Specs: 304

Chromium - Nickel

General Properties

Alloys 304 (S30400), 304L (S30403), and 304H (S30409) stainless steels are variations of the 18 percent chromium – 8 percent 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. The 18-8 stainless steels, principally Alloys 304, 304L, and 304H, are available in a wide range of product forms including sheet, strip, 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.

Alloy 304 is the standard alloy since AOD technology has made lower carbon levels more easily attainable and economical. Alloy 304L is used for welded products which might be exposed to conditions which could cause intergranular corrosion in service.

Alloy 304H is a modification of Alloy 304 in which the carbon content is controlled to a range of 0.04-0.10 to provide improved high temperature strength to parts exposed to temperatures above 800°F.

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Chemical Composition

Chemistries per ASTM A240 and ASME SA-240:

Element	***Percentage by Weight Maximum Unless Range is Specified***		
	304	***304L***	***304H***
Carbon	0.08	0.030	0.04 – 0.01
Manganese	2.00	2.00	2.00
Phosphorus	0.045	0.045	0.045
Sulfur	0.030	0.030	0.030
Silicon	0.75	0.75	0.75
Chromium	18.00 20.00	18.00 20.00	18.00 20.00
Nickel	8.00 10.50	8.00 12.00	8.0 10.5
Nitrogen	0.10	0.10	0.10

Data are typical and should not be construed as maximum or minimum values for specification or for final design. Data on any particular piece of material may vary from those shown herein.

Resistance to Corrosion

General Corrosion

The Alloys 304, 304L, and 304H 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.

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 Alloy 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)

Alloys 304, 304L, and 304H 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.

In some cases, the low carbon Alloy 304L may show a lower corrosion rate than the higher carbon Alloy 304. The data for formic acid, sulfamic acid, and sodium hydroxide illustrate this. Otherwise, the Alloys 304, 304L, and 304H 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 Alloy 304L is preferred for use in such media in the welded condition since the low carbon level enhances resistance to intergranular 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 Alloy 304 may allow sensitization to occur from thermal conditions experienced by autogenous welds and heat-affected zones of welds. For this reason, the low carbon Alloy 304L 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	***Corrosion Rate, Mils/Yr (mm/a)***	
	304	***304L***
Practice E Base Metal Welded	 No Fissures on Bend Some Fissures on Weld (unacceptable)	 No fissures No fissures
Practice A Base Metal Welded	 Step Structure Ditched (unacceptable)	 Step Structure Step Structure

Stress Corrosion Cracking

The Alloys 304, 304L, and 304H 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: (1) presence of halide ions (generally chloride), (2) residual tensile stresses, and (3) 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 tube sheets 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 Alloy 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	***U-Bend (Highly Stressed) Samples***	
	304	
33% Lithium Chloride, Boiling	Base Metal Welded	Cracked, 14 to 96 hours Cracked, 18 to 90 hours
26% Sodium Chloride, Boiling	Base Metal Welded	Cracked, 142 to 1004 hours Cracked, 300 to 500 hours
40% Calcium Chloride, Boiling	Base Metal	Cracked, 144 hours --
Ambient Temperature Seacoast Exposure	Base Metal Welded	No Cracking No Cracking

Pitting/Crevice Corrosion

The 18-8 alloys have been used very successfully in fresh waters containing low levels of chloride ion. 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 Alloy 316 should be considered. The 18-8 alloys are not recommended for exposure to marine environments.

Physical Properties

Density: 0.285 lb/in^3 (7.90 g/cm3)

Modulus of Elasticity in Tension: 29 x 10^6 psi (200 GPa)

Linear Coefficient of Thermal Expansion:

Temperature Range		***Coefficients***	
°F	***°C***	***in/in/°F***	***cm/cm/°C***
68 – 212	20 – 100	9.2 x 10^{-6}	16.6 x 10^{-6}
18 – 1600	20 – 870	11.0 x 10^{-6}	19.8 x 10^{-6}

Thermal Conductivity:

Temperature Range		***Btu/hr•ft•°F***	***W/m•K***
°F	***°C***		
212	100	9.4	16.3
932	500	12.4	21.4

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.

Specific Heat:

°F	***°C***	***Btu/lb/°F***	***J/kg•K***
32 – 212	0 – 100	0.12	500

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. Permeability values will vary with composition and will increase with cold work.

Percent Cold Work	Magnetic Permeability	
	304	304L
0	1.005	1.015
10	1.009	1.064
30	1.163	3.235
50	2.291	8.480

Mechanical Properties

Room Temperature Mechanical Properties

Minimum mechanical properties for annealed Alloys 304 and 304L austenitic stainless steel plate as required by ASTM specifications A240 and ASME specification SA-240 are shown below.

Property	Minimum Mechanical Properties Required by ASTM A240 & ASME SA-240		
	304	304L	304H
0.2% Offset Yield Strength, psi MPa	 30,000 205	 25,000 170	 30,000 205
Ultimate Tensile Strength, psi MPa	 75,000 515	 70,000 485	 75,000 515
Percent Elongation in 2 in. or 51 mm	40.0	40.0	40.0
Hardness, Max., Brinell R_B	 201 92	 201 92	 201 92

Low and Elevated Temperature Properties

Typical short time tensile property data for low and elevated temperatures are shown below. At temperatures of 1000°F (538°C) or higher, creep and stress rupture become considerations. Typical creep and stress rupture data are also shown below.

Test Temperature		0.2% Yield Strength		Tensile Strength		Elongation
°F	°C	psi	(MPa)	psi	(MPa)	Percent in 2" or 51 mm
-423	-253	100,000	690	250,000	1725	25
-320	-196	70,000	485	230,000	1585	35
-100	-79	50,000	354	150,000	1035	50
70	21	35,000	240	90,000	620	60
400	205	23,000	160	70,000	485	50
800	427	19,000	130	66,000	455	43
1200	650	15,500	105	48,000	330	34
1500	815	13,000	90	23,000	160	46

Impact Resistance

The annealed austenitic stainless steels maintain high impact resistance even at cryogenic temperatures, a property which, in combination with their low temperature strength and fabricability, has led to their use in handling liquified natural gas and other cryogenic environments. Typical Charpy V-notch impact data are shown below.

Temperature		Charpy V-Notch Energy Absorbed	
°F	°C	Foot – pounds	Joules
75	23	150	200
-320	-196	85	115
-425	-254	85	115

Fatigue Strength

The fatigue strength or endurance limit is the maximum stress below which material is unlikely to fail in 10 million cycles in air environment. The fatigue strength for austenitic stainless steels, as a group, is typically about 35 percent of the tensile strength. Substantial variability in service results is experienced since additional variables influence fatigue strength. As examples – increased smoothness of surface improves strength, increased corrosivity of service environment decreases strength.

Welding

The austenitic stainless steels are considered to be the most weldable of the high-alloy steels and can be welded by all fusion and resistance welding processes. The Alloys 304 and 304L are typical of the austenitic stainless steels.

Two important considerations in producing weld joints in the austenitic stainless steels are: 1) preservation of corrosion resistance, and 2) avoidance of cracking.

A temperature gradient is produced in the material being welded which ranges from above the melting temperature in the molten pool to ambient temperature at some distance from the weld. The higher the carbon level of the material being welded, the greater the likelihood that the welding thermal cycle will result in the chromium carbide precipitation which is detrimental to corrosion resistance. To provide material at the best level of corrosion resistance, low carbon material (Alloy 304L) should be used for material put in service in the welded condition. Alternately, full annealing dissolves the chromium carbide and restores a high level of corrosion resistance to the standard carbon content materials.

Weld metal with a fully austenitic structure is more susceptible to cracking during the welding operation. For this reason, Alloys 304 and 304L are designed to resolidify with a small amount of ferrite to minimize cracking susceptibility.

Alloy 309 (23% Cr – 13.5% Ni) or nickel-base filler metals are used in joining the 18-8 austenitic alloys to carbon steel.

Heat Treatment

The austenitic stainless steels are heat treated to remove the effects of cold forming or to dissolve precipitated chromium carbides. The surest heat treatment to accomplish both requirements is the solution anneal which is conducted in the 1850°F to 2050°F range (1010°C to 1121°C). Cooling from the anneal temperature should be at sufficiently high rates through 1500-800°F (816°C - 427°C) to avoid reprecipitation of chromium carbides.

These materials cannot be hardened by heat treatment.

Cleaning

Despite their corrosion resistance, stainless steels need care in fabrication and use to maintain their surface appearance even under normal conditions of service.

In welding, inert gas processes are used. Scale or slag that forms from welding processes is removed with a stainless steel wire brush. Normal carbon steel wire brushes will leave carbon steel particles in the surface which will eventually produce surface rusting. For more severe applications, welded areas should be treated with a descaling solution such as a mixture of nitric and hydrofluoric acids, and these should be subsequently washed off.

For material exposed inland, light industrial, or milder service, minimum maintenance is required. Only sheltered areas need occasional washing with a stream of pressurized water. In heavy industrial areas, frequent washing is advisable to remove dirt deposits which might eventually cause corrosion and impair the surface appearance of the stainless steel.

Stubborn spots and deposits like burned-on food can be removed by scrubbing with a non-abrasive cleaner and fiber brush, a sponge, or pad of stainless steel wool. The stainless steel wool will leave a permanent mark on smooth stainless steel surfaces.

Many of these uses of stainless steel involve cleaning or sterilizing on a regular basis. Equipment is cleaned with specially designed caustic soda, organic solvent, or acid solutions such as phosphoric or sulfamic acid (strongly reducing acids such as hydrofluoric or hydrochloric may be harmful to these stainless steels).

Cleaning solutions need to be drained and stainless steel surfaces rinsed thoroughly with fresh water.

Design can aid cleanability. Equipment with rounded corners, fillets, and absence of crevices facilitates cleaning as do smooth ground welds and polished surfaces.