



Product Test Report

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

PTR-1968
Ver 03
September 2022
Page 1 of 4

TITLE

Rotary Flexure Test of 316 Stainless Steel Swagelok® Medium-Pressure Tube Fittings with SAF 2507™ Super Duplex Stainless Steel Tubing

PRODUCT TESTED

The following stainless steel Swagelok medium-pressure tube fittings were tested with the identified SAF 2507 super duplex stainless steel tubing.

| Ordering Number | Quantity Tested | SAF 2507 Tubing in. | Tubing Hardness Rc |
|-----------------|-----------------|---------------------|--------------------|
| SS-4FK0-1-4 | 3 | 1/4 × 0.049 | 32 |
| SS-6FK0-1-4 | 3 | 3/8 × 0.083 | 29 |
| SS-8FK0-1-4 | 3 | 1/2 × 0.095 | 25 |
| SS-12FK0-1-16 | 6 | 3/4 × 0.134 | 34 |

PURPOSE

The assemblies were tested to observe the fatigue endurance of 316 stainless steel Swagelok medium-pressure tube fittings with SAF 2507 super duplex stainless steel tubing under laboratory conditions at various levels of applied alternating bending stress of the tube.

TEST CONDITIONS

Original test date: March 2009

Each sample tested consisted of one tube length and one test fitting. The fitting was assembled according to the Swagelok medium-pressure tube fitting installation instructions. The test 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. The test samples were flexed until either the fitting leaked, the tube fractured, or at least 10 million cycles were achieved, whichever occurred first.

ASME Pressure Vessel and Piping, volume 62 (ASME PVP-62) reports that vibration at or above an alternating stress of 200 $\mu\text{in./in.}$ peak-to-peak strain level results in frequent piping system failures. For SAF 2507, the 200 $\mu\text{in./in.}$ strain level calculates to an alternating stress of 2900 lb/in.^2 (19.9 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.

Product Test Report

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

PTR-1968
Ver 03
September 2022
Page 2 of 4

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.

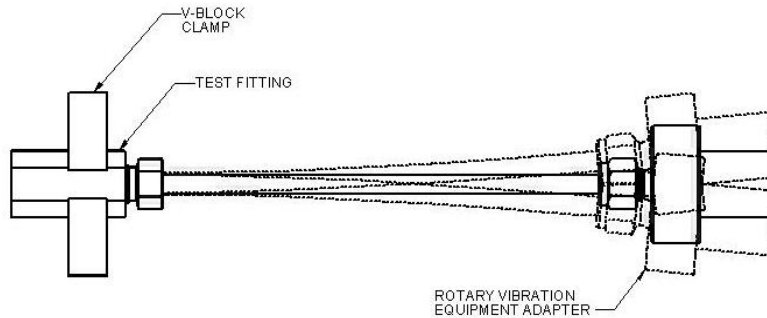


Figure 1

2. A bending stress was applied to each sample by a gimbaled rotary offset. The stress level supports a highly accelerated life test protocol and is 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 |
| 18 000 (124.0) | 2 |
| 15 000 (103.4) | 9 |
| 13 000 (89.5) | 2 |
| 10 000 (68.9) | 2 |

① Zero-to-Peak stress



Product Test Report

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

PTR-1968
Ver 03
September 2022
Page 3 of 4

4. Test samples for the 1/2 inch and smaller sizes were pressurized to 10 000 psig (689 bar) with hydraulic oil. Test samples for the 3/4 inch size were pressurized to 6500 psig 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. The test data was included into a bending stress versus number of cycles graph (S/N) made from historical Swagelok medium-pressure tube fitting rotary flex data and the results were compared to the ASME based data described earlier.
7. Test samples passed the rotary flex test if all samples remained leak-tight over the duration of the test and demonstrated for a given bending stress the number of cycles that met or exceeded the predicted number of cycles for fittings having a stress intensification factor of $i = 1.3$.

TEST RESULTS

- All tested fittings passed.
- 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 historical stainless steel Swagelok medium-pressure tube fitting rotary flex 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. The data from the current testing of Swagelok medium-pressure tube fittings with SAF 2507 super duplex tubing fits within this shaded area.
- 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 medium-pressure 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.

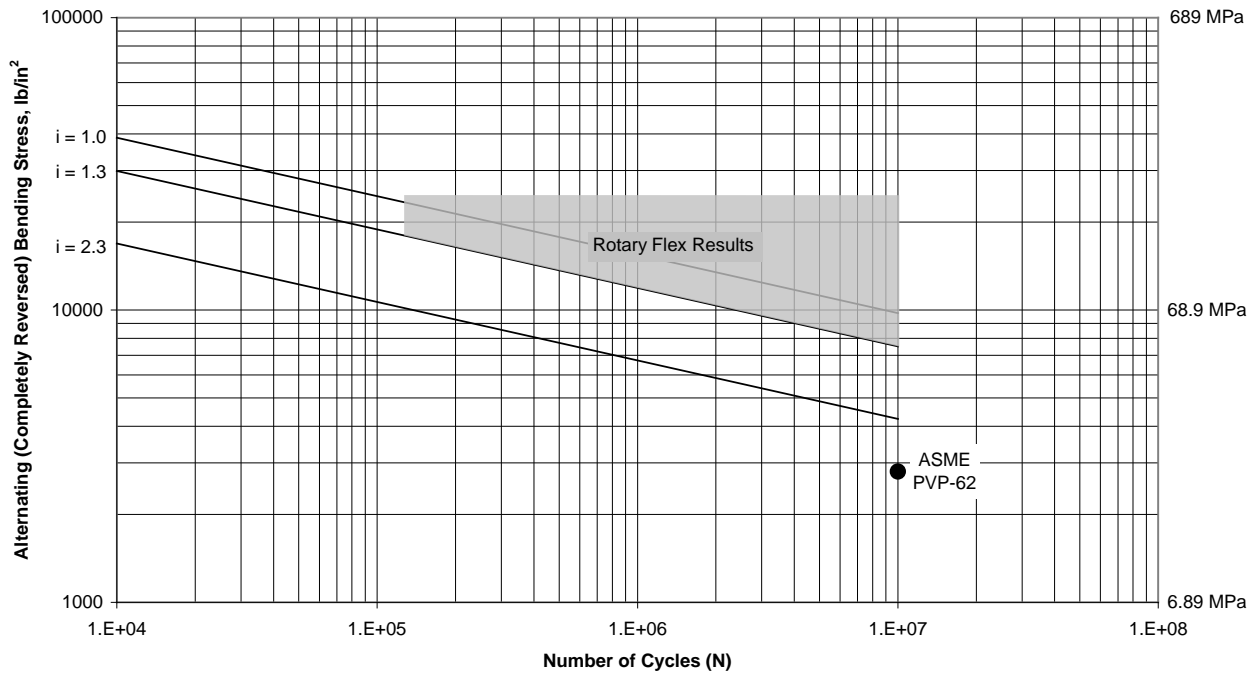


Product Test Report

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

PTR-1968
Ver 03
September 2022
Page 4 of 4

Rotary Flex Testing of Stainless Steel Swagelok Medium-Pressure Tube Fitting



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