with 316 stainless steel seamless tubing.

Ordering Number	Form	Tubing Size in.	Tubing Hardness HRB
SS-810-6-4	Bar stock	1/4 × 0.065	77
SS-810-9	Forging	1/2 × 0.083	84
SS-810-3	Forging		

PURPOSE

These assemblies were tested under laboratory conditions to observe the performance of Swagelok tube fittings with advanced geometry back ferrules when exposed to a 1500°F (815°C) burn and a water quench.

TEST CONDITIONS

Tube preparation:

Tubing samples were cut to length using a tube cutter for 1/2 in. diameter and under. The samples were a minimum of three diameter lengths between fittings after assembly.

Fitting assembly:

The test fittings and tubing were assembled 1 1/4 turns past finger-tight according to Swagelok tube fitting installation instructions.

TEST METHOD

API Standard 607, fire test for soft-seated quarter turn valves, was adapted for tube fittings as follows:

1. Eight 1/2 in. Swagelok tube fittings and two 1/4 in. Swagelok tube fittings were assembled into a single test loop.
2. The loop was attached to the fire test stand.
3. The samples were pressurized to a constant 4500 psig (310 bar) with a fixed reservoir of water and examined for leakage.
4. Two thermocouples were positioned within the flame zone to measure flame temperature.
5. Eight burners were lit and focused on the test loop.
6. The samples were exposed to flame (1400 to 1800°F, 1500°F average) [760 to 982°C, 815°C average] for a period of 40 minutes.
7. Upon completion of the burn portion of the test, the samples were quenched with water from two overhead spray nozzles for a period of five minutes.
8. The samples were monitored for leakage and loss of water during the quench process.



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TEST RESULTS

Ordering Number	Form	Tubing Size in.	Samples Tested	Result
SS-810-6-4	Bar stock	1/4 x 0.065	2	Pass—No Detectable Leakage
SS-810-9	Forging	1/2 x 0.083	8	Pass—No Detectable Leakage
SS-810-3	Forging			

Figures 1 and 2 show the samples during the test.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.

REFERENCED DOCUMENTS

API Standard 607, *Fire Test for Soft-Seated Quarter-Turn Valves*, Fourth Edition, May 1993

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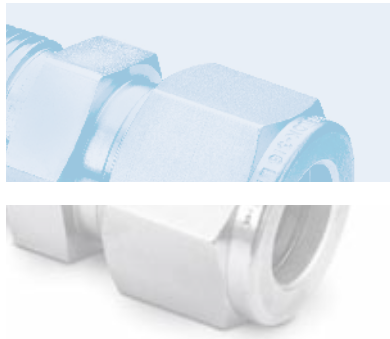
Figure 1: Samples during flame exposure.



Figure 2: Samples during water quench.



Gas Seal



Nitrogen Gas Pressure Test—Thin Wall Tubing / Continuous
Production Performance Testing—316 Stainless Steel **PTR-3221**
—1/4 to 1 in. and 6 to 25 mm

Nitrogen Gas Pressure / Repeated Reassembly Test—Thin-Wall Tubing /
Continuous Production Performance Testing—316 Stainless Steel **PTR-1192**
—5/8 to 1 in. and 14 to 25 mm

Helium Proof / Nitrogen Gas Pressure / Repeated Reassembly Test **PTR-383**
—Heavy-Wall Tubing —316 Stainless Steel
—1/4 to 1/2 in. and 6 to 12 mm

Nitrogen Gas Pressure / Repeated Reassembly Test **PTR-395**
—Thin-Wall Tubing—316 Stainless Steel
—1/4 to 1/2 in. and 6 to 12 mm

Thermal Cycle Test—Repeated 537°C (1000°F) / Cool Down **PTR-386**
—316 Stainless Steel
—1/4 to 1/2 in.

Steam Cycle / Thermal Shock Test—Repeated 192°C (377°F) **PTR-392**
Quench—316 Stainless Steel
—1/4 and 1/2 in.

Cryogenic Temperature Leak Test—Inboard Helium Leak Test **PTR-1369**
—Thin-Wall Tubing—316 Stainless Steel
—1/4 and 1 in.

Cryogenic Temperature Leak Test—Outboard Helium Leak Test **PTR-1388**
—Thin-Wall Tubing—316 Stainless Steel
—1/4 and 1 in.





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TITLE

Nitrogen Gas Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Thin-Wall Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested.

Fractional

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
SS-400-1-4	Bar stock	1/4 × 0.028	71 to 83
SS-400-9	Forging		
SS-600-1-4	Bar stock	3/8 × 0.035	72 to 87
SS-600-9	Forging		
SS-810-1-4	Bar stock	1/2 × 0.049	72 to 86
SS-810-9	Forging		
SS-1010-1-4	Bar stock	5/8 × 0.065	82 to 83
SS-1010-9	Forging		
SS-1210-1-8	Bar stock	3/4 × 0.065	76 to 82
SS-1210-9	Forging		
SS-1410-6-8	Bar stock	7/8 × 0.083	65 to 74
SS-1410-2-8	Forging		
SS-1610-1-4	Bar stock	1 × 0.083	72 to 78
SS-1610-9	Forging		



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Metric

Ordering Number	Form	Tubing Size mm	Tubing Hardness HRB
SS-6M0-1-4	Bar stock	6 x 0.8	86 to 88
SS-6M0-9	Forging		
SS-8M0-1-4	Bar stock	8 x 1.0	75 to 82
SS-8M0-9	Forging		
SS-10M0-1-4	Bar stock	10 x 1.0	74 to 82
SS-10M0-9	Forging		
SS-12M0-1-4	Bar stock	12 x 1.0	72 to 78
SS-12M0-9	Forging		
SS-14M0-1-8	Bar stock	14 x 1.2	74 to 76
SS-14M0-9	Forging		
SS-15M0-1-8	Bar stock	15 x 1.5	73 to 80
SS-15M0-9	Forging		
SS-16M0-1-8	Bar stock	16 x 1.5	76 to 79
SS-16M0-9	Forging		
SS-18M0-1-8	Bar stock	18 x 1.5	78 to 81
SS-18M0-9	Forging		
SS-20M0-1-8	Bar stock	20 x 1.8	75 to 78
SS-20M0-9	Forging		
SS-22M0-1-8	Bar stock	22 x 2.0	75 to 80
SS-22M0-9	Forging		
SS-25M0-1-8	Bar stock	25 x 2.2	70 to 76
SS-25M0-9	Forging		

PURPOSE

These assemblies were tested to observe the leak-tight performance of stainless steel Swagelok tube fittings with thin-wall, stainless steel tubing during a gas seal test under laboratory conditions.

TEST CONDITIONS

Each sample tested consisted of one tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions.



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TEST METHOD

1. The assemblies were attached to a positive pressure gas test stand, submerged in water, pressurized to working pressure with nitrogen gas for at least 10 minutes, and monitored for leakage.
2. Pressure was dropped, and fittings showing any leaks were tightened with a 1/8 turn-of-the-nut tightening.
3. Retightened fittings were reattached to a positive pressure gas test stand, submerged in water, pressurized to working pressure with nitrogen gas for at least 10 minutes, and monitored for leakage.

TEST RESULTS

The following data sets include production fittings tested from 2010 through 2012 year to date.

Fractional

Tube Size in.	Quantity Tested	Working Pressure psig (bar)	Number of Samples Leaking	
			After Standard Assembly (1 1/4 Turns) and Initial Test qty. (%)	After Additional 1/8 Turn ^① and Retest qty. (%)
1/4 × 0.028	552	4000 (275)	0 / 552 (0.00 %)	0 / 552 (0.00 %)
3/8 × 0.035	384	3300 (227)	1 / 384 (0.26 %)	1 / 384 (0.26 %)
1/2 × 0.049	384	3700 (254)	0 / 384 (0.00 %)	0 / 384 (0.00 %)
5/8 × 0.065	84	4000 (275)	0 / 84 (0.00 %)	0 / 84 (0.00 %)
3/4 × 0.065	164	3300 (227)	0 / 164 (0.00 %)	0 / 164 (0.00 %)
7/8 × 0.083	20	3600 (248)	4 / 20 (20.00 %)	1 / 20 (5.00 %)
1 × 0.083	168	3100 (689)	0 / 168 (0.00 %)	0 / 168 (0.00 %)

① For thin-wall tubing using gas at maximum working pressure, use of the installation instructions for High-Pressure Applications and High Safety-Factor Systems is appropriate. Samples demonstrating leakage were tightening an additional 1/8 turn as defined in the Test Method. Subsequent nitrogen gas proof testing resulted in no detectable leakage for any of the re-tested samples.

Note: Working pressure was based on the Swagelok Tubing Data sheet, MS-01-107.



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Metric

Tube Size mm	Quantity Tested	Working Pressure bar (psig)	Number of Samples Leaking	
			After Standard Assembly (1 1/4 Turns) and Initial Test qty. (%)	After Additional 1/8 Turn ^① and Retest qty. (%)
6 x 0.8	168	310 (4499)	0 / 168 (0.00 %)	0 / 168 (0.00 %)
8 x 1.0	120	310 (4499)	0 / 120 (0.00 %)	0 / 120 (0.00 %)
10 x 1.0	108	240 (3483)	0 / 108 (0.00 %)	0 / 108 (0.00 %)
12 x 1.0	143	200 (2902)	0 / 143 (0.00 %)	0 / 143 (0.00 %)
14 x 1.2	60	200 (2902)	0 / 60 (0.00 %)	0 / 60 (0.00 %)
15 x 1.5	68	250 (3628)	0 / 68 (0.00 %)	0 / 68 (0.00 %)
16 x 1.5	118	230 (3338)	0 / 118 (0.00 %)	0 / 118 (0.00 %)
18 x 1.5	96	200 (2902)	0 / 96 (0.00 %)	0 / 96 (0.00 %)
20 x 1.8	44	230 (3338)	0 / 44 (0.00 %)	0 / 44 (0.00 %)
22 x 2.0	28	230 (3338)	0 / 28 (0.00 %)	0 / 28 (0.00 %)
25 x 2.2	44	230 (3338)	0 / 44 (0.00 %)	0 / 44 (0.00 %)

① For thin-wall tubing using gas at maximum working pressure, use of the installation instructions for High-Pressure Applications and High Safety-Factor Systems is appropriate. Samples demonstrating leakage were tightening an additional 1/8 turn as defined in the Test Method. Subsequent nitrogen gas proof testing resulted in no detectable leakage for any of the re-tested samples.

Note: Working pressure was based on the Swagelok Tubing Data sheet, MS-01-107.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.



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These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

Swagelok Company
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PTR-1192
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TITLE

Nitrogen Gas Seal Test with Repeated Reassembly of 316 Stainless Steel Swagelok® Tube Fittings at 1.25 Times the Working Pressure

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested:

Fractional

Ordering Number	Form	Tubing Size in.	Tubing Hardness HRB
SS-1010-1-4	Bar stock	5/8 × 0.065	81
SS-1010-9	Forging		
SS-1010-1-4	Bar stock	5/8 × 0.095	86
SS-1010-9	Forging		
SS-1210-1-8	Bar stock	3/4 × 0.065	76
SS-1210-9	Forging		
SS-1210-1-8	Bar stock	3/4 × 0.109	81
SS-1210-9	Forging		
SS-1410-6-8	Bar stock	7/8 × 0.083	78
SS-1410-2-8	Forging		
SS-1410-6-8	Bar stock	7/8 × 0.109	81
SS-1410-9	Forging		
SS-1610-1-8	Bar stock	1 × 0.083	78
SS-1610-9	Forging		
SS-1610-1-8	Bar stock	1 × 0.120	81
SS-1610-9	Forging		



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Metric

Ordering Number	Form	Tubing Size mm	Tubing Hardness HRB
SS-14M0-1-8	Bar stock	14 x 1.2	78
SS-14M0-9	Forging		
SS-14M0-1-8	Bar stock	14 x 2.2	83
SS-14M0-9	Forging		
SS-15M0-1-8	Bar stock	15 x 1.5	78
SS-15M0-9	Forging		
SS-16M0-1-8	Bar stock	16 x 1.5	79
SS-16M0-9	Forging		
SS-18M0-1-8	Bar stock	18 x 1.5	89
SS-18M0-9	Forging		
SS-20M0-1-8	Bar stock	20 x 1.8	80
SS-20M0-9	Forging		
SS-22M0-1-8	Bar stock	22 x 2.0	79
SS-22M0-9	Forging		
SS-25M0-1-8	Bar stock	25 x 2.2	72
SS-25M0-9	Forging		
SS-25M0-1-8	Bar stock	25 x 3.0	76
SS-25M0-9	Forging		

PURPOSE

The assemblies were tested to observe the performance of 316 stainless steel Swagelok tube fittings with advanced geometry back ferrules during a reassembly gas seal test.

TEST CONDITIONS

Each sample tested consisted of one thin-wall tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions. Testing was conducted at ambient room temperature.

TEST METHOD

1. The test samples were attached to a gas test stand, submerged in water, pressurized to 1.25 times working pressure with nitrogen for 10 minutes and monitored for leakage. The judgment criterion was less than 1 bubble per minute at the applied pressure. If necessary, the fittings were tightened slightly (up to 1/8 turn) and re-tested.
2. Pressure was dropped, and the fittings were disassembled. The fittings were reassembled back to at least the previously pulled-up position and to at least the previously pulled-up torque.
3. The fittings were leak tested using nitrogen at 1.25 times the working pressure following the instructions and judgment criteria from step 1 at every fifth reassembly.
4. A total of 25 reassemblies were conducted on each test sample end.



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TEST RESULTS

Fractional

Tubing Size in.	Samples Tested	Working Pressure psig (bar)	Test Pressure psig (bar)	Results
5/8 × 0.065	24	4000 (275)	5000 (344)	Pass
5/8 × 0.095	12	6000 (413)	7500 (516)	Pass
3/4 × 0.065	24	3300 (227)	4125 (284)	Pass
3/4 × 0.109	12	5800 (399)	7250 (499)	Pass
7/8 × 0.083	24	3600 (248)	4500 (310)	Pass
7/8 × 0.109	12	4800 (330)	6000 (413)	Pass
1 × 0.083	12	3100 (213)	3900 (269)	Pass
1 × 0.120	12	4700 (324)	5900 (407)	Pass

Metric

Tubing Size mm	Samples Tested	Working Pressure bar (psig)	Test Pressure bar (psig)	Results
14 × 1.2	24	200 (2902)	250 (3625)	Pass
14 × 2.2	12	430 (6240)	537 (7795)	Pass
15 × 1.5	12	250 (3628)	313 (4539)	Pass
16 × 1.5	12	230 (3338)	287 (4170)	Pass
18 × 1.5	12	200 (2902)	250 (3625)	Pass
20 × 1.8	12	230 (3338)	287 (4170)	Pass
22 × 2.0	12	230 (3338)	287 (4170)	Pass
25 × 2.2	22	230 (3338)	287 (4170)	Pass
25 × 3.0	12	320 (4640)	400 (5800)	Pass

The stainless steel Swagelok tube fitting demonstrated both initial assembly gas seal and repeated gas seal through 25 reassemblies at 1.25 times the working pressure, under laboratory conditions.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.



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These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

PTR-383

Swagelok Company
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TITLE

Positive Pressure Helium Leak Test / Nitrogen Gas Seal Test with Repeated Reassembly of 316 Stainless Steel Swagelok® Tube Fittings with Heavy-Wall Stainless Steel Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested with 316 stainless steel seamless tubing.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.065	82
SS-400-9	Forging		
SS-500-1-4	Bar stock	5/16 × 0.065	81
SS-500-9	Forging		
SS-600-1-4	Bar stock	3/8 × 0.065	83
SS-600-9	Forging		
SS-810-1-4	Bar stock	1/2 × 0.083	85
SS-810-9	Forging		
Metric, mm			
SS-6M0-1-4	Bar stock	6 × 1.5	79
SS-6M0-9	Forging		
SS-8M0-1-4	Bar stock	8 × 1.5	78
SS-8M0-9	Forging		
SS-10M0-1-4	Bar stock	10 × 2.0	84
SS-10M0-9	Forging		
SS-12M0-1-4	Bar stock	12 × 2.0	84
SS-12M0-9	Forging		

PURPOSE

These assemblies were tested to observe the performance of stainless steel Swagelok tube fittings with advanced geometry back ferrules with heavy-wall stainless steel tubing during a gas seal test with repeated reassembly under laboratory conditions.

TEST CONDITIONS

Tube preparation:

Tubing samples were cut to length using a tube cutter for 1/2 in. diameter and under.

Fitting assembly:

The test fittings and tubing were initially assembled 1 1/4 turns past finger-tight according to Swagelok tube fitting installation instructions.



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TEST METHOD

1. The assemblies were attached to a positive pressure gas test stand, submerged in water, pressurized to 1.5 times the working pressure with helium gas for at least 10 minutes, and monitored for leakage.
2. The pressure was dropped, and fittings were then re-pressurized to working pressure with nitrogen gas for at least 10 minutes, and monitored for leakage.
3. The fittings were disassembled and reassembled according to the proper Swagelok reassembly specifications.
4. The fittings were leak tested using nitrogen gas at the working pressure for at least 10 minutes at every fifth reassembly.
5. A total of 25 reassemblies were conducted on each test end.

TEST RESULTS

Fractional

Size in.	Samples Tested	Working Pressure psig (bar)	1.5 × Working Pressure psig (bar)	Results
1/4 × 0.065	32	10 200 (702)	15 300 (1 054)	Pass
5/16 × 0.065	8	8 000 (551)	12 000 (826)	Pass
3/8 × 0.065	16	6 500 (447)	9 750 (671)	Pass
1/2 × 0.083	16	6 700 (461)	10 500 (692)	Pass

Metric

Size mm	Samples Tested	Working Pressure bar (psig)	1.5 × Working Pressure bar (psig)	Results
6 × 1.5	8	710 (10 304)	1 065 (15 457)	Pass
8 × 1.5	4	520 (7 547)	780 (11 320)	Pass
10 × 2.0	24	580 (8 417)	870 (12 626)	Pass ^①
12 × 2.0	16	470 (6 821)	705 (10 232)	Pass

① One 10 mm sample experienced an estimated 0.03 std cm³/min leak rate at the 25th reassembly due to improper re-tightening of the nut. After an additional tightening, the sample was re-tested with no detectable leakage.

No detectable leakage (except as indicated) was observed on any of the products tested during initial testing and after the 5th, 10th, 15th, 20th, and 25th reassemblies.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.



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These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

PTR-395

Swagelok Company
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October 2012
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TITLE

Nitrogen Gas Seal Test with Repeated Reassembly of 316 Stainless Steel Swagelok® Tube Fittings with Thin-Wall Stainless Steel Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested with 316 stainless steel seamless tubing.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.028	77 to 84
SS-400-9	Forging		
SS-500-1-4	Bar stock	5/16 × 0.035	84
SS-500-9	Forging		
SS-600-1-4	Bar stock	3/8 × 0.035	88
SS-600-9	Forging		
SS-810-1-4	Bar stock	1/2 × 0.049	76
SS-810-9	Forging		
Metric, mm			
SS-6M0-1-4	Bar stock	6 × 0.8	79
SS-6M0-9	Forging		
SS-10M0-1-4	Bar stock	10 × 1.0	82
SS-10M0-9	Forging		
SS-12M0-1-4	Bar stock	12 × 1.0	83
SS-12M0-9	Forging		

PURPOSE

These assemblies were tested to observe the performance of stainless steel Swagelok tube fittings with advanced geometry back ferrules with thin-wall stainless steel tubing during a gas seal test with repeated reassembly under laboratory conditions.

TEST CONDITIONS

Tube preparation:

Tubing samples were cut to length using a tube cutter for 1/2 in. diameter and under.

Fitting assembly:

The test fittings and tubing were initially assembled 1 1/4 turns past finger-tight per Swagelok tube fitting installation instructions.



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TEST METHOD

1. The assemblies were attached to a positive pressure gas test stand, submerged in water, pressurized to working pressure with nitrogen gas for at least 10 minutes and monitored for leakage.
2. Pressure was dropped, and the fittings were reassembled according to the proper Swagelok reassembly specifications.
3. The fittings were leak tested using nitrogen gas at the working pressure for at least 10 minutes at every fifth reassembly.
4. A total of 25 reassemblies were conducted on each test end.

TEST RESULTS

Fractional

Size in.	Samples Tested	Working Pressure psig (bar)	Results
1/4 × 0.028	16	4000 (275)	Pass
5/16 × 0.035	16	4000 (275)	Pass
3/8 × 0.035	16	3300 (227)	Pass
1/2 × 0.049	16	3700 (254)	Pass ^①

Metric

Size mm	Samples Tested	Working Pressure bar (psig)	Results
6 × 0.8	8	310 (4499)	Pass
10 × 1.0	16	240 (3483)	Pass ^①
12 × 1.0	8	200 (2912)	Pass

① One ½ in. sample experienced an estimated 0.05 std cm³/min leak rate at the 15th reassembly, and one 10 mm sample experienced an estimated 0.1 std cm³/min leak rate at the 10th reassembly, both due to improper re-tightening of the nut. After an additional tightening, the samples were re-tested with no detectable leakage.

No detectable leakage (except as indicated) was observed on any of the products tested during initial testing and after the 5th, 10th, 15th, 20th, and 25th reassemblies.



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These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

PTR-386

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

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August 2008
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TITLE

Thermal Cycle Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Tubing

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested with 316 stainless steel seamless tubing.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.028	84
SS-400-9	Forging		
SS-400-1-4	Bar stock	1/4 × 0.065	82
SS-400-9	Forging		
SS-600-1-4	Bar stock	3/8 × 0.035	85
SS-600-9	Forging		
SS-600-1-4	Bar stock	3/8 × 0.065	83
SS-600-9	Forging		
SS-810-1-4	Bar stock	1/2 × 0.083	85
SS-810-9	Forging		

PURPOSE

These assemblies were tested to observe the performance of Swagelok tube fittings with advanced geometry back ferrules under nitrogen gas pressure, to the lesser of tubing working pressure or 5 000 psig (344 bar), and multiple 1000 to 68°F (537 to 20°C) thermal cycles (air cool).

TEST CONDITIONS

Tube preparation:

Tubing samples were cut to length using a tube cutter for 1/2 in. diameter and under.

Fitting assembly:

The test fittings and tubing were assembled 1 1/4 turns past finger-tight according to Swagelok tube fitting installation instructions.

TEST METHOD

1. The fitting assemblies were attached to a positive pressure gas test stand, submerged in water, pressurized to the lesser of working pressure or 5 000 psig (344 bar) nitrogen gas for at least 10 minutes, and monitored for leakage.
2. The samples were placed into a furnace and elevated to a temperature of 1000°F (537°C).
3. The samples were allowed to stabilize at temperature.
4. The samples were removed from the furnace and allowed to air cool.
5. The above cycle was repeated for a total of ten thermal cycles.
6. The samples were re-attached to a positive pressure gas test stand, submerged in water, pressurized to the lesser of working pressure or 5 000 psig (344 bar) nitrogen gas for at least 10 minutes, and monitored for leakage.



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TEST RESULTS

Size in.	Samples Tested	Test Pressure psig (bar)	Results
1/4 x 0.028	4	4 000 (275)	Pass—No Leakage
1/4 x 0.065	4	5 000 (344)	Pass—No Leakage
3/8 x 0.035	5	3 300 (227)	Pass—No Leakage
3/8 x 0.065	5	5 000 (344)	Pass—No Leakage
1/2 x 0.083	5	5 000 (344)	Pass—No Leakage

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

PTR-392

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

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August 2008
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TITLE

Steam Cycle and Thermal Shock Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Tubing

PRODUCT TESTED

The following Swagelok tube fittings were tested with 316 stainless steel seamless tubing.

Ordering Number	Part Form	Tubing Size in.	Tubing Hardness HRB
SS-400-3	Forging	1/4 × 0.028	85
SS-400-6	Bar stock		
SS-400-1-4	Bar stock	1/4 × 0.065	84
SS-400-1-6	Bar stock		
SS-600-6	Bar stock	3/8 × 0.035	85
SS-600-6-4	Bar stock		
SS-600-6	Bar stock	3/8 × 0.065	81
SS-600-6-4	Bar stock		
SS-810-3	Forging	1/2 × 0.049	82
SS-810-6	Bar stock		
SS-810-1-6	Bar stock		
SS-810-1-4	Bar stock	1/2 × 0.083	74
SS-810-6	Bar stock		
SS-810-1-6	Bar stock		

PURPOSE

These assemblies were tested to evaluate the performance of Swagelok tube fittings with advanced geometry back ferrules when exposed to steam cycles and thermal shock using saturated steam and cool tap water as a test media.

TEST CONDITIONS

Tube preparation:

Tubing samples were cut to length using a tube cutter for 1/2 in. diameter and under. The samples were a minimum of three diameter lengths between fittings after assembly.

Fitting assembly:

The test fittings and tubing were assembled 1 1/4 turns past finger-tight according to Swagelok tube fitting installation instructions.



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TEST METHOD

1. Each assembled sample was attached in turn to a positive pressure gas test stand.
2. Each sample was pressurized with nitrogen gas to 4 000 psig (275 bar) for thin wall tubing and 5 100 psig (351 bar) for heavy wall tubing and monitored for leakage.
3. The samples were assembled in series and attached to a thermal shock test stand.
4. The samples were internally pressurized with saturated steam to 175 psig (377°F) and held at pressure for a period of one minute
5. The samples were then rapidly cooled with tap water (55 to 65°F) [12 to 18°C] for a period of one minute.
6. The steam / quench cycles were repeated 1 100 times and monitored for leakage.
7. The samples were removed from the thermal shock test stand, attached to a positive pressure nitrogen gas leak test stand, pressurized with nitrogen gas to 4 000 psig (275 bar) for thin wall tubing and 5 100 psig (351 bar) for heavy wall tubing and monitored for leakage.

TEST RESULTS

Tubing Size in.	Samples Tested	Results
1/4 × 0.028	12	Pass
1/4 × 0.065	12	Pass
3/8 × 0.035	12	Pass
3/8 × 0.065	12	Pass
1/2 × 0.049	12	Pass
1/2 × 0.083	12	Pass

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

Swagelok Company
29500 Solon Rd.
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PTR-1369

Rev. B

August 2008

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TITLE

Inboard Helium Leak Test of 316 Stainless Steel Swagelok® Tube Fittings at Cryogenic Temperature

PRODUCT TESTED

The following 316 stainless steel Swagelok tube fittings were tested with the identified stainless steel tubing.

Ordering Number	Quantity Tested	Tubing in.	Tubing Hardness HRB
SS-400-6	8	1/4 × 0.028	85
SS-400-9	8		
SS-400-P	8		
SS-600-6-4	8	3/8 × 0.035	77
SS-600-9	8		
SS-600-P	8		
SS-810-6-4	8	1/2 × 0.049	75
SS-810-9	8		
SS-810-P	8		
SS-1210-6-4	8	3/4 × 0.065	75
SS-1210-9	8		
SS-1210-P	8		
SS-1610-6-4	8	1 × 0.083	77
SS-1610-9	8		
SS-1610-P	8		

PURPOSE

These assemblies were tested to observe the performance of 316 stainless steel Swagelok tube fittings at cryogenic temperature under laboratory conditions.

TEST CONDITIONS

Each sample tested consisted of one tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions.

TEST METHOD

Mass Spectrometry (Inboard leakage)

1. The test sample was connected to the mass spectrometer, and a vacuum pressure of less than 1×10^{-3} torr (1.33×10^{-7} MPa) was applied to the test sample.
2. The helium background was measured.
3. The spray probe was used to introduce helium to each connection in turn.
4. The leak rate was measured at each connection.
5. The test sample was submerged into the liquid nitrogen at -325°F (-200°C).
6. The test sample was soaked for at least 10 minutes to assure thermal stabilization.



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7. After stabilization the test sample was raised to just above the surface of the liquid nitrogen and the spray probe was used to introduce helium to each connection in turn. The test sample temperature stabilized at -304°F (-186°C) when raised above the surface of the liquid nitrogen.
8. The test sample was exposed to ambient room temperature until all frost and condensation was removed.
9. The test sample was cycled from room temperature to cryogenic temperature 3 times and was tested for leakage each time.
10. The judgment criterion was no detectable leakage above the measured helium background.

TEST RESULTS

For all samples tested, the helium leak rate did not change from the measured helium background indicating no leakage detected during the three cryogenic cycles.

Mass Spectrometry (Inboard Leakage Helium)				
Ordering Number	Quantity Tested	Tubing in.	Helium Background std cm^3/s	Test Result
SS-400-6	8	1/4 x 0.028	1.5×10^{-5}	Passed
SS-400-9	8			
SS-400-P	8			
SS-600-6-4	8	3/8 x 0.035	1.2×10^{-5}	Passed
SS-600-9	8			
SS-600-P	8			
SS-810-6-4	8	1/2 x 0.049	5.0×10^{-5}	Passed
SS-810-9	8			
SS-810-P	8			
SS-1210-6-4	8	3/4 x 0.065	9.8×10^{-5}	Passed
SS-1210-9	8			
SS-1210-P	8			
SS-1610-6-4	8	1 x 0.083	1.8×10^{-6}	Passed
SS-1610-9	8			
SS-1610-P	8			

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. Test results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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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Swagelok Company
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TITLE

Outboard Helium Leak Test of 316 Stainless Steel Swagelok® Tube Fittings at Cryogenic Temperature

PRODUCT TESTED

The following 316 stainless steel Swagelok tube fittings were tested with the identified stainless steel tubing.

Ordering Number	Quantity Tested	Tubing in.	Tubing Hardness HRB
SS-400-6	8	1/4 × 0.028	85
SS-400-9	8		
SS-400-P	8		
SS-600-6-4	8	3/8 × 0.035	77
SS-600-9	8		
SS-600-P	8		
SS-810-6-4	8	1/2 × 0.049	75
SS-810-9	8		
SS-810-P	8		
SS-1210-6-4	8	3/4 × 0.065	75
SS-1210-9	8		
SS-1210-P	8		
SS-1610-6-4	8	1 × 0.083	77
SS-1610-9	8		
SS-1610-P	8		

PURPOSE

These assemblies were tested to observe performance of 316 stainless steel Swagelok tube fittings at cryogenic temperature when pressurized with helium at the rated pressure of the tubing under laboratory conditions and compare to industry regulations *ECE Regulation No. 110* and *EHIP Rev. 12B Draft*.

TEST CONDITIONS

Each sample tested consisted of one tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions.

TEST METHOD

Mass Spectrometry (Outboard Leakage Test —Detector Probe Method)

1. The Detector Probe method was used to measure the helium leakage of the test sample.
2. The test sample was pressurized with helium to the specified test pressure at room temperature and the detector probe was used to check each connection for leakage.
3. The test sample was submerged into the liquid nitrogen at -325°F (-200°C), and the helium pressure was adjusted to maintain the specified test pressure.
4. The test sample was soaked for at least 10 minutes to ensure thermal stabilization.



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5. After stabilization the test sample was raised above the surface of the liquid nitrogen and the detector probe was used to check each connection for leakage. The test sample temperature stabilized at -304°F (-186°C) when raised above the surface of the liquid nitrogen.
6. The test sample was exposed to ambient room temperature until all frost and condensation was removed. The helium pressure was adjusted to maintain the specified test pressure.
7. The test sample was cycled from room temperature to cryogenic temperature 3 times and was tested for leakage each time.
8. The judgment criteria were leakage less than the values listed in industry regulations *ECE Regulation No. 110* and *EHP Rev. 12B Draft*.
 - *ECE Regulation No. 110* lists a maximum leak rate of $15\text{ cm}^3/\text{hr}$ ($4.2 \times 10^{-3}\text{ std cm}^3/\text{s}$)
 - *EHP Rev. 12B Draft* lists a maximum leak rate of $10\text{ cm}^3/\text{hr}$ ($2.8 \times 10^{-3}\text{ std cm}^3/\text{s}$)

TEST RESULTS

The Swagelok tube fitting meets and outperforms these industry regulation leak rate requirements while experiencing cyclic exposure to cryogenic temperatures at the rated working pressure of the tubing.

Mass Spectrometry (Outboard Leakage Helium)				
Ordering Number	Quantity Tested	Tubing in.	Test Pressure psig (bar)	Test Result
SS-400-6	8	1/4 x 0.028	4000 (275)	Passed
SS-400-9	8			
SS-400-P	8			
SS-600-6-4	8	3/8 x 0.035	3300 (227)	Passed
SS-600-9	8			
SS-600-P	8			
SS-810-6-4	8	1/2 x 0.049	3700 (254)	Passed
SS-810-9	8			
SS-810-P	8			
SS-1210-6-4	8	3/4 x 0.065	3300 (227)	Passed
SS-1210-9	8			
SS-1210-P	8			
SS-1610-6-4	8	1 x 0.083	3100 (213)	Passed
SS-1610-9	8			
SS-1610-P	8			

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. Test results are not offered as statistically significant. See the product catalog for technical data.



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SAFE PRODUCT SELECTION

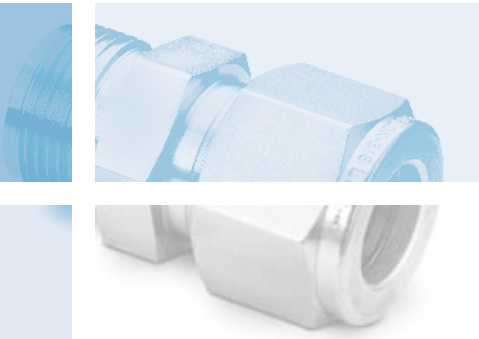
When selecting a product, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

REFERENCES

ECE Regulation No. 110, *Uniform provisions concerning the approval of specific components of motor vehicles using compressed natural gas (CNG) in their propulsion system, dated 2001-06-19, incl. Corrigendum 2 of 2001-08-03*, UNECE United Nations Economic Commission for Europe

EIHP Rev. 12B Draft, *Uniform provisions concerning the approval of specific components of motor vehicles using compressed gaseous hydrogen, dated 2003-12-10*, UNECE United Nations Economic Commission for Europe

Vibration Resistance



Rotary Flex Test—Thin-Wall Tubing—316 Stainless Steel **PTR-3222**
—1/4 to 1 in. and 6 to 25 mm

Shaker Table Vibration Test—316 Stainless Steel **PTR-976**
—1/4 to 1 in.

Seismic Intensity Analysis—316 Stainless Steel **PTR-3216**
—1/4 to 1 1/2 in. and 10 to 28 mm





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TITLE

Rotary Flexure Test of 316 Stainless Steel Swagelok® Tube Fittings with Stainless Steel Tubing

PRODUCT TESTED

The following stainless steel Swagelok tube fittings were tested with stainless steel tubing. Each tubing size was represented with a minimum of 8 samples.

Ordering Number	Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
SS-400-1-4	Bar stock	1/4 × 0.028	86
SS-600-1-4	Bar stock	3/8 × 0.035	84
SS-810-1-4	Bar stock	1/2 × 0.035	81
SS-1010-1-8	Bar stock	5/8 × 0.049	84
SS-1210-1-8	Bar stock	3/4 × 0.049	79
SS-1410-1-8	Bar stock	7/8 × 0.049	78
SS-1610-1-8	Bar stock	1 × 0.065	78
Metric, mm			
SS-6M0-1-4	Bar stock	6 × 0.8	80
SS-10M0-1-4	Bar stock	10 × 1.0	83
SS-12M0-1-4	Bar stock	12 × 1.0	86
SS-14M0-1-8	Bar stock	14 × 1.0	78
SS-15M0-1-8	Bar stock	15 × 1.0	78
SS-16M0-1-8	Bar stock	16 × 1.2	82
SS-18M0-1-8	Bar stock	18 × 1.2	79
SS-20M0-1-8	Bar stock	20 × 1.2	80
SS-22M0-1-8	Bar stock	22 × 1.2	78
SS-25M0-1-8	Bar stock	25 × 1.8	79

PURPOSE

The assemblies were tested to observe the fatigue endurance of 316 stainless steel Swagelok tube fittings with advanced geometry back ferrules under laboratory conditions at various levels of applied alternating bending stress of the tube.

TEST CONDITIONS

- Each sample tested consisted of one tube length and one test fitting. The fitting was assembled according to the Swagelok tube fitting installation instructions.
- Test conducted at room temperature.

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TEST METHOD

Rotary flexure testing procedures have been derived from SAE-ARP-1185. This method applies a completely reversed bending stress on the fitting connection while pressurized with hydraulic oil at the tubing working pressure. The test samples were flexed until either the fitting leaked, the tube fractured, or at least 10 million cycles were achieved, whichever occurred first.

ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 $\mu\text{in./in.}$ peak-to-peak strain level results in frequent piping system failures. For stainless steel, the 200 $\mu\text{in./in.}$ strain level calculates to an alternating stress of 2800 lb/in.^2 (19.2 MPa). ASME PVP-62 also reports that measured field data for piping systems suggest that if the system lasts beyond 10 million cycles, it will have infinite life.

The ASME BPV Code, Section III NC-3673, lists stress intensification factors for various types of fittings. For example, for certain butt-welds $i = 1.0$, socket welds $i = 1.3$ to 1.9, brazed joints $i = 2.1$ and pipe joints $i = 2.3$. The stress intensity lines, $i = 1.0$, 1.3, and 2.3, that are shown on the graph are based on fatigue bend testing of mild carbon steel fittings. The lines allow visual comparison to other fitting types and are defined by the following equation from the ASME BPV Code, Section III, NC-3673:

$$i \times S = 245\,000 \times N^{-0.2}$$

S = amplitude of the applied bending stress at the point of failure, (lb/in.^2)

N = number of cycles to failure

i = stress intensification factor

The following procedure was followed:

1. Each test sample was attached to a rotary flex test stand. Refer to figure 1.

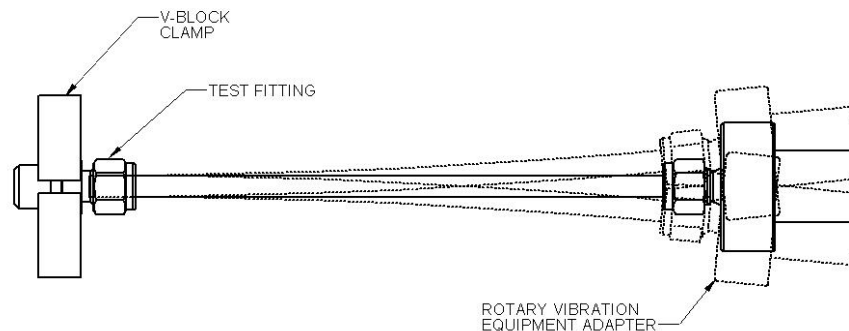


Figure 1

2. A bending stress was applied to each sample by a gimbaled rotary offset. The bending stresses were selected to generate a stress versus number of cycles (S/N) graph. The stress levels support a highly accelerated life test protocol and are not indicative of any specific application.
3. The alternating bending stress was computed from the actual measured flexure strain in the tubing (1/2 of alternating peak-to-peak flexure range).



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Table 1	
Nominal Alternating Bending Stress ^① lb/in. ² (MPa)	Samples Tested
20 000 (137.8)	60
15 000 (103.3)	60
10 000 (68.9)	60
TOTAL	180

① Zero to Peak stress

4. Test samples were pressurized to the working pressure of the tube with hydraulic oil.
5. The test samples were flexed until either the fitting leaked, the tube fractured, or 10 million cycles were achieved, whichever occurred first. An in-line pressure transducer stopped the test if fitting leakage or tube fatigue fracture occurred.
6. A bending stress versus number of cycles graph (S/N) was made from the data and the results were compared to the ASME based data describe earlier.
7. Test samples pass the rotary flex test if all samples remain leak-tight over the duration of the test and demonstrate for a given bending stress the number of cycles that meets or exceeds the predicted number of cycles for fittings having a stress intensification factor of $i = 1.3$.

TEST RESULTS

- No fitting leakage was detected throughout the test. The test was stopped when the tube fractured or the test sample exceeded 10 million cycles.
- The shaded area of the following S/N graph envelopes the test results of the stainless steel Swagelok tube fitting rotary flex test. The shaded area is truncated at 10 million cycles to indicate testing was suspended without leakage at 10 million cycles in accordance with the test method.
- Point AMSE PVP-62 on the graph is the intersection of 2800 lb/in.² (19.2 MPa) and 10 million cycles.
- The 316 stainless steel Swagelok tube fitting remained leak tight while protecting the tubing from premature fracture at alternating stresses greatly exceeding the ASME PVP-62 recommended upper limit. The fitting's performance also resulted in a calculated endurance stress at ten million cycles which exceeds a stress intensification factor of $i = 1.3$ as defined in ASME BPV Code Section III, NC-3673, therefore passing the rotary flex test.
- ASME B31J, *Standard Test Method for Determining Stress Intensification Factors (i-Factors) for Metallic Piping Components*, recommends reporting the average stress intensification, i , factor from several tests. The average stress intensification factor for the stainless steel Swagelok Tube Fitting is $i = 1.0$

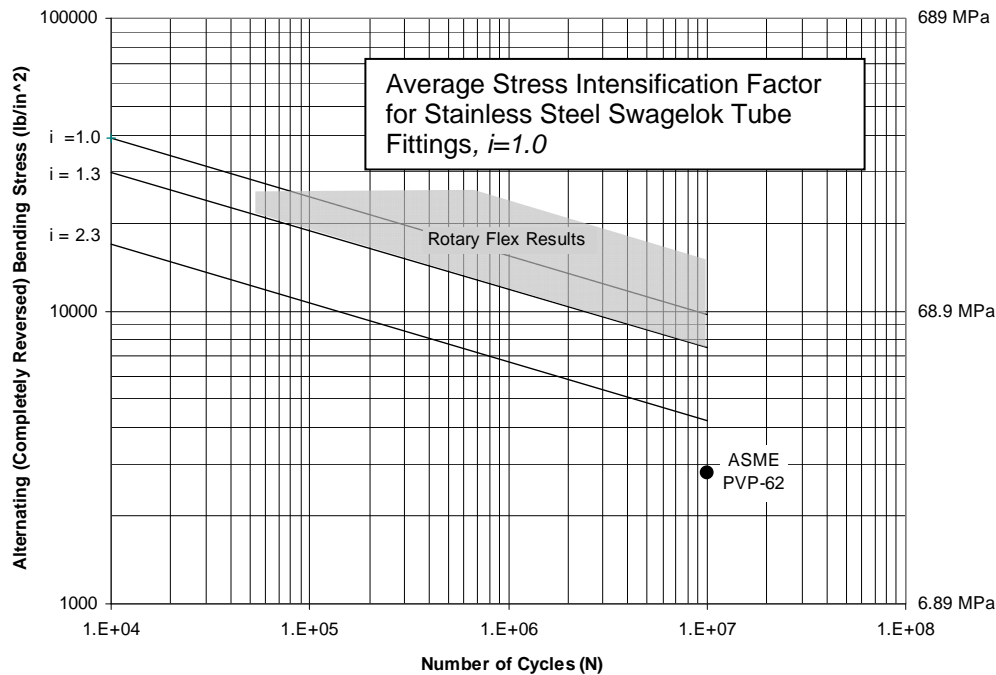


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Rotary Flex Testing of Swagelok Stainless Steel Tube Fitting



These tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.

Referenced Documents:

SAE-ARP-1185, *Flexure Testing of Hydraulic Tubing Joints and Fittings*, SAE International, 400 Commonwealth Drive, Warrendale, PA 15096

ASME *Pressure Vessel and Piping (PVP)*, Vol. 62, 1982, ASME B31J-2008, *Standard Test Method for Determining Stress Intensification Factors (i-Factors) for Metallic Piping Components* and ASME *Boiler and Pressure Vessel (BPV) Code, Section III*, 2007, ASME International, Three Park Avenue, New York, NY 10016-5990, www.asme.org



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PTR-976

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TITLE

Summary of Vibration Test Performance Data Using a Shaker Table for 316 Stainless Steel 1/4, 1/2, 3/4, and 1 Inch Swagelok® Tube Fittings With 316 Stainless Steel Tubing

PRODUCT TESTED

Ordering Number	Tubing Size OD x Wall in.	Tubing Hardness HRB	Samples Tested
SS-400-6	1/4 x 0.035	90 max	2
SS-400-6	1/4 x 0.065	90 max	2
SS-810-6	1/2 x 0.065	90 max	5
SS-1210-6	3/4 x 0.095	90 max	5
SS-1610-6	1 x 0.109	90 max	1

PURPOSE

These assemblies were tested to observe the vibration performance of selected Swagelok tube fittings using a shaker table under laboratory conditions.

TEST CONDITIONS

Room temperature laboratory conditions

TEST METHOD

Vibration Test

1. The samples were filled with hydraulic oil and installed into the vibration test apparatus.
2. The samples were pressurized to the vibration test pressures, as listed in the Test Results section.
3. The tests were conducted in accordance with MIL-STD-167 Type 1.
4. The tests were conducted in the axial (X), transverse (Y), and transverse rotated 90° (Z) axes.
5. Sample testing was conducted in the following conditions:
 - a. X-Axis – Exploratory Vibration
 - b. X-Axis – Variable Frequency
 - c. X-Axis – Endurance Test
 - d. Y-Axis – Exploratory Vibration
 - e. Y-Axis – Variable Frequency
 - f. Y-Axis – Endurance Test
 - g. Z-Axis – Exploratory Vibration
 - h. Z-Axis – Variable Frequency
 - i. Z-Axis – Endurance Test



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6. Exploratory vibration tests were conducted in frequencies from 4 to 50 Hz for 1/4 and 1 in. samples; from 4 to 60 Hz for 1/2 and 3/4 in. samples at the displacement amplitudes listed in the table below in discrete frequency intervals of 1 Hz. At each frequency interval, the vibration was maintained for a period of 15 seconds to determine the frequency at which the presence, location and frequency of resonance occurs.

Exploratory Vibration Test Parameters	
Frequency Range, Hz	Peak Displacement Amplitude, in.
4 to 33	0.010 ± 0.002
34 to 50 ^①	0.003 + 0.000 - 0.001
34 to 60 ^②	0.003 + 0.000 - 0.001

Notes:

① 1/4 and 1 in. samples

② 1/2 and 3/4 in. samples: MIL-STD-167 Type 1 requires testing to 50 Hz; Testing was extended to 60 Hz.

Variable frequency tests were conducted in frequencies from 4 to 50 Hz for 1/4 and 1 in. samples; from 4 to 60 Hz for 1/2 and 3/4 in. samples at the displacement amplitudes listed in the table below in discrete frequency intervals of 1 Hz. At each integral frequency, the vibration was maintained for a period of 5 minutes.

Variable Frequency Parameters	
Frequency Range, Hz	Peak Displacement Amplitude, in.
4 to 15	0.030 ± 0.006
16 to 25	0.020 ± 0.004
26 to 33	0.010 ± 0.002
34 to 40	0.005 ± 0.001
41 to 50 ^①	0.003 ± 0.000
41 to 50 ^②	0.003 + 0.000 - 0.001
51 to 60 ^③	0.002 ± 0.000

Notes:

① 1/2 and 3/4 in. samples

② 1/4 and 1 in. samples

③ 1/2 and 3/4 in. samples: MIL-STD-167 Type 1 requires testing to 50 Hz. Testing was extended to 60 Hz.

With the 1/4 and 1 in. samples, the resonant frequency occurred at 4 Hz. Therefore, the endurance tests with 1/4 and 1 in. samples were conducted at 4 Hz for a period of 2 hours. With 1/2 and 3/4 in. samples, no resonant frequency was detected during the exploratory vibration tests. Therefore, the endurance tests were conducted at 60 Hz for a period of 2 hours.

7. Upon successful completion, all samples underwent a 5-minute hydrostatic proof test at 150 % (+/- 5 %) of the vibration test pressure.



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TEST RESULTS

Vibration Test

Ordering Number	Tubing Size in.	Samples Tested	Resonant Condition	Vibration Test Pressure psig (bar)	Post-Vibration Proof Pressure psig (bar)	Hydrostatic Proof After Vibration
SS-400-6	1/4 x 0.035	2	4 Hz Endurance tested at 4 Hz	3750 (258)	5625 (387)	No visible leakage 2/2 samples
SS-400-6	1/4 x 0.065	2	4 Hz Endurance tested at 4 Hz	3750 (258)	5625 (387)	No visible leakage 2/2 samples
SS-810-6	1/2 x 0.065	5	None to 60 Hz Endurance tested at 60 Hz	5100 (351)	7650 (527)	No visible leakage 5/5 samples
SS-1210-6	3/4 x 0.095	5	None to 60 Hz Endurance tested at 60 Hz	4900 (337)	7350 (506)	No visible leakage 5/5 samples
SS-1610-6	1 x 0.109	1	4 Hz Endurance tested at 4 Hz	3750 (258)	5625 (387)	No visible leakage 1/1 sample

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.

Referenced Documents

MIL-STD-167, *Mechanical Vibrations of Shipboard Equipment (Type 1—Environmental and Type II— Internally Excited)*, Department of Defense, Documentation Automation and Productions Services, 5450 Carlisle Pike Bldg., 09, P.O. Box 2020, Mechanicsburg, PA 17055-0788



Product Test Report

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Swagelok Company
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TITLE

Seismic Intensity Analysis of Laboratory Testing of Installed Stainless Steel Swagelok® Tube Fittings

ABSTRACT

Installed stainless steel Swagelok tube fittings were reported to have survived as many as two severe earthquake events intact without leakage. Subsequent customer requests have prompted completion of a product line seismic intensity analysis of laboratory tests to observe this capability.

Laboratory vibration testing of stainless steel Swagelok tube fittings simulated seismic Peak Ground Acceleration (PGA) intensities transmitted to assembled tube fittings both with and without amplification that can result from tubing system resonance during seismic excitation.

- When there is no tubing system resonance, vibration testing demonstrated leak-tight performance at simulated seismic PGA intensities corresponding to earthquake events up to a **10** on the **Modified Mercalli** scale, **7** on the **Omori** scale, and **9** on the **Richter** scale.
- When tubing system resonance effects are present, vibration testing demonstrated leak-tight performance corresponding to earthquake events up to an **8** on the **Modified Mercalli** scale, **7** on the **Omori** scale, and **8** on the **Richter** scale.

This analysis comprises a seismic intensity scale comparison with Vibration Table and High Impact Shock laboratory tests and does not represent a seismic intensity product rating.



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PRODUCT TESTED

The following stainless steel Swagelok tube fittings were tested with stainless steel tubing.

Table 1

Tube OD	Tube Fitting Ordering Number	Number of Test Fitting Ends	Tube Wall Thickness
Vibration Table Tests			
Fractional Tube, in. (mm)			
1/4	SS-400-6	2	0.035 (0.89)
1/4	SS-400-6	2	0.065 (1.65)
1/2	SS-810-6	6	0.049 (1.24)
1	SS-1610-6	2	0.109 (2.77)
1 1/2	SS-2400-6	6	0.134 (3.40)
Metric Tube, mm (in.)			
10	SS-10M0-6	1	1.0 (0.039)
15	SS-15M0-6	1	1.5 (0.059)
18	SS-18M0-6	1	1.5 (0.059)
22	SS-22M0-6	1	2.0 (0.079)
28	SS-28M0-6	1	2.0 (0.079)
High Impact Shock Tests, in. (mm)			
1/4 (test A)	SS-400-6	2	0.035 (0.89)
1/4 (test A)	SS-400-6	2	0.065 (1.65)
1 (test A)	SS-1610-6	2	0.109 (2.77)
1 (test B)	SS-1610-6	10	0.109 (2.77)

A principle measure of earthquake intensity is Peak Ground Acceleration (PGA) [ref 1]. Earthquake intensities and corresponding nominal PGAs were compared between the Richter seismic intensity scale and two other major seismic intensity scales, the Modified Mercalli scale [ref 2] [ref 3] and the Omori scale [ref 4] [ref 5]. Nominal PGAs based on the Richter scale magnitudes are correlated in Equation 1 [ref 6]. **Appendix One** shows a PGA aligned comparison of these three seismic intensity scales. Comparisons of Peak Ground Velocity and Peak Ground Displacement were not made.

$$\log a_0 = -2.1 + 0.81 M - 0.027 M^2 \quad (1)$$

M = Richter seismic intensity magnitude
 a_0 = PGA (cm/sec²)

Laboratory tests of installed Swagelok tube fittings were examined with a computed equivalent PGA, or maximum vibratory acceleration of the driving vibration in the test. The PGAs were calculated according to Equation 2 in terms of gravitational acceleration at the Earth's surface

(G). In test conditions where the Swagelok tube fittings successfully retained a no-leak performance, the equivalent PGAs were then compared to the nominal PGAs of corresponding seismic intensity scale magnitudes.

$$\text{equivalent PGA} = d_{\max} (2 \pi f)^2 / (981 \text{ cm/sec}^2) \quad (2)$$

d_{\max} = maximum deflection of driving vibration (cm), *half of full displacement amplitude*

f = frequency of driving vibration (Hz)

$G = a_0 / (981 \text{ cm/sec}^2)$

TEST PROCEDURES

(a) **Table Vibration Tests (Part 1)**—Table vibration tests were performed on Swagelok tube fittings installed on a run of tubing between two tube supports attached to a vibration table as shown in Figure 1.

Figure 1: Table Vibration Setup

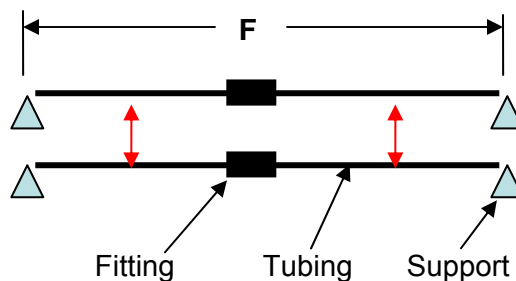


Table vibration tests were performed at room temperature under laboratory conditions at the Southwest Research Institute facilities [ref 7] in accordance with ASTM F1387 [ref 8]. The setup used in the testing is shown in Figure 1. The length “F” between tube supports (also from ASTM F1387) and the tube fitting test pressures, during and after vibration testing, for each size tube fitting were specified as shown in **Table 2**.

Table 2: Vibration Test Tube Fitting Assembly Set-up (Part 1)

Tube OD in.	Tube Wall Thickness in. (mm)	Tube Support Spacing “F” mm	Internal Hydraulic Test Pressure MPa (psig)	Post Vibration Test Hydraulic Pressure MPa (psig)
1/4	0.035 (0.89)	420	25.9 (3750)	38.8 (5625)
1/4	0.065 (1.65)	420	25.9 (3750)	38.8 (5625)
1/2	0.049 (1.24)	480	22.7 (3300)	34.1 (4950)
1	0.109 (2.77)	640	25.9 (3750)	38.8 (5625)
1 1/2	0.134 (3.40)	790	22.7 (3300)	34.1 (4950)



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The test fittings were assembled following Swagelok tube fitting installation instructions [ref 9], hydraulically pressurized to the specified pressure then subjected to table vibration testing according to MIL-STD-167 (type 1—environmental vibration) [ref 10]. This testing comprised a repeated sequence of three separate steps: Variable Frequency, Exploratory, and Endurance vibration. All three of these vibration test steps were each performed in sequence three times, each time varying the direction of input vibration displacement in each rectilinear axis of tube fitting assembly, longitudinal with the tube axis, and “x” and “y” perpendicular to the tube axis.

The Variable Frequency test ranged from 4 to 50 Hz, dwelling at every 1 Hz interval for 5 minutes, while holding specified single amplitude input displacements as shown in **Table 3**. Also shown are the ranges of equivalent PGAs, presuming no resonance amplification, (according to Equation 2) computed for the range of driving frequencies at each displacement.

Table 3: Variable Frequency Test Input Displacements and Equivalent PGAs

Variable Table Frequency (f) Range Hz	Single Amplitude (d_{max}) Input Displacement mm	Equivalent PGA Range G
4 to 15	0.76	0.05 to 0.69
16 to 25	0.51	0.53 to 1.28
26 to 33	0.25	0.68 to 1.10
34 to 40	0.13	0.60 to 0.84
41 to 50	0.08	0.54 to 0.80

No tube fitting leakage (hydraulic) was detected throughout any of the Variable Frequency testing, both during and post vibration. The testing applied equivalent PGAs on all the Swagelok tube fitting sizes up to 1.28 G. This magnitude corresponds to a **10** seismic intensity on the **Modified Mercalli** scale, a **7** on the **Omori** scale, and a **9** on the **Richter** scale, and would compare to installed tubing fittings that do not encounter a resonance induced amplification of PGA during an earthquake event.

The Exploratory testing specifically searched for resonance responses in the tube fitting assemblies on the vibration table. Accelerometers were positioned on the tube fittings and on the vibration table. Frequency sweeps were applied over a range of 4 to 33 Hz at a 0.25 mm single amplitude displacement of the table, followed by 34 to 50 Hz at 0.08 mm single amplitude, dwelling at every interval of 1 Hz for 15 seconds.

Resonance or near resonance responses in vibration are important because these induce a side-to-side oscillating bending flexure of the tube at the tube fitting connection that would not occur if there was a no resonance response.



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Near resonance responses were found with some but not all sizes. (Table Vibration Tests [Part 2] was more successful.) For each tube fitting size, **Table 4** shows the greatest amplified transmitted acceleration ratio (maximum vibratory acceleration measured at the tube fitting over the same applied at the vibration table) and frequency where each greatest response was found. As the greatest responses were found at the low limit of the frequency sweeps, 4 Hz, the responses found may not have been at a resonance peak maximum.

Table 4: Vibration Resonance Response Findings [Part 1]

Tube OD in.	Tube Wall Thickness in. (mm)	Greatest Transmitted Acceleration Ratio, Frequency Where Found
1/4	0.035 (0.89)	6.0 at 4 Hz
1/4	0.065 (1.65)	3.0 at 4 Hz
1/2	0.049 (1.24)	1.0 across 4 to 50 Hz
1	0.109 (2.77)	6.5 at 4 Hz
1 1/2	0.134 (3.40)	1.0 across 4 to 50 Hz

The Endurance testing comprised a two-hour vibration dwell at the frequency showing the greatest ratio of transmitting acceleration, with specified vibration table amplitude the same as that used in the Variable Frequency tests. For those sizes where no resonance effect was found, the Endurance testing was conducted at 50 Hz, the high limit of the frequency sweeps.

No tube fitting leakage was detected throughout any of the Endurance testing, both during and post vibration. For those sizes of tube fittings installed wherein their vibration table tubing assemblies had shown a resonance response, the driving vibration at the table simulated an equivalent PGA no greater than 0.05 G (per **Table 3**). This magnitude corresponds to a 5 seismic intensity on the Modified Mercalli scale, a 2 on the Omori scale, and a 6 on the Richter scale. These maximums would correspond to tubing systems that do encounter a resonance induced amplification of PGA at installed Swagelok tube fittings during an earthquake event, but are too low to represent a meaningful Swagelok tube fitting performance comparison.



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(b) **Table Vibration Tests [Part 2]** – To further explore resonance responses in tube fitting assemblies, table vibration tests were performed at room temperature at the Swagelok Company facilities under laboratory conditions in accordance with JIS E 4031 [ref 11]. The setup used followed ASTM F1387 [ref 8], the same shown in Figure 1. The length “F” and the test pressures, both initially and after vibration testing, for each size tube fitting were specified as shown in **Table 5**. The tube fitting assemblies were not pressurized during vibration testing.

Table 5: Vibration Test Tube Fitting Assembly Set-up [Part 2]

Tube OD mm	Tube Wall Thickness mm (in.)	Tube Support Spacing “F” mm	Internal Hydraulic Test Pressure MPa (psig)	Internal Nitrogen Test Pressure MPa (psig)
10	1.0 (0.039)	600	1.00 (145)	1.00 (145)
15	1.5 (0.059)	600	1.00 (145)	1.00 (145)
18	1.5 (0.059)	600	1.00 (145)	1.00 (145)
22	2.0 (0.079)	600	1.00 (145)	1.00 (145)
28	2.0 (0.079)	600	1.00 (145)	1.00 (145)

The test fittings were assembled following Swagelok tube fitting installation instructions [ref 9], pneumatically and hydraulically pressure tested, then fastened to a vibration table with accelerometers positioned on the tube fittings and on the vibration table. Frequency sweeps were applied continuously, raised and lowered twice over ranges spanning 5 to 190 Hz. The single amplitude displacement of the table was also varied such that the calculated and measured acceleration at the table simulated a constant equivalent PGA of 0.50 G.

These frequency sweeps were conducted in sequence three times for each tube fitting, each time varying the direction of input vibration displacement in each rectilinear axis of tube fitting assembly, longitudinal with the tube axis, and “x” and “y” perpendicular to the tube axis. The rate of frequency sweep was conducted such that each tube fittings was subjected to a total of five hours of vibration in each axis, 15 hours total.

Resonance responses were found with all sizes. For each tube fitting size, **Table 6** shows the greatest amplified transmitted acceleration ratio and frequency where each greatest response was found. These responses all represented resonance peak maximums.

Table 6: Vibration Resonance Response Findings [Part 2]

Tube OD mm	Greatest Transmitted Acceleration Ratio, Frequency Where Found
10	5.5 at 170 Hz
15	3.1 at 141 Hz
18	4.0 at 133 Hz

Tube OD mm	Greatest Transmitted Acceleration Ratio, Frequency Where Found
22	5.5 at 139 Hz
28	7.4 at 139 Hz

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No tube fitting leakage was detected, both before and after vibration. For all sizes of tube fittings the driving vibration at the table simulated an equivalent PGA of 0.50 G. This magnitude corresponds to an **8** seismic intensity on the **Modified Mercalli** scale, a **7** on the **Omori** scale, and an **8** on the **Richter** scale, and would correspond to tubing systems that do encounter resonance induced PGA amplification at installed Swagelok tube fittings during an earthquake event.

(c) **High Impact Shock Tests**—To apply an extreme vibratory acceleration test, various sizes of installed stainless steel Swagelok tube fittings were subjected to repeated high impact shock testing according to MIL-S-901D (Grade A, Class 1, Type A, hull mounted) [ref 12]. As stated in the standard, “The purpose of these requirements is to verify the ability of shipboard installations to withstand shock loadings which may occur during wartime service due to the effects of nuclear or conventional weapons.”

Swagelok tube fitting unions pull assembled on two opposing lengths of tubing. For shock test A, each test assembly was cantilever suspended by a single tube support on one of the lengths of tubing clamped to the anvil table of a shock machine. The union tube fittings were all positioned 51 mm (2 in.) from the tube support. On the other tube length a specified free weight was clamped on the tube at specified tube spacing from the union tube fitting as shown in **Table 7**. For shock test B, each test assembly was mounted with two tube supports as shown in Figure 1 with an “F” spacing of 417 mm (16.4 in.).

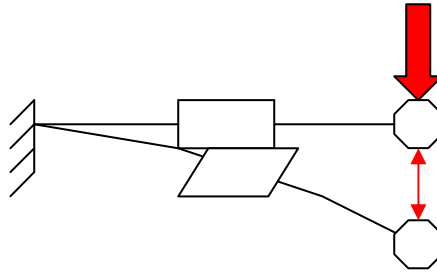
Table 7: Tube Fitting Assembly High Impact Shock Test Set-up

Tube OD in.	Free Weight kg	Free Weight Tube Spacing mm	Internal Hydraulic Test Pressure MPa (psig)	Post Shock Hydraulic Test Pressure MPa (psig)
1/4 (test A)	1.3	190	25.9 (3750)	38.8 (5625)
1/4 (test A)	1.5	190	25.9 (3750)	38.8 (5625)
1 (test A)	32	370	25.9 (3750)	38.8 (5625)
1 (test B)	N/A	370	25.9 (3750)	38.8 (5625)

High impact shock tests A were performed at room temperature in laboratory conditions at the Southwest Research Institute facilities [ref 7]. Test fittings were assembled according to Swagelok tube fitting installation instructions [ref 9] and hydraulically pressurized to a specified pressure during shock testing and again for a 10 minutes period for the post shock testing as shown in **Table 7**. High impact shock tests B were performed at Aero Nav Labs facilities [ref 13] where the test fittings were additionally subjected to a final 1 minute hydraulic pressure at 103 MPa (15000 psig) after the shock and post shock hydraulic pressure tests.

While under test pressure each Swagelok tube fitting union was subjected to high impact shocks as shown in Figure 2 for test A, and as shown in Figure 1 for test B. The high impact shock testing comprised a sequence of specified 1, 3, and 5 ft (0.30, 0.91, 1.5 m) hammer drops against the anvil table to which the test assemblies were mounted and were repeated again in each rectilinear axis of the table.

Figure 2: High Impact Shock Test Setup



Computing an equivalent PGA seismic driver that could induce these elevated levels of shock acceleration starts with Equation 3 which relates the system resonance amplification of vibratory acceleration at an installed tube fitting as a function of driving frequency and tube system harmonic properties [ref 14].

$$\frac{\text{Maximum Acceleration at the test fitting}}{\text{Peak Ground Acceleration}} = \left[\frac{1 + (2\xi r)^2}{(1 - r^2)^2 + (2\xi r)^2} \right]^{\frac{1}{2}} \quad (3)$$

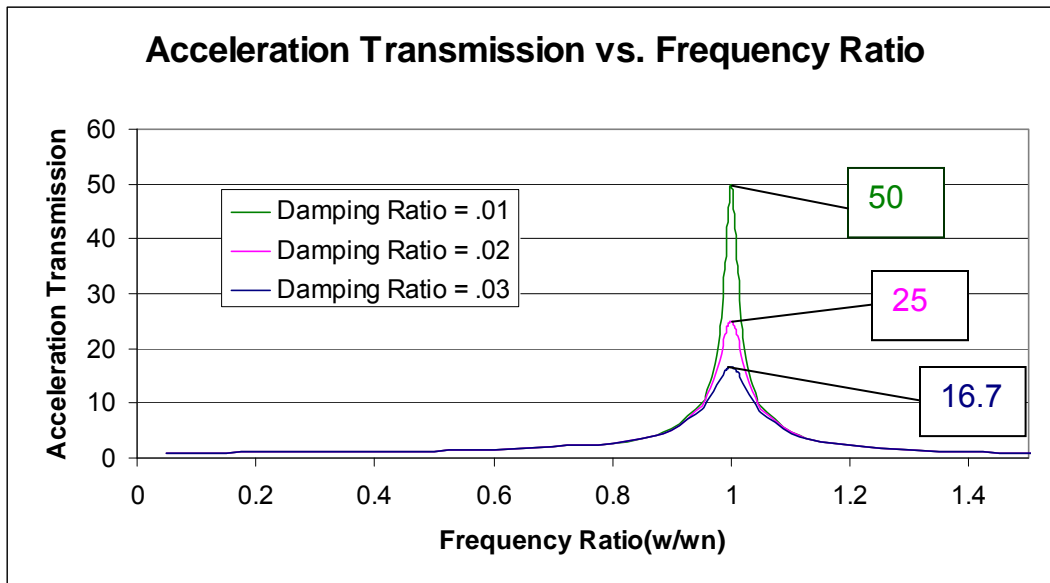
ξ = Damping Ratio
 r = Frequency Ratio (ω/ω_n)

The damping ratio (ξ) is defined as the ratio of damping (internal or material) in a system over the critical damping of the system. Critical damping is defined as the level of damping at which a vibrating system will not overshoot its equilibrium position, returning to equilibrium in the minimum amount of time [ref 14].

The damping in tube and tube fitting system would be considered hysteresis damping which is energy lost within a moving structure. "In hysteresis damping, some of the energy involved in the repetitive internal deformation and restoration to original shape is dissipated in the form of random vibrations of the crystal lattice in solids and random kinetic energy of the molecules in a fluid"[ref 15]. For a typical tube fitting and tube system the damping ratio is in the range of 0.01 to 0.03 [ref 16].

The frequency ratio (r) is the ratio of the frequency (ω) of the driving ground (or seismic) vibration over the natural frequency (ω_n) of a tube run system comprising installed tube fittings and other components. The natural frequency of the system is based on the installed component masses and spring constants of tubing. The maximum transmission of acceleration occurs at resonance or at $r = 1$. This value was used to find the maximum ratio or amplification of fitting acceleration from a PGA seismic driver. Applying equation (3), the amplified acceleration transmission can range from 16.7 to 50, as shown in Figure 3.

Figure 3: Acceleration Transmission



Finally, the high impact shock testing was literature researched for acceleration imparted during impacts. Peak values of acceleration measured in the 250 to 550g range [ref 17]. The lowest value of this range shock induced G equivalent acceleration (250), divided by the maximum amplification of tube fitting acceleration from a PGA seismic driver (50 in Figure 3) computes to a lowest equivalent PGA of 5.0, which is still well above the greatest seismic PGA (2.04) listed in the **Appendix One** major seismic intensity scales. In all cases the tube fittings sustained these elevated levels of shock acceleration without leakage.

While this test result demonstrates the robust performance of the Swagelok tube fitting, high impact shock testing should not alone constitute a seismic intensity scale comparison. Rather, this result serves to reinforce the comparisons derived from the table vibration testing as reported in the Abstract of this report and in the following summary of Test Results.

TEST RESULTS

Table Vibration Tests [Part 1]—With durations of exposure well exceeding those of major seismic events, based on driving peak accelerations of table vibration, presuming no tubing system resonance based amplification of peak acceleration at installed test fittings, Swagelok tube fittings were subjected to peak table vibration accelerations that compare to Peak Ground Accelerations corresponding to earthquake events up to a **10** on the **Modified Mercalli** scale, **7** on the **Omori** scale, and **9** on the **Richter** scale.

No tube fitting leakage was detected throughout any of the vibration exposure, nor during the 150 % of test pressure exposure subsequent to vibration exposure.



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Table Vibration Tests [Part 2]—With durations of exposure well exceeding those of major seismic events, based on the driving peak acceleration of table vibration, specifically at vibration frequencies of tubing system resonance with measured 3.1 to 7.4 amplification of peak acceleration at installed test fittings, Swagelok tube fitting were subjected to peak table vibration acceleration that compares to Peak Ground Accelerations corresponding to earthquake events up to an **8** on the **Modified Mercalli** scale, **7** on the **Omori** scale, and **8** on the **Richter** scale.

No tube fitting leakage was detected both before and after any vibration exposure.

High Impact Shock Tests—With repeated exposure to a series of high acceleration inducing hammer blows on installed test fittings, based on prior study and measurement of shock induced acceleration with this laboratory set-up, Swagelok tube fittings were subjected to minimum calculated peak driving accelerations, presuming a worse case tubing system resonance, that are still over twice the Peak Ground Accelerations corresponding to the highest level on all the three major seismic intensity scales.

No tube fitting leakage was detected throughout the repeated shock test exposure. In some cases the tubing attached to the Swagelok tube fittings became permanently damaged, but nevertheless with no leakage detected.

This analysis comprises a seismic intensity scale comparison with Vibration Table and High Impact Shock laboratory tests and does not represent a seismic intensity product rating.

These tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

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



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Appendix One: Peak Ground Acceleration (PGA) Comparison of Three Major Seismic Intensity Scales

Modified Mercalli		Omori(JMA)		Richter	
Nominal PGA cm/s ² (G equivalent)	Scale Description	Nominal PGA cm/s ² (G equivalent)	Scale Description	Nominal PGA cm/s ² (G equivalent)	Scale Description
				0.05 (4.89E-6)	1. Micro earthquake, not felt
<1.67 (≤0.002)	1. Felt by very few under favorable conditions			0.258 (2.63E-4)	2. Generally not felt, but recorded
1.67 (0.002)	2. Felt by few at rest, especially in higher floors			1.22 (0.001)	3. Often felt, but rarely causes damage
7.7 (0.008)	3. Felt noticeably indoors, vibration similar to passing truck			5.1 (0.005)	4. Noticeable shaking of indoor items, rattling noises, significant damage unlikely
				18.8 (0.019)	5. Major damage to poorly constructed buildings. Slight damage to well designed buildings
26 (0.027)	4. Felt indoors and outdoors, walls cracking, similar to truck striking building	30 (0.031)	1. Shock strong, walls crack slightly, furniture overturned, trees shaken		
64.3 (0.065)	5. Felt by almost everyone, unstable objects overturned	60 (0.061)	2. Wooden walls crack, small stone structures overturned	61.4 (0.063)	6. Destructive in areas about 160 km across in populated areas
		105 (0.107)	3. 1/4 of factory chimneys destroyed, brick partially or totally destroyed		
133 (0.136)	6. Felt by everyone, heavy furniture moved, damage slight				
		160 (0.163)	4. All factory chimneys ruined, most brick and some wood houses destroyed, crevices in ground	177 (0.180)	7. Serious damage over large areas



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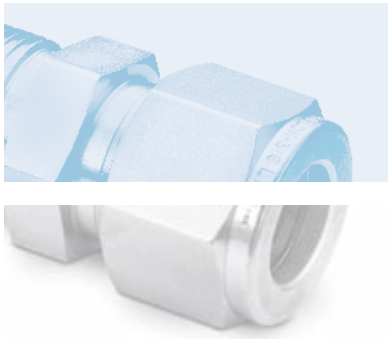
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255 (0.260)	<u>7.</u> Negligible to considerable damage to buildings based on quality of construction	225 (0.229)	<u>5.</u> All brick houses seriously damaged, 3 % of wooden houses destroyed		
		325 (0.331)	<u>6.</u> 50 to 80 % of wooden houses destroyed, iron bridges destroyed, wooden bridges partially or totally damaged		
485 (0.494)	<u>8.</u> Considerable structure damage, partial collapse, heavy furniture overturned	≥400 (≥0.408)	<u>7.</u> All buildings destroyed except a few wooden structures	449 (0.458)	<u>8.</u> Serious damage in areas hundreds of kilometers across
927 (0.945)	<u>9.</u> Damage considerable to all buildings. Buildings shifted off of foundation			1000 (1.02)	<u>9.</u> Devastating in areas several thousand kilometers across
1220 (1.24)	<u>10.</u> Well built wooden structures destroyed, most masonry structures destroyed, rails bent				
>1220 (>1.24)	<u>11.</u> Few, if any structures remain standing, bridges destroyed, rails bent greatly				
>1220 (>1.24)	<u>12.</u> Lines of sight and level are distorted, objects thrown in air			2000 (2.04)	<u>10.</u> Widespread devastation over very large areas. Never recorded

Alloys



Alloy 625 Swagelok Tube Fittings with Alloy 625 Tubing

Tube Grip

Tensile Pull Test—1/4 to 1/2 in. and 6 to 12 mm **PTR-1433**

Hydrostatic Pressure Test—1/4 to 1/2 in. and 6 to 12 mm **PTR-1434**

Gas Seal

Nitrogen Gas Pressure / Repeated Reassembly Test
—1/4 to 1/2 in. and 6 to 12 mm **PTR-1432**

Vibration Resistance

Rotary Flex Test—1/4 to 1/2 in. and 6 to 12 mm **PTR-1435**

Alloy 825 Swagelok Tube Fittings with Alloy 625 Tubing

Tube Grip

Hydrostatic Pressure Test—1/4 to 1/2 in. and 6 to 12 mm **PTR-864**

Tensile Pull Test—1/4 to 1/2 in. and 6 to 12 mm **PTR-867**

Gas Seal

Nitrogen Gas Pressure / Repeated Reassembly Test
—1/4 to 1/2 in. and 6 to 12 mm **PTR-865**

Vibration Resistance

Rotary Flex Test—1/4 to 1/2 in. and 6 to 12 mm **PTR-866**

316 SS Swagelok Tube Fittings with 254 SMO® (6-Moly) SS Tubing

Tube Grip

Tensile Pull Test—1/4 to 1/2 in. **PTR-2834**

Impulse and Hydrostatic Proof Test—1/4 to 1/2 in. **PTR-2849**

Hydrostatic Pressure Test—1/4 to 1/2 in. **PTR-2852**

Gas Seal

High-Temperature Thermal Cycling and Hydrostatic Proof Test
—1/4 to 1/2 in. **PTR-2835**

Low-Temperature Thermal Cycling and Hydrostatic Proof Test
—1/4 to 1/2 in. **PTR-2836**

Nitrogen Gas Pressure / Repeated Reassembly Test—1/4 to 1/2 in. **PTR-2853**

Vibration Resistance

Rotary Flex Test—1/4 to 1/2 in. **PTR-2841**





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TITLE

Tensile Pull Test of Alloy 625 Swagelok® Tube Fittings with Alloy 625 Tubing

PRODUCT TESTED

The following alloy 625 Swagelok tube fittings were tested.

Ordering Number	Form	Tubing Size	Tubing Hardness Rb
Fractional, in.			
625-400-1-4	Bar stock	1/4 × 0.065	97
625-600-1-4	Bar stock	3/8 × 0.065	90
625-810-1-4	Bar stock	1/2 × 0.065	88
Metric, mm			
625-6M0-1-4	Bar stock	6 × 1.2	96
625-10M0-1-4	Bar stock	10 × 1.5	94
625-12M0-1-4	Bar stock	12 × 1.8	89

PURPOSE

The assemblies were tested to observe the tensile pull performance of the alloy 625 Swagelok tube fitting with alloy 625 tubing under laboratory conditions.

TEST CONDITIONS

Each non-pressurized sample tested consisted of one tube length and two test fittings. The fittings were assembled according to the Swagelok tube fitting installation instructions. Testing was conducted at room temperature.

TEST METHOD

1. Each sample was attached in turn to a tensile test stand.
2. A constant tensile load was applied to the sample at a rate of 3/8 in. (9.5 mm) per minute until either the tube pulled out of the fitting or the tube fractured.
3. The judgment criterion is taken from ASTM F1387, Annex A7.

Calculated tensile load = $A_p \times S_y$

where:

A_p = cross-section area of the tube based on wall thickness

S_y = minimum specified yield strength of tube.

4. The samples pass this test when the calculated tensile load is achieved without the tube pulling out of the fitting or the tube fracturing.



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TEST RESULTS

Tubing Size	Samples Tested	ASTM F1387 Calculated Tensile Load lb (kg)	Samples Attaining ASTM F1387 Calculated Tensile Load
Fractional, in.			
1/4 × 0.065	6	2267 (1028)	6 / 6
3/8 × 0.065	6	3798 (1722)	6 / 6
1/2 × 0.065	12	5830 (2644)	12 / 12
Metric, mm			
6 × 1.2	6	1683 (763)	6 / 6
10 × 1.5	6	3725 (1689)	6 / 6
12 × 1.8	12	8399 (3809)	12 / 12

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.

Referenced Documents

ASTM F1387-99, *Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings*, American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428



Product Test Report

Swagelok Company
29500 Solon Rd.
Solon, Ohio 44139 U.S.A.

PTR-1434

Rev. A

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TITLE

Hydrostatic Pressure Test of Alloy 625 Swagelok® Tube Fittings with Alloy 625 Tubing

PRODUCT TESTED

The following alloy 625 Swagelok tube fittings were tested.

Ordering Number	Form	Tubing Size	Tubing Hardness Rb
Fractional, in.			
625-400-1-4	Bar stock	1/4 × 0.065	97
625-400-C	Bar stock		
625-600-1-4	Bar stock	3/8 × 0.065	90
625-600-C	Bar stock		
625-810-1-4	Bar stock	1/2 × 0.065	88
625-810-9	Forging		
Metric, mm			
625-6M0-1-4	Bar stock	6 × 1.2	96
625-6M0-C	Bar stock		
625-10M0-1-4	Bar stock	10 × 1.5	94
625-10M0-C	Bar stock		
625-12M0-1-4	Bar stock	12 × 1.8	89
625-12M0-9	Forging		

PURPOSE

The assemblies were tested to observe the tube grip performance of alloy 625 Swagelok tube fittings with alloy 625 tubing under hydrostatic pressure in laboratory conditions.

TEST CONDITIONS

Each sample tested consisted of one tube length and two test fittings. The fittings were assembled according to the Swagelok tube fitting installation instructions. Testing was conducted at room temperature.

TEST METHOD

The fittings were tested as follows:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks thereby forcing a failure at the fitting-to-tubing engagement.
3. Pressure was gradually increased and the pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.



Product Test Report

Swagelok Company
29500 Solon Rd.
Solon, Ohio 44139 U.S.A.

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TEST RESULTS

Fractional

Tubing Size in.	Samples Tested	Working Pressure (W.P.) psig (bar)	4 × Working Pressure psig (bar)	Samples Attaining 4 × W.P.
1/4 × 0.065	22	14 600 (1 005)	58 400 (4 023)	22 / 22
3/8 × 0.065	22	9 400 (647)	37 600 (2 590)	22 / 22
1/2 × 0.065	22	6 800 (468)	27 200 (1 874)	22 / 22

Metric

Tubing Size mm	Samples Tested	Working Pressure (W.P.) bar (psig)	4 × Working Pressure bar (psig)	Samples Attaining 4 × W.P.
6 × 1.2	22	750 (10 885)	3 000 (43 541)	22 / 22
10 × 1.5	22	550 (7 982)	2 200 (31 930)	22 / 22
12 × 1.8	16	550 (7 982)	2 200 (31 930)	16 / 16

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

Swagelok Company
29500 Solon Rd.
Solon, Ohio 44139 U.S.A.

PTR-1432

Rev. A

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TITLE

Nitrogen Gas Seal Test with Repeated Reassembly of Alloy 625 Swagelok® Tube Fittings with Alloy 625 Tubing at 1.25 Times the Tubing Working Pressure

PRODUCT TESTED

The following alloy 625 Swagelok tube fittings were tested.

Fractional

Ordering Number	Form	Tubing Size in.	Tubing Hardness HRB
625-400-1-4	Bar stock	1/4 × 0.035	93
625-400-C	Bar stock		
625-400-1-4	Bar stock	1/4 × 0.065	97
625-400-C	Bar stock		
625-600-1-4	Bar stock	3/8 × 0.035	92
625-600-C	Bar stock		
625-600-1-4	Bar stock	3/8 × 0.065	90
625-600-C	Bar stock		
625-810-1-4	Bar stock	1/2 × 0.035	92
625-810-9	Forging		
625-810-1-4	Bar stock	1/2 × 0.065	88
625-810-9	Forging		

Metric

Ordering Number	Form	Tubing Size mm	Tubing Hardness HRB
625-6M0-1-4	Bar stock	6 × 0.8	96
625-6M0-C	Bar stock		
625-6M0-1-4	Bar stock	6 × 1.2	96
625-6M0-C	Bar stock		
625-10M0-1-4	Bar stock	10 × 1.0	90
625-10M0-C	Bar stock		
625-10M0-1-4	Bar stock	10 × 1.5	94
625-10M0-C	Bar stock		
625-12M0-1-4	Bar stock	12 × 1.0	90
625-12M0-9	Forging		
625-12M0-1-4	Bar stock	12 × 1.8	89
625-12M0-9	Forging		



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PURPOSE

The assemblies were tested to observe the leak-tight integrity of alloy 625 Swagelok tube fittings with alloy 625 tubing during a gas seal test with reassembly under laboratory conditions.

TEST CONDITIONS

Each sample tested consisted of one tube length and two test fittings. The fittings were assembled according to the Swagelok tube fitting installation instructions. Testing was conducted at room temperature.

TEST METHOD

1. The test samples were attached to a gas test stand, submerged in water, pressurized to 1.25 times the tube working pressure with nitrogen for 10 minutes, and monitored for leakage. The judgment criterion was less than 1 bubble per minute at the applied pressure. If necessary, the fittings were tightened slightly (up to 1/8 turn) and re-tested.
2. Pressure was reduced to zero and the fittings were disassembled.
3. The fittings were reassembled according to Swagelok reassembly instructions.
4. The fittings were leak tested at every fifth reassembly.
5. A total of 25 reassemblies were conducted on each test sample end.

TEST RESULTS

Fractional

Tubing Size in.	Samples Tested	Working Pressure ^① psig (bar)	Test Pressure psig (bar)	Samples Attaining Repeated Gas Seal Through 25 Reassemblies
1/4 × 0.035	24	7 300 (502)	9 125 (628)	24 / 24
1/4 × 0.065	24	14 600 (1005)	18 250 (1257)	24 / 24
3/8 × 0.035	24	4 700 (323)	5 875 (404)	24 / 24
3/8 × 0.065	24	9 400 (647)	11 750 (809)	24 / 24
1/2 × 0.035	16	3 500 (241)	4 375 (301)	16 / 16
1/2 × 0.065	8	6 800 (468)	8 500 (585)	8 / 8

① Working pressure was based on the Swagelok Alloy 625 Tubing Data sheet.



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Metric

Tubing Size mm	Samples Tested	Working Pressure ^① bar (psig)	Test Pressure bar (psig)	Samples Attaining Repeated Gas Seal Through 25 Reassemblies
6 × 0.8	24	470 (6 821)	588 (8 534)	24 / 24
6 × 1.2	24	750 (10 885)	938 (13 613)	24 / 24
10 × 1.0	24	350 (5 079)	438 (6 357)	24 / 24
10 × 1.5	24	550 (7 982)	688 (9 985)	24 / 24
12 × 1.0	16	290 (4 208)	363 (5 268)	16 / 16
12 × 1.8	8	550 (7 982)	688 (9 985)	8 / 8

① Working pressure was based on the Swagelok Alloy 625 Tubing Data sheet.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

PTR-1435

Rev. A

July 2008

Page 1 of 4

TITLE

Rotary Flexure Test of Alloy 625 Swagelok® Tube Fittings with Alloy 625 Tubing

PRODUCT TESTED

The following alloy 625 Swagelok tube fittings were tested with alloy 625 tubing. Each tubing size was represented with a minimum of 8 samples.

Ordering Number	Form	Tubing Size	Tubing Hardness Rb
Fractional, in.			
625-400-1-4	Bar stock	1/4 × 0.035	93
625-600-1-4	Bar stock	3/8 × 0.035	92
625-810-1-4	Bar stock	1/2 × 0.035	92
Metric, mm			
625-6M0-1-4	Bar stock	6 × 0.8	96
625-10M0-1-4	Bar stock	10 × 1.0	90
625-12M0-1-4	Bar stock	12 × 1.0	90

PURPOSE

The assemblies were tested to observe the fatigue endurance of alloy 625 Swagelok tube fittings with advanced geometry back ferrules under laboratory conditions at various levels of applied alternating bending stress of the tube.

TEST CONDITIONS

- Each sample tested consisted of one tube length and one test fitting. The fitting was assembled according to the Swagelok tube fitting installation instructions.
- Test conducted at room temperature.

TEST METHOD

Rotary flexure testing procedures have been derived from SAE-ARP-1185. This method applies a completely reversed bending stress on the fitting connection while pressurized with hydraulic oil at the tubing working pressure. The test samples were flexed until either the fitting leaked, the tube fractured, or at least 10 million cycles were achieved, whichever occurred first.

ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 $\mu\text{in./in.}$ peak-to-peak strain level results in frequent piping system failures. For alloy 625, the 200 $\mu\text{in./in.}$ strain level calculates to an alternating stress of 2980 lb/in.^2 (20.5 MPa). ASME PVP-62 also reports that measured field data for piping systems suggest that if the system lasts beyond 10 million cycles, it will have infinite life.

The ASME BPV Code, Section III NC-3673, lists stress intensification factors for various types of fittings. For example, for certain butt-welds $i = 1.0$, socket welds $i = 1.3$ to 1.9, brazed joints $i = 2.1$ and pipe joints $i = 2.3$. The stress intensity lines, $i = 1.0$, 1.3, and 2.3, that are shown on

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the graph are based on fatigue bend testing of mild carbon steel fittings. The lines allow visual comparison to other fitting types and are defined by the following equation from the ASME BPV Code, Section III, NC-3673:

$$i \times S = 245\,000 \times N^{-0.2}$$

S = amplitude of the applied bending stress at the point of failure, (lb/in.²)
 N = number of cycles to failure
 i = stress intensification factor

The following procedure was followed:

1. Each test sample was attached to a rotary flex test stand. Refer to figure 1.

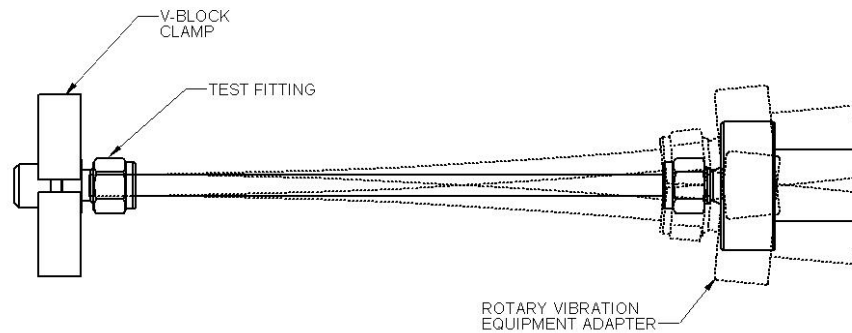


Figure 1

2. A bending stress was applied to each sample by a gimbaled rotary offset. The bending stresses were selected to generate a stress versus number of cycles (S/N) graph. The stress levels support a highly accelerated life test protocol and are not indicative of any specific application.
3. The alternating bending stress was computed from the actual measured flexure strain in the tubing (1/2 of alternating peak-to-peak flexure range).

Table 1	
Nominal Alternating Bending Stress^① lb/in. ² (MPa)	Samples Tested
25 000 (172.2)	4
20 000 (137.8)	20
15 000 (103.3)	18
10 000 (68.9)	19
TOTAL	61

① Zero to peak stress



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4. Test samples were pressurized to the working pressure of the tube with hydraulic oil.
5. The test samples were flexed until either the fitting leaked, the tube fractured, or 10 million cycles were achieved, whichever occurred first. An in-line pressure transducer stopped the test if fitting leakage or tube fatigue fracture occurred.
6. A bending stress versus number of cycles graph (S/N) was made from the data and the results were compared to the ASME based data describe earlier.
7. Test samples pass the rotary flex test if all samples remain leak-tight over the duration of the test and demonstrate for a given bending stress the number of cycles that meets or exceeds the predicted number of cycles for fittings having a stress intensification factor of $i = 1.3$.

TEST RESULTS

- No fitting leakage was detected throughout the test. The test was stopped when the tube fractured or the test sample exceeded 10 million cycles.
- The shaded area of the following S/N graph envelopes the test results of the alloy 625 Swagelok tube fitting rotary flex test. The shaded area is truncated at 10 million cycles to indicate testing was suspended without leakage at 10 million cycles in accordance with the test method.
- Point AMSE PVP-62 on the graph is the intersection of 2980 lb/in.² (20.5 MPa) and 10 million cycles.
- The alloy 625 Swagelok tube fitting remained leak tight while protecting the tubing from premature fracture at alternating stresses greatly exceeding the ASME PVP-62 recommended upper limit. The fitting's performance also resulted in a calculated endurance stress at ten million cycles which exceeds a stress intensification factor of $i = 1.3$ as defined in ASME BPV Code Section III, NC-3673, therefore passing the rotary flex test.

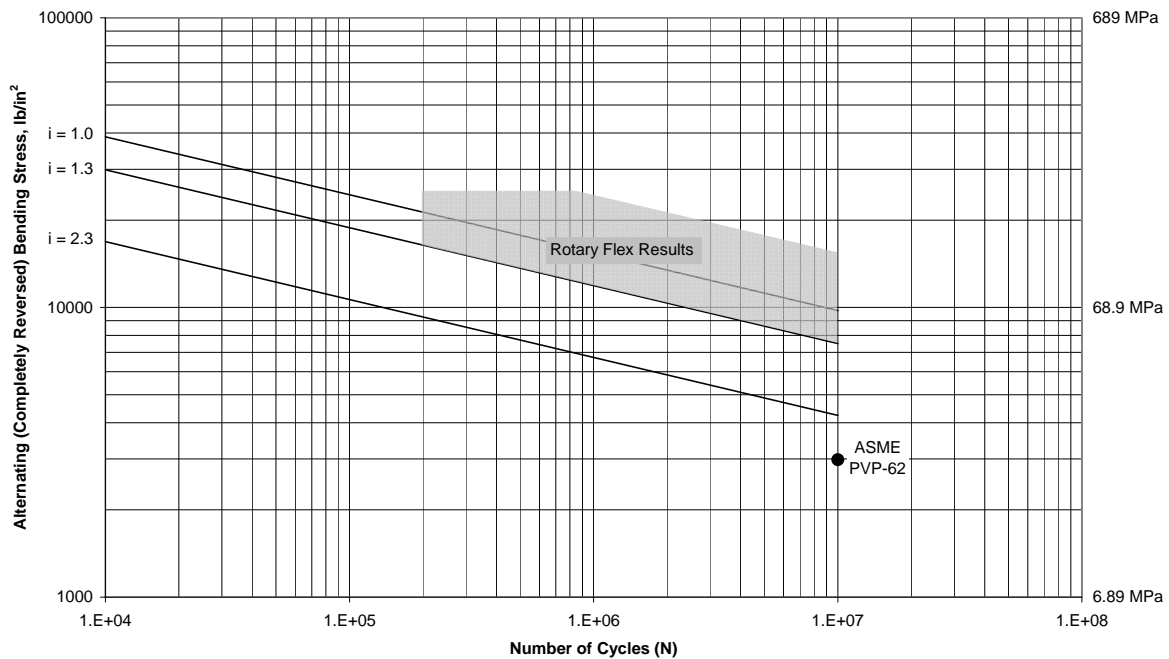


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Page 4 of 4

Rotary Flex Testing of Alloy 625 Swagelok Tube Fitting



These tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.

Referenced Documents:

SAE-ARP-1185, *Flexure Testing of Hydraulic Tubing Joints and Fittings*, SAE International, 400 Commonwealth Drive, Warrendale, PA 15096

ASME *Pressure Vessel and Piping (PVP)*, Vol. 62, 1982, and ASME *Boiler and Pressure Vessel (BPV) Code, Section III*, 2007, ASME International, Three Park Avenue, New York, NY 10016-5990, www.asme.org



Product Test Report

PTR-864

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

Rev. C
October 2011
Page 1 of 2

TITLE

Hydrostatic Pressure Test of Alloy 825 Swagelok® Tube Fittings with Alloy 825 Tubing

PRODUCT TESTED

The following alloy 825 (UNS N08825) bar stock and forged body Swagelok tube fittings were tested with alloy 825 tubing.

Ordering Number	Form	Tubing Size	Tubing Hardness Rb
Fractional, in.			
825-400-1-4	Bar stock	1/4 × 0.065	88
825-400-9	Forging		
825-600-1-4	Bar stock	3/8 × 0.065	87
825-600-9	Forging		
825-810-1-4	Bar stock	1/2 × 0.065	89
825-810-9	Forging		
Metric, mm			
825-6M0-1-4	Bar stock	6 × 1.2	90
825-6M0-9	Forging		
825-10M0-1-4	Bar stock	10 × 1.5	88
825-10M0-9	Forging		
825-12M0-1-4	Bar stock	12 × 1.8	88
825-12M0-9	Forging		

PURPOSE

The assemblies were tested to observe the tube grip performance of alloy 825 Swagelok tube fittings with alloy 825 tubing under hydrostatic pressure in laboratory conditions.

TEST CONDITIONS

Each sample tested consisted of one tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions.

TEST METHOD

The fittings were tested as follows:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks thereby forcing a failure at the fitting-to-tubing engagement.
3. Pressure was gradually increased and the pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.



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Swagelok Company
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TEST RESULTS

Tubing Size	Samples Tested	Working Pressure psig (bar)	Samples Attaining 4 x Working Pressure
Fractional, in.			
1/4 x 0.065	22	11 600 (799)	22/22
3/8 x 0.065	22	8 200 (564)	22/22
1/2 x 0.065	22	5 900 (406)	22/22
Metric, mm			
6 x 1.2	22	9 580 (660)	22/22
10 x 1.5	22	6 967 (480)	22/22
12 x 1.8	22	6 967 (480)	22/22

The alloy 825 Swagelok tube fitting demonstrates the ability to hold pressure in excess of 4 times the working pressure when assembled according to Swagelok tube fitting installation instructions.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

PTR-867

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

Rev. C
October 2012
Page 1 of 2

TITLE

Tensile Pull Test of Alloy 825 Swagelok® Tube Fittings with Alloy 825 Tubing

PRODUCT TESTED

The following alloy 825 (UNS N08825) bar stock Swagelok tube fittings were tested with alloy 825 tubing.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
825-400-1-4	Bar stock	1/4 × 0.065	88
825-600-1-4	Bar stock	3/8 × 0.065	87
825-810-1-4	Bar stock	1/2 × 0.065	89
Metric, mm			
825-6M0-1-4	Bar stock	6 × 1.2	90
825-10M0-1-4	Bar stock	10 × 1.5	88
825-12M0-1-4	Bar stock	12 × 1.8	88

PURPOSE

These assemblies were tested to evaluate the tensile pull performance of the alloy 825 Swagelok tube fitting with alloy 825 tubing under laboratory conditions.

TEST CONDITIONS

Each non-pressurized sample tested consisted of one tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions.

TEST METHOD

1. Each sample was attached in turn to a tensile test machine
2. Samples were tensile pulled at a rate of 0.125 inch (3.2 mm) per minute until either the tube pulled out of the fitting or the tube fractured.
3. The judgment criterion is taken from ASTM F1387, Annex A7.

$$\text{Calculated tensile load} = A_p \times S_y$$

where:

A_p = cross-section area of the tube based on wall thickness

S_y = minimum specified yield strength of the tube.

4. The test result should exceed the calculated tensile load.



Product Test Report

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TEST RESULTS

Tubing Size	Samples Tested	ASTM F1387 Calculated Tensile Load lb (kg)	Samples Attaining ASTM F1387 Calculated Tensile Load
1/4 × 0.065	12	1435 (650)	12/12
3/8 × 0.065	12	2418 (1096)	12/12
1/2 × 0.065	12	3400 (1542)	12/12
6 × 1.2	6	980 (444)	6/6
10 × 1.5	12	2173 (985)	12/12
12 × 1.8	12	3131 (1420)	12/12

The alloy 825 Swagelok tube fitting achieved a tensile load in excess of the calculated load under laboratory conditions.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.

Referenced Documents

ASTM F1387-99, *Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings*, American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428



Product Test Report

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 U.S.A.

PTR-865
Rev. D
October 2012
Page 1 of 2

TITLE

Nitrogen Gas Seal Test with Repeated Reassembly of Alloy 825 Swagelok® Tube Fittings with Alloy 825 Tubing at 1.25 Times the Working Pressure

PRODUCT TESTED

The following bar stock and forged body Swagelok tube fittings were tested.

Ordering Number	Part Form	Tubing Size	Tubing Hardness HRB
Fractional, in.			
825-400-1-4	Bar stock	1/4 × 0.035	88
825-400-9	Forging		
825-600-1-4	Bar stock	3/8 × 0.035	88
825-600-9	Forging		
825-810-1-4	Bar stock	1/2 × 0.035	80
825-810-9	Forging		
Metric, mm			
825-6M0-1-4	Bar stock	6 × 0.8	88
825-6M0-9	Forging		
825-10M0-1-4	Bar stock	10 × 1.0	88
825-10M0-9	Forging		
825-12M0-1-4	Bar stock	12 × 1.0	80
825-12M0-9	Forging		

PURPOSE

The assemblies were tested to observe the performance of alloy 825 Swagelok tube fittings with alloy 825 tubing during a gas seal test with reassembly under laboratory conditions.

TEST CONDITIONS

Each sample tested consisted of one tube length and two test fittings. The fitting was assembled according to the Swagelok tube fitting installation instructions. Testing was conducted at ambient room temperature.

TEST METHOD

1. The test samples were attached to a gas test stand, submerged in water, pressurized to 1.25 times the tube working pressure with nitrogen for 10 minutes, and monitored for leakage. The judgment criterion was less than 1 bubble per minute at the test pressure. If leakage was observed, the fitting was tightened slightly (up to 1/8 turn) and re-tested.
2. Pressure was reduced to zero, and the fittings were disassembled. The fittings were reassembled according to Swagelok reassembly instructions.
3. The fittings were leak tested using nitrogen at 1.25 times the working pressure following the instructions and judgment criteria from step 1 at every fifth reassembly.
4. A total of 25 reassemblies were conducted on each test sample end.



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29500 Solon Road
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TEST RESULTS

Tubing Size	Samples Tested	Working Pressure psig (bar)	Test Pressure psig (bar)	Results
Fractional, in.				
1/4 × 0.035	44	6400 (440)	8000 (551)	Pass
3/8 × 0.035	44	4100 (282)	5125 (353)	Pass
1/2 × 0.035	44	3000 (206)	3750 (258)	Pass
Metric, mm				
6 × 0.8	44	5950 (410)	7440 (512)	Pass
10 × 1.0	44	4350 (300)	5440 (374)	Pass
12 × 1.0	44	3630 (250)	4540 (312)	Pass

Note: Working pressure was based on the Swagelok Tubing Data, MS-01-107.

The alloy 825 Swagelok tube fitting demonstrated both initial assembly gas seal and repeated gas seal through 25 reassemblies at 1.25 times the working pressure, under laboratory conditions.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. The results are not offered as statistically significant. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.



Product Test Report

PTR-866

Swagelok Company
29500 Solon Road
Solon, OH 44139 U.S.A.

Rev. B
July 2008
Page 1 of 4

TITLE

Rotary Flexure Test of Alloy 825 Swagelok® Tube Fittings with Alloy 825 Tubing

PRODUCT TESTED

The following alloy 825 Swagelok tube fittings were tested with alloy 825 tubing. Each tubing size was represented with a minimum of 8 samples.

Ordering Number	Form	Tubing Size	Tubing Hardness Rb
Fractional, in.			
825-400-1-4	Bar stock	1/4 × 0.035	88
825-600-1-4	Bar stock	3/8 × 0.035	88
825-810-1-4	Bar stock	1/2 × 0.035	80
Metric, mm			
825-6M0-1-4	Bar stock	6 × 0.8	88
825-10M0-1-4	Bar stock	10 × 1.0	88
825-12M0-1-4	Bar stock	12 × 1.0	80

PURPOSE

The assemblies were tested to observe the fatigue endurance of alloy 825 Swagelok tube fittings with advance geometry back ferrules under laboratory conditions at various levels of applied alternating bending stress of the tube.

CONDITIONS

- Each sample tested consisted of one tube length and one test fitting. The fitting was assembled according to the Swagelok tube fitting installation instructions.
- Test conducted at room temperature.

TEST METHOD

Rotary flexure testing procedures have been derived from SAE-ARP-1185. This method applies a completely reversed bending stress on the fitting connection while pressurized with hydraulic oil at the tubing working pressure. The test samples were flexed until either the fitting leaked, the tube fractured, or at least 10 million cycles were achieved, whichever occurred first.

ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 $\mu\text{in./in.}$ peak-to-peak strain level results in frequent piping system failures. For alloy 825, the 200 $\mu\text{in./in.}$ strain level calculates to an alternating stress of 3000 lb/in.^2 (20.6 MPa). ASME PVP-62 also reports that measured field data for piping systems suggest that if the system lasts beyond 10 million cycles, it will have infinite life.

The ASME BPV Code, Section III NC-3673, lists stress intensification factors for various types of fittings. For example, for certain butt-welds $i = 1.0$, socket welds $i = 1.3$ to 1.9, brazed joints $i = 2.1$ and pipe joints $i = 2.3$. The stress intensity lines, $i = 1.0$, 1.3, and 2.3, that are shown on

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the graph are based on fatigue bend testing of mild carbon steel fittings. The lines allow visual comparison to other fitting types and are defined by the following equation from the ASME BPV Code, Section III, NC-3673:

$$i \times S = 245\,000 \times N^{-0.2}$$

S = amplitude of the applied bending stress at the point of failure, (lb/in.²)

N = number of cycles to failure

i = stress intensification factor

The following procedure was followed:

1. Each test sample was attached to a rotary flex test stand. Refer to figure 1.

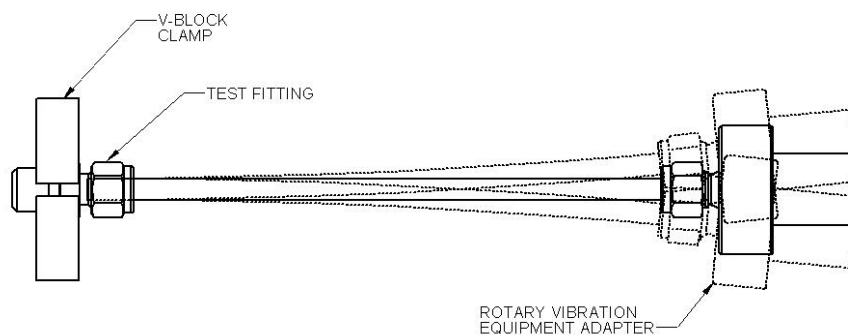


Figure 1

2. A bending stress was applied to each sample by a gimbaled rotary offset. The bending stresses were selected to generate a stress versus number of cycles (S/N) graph. The stress levels support a highly accelerated life test protocol and are not indicative of any specific application.
3. The alternating bending stress was computed from the actual measured flexure strain in the tubing (1/2 of alternating peak-to-peak flexure range).

Table 1	
Nominal Alternating Bending Stress^① lb/in. ² (MPa)	Samples Tested
25 000 (172.2)	24
20 000 (137.8)	24
15 000 (103.3)	24
10 000 (68.9)	24
Total	96

① Zero to Peak stress



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4. Test samples were pressurized to the working pressure of the tube with hydraulic oil.
5. The test samples were flexed until either the fitting leaked, the tube fractured, or 10 million cycles were achieved, whichever occurred first. An in-line pressure transducer stopped the test if fitting leakage or tube fatigue fracture occurred.
6. A bending stress versus number of cycles graph (S/N) was made from the data and the results were compared to the ASME based data describe earlier.
7. Test samples pass the rotary flex test if all samples remain leak-tight over the duration of the test and demonstrate for a given bending stress the number of cycles that meets or exceeds the predicted number of cycles for fittings having a stress intensification factor of $i = 1.3$.

TEST RESULTS

- No fitting leakage was detected throughout the test. The test was stopped when the tube fractured or the test sample exceeded 10 million cycles.
- The shaded area of the following S/N graph envelopes the test results of the stainless steel Swagelok tube fitting rotary flex test. The shaded area is truncated at 10 million cycles to indicate testing was suspended without leakage at 10 million cycles in accordance with the test method.
- Point AMSE PVP-62 on the graph is the intersection of 3000 lb/in.² (20.6 MPa) and 10 million cycles.
- The alloy 825 Swagelok tube fitting remained leak tight while protecting the tubing from premature fracture at alternating stresses greatly exceeding the ASME PVP-62 recommended upper limit. The fitting's performance also resulted in a calculated endurance stress at ten million cycles which exceeds a stress intensification factor of $i = 1.3$ as defined in ASME BPV Code Section III, NC-3673, therefore passing the rotary flex test.



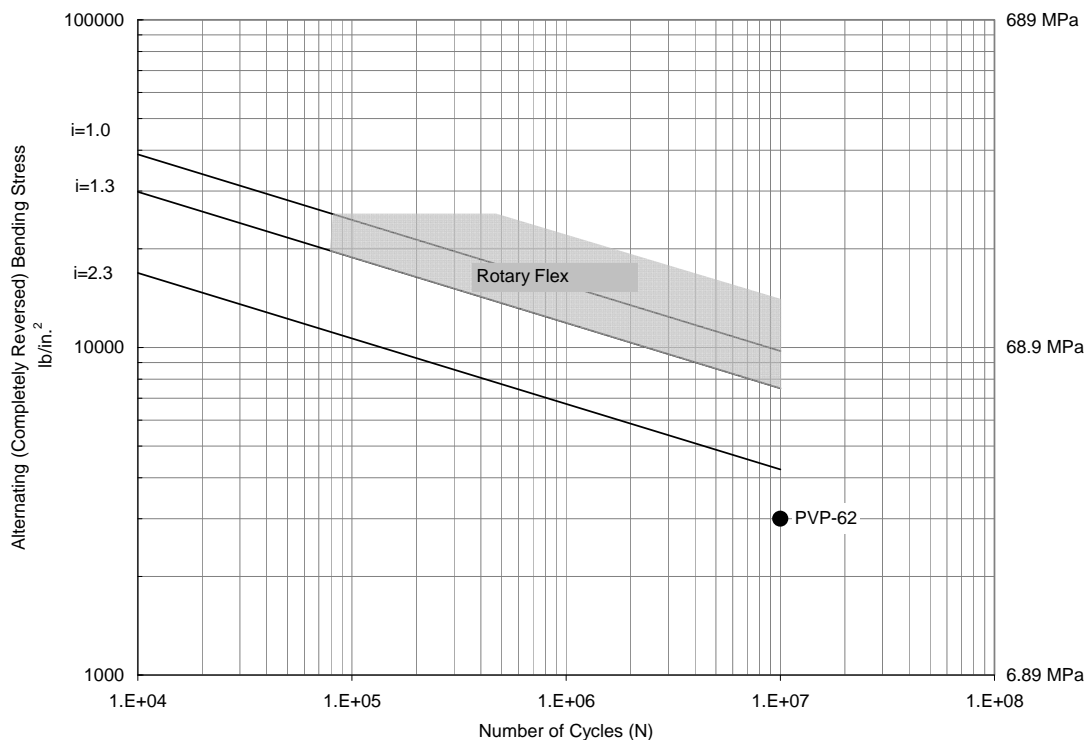
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Rotary Flex Testing of Swagelok Alloy 825 Tube Fitting



These tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application and are not a guarantee of performance in actual service. Swagelok Company makes no representation or warranties regarding these selected conditions or the results attained there from. Laboratory tests cannot duplicate the variety of actual operating conditions. See the product catalog for technical data.

SAFE PRODUCT SELECTION

When selecting a product, 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.

Referenced Documents:

SAE-ARP-1185, *Flexure Testing of Hydraulic Tubing Joints and Fittings*, SAE International, 400 Commonwealth Drive, Warrendale, PA 15096

ASME *Pressure Vessel and Piping (PVP)*, Vol. 62, 1982, and ASME *Boiler and Pressure Vessel (BPV) Code, Section III*, 2007, ASME International, Three Park Avenue, New York, NY 10016-5990, www.asme.org



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TITLE

Tensile Pull Test of Super Austenitic 254 SMO[®] (6-moly) Stainless Steel Tubing With Stainless Steel Swagelok[®] Tube Fittings

PRODUCT TESTED

Samples Tested	254 SMO SS Tubing Size OD x Wall in.	Tubing Hardness HRB	Part Description Ordering Number
6	1/4 x 0.065	95	Male Connector SS-400-1-4
6	1/2 x 0.083	87	Male Connector SS-810-1-4

PURPOSE

These assemblies were tested under laboratory conditions to observe the tube grip performance of stainless steel Swagelok tube fittings when installed on 254 SMO stainless steel heavy-wall tubing under tensile load.

TEST CONDITIONS

Laboratory environment

TEST METHOD

Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube O.D. with the United Hardness Tester using the 15-T scale with the 1/16-inch diameter ball penetrator.
2. Reported the average of the five measurements.
3. Added the tubing cylindrical values taken from the Wilson Chart #53 Cylindrical Conversion Table.
4. Used the ASTM E140 Table 6—Austenitic Stainless Steel hardness conversion chart to convert the 15-T readings to the HRB values.

Tensile Pull Test (Reference ASTM F1387):

1. For each sample, assembled one tube length and two male connectors according to Swagelok assembly procedures.
2. Attached non-pressurized samples to a tensile test machine.
3. Tensile pulled samples at a rate of 0.125 in. (3.2 mm) per minute until either the tube pulled out of the fitting or the tube fractured.



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4. The acceptance criterion is taken from ASTM F1387, Annex A7.

$$\text{Calculated tensile load} = A_p \times S_y$$

where:

A_p = cross-section area of the tube based on wall thickness

S_y = minimum specified yield strength of the tube.

5. The test result should exceed the calculated tensile load.

TEST RESULTS

Tensile Pull Test

254 SMO SS Tubing Size OD x Wall in.	Acceptance Criterion (Minimum Load) lbf (N)	Minimum Load Attained lbf (N)	Results
1/4 x 0.065	1 976 (8 789)	2 957 (13 152)	Pass
1/2 x 0.083	5 565 (24 753)	8 896 (39 569)	Pass

These tests do not simulate any specific application. These tests were performed to support use of this product under a specific set of published product pressure and temperature ratings and should not be considered valid outside those ratings. Laboratory tests cannot duplicate the variety of actual operating conditions. Material compatibility was not examined as part of these tests.

SAFE PRODUCT SELECTION

When selecting a product, 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.

REFERENCES

Wilson Cylindrical Correction Chart # 53, Wilson Instrument Division, 929 Connecticut Avenue, Bridgeport, CT 06602

ASTM E140, *Table 6—Approximate Hardness Conversion Numbers for Austenitic SS*, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2858

ASTM F1387-99, *Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings*, American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428



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TITLE

Hydraulic Impulse Test and Hydrostatic Proof Test of Super Austenitic 254 SMO[®] (6-moly) Stainless Steel Tubing With Stainless Steel Swagelok[®] Tube Fittings

PRODUCT TESTED

Samples Tested	254 SMO SS Tubing Size OD x Wall in.	Tubing Hardness HRB	Working Pressure ^① psig (bar)	Part Description Ordering Number	Part Description Ordering Number
6	1/4 x 0.028	84	4 000 (275)	Union Straight SS-400-6	Union Elbow SS-400-9
6	1/4 x 0.065	96	10 200 (702)	Union Straight SS-400-6	Union Elbow SS-400-9
6	1/2 x 0.035	87	2 600 (179)	Union Straight SS-810-6	Union Elbow SS-810-9
6	1/2 x 0.083	86	6 700 (461)	Union Straight SS-810-6	Union Elbow SS-810-9

① Working pressures were calculated from an S value of 20 000 psig (137.8 MPa) for ASTM A269 tubing at -20 to 100°F (-28 to 37°C), as listed in ASME B31.3 and ASME B31.1.

PURPOSE

These assemblies were tested under laboratory test conditions to observe the hydraulic performance (during and after impulse testing) of stainless steel Swagelok tube fittings when installed on 254 SMO stainless steel tubing.

TEST CONDITIONS

Laboratory environment

TEST METHOD

Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube O.D. with the United Hardness Tester using the 15-T scale with the 1/16-inch diameter ball penetrator.
2. Reported the average of the five measurements.
3. Added the tubing cylindrical values taken from the Wilson Chart #53 Cylindrical Conversion Table.
4. Used the ASTM E140 Table 6—Austenitic Stainless Steel hardness conversion chart to convert the 15-T readings to the HRB values.

Impulse Test with Repeat Assembly (Reference ASTM F1387):

1. Assembled one tube length with one union straight and one union elbow according to Swagelok assembly procedures.
2. Prior to impulse testing, some of the samples were identified for repeat assembly according to ASTM F1837 Annex A9. These samples were disassembled and reassembled once according to Swagelok procedures. In order to reseal the ferrules at a different location, the disassembled samples were rotated approximately 90° between each disassembly / reassembly cycle.



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- Impulse testing was then performed according to ASTM F1387 Annex A5. The samples were attached to an impulse stand, pressurized with hydraulic oil to 133 +/- 5 % of the working pressure, and then depressurized to 20 +/- 5 % of the working pressure. This constituted one impulse cycle.
- Impulse cycles were modeled with a square waveform, and cycling continued for 1 000 000 cycles at a rate of one Hz (one cycle per second) with the rate not exceeding 75 cycles per minute.
- At the conclusion of 250 000 impulse cycles, the samples identified for repeat assembly were disassembled and reassembled twice as described in step 2.
- This cycling and reassembly process was repeated with two remakes of the identified samples at the conclusion of 500 000, 750 000, and 1 000 000 of the impulse cycles. There were 9 total reassemblies for the repeat assembly samples.
- Monitored the samples for leakage during the test; the pass criterion was no visible leakage.

Hydrostatic Proof Test Procedure (Reference ASTM F1387 Annex A4):

- Upon completion of the Impulse Test with Repeat Assembly, the samples were subjected to a hydrostatic proof test at ambient laboratory temperature.
- Samples were pressurized to 100 psig (6.8 bar) and held for a period of five minutes.
- After 5 minutes at 100 psig (6.8 bar), the samples were pressurized to 150 % (+/- 5%) of the working pressure and held for an additional period of 5 minutes.
- Monitored the samples for leakage throughout the test; the pass criterion was no visible leakage.

TEST RESULTS

Impulse Test with Repeat Assembly

254 SMO SS Tubing Size OD x Wall in.	Impulse Test Pressure Cycle psig (bar)	Samples Tested	Number of Reassemblies at % of 1 000 000 Total Cycles					Results
			0 % (Prior to Impulse)	25 %	50 %	75 %	100 %	
1/4 x 0.028	800 to 5 320 (55.1 to 366)	2	Not required					Pass
		4	1	2	2	2	2	Pass
1/4 x 0.065	2 040 to 13 566 (140 to 934)	2	Not required					Pass
		4	1	Pass	2	2	2	Pass
1/2 x 0.035	520 to 3 458 (35.8 to 238)	2	Not required					Pass
		4	1	Pass	2	2	2	Pass
1/2 x 0.083	1340 to 8 911 (92.3 to 613)	2	Not required					Pass
		4	1	Pass	2	2	2	Pass



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Hydrostatic Proof Test

254 SMO SS Tubing Size OD x Wall in.	Samples Tested	Test Pressure psig (bar)	Test Results
1/4 x 0.028	6	6 000 (413)	Pass
1/4 x 0.065	6	15 300 (1054)	Pass
1/2 x 0.035	6	3 900 (268)	Pass
1/2 x 0.083	6	10 050 (692)	Pass

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application. These tests were performed to support use of this product under a specific set of published product pressure and temperature ratings and should not be considered valid outside those ratings. Laboratory tests cannot duplicate the variety of actual operating conditions. Material compatibility was not examined as part of these tests.

SAFE PRODUCT SELECTION

When selecting a product, 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.

REFERENCES

Wilson Cylindrical Correction Chart # 53, Wilson Instrument Division, 929 Connecticut Avenue, Bridgeport, CT 06602

ASTM E140, *Table 6—Approximate Hardness Conversion Numbers for Austenitic SS*, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2858

ASME B31.1, *Power Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASME B31.3, *Process Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 100 Barr Harbor Drive, West Conshohocken, PA 19428

ASTM F1387-99, *Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings*, American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428



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TITLE

Hydrostatic Pressure Test of Super Austenitic 254 SMO[®] (6-moly) Stainless Steel Tubing With Stainless Steel Swagelok[®] Tube Fittings

PRODUCT TESTED

Samples Tested	254 SMO SS Tubing Size OD x Wall in.	Tubing Hardness HRB	Part Description Ordering Number	Form
28	1/4 x 0.065	94	Male Connector SS-400-1-4	Bar stock
			Union Elbow SS-400-9	Forging
			Plug SS-400-P	Bar stock
28	1/2 x 0.083	86	Male Connector SS-810-1-4	Bar stock
			Union Elbow SS-810-9	Forging
			Plug SS-810-P	Bar stock

PURPOSE

These assemblies were tested under laboratory conditions to observe the tube grip performance of stainless steel Swagelok tube fittings when installed on 254 SMO heavy-wall stainless steel tubing with hydrostatic pressure.

TEST CONDITIONS

- Each sample tested consisted of one tube length and two test fittings. The fittings were assembled according to Swagelok tube fitting installation instructions.
- Testing was conducted at room temperature in a laboratory environment.

TEST METHOD

Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube O.D. with the United Hardness Tester using the 15-T scale with the 1/16-inch diameter ball penetrator.
2. Reported the average of the five measurements.
3. Added the tubing cylindrical values taken from the Wilson Chart #53 Cylindrical Conversion Table.
4. Used the ASTM E140 Table 6—Austenitic Stainless Steel hardness conversion chart to convert the 15-T readings to the HRB values.



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Hydrostatic Pressure Test:

1. Each sample was attached to a hydraulic test stand.
2. The tubing was restricted from burst by clamping blocks, thereby forcing a failure at the fitting-to-tubing engagement.
3. Pressure was gradually increased and the pressure was recorded when loss of tube grip, material rupture or leakage that prevented applying higher pressure occurred, whichever came first.
4. Results were compared to the tubing working pressure.

TEST RESULTS

Samples Tested	254 SMO SS Tubing Size OD x Wall in.	Working Pressure ^① psig (bar)	4 x Working Pressure psig (bar)	Samples Attaining 4 x W.P.
28	1/4 x 0.065	10 200 (702)	40 800 (2 811)	28 / 28
28	1/2 x 0.083	6 700 (461)	26 800 (1 846)	28 / 28

① Allowable working pressures are based on equations from ASME B31.3 and ASME B31.1 for a maximum S value of 20 000 psi (137.8 MPa).

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application. These tests were performed to support use of this product under a specific set of published product pressure and temperature ratings and should not be considered valid outside those ratings. Laboratory tests cannot duplicate the variety of actual operating conditions. Material compatibility was not examined as part of these tests.

SAFE PRODUCT SELECTION

When selecting a product, 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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REFERENCES

Wilson Cylindrical Correction Chart # 53, Wilson Instrument Division, 929 Connecticut Avenue, Bridgeport, CT 06602

ASTM E140, *Table 6—Approximate Hardness Conversion Numbers for Austenitic SS*, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2858

ASME B31.1, *Power Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASME B31.3, *Process Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 100 Barr Harbor Drive, West Conshohocken, PA 19428



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TITLE

High-Temperature Thermal Cycling and Hydrostatic Proof Test of Super Austenitic 254 SMO[®] (6-moly) Stainless Steel Tubing With Stainless Steel Swagelok[®] Tube Fittings

PRODUCT TESTED

Samples Tested	254 SMO SS Tubing Size OD x Wall in.	Tubing Hardness HRB	Part Description Ordering Number	Part Description Ordering Number
4	1/4 x 0.028	84	Union Straight SS-400-6	Union Elbow SS-400-9
4	1/4 x 0.065	95	Union Straight SS-400-6	Union Elbow SS-400-9
4	1/2 x 0.035	83	Union Straight SS-810-6	Union Elbow SS-810-9
4	1/2 x 0.083	87	Union Straight SS-810-6	Union Elbow SS-810-9

PURPOSE

These assemblies were tested under laboratory test conditions to observe the leakage performance (during and after thermal cycling) of stainless steel Swagelok tube fittings when installed on 254 SMO stainless steel tubing.

TEST CONDITIONS

Laboratory environment

TEST METHOD

Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube O.D. with the United Hardness Tester using the 15-T scale with the 1/16-inch diameter ball penetrator.
2. Reported the average of the five measurements.
3. Added the tubing cylindrical values taken from the Wilson Chart #53 Cylindrical Conversion Table.
4. Used the ASTM E140 Table 6—Austenitic Stainless Steel hardness conversion chart to convert the 15-T readings to the HRB values.

High-Temperature Thermal Cycling Procedure:

1. Assembled one tube length with one union straight and one union elbow according to Swagelok assembly procedures.
2. Attached the test samples to a high-temperature furnace and pressurized to test pressure.
3. Increased the samples to test temperature of 750°F (398°C) within a period of one hour. The samples were allowed to stabilize at temperature for a minimum of 2 hours while being monitored for pressure decay.



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4. The temperature was then lowered to laboratory room temperature (within one hour) while the test pressure was maintained. Samples were then stabilized at room temperature for a minimum of two hours while being monitored for pressure decay.
5. Repeated the above cycle two additional times.
6. Monitored the samples for leakage during the test; the pass criterion was no pressure decay.

Hydraulic Proof Test Procedure:

1. Upon completion of the high-temperature thermal cycling procedure, the samples were subjected to a hydraulic proof test at ambient laboratory temperature.
2. Samples were pressurized to 100 psig (6.8 bar) and held for a period of five minutes.
3. After 5 minutes at 100 psig (6.8 bar), the samples were pressurized to test pressure (1.5 times ambient working pressure) and held for an additional period of 5 minutes.
4. Monitored the samples for leakage throughout the test; the pass criterion was no visible leakage.

TEST RESULTS

High-Temperature Thermal Cycle Test

254 SMO SS Tubing Size OD x Wall in.	Ambient Working Pressure ^① psig (bar)	Test Pressure at Elevated Temperature ^② psig (bar)	Test Results
1/4 x 0.028	4 000 (275)	2360 (162)	Pass
1/4 x 0.065	10 200 (702)	6018 (414)	Pass
1/2 x 0.035	2 600 (179)	1534 (105)	Pass
1/2 x 0.083	6 700 (461)	3953 (272)	Pass

① Ambient working pressures were calculated from an S value of 20 000 psig (137.8 MPa) for ASTM A269 tubing at -20 to 100°F (-28 to 37°C), as listed in ASME B31.3 and ASME B31.1.

② A de-rating factor of 0.59 was applied to the ambient working pressures to determine the test pressures.



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Hydraulic Proof Test

254 SMO SS Tubing Size OD x Wall in.	Test Pressure psig (bar)	Test Results
1/4 x 0.028	6 000 (413)	Pass
1/4 x 0.065	15 300 (1054)	Pass
1/2 x 0.035	3 900 (268)	Pass
1/2 x 0.083	10 050 (692)	Pass

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application. These tests were performed to support use of this product under a specific set of published product pressure and temperature ratings and should not be considered valid outside those ratings. Laboratory tests cannot duplicate the variety of actual operating conditions. Material compatibility was not examined as part of these tests.

SAFE PRODUCT SELECTION

When selecting a product, 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.

REFERENCES

Wilson Cylindrical Correction Chart # 53, Wilson Instrument Division, 929 Connecticut Avenue, Bridgeport, CT 06602

ASTM E140, *Table 6—Approximate Hardness Conversion Numbers for Austenitic SS*, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2858

ASME B31.1, *Power Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASME B31.3, *Process Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 100 Barr Harbor Drive, West Conshohocken, PA 19428



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TITLE

Low-Temperature Thermal Cycling and Hydrostatic Proof Test of Super Austenitic 254 SMO[®] (6-moly) Stainless Steel Tubing With Stainless Steel Swagelok[®] Tube Fittings

PRODUCT TESTED

Samples Tested	254 SMO SS Tubing Size OD × Wall in.	Tubing Hardness HRB	Part Description Ordering Number	Part Description Ordering Number
4	1/4 × 0.028	84	Union Straight SS-400-6	Union Elbow SS-400-9
4	1/4 × 0.065	95	Union Straight SS-400-6	Union Elbow SS-400-9
4	1/2 × 0.035	87	Union Straight SS-810-6	Union Elbow SS-810-9
4	1/2 × 0.083	86	Union Straight SS-810-6	Union Elbow SS-810-9

PURPOSE

These assemblies were tested under laboratory test conditions to observe the leakage performance (during and after thermal cycling) of stainless steel Swagelok tube fittings when installed on 254 SMO stainless steel tubing.

TEST CONDITIONS

Laboratory environment

TEST METHOD

Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube O.D. with the United Hardness Tester using the 15-T scale with the 1/16-inch diameter ball penetrator.
2. Reported the average of the five measurements.
3. Added the tubing cylindrical values taken from the Wilson Chart #53 Cylindrical Conversion Table.
4. Used the ASTM E140 Table 6—Austenitic Stainless Steel hardness conversion chart to convert the 15-T readings to the HRB values.

Low Temperature Thermal Cycling Procedure:

1. Assembled one tube length with one union straight and one union elbow according to Swagelok assembly procedures.
2. Placed test samples in an environmental chamber and pressurized to test pressure with nitrogen.
3. Decreased the samples to test temperature of -58°F (-50°C) within a period of one hour. The samples were allowed to stabilize at temperature for a minimum of 2 hours while being monitored for pressure decay.



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- The temperature was then increased to laboratory room temperature (within one hour) while the test pressure was maintained. Samples were then stabilized at room temperature for a minimum of two hours while being monitored for pressure decay.
- Repeated the above cycle two additional times.
- Recorded any pressure decay; the pass criterion was no pressure decay.

Hydraulic Proof Test Procedure:

- Upon completion of the low-temperature thermal cycling procedure, the samples were subjected to a hydraulic proof test at ambient laboratory temperature.
- Samples were pressurized to 100 psig (6.8 bar) and held for a period of five minutes.
- After 5 minutes at 100 psig (6.8 bar), the samples were pressurized to test pressure (1.5 times ambient working pressure) and held for an additional period of 5 minutes.
- Monitored the samples for leakage throughout the test; the pass criterion was no visible leakage.

TEST RESULTS

Low-Temperature Thermal Cycle Test

254 SMO SS Tubing Size OD x Wall in.	Ambient Working Pressure ^① psig (bar)	Test Pressure at Reduced Temperature psig (bar)	Test Results
1/4 x 0.028	4 000 (275)	4 000 (275)	Pass
1/4 x 0.065	10 200 (702)	10 200 (702)	Pass
1/2 x 0.035	2 600 (179)	2 600 (179)	Pass
1/2 x 0.083	6 700 (461)	6 700 (461)	Pass

① Ambient working pressures were calculated from an S value of 20 000 psig (137.8 MPa) for ASTM A269 tubing at -20 to 100°F (-28 to 37°C), as listed in ASME B31.3 and ASME B31.1.

Hydraulic Proof Test

254 SMO SS Tubing Size OD x Wall in.	Test Pressure psig (bar)	Test Results
1/4 x 0.028	6 000 (413)	Pass
1/4 x 0.065	15 300 (1054)	Pass
1/2 x 0.035	3 900 (268)	Pass
1/2 x 0.083	10 050 (692)	Pass



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The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application. These tests were performed to support use of this product under a specific set of published product pressure and temperature ratings and should not be considered valid outside those ratings. Laboratory tests cannot duplicate the variety of actual operating conditions. Material compatibility was not examined as part of these tests.

SAFE PRODUCT SELECTION

When selecting a product, 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.

REFERENCES

Wilson Cylindrical Correction Chart # 53, Wilson Instrument Division, 929 Connecticut Avenue, Bridgeport, CT 06602

ASTM E140, *Table 6—Approximate Hardness Conversion Numbers for Austenitic SS*, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2858

ASME B31.1, *Power Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASME B31.3, *Process Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 100 Barr Harbor Drive, West Conshohocken, PA 19428



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TITLE

Nitrogen Gas Seal Test with Repeated Reassembly of Super Austenitic 254 SMO[®] Stainless Steel (6-moly) Tubing With Stainless Steel Swagelok[®] Tube Fittings

PRODUCT TESTED

Samples Tested	254 SMO SS Tubing Size OD x Wall in.	Tubing Hardness HRB	Working Pressure ^① psig (bar)	Part Description Ordering Number	Part Description Ordering Number
12	1/4 x 0.028	85	4 000 (275)	Union Straight SS-400-6	Union Elbow SS-400-9
12	1/4 x 0.065	95	10 200 (702)	Union Straight SS-400-6	Union Elbow SS-400-9
12	1/2 x 0.035	87	2 600 (179)	Union Straight SS-810-6	Union Elbow SS-810-9
12	1/2 x 0.083	87	6 700 (461)	Union Straight SS-810-6	Union Elbow SS-810-9

① Working pressures were calculated from an S value of 20 000 psig (137.8 MPa) for ASTM A269 tubing at -20 to 100°F (-28 to 37°C), as listed in ASME B31.3 and ASME B31.1.

PURPOSE

These assemblies were tested under laboratory test conditions to observe the gas seal reassembly performance of stainless steel Swagelok tube fittings when installed on 254-SMO stainless steel tubing.

TEST CONDITIONS

- Each sample tested consisted of one tube length and two test fittings. The fittings were assembled according to the Swagelok tube fitting installation instructions.
- Testing was completed in a room temperature laboratory environment.

TEST METHOD

Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube O.D. with the United Hardness Tester using the 15-T scale with the 1/16-inch diameter ball penetrator.
2. Reported the average of the five measurements.
3. Added the tubing cylindrical values taken from the Wilson Chart #53 Cylindrical Conversion Table.
4. Used the ASTM E140 Table 6—Austenitic Stainless Steel hardness conversion chart to convert the 15-T readings to the HRB values.



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Gas Remake Testing:

1. The samples were attached to a positive pressure gas test stand, submerged in water, and pressurized to working pressure with nitrogen gas for at least 10 minutes.
2. If leakage was observed, the pressure was dropped and samples showing leaks were tightened with a 1/8 turn-of-the-nut tightening. Step 1 was then repeated.
3. If leakage was not observed, the pressure was increased to 1.25 times working pressure for at least 10 minutes.
4. The pressure was dropped, and all samples were disassembled and reassembled one time according to Swagelok tube fitting installation instructions. This constitutes 1 reassembly of the fitting. Steps 1 and 3 were then repeated.
5. Samples were reassembled according to step 4 and tested for at least 10 minutes at 1 times working pressure and 1.25 times working pressure at the following reassembly points: 5, 10, 15, 20 and 25.
6. Samples were monitored for leakage throughout the test. The acceptance criterion was less than 1 bubble per minute at the applied pressure.

TEST RESULTS

Tubing Size OD x Wall in.	1.25 x WP psig (bar)	End Connections Tested	Number of Acceptable Samples		
			After Standard Assembly and Initial Test	After Additional 1/8 Turn and Retest	After 1, 5, 10, 15, 20 and 25 Reassemblies
1/4 x 0.028	5 000 (344)	24	24 / 24	24 / 24	24 / 24
1/4 x 0.065	12 750 (878)	24	24 / 24	24 / 24	24 / 24
1/2 x 0.035	3 250 (223)	24	24 / 24	24 / 24	24 / 24
1/2 x 0.083	8 375 (577)	24	21 / 24	24 / 24	23 / 24 ^①

① One fitting end leaked at reassemblies 1 and 5, but sealed upon subsequent reassemblies.

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

These tests do not simulate any specific application. These tests were performed to support use of this product under a specific set of published product pressure and temperature ratings and should not be considered valid outside those ratings. Laboratory tests cannot duplicate the variety of actual operating conditions. Material compatibility was not examined as part of these tests.



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SAFE PRODUCT SELECTION

When selecting a product, 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.

REFERENCES

Wilson Cylindrical Correction Chart # 53, Wilson Instrument Division, 929 Connecticut Avenue, Bridgeport, CT 06602

ASTM E140, *Table 6—Approximate Hardness Conversion Numbers for Austenitic SS*, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2858

ASME B31.1, *Power Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASME B31.3, *Process Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 100 Barr Harbor Drive, West Conshohocken, PA 19428

ASTM F1387-99, *Standard Specification for Performance of Piping and Tubing Mechanically Attached Fittings*, American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428



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TITLE

Rotary Flexure Test of Super Austenitic 254 SMO[®] (6-moly) Stainless Steel Tubing With Stainless Steel Swagelok[®] Tube Fittings

PRODUCT TESTED

Samples Tested	254 SMO SS Tubing Size OD × Wall in.	Tubing Hardness HRB	Part Description Ordering Number	Working Pressure ^① psig (bar)
16	1/4 × 0.028	85	Male Connector SS-400-1-4	4 000 (275)
16	1/2 × 0.035	87	Male Connector SS-810-1-4	2 600 (179)

① Working pressures were calculated from an S value of 20 000 psig (137.8 MPa) for ASTM A269 tubing at -20 to 100°F (-28 to 37°C), as listed in ASME B31.3 and ASME B31.1.

PURPOSE

The assemblies were tested under laboratory conditions to observe the fatigue endurance of stainless steel Swagelok tube fittings when installed on 254 SMO stainless steel tubing at various levels of applied alternating bending stress of the tube.

TEST CONDITIONS

- Each sample tested consisted of one tube length and one test fitting. The fitting was assembled according to the Swagelok assembly procedures.
- Testing was conducted at room temperature.

TEST METHOD

Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube O.D. with the United Hardness Tester using the 15-T scale with the 1/16-inch diameter ball penetrator.
2. Reported the average of the five measurements.
3. Added the tubing cylindrical values taken from the Wilson Chart #53 Cylindrical Conversion Table.
4. Used the ASTM E140 Table 6—Austenitic Stainless Steel hardness conversion chart to convert the 15-T readings to the HRB values.

Rotary Flexure Testing:

Rotary flexure testing procedures have been derived from SAE-ARP-1185. This method applies a completely reversed bending stress on the fitting connection while pressurized with hydraulic oil at the tubing working pressure. The test samples were flexed until either the fitting leaked, the tube fractured, or at least 10 million cycles were achieved, whichever occurred first.

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ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 $\mu\text{in./in.}$ peak-to-peak strain level results in frequent piping system failures. The 200 $\mu\text{in./in.}$ strain level calculates to an alternating stress of 2 900 lb/in.^2 (19.9 MPa) for 254 SMO stainless steel tubing. ASME PVP-62 also reports that measured field data for piping systems suggest that if the system lasts beyond 10 million cycles, it will have infinite life.

The ASME BPV Code, Section III NC-3673, lists stress intensification factors for various types of fittings. For example, for certain butt-welds $i = 1.0$, socket welds $i = 1.3$ to 1.9, brazed joints $i = 2.1$ and pipe joints $i = 2.3$. The stress intensity lines, $i = 1.0$, 1.3, and 2.3, that are shown on the graph are based on fatigue bend testing of 254 SMO stainless steel tubing. The lines allow visual comparison to other fitting types and are defined by Equation 3 and Equation 5a from the ASME B31J Code, Standard Test Method for Determining Stress Intensification Factors (i -Factors) for Metallic Piping Components:

$$\text{Equation 3: } i = C/S(N)^b$$

where

- b = material exponent, 0.2 for metals
- C = material constant, 245 000 psi for a carbon steel test specimen
- i = stress intensification factor
- N = number of cycles to failure
- S = nominal stress amplitude at the leak point (lb/in.^2)

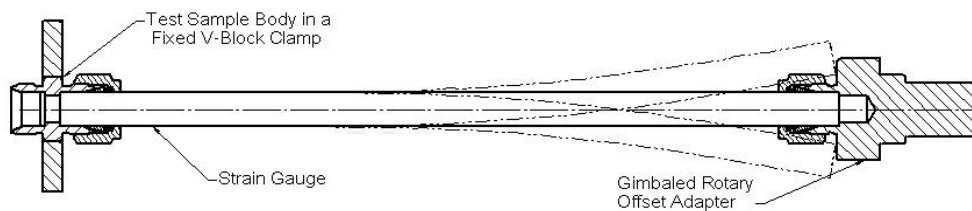
$$\text{Equation 5a: } C (\text{other material}) = 245\,000 \times E (\text{other material}) / 27\,800\,000 \text{ psi}$$

where

- C = Material constant, for use in Equation 3 (psi)
- E = Modulus of Elasticity (psi) for 254 SMO

Test Procedure

1. Each test sample was attached to a rotary flex test stand. Refer to the figure below.



2. A bending stress was applied to each sample by a gimbaled rotary offset. The bending stresses were selected to generate the stress versus number of cycles (S/N) graph. The stress levels support a highly accelerated life test protocol and are not indicative of any specific application.



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- The alternating bending stress was computed from the actual measured flexure strain in the tubing (1/2 of alternating peak-to-peak flexure range).

Nominal Alternating Bending Stress ^① lb/in. ² (MPa)	Samples Tested
25 000 (172.2)	8
20 000 (137.8)	8
15 000 (103.3)	8
10 000 (68.9)	8
TOTAL	32

① Zero-to-peak stress

- Test samples were pressurized to working pressure with hydraulic oil and rotated at a speed greater than 1750 rpm.
- The test samples were flexed until either the fitting leaked, the tube fractured, or 10 million cycles were achieved, whichever occurred first. An in-line pressure transducer stopped the test if fitting leakage or tube fatigue fracture occurred.
- A bending stress versus number of cycles graph (S/N) was made from the data and the results were compared to the ASME based data describe earlier.
- Test samples pass the rotary flex test if all samples remain leak-tight over the duration of the test and demonstrate for a given bending stress the number of cycles that meets or exceeds the predicted number of cycles for fittings having a stress intensification factor of $i = 1.3$.

TEST RESULTS

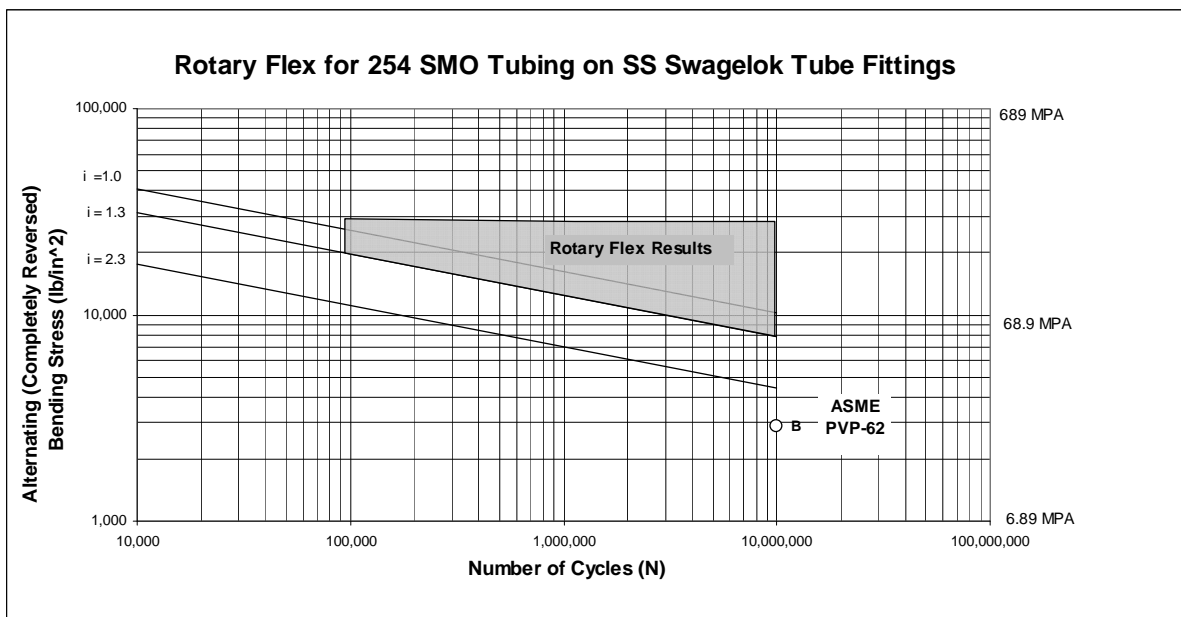
- No fitting leakage was detected throughout the testing criteria. The test was stopped when the tube fractured or the test sample exceeded 10 million cycles.
- The shaded area of the following S/N graph envelopes the test results of the rotary test data. The shaded area is truncated at 10 million cycles to indicate testing was suspended without leakage at 10 million cycles in accordance with the test method.
- Point AMSE PVP-62 on the graph is the intersection of 2900 lb/in.² (19.9 MPa) and 10 million cycles.
- The 316 stainless steel Swagelok tube fittings remained leak tight while protecting the 254 SMO stainless steel tubing from premature fracture at alternating stresses greatly exceeding the ASME PVP-62 recommended upper limit. The fitting's performance also resulted in a calculated endurance stress at ten million cycles which exceeds a stress intensification factor of $i = 1.3$ as defined in ASME BPV Code Section III, NC-3673, therefore passing the rotary flex test.



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The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

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SAFE PRODUCT SELECTION

When selecting a product, 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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REFERENCES

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ASME B31.1, *Power Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

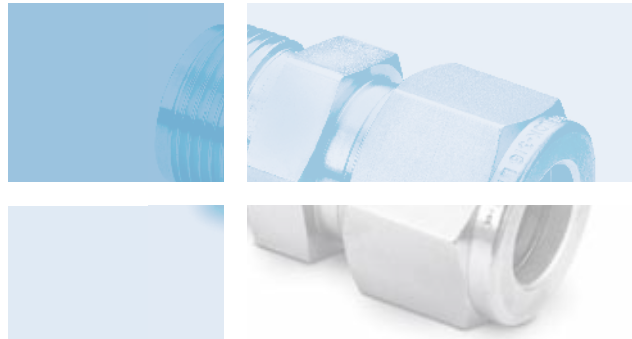
ASME B31.3, *Process Piping*, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5590.

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 100 Barr Harbor Drive, West Conshohocken, PA 19428

ASME Pressure Vessel and Piping (PVP), Vol. 62, 1982, and ASME Boiler and Pressure Vessel (BPV) Code, Section III, 2007, ASME International, Three Park Avenue, New York, NY 10016-5990, www.asme.org

ASME B31J-2008, *Standard Test Method for Determining Stress Intensification Factors (i-Factors) for Metallic Piping Components*, The American Society of Mechanical Engineers, New York, NY 10016-5990

SAE-ARP-1185, *Flexure Testing of Hydraulic Tubing Joints and Fittings*, SAE International, 400 Commonwealth Drive, Warrendale, PA 15096



Third Party

Summary of Third Party Product Approvals and Registrations

ASTM F1387 Testing of Swagelok Tube Fittings
Witnessed and Approved by the United States Department of the Navy



Swagelok Company
Product Approvals and Registrations - Fittings

Approval or Registration By:	Approval or Registration To: Specs / Regulations	Applicable Products *
Vd TUV	PED 97/23/EC Type test: Vd TUV Merkblatt 1065, TA-Luft.	Stainless Steel Swagelok tube fittings 1/16 to 2 in., 2 to 50 mm
TUV Automotive GMBH / TUV Sueddeutschland	Technical Report for ECE Regulation 110	Stainless Steel Swagelok tube fittings 1/16 to 2 in., 2 to 50 mm Stainless Steel Swagelok Tube Fittings ST Fittings 4, 6, 8, 10 ST SAE/MS male connector ends
	EIHP Draft	Stainless Steel Swagelok Tube Fittings Positionable ST and 12ST 12ST for SAE/male connector 4ST thru 12ST positionable male connectors Stainless Steel 15 KSI Fittings (1/4, 3/8, 1/2 in. fractional only)
	Technical Report for ECE Regulation 67	Stainless Steel Swagelok tube fittings 1/16 to 2 in., 2 to 50 mm Stainless Steel Swagelok Tube Fittings ST Fittings 4, 6, 8, 10 ST SAE/MS male connector ends
DVGW	Deutsch Vasser und Gas Werks Regulations	Select SS metric tube fittings from MS-01-140
Department of the Navy (U.S.)	ASTM F1387-99 "Specification for Performance of Mechanically Attached Fittings".	Swagelok Tube Fittings, 1/4 through 1 inch, 316 Stainless Steel Swagelok Tube Fittings, 1/4 through 1 inch, Alloy 400/405
Det Norske Veritas (DNV)	Rules for Classification of Ships & Mobile Offshore Units, Certification Note 2.9 No. 5-797.20	Stainless steel, carbon steel, brass, SAF-2507 Duplex alloy, Alloy 400, Alloy C-276, Alloy C-20, Alloy 600, Titanium, Alloy 825 Swagelok tube fittings, 1/16 to 2 in., 3 to 50 mm
Nippon Kaiji Kyokai (NK)	Society Rules for Machines and Equipment on Ships (Group I&II, Requirements 12.3.2, Chapter 12, Part D)	Stainless steel and carbon steel Swagelok tube fittings, 1/16 to 2 in. and 3 to 38 mm.; Alloy 400 and brass Swagelok tube fittings, 1/8 to 1 in. and 6 to 25 mm.
American Bureau of Shipping (ABS)	ABS Rules for Classification of Steel Vessels, MODUs, FPSOs and Other Maritime Industries.	Flange adapters--SS, M 1/4 to 2 in. and 6 to 50 mm Swagelok Flange Adapters catalog, MS-02-200
		Tube Fittings- SS, S, M, B 1/16 to 2 in. and 2 to 50 mm Swagelok Tube/Pipe Fittings in catalog, MS-01-140
		Swagelok Tube Fittings in catalog, MS-02-10 1/4 to 1/2 in.
Lloyd's Register of Shipping (LR)	LR Rules for Classification of Ships, Mobile Offshore Units and Fixed Offshore Installations.	Stainless steel and carbon steel - 1/16 to 2 in. and 2 to 50 mm, 400/R-405 alloy - 1/8 to 1 in., 360 and/or 377 brass - 1/8 to 1 1/8 in., SAF-2507 Duplex alloy, Alloy 20, Alloy C-276, Alloy 600, Alloy 825 and titanium - 1/4 to 1/2 in. Swagelok Tube/Pipe Fittings in catalog, MS-01-140 (1998)
Bureau Veritas (BV)	Bureau Veritas rules for the classification of steel ships Bureau Veritas rules for the classification of offshore units IACS P2.11 (Nov. 2001) as amended	Stainless steel Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 inch and 2 to 50 mm
RS Maritime	RS maritime rules for classification of ships	Stainless steel, Carbon steel, and Brass Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 inch and 2 to 50 mm
Canadian Provincial Agencies (CRN)	CSA B51 for Industrial Applications, CAN/CSA-N285.0- 95 for Nuclear Applications in CANDU Nuclear Power Plants.	Most fitting products. Contact Swagelok Company Customer Service for a list.
Russian GOST R	Russian Federation Import Laws	Material types-ordering number prefixes starting with SS-, C20-, M-, INC-, HC-, A-, B-, NY-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-. Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 in. and 2 to 50 mm
Russian RTN	Russian Federation "Industrial Safety of Hazardous Production Facilities" Law	Material types-ordering number prefixes starting with SS-, C20-, M-, INC-, HC-, A-, B-, NY-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-. Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 in. and 2 to 50 mm
GOST K for Kazakhstan	Kazakhstan Import laws	Material types-ordering number prefixes starting with SS-, C20-, M-, INC-, HC-, A-, B-, NY-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-. Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 in. and 2 to 50 mm
UkSepro for Ukraine	Ukraine Import laws	Material types-ordering number prefixes starting with SS-, C20-, M-, INC-, HC-, A-, B-, NY-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-. Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 in. and 2 to 50 mm
Inspecta Nuclear for Sweden	Swedish regulations SSMFS 2008:13, AFS 1999:4 (PED), KBM Edition 5	Material types-ordering number prefixes starting with SS-, C20-, M-, INC-, HC-, A-, B-, NY-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-. Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 in. and 2 to 50 mm
METI/KHK	Japanese High Pressure Gas law	Material types-ordering number prefixes starting with SS, HB, HC, 316L, 6LV, 6LVV. Swagelok Tube fittings
Engineers India Limited (EIL)	Rules for Engineers India Limited Approval	Material types-ordering number prefixes starting with SS-, M-, B-. Swagelok Tube Fittings in catalog, MS-01-140 Product sizes - including 1/16 to 2 in. and 2 to 50 mm

* Products which meet the requirements of the approvals and registrations listed may have special part numbers or designators. Contact Swagelok Company Customer Service for Ordering Information. See certificate for specific scope of products, sizes, and material types.

ASTM F1387 Testing of Swagelok® Tube Fittings Witnessed and Approved by the United States Department of the Navy

Swagelok Company

Abstract: The United States Department of the Navy has issued an approval for 1/4 to 1 in. (8 to 25 mm) stainless steel Swagelok tube fittings in applications up to 3750 psig (258 bar) and 1000°F (537°C). This approval is based on a testing program established under the guideline of ASTM F1387. The guideline sets a rigorous test protocol to evaluate Mechanically Attached Fittings or MAF in four main areas of performance:

- . •Vibration Resistance
- . •Thermal shock and high temperature resistance
- . •Tube grip
- . •Corrosion Resistance

To obtain a copy of the U.S. Navy approval letter, go to:
www.swagelok.com/references/certifications

Background: As commercial and military shipbuilders look to increase onboard system performance while drastically reducing purchasing and operating costs, the performance testing and approval of modern connection technology becomes a key requirement to facilitate the replacement of uneconomical and outdated connection devices used in the past.

ASTM F1387 is a detailed test specification for evaluating the performance of piping and tubing connectors developed by the American Society for Testing Materials, or ASTM. The U.S. Navy has adopted ASTM F1387 as a guideline for military shipboard service in non-nuclear machinery space applications for its surface warship fleet.

As the awareness of ASTM F1387 propagates into the industry, more and more companies outside the shipbuilding industry are adopting it as a qualification protocol for MAFs in their facilities as well.

Summary of Test Plan Requirements: Dependent on the chemical composition of the MAF material, product qualification and approval may require conformance of up to 15 tests.

MAFs are taken from commercially available inventory and inspected for any non-conformances. Upon acceptance, samples are assembled onto tubing according to the manufacturer's assembly instructions.

All test connections are assembled and evaluated initially under low-pressure gas and monitored for leakage to verify proper assembly of the components. Fittings to be used in tests subject to hydraulic pressurization are then evaluated under a low-pressure hydraulic test with hydraulic oil or water (either is acceptable) as a secondary proof test.

Upon verification of proper assembly, samples are assigned to each test, given a unique serial number, and subjected to the requirements of the test protocol. These tests are summarized in the following four categories:

Vibration Resistance: Any system may be subjected to vibration during system operation. Rotary equipment such as pumps or compressors can impart impulse / vibration or rotary vibration on tubing runs. Because tube fittings grip the surface of the tubing, these rigid points become the focal point of bending or axial stresses. ASTM F1387 verifies resistance to vibration by subjecting MAFs to five key tests:

Impulse test – Samples are exposed to a square wave impulse shock. The shock profile typically peaks at 150 % of the rated working pressure. No detectable leakage is allowed during the test. This test demonstrates that the fitting can retain the tubing when large axial shock forces are imposed on the fitting.

Rotary flex test – Pressurized and fully cantilevered samples are subjected to a bending deflection which is then rotated 360° to expose all sides of the fitting grip point to a predetermined bending stress level. No detectable leakage is allowed during the test. This test demonstrates that the fitting can retain the tubing or minimize the effects of stress at the gripping point over a sustained period of time.

Flexure fatigue test – Pressurized and fully cantilevered samples are subjected to a bending deflection which is then rotated 360° to expose all sides of the fitting grip point to a predetermined bending stress level. In this case, the stress level is typically above the yield strength of the material. No detectable leakage is allowed during the test. This test demonstrates the ability of the fitting to collet, or isolate, the effects of load that can induce plastic deformation of the tubing.

Vibration test – Samples are exposed to specific axis vibration to assess the effects of varying frequencies and the time-dependent resistance to exposure. This test is divided into three sections:

- Exploratory vibration – This test is to determine the resonant frequencies of the assembled MAF.
- Variable frequency vibration – Samples are then vibrated at 1Hz intervals in the 4 to 50 Hz range. They are held at each discrete frequency interval for a period of five minutes. This test is to expose the MAF to various frequencies.
- Endurance test – All samples are vibrated for a period of two hours at the resonant frequency determined during the exploratory vibration test. This test is to determine the effects of long-term exposure to a resonant frequency.
- Samples are pressure tested upon completion of the Endurance test. No detectable leakage is allowed.

High Impact Shock Test (MIL-S-901) – The samples are exposed to an impact shock test in all three principal axes. The equivalent acceleration imposed on the samples typically exceeds 300 Gs. This test demonstrates the resistance to high impact shock, as well as to evaluate the effects of relative displacement of the tube / MAF connection. Samples are pressure tested upon completion of the impact shock exposure. No detectable leakage is allowed.

Thermal Shock and High Temperature Resistance: Tubing systems are often exposed to varying temperatures, extremely high temperatures, and even more importantly, the effects of rapidly changing temperatures. To ascertain the performance characteristics of MAFs under these conditions, samples are subjected to three tests:

Thermal Cycle (Hot / Cold) – Samples are heated or cooled to a specific temperature and then returned to room temperature while exposed to pressure. No detectable leakage is allowed during the test. This test demonstrates resistance to rapid changes in temperature

Elevated Temperature Soak – Samples are heated to specific temperature and held under pressure at that temperature for 100 hours. No detectable leakage is allowed during the test. This test demonstrates high temperature performance of the MAF.

Fire Test – Samples are pressurized with gas and exposed to flames at approximately 1800°F (982°C) for a period of 30 minutes. Upon completion of the flame exposure, samples are cooled to ambient and proof tested with liquid. No detectable leakage during the flame exposure or the subsequent proof test is allowed. This test demonstrates the effects of extremely high temperature exposure on the MAFs.

Note - Companies utilizing systems susceptible to catastrophic failure in the event of fire are often required to perform a product qualification to maintain their fire hazard insurance. Two such standards – API 607 issued by the American Petroleum Institute, and 7440 published by Factory Mutual System are often referenced as a medium for qualification of products to be used in fire hardened service. Both of these standards are of similar severity to the fire test described in ASTM F1387.

Tube Grip and Reliability of Seal: The main function of a MAF is to tightly grip the tubing so that high-pressure fluid can be contained. The following tests are conducted to quantify the ability of the MAF to retain tubing under high-pressure conditions:

Tensile Test – Samples are subjected to an axial tensile load, which physically pulls the tubing from the fitting. Pull out load must exceed the equivalent hydraulic force imparted by the fluid at 4.0 x working pressure. This test demonstrates the high level of mechanical grip that the fitting imparts on the tube.

Torsion Test – Samples are subjected to a torsional load placed on the tubing causing the tubing to rotate with respect to the fitting body. Samples are pressure tested after deflection to verify the integrity of the seal. No detectable leakage is allowed. This test demonstrates reliability of seal after tubing has slipped with respect to the initial ferrule position.

Hydrostatic Burst Test – Samples are exposed to a pressure equivalent to four times the rated test pressure. Resistance to slippage or leakage is required. No detectable leakage is allowed. This test demonstrates the reliability of the MAF when exposed to hydraulic overpressure.

Repeated Assembly Test – Several of the samples subjected to the Impulse Test and Flexure Fatigue Tests are periodically removed from the test setups and disassembled / reassembled. Upon reassembly, the samples are placed back into the test equipment and the tests are continued. Samples are monitored for leakage during the test. No detectable leakage is allowed. This test demonstrates the ability for the MAF to be disassembled, reassembled, and placed back into service without concern of leakage.

Corrosion Resistance: Due to the saltwater exposure common in shipbuilding applications, as well as the associated risk of chloride-induced stress corrosion cracking, MAFs are subjected to the following test:

Stress Corrosion Test – A bending stress is applied to each sample. Samples are then pressurized and subjected to a salt spray test (according to ASTM B117) for a period of 50 hours. Upon removal, samples are pressurized and evaluated for leakage. No detectable leakage is allowed. The samples are then sectioned and inspected under a microscope for signs of pitting or cracking. This test demonstrates the resistance to a high-chloride environment when subjected to an applied stress.

Summary: Successful completion of this rigorous program demonstrates the ability of a specific MAF design, in this case, the Swagelok tube fitting, to perform under demanding test conditions. The issuance of a third-party approval adds significant credibility to these claims of MAF performance.