# Tube Fitting Performance
# Product Test Reports PTRs

## and Third-Party Product Approvals and Registrations

Swagelok®

# Index

*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, heavy-wall 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 heavy-wall 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 . . . . . . . . . . . . 15

**PTR-4060** Tensile Pull Test—Heavy-Wall Tubing—316 Stainless Steel —1/4 to 1 in. and 6 to 25 mm . . . . . . . . . . . . . 19

**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 . . . 22

**PTR-390** Hydrostatic Pressure Test—Under-Tightened Fittings on Normal to Extra-Hard Tubing / Tubing Bottomed and Not Bottomed—316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm . . . . . . 25

**PTR-391** Hydrostatic Pressure Test—Extra-Heavy-Wall Tubing —316 Stainless Steel—1/4 to 1/2 in. and 6 to 12 mm . . . . . . . . . . . . . . . . . . 29

**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 . . . . . . . . . . . 32

**PTR-393** Fire (Burn) Test with Water Quench (Reference API-607) —316 Stainless Steel—1/4 and 1/2 in. . . . . . . . . . . . . . . . 35

**PTR-4012** Hydraulic Impulse Test and Hydrostatic Proof Test —316 Stainless Steel—1/4 to 1 in. . . . . . . . . . . . . . . . . . . . . 38

# Index

## 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 . . . . . . . . . . . . 45

**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 . . . . . . . . . 49

**PTR-1192** Nitrogen Gas Pressure / Repeated Reassembly Test—Thin-Wall Tubing—316 Stainless Steel—5/8 to 1 in. and 14 to 25 mm . . . . . . . . . 52

**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 . . . . . . . . . . 56

**PTR-386** Thermal Cycle Test—Repeated 537°C (1000°F) / Cool Down —316 Stainless Steel—1/4 to 1/2 in. . . . . . . . . . . . . 59

**PTR-392** Steam Cycle / Thermal Shock Test—Repeated 192°C (377°F) Quench—316 Stainless Steel—1/4 and 1/2 in. . . . . . . . . . . . 61

**PTR-1369** Cryogenic Temperature Leak Test—Inboard Helium Leak Test —Thin-Wall Tubing—316 Stainless Steel—1/4 and 1 in. . . . . . . . . . . . 63

**PTR-1388** Cryogenic Temperature Leak Test—Outboard Helium Leak Test —Thin-Wall Tubing—316 Stainless Steel—1/4 and 1 in. . . . . . . . . . . 65

# Index

## 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 / Continuous Production . . . . . . . . . . . . 71
Performance Testing—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. . . . . . . . . . . . . 75

**PTR-3216** Seismic Intensity Analysis—316 Stainless Steel . . . . . . . . . . . . . . . . . . . . . . 78
—1/4 to 1 1/2 in. and 10 to 28 mm

# Index

## 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-1434** Hydrostatic Pressure Test—1/4 to 1/2 in. and 6 to 12 mm . . . . . . . . . . . 95

**PTR-1433** Tensile Pull Test—1/4 to 1/2 in. and 6 to 12 mm . . . . . . . . . . . . . . . . . . . 97

*Gas Seal*

**PTR-1432** Nitrogen Gas Pressure / Repeated Reassembly Test . . . . . . . . . . . . . . . 99
—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. . . . . . . . . . . . . . . . . . 102

### Alloy 825 Swagelok Tube Fittings with Alloy 825 Tubing

*Tube Grip*

**PTR-864** Hydrostatic Pressure Test—1/4 to 1/2 in. and 6 to 12 mm . . . . . . . . . . 106

**PTR-3266** Hydrostatic Pressure Test—3/4 to 1 in. and 18 to 25 mm. . . . . . . . . . . 108

**PTR-867** Tensile Pull Test—1/4 to 1/2 in. and 6 to 12 mm . . . . . . . . . . . . . . . . . . 112

**PTR-3267** Tensile Pull Test—3/4 to 1 in. and 18 to 25 mm . . . . . . . . . . . . . . . . . . 114

*Gas Seal*

**PTR-865** Nitrogen Gas Pressure / Repeated Reassembly Test . . . . . . . . . . . . . . 117
—1/4 to 1/2 in. and 6 to 12 mm

**PTR-3269** Nitrogen Gas Pressure / Repeated Reassembly Test . . . . . . . . . . . . . . 119
—3/4 to 1 in. and 18 to 25 mm

*Vibration Resistance*

**PTR-866** Rotary Flex Test—1/4 to 1/2 in. and 6 to 12 mm. . . . . . . . . . . . . . . . . . 123

**PTR-3268** Rotary Flex Test—3/4 to 1 in. and 18 to 25 mm . . . . . . . . . . . . . . . . . . 127

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

*Tube Grip*

**PTR-3260** Hydrostatic Pressure Test—1/4 to 1/2 in. . . . . . . . . . . . . . . . . . . . . . . . 132

**PTR-3261** Tensile Pull Test—1/4 to 1/2 in. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 135

*Gas Seal*

**PTR-3263** Nitrogen Gas Pressure / Repeated Reassembly Test—1/4 to 1/2 in. . . 137

*Vibration Resistance*

**PTR-3262** Rotary Flex Test—1/4 to 1/2 in. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 140


# Index

## 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 . . . . . . . . . . . . 147
- ASTM F1387 Testing of Swagelok Tube Fittings Witnessed and Approved by the United States Department of the Navy . . . . . . . . . . 148


# Tube Grip

## Product Test Reports

Swagelok

# Product Test Report

**PTR-3220**
Ver 02
November 2018
Page 1 of 4

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

## 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 | | |

## 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

Original test date: September 2012

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.

Swagelok

# Product Test Report

**PTR-3220**

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



## 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 2013 through 2015.

### Fractional

| Tubing Size in. | Working Pressure (WP) psig (bar) | Samples Attaining a Minimum of η × WP Without Tube Slip | | |
|---|---|---|---|---|
| | | Target Performance Factor, η ① | Samples Tested | Samples Passed |
| 1/4 × 0.065 | 10 200 (702) | 4.0 | 168 | 168 |
| 3/8 × 0.083 | 7500 (516) | 4.0 | 144 | 144 |
| 1/2 × 0.083 | 6700 (461) | 4.0 | 120 | 120 |
| 5/8 × 0.095 | 6000 (413) | 4.0 | 108 | 108 |
| 3/4 × 0.109 | 5800 (399) | 4.0 | 120 | 120 |
| 7/8 × 0.109 | 4800 (330) | 4.0 | 60 | 60 |
| 1 × 0.120 | 4700 (323) | 3.5 | 144 | 144 |

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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**Product Test Report** **PTR-3220**

Swagelok Company
29500 Solon Road
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**Metric**

| Tubing Size mm | Working Pressure (WP) bar (psig) | Samples Attaining a Minimum of η × WP Without Tube Slip | | |
|---|---|---|---|---|
| | | Target Performance Factor, η ① | Samples Tested | Samples Passed |
| 6 × 1.5 | 710 (10 304) | 4.0 | 144 | 144 |
| 8 × 1.5 | 520 (7547) | 4.0 | 144 | 144 |
| 10 × 2.0 | 580 (8417) | 4.0 | 120 | 120 |
| 12 × 2.0 | 470 (6821) | 4.0 | 144 | 144 |
| 14 × 2.2 | 430 (6240) | 4.0 | 84 | 84 |
| 15 × 2.2 | 400 (5805) | 4.0 | 72 | 72 |
| 16 × 2.5 | 400 (5805) | 4.0 | 108 | 108 |
| 18 × 2.5 | 370 (5370) | 4.0 | 72 | 72 |
| 20 × 2.8 | 380 (5515) | 4.0 | 84 | 84 |
| 22 × 2.8 | 340 (4934) | 4.0 | 60 | 60 |
| 25 × 3.0 | 320 (4644) | 3.5 | 60 | 60 |

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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

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

**PTR-4060**
Ver 01
November 2018


## 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-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 | | |
| 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-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 | | |
| 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 |

## Product Test Report

**PTR-4060**
Ver 01
November 2018
Page 2 of 3

Swagelok Company
29500 Solon Road
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### 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
Original test date: January 2016

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.

    Calculated tensile load = Ap x Sy; where:
    Ap = cross-section area of the tube based on wall thickness
    Sy = minimum specified yield strength of tube.
4. The test result should exceed the calculated tensile load.

### 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 | 24 | 1237 (561) | 24 / 24 |
| 3/8 × 0.065 | 24 | 2079 (943) | 24 / 24 |
| 1/2 × 0.083 | 20 | 3560 (1614) | 20 /20 |
| 5/8 × 0.095 | 12 | 4745 (2152) | 12 / 12 |
| 3/4 × 0.109 | 12 | 6585 (2986) | 12 / 12 |
| 7/8 × 0.109 | 12 | 7869 (3569) | 12 / 12 |
| 1 × 0.120 | 12 | 9130 (4141) | 12 / 12 |
| **Metric,** mm | | | |
| 6 × 1.5 | 4 | 984 (446) | 4 / 4 |
| 8 × 1.5 | 16 | 1590 (721) | 16 / 16 |
| 10 × 2.0 | 4 | 2542 (1153) | 4 / 4 |
| 12 × 2.0 | 4 | 3178 (1441) | 4 / 4 |
| 14 × 2.2 | 6 | 3792 (1720) | 6 / 6 |
| 15 × 2.2 | 6 | 4114 (1866) | 6 / 6 |
| 16 × 2.5 | 6 | 4930 (2236) | 6 / 6 |
| 18 × 2.5 | 6 | 5661 (2567) | 6 / 6 |
| 20 × 2.8 | 6 | 7035 (3191) | 6 / 6 |
| 22 × 2.8 | 6 | 7854 (3562) | 6 / 6 |
| 25 × 3.0 | 6 | 10 236 (4642) | 6 / 6 |

Swagelok

# Product Test Report

**PTR-4060**

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



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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

### 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

Swagelok

# Product Test Report

**PTR-385**

Swagelok Company
29500 Solon Road
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Ver 05
November 2018
Page 1 of 3

## 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 × wall** | **Tubing Hardness** HRB |
|---|---|---|---|
| **Fractional**, in. | | | |
| SS-400-1-4 | Bar stock | 1/4 × 0.065 | 100+ |
| SS-400-9 | Forging | | |
| SS-600-1-4 | Bar stock | 3/8 × 0.065 | 100+ |
| SS-600-9 | Forging | | |
| SS-810-1-4 | Bar stock | 1/2 × 0.083 | 100+ |
| SS-810-9 | Forging | | |
| **Metric**, mm | | | |
| SS-10M0-1-4 | Bar stock | 10 × 2.0 | 90 |
| SS-10M0-9 | Forging | | |
| SS-12M0-1-4 | Bar stock | 12 × 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 × working pressure without hydraulic leakage and up to 4.0 × working pressure without fitting material rupture or tube slippage.

## TEST CONDITIONS
Original test date: December 2001

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).

Swagelok

# Product Test Report

**PTR-385**

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

Ver 05
November 2018


## 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 (6821) | 12 / 12 | 12 / 12 | 12 / 12 |

Swagelok

# Product Test Report

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



## 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) | 13① / 16 | 12 / 16 | 12 / 16 |
| 3/8 × 0.065 | 100+ | 16 | 6500 (447) | 16 / 16 | 16 / 16 | 14 / 16 |
| 1/2 × 0.083 | 100+ | 16 | 6700 (461) | 16 / 16 | 13 / 16 | 10 / 16 |

① 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 (8417) | 16 / 16 | 16 / 16 | 16 / 16 |
| 12 × 2.0 | 100+ | 8 | 470 (6821) | 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-390**
Ver 05
November 2018
Page 1 of 4

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

## 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.

# Product Test Report

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



## TEST CONDITIONS

Original test date: December 2001

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 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) | 5① / 6 | 5 / 6 | 5 / 6 |
| 3/8 × 0.065 | 83 to 88 | 16 | 6500 (447) | 16 / 16 | 16 / 16 | 16 / 16 |
| | 100+ | 6 | 6500 (447) | 6 / 6 | 6 / 6 | 5 / 6 |
| 3/8 × 0.083 | 78 to 80 | 24 | 7500 (516) | 24 / 24 | 24 / 24 | 24 / 24 |
| | 100+ | 4 | 7500 (516) | 4 / 4 | 4 / 4 | 4 / 4 |
| 1/2 × 0.083 | 86 to 88 | 24 | 6700 (461) | 24 / 24 | 24 / 24 | 24 / 24 |
| | 98 | 34 | 6700 (461) | 34 / 34 | 34 / 34 | 34 / 34 |
| | 100+ | 18 | 6700 (461) | 18 / 18 | 17 / 18 | 16 / 18 |

① Lowest observed was 2.6 × W.P.

Swagelok

**Product Test Report** **PTR-390**

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

Ver 05
November 2018
Page 3 of 4

## 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 (7547) | 8 / 8 | 8 / 8 | 8 / 8 |
| 10 × 2.0 | 90 | 31 | 580 (8417) | 31 / 31 | 31 / 31 | 30 / 30 |
| 12 × 2.0 | 100+ | 16 | 470 (6821) | 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 | 6500 (447) | 4 / 4 | 4 / 4 | 4 / 4 |
| | 100+ | 4 | 6500 (447) | 4 / 4 | 4 / 4 | 3 / 4 |
| 1/2 × 0.083 | 88 | 4 | 6700 (461) | 4 / 4 | 4 / 4 | 4 / 4 |
| | 98 | 4 | 6700 (461) | 4 / 4 | 4 / 4 | 4 / 4 |

Swagelok

# Product Test Report

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



**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 | 6500 (447) | 12 / 12 | 12 / 12 | 12 / 12 |
| 3/8 × 0.083 | 100+ | 4 | 7500 (516) | 2① / 4 | 2 / 4 | 2 / 4 |
| 1/2 × 0.083 | 86 to 87 | 20 | 6700 (461) | 20 / 20 | 20 / 20 | 19 / 19 |
| | 100+ | 4 | 6700 (461) | 4 / 4 | 3 / 4 | 3 / 4 |

① 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 (8417) | 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.**

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

# Product Test Report

**PTR-391**

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

Ver 05
November 2018
Page 1 of 3

## 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.

Swagelok

# Product Test Report

**PTR-391**

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



## TEST CONDITIONS

Original test date: December 2001

### 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 × WP Without Leakage** | **Samples Attaining 3.5 × WP Without Leakage** | **Samples Attaining 4 × WP Without Tube Slip** |
|---|---|---|---|---|---|---|
| 1/4 × 0.083 | 82 | 8 | 12 000 (826) | 8 / 8 | 8 / 8 | 8 / 8 |
| 1/4 × 0.083① | 82 | 8 | 12 000 (826) | 8 / 8 | 8 / 8 | 8 / 8 |
| 5/16 × 0.083 | 80 | 4 | 10 500 (723) | 4 / 4 | 4 / 4 | 0 / 0 |
| 5/16 × 0.083① | 80 | 4 | 10 500 (723) | 4 / 4 | 4 / 4 | 4 / 4 |
| 1/2 × 0.095 | 77 | 8 | 7800 (537) | 8 / 8 | 8 / 8 | 7 / 7 |
| 1/2 × 0.095① | 77 | 8 | 7800 (537) | 8 / 8 | 8 / 8 | 8 / 8 |

Swagelok

# Product Test Report

**PTR-391**

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

Ver 05
November 2018


**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** |
|---|---|---|---|---|---|---|
| 6 × 1.8① | 85 | 8 | 830 (12 046) | 8 / 8 | 8 / 8 | 8 / 8 |
| 10 × 2.2 | 72 | 4 | 620 (8998) | 4 / 4 | 4 / 4 | 0 / 0 |
| 10 × 2.2① | 72 | 8 | 620 (8998) | 8 / 8 | 8 / 8 | 7 / 7 |
| 12 × 2.5① | 85 | 8 | 590 (8563) | 8 / 8 | 8 / 8 | 8 / 8 |

①Bar stock bodies only

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-394**

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

Ver 05
November 2018
Page 1 of 3

## 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.

Swagelok



## TEST CONDITIONS
Original test date: December 2001

**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 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 × WP Without Leakage** | **Samples Attaining 3.5 × WP Without Leakage** | **Samples Attaining 4 × WP Without Tube Slip** |
|---|---|---|---|---|---|---|
| 1/4 × 0.083 | 82 | 24 | 12 000 (826) | 24 / 24 | 24 / 24 | 21 / 21 |
| 1/4 × 0.083 | 95 | 24 | 12 000 (826) | 24 / 24 | 16 / 24 | 8 / 8 |
| 5/16 × 0.083 | 80 | 12 | 10 500 (723) | 12 / 12 | 6 / 12 | 2 / 3 |
| 1/2 × 0.095 | 77 | 24 | 7800 (537) | 24 / 24 | 24 / 24 | 3 / 3 |
| 1/2 × 0.095① | 77 | 17 | 7800 (537) | 17 / 17 | 17 / 17 | 17 / 17 |
| 1/2 × 0.095 | 99 | 16 | 7800 (537) | 16 / 16 | 15 / 16 | 5 / 16 |

Swagelok

# Product Test Report

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



**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 |
|---|---|---|---|---|---|---|
| 8 × 1.8 | 100+ | 8 | 650 (9433) | 8 / 8 | 8 / 8 | 6 / 8 |
| 8 × 2.0 | 80 | 8 | 720 (10 449) | 8 / 8 | 3 / 8 | 1 / 1 |
| 10 × 2.2 | 72 | 16 | 620 (8998) | 16 / 16 | 5 / 16 | 0 / 0 |
| 10 × 2.2 | 98 | 16 | 620 (8998) | 16 / 16 | 16 / 16 | 11 / 14 |
| 12 × 2.5 | 100+ | 32 | 590 (8563) | 32 / 32 | 32 / 32 | 4 / 24 |

① Bar stock bodies only

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-393**

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

Ver 05
November 2018
Page 1 of 3

## 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
Original test date: December 2001

**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.

# Product Test Report

**PTR-393**

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

Ver 05
November 2018


## TEST RESULTS

| Ordering Number | Form | Tubing Size in. | Samples Tested | Result |
|---|---|---|---|---|
| SS-810-6-4 | Bar stock | 1/4 × 0.065 | 2 | Pass—No Detectable Leakage |
| SS-810-9 | Forging | 1/2 × 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

## REFERENCED DOCUMENTS

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

# Product Test Report

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



Figure 1: Samples during flame exposure.

Figure 2: Samples during water quench.

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# Product Test Report

**PTR-4012**

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

Ver 01
November 2018
Page 1 of 4

## TITLE

Hydraulic Impulse Test and Hydrostatic Proof Test of Stainless Steel Tubing with Stainless Steel Swagelok® Tube Fittings

## PRODUCT TESTED

| Fitting Ends Tested | Tubing Size OD × Wall in. | Tubing Hardness HRB | Working Pressure psig (bar) | Part Description Ordering Number | Part Description Ordering Number |
|---|---|---|---|---|---|
| 6 | 1/4 × 0.028 | 76 | 4000 (275) | Union Straight SS-400-6 | Union Elbow SS-400-9 |
| 6 | 1/4 × 0.065 | 79 | 10 200 (702) | Union Straight SS-400-6 | Union Elbow SS-400-9 |
| 6 | 3/8 × 0.035 | 70 | 3300 (227) | Union Straight SS-600-6 | Union Elbow SS-6400-9 |
| 6 | 3/8 × 0.083 | 88 | 7500 (517) | Union Straight SS-600-6 | Union Elbow SS-600-9 |
| 6 | 1/2 × 0.035 | 75 | 2600 (179) | Union Straight SS-810-6 | Union Elbow SS-810-9 |
| 6 | 1/2 × 0.083 | 80 | 6700 (461) | Union Straight SS-810-6 | Union Elbow SS-810-9 |
| 6 | 3/4 × 0.049 | 75 | 2400 (165) | Union Straight SS-1210-6 | Union Elbow SS-1210-9 |
| 6 | 3/4 × 0.109 | 79 | 5800 (399) | Union Straight SS-1210-6 | Union Elbow SS-1210-9 |
| 6 | 1 × 0.065 | 75 | 2400 (165) | Union Straight SS-1610-6 | Union Elbow SS-1610-9 |
| 6 | 1 × 0.120 | 78 | 4700 (323) | Union Straight SS-1610-6 | Union Elbow SS-1610-9 |

## 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 stainless steel tubing.

## TEST CONDITIONS

Original test date: October 2015

Laboratory environment

## TEST METHOD

**Hardness Measurements of Tubing:**

1. Performed five measurements equally spaced apart on each tube OD 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.

**Impulse Test with Repeat Assembly (Reference ASTM F1387):**

1. Assembled one tube length with one union straight and one union elbow according to the Swagelok tube fitting installation instructions.
2. Prior to impulse testing, some of the samples were identified for repeat assembly according to ASTM F1387 Annex A9. These samples were disassembled and reassembled once according to Swagelok procedures. In order to reseat the ferrules at a different location, the disassembled samples were rotated approximately 90° between each disassembly / reassembly cycle.
3. 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.
4. 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.
5. At the conclusion of 250 000 impulse cycles, the samples identified for repeat assembly were disassembled and reassembled twice as described in step 2.
6. 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.
7. Monitored the samples for leakage during the test; the pass criterion was no visible leakage.

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

1. Upon completion of the Impulse Test with Repeat Assembly, the samples were subjected to a hydrostatic proof test at ambient laboratory temperature.
2. Samples were pressurized to 100 psig (6.8 bar) with hydraulic oil and held for a period of five minutes.
3. After 5 minutes at 100 psig (6.8 bar), the samples were pressurized to 150 % (+/- 5%) of the working pressure with hydraulic oil 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.

Swagelok

# Product Test Report

**PTR-4012**

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

Ver 01
November 2018


## TEST RESULTS

### Impulse Test with Repeat Assembly

| Tubing Size OD × Wall in. | Impulse Test Pressure Cycle psig (bar) | Ends Tested | Number of Reassemblies at % of 1 000 000 Total Cycles | | | | | Results |
|---|---|---|---|---|---|---|---|---|
| | | | 0 % (Prior to Impulse) | 25 % | 50 % | 75 % | 100 % | |
| 1/4 × 0.028 | 800 to 5 320 (55.1 to 366) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 1/4 × 0.065 | 2040 to 13 560 (140 to 934) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 3/8 × 0.035 | 660 to 4390 (45.4 to 302) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 3/8 × 0.083 | 1500 to 9975 (103 to 688) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 1/2 × 0.035 | 520 to 3460 (35.8 to 238) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 1/2 × 0.083 | 1340 to 8910 (92.3 to 613) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 3/4 × 0.049 | 480 to 3190 (33.0 to 219) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 3/4 × 0.109 | 1160 to 7710 (79.9 to 531) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 1 × 0.065 | 480 to 3190 (45.4 to 303) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |
| 1 × 0.120 | 940 to 6 250 (64.7 to 430) | 3 | Reassembly not required | | | | | Pass |
| | | 3 | 1 | 2 | 2 | 2 | 2 | Pass |

### Hydrostatic Proof Test

| Tubing Size OD × Wall in. | Ends Tested | 150 % Proof Test Pressure psig (bar) | Test Results |
|---|---|---|---|
| 1/4 × 0.028 | 6 | 6000 (413) | Pass |
| 1/4 × 0.065 | 6 | 15 300 (1054) | Pass |
| 3/8 × 0.035 | 6 | 4950 (340) | Pass |
| 3/8 × 0.083 | 6 | 9750 (670) | Pass |
| 1/2 × 0.035 | 6 | 3900 (268) | Pass |
| 1/2 × 0.083 | 6 | 10 050 (692) | Pass |
| 3/4 × 0.049 | 6 | 3600 (248) | Pass |
| 3/4 × 0.109 | 6 | 8700 (599) | Pass |
| 1 × 0.065 | 6 | 6300 (434) | Pass |
| 1 × 0.120 | 6 | 7050 (485) | Pass |

## Product Test Report

**PTR-4012**
Ver 01
November 2018


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

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

### Referenced Documents

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

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

# Gas Seal

## Product Test Reports

Swagelok

# Product Test Report

**PTR-3221**

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

Ver 04
November 2018


## 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 | 80 to 84 |
| SS-400-9 | Forging | | |
| SS-600-1-4 | Bar stock | 3/8 × 0.035 | 70 to 88 |
| SS-600-9 | Forging | | |
| SS-810-1-4 | Bar stock | 1/2 × 0.049 | 72 to 83 |
| SS-810-9 | Forging | | |
| SS-1010-1-4 | Bar stock | 5/8 × 0.065 | 77 to 83 |
| SS-1010-9 | Forging | | |
| SS-1210-1-8 | Bar stock | 3/4 × 0.065 | 76 to 80 |
| SS-1210-9 | Forging | | |
| SS-1410-6-8 | Bar stock | 7/8 × 0.083 | 74 to 78 |
| SS-1410-2-8 | Forging | | |
| SS-1610-1-4 | Bar stock | 1 × 0.083 | 74 to 80 |
| SS-1610-9 | Forging | | |

Product Test Report



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

## Metric

| Ordering Number | Form | Tubing Size mm | Tubing Hardness HRB |
|---|---|---|---|
| SS-6M0-1-4 | Bar stock | 6 × 0.8 | 75 to 92 |
| SS-6M0-9 | Forging | | |
| SS-8M0-1-4 | Bar stock | 8 × 1.0 | 75 to 86 |
| SS-8M0-9 | Forging | | |
| SS-10M0-1-4 | Bar stock | 10 × 1.0 | 78 to 84 |
| SS-10M0-9 | Forging | | |
| SS-12M0-1-4 | Bar stock | 12 × 1.0 | 77 to 88 |
| SS-12M0-9 | Forging | | |
| SS-14M0-1-8 | Bar stock | 14 × 1.2 | 74 to 85 |
| SS-14M0-9 | Forging | | |
| SS-15M0-1-8 | Bar stock | 15 × 1.5 | 78 to 82 |
| SS-15M0-9 | Forging | | |
| SS-16M0-1-8 | Bar stock | 16 × 1.5 | 76 to 88 |
| SS-16M0-9 | Forging | | |
| SS-18M0-1-8 | Bar stock | 18 × 1.5 | 74 to 84 |
| SS-18M0-9 | Forging | | |
| SS-20M0-1-8 | Bar stock | 20 × 1.8 | 76 to 82 |
| SS-20M0-9 | Forging | | |
| SS-22M0-1-8 | Bar stock | 22 × 2.0 | 72 to 80 |
| SS-22M0-9 | Forging | | |
| SS-25M0-1-8 | Bar stock | 25 × 2.2 | 74 to 80 |
| 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

Original Test Date: September 2012

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

Swagelok

# Product Test Report

**PTR-3221**

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



## TEST METHOD

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.

## TEST RESULTS

The following data sets include production fittings tested from 2012 through 2015 year to date.

### Fractional

| **Tube Size** in. | **Quantity Tested** | **Working Pressure** psig (bar) | **Number of Leak-Tight Samples After Standard Assembly (1 1/4 Turns) and Initial Test** qty. (%) |
|---|---|---|---|
| 1/4 × 0.028 | 192 | 4000 (275) | 192 / 192 (100 %) |
| 3/8 × 0.035 | 144 | 3300 (227) | 144 / 144 (100 %) |
| 1/2 × 0.049 | 132 | 3700 (254) | 132 / 132 (100 %) |
| 5/8 × 0.065 | 108 | 4000 (275) | 108 / 108 (100 %) |
| 3/4 × 0.065 | 120 | 3300 (227) | 120/ 120 (100 %) |
| 7/8 × 0.083 | 60 | 3600 (248) | 59 / 60 (98.3 %) |
| 1 × 0.083 | 144 | 3100 (213) | 143/ 144 (99.3 %) |
| Total Samples | 900 | — | 898 / 900 (99.7 %) |

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

Swagelok

# Product Test Report



## Metric

| Tube Size mm | Quantity Tested | Working Pressure bar (psig) | Number of Leak-Tight Samples After Standard Assembly (1 1/4 Turns) and Initial Test qty. (%) |
|---|---|---|---|
| 6 × 0.8 | 144 | 310 (4499) | 144 / 144 (100 %) |
| 8 × 1.0 | 120 | 310 (4499) | 120 / 120 (100 %) |
| 10 × 1.0 | 120 | 240 (3483) | 120 / 120 (100 %) |
| 12 × 1.0 | 120 | 200 (2902) | 120 / 120 (100 %) |
| 14 × 1.2 | 72 | 200 (2902) | 72 / 72 (100 %) |
| 15 × 1.5 | 72 | 250 (3628) | 72 / 72 (100 %) |
| 16 × 1.5 | 108 | 230 (3338) | 108 / 108 (100 %) |
| 18 × 1.5 | 84 | 200 (2902) | 84 / 84 (100 %) |
| 20 × 1.8 | 60 | 230 (3338) | 60 / 60 (100 %) |
| 22 × 2.0 | 60 | 230 (3338) | 60 / 60 (100 %) |
| 25 × 2.2 | 60 | 230 (3338) | 60 / 60 (97.2 %) |
| Total Samples | 1020 | — | 1020 / 1020 (100 %) |

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

# Product Test Report

**PTR-395**

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

Ver 05
November 2018


## 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
Original test date: December 2001

**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.

Swagelok

# Product Test Report

**PTR-395**

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



## 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) | Pass① |

**Metric**

| Size mm | Samples Tested | Working Pressure bar (psig) | Results |
|---|---|---|---|
| 6 × 0.8 | 8 | 310 (4499) | Pass |
| 10 × 1.0 | 16 | 240 (3483) | Pass① |
| 12 × 1.0 | 8 | 200 (2912) | Pass |

① One ½ in. sample experienced an estimated 0.05 std $cm^3$/min leak rate at the 15th reassembly, and one 10 mm sample experienced an estimated 0.1 std $cm^3$/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.

# Product Test Report

**PTR-395**

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

Ver 05
November 2018


These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-1192**

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

Ver 04
November 2018
Page 1 of 4

## 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 | | |

Swagelok

## Product Test Report

**PTR-1192**

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

Ver 04
November 2018


**Metric**

| Ordering Number | Form | Tubing Size mm | Tubing Hardness HRB |
|---|---|---|---|
| SS-14M0-1-8 | Bar stock | 14 × 1.2 | 78 |
| SS-14M0-9 | Forging | | |
| SS-14M0-1-8 | Bar stock | 14 × 2.2 | 83 |
| SS-14M0-9 | Forging | | |
| SS-15M0-1-8 | Bar stock | 15 × 1.5 | 78 |
| SS-15M0-9 | Forging | | |
| SS-16M0-1-8 | Bar stock | 16 × 1.5 | 79 |
| SS-16M0-9 | Forging | | |
| SS-18M0-1-8 | Bar stock | 18 × 1.5 | 89 |
| SS-18M0-9 | Forging | | |
| SS-20M0-1-8 | Bar stock | 20 × 1.8 | 80 |
| SS-20M0-9 | Forging | | |
| SS-22M0-1-8 | Bar stock | 22 × 2.0 | 79 |
| SS-22M0-9 | Forging | | |
| SS-25M0-1-8 | Bar stock | 25 × 2.2 | 72 |
| SS-25M0-9 | Forging | | |
| SS-25M0-1-8 | Bar stock | 25 × 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
Original test date: February 2006

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.

Swagelok

# Product Test Report

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



## 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.**

# Product Test Report

**PTR-1192**

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

Ver 04
November 2018


These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

# Product Test Report

**PTR-383**

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

Ver 05
November 2018
Page 1 of 3

## 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

Original test date: December 2001

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.

Swagelok

# Product Test Report

**PTR-383**

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

Ver 05
November 2018
Page 2 of 3

## 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 (1054) | Pass |
| 5/16 × 0.065 | 8 | 8000 (551) | 12 000 (826) | Pass |
| 3/8 × 0.065 | 16 | 6500 (447) | 9750 (671) | Pass |
| 1/2 × 0.083 | 16 | 6700 (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) | 1065 (15 457) | Pass |
| 8 × 1.5 | 4 | 520 (7547) | 780 (11 320) | Pass |
| 10 × 2.0 | 24 | 580 (8417) | 870 (12 626) | Pass① |
| 12 × 2.0 | 16 | 470 (6821) | 705 (10 232) | Pass |

① One 10 mm sample experienced an estimated 0.03 std $cm^3$/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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Product Test Report

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



## 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 5000 psig (344 bar), and multiple 1000 to 68°F (537 to 20°C) thermal cycles (air cool).

## TEST CONDITIONS
Original test date: December 2001

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 5000 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.

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## Product Test Report

**PTR-386**

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

Ver 05
November 2018


6. The samples were re-attached to a positive pressure gas test stand, submerged in water, pressurized to the lesser of working pressure or 5000 psig (344 bar) nitrogen gas for at least 10 minutes, and monitored for leakage.

### TEST RESULTS

| **Size** in. | **Samples Tested** | **Test Pressure** psig (bar) | **Results** |
|---|---|---|---|
| 1/4 × 0.028 | 4 | 4000 (275) | Pass—No Leakage |
| 1/4 × 0.065 | 4 | 5000 (344) | Pass—No Leakage |
| 3/8 × 0.035 | 5 | 3300 (227) | Pass—No Leakage |
| 3/8 × 0.065 | 5 | 5000 (344) | Pass—No Leakage |
| 1/2 × 0.083 | 5 | 5000 (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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

# Product Test Report

**PTR-392**

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

Ver 04
November 2018
Page 1 of 2

## 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
Original Test Date: December 2001

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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# Product Test Report

**PTR-392**

Swagelok Company
29500 Solon Road
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Ver 04
November 2018
Page 2 of 2

## 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 4000 psig (275 bar) for thin wall tubing and 5100 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 1100 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 4000 psig (275 bar) for thin wall tubing and 5100 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

# Product Test Report

**PTR-1369**
Ver 03
November 2018


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

## 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
Original Test Date: February 2007

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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# Product Test Report

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Solon, Ohio 44139 U.S.A.



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 × 0.028 | $1.5 \times 10^{-5}$ | Passed |
| SS-400-9 | 8 | | | |
| SS-400-P | 8 | | | |
| SS-600-6-4 | 8 | 3/8 × 0.035 | $1.2 \times 10^{-5}$ | Passed |
| SS-600-9 | 8 | | | |
| SS-600-P | 8 | | | |
| SS-810-6-4 | 8 | 1/2 × 0.049 | $5.0 \times 10^{-5}$ | Passed |
| SS-810-9 | 8 | | | |
| SS-810-P | 8 | | | |
| SS-1210-6-4 | 8 | 3/4 × 0.065 | $9.8 \times 10^{-5}$ | Passed |
| SS-1210-9 | 8 | | | |
| SS-1210-P | 8 | | | |
| SS-1610-6-4 | 8 | 1 × 0.083 | $1.8 \times 10^{-6}$ | Passed |
| SS-1610-9 | 8 | | | |
| SS-1610-P | 8 | | | |

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-1388**
Ver 04
November 2018
Page 1 of 3

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

## 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
Original Test Date: February 2007

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.

Swagelok

# Product Test Report



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

4. The test sample was soaked for at least 10 minutes to ensure thermal stabilization.
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 *EHIP Rev. 12B Draft.*
   - *ECE Regulation No. 110* lists a maximum leak rate of 15 $cm^3$/hr (4.2 x $10^{-3}$ std $cm^3$/s)
   - *EIHP Rev. 12B Draft* lists a maximum leak rate of 10 $cm^3$/hr (2.8 x $10^{-3}$ std $cm^3$/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 × 0.028 | 4000 (275) | Passed |
| SS-400-9 | 8 | | | |
| SS-400-P | 8 | | | |
| SS-600-6-4 | 8 | 3/8 × 0.035 | 3300 (227) | Passed |
| SS-600-9 | 8 | | | |
| SS-600-P | 8 | | | |
| SS-810-6-4 | 8 | 1/2 × 0.049 | 3700 (254) | Passed |
| SS-810-9 | 8 | | | |
| SS-810-P | 8 | | | |
| SS-1210-6-4 | 8 | 3/4 × 0.065 | 3300 (227) | Passed |
| SS-1210-9 | 8 | | | |
| SS-1210-P | 8 | | | |
| SS-1610-6-4 | 8 | 1 × 0.083 | 3100 (213) | Passed |
| SS-1610-9 | 8 | | | |
| SS-1610-P | 8 | | | |

# Product Test Report

**PTR-1388**

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



These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

## Referenced Documents

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

## Product Test Reports

Swagelok

# Product Test Report

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 USA

PTR-3222
Ver 02
November 2018
Page 1 of 4

## 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 4 samples.

The following data sets include product tested 2013 through 2015.

| 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
Original Test Date: September 2012

- 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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# Product Test Report

**PTR-3222**

Swagelok Company
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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 µin./in. peak-to-peak strain level results in frequent piping system failures. For stainless steel, the 200 µin./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.

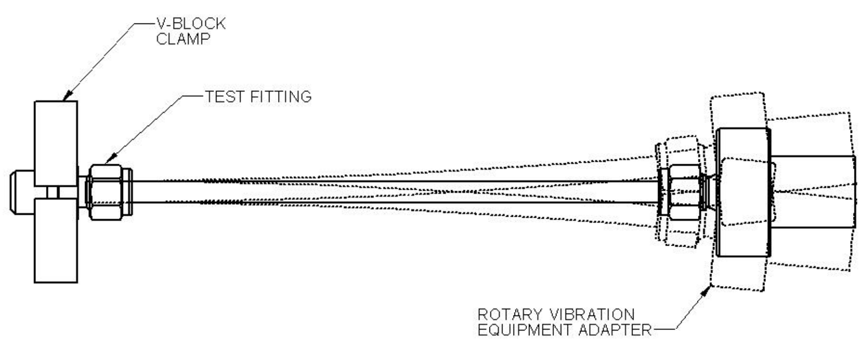


**Figure 1**

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).

Swagelok

## Product Test Report



Swagelok Company
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| Table 1 | |
|---|---|
| **Nominal Alternating Bending Stress**① lb/in.$^2$ (MPa) | **Samples Tested** |
| 20 000 (137.8) | 154 |
| 15 000 (103.3) | 154 |
| 10 000 (68.9) | 154 |
| **TOTAL** | **462** |

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*

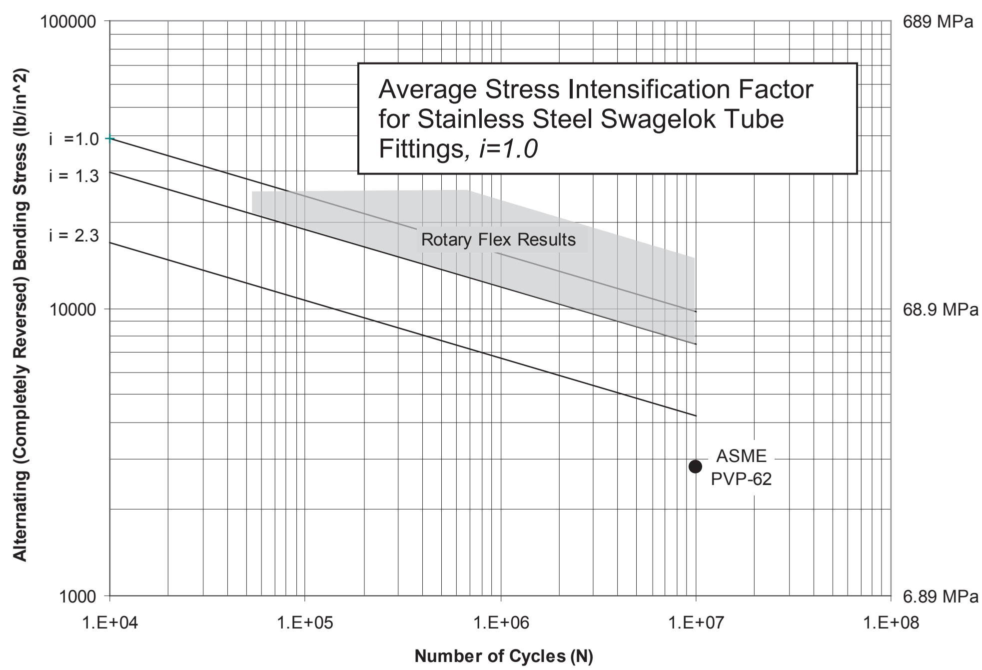
Swagelok

# Product Test Report

**PTR-3222**
Ver 02
November 2018
Page 4 of 4

Swagelok Company
29500 Solon Road
Solon, Ohio 44139 USA

**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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

## 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

Swagelok

# Product Test Report

**PTR-976**

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

Ver 07
November 2018
Page 1 of 3

## 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 × Wall in. | Tubing Hardness HRB | Samples Tested |
|---|---|---|---|
| SS-400-6 | 1/4 × 0.035 | 90 max | 2 |
| SS-400-6 | 1/4 × 0.065 | 90 max | 2 |
| SS-810-6 | 1/2 × 0.065 | 90 max | 5 |
| SS-1210-6 | 3/4 × 0.095 | 90 max | 5 |
| SS-1610-6 | 1 × 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
Original Test Date: April 2005

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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# Product Test Report

**PTR-976**

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Ver 07
November 2018
Page 2 of 3

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 50① | 0.003 + 0.000 − 0.001 |
| 34 to 60② | 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 50① | 0.003 ± 0.000 |
| 41 to 50② | 0.003 + 0.000 − 0.001 |
| 51 to 60③ | 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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**PTR-976**

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Ver 07
November 2018
Page 3 of 3

## 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 × 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 × 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 × 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 × 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 × 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

### 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

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# Product Test Report

**PTR-3216**

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Ver 01
November 2018


## 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.**

## PRODUCT TESTED

Original test date: September 2012

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.

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

$M$ = Richter seismic intensity magnitude
$a_0$ = PGA (cm/sec$^2$)

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.

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

$d_{max}$ = maximum deflection of driving vibration (cm), *half of full displacement amplitude*
f = frequency of driving vibration (Hz)
G = $a_0$ / (981 cm/sec$^2$)

## TEST PROCEEDURES

(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**

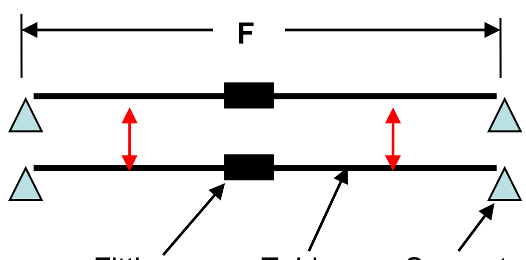


Table vibration tests were performed at room temperature under laboratory conditions at the Southwest Research Institute facilities [ref 7] in accordance with ASTM F1387 [ref 8]. The setup used in the testing is shown in Figure 1. The length "F" between tube supports (also from ASTM F1387) and the tube 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) |
| 11/2 | 0.134 (3.40) | 790 | 22.7 (3300) | 34.1 (4950) |

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 |
| 11/2 | 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.

(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 |

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.).

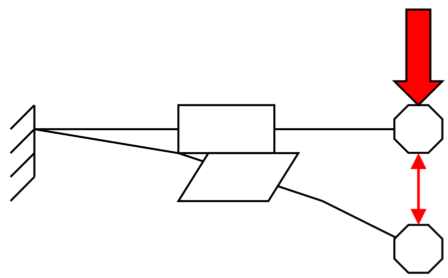
**Table 7: Tube Fitting Assembly High Impact Shock Test Set-up**

| **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].

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

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

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 (w) of the driving ground (or seismic) vibration over the natural frequency (wn) 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.

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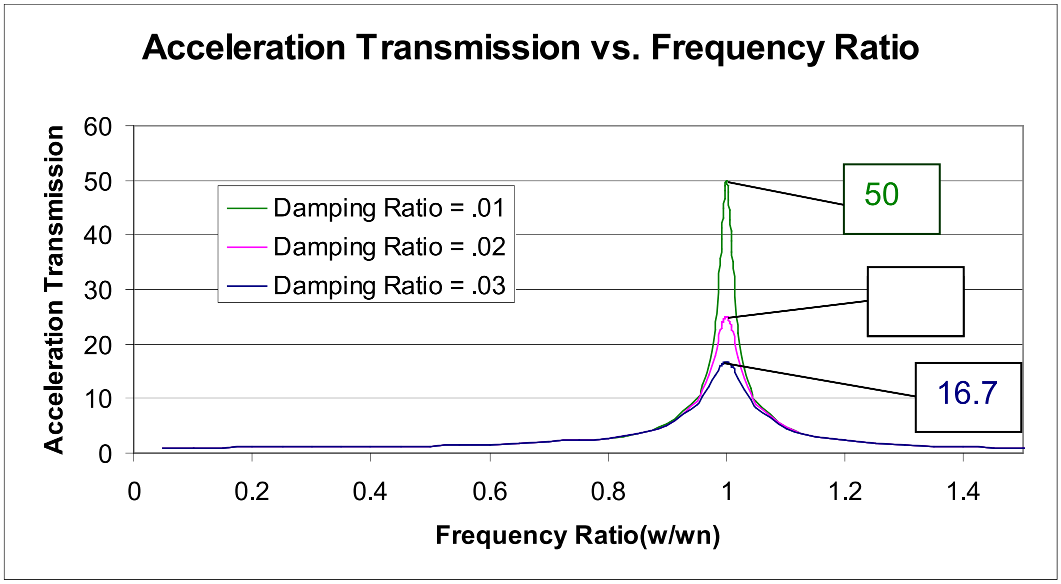
November 2018


**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.

**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 where conducted beyond the product's recommended operating parameters and do not modify the published product ratings.**

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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 operation. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

**Referenced Documents**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[15] *Damping*, Encyclopædia Britannica [10 August 2011], available from http://www.britannica.com/EBchecked/topic/150616/damping

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Swagelok

# Product Test Report



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

## 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 |

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

# Alloys

## Product Test Reports

Swagelok

# Product Test Report

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

**PTR-1434**
Ver 02
November 2018


## 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
Original test date: July 2007

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.

Swagelok

# Product Test Report

**PTR-1434**
Ver 02
November 2018
Page 2 of 2

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

## 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 (1005) | 58 400 (4023) | 22 / 22 |
| 3/8 × 0.065 | 22 | 9400 (647) | 37 600 (2590) | 22 / 22 |
| 1/2 × 0.065 | 22 | 6800 (468) | 27 200 (1874) | 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) | 3000 (43 541) | 22 / 22 |
| 10 × 1.5 | 22 | 550 (7982) | 2200 (31 930) | 22 / 22 |
| 12 × 1.8 | 16 | 550 (7982) | 2200 (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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

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



## 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
Original test date: July 2007

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 = Ap × Sy

   where:

   Ap = cross-section area of the tube based on wall thickness
   Sy = 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.

Swagelok

## Product Test Report

**PTR-1433**
Ver 02
November 2018
Page 2 of 2

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

## 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

### 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

Swagelok

## Product Test Report

**PTR-1432**
Ver 02
November 2018
Page 1 of 3

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

## 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 | | |

Swagelok

# Product Test Report



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

## 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

Original test date: July 2007

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 | 7300 (502) | 9125 (628) | 24 / 24 |
| 1/4 × 0.065 | 24 | 14 600 (1005) | 18 250 (1257) | 24 / 24 |
| 3/8 × 0.035 | 24 | 4700 (323) | 5875 (404) | 24 / 24 |
| 3/8 × 0.065 | 24 | 9400 (647) | 11 750 (809) | 24 / 24 |
| 1/2 × 0.035 | 16 | 3500 (241) | 4375 (301) | 16 / 16 |
| 1/2 × 0.065 | 8 | 6800 (468) | 8500 (585) | 8 / 8 |

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

Swagelok

# Product Test Report

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

**PTR-1432**
Ver 02
November 2018


**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 (6821) | 588 (8534) | 24 / 24 |
| 6 × 1.2 | 24 | 750 (10 885) | 938 (13 613) | 24 / 24 |
| 10 × 1.0 | 24 | 350 (5079) | 438 (6357) | 24 / 24 |
| 10 × 1.5 | 24 | 550 (7982) | 688 (9985) | 24 / 24 |
| 12 × 1.0 | 16 | 290 (4208) | 363 (5268) | 16 / 16 |
| 12 × 1.8 | 8 | 550 (7982) | 688 (9985) | 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-1435**

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

Ver 02
November 2018


## 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
Original Test Date: November 2007

- 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 µin./in. peak-to-peak strain level results in frequent piping system failures. For alloy 625, the 200 µin./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.

Swagelok

# Product Test Report

**PTR-1435**

Swagelok Company
29500 Solon Road
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Ver 02
November 2018


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.

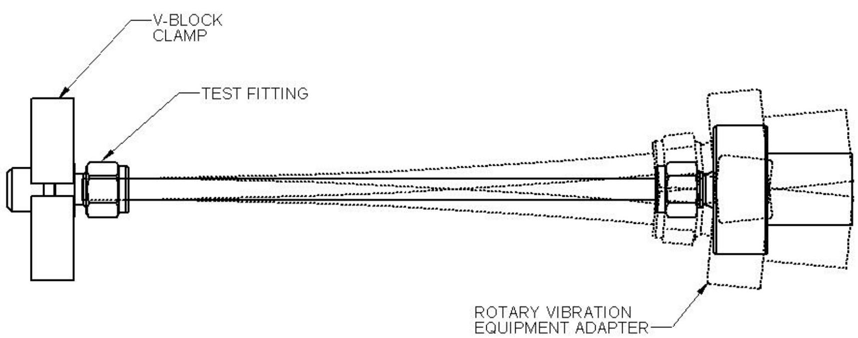



**Figure 1**

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).

Swagelok

## Product Test Report

**PTR-1435**

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



| **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

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.

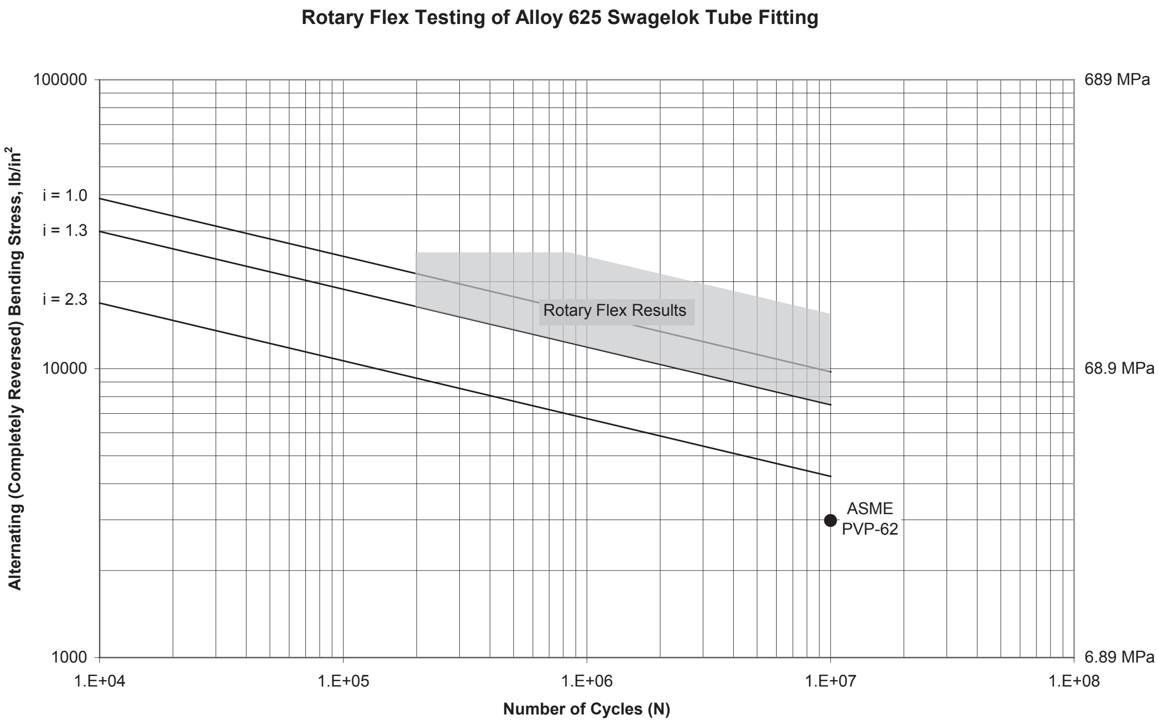
Swagelok

# Product Test Report

**PTR-1435**

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






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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

## 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

Swagelok

# Product Test Report

**PTR-864**

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

Ver 04
November 2018
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

Original Test Date: December 2004

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.

Swagelok

# Product Test Report

**PTR-864**

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



## TEST RESULTS

| Tubing Size | Samples Tested | Working Pressure psig (bar) | Samples Attaining 4 x Working Pressure |
|---|---|---|---|
| **Fractional,** in. | | | |
| 1/4 × 0.065 | 22 | 11 600 (799) | 22/22 |
| 3/8 × 0.065 | 22 | 8200 (564) | 22/22 |
| 1/2 × 0.065 | 22 | 5900 (406) | 22/22 |
| **Metric,** mm | | | |
| 6 × 1.2 | 22 | 9580 (660) | 22/22 |
| 10 × 1.5 | 22 | 6967 (480) | 22/22 |
| 12 × 1.8 | 22 | 6967 (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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-3266**

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

Ver 01
November 2018
Page 1 of 4

## TITLE

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

## PRODUCT TESTED

| **Samples Tested** | **Alloy 825 Tubing Size OD × Wall** in. | **Tubing Hardness** 15-T | **Description Ordering Number** | **Form** |
|---|---|---|---|---|
| 12 | 3/4 × 0.095 | 75 | Male Connector 825-1210-1-8 | Bar stock |
| | | | Union Elbow 825-1210-9 | Forging |
| | | | Plug 825-1210-P | Bar stock |
| 12 | 1 × 0.109 | 80 | Male Connector 825-1610-1-8 | Bar stock |
| | | | Union Elbow 825-1610-9 | Forging |
| | | | Plug 825-1610-P | Bar stock |

| **Samples Tested** | **Alloy 825 Tubing Size OD × Wall** mm | **Tubing Hardness** 15-T | **Description Ordering Number** | **Form** |
|---|---|---|---|---|
| 12 | 18 × 2.5 | 87 | Male Connector 825-18M0-1-8 | Bar stock |
| | | | Union Elbow 825-18M0-9 | Forging |
| | | | Plug 825-18M0-P | Bar stock |
| 12 | 25 × 2.8 | 78 | Male Connector 825-25M0-1-8 | Bar stock |
| | | | Union Elbow 825-25M0-9 | Forging |
| | | | Plug 825-25M0-P | Bar stock |

Swagelok

# Product Test Report

**PTR-3266**

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



## PURPOSE

These assemblies were tested under laboratory conditions to observe the tube grip performance of alloy 825 Swagelok tube fittings when installed on alloy 825 heavy-wall tubing and subjected to hydrostatic pressure.

## TEST CONDITIONS

Original test date: November 2012

- 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 OD 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.

**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 rated pressures.

Swagelok

# Product Test Report



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

## TEST RESULTS

| Samples Tested | Alloy 825 Tubing Size OD × Wall in. | Working Pressure (WP)① psig (bar) | 4 × Working Pressure psig (bar) | Samples Attaining 4 × WP |
|---|---|---|---|---|
| 12 | 3/4 × 0.095 | 5800 (399) | 23 200 (1598) | 12/12 |
| 12 | 1 × 0.109 | 4200 (289) | 16 800 (1157) | 12/12 |

| Samples Tested | Alloy 825 Tubing Size OD × Wall mm | Working Pressure (WP)① bar (psig) | 4 × Working Pressure bar (psig) | Samples Attaining 4 × WP |
|---|---|---|---|---|
| 12 | 18 × 2.5 | 400 (5805) | 1600 (23 222) | 12/12 |
| 12 | 25 × 2.8 | 300 (4354) | 1200 (17 416) | 12/12 |

① Working pressures according to published ratings.

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

**Product Test Report**

**PTR-3266**

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



## Referenced Documents

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

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 A312, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*, 100 Barr Harbor Drive, West Conshohocken, PA 19428

# Product Test Report

**PTR-867**

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

Ver 04
November 2018
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
Original Test Date: December 2004

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.

   Calculated tensile load = Ap × Sy

   where:

   Ap = cross-section area of the tube based on wall thickness
   Sy = minimum specified yield strength of the tube.

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

## 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

## 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-3267**

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

Ver 01
November 2018


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

## PRODUCT TESTED

| **Samples Tested** | **Alloy 825 Tubing Size OD × Wall** in. | **Tubing Hardness** 15-T | **Description Ordering Number** |
|---|---|---|---|
| 6 | ¾ × 0.095 | 78 | Male Connector 825-1210-1-8 |
| 6 | 1 × 0.109 | 78 | Male Connector 825-1610-1-8 |

| **Samples Tested** | **Alloy 825 Tubing Size OD × Wall** mm | **Tubing Hardness** 15-T | **Description Ordering Number** |
|---|---|---|---|
| 6 | 18 × 2.5 | 83 | Male Connector 825-18M0-1-8 |
| 6 | 25 × 2.8 | 78 | Male Connector 825-25M0-1-8 |

## PURPOSE
These assemblies were tested under laboratory conditions to observe the tensile pull performance of alloy 825 Swagelok tube fittings when installed on alloy 825 heavy-wall tubing.

## TEST CONDITIONS
Original test date: November 2012

Laboratory environment

## TEST METHOD

**Hardness Measurements of Tubing:**

1. Performed five measurements equally spaced apart on each tube OD 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.

Swagelok

## Product Test Report

**PTR-3267**

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



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

   Calculated tensile load = Ap × Sy

   where:

   Ap = cross-section area of the tube based on wall thickness
   Sy = minimum specified yield strength of the tube.

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

## TEST RESULTS

### Tensile Pull Test

| **Alloy 825 Tubing Size OD × Wall** in. | **ASTM F1387 Calculated Tensile Load** lbf (N) | **Samples Attaining ASTM F1387 Calculated Tensile Load** |
|---|---|---|
| ¾ × 0.095 | 7474 (33 244) | 6 / 6 |
| 1 × 0.109 | 11 610 (51 641) | 6 / 6 |

| **Alloy 825 Tubing Size OD × Wall** mm | **ASTM F1387 Calculated Tensile Load** lbf (N) | **Samples Attaining ASTM F1387 Calculated Tensile Load** |
|---|---|---|
| 18 × 2.5 | 32 063 (7208) | 6 / 6 |
| 25 × 2.8 | 51 488 (11 575) | 6 / 6 |

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

# Product Test Report

**PTR-3267**

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

Ver 01
November 2018


## 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

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

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

Swagelok

# Product Test Report

**PTR-865**

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



## 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

Original Test Date: December 2004

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.

## 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 were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-3269**

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

Ver 01
November 2018


## TITLE
Nitrogen Gas Seal Test with Repeated Reassembly of Alloy 825 Swagelok® Tube Fittings with Alloy 825 Tubing

## PRODUCT TESTED

| Samples Tested | Alloy 825 Tubing Size OD × Wall in. | Tubing Hardness 15-T | Working Pressure① psig (bar) | Part Description Ordering Number | Part Description Ordering Number |
|---|---|---|---|---|---|
| 12 | 3/4 × 0.065 | 78 | 3800 (261) | Union Straight 825-1210-6 | Union Elbow 825-1210-9 |
| 12 | 3/4 x 0.095 | 78 | 5800 (399) | Union Straight 825-1210-6 | Union Elbow 825-1210-9 |
| 12 | 1 × 0.083 | 80 | 3600 (248) | Union Straight 825-1610-6 | Union Elbow 825-1610-9 |
| 12 | 1 × 0.109 | 84 | 4200 (289) | Union Straight 825-1610-6 | Union Elbow 825-1610-9 |

| Samples Tested | Alloy 825 Tubing Size OD × Wall mm | Tubing Hardness 15-T | Working Pressure① bar (psig) | Part Description Ordering Number | Part Description Ordering Number |
|---|---|---|---|---|---|
| 12 | 18 × 1.5 | 83 | 240 (3483) | Union Straight 825-18M0-6 | Union Elbow 825-18M0-9 |
| 12 | 18 × 2.5 | 87 | 400 (5805) | Union Straight 825-18M0-6 | Union Elbow 825-18M0-9 |
| 12 | 25 × 2.0 | 80 | 240 (3483) | Union Straight 825-25M0-6 | Union Elbow 825-25M0-9 |
| 12 | 25 × 2.8 | 81 | 300 (4354) | Union Straight 825-25M0-6 | Union Elbow 825-25M0-9 |

① Working pressures according to published ratings.

## PURPOSE
These assemblies were tested under laboratory test conditions to observe the gas seal reassembly performance of alloy 825 Swagelok tube fittings when installed on alloy 825 tubing.

## TEST CONDITIONS
Original Test Date: November 2012

- 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.

Swagelok

# Product Test Report

**PTR-3269**

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

Ver 01
November 2018


## TEST METHOD

### Hardness Measurements of Tubing:

1. Performed five measurements equally spaced apart on each tube OD 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.

### 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 5th and 10th reassembly.
6. Samples were monitored for leakage throughout the test. The acceptance criterion was less than 1 bubble per minute at the applied pressure.

Swagelok



## TEST RESULTS

| Tubing Size OD × Wall in. | 1.25 × WP psig (bar) | End Connections Tested | Number of Acceptable Samples | | |
|---|---|---|---|---|---|
| | | | After Standard Assembly and Initial Test | After Additional 1/8 Turn and Retest | After 10 Reassemblies |
| 3/4 × 0.065 | 4750 (327) | 24 | 24 / 24 | 24 / 24 | 23 / 24① |
| 3/4 x 0.095 | 7250 (500) | 24 | 24 / 24 | 24 / 24 | 24 / 24 |
| 1 × 0.083 | 4500 (310) | 24 | 23 / 24 | 24 / 24 | 23 / 24① |
| 1 × 0.109 | 5250 (361) | 24 | 24 / 24 | 24 / 24 | 24 / 24 |

① One fitting leaked at the 10th reassembly; upon reassembly, no leakage was detected.

| Tubing Size OD × Wall mm | 1.25 × WP bar (psig) | End Connections Tested | Number of Acceptable Samples | | |
|---|---|---|---|---|---|
| | | | After Standard Assembly and Initial Test | After Additional 1/8 Turn and Retest | After 10 Reassemblies |
| 18 × 1.5 | 300 (4354) | 24 | 24 / 24 | 24 / 24 | 24 / 24 |
| 18 × 2.5 | 500 (7256) | 23 | 23 / 23 | 23 / 23 | 23 / 23 |
| 25 × 2.0 | 302 (4383) | 32 | 29 /32 | 30 / 32① | 32 / 32 |
| 25 × 2.8 | 375 (5442) | 24 | 24 / 24 | 24 / 24 | 24 / 24 |

① Two fittings leaked after the additional 1/8 turn; upon reassembly, no leakage was detected.

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

# Product Test Report

**PTR-3269**

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

Ver 01
November 2018
Page 4 of 4

## Referenced Documents

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

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 A312, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*, 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

# Product Test Report

**PTR-866**

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

Ver 03
November 2018


## 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.

## TEST CONDITIONS

Original Test Date: December 2004

- 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 µin./in. peak-to-peak strain level results in frequent piping system failures. For alloy 825, the 200 µin./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.

Swagelok

# Product Test Report

**PTR-866**

Swagelok Company
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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.

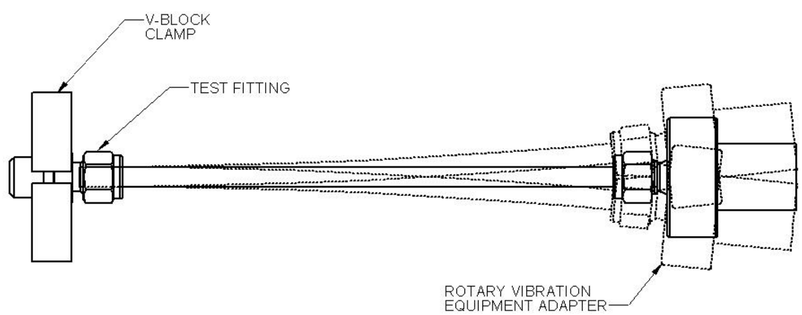



**Figure 1**

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).

| **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

Swagelok

# Product Test Report

**PTR-866**

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

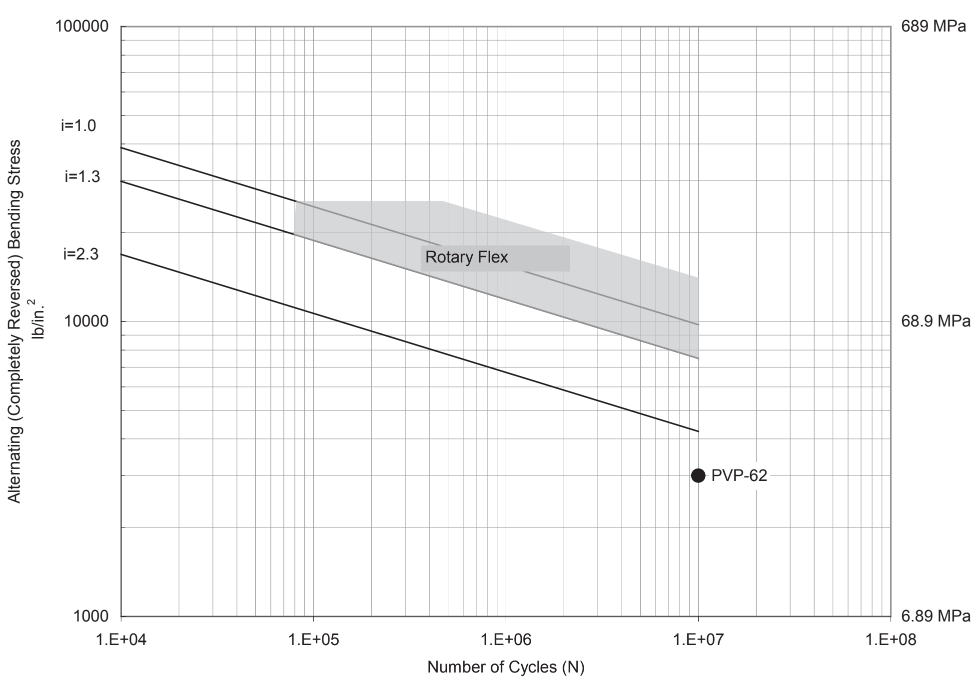
Ver 03
November 2018


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.

**Rotary Flex Testing of Swagelok Alloy 825 Tube Fitting**



# Product Test Report



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



**These 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.

## 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-3268**

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

Ver 01
November 2018


## TITLE

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

## PRODUCT TESTED

| Samples Tested | Alloy 825 Tubing Size OD × Wall | Tubing Hardness 15-T | Description Ordering Number | Working Pressure① psig (bar) |
|---|---|---|---|---|
| 16 | ¾ × 0.065 in. | 78 | Male Connector 825-1210-1-8 | 3800 (261) |
| 16 | 1 × 0.065 in. | 76 | Male Connector 825-1610-1-8 | 2800 (192) |
| 16 | 18 × 1.5 mm | 88 | Male Connector 825-18M0-1-8 | 3481 (239) |
| 16 | 25 × 2.0 mm | 78 | Male Connector 825-25M0-1-8 | 3481 (239) |

① Working pressures according to published ratings.

## PURPOSE

The assemblies were tested under laboratory conditions to observe the fatigue endurance of alloy 825 Swagelok tube fittings when installed on alloy 825 tubing at various levels of applied alternating bending stress of the tube.

## TEST CONDITIONS

Original test date: November 2012

- 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 OD 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 from the Wilson Chart #53 Cylindrical Conversion Table.

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Solon, Ohio 44139 U.S.A.

**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.

ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 µin./in. peak-to-peak strain level results in frequent piping system failures. The 200 µin./in. strain level calculates to an alternating stress of 2830 $lb/in.^2$ (19.5 MPa) for alloy 825 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 alloy 825 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:

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 ($lb/in.^2$)

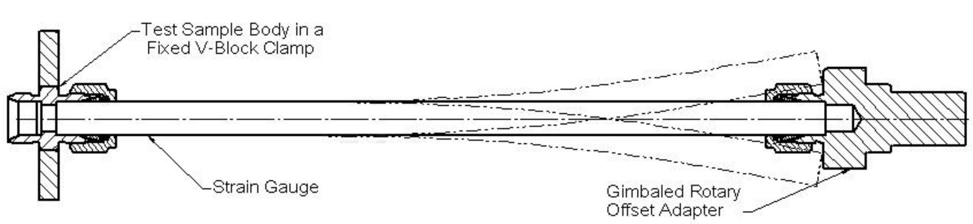
Equation 5a: C (other material) = 245 000 × E (other material)/27 800 000 psi

where

- C = Material constant, for use in Equation 3 (psi)
- E = Modulus of Elasticity (psi) for alloy 825

## Test Procedure

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



# Product Test Report



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Solon, Ohio 44139 U.S.A.

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.
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).

| **Nominal Alternating Bending Stress**① lb/in.$^2$ (MPa) | **Samples Tested** |
|---|---|
| 25 000 (172.2) | 16 |
| 20 000 (137.8) | 16 |
| 15 000 (103.3) | 16 |
| 10 000 (68.9) | 16 |
| **TOTAL** | **64** |

① Zero-to-peak stress

4. Test samples were pressurized to working pressure with hydraulic oil and rotated at a speed greater than 2350 rpm.
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 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 2830 lb/in.$^2$ (19.5 MPa) and 10 million cycles.

# Product Test Report

**PTR-3268**

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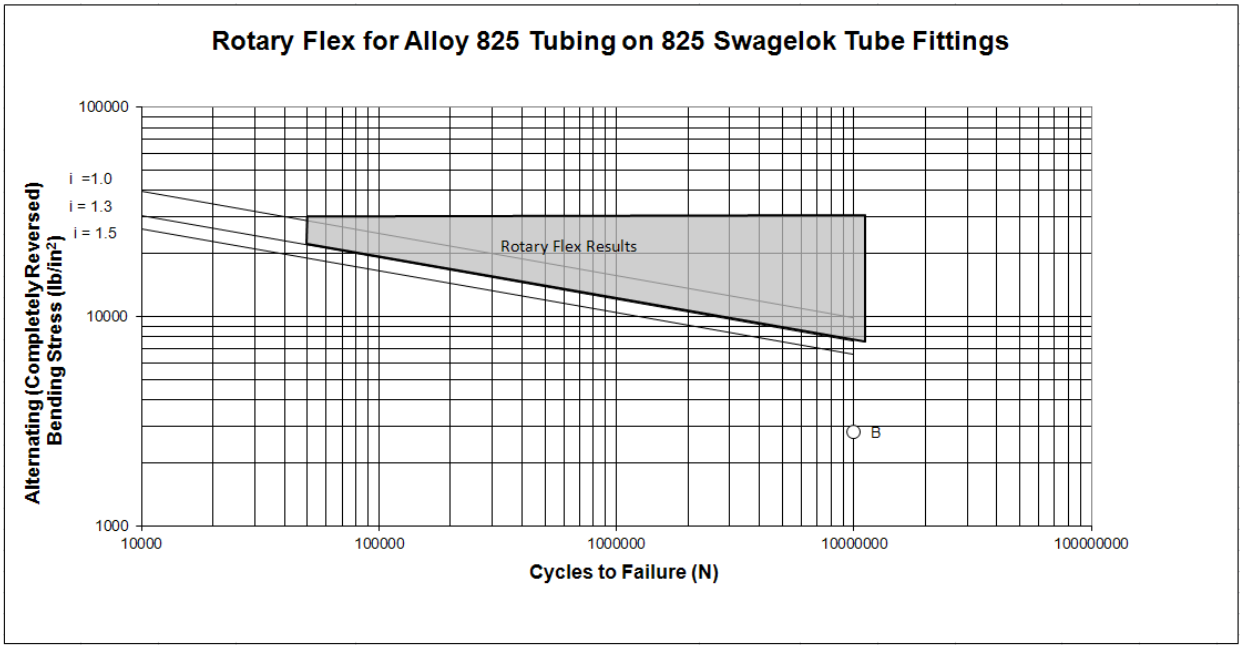
Solon, Ohio 44139 U.S.A.



- The alloy 825 Swagelok tube fittings remained leak-tight while protecting the alloy 825 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 alloy 825 Swagelok tube fitting is *i = 1.0.*




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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

## Product Test Report

**PTR-3268**

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



### Referenced Documents

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

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 A312, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*, 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

Swagelok

# Product Test Report

**PTR-3260**

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

Ver 01
June 2018


## TITLE

Hydrostatic Pressure Test of Super Austenitic 6Mo (6-moly) Stainless Steel Tubing With 6Mo Stainless Steel (6-moly) Swagelok® Tube Fittings

## PRODUCT TESTED

| Samples Tested | 6Mo SS Tubing Size OD × Wall in. | Tubing Hardness HRB | Description / Ordering Number | Form |
|---|---|---|---|---|
| 28 | 1/4 × 0.065 | 83 | Male Connector 6Mo-400-1-4 | Bar stock |
| | | | Union Elbow 6Mo-400-9 | Forging |
| | | | Plug 6Mo-400-P | Bar stock |
| 28 | 1/2 × 0.083 | 88 | Male Connector 6Mo-810-1-4 | Bar stock |
| | | | Union Elbow 6Mo-810-9 | Forging |
| | | | Plug 6Mo-810-P | Bar stock |

## PURPOSE

These assemblies were tested under laboratory conditions to observe the tube grip performance of 6Mo Swagelok tube fittings when installed on 6Mo stainless steel, heavy-wall tubing with hydrostatic pressure.

## TEST CONDITIONS

Original Test Date: October 2012

- Each sample tested consisted of one tube length and two test fittings. The fittings were assembled according to Swagelok assembly procedures.
- 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 OD 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.

Swagelok

# Product Test Report

**PTR-3260**

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

Ver 01
June 2018


**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 (WP).

## TEST RESULTS

| Samples Tested | 6Mo SS Tubing Size OD × Wall in. | Working Pressure① psig (bar) | 4 × Working Pressure psig (bar) | Samples Attaining 4 × WP |
|---|---|---|---|---|
| 28 | 1/4 × 0.065 | 13 900 (957) | 55 600 (3 830) | 28 / 28 |
| 28 | 1/2 × 0.083 | 9 000 (620) | 36 000 (2 480) | 28 / 28 |

① Working pressures were calculated from an S value of 27 100 psig (186.7 MPa) for ASTM A213 tubing at –20 to 100°F (–28 to 37°C), as listed in ASME B31.1.

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

# Product Test Report

**PTR-3260**

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



## Referenced Documents

*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*, ASTM International, 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 A312, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2858

Swagelok

# Product Test Report

**PTR-3261**

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

Ver 01
June 2018


## TITLE

Tensile Pull Test of Super Austenitic 6Mo (6-moly) Stainless Steel Tubing With 6Mo Stainless Steel (6-moly) Swagelok® Tube Fittings

## PRODUCT TESTED

| Samples Tested | 6Mo SS Tubing Size OD × Wall in. | Tubing Hardness HRB | Description / Ordering Number |
|---|---|---|---|
| 6 | 1/4 × 0.065 | 83 | Male Connector 6Mo-400-1-4 |
| 6 | 1/2 × 0.083 | 86 | Male Connector 6Mo-810-1-4 |

## PURPOSE

These assemblies were tested under laboratory conditions to observe the tube grip performance of 6Mo stainless steel Swagelok tube fittings when installed on 6Mo stainless steel heavy-wall tubing under tensile load.

## TEST CONDITIONS

Original Test Date: October 2012

Laboratory environment

## TEST METHOD

**Hardness Measurements of Tubing:**

1. Performed five measurements equally spaced apart on each tube OD 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.

Swagelok

# Product Test Report



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

   Calculated tensile load = Ap × Sy

   where:

   Ap = cross-section area of the tube based on wall thickness
   Sy = minimum specified yield strength of the tube.

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

## TEST RESULTS

### Tensile Pull Test

| **6Mo SS Tubing Size OD × Wall** in. | **Acceptance Criterion (Minimum Load)** lbf (N) | **Minimum Load Attained** lbf (N) | **Samples Exceeding Calculated Tensile Load** |
|---|---|---|---|
| 1/4 × 0.065 | 1 845 (8 206) | 3 136 (13 948) | 6/6 |
| 1/2 × 0.083 | 5 564 (24 748) | 8 511 (37 856) | 6/6 |

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

## Referenced Documents

*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*, ASTM International,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*, ASTM International, 100 Barr Harbor Drive, West, Conshohocken, PA 19428-2858

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# Product Test Report

**PTR-3263**

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

Ver 01
June 2018


## TITLE

Nitrogen Gas Seal Test with Repeated Reassembly of Super Austenitic 6Mo Stainless Steel (6-moly) Tubing with 6Mo Stainless Steel (6-moly) Swagelok® Tube Fittings

## PRODUCT TESTED

| **Samples Tested** | **6Mo SS Tubing Size OD × Wall** in. | **Tubing Hardness** HRB | **Working Pressure**① psig (bar) | **Description / Ordering Number** | **Description / Ordering Number** |
|---|---|---|---|---|---|
| 12 | 1/4 × 0.028 | 87 | 5 400 (372) | Union Straight 6Mo-400-6 | Union Elbow 6Mo-400-9 |
| 12 | 1/4 × 0.065 | 92 | 13 900 (957) | Union Straight 6Mo-400-6 | Union Elbow 6Mo-400-9 |
| 12 | 1/2 × 0.035 | 88 | 3 500 (241) | Union Straight 6Mo-810-6 | Union Elbow 6Mo-810-9 |
| 12 | 1/2 × 0.083 | 95 | 9 000 (620) | Union Straight 6Mo-810-6 | Union Elbow 6Mo-810-9 |

① Working pressures were calculated from an S value of 27 100 psig (186.7 MPa) for ASTM A213 tubing at –20 to 100°F (–28 to 37°C), as listed in ASME B31.1.

## PURPOSE

These assemblies were tested under laboratory test conditions to observe the gas seal reassembly performance of stainless steel 6Mo Swagelok tube fittings when installed on 6Mo stainless steel tubing.

## TEST CONDITIONS

Original Test Date: October 2012

- Each sample tested consisted of one tube length and two test fittings. The fittings were assembled according to Swagelok assembly procedures.
- 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 OD 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.

Swagelok

# Product Test Report

**PTR-3263**

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

Ver 01
June 2018


**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 and 10.
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 × Wall** in. | **1.25 × WP** psig (bar) | **End Connections Tested** | **Number of Acceptable Samples** | |
|---|---|---|---|---|
| | | | **After Standard Assembly and Initial Test** | **After 1, 5, and 10 Reassemblies** |
| 1/4 × 0.028 | 6 750 (465) | 24 | 24 / 24 | 24 / 24 |
| 1/4 × 0.065 | 17 375 (1 197) | 24 | 24 / 24 | 24 / 24 |
| 1/2 × 0.035 | 4 375 (301) | 24 | 24 / 24 | 24 / 24 |
| 1/2 × 0.083 | 11 250 (775) | 24 | 24 / 24 | 24 / 24 |

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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

Swagelok

**Product Test Report** **PTR-3263**

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



## Referenced Documents

*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*, ASTM International, 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 A312, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428

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

Swagelok

# Product Test Report

**PTR-3262**

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

Ver 01
June 2018


## TITLE

Rotary Flexure Test of Super Austenitic 6Mo (6-moly) Stainless Steel Tubing With 6Mo Stainless Steel (6-moly) Swagelok® Tube Fittings

## PRODUCT TESTED

| Samples Tested | 6Mo SS Tubing Size OD × Wall in. | Tubing Hardness HRB | Description / Ordering Number | Working Pressure① psig (bar) |
|---|---|---|---|---|
| 16 | 1/4 × 0.028 | 89 | Male Connector 6Mo-400-1-4 | 5400 (372) |
| 16 | 1/2 × 0.035 | 89 | Male Connector 6Mo-810-1-4 | 3500 (241) |

① Working pressures were calculated from an S value of 27 100 psig (186.7 MPa) for ASTM A213 tubing at –20 to 100°F (–28 to 37°C), as listed in ASME B31.1.

## PURPOSE

The assemblies were tested under laboratory conditions to observe the fatigue endurance of 6Mo Swagelok tube fittings when installed on 6Mo stainless steel tubing at various levels of applied alternating bending stress of the tube.

## TEST CONDITIONS

Original Test Date: October 2012

- 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 OD 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.

# Product Test Report

**PTR-3262**

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



**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.

ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 µin./in. peak-to-peak strain level results in frequent piping system failures. The 200 µin./in. strain level calculates to an alternating stress of 2 900 lb/in.2 (19.9 MPa) for 6Mo 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 6Mo 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:

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 ($lb/in.^2$)

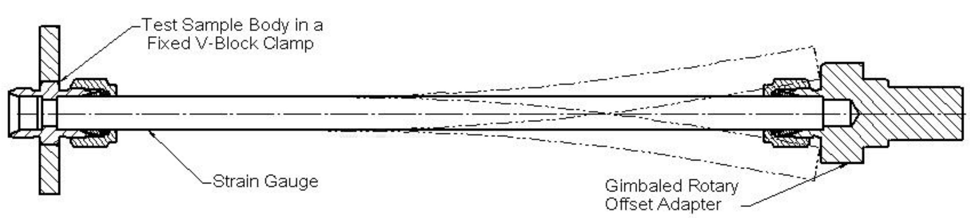
Equation 5a: C (other material) = 245 000 × E (other material)/27 800 000 psi

where

C = Material constant, for use in Equation 3 (psi)
E = Modulus of Elasticity (psi) for 6Mo

## Test Procedure

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



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**Product Test Report**

**PTR-3262**

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Solon, Ohio 44139 U.S.A.



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.
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).

| **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

4. Test samples were pressurized to working pressure with hydraulic oil and rotated at a speed greater than 1750 rpm.
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 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 6Mo stainless steel Swagelok tube fittings remained leak tight while protecting the 6Mo 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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## Product Test Report

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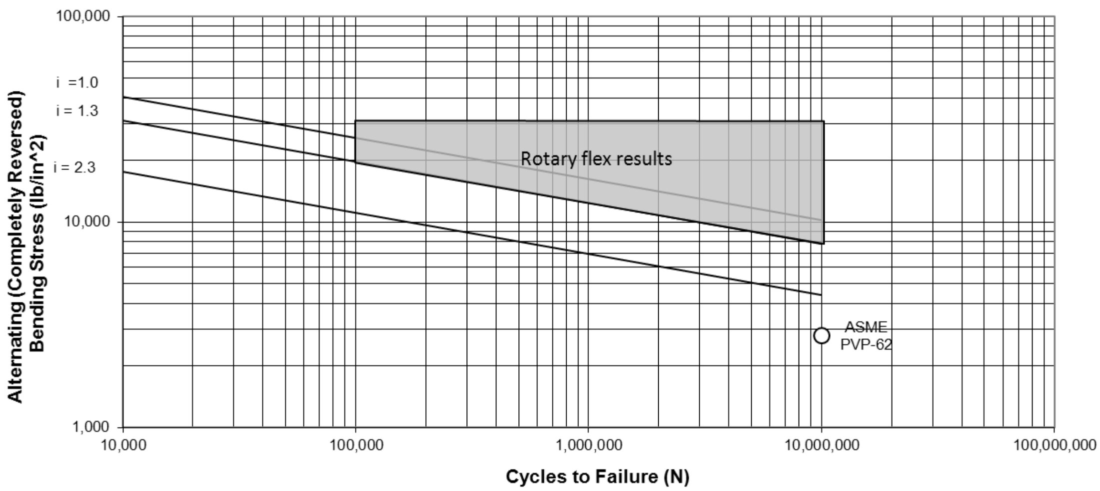
### Rotary Flex Testing of 6Mo Swagelok Tube Fitting with 6Mo Tubing




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

These tests were performed to consider a specific set of conditions and should not be considered valid outside those conditions. 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.

## Referenced Documents

*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*, ASTM International, 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 A312, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*, ASTM International, 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

## Approvals and Registrations

# 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<br>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 Suddeutschland** | 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<br>4, 6, 8, 10 ST SAE/MS male connector ends |
| | EIHP Draft | Stainless Steel Swagelok Tube Fittings<br>Positionable ST and 12ST<br>12ST for SAE/male connector<br>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<br>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<br>"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 600, Titanium, Alloy 825<br>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<br>1/4 to 2 in. and 6 to 50 mm<br>Swagelok Flange Adapters catalog, MS-02-200 |
| | | Tube Fittings- SS, S, M, B<br>1/16 to 2 in. and 2 to 50 mm<br>Swagelok Tube/Pipe Fittings in catalog, MS-01-140 |
| | | Swagelok Tube Fittings in catalog, MS-02-10<br>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,<br>400/R-405 alloy - 1/8 to 1 in.,<br>360 and/or 377 brass - 1/8 to 1 1/8 in.,<br>SAF-2507 Duplex alloy, Alloy C-276, Alloy 600, Alloy 825 and titanium - 1/4 to 1/2 in.<br>Swagelok Tube/Pipe Fittings in catalog, MS-01-140 (1998) |
| **Bureau Veritas (BV)** | Bureau Veritas rules for the classification of steel ships<br>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<br>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<br>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-, M-, INC-, HC-, A-, B-, T-, 2507-, TI-, ZR2-, ZR-,TA-, NI-, S-.<br>Swagelok Tube Fittings in catalog, MS-01-140<br>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-, M-, INC-, HC-, A-, B-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-.<br>Swagelok Tube Fittings in catalog, MS-01-140<br>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-, M-, INC-, HC-, A-, B-, T-, 2507-, TI-, ZR2-, ZR-,TA-, NI-, S-.<br>Swagelok Tube Fittings in catalog, MS-01-140<br>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-, M-, INC-, HC-, A-, B-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-.<br>Swagelok Tube Fittings in catalog, MS-01-140<br>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-, M-, INC-, HC-, A-,B-, T-, 2507-, TI-, ZR2-, ZR-, TA-, NI-, S-.<br>Swagelok Tube Fittings in catalog, MS-01-140<br>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.<br>Swagelok Tube fittings |
| **Engineers India Limited (EIL)** | Rules for Engineers India Limited Approval | Material types-ordering number prefixes starting with SS-, M-, B-.<br>Swagelok Tube Fittings in catalog, MS-01-140<br>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.