TITLE

Chloride Stress Corrosion Cracking (CSCC) Test of 316 Stainless Steel Swagelok® Tube Fitting Engineered Combinations Using 65°C Cyclic Salt Spray with Substitute Ocean Water

PRODUCT TESTED

Ordering Number	Tubing Material	Number of Fittings Tested	Test Pressure psig (MPa)	Tubing Size and Wall in.	Tubing Hardness HRB
SS-600-6	Alloy 254	4	7500 (51.6)	3/8 × 0.065	87
SS-600-9		4			
SS-600-6	Alloy 825	4	7500 (51.6)	3/8 × 0.065	87
SS-600-9		4			
SS-600-6	Tungum	4	7500 (51.6)	3/8 × 0.065	40
SS-600-9		4			
SS-600-6	Alloy 316	4	7500 (51.6)	3/8 × 0.083	88
SS-600-9		4			
SS-810-6	Alloy 254	4	6700 (46.6)	1/2 × 0.083	80
SS-810-9		4			
SS-810-6	Alloy 825	4	6700 (46.6)	1/2 × 0.065	76
SS-810-9		4			
SS-810-6	Tungum	4	6700 (46.6)	1/2 × 0.065	42
SS-810-9		4			
SS-810-6	Alloy 316	4	6700 (46.6)	1/2 × 0.083	82
SS-810-9		4			

PURPOSE

Assemblies of 316 stainless steel Swagelok tube fittings with stainless steel tubing and with various tubing materials described in Swagelok's Engineered Combinations catalog MS-06-117 were tested under laboratory conditions to observe the effects of an environment that promotes CSCC of 316 stainless steel.

The assemblies were exposed at 65ºC (149ºF) for 720h to alternate cycles of (a) salt spray (substitute ocean water per ASTM D1141) and (b) controlled humidity (60 to 70 %) to encourage concentrating chlorides in surface pits and crevices to particularly accelerate CSCC of 316 SS. Assemblies of one and seven-eighths turns past finger tight (TPFT) were included to increase tensile stress in the tube fitting components to further increase the risk of CSCC.

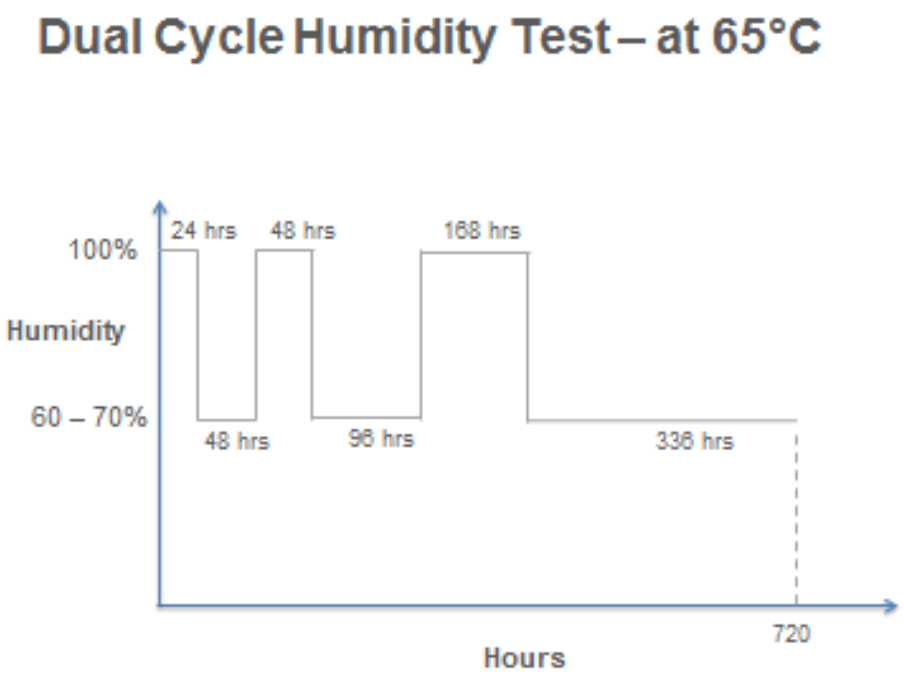
TEST METHOD

1. Eight samples were prepared for each size. Each tubing assembly was comprised of two fittings, one barstock, and one forging, assembled to a 64 mm (2 1/2 in.) length of tubing.
2. Additional sample fitting components and tubing of each size were set aside to comprise a control group for comparing surface structures before and after the CSCC test.
3. Four each of 3/8 inch and 1/2 inch size sample fittings were assembled according to Swagelok tube fitting installation instructions: one and one-quarter turns past finger-tight (TPFT). The other four of each size were assembled one and seven-eighths TPFT.
4. Each sample was pressurized with nitrogen to the test pressure and monitored for leakage for 10 minutes prior to the CSCC test.
5. Samples were placed into a salt spray chamber that utilized substitute ocean water per ASTM D1141.
6. Samples were pressurized with water to the test pressure and held at that pressure throughout the CSCC test.
7. The chamber temperature was elevated to 65°C (149°F) and the following salt spray schedule, derived from SAE J2334 and ASTM B117, was initiated:
    a. continuous salt spray maintained at 65°C for 24 hours
    b. salt spray turned off, 60 % to 70 % relative humidity maintained at 65°C for 48 hours
    c. repeat step a for 48 hours
    d. repeat step b for 96 hours
    e. repeat step a for 168 hours
    f. repeat step b for 336 hours, for a schedule total of 720 hours (see **Figure 1**)
8. Upon completion of the 720 hours, the samples were removed and rinsed in de-ionized water.
9. Each sample was again pressurized with nitrogen to its test pressure and monitored for leakage for 10 minutes.
10. Samples were then disassembled. The components (nut, body, and ferrules) swaged on the tubing were then liquid penetrant examined per ASTM E165 to reveal any cracks.
11. Sample components were then sectioned and metallurgically examined by 100× optical microscope for signs of CSCC.

TEST RESULTS

- All samples (64 ends total) successfully passed 720 hours in the salt spray chamber without loss of pressure.
- All samples successfully passed the pre- and post-salt spray nitrogen gas pressure tests without leakage.
- Liquid penetrant evaluation of the sample components found no evidence of crack formation.
- No evidence of CSCC crack initiation and propagation beyond surface structures of the sample components was observed.

Figure 1: Cyclic humidity corrosion salt spray schedule



This test was 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 D1141: *Standard Practice for the Preparation of Substitute Ocean Water*, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428

ASTM E165-95: *Standard Test Method for Liquid Penetrant Examination*, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428

ASTM B117-95: *Practice for Operating Salt Spray (Fog) Apparatus,* ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428

SAEJ2334: *Cosmetic Corrosion Lab Test*, SAE International, 400 Commonwealth Drive, Warrendale, PA 15096

APPENDIX

Auto Technology Cyclic Corrosion Chamber

Assembled and Pressurized Tube Fittings Installed in Cyclic Salt Spray Chamber

Tubing Data—Engineered Combinations

Scope

This data sheet contains suggested allowable working pressures for assemblies of Swagelok® tube fittings with tubing of diverse materials.

Although matching tubing and fitting materials is common practice for optimal system operation, the performance advantages of Swagelok 316 stainless steel tube fittings enable successful mixed-material combinations, even in severe environments. These advantages include:

- Higher chromium and nickel concentrations than standard 316 stainless steel for enhanced corrosion resistance.
- Superior tube grip achieved with Swagelok's patented hinging-colleting™ back ferrule design that translates axial motion into radial swaging action on the tube, yet operates with a low assembly torque requirement.

Consequently, for example, the combination of Swagelok 316 tube fittings and alloy 254 tubing can provide an economical, corrosion-resistant solution for installations that might be exposed to sea water. As with any mixed-material assembly, pressure ratings for tubing and fittings from different alloys will be governed by the lower material rating.

See the Swagelok *Gaugeable Tube Fittings and Adapter Fittings* catalog (MS-01-140) for more information about Swagelok tube fitting features and performance.

Contents

Tubing Selection 1

Tubing Handling 2

Gas Service 2

Tubing Installation 2

Suggested Allowable Working Pressure Tables

316 SS Tube Fittings with Alloy 254 Tubing 4

316 SS Tube Fittings with Type 904L Tubing 5

316 SS Tube Fittings with UNS C69100 Copper Alloy (Tungum®) Tubing 6

316 SS Tube Fittings with Alloy 825 Tubing 7

Pressure Ratings at Elevated Temperatures 3

Tubing Selection

Proper selection, handling, and installation of tubing, when combined with proper selection of Swagelok® tube fittings, are essential to reliable tubing systems.

The following variables should be considered when ordering tubing for use with Swagelok tube fittings:

- Surface finish
- Material
- Hardness
- Wall thickness.

Tubing Surface Finish

Many ASTM specifications cover the above requirements, but they often are not very detailed on surface finish. For example, ASTM A450, a general tubing specification, reads:

> 11. Straightness and Finish
>
> 11.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. Surface imperfections (Note) may be removed by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed.
>
> **Note:** An imperfection is any discontinuity or irregularity found in the tube.

Tubing Material

Our suggested ordering instructions for each type of tubing are shown under the respective tables.

Tubing Outside Diameter Hardness

The key to selecting proper tubing for use with metal Swagelok tube fittings is that the tubing must be softer than the fitting material. Swagelok tube fittings are designed to work properly with the tubing that is suggested in the ordering instructions.

Swagelok

Tubing Wall Thickness

The accompanying tables show working pressure ratings of tubing in a wide range of wall thicknesses. Allowable pressure ratings are calculated from *S* values for the lower-strength material as specified by ASME B31.3, ASME BPV Section II, Part D, or based on repeated pressure testing of the Swagelok tube fitting with a 4:1 design factor based on hydraulic fluid leakage.

Swagelok tube fittings have been repeatedly tested in both the minimum and maximum wall thicknesses shown.

Swagelok tube fittings are not recommended for tube wall thicknesses outside the ranges shown in the accompanying tables for each size.

Tubing Handling

Good handling practices can greatly reduce scratches on tubing and protect the good surface finish that reliable tube manufacturers supply.

- Tubing should never be dragged out of a tubing rack or across a rough surface.
- Tube cutters or hacksaws should be sharp. Do not take deep cuts with each turn of the cutter or stroke of the saw.
- Tube ends should be deburred. This helps to ensure that the tubing will go all the way through the ferrules without damaging the ferrule sealing edge.

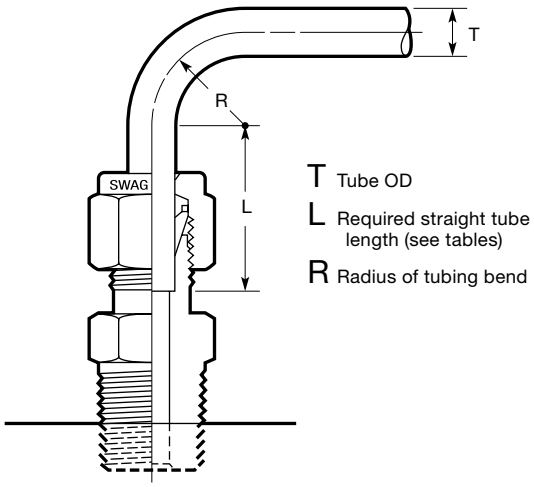
Gas Service

Gases (air, hydrogen, helium, nitrogen, etc.) have very small molecules that can escape through even the most minute leak path. Some surface defects on the tubing can provide such a leak path. As tube outside diameter (OD) increases, so does the likelihood of a scratch or other surface defect interfering with proper sealing.

The most successful connection for gas service will occur if all installation instructions are carefully followed and the heavier wall thicknesses of tubing on the accompanying tables are selected.

A heavy-wall tube resists ferrule action more than a thin-wall tube, allowing the ferrules to coin out minor surface imperfections. A thin-wall tube offers less resistance to ferrule action during installation, reducing the chance of coining out surface defects, such as scratches. Within the applicable suggested allowable working pressure table, select a tube wall thickness whose working pressure is *outside* of the shaded areas.

Tubing Installation



Tubing properly selected and handled, combined with properly installed Swagelok tube fittings, will give you a leak-tight system and provide reliable service in a wide variety of applications.

For maximum assurance of reliable performance, use:

- properly selected and handled high-quality tubing—such as provided by Swagelok
- Swagelok tube fittings assembled in accordance with catalog instructions
- an appropriate tube support system to limit the movement of tubing and fluid system components.

When installing fittings near tube bends, there must be a sufficient straight length of tubing to allow the tube to be bottomed in the Swagelok fitting (see tables).

Fractional, in.	
T **Tube OD**	**L**①
1/16	1/2
1/8	23/32
3/16	3/4
1/4	13/16
5/16	7/8
3/8	15/16
1/2	1 3/16
5/8	1 1/4
3/4	
7/8	1 5/16
1	1 1/2

① Required straight tube length.

Metric, mm	
T **Tube OD**	**L**①
3	19
6	21
8	23
10	25
12	31
14	32
15	
16	
18	
20	34
22	
25	40

Suggested Allowable Working Pressure Tables

Figure and tables are for reference only. No implication is made that these values can be used for design work. Applicable codes and practices in industry should be considered. ASME Codes are the successor to and replacement of ASA Piping Codes.

- All pressures are calculated from equations in ASME B31.3, Process Piping. See factors for calculating working pressures in accordance with ASME B31.1, Power Piping.
- Calculations are based on maximum OD and minimum wall thickness, except as noted in individual tables.

  Example: 1/2 in. OD × 0.035 in. wall alloy 254 tubing purchased to ASTM A269:

  OD Tolerance ± 0.005 in. / Wall Thickness ± 10 %

  Calculations are based on 0.505 in. OD × 0.0315 in. wall tubing.
- No allowance is made for corrosion or erosion.

Pressure Ratings at Elevated Temperatures

Elevated temperature factors were derived from allowable stress in accordance with ASME B31.3 or ASME BPV Section II, Part D.

Table 1—Elevated Temperature Factors

Temperature		Tubing Materials			
°F	°C	Alloy 254	UNS C69100 Temper TF00	Type 904L	Alloy 825
200	93	0.88	1.00	0.82	1.00
300	149	0.79	1.00	0.74	0.95
400	204	0.73	0.96	0.68	0.90
500	260	0.69		0.63	0.87
600	315	0.66		0.58	0.84
700	371	0.64		0.56	0.81
800	426				0.79

To determine allowable working pressure at elevated temperatures, multiply allowable working pressures from Tables 2 through 7 by a factor shown in Table 1.

Example: Alloy 254 1/2 in. OD × 0.065 in. wall at 600°F

1. The allowable working pressure at –20 to 100°F (–28 to 37°C) is 5100 psig (Table 2, page 4).
2. The elevated temperature factor for 600°F (315°C) is 0.66 (Table 1, above):

   5100 psig × 0.66 = 3366 psig

The allowable working pressure for alloy 254 1/2 in. OD × 0.065 in. wall at 600°F is 3366 psig.

316 Stainless Steel Tube Fittings with Alloy 254 Tubing

Swagelok 316 stainless steel tube fittings in 1/4 to 1 in. and 6 to 25 mm sizes may be used with high quality, fully annealed (seamless or welded and drawn) alloy 254 hydraulic tubing.

For welded and drawn tubing, a derating factor must be applied for weld integrity: for double-welded tubing, multiply working pressure by 0.85; for single-welded tubing, multiply working pressure by 0.80.

Table 2—Fractional Sizes

Allowable working pressures are based on repeated pressure testing of the Swagelok tube fitting with a 4:1 design factor based on hydraulic fluid leakage

Tube OD in.	Tube Wall Thickness, in.								Fitting Series	Installation Method	
	0.028	0.035	0.049	0.065	0.083	0.095	0.109	0.120		1 1/4 Turns	Pre-swage
	Working Pressure, psig **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)										
1/4	4000	5100	7500	10 200					400	Yes	Yes
3/8		3300	4800	6 500					600	Yes	Yes
1/2		2600	3700	5 100	6700				800	Yes	Yes
5/8①			4000	5 400	6000	6000			1010	No	Yes
3/4①			3300	4 400	4900	4900	4900		1210	No	Yes
7/8①			2800	3 700	4800	4800	4800		1410	No	Yes
1①				3 300	3600	3600	3600	3600	1610	No	Yes

① Requires a preswage tool or the Swagelok multihead hydraulic swaging unit (MHSU) for installation. See the Swagelok *Gaugeable Tube Fittings and Adapter Fittings* catalog (MS-01-140) for more information.

Table 3—Metric Sizes

Allowable working pressures are based on repeated pressure testing of the Swagelok tube fitting with a 4:1 design factor based on hydraulic fluid leakage

Tube OD mm	Tube Wall Thickness, mm										Fitting Series	Installation Method	
	0.8	1.0	1.2	1.5	1.8	2.0	2.2	2.5	2.8	3.0		1 1/4 Turns	Pre-swage
	Working Pressure, bar **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)												
6	310	420	540	710							6M0	Yes	Yes
8		310	390	520							8M0	Yes	Yes
10		240	300	400							10M0	Yes	Yes
12		200	250	330	410	470					12M0	Yes	Yes
18①			210	280	320	320	320				18M0	No	Yes
20①			190	250	290	290	290				20M0	No	Yes
22①			170	220	260	260	260				22M0	No	Yes
25①					240	240	240	240	240	240	25M0	No	Yes

① Requires a preswage tool or the Swagelok multihead hydraulic swaging unit (MHSU) for installation. See the Swagelok *Gaugeable Tube Fittings and Adapter Fittings* catalog (MS-01-140) for more information.

Suggested Ordering Information

High-quality, fully annealed seamless or welded and drawn alloy 254 hydraulic tubing, ASTM A269 or ASTM A213, or equivalent. Hardness not to exceed 96 HRB. Tubing to be free of scratches, suitable for bending and flaring.

316 Stainless Steel Tube Fittings with Type 904L Stainless Steel Tubing

Swagelok 316 stainless steel tube fittings in 1/4 to 1 in. and 6 to 25 mm sizes may be used with high quality, seamless Type 904L stainless steel hydraulic tubing.

Table 4—Fractional Sizes

Allowable working pressures are based on equations from ASME B31.3 and B31.1 for a maximum *S* value of 20 000 psi (137.8 MPa).

Tube OD in.	Tube Wall Thickness, in.								Fitting Series
	0.028	0.035	0.049	0.065	0.083	0.095	0.109	0.120	
	Working Pressure, psig **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)								
1/4	4000	5100	7500	10 200					400
5/16		4000	5800	8 000					500
3/8		3300	4800	6 500	7500				600
1/2		2600	3700	5 100	6700				800
5/8			2900	4 000	5200	6000			1010
3/4			2400	3 300	4200	4900	5800		1210
7/8			2000	2 800	3600	4200	4800		1410
1				2 400	3100	3600	4200	4700	1610

Table 5—Metric Sizes

Allowable working pressures are based on equations from ASME B31.3 and B31.1 for a maximum *S* value of 137.8 MPa (20 000 psi).

Tube OD mm	Tube Wall Thickness, mm										Fitting Series
	0.8	1.0	1.2	1.5	1.8	2.0	2.2	2.5	2.8	3.0	
	Working Pressure, bar **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)										
6	310	420	540	710							6M0
8		310	390	520							8M0
10		240	300	400	510	580					10M0
12		200	250	330	410	470					12M0
14		160	200	270	340	380	430				14M0
15		150	190	250	310	360	400				15M0
16			170	230	290	330	370	400			16M0
18			150	200	260	290	320	370			18M0
20			140	180	230	260	290	330	380		20M0
22			140	160	200	230	260	300	340		22M0
25					180	200	230	260	290	320	25M0

Suggested Ordering Information

High quality, fully annealed, Type 904L, seamless hydraulic tubing, ASTM 269 and ASTM B677 or equivalent. Hardness not to exceed 90 HRB or 200 HV. Tubing to be free of scratches, suitable for bending and flaring.

316 Stainless Steel Tube Fittings with UNS C69100 Copper Alloy (Tungum) Tubing

Swagelok 316 stainless steel tube fittings in 1/4 to 1 in. and 6 to 25 mm sizes may be used with high-quality, precipitation-hardened, temper TF00, seamless UNS C69100, ASTM B706 copper alloy hydraulic tubing.

Table 6—Fractional Sizes

Allowable working pressures are calculated from an *S* value of 20 000 psi (137.8 MPa) for precipitation hardened, temper TF00, seamless UNS C69100, ASTM B706 copper alloy (Tungum or equivalent) tubing at –20 to 100°F (–28 to 37°C) as listed in ASME B31.3.

Tube OD in.	**Tube Wall Thickness,** in.							**Fitting Series**
	0.028	**0.035**	**0.049**	**0.065**	**0.083**	**0.109**	**0.120**	
	Working Pressure, psig **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)							
1/4	4000	5100	7500	10 200				400
5/16		4000	5800	8 000				600
3/8		3300	4800	6 500				800
1/2		2600	3700	5 100	6700			1010
5/8			2900	4 000	5200			1210
3/4			2400	3 300	4200	5800		1410
1				2 400	3100	4200	4700	1610

Table 7—Metric Sizes

Allowable working pressures are calculated from an *S* value of 137.8 MPa (20 000 psi) for precipitation hardened, temper TF00, seamless UNS C69100, ASTM B706 copper alloy (Tungum or equivalent) tubing at –28 to 37°C (–20 to 100°F) as listed in ASME B31.3.

Tube OD mm	**Tube Wall Thickness,** mm								**Fitting Series**
	0.8	**1.0**	**1.2**	**1.5**	**2.0**	**2.2**	**2.5**	**3.0**	
	Working Pressure, bar **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)								
6	310	420	540						6M0
8		310	390	520					8M0
10		240	300	400	580				10M0
12		200	250	330	470				12M0
14		160	200	270	380	430			14M0
16			170	230	330	370	400		16M0
20				180	260	290	330		20M0
25					200	230	260	320	25M0

Suggested Ordering Information

High-quality, precipitation-hardened, temper TF00, seamless copper alloy tubing, UNS C69100, ASTM B706 or equivalent. Hardness not to exceed 90 HRB. Tubing to be free of scratches, suitable for bending and flaring.

316 Stainless Steel Tube Fittings with Alloy 825 Tubing

Swagelok 316 stainless steel tube fittings in 1/4 to 1 in. and 6 to 25 mm sizes may be used with high quality, seamless Alloy 825 hydraulic tubing.

Table 8—Fractional Sizes

Allowable working pressures are based on repeated pressure testing of the Swagelok tube fitting with a 4:1 design factor based on hydraulic fluid leakage.

Tube OD in.	**Tube Wall Thickness,** in.						**Fitting Series**
	0.035	**0.049**	**0.065**	**0.083**	**0.095**	**0.109**	
	Working Pressure, psig **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)						
1/4	6400	9300	10200				400
3/8	4100	5900	7500				600
1/2	3000	4300	5900				800
3/4			3800	4900	5800		1210
1			2800	3600	4200	4200	1610

Table 9—Metric Sizes

Allowable working pressures are based on repeated pressure testing of the Swagelok tube fitting with a 4:1 design factor based on hydraulic fluid leakage.

Tube OD mm	**Tube Wall Thickness,** mm								**Fitting Series**
	0.8	**1.0**	**1.2**	**1.5**	**1.8**	**2.0**	**2.2**	**2.5**	
	Working Pressure, bar **Note:** For gas service, select a tube wall thickness outside of the shaded area. (See **Gas Service,** page 2.)								
6	410	530	660						6M0
10		300	370	480					10M0
12		250	300	390	470				12M0
18				240	300	340	370	370	18M0
25						240	260	300	25M0

Suggested Ordering Information

High-quality, fully annealed seamless alloy 825 tubing, ASTM B163, ASTM B423, or equivalent. Fully annealed welded alloy 825 tubing, ASTM B704, class 1 or equivalent. Hardness not to exceed HR15T90 or 201 HV. Tubing to be free of scratches, suitable for bending and flaring. Wall thickness tolerances not to exceed ± 10 %.

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.

September 2015, R2
MS-06-117

Swagelok