New Castle
Stainless Plate, LLC

Type 2304

UNS S32304

General Properties

2304 is a low-alloyed, general purpose duplex stainless steel combining the most desirable properties of both ferritic and austenitic steels. Its high mechanical strength is similar to that of other duplex grades and its good corrosion resistance is on par with that of most standard austenitic stainless steel grades. These properties can be combined to achieve an optimal design with respect to strength, maintenance, durability and long-term cost efficiency.

Plate Product Sizes

Plate product is available up to 2 inches thick and up to 120 inches wide depending on the thickness.

Chemical Composition

The typical chemical composition is shown in Table 1.

Mechanical and Physical Properties

2304 combines high tensile and impact strength with a low coefficient of thermal expansion and high thermal conductivity. These properties are suitable for many structural and mechanical components. 2304 is not recommended for applications which require long exposures to temperatures in excess of 570°F (300°C) because of the increased risk of alpha prime precipitation and a reduction in toughness. The data listed in this brochure are typical for wrought products and should not be regarded as a maximum or minimum value unless specifically stated.

Design Features

- High strength
- Good resistance to pitting, crevice and general corrosion
- High resistance to stress corrosion cracking
- Low thermal expansion
- High thermal conductivity
- Good weldability and workability
- High energy absorption

Applications

- General-purpose applications and environments
- Buildings, bridges, and storage construction
- Storage tanks
- Evaporators
- Water treatment
- Pulp and paper equipment
- Structural members
- Heat Exchangers

Chemical Composition (wt%) *Table 1*

	C	Mn	Cr	Ni	Mo	N	Other
Typical	0.02	1.2	22.7	4.7	0.1	0.02	
UNS S31600	≤0.030	≤2.50	21.50-24.50	3.00-5.50	≤0.6	≤0.20	

Microstructure

The balanced chemical composition of 2304 results in a microstructure containing approximately equal amounts of ferrite and austenite after annealing at a temperature of about 1920F/1050C. Due to its relatively low alloying content, 2304 is less prone to precipitation of intermetallic phases than other duplex steels.

Atmospheric corrosion

A steel's resistance to atmospheric corrosion is strongly linked to its resistance to uniform corrosion and localized corrosion such as pitting and crevice corrosion. Since 2304 shows good resistance to these types of corrosion, it may be assumed that the resistance to atmospheric corrosion is good. Accordingly, 2304 should be sufficiently resistant in most environments.

Stress corrosion cracking

Like all duplex steels, 2304 shows good resistance to chloride-induced stress corrosion cracking (SCC). Many test methods are used to rank the different steel grades with respect to their resistance to SCC. One such test method is the U-bend test according to MTI Manual no. 3, in which the specimens are exposed to 3M magnesium chloride (MgCl2) solution at 212F (100C) for 500 hours. The U-bending was performed both longitudinal and transverse to the rolling direction. The results are shown in Table 4.

Intergranular corrosion

Due to its duplex microstructure 2304 offers very good resistance to intergranular corrosion. Duplex stainless steels are less susceptible to this type of corrosion than austenitic steels.

Mechanical Properties per ASTM A240 *Table 2*

	Typical	2304
Yield Strength $R_{p0.2}$ (KSI)	70	58 min
Tensile Strength R_m (KSI)	98	87 min
Elongation (%)	38	25 min
Hardness (Rockwell C)	20	32 max

Physical Properties ***Table 3***

	Typical
Density (lb/in^3)	0.282
Modulus of Elasticity (psi)	$29.0x10^6$
Coefficient of Thermal Expansion 68-212°F [μin/(in*°F)]	7.2
Thermal Conductivity [BTU/(hr*°F)]	8.7
Thermal Capacity [BTU/(lbm*°F)]	0.119
Electrical Resistivity (μΩ*in)	31.5

Corrosion performance of stainless steels

Table 5 compares the performance of Type 2304 with other stainless steels in a variety of common corrosive environments. The table shows the lowest temperature at which the corrosion rate exceeds 5 mpy. All testing was done in accordance with the requirements of the Materials Technology Institute of the Chemical Process Industries (MTI).

Stress Corrosion Cracking Resistance *Table 4*

Grade	Boiling 42% $MgCl_2$	Wick Test	Boiling 25% NaCl
2304	**F**	**P**	**P**
254SMO	F	P	P
Type 316L	F	F	F
Type 317L	F	F	F
Alloy 904L	F	P or F	P or F
Alloy 20	F	P	P

(P=Pass, F=Fail)

Lowest Temperature (°F) at Which the Corrosion Rate Exceeds 5 mpy

Corrosion Environment	654 SMO®	254 SMO®	904L	Type 316L (2.7 Mo)	Type 304	2507	2205 Code Plus Two®	2304
0.2% Hydrochloric Acid	>Boiling	>Boiling	>Boiling	>Boiling	**>Boiling**	>Boiling	>Boiling	>Boiling
1% Hydrochloric Acid	203	158	122	86	**86p**	>Boiling	185	131
10% Sulfuric Acid	158	140	140	122	—	167	140	149
60% Sulfuric Acid	104	104	185	<54	—	<57	<59	<<55
96% Sulfuric Acid	86	68	95	113	—	86	77	59
85% Phosphoric Acid	194	230	248	203	**176**	203	194	203
10% Nitric Acid	>Boiling	>Boiling	>Boiling	>Boiling	**>Boiling**	>Boiling	>Boiling	>Boiling
65% Nitric Acid	221	212	212	212	**212**	230	221	203
80% Acetic Acid	>Boiling	>Boiling	>Boiling	>Boiling	**212p**	>Boiling	>Boiling	>Boiling
50% Formic Acid	158	212	212p	104	**≤50**	194	194	59
50% Sodium Hydroxide	275	239	Boiling	194	**185**	230	194	203
83% Phosphoric Acid + 2% Hydrofluoric Acid	185	194	248	149	**113**	140	122	95
60% Nitric Acid + 2% Hydrochloric Acid	>140	140	>140	>140	**>140**	>140	>140	>140
50% Acetic Acid + 50% Acetic Anhydride	>Boiling	>Boiling	>Boiling	248	**>Boiling**	230	212	194
1% Hydrochloric Acid + 0.3% Ferric Chloride	>Boiling, p	203ps	140ps	77p	**68p**	203ps	113ps	68p
10% Sulfuric Acid + 2000ppm Cl^- + N_2	149	104	131	77	—	122	95	<55
10% Sulfuric Acid + 2000ppm Cl^- + SO_2	167	140	122	<<59p	—	104	<59	<<50
WPA1, High Cl^- Content	203	176	122	≤50	**<<50**	203	113	86
WPA2, High F^- Content	176	140	95	≤50	**<<50**	167	140	95

ps = pitting can occur
ps = pitting/crevice corrosion can occur

WPA	P_2O_5	Cl^-	F^-	H_2SO_4	Fe_2O_3	Al_2O_3	SiO_2	CaO	MgO
1	54	0.20	0.50	4.0	0.30	0.20	0.10	0.20	0.70
2	54	0.02	2.0	4.0	0.30	0.20	0.10	0.20	0.70

Fabrication

Hot Forming

Hot forming is performed in the temperature range 2000-1650°F (1100-900°C) and should be followed by solution annealing and a rapid air or water quench. 2304 has low strength at these high temperatures and is readily formed.

Cold Forming

Due to the high yield strength of duplex stainless steel, higher forces are required when compared to cold forming austenitic stainless steels. 2304 is suitable for most forming operations used in stainless steel fabrication. However, due to the grade's higher mechanical strength and lower toughness, operations such as deep drawing, stretch forming and spinning are more difficult to perform than with austenitic steel. The grade's high strength, may give rise to a relatively high spring back.

Heat treatment

2304 is solution annealed typically within the range of 1750-1950°F (954-1065°C). Rapid cooling is recommended after annealing.

Machining

2304 has shown good machining properties in contrast to other duplex steels. Duplex steels are generally more difficult to machine than conventional austenitic stainless steel such as 316L, due to the higher hardness.

Welding

Welders who are experienced in austenitic stainless steels, such as 304 and 316L, are aware of the need for low heat input to prevent hot cracking of the weld. Hot cracking is avoided by minimizing heat input and, where possible, using a filler metal that will form a significant volume fraction of ferrite. To achieve low heat input an austenitic material may be welded by a series of small passes, i.e., the use of stringer beads with minimal weave. Problems occurring in the HAZ of an austenitic stainless steel are not likely if a low carbon or stabilized grade is used for welded applications.

The problems encountered with duplex stainless steels are completely different. The duplex filler metals have a large volume of ferrite, so hot cracking of the weld metal is rare. Instead, the problems with duplex stainless steel relate to embrittlement of the HAZ either by too much ferrite or by formation of intermetallic phases. Intermetallic phases form due to being at higher temperature for too long a time. Because the time at temperature is a cumulative effect, it does not help for the welder of a duplex stainless steel to make many small passes as with a difficult austenitic material. In fact, it is often far better to make a duplex weld with a higher heat input procedure, provided that a larger weld deposition rate will enable a lower total time at temperature for the HAZ for the whole welding procedure.

The interpass temperature should be as low as necessary to help keep the total time at temperature for a particular weld below the range where precipitation of carbides and sigma phase may occur. The limit on interpass temperature can be higher for 2304 because it takes significantly longer to form intermetallic phases than for 2205 Code Plus Two®. To keep the total time at temperature short, stress relief heat treatment after welding is not recommended. It is important to qualify a welding procedure by demonstrating that the procedure when applied to the proposed size will not lead to significant loss of toughness or corrosion resistance.

Technical support

New Castle assists end users and fabricators in the selection, qualification, installation, operation, and maintenance of 2304 duplex stainless steel. New Castle is prepared to discuss individual applications and to provide data and experience as a basis for selection and application of 2304.

New Castle works closely with its distributors to ensure timely availability of 2304 in the sizes, and quantities required by the end user. For assistance with technical questions and to obtain top quality 2304, please call New Castle at 1-800-349-0023.

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