CCSi TechNotes: Stainless Steel

CCSi presents this information about Stainless as a general overview of the types of stainless steel that are used in manufacturing our products. It is not intended as a definitive guide! If more comprehensive information is required, please techinfo@ccsi-inc.com.

Stainless Steels: Chromium-Nickel Types 302, 304, 304L, & 305

GENERAL PROPERTIES

Types 302, 304, 304L, and 305 stainless steels are variations of the 18% chromium / 8% nickel austenitic alloy, the most familiar and most frequently used alloy in the stainless steel family.

These alloys may be considered for a wide variety of applications where one or more of the following properties are important:

- Resistance to corrosion;
- Prevention of product contamination;
- Resistance to oxidation;
- Ease of fabrication;
- Excellent formability;
- Beauty of appearance;
- Ease of cleaning;
- High strength with low weight;
- Good strength and toughness at cryogenic temperatures;
- Ready availability of a wide range of product forms;

Each alloy represents an excellent combination of corrosion resistance and fabricability. This combination of properties is the reason for the extensive use of these alloys which represent nearly one half of the total U.S. stainless steel production.

Type 304 represents the largest volume followed by Type 304L. Types 302 and 305 are used in smaller quantities. The 18-8 stainless steels, principally Types 304 and 304L, are available in a wide range of product forms including sheet, strip, foil and plate. The alloys are covered by a variety of specifications and codes relating to, or regulating, construction or use of equipment manufactured from these alloys for specific conditions. Food and beverage,sanitary, cryogenic, and pressure-containing applications are examples.

Past users of Type 302 are generally now using Type 304 since AOD technology has made lower carbon levels more easily attainable and economical. There are instances, such as in temper rolled products, when Type 302 is preferred over Type 304 since the higher carbon permits meeting of yield and tensile strength requirements while maintaining a higher level of ductility (elongation) versus that of the lower carbon T304.

Type 304L is used for welded products which might be exposed to conditions which could cause intergranular corrosion in service. Type 305 is used for applications requiring a low rate of work hardening during severe cold forming operations such as deep drawing. Other less frequently specified 18-8 stainless steel grades, such as Type 304N and Type 304LN are also available.

CHEMICAL COMPOSITION

Chemistries per ASTM A240 and ASME SA-240:

Element	Percentage by Weight: Maximum Unless Range is Specified			
	302	304	304L	305
Carbon	00.150	00.080	00.030	00.120
Manganese	02.000	02.000	02.000	02.000
Phosphorus	00.045	00.045	00.045	00.045
Sulfur	00.030	00.030	00.030	00.030
Silicon	00.750	00.750	00.750	00.750
Chromium	17.000	18.000	18.000	17.000
	19.000	20.000	20.000	19.000
Nickel	08.000	08.000	08.000	10.500
	10.000	10.500	12.000	13.000
Nitrogen	0.10	0.10	0.10	--

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RESISTANCE TO CORROSION: General Corrosion

The Types 302, 304, 304L and 305 austenitic stainless steels provide useful resistance to corrosion on a wide range of moderately oxidizing to moderately reducing environments. The alloys are used widely in equipment and utensils for processing and handling of food, beverages and dairy products. Heat exchangers, piping, tanks and other process equipment in contact with fresh water also utilize these alloys.

Building facades and other architectural and structural applications exposed to non-marine atmospheres also heavily utilize the 18-8 alloys. In addition, a large variety of applications involve household and industrial chemicals.

The 18 to 19 percent of chromium which these alloys contain provides resistance to oxidizing environments such as dilute nitric acid, as illustrated by data for Type 304 below:

% Nitric Acid	Temperature °F (°C)	Corrosion Rate Mils/Yr (mm/a)
10	300 (149)	5.0 (0.13)
20	300 (149)	10.1 (0.25)
30	300 (149)	17.0 (0.43)

Other laboratory data for Types 304 and 304L in the table below illustrate that these alloys are also resistant to moderately aggressive organic acids such as acetic, and reducing acids such as phosphoric. The 9 to 11 percent of nickel contained by these 18-8 alloys assists in providing resistance to moderately reducing environments.

The more highly reducing environments such as boiling dilute hydrochloric and sulfuric acids are shown to be too aggressive for these materials. Boiling 50 percent caustic is likewise too aggressive.

General Corrosion in Boiling Chemicals

Boiling Environment	Material	Type 304 [2]		Type 304L	
		Corrosion Rate			
		Mils/Yr	(mm/a)	Mils/Yr	(mm/a)
20% Acetic Acid	Base Metal	0.10	(<0.01)	0.10	(<0.01)
	Welded [1]	1.00	(0.03)	0.10	(<0.01)
45% Formic Acid	Base Metal	55.00	(1.40)	15.00	(1.40)
	Welded [1]	52.00	(1.30)	19.00	(1.50)
10% Sulfamic Acid	Base Metal	144.00	(3.70)	50.00	(1.30)
	Welded [1]	144.00	(3.70)	57.00	(1.40)
1% Hydrochloric Acid	Base Metal	98.00	(2.50)	85.00	(2.20)
	Welded [1]	112.00	(2.80)	143.00	(3.60)
20% Phosphoric Acid	Base Metal	<0.10	(<0.03)	—	—
	Welded [1]	<0.10	(<0.03)	—	—
65% Nitric Acid	Base Metal	9.20	(0.20)	8.90	(0.20)
	Welded [1]	9.40	(0.20)	7.40	(0.20)
10% Sulfuric Acid	Base Metal	445.00	(11.30)	662.00	(16.80)
	Welded [1]	494.00	(12.50)	879.00	(22.30)
50% Sodium Hydroxide	Base Metal	118.00	(3.00)	71.00	(1.80)
	Welded [1]	130.00	(3.30)	87.00	(2.20)

[1] Autogenous weld on base metal sample.
[2] Types 302 and 305 exhibit similar performance.

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In some cases, the low carbon Type 304L alloy may show a lower corrosion rate than the higher carbon Type 304 alloy. The data for formic acid, sulfamic acid and sodium hydroxide illustrate this. Otherwise, the Types 302, 304, 304L and 305 alloys may be considered to perform equally in most corrosive environments.

A notable exception is in environments sufficiently corrosive to cause intergranular corrosion of welds and heat-affected zones on susceptible alloys. The Type 304L alloy is preferred for use in such media in the welded condition since the low carbon level enhances resistance to intergranular corrosion.

RESISTANCE TO CORROSION: Intergranular Corrosion

Exposure of the 18-8 austenitic stainless steels to temperatures in the 800 F° to 1500 F° (427 C° to 816 C°) range may cause precipitation of chromium carbides in grain boundaries. Such steels are "sensitized" and subject to intergranular corrosion when exposed to aggressive environments. The carbon content of Types 302, 304, and 305 may allow sensitization to occur from thermal conditions experienced by autogenous welds and heat-affected zones of welds.

For this reason, the low carbon Type 304L alloy is preferred for applications in which the material is put into service in the as-welded condition. Low carbon content extends the time necessary to precipitate a harmful level of chromium carbides, but does not eliminate the precipitation reaction for material held for long times in the precipitation temperature range.

Intergranular Corrosion Tests						
ASTM A262 Evaluation Test	Material	Type 302, 304, 305		Type 304L		
		Corrosion Rate				
		Mils/Yr	(mm/a)	Mils/Yr	(mm/a)	
ASTM A262, Practice B	Base Metal	20	(0.5)	20	(0.5)	
	Welded	23 [1]	(0.6) [1]	20	(0.5)	
ASTM A262, Practice E	Base Metal	[2]		[4]		
	Welded	[3]		[4]		
ASTM A262, Practice A	Base Metal	[5]		[5]		
	Welded	[6]		[5]		

[1] Intergranular Corrosion.
[2] No Fissures on Bend.
[3] Some Fissures on Weld (unacceptable).
[4] No Fissures.
[5] Step Structure.
[5] Ditched (unacceptable).

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RESISTANCE TO CORROSION: Stress Corrosion Cracking

The Type 302, 304, 304L and 305 alloys are the most susceptible of the austenitic stainless steels to stress corrosion cracking (SCC) in halides because of their relatively low nickel content. Conditions which cause SCC are:

- presence of halide ions (generally chloride),
- residual tensile stresses, and
- temperatures in excess of about 120°F (49°C).

Stresses may result from cold deformation of the alloy during forming, or by roller expanding tubes into tubesheets, or by welding operations which produce stresses from the thermal cycles used. Stress levels may be reduced by annealing or stress relieving heat treatments following cold deformation, thereby reducing sensitivity to halide SCC. The low carbon Type 304L material is the better choice for service in the stress relieved condition in environments which might cause intergranular corrosion.

Halide (Chloride) Stress Corrosion Tests		
Test	Material	U-Bend: Highly Stressed Samples
		Type 302, 304, 304L, 305
42% Magnesium Chloride [1]	Base Metal	Cracked: 01 to 20 hours
	Welded	Cracked: .5 to 21 hours
33% Lithium Chloride [1]	Base Metal	Cracked: 24 to 96 hours
	Welded	Cracked: 18 to 90 hours
26% Sodium Chloride [1]	Base Metal	Cracked: 142 to 1004 hours
	Welded	Cracked: 300 to 500 hours
40% Calcium Chloride [1]	Base Metal	Cracked: 144 hours
	Welded	–
Ambient Temperature Seacoast Exposure	Base Metal	No Cracking
	Welded	No Cracking

[1] Chemicals were brought to their boiling point.

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The above data illustrate that various hot chloride solutions may cause failure after differing lengths of time. The important thing to note is that failure eventually occurs under these conditions of chloride presence, high stresses and elevated temperatures.

RESISTANCE TO CORROSION: Pitting / Crevice Corrosion

The 18-8 alloys have been used very successfully in fresh waters containing low levels of chloride ion. Although Type 304 tubing has been used in power plant surface condenser cooling water with as much as 1000 ppm chloride, this performance can only result from careful cleaning of the tubes during use and care to avoid stagnant waters from remaining in contact with the tube. Generally, 100 ppm chloride is considered to be the limit for the 18-8 alloys, particularly if crevices are present.

Higher levels of chloride might cause crevice corrosion and pitting. For the more severe conditions of higher chloride levels, lower pH and/or higher temperatures, alloys with higher molybdenum content such as Type 316 or AL-6XN® alloy should be considered. Interestingly, Types 304 and 304L stainless steels pass the 100 hour, 5 percent neutral salt spray test (ASTM B117) with no rusting or staining of samples.

However, Type 304 building exteriors exposed to salt mists from the ocean are prone to pitting and crevice corrosion accompanied by severe discoloration. The 18-8 alloys are not recommended for exposure to marine environments.

PHYSICAL PROPERTIES: Density

0.285 lb / in^3 (7.90 g / cm^3)

PHYSICAL PROPERTIES: Modulus of Elasticity in Tension

29 x 10^6 psi (200 GPa)

PHYSICAL PROPERTIES: Linear Coefficient of Thermal Expansion

Linear Coefficient of Thermal Expansion			
Temperature		Coeficients	
F°	C°	in/in/F°	cm/cm/C°
68 - 212	20 - 100	9.2 x 10^{-6}	16.6 x 10^{-6}
68 - 1600	20 - 870	11.0 x 10^{-6}	19.8 x 10^{-6}

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PHYSICAL PROPERTIES: Thermal Conductivity

Thermal Conductivity			
Temperature Range			
F°	C°	Btu/hr · ft · F°	W/m · K°
212	100	09.4	16.3
932	500	12.4	21.4

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The overall heat transfer coefficient of metals is determined by factors in addition to the thermal conductivity of the metal. The ability of the 18-8 stainless grades to maintain clean surfaces often allows better heat transfer than other metals having higher thermal conductivity.

PHYSICAL PROPERTIES: Specific Heat

Specific Heat			
F°	C°	Btu / lb / F°	J / kg · K°
32 — 212	0 — 100	0.12	500

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PHYSICAL PROPERTIES: Magnetic Permeability

The 18-8 alloys are generally non-magnetic in the annealed condition with magnetic permeability values typically less than 1.02 at 200H. As illustrated below, permeability values will vary with composition and will increase with cold work. Type 305 with the highest nickel content is the most stable of these austenitic alloys and will have the lowest permeability when cold worked. The following data are illustrative:

Magnetic Permeability				
% Cold Work	302	304	304L	305
0	1.004	1.005	1.015	1.002
10	1.039	1.009	1.064	1.003
30	1.414	1.163	3.235	1.004
50	3.214	2.291	8.480	1.008

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Credits:

Author: Allegheny Ludlum Corporation, Pittsburgh, Pennsylvania USA.

Excerpted from the Allegheny Ludlum Technical Data Blue Sheet, *Stainless Steels Chromium-Nickel Types 302 (S30200), 304 (S30400), 304L (S30403), 305 (S30500)*. Modified in content and format for presentation.