Product Test Report

Swagelok Company
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TITLE

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

PRODUCT TESTED

Samples Tested	**254 SMO SS Tubing Size OD × Wall** in.	**Tubing Hardness** HRB	**Part Description Ordering Number**	**Working Pressure** psig (bar)
16	1/4 × 0.028	85	Male Connector SS-400-1-4	4000 (275)
16	1/2 × 0.035	87	Male Connector SS-810-1-4	2600 (179)
16	3/4 × 0.049	86	Male Connector SS-1210-1-8	3300 (227)
16	1 × 0.065	83	Male Connector SS-1610-1-8	3300 (227)

PURPOSE

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

TEST CONDITIONS

Original test date: October 2011

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

TEST METHOD

Hardness Measurements of Tubing:

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

Rotary Flexure Testing:

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

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 254 SMO stainless steel tubing. ASME PVP-62 also reports that measured field data for piping systems suggest that if the system lasts beyond 10 million cycles, it will have infinite life.

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

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 ($lb/in.^2$)

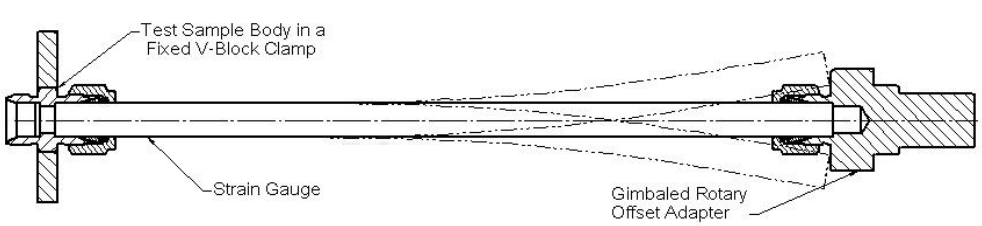
Equation 5a: C (other material) = 245 000 × E (other material)/27 800 000 psi

where

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

Test Procedure

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



2. A bending stress was applied to each sample by a gimbaled rotary offset. The bending stresses were selected to generate the stress versus number of cycles (S/N) graph. The stress levels support a highly accelerated life test protocol and are not indicative of any specific application.
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 Stress① 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 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 316 stainless steel Swagelok tube fittings remained leak tight while protecting the 254 SMO stainless steel tubing from premature fracture at alternating stresses greatly exceeding the ASME PVP-62 recommended upper limit. The fitting's performance also resulted in a calculated endurance stress at ten million cycles which exceeds a stress intensification factor of i = 1.3 as defined in ASME BPV Code Section III, NC-3673, therefore passing the rotary flex test.

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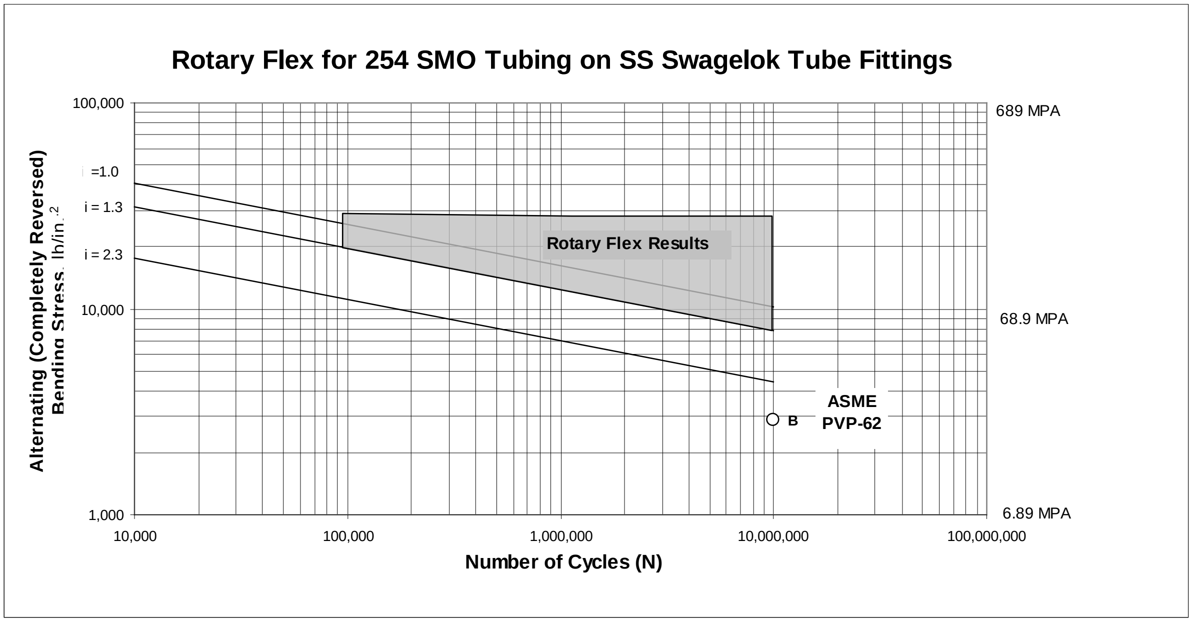

The tests were conducted beyond the product's recommended operating parameters and do not modify the published product ratings.

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

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

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

ASME 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