



## Product Test Report

**PTR-2813**

Swagelok Company  
29500 Solon Road  
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Ver 02  
November 2022  
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### TITLE

Metallurgical Assessment of Swagelok® 316/316L Stainless Steel Tubing Manufactured by Salzgitter Mannesmann and Sandvik®

### PRODUCT TESTED

- Stock samples of seamless tubes fabricated from TP 316/316L austenitic stainless steel (UNS S31600/S31603).
- Manufactured to ASTM A213/A269 and NACE MR0103/MR0175 requirements.
- Supplied in the cold-finished and bright-annealed condition (i.e., free from scale),

Tube OD Size in.	Ordering Number	Tubing Manufacturers
3/8	SS-T6-S-049-20-S	Sandvik and Salzgitter
1/2	SS-T8-S-049-20-S	

### PURPOSE

These tubing samples were tested under laboratory conditions to observe the surface condition, grain structure, and bending properties of Salzgitter- and Sandvik-supplied tubing. Mechanical properties were assessed through analysis of suppliers' certifications.

### TEST CONDITIONS

Original test date: August 2011

Testing was performed under normal laboratory conditions.

### TEST METHODS

#### Sample Preparation:

- Each tube was cut to produce samples of both transverse and radial longitudinal cross-sections.
- Samples for microhardness testing were mounted in epoxy and polished; the samples used for microstructural examination were also acid etched.

#### Test Procedures:

- Visual examination of each tube OD/ID at low magnification (1× to 60×).
- Rockwell 15-T (HR15TW) macrohardness on the OD surface of each tube. Standard conversion tables were used to determine equivalent Rockwell B hardness values.
- Knoop microhardness testing on mounted tube wall cross-sections. Standard conversion tables were used to determine equivalent Rockwell B hardness values.
- Grain size determination (at 100× magnification) on the transverse tube cross-sections.
- Microstructural examination of the transverse and radial longitudinal tube cross-sections.
- U-bend test and crack examination for each tube size using Swagelok hand benders.



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### TEST RESULTS

#### Visual Examination for Surface Condition

The physical condition of external surfaces (OD/ID) for both manufacturers was similar:

- Closely-spaced grinding/burnishing marks were present on the OD suggesting that the tubes had been turned.
- Minor surface imperfections such as linear draw marks, typical of this type of tubing, were observed on the OD.
- The internal surfaces (ID) exhibited a defect-free, frosted appearance.

#### Macrohardness

- The **exterior** surface hardness of all tubes exhibited a slightly greater hardness than the **interior** by various degrees due to variations/degrees of cold-working. The Salzgitter tubing was slightly harder than the Sandvik tubing and well within the specified limits.
- **The hardness of all tubes samples met the maximum allowable of 90 HRBW** as required by Swagelok specification, ASTM A213/A269 and NACE MR0103/MR0175.

#### Microhardness, Grain Size, and Microstructure

- **The hardness of all tube samples met the maximum allowable of 90 HRBW** as required by Swagelok specification, ASTM A213/A269 and NACE MR0103/MR0175.
- Grain size: Uniform
- Microstructure: Typical for material
- Microhardness: Within specification limits at all measured locations.

#### Mechanical Properties

- No mechanical property testing was conducted as part of this tube comparison. However, a review of the manufacturer's certified material test reports (MTR) was conducted. All data was well within the ASTM specification for these materials.
- MTR test data for yield strength (0.2% off-set), tensile strength, and % elongation for tubing manufactured from the material heat codes showed that all material met the requirements of the standards referenced in this report.
- The yield strength and tensile strength of the Salzgitter tubing was observed to be somewhat higher than that of the Sandvik tubing. Reported yield strength is typically 25 to 30% higher. Again, both materials meet all specifications for strength and ductility.



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### Tube Bend Test

#### 3/8 in. OD Tube

- No differences in effort were noted when making the u-bends from either supplier's tube.
- No cracks or other surface anomalies were observed on the tube extrados as a result of the bending procedure.

#### 1/2 in. OD Tube

- A slight increase in effort was required when making the u-bend in the Salzgitter tube. This is consistent with the higher reported tensile strength. This was not quantified as all tested tubing was bent manually.
- No cracks or other surface anomalies were observed on the tube extrados as a result of the bending procedure.

### CONCLUSIONS

- The test data, including that provided by the supplier MTRs, indicates that the 316/316L stainless steel tubing manufactured by both Sandvik and Salzgitter, have very similar microstructures and both are well within the ASTM specifications for the material.

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.



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### Referenced Documents

- ASTM Standard E18, *Test Methods for Rockwell Hardness of Metallic Materials*, (Volume 03.01: Metals Test Methods and Analytical Procedures), American Society for Testing Materials International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org)
- ASTM Standard E384, *Test Methods for Microindentation Hardness of Materials*, (Volume 03.01: Metals Test Methods and Analytical Procedures), American Society for Testing Materials International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org)
- ASTM Standard E140, *Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness*, (Volume 03.01: Metals Test Methods and Analytical Procedures), American Society for Testing Materials International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org)
- ASTM Standard E3, *Guide for Preparation of Metallographic Specimens*, (Volume 03.01: Metals Test Methods and Analytical Procedures), American Society for Testing Materials International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org)
- ASTM Standard E112, *Test Methods for Determining Average Grain Size*, (Volume 03.01: Metals Test Methods and Analytical Procedures), American Society for Testing Materials International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org)
- ASTM Standard A213, *Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes*, (Volume 01.01: Steel – Piping, Tubing, Fittings), American Society for Testing Materials International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org)
- A269, *Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, (Volume 01.01: Steel – Piping, Tubing, Fittings), American Society for Testing Materials International, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, [www.astm.org](http://www.astm.org)
- NACE MR0103, *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*, NACE International, 1440 South Creek Dr., Houston, TX 77084-4906, [www.nace.org](http://www.nace.org)
- NACE Standard MR0175, *Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*, NACE International, 1440 South Creek Dr., Houston, TX 77084-4906, [www.nace.org](http://www.nace.org)

Sandvik—TM Sandvik AB  
Swagelok—TM Swagelok Company