Product Test Report

PTR-4132

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TITLE

Rotary Flexure Test of 4ABT, 6ABT, 8ABT, 6MABT, 8MABT, 10MABT, and 12MABT Series Stainless Steel Swagelok® Assembly-by-Torque (AbT) Tube Fitting Assembled to Stainless Steel Tubing

PRODUCT TESTED

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

Fractional

Ordering Number	Part Form	ABT Hardware Set	Stainless Steel Tubing Size in.	Tubing Hardness HRB
1/4 in.				
Male Connector SS-400-1-4BO	Bar stock	Nut Ferrule Set SS-4ABT-NFSET	1/4 × 0.028	77
Male Connector SS-400-1-4BO	Bar stock	Nut Ferrule Set SS-4ABT-NFSET	1/4 × 0.035	78
Male Connector SS-400-1-4BO	Bar stock	Nut Ferrule Set SS-4ABT-NFSET	1/4 × 0.049	77
3/8 in.				
Male Connector SS-600-1-4BO	Bar stock	Nut Ferrule Set SS-6ABT-NFSET	3/8 × 0.049	85
Male Connector SS-600-1-4BO	Bar stock	Nut Ferrule Set SS-6ABT-NFSET	3/8 × 0.065	80
1/2 in.				
Male Connector SS-810-1-4BO	Bar stock	Nut Ferrule Set SS-8ABT-NFSET	1/2 × 0.049	81
Male Connector SS-810-1-4BO	Bar stock	Nut Ferrule Set SS-8ABT-NFSET	1/2 × 0.083	79

Metric

Ordering Number	Part Form	ABT Hardware Set	Stainless Steel Tubing Size mm	Tubing Hardness HRB
6 mm				
Male Connector SS-6M0-1-4BO	Bar stock	Nut Ferrule Set SS-6MABT-NFSET	6 × 1.0	82
8 mm				
Male Connector SS-8M0-1-4BO	Bar stock	Nut Ferrule Set SS-8MABT-NFSET	8 × 1.0	81
Male Connector SS-8M0-1-4BO	Bar stock	Nut Ferrule Set SS-8MABT-NFSET	8 × 1.2	80
10 mm				
Male Connector SS-10M0-1-4BO	Bar stock	Nut Ferrule Set SS-10MABT-NFSET	10 × 1.0	80
Male Connector SS-10M0-1-4BO	Bar stock	Nut Ferrule Set SS-10MABT-NFSET	10 × 1.5	80
12 mm				
Male Connector SS-12M0-1-4BO	Bar stock	Nut Ferrule Set SS-12MABT-NFSET	12 × 1.5	81
Male Connector SS-12M0-1-4BO	Bar stock	Nut Ferrule Set SS-12MABT-NFSET	12 × 1.8	82

PURPOSE

The assemblies were tested under laboratory conditions to observe the fatigue endurance of the 4ABT, 6ABT, 8ABT, 6MABT, 8MABT, 10MABT, and 12MABT series stainless steel Swagelok tube fittings at various levels of applied alternating bending stress of the tube at room temperature.

TEST CONDITIONS

Original test dates: August 2016, November 2019, and November 2020.

- Each sample tested consisted of one tube length and one fitting.
- Tube assemblies were preswaged and assembled into fitting bodies according to *Assembly-by-Torque (AbT) Fittings* catalog, MS-02-466.
- Testing was 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 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:

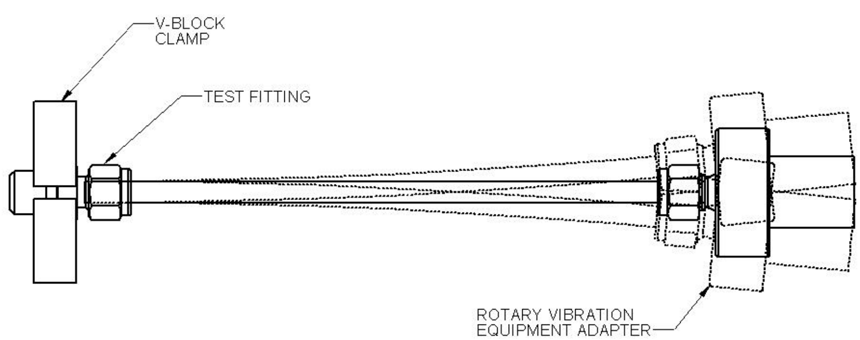

Figure 1
Test Stand Set-up

1. Each test sample was attached to a rotary flex test stand. Refer to 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). Refer to Tables 1 and 2.

Table 1
Bending Stresses for Fractional Parts

Nominal Alternating Bending Stress① lb/in.^{2} (MPa)	**Samples Tested**
1/4 in.	
20 000 (137.8)	12
15 000 (103.3)	12
10 000 (68.9)	12
TOTAL	**36**
3/8 in.	
20 000 (137.8)	16
15 000 (103.3)	16
10 000 (68.9)	16
TOTAL	**48**
1/2 in.	
20 000 (137.8)	16
15 000 (103.3)	16
10 000 (68.9)	16
TOTAL	**48**

Table 2
Bending Stresses for Metric Parts

Nominal Alternating Bending Stress① lb/in.^{2} (MPa)	**Samples Tested**
6 mm	
20 000 (137.8)	4
15 000 (103.3)	4
10 000 (68.9)	4
TOTAL	**12**
8 mm	
20 000 (137.8)	12
15 000 (103.3)	12
10 000 (68.9)	12
TOTAL	**36**
10 mm	
20 000 (137.8)	15
15 000 (103.3)	15
10 000 (68.9)	15
TOTAL	**45**
12 mm	
20 000 (137.8)	15
15 000 (103.3)	15
10 000 (68.9)	15
TOTAL	**45**

① Zero to peak stress

4. Test samples were pressurized with hydraulic oil to at least the working pressure rating, indicated in Tables 3 and 4 below.

Table 3
Working Pressures for Fractional Parts

Stainless Steel	**Stainless Steel Tubing Size** in.	**Working Pressure** psig (bar)
316/316L	1/4 × 0.028	4000 (275)
316/316L	1/4 × 0.035	5100 (351)
316/316L	1/4 × 0.049	7500 (516)
316/316L	3/8 × 0.049	4800 (330)
316/316L	3/8 × 0.065	6500 (447)
316/316L	1/2 × 0.049	3700 (254)
316/316L	1/2 × 0.083	6700 (461)

Table 4
Working Pressures for Metric Parts

Stainless Steel	**Stainless Steel Tubing Size** mm	**Working Pressure** psig (bar)
316/316L	6 × 1.0	6092 (419)
316/316L	8 × 1.0	4500 (310)
316/316L	8 × 1.2	5100 (351)
316/316L	10 × 1.0	3480 (239)
316/316L	10 × 1.5	5100 (351)
316/316L	12 × 1.5	4790 (330)
316/316L	12 × 1.8	5100 (351)

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 passed the rotary flex test if they remained leak-tight over the duration of the test and demonstrated 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 (Figure 2) envelops the test results, with 90% reliability and 95% one-sided confidence, of the 4ABT, 6ABT, 8ABT, 6MABT, 8MABT, 10MABT, and 12MABT series stainless steel Swagelok tube fittings. 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 ASME PVP-62 on the graph is the intersection of 2800 $lb/in.^2$ (19.2 MPa) and 10 million cycles.
- The 316 stainless steel 4ABT, 6ABT, 8ABT, 6MABT, 8MABT, 10MABT, and 12MABT series 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 stress intensification factor which is equal to or less than i = 1.3 as defined in ASME B31J, 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.

Rotary Flex Testing of Swagelok Stainless Steel Tube Fitting

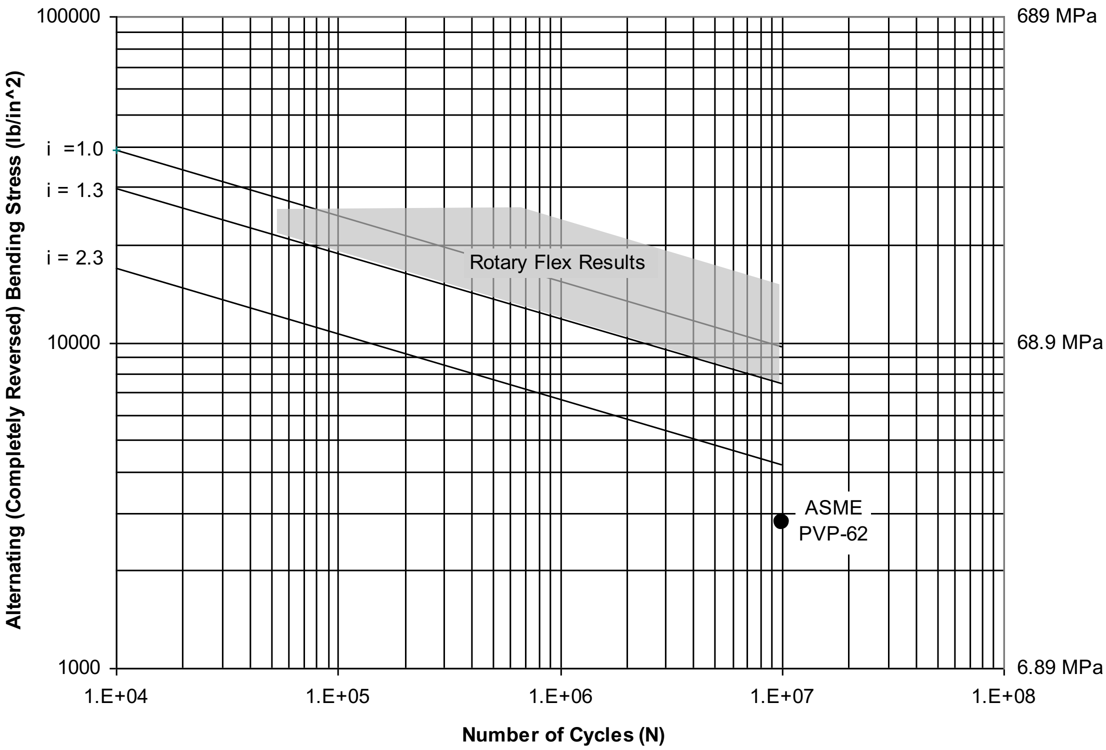

Figure 2
S/N Graph (Bending Stress Versus Number of Cycles)

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