Stainless steels for corrosive environments

Outokumpu Core range datasheet

General characteristics

The Core range contains 15 stainless steel products meant for mild to medium corrosive environments.

Key products

Outokumpu name	Typical applications	Product forms
Core 304/4301 Core 304/4301 is a classic 18 %chromium, 8 %nickel austenitic stainless steel. It's an all-purpose product with good corrosion resistance and is suitable for a wide variety of applications that require good formability and weldability. Core 304/4301 can be delivered with a variety of surface finishes.	• Household appliances and consumer goods • Kitchen equipment • Indoor and outdoor cladding, handrails and window frames • Food and beverage industry equipment • Storage tanks • Flanges and valves	C, H, P, B, R, S, T
Core 304L/4307 Core 304L/4307 is a low-carbon alternative to Core 304/4301. The lower carbon content minimizes carbide precipitation as a result of heat input, for example during welding, giving improved resistance against intergranular corrosion. Core 304L/4307 is suitable for a wide variety of applications that require good formability and weldability, and can be delivered with a variety of surface finishes.	• Food and beverage industry equipment • Chemical and pharmaceutical industry equipment (mild to medium corrosive environments • Heat exchangers • Storage tanks • Tank containers • Pipes and tubes • Flanges and valves	C, H, P, B, R, S, T

Alternatives

Outokumpu name	Typical applications	Product forms
Core 304LN/4311 A low-carbon, higher nickel and nitrogen alloyed alternative to Core 304L/4307 with improved strength and low-temperature toughness. Suitable for applications that require high tensile strength.	• Railroad cars • Pressure vessels • Chemical plant equipment (mild to medium corrosive environments) • Flanges and valves	C, H, P, R, S
Core 304L/4306 A higher nickel alternative to Core 304L/4307 with improved formability and deep drawability.	• Chemical and pharmaceutical plant equipment (mild to medium corrosive environments) • Flanges and valves	C, H, P, B, R, S, T
Core 305/4303 A high-nickel alternative to Core 304/4301 with reduced strain hardening and excellent cold-forming properties. Ideal for parts that require high degree of deformation.	• Industrial parts with complex shapes • Sinks and other deep-drawn products • Complex stamping processes • Re-rollers producing very thin-gauge coils	C, H, R, S
Core 321/4541 A titanium-stabilized austenitic stainless steel with improved intergranular corrosion resistance for an extended temperature range.	• Anneailing covers • Stack liners • Automotive exhaust systems • Welded pressure vessels • Flanges and valves	C, H, P, B, R, S, T
Core 347/4550 Core 347/4550 is a niobium stabilized alternative to Core 321/4541 with improved intergranular corrosion resistance and good mechanical properties at high temperatures. Core 347/4550 is particularly useful in applications with intermittent heating in the range 400–900 °C/750–1650 °F.	• High temperature gaskets • Rocket engine parts • Expansion joints • Aircraft collector rings • Exhaust manifolds • Chemical production equipment • Flanges and valves	C, H, P, B, R, S, T
Core 301LN/4318 A low-carbon, nitrogen alloyed alternative to Core 301/4310 with elevated strength, making it particularly suitable for lightweight construction.	• Automotive applications, especially vehicles chassis • Railroad cars	C, H, S
Core 301/4310 A lower chromium and nickel alternative to Core 304/4301 with high work hardening capacity, this is a good choice for applications subjected to high mechanical loading.	• Springs • Press plates • Conveyor chains • Mixer blades • Sinks	C, H, B, R, S

Low-nickel stainless steels

Outokumpu name	Typical applications	Product forms
Core 201/4372 This low-nickel stainless steel has properties approaching Core 301/4310 but with a higher work hardening coefficient.	• Household appliances • Kitchen utensils • Sinks • Doors and windows • Railroad cars	C, H, S
Core 201LN/4372 This low-nickel stainless steel also has properties approaching Core 301/4310, but has a higher strength than Core 201/4372. It hardens more quickly due to its higher work hardening coefficient.	• Railroad freight cars • Truck trailers • Coal handling • Bulk transport equipment	C, H, S

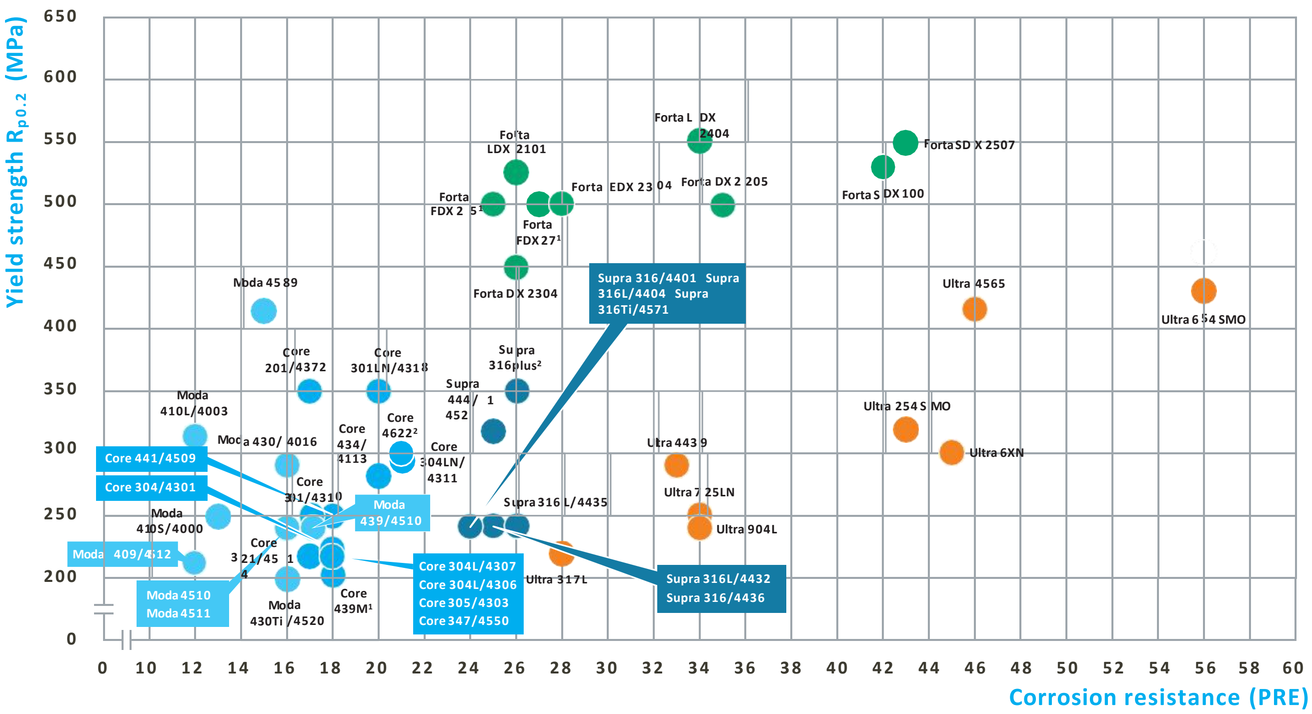
Nickel-free stainless steels

Outokumpu name	Typical applications	Product forms
Core 441/4509 A nickel-free 17 % chromium ferritic stainless steel grade with good corrosion resistance and high-temperature strength was originally designed for exhaust systems. Core 441/4509 is available with single (niobium) or dual (niobium and titanium) stabilization. Due to good formability and weldability it is often a suitable replacement for Core 301/4310.	• Indoor claddings • Restaurant equipment and appliances • Tubes • Heat exchangers	C, H, S
Core 439M Very similar to Core 441/4509, but dual stabilized with titanium and niobium for a more even surface appearance and enhanced weldability. With 1 % more chromium, it also has slightly better corrosion resistance.	• Automotive exhaust systems • Sugar industry equipment • Household appliances	C, H, S
Core 4622 A nickel-free, high-chromium (21Cr) ferritic stainless steel with equal corrosion resistance to Core 304/4301. Core 4622 has excellent deep drawability and is almost ridging free, meaning it is easier to polish and has a lower overall production cost.	• Household, catering and architectural applications (indoor and outdoor) • Tubular products for automotive and process industries • Building facades • Tanks and process equipment	C, H
Core 434/4113 A molybdenum-alloyed ferritic stainless steel that offers improved corrosion resistance.	• Automotive trim and fittings	C, H, S

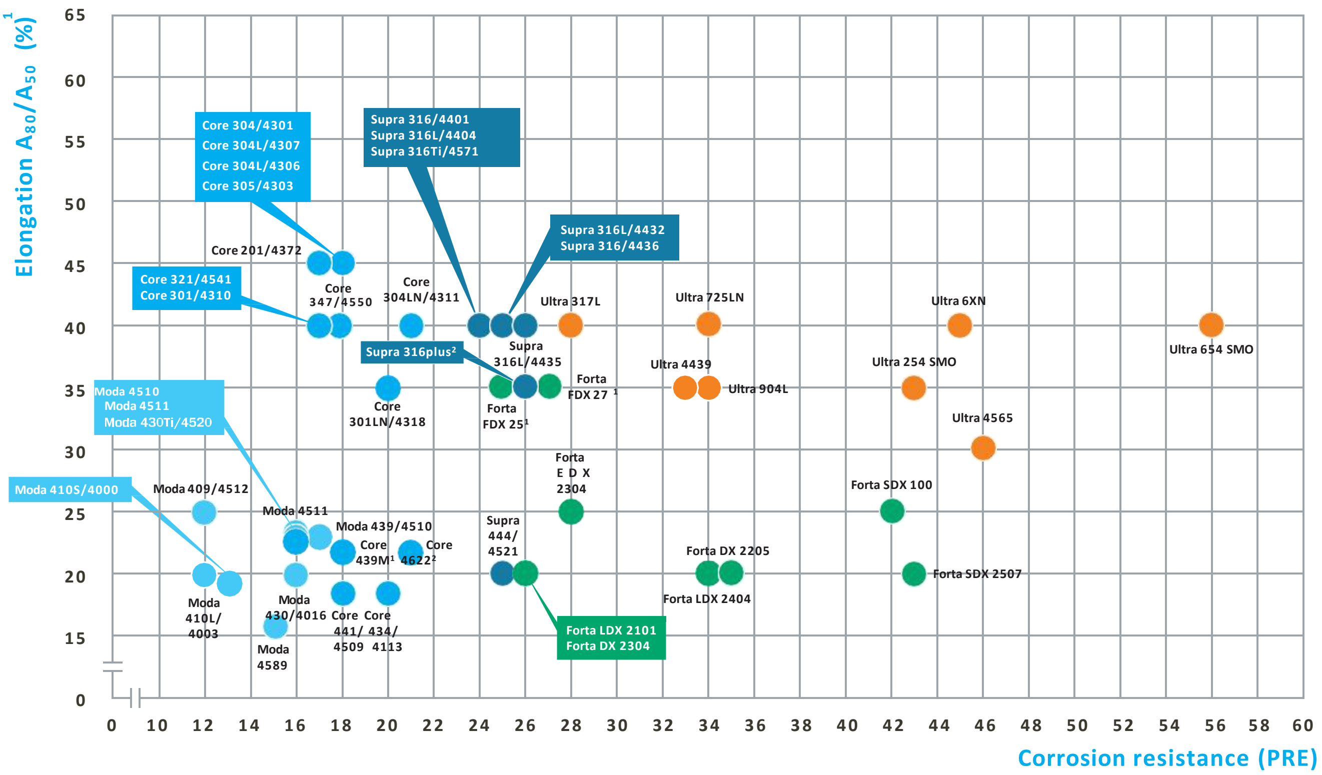
Product forms:
C = Cold rolled coil and sheet H = Hot rolled coil and sheet P = Quarto plate
B = Bar
R = Wire rod
S = Semifinished (bloom, billet, ingot & slab)
T = Pipe

Product performance comparison

Yield strength vs. corrosion resistance



Fracture elongation vs. corrosion resistance



- Moda - Mildly corrosive environments
- Core - Corrosive environments
- Supra - Highly corrosive environments
- Forta - Duplex and other high strength (PRE 16 to 43)
- Ultra - Extremely corrosive environments (PRE > 27)

PRE calculation = %Cr + 3.3 x %Mo + 16 x %N

Note: PRE values shown are based on Outokumpu typical composition. Yield strength ($R_{p0.2}$) and Elongation (A_{80}) % according to EN 10088-2 minimum values for cold rolled strip.

¹⁾ According to ASTM A240.

²⁾ According to EN 10028-7.

For more values by product, please see **steelfinder.yttzhj.com**

Products and dimensions

To find the minimum and maximum thickness and width by surface finish for a specific product in the Core range, please visit **steelfinder.yttzhj.com**

Chemical composition

Core 304/4301 and Core 304L/4307 are used in the majority of applications, and are readily available around the world. Some applications require more specific properties, and for this reason a number of other closely related austenitic steels, generally with modified alloying compositions, are also available. These include:

- Austenitic alloys with titanium and niobium additions to improve resistance to intergranular corrosion
- Ferritic alloys with titanium and niobium additions to improve weldability and formability
- Stainless steels with lower nickel content to promote higher work-hardening
- Stainless steels with higher nickel content for specialist cryogenic applications or to increase deep drawability
- Higher-strength grades containing nitrogen
- Grades containing molybdenum, and sometimes copper, to improve corrosion resistance

The Core range also includes nickel-free ferritic steels. The chemical compositions of the stainless steels in the Core range are shown in the following table as % by mass.

Outokumpu name	EN	ASTM		C	Cr	Ni	Mo	N	Others	Family
		Type	UNS							
Key products										
Core 304/4301	1.4301	304	S30400	0.04	18.1	8.1	–	–	–	A
Core 304L/4307	1.4307	304L	S30403	0.02	18.1	8.1	–	–	–	A
Alternatives										
Core 304LN/4311	1.4311	304LN	S30453	0.02	18.5	9.2	–	0.14	–	A
Core 304L/4306	1.4306	304L	S30403	0.02	18.2	10.1	–	–	–	A
Core 305/4303	1.4303	305	S30500	0.04	17.7	12.5	–	–	–	A
Core 321/4541	1.4541	321	S32100	0.04	17.3	9.1	–	–	Ti	A
Core 347/4550	1.4550	347	S34700	0.05	17.5	9.5	–	–	Nb	A
Core 301LN/4318	1.4318	301LN	S30153	0.02	17.7	6.5	–	0.14	–	A
Core 301/4310	1.4310	301	S30100	0.10	17.0	7.0	–	–	–	A
Low-nickel stainless steel										
Core 201/4372	1.4372	201	S20100	0.05	17.0	4.0	–	0.20	7Mn	A
Core 201LN/4372	1.4372	201LN	S20153	0.03	16.2	4.0	0.2	0.20	Cu, 6.5Mn	A
Nickel-free stainless steels										
Core 441/4509	1.4509	–	S43940	0.02	17.6	–	–	–	Nb, Ti	F
Core 439M	–	439M	S43932	0.02	17.6	–	–	–	Ti, Nb	
Core 4622	1.4622	–	S44330	0.02	21.0	–	–	–	Nb, Ti, Cu	F
Core 434/4113	1.4113	434	S43400	0.04	16.5	–	1.0	–	–	F

The table shows Outokumpu typical values.

For the chemical composition list for different standards by stainless steel product, see **steelfinder.yttzhj.com**

Corrosion resistance

Product name	EN	ASTM		PRE
		Type	UNS	
Key grades				
Core 304/4301	1.4301	304	S30400	18
Core 304L/4307	1.4307	304L	S30403	18
Alternatives				
Core 304LN/4311	1.4311	304LN	S30453	21
Core 304L/4306	1.4306	304L	S30403	18
Core 305/4303	1.4303	305	S30500	18
Core 321/4541	1.4541	321	S32100	17
Core 347/4550	1.4550	347	S34700	18
Core 301LN/4318	1.4318	301LN	S30153	20
Core 301/4310	1.4310	301	S30100	17
Low-nickel stainless steel				
Core 201/4372	1.4372	201	S20100	17
Core 201LN/4372	1.4372	201LN	S20153	19
Nickel-free stainless steels				
Core 441/4509	1.4509	–	S43940	18
Core 439M	–	439M	S43932	18
Core 4622	1.4622	–	S44330	21
Core 434/4113	1.4113	434	S43400	20

Pitting Resistance Equivalent is calculated using the following formula: PRE = %Cr + 3.3 x %Mo + 16 x %N

Surface finish and other factors determine the actual corrosion resistance of a particular product. Contact us at yttzhj.com/contacts to discuss what product is right for your next project.

Corrosion resistance of Core range austenitics

Core range austenitics have good corrosion resistance and are suitable for a wide range of applications.

Uniform corrosion

Uniform corrosion is characterized by a uniform attack on the steel surface in contact with a corrosive medium. The corrosion resistance is generally considered good if the corrosion rate is less than 0.1 mm/year (0.004 in/year).

Pitting and crevice corrosion

Pitting and crevice corrosion may occur in acidic or neutral chloride solutions. Core range products have good resistance to these types of corrosion. Resistance to pitting and crevice corrosion is enhanced by increasing the chromium, molybdenum, and nitrogen content. Nickel reduces the pitting propagation rate and facilitates re-passivation after pitting corrosion has started.

Atmospheric corrosion

Core range austenitic stainless steels offer good resistance to atmospheric corrosion in applications where superficial surface staining from incipient pitting or crevice corrosion is usually undesirable. From an appearance point of view, products without molybdenum alloying are usually sufficiently resistant in rural and light-urban environments.

When high amounts of chlorides or pollutants are present, as is the case in certain industrial areas or in marine splashing zones, higher-alloyed stainless steels from the Forta duplex or Ultra range may need to be considered, especially if the environment is also hot or humid.

Core range stainless steels are not suitable for load-bearing structures in swimming pool halls, such as hangers for roof constructions. To address the risk of stress corrosion cracking (SCC) in pool environments, only the steel grades given in Eurocode 3, EN 1993-1-4 should be used for load-bearing parts exposed to environments above indoor swimming pools.

Stress corrosion cracking (SCC)

Core range austenitic stainless steels are susceptible to chloride-induced SCC. Critical service conditions – i.e. applications subjected to combinations of tensile stresses, temperatures above about 50 °C/120 °F, and solutions containing chlorides – should be avoided. Stress corrosion cracking may also occur in hot, strong alkaline solutions (above 110 °C/230 °F). Depending on the specific application, ferritic, duplex or high performance austenitic stainless steels are usually more suitable for applications demanding high resistance to SCC.

Intergranular corrosion

A low carbon content extends the time required for significant sensitization. Modern steel making methods enable much lower carbon contents to be achieved. An exception is the readily work hardened product Core 301/4310 with a carbon content of about 0.1%, which is not intended for use in applications where intergranular corrosion may occur.

Still, operations that increase the risk of intergranular corrosion are welding of thick sections, heat treatment operations within the critical temperature interval 550–850 °C/1020–1560 °F, and slow cooling after heat treatment or hot forming. Steels with low carbon content (< 0.03%) or with a titanium addition have better resistance to intergranular corrosion after such operations.

For further information on corrosion resistance, please refer to the Outokumpu Corrosion Handbook, available from our sales offices.

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Corrosion resistance of Core range ferritic stainless steels

The corrosion resistances of Core range ferritic stainless steels are superior to that of carbon steels because of their higher chromium content.

Uniform corrosion

Uniform corrosion is characterized by a uniform attack on the steel surface in contact with a corrosive medium. The corrosion resistance is generally considered good if the corrosion rate is less than 0.1 mm/year (0.004 in/ year). Uniform corrosion is relatively easily measured and predicted, making disastrous failures relatively rare. It can be limited or prevented by an appropriate choice of mate- rial. In many cases, it is undesirable only from an appearance point of view.

Pitting and crevice corrosion

Pitting and crevice corrosion may occur in chloride-containing environments, depending on various parameters such as chloride concentration, temperature, pH value, redox potential, and crevice geometry.

The relatively high chromium content of Core 441/4509 improves its resistance to localized corrosion. This kind of stabilized ferritic steel has good resistance to pitting corrosion, and has only slightly lower resistance than Core 304/4301 and Core 304L/4307.

Stress corrosion cracking (SCC)

This type of corrosion is characterized by the cracking of materials that are subject to both tensile stress and corrosive environments. The environments that most frequently cause stress corrosion cracking (SCC) in stainless steels are aqueous solutions containing chlorides. Apart from the presence of chlorides and tensile stresses, an elevated temperature (> 60 °C/140 °F) is normally required for SCC to occur in stainless steels. The risk of SCC is strongly affected by both the nickel content and the microstruc- ture. Both high and low nickel content gives a better resistance to SCC. Nickel-free ferritic steels therefore have excellent resistance to chloride-induced SCC.

Intergranular corrosion

This type of corrosion is also called grain boundary attack and is characterized by corrosion in a narrow band of material along the grain boundaries. A low carbon content extends the time required for significant sensitization. Modern steel making methods enable much lower carbon contents to be achieved.

Operations that increase the risk of intergranular corrosion are welding of heavy gauges, heat treatment operations within the critical temperature interval (900–950 °C/1650–1740 °F), and slow cooling after heat treatment or hot forming.

The risk of intergranular corrosion can be reduced by decreasing the carbon content and/or by stabilizing the steel, i.e. alloying with an element (titanium or niobium) that forms more stable carbides than chromium. For example, the titanium and niobium alloying of Core 441/4509 reduces its sensitivity to intergranular corrosion.

Atmospheric corrosion

Atmospheric corrosion refers to both indoor and outdoor, and all local forms of corrosion. Atmospheric corrosion may occur on a steel surface in the thin, wet film created by a combination of humidity and impurities in the air. Core range ferritic stainless steels can be used in many atmospheric applications. In the case of an aggressive atmosphere, see the Supra, Forta duplex and Ultra range for suitable products.

For further information on corrosion resistance, please refer to the Outokumpu Corrosion Handbook, available from our sales offices.

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Mechanical properties

Metric									
Outokumpu name	EN	ASTM		Product form	Yield strength $R_{p0.2}$ (MPa)	Yield strength $R_{p1.0}$ (MPa)	Tensile strength R_m (MPa)	Elongation A (%)	Elongation A_{80} (%)
		Type	UNS						
Key products									
Core 304/4301	1.4301	304	S30400	C	230	260	540–750	45	45
				H	210	250	520–720	45	45
				P	210	250	520–720	45	45
				R*	290	330	600	55	–
				B*	400	–	600	25	–
Core 304L/4307	1.4307	304L	S30403	C	220	250	520–700	45	45
				H	200	240	520–700	45	45
				P	200	240	500–700	45	45
				R*	280	320	580	55	–
				B*	400	–	600	25	–
Alternatives									
Core 304LN/4311	1.4311	304LN	S30453	C	290	320	550–750	40	40
				H	270	310	550–750	40	40
				P	270	310	550–750	40	40
				R*	320	360	640	55	–
				B*	–	–	–	–	–
Core 304L/4306	1.4306	304L	S30403	C	220	250	520–700	45	45
				H	200	240	520–700	45	45
				P	200	240	500–700	45	45
				R*	280	320	580	55	–
				B*	400	–	600	25	–
Core 305/4303	1.4303	305	S30500	C	220	250	500–650	45	45
				R*	250	280	570	50	–
Core 321/4541	1.4541	321	S32100	C	220	250	520–720	40	40
				H	200	240	520–720	40	40
				P	200	240	500–700	40	40
				R*	250	290	570	55	–
Core 347/4550	1.4550	347	S34700	C	220	250	520–720	40	40
				H	200	240	520–720	40	40
				P	200	240	500–700	40	40
				R*	230	290	590	65	–
Core 301LN/4318	1.4318	301LN	S30153	C	350	380	650–850	40	35
				H	330	370	650–850	40	35
Core 301/4310	1.4310	301	S30100	C	250	280	600–950	40	40
				R*	300	330	800	50	–
Low–nickel stainless steel									
Core 201/4372	1.4372	201	S20100	C	350	380	680–880	45	45
				H	330	370	680–880	45	45
Core 201LN/4372	1.4372	201LN	S20153	C	350	380	680–880	45	45
				H	330	370	680–880	45	45
Nickel–free stainless steels									
Core 441/4509	1.4509	–	S43940	C	250	–	430–630	18	18
Core 439M	–	439M	S43932	C**	205	–	415	–	22
				H**	205	–	415	–	22
Core 4622	1.4622	–	S44330	C***	300	–	430–630	–	22
				H**	205	–	390	–	22
Core 434/4113	1.4113	434	S43400	C	280	–	450–630	18	18
				H	280	–	450–630	18	18

Note: Values according to EN 10088–2:2014 unless marked otherwise.
*)Outokumpu typical values.
**)According to ASTM A240.
***)According to EN 10028-7.

A_{80} initial length = 80 mm, A initial length = $5.65\sqrt{S_0}(A_s)$

Product forms: cold rolled coil and sheet (C), hot rolled coil and sheet (H), quarto plate (P), wire rod (R), cold drawn bar, 10 < d ≤ 16 mm (B). More product forms may be available than are shown in table.

For more information, please see **steelfinder.yttzhj.com**

Imperial								
Outokumpu name	EN	ASTM		Product form	Yield strength $R_{p0.2}$ (ksi)	Yield strength $R_{p1.0}$ (ksi)	Tensile strength R_m (ksi)	Elongation A_{50} (%)
		Type	UNS					
Key products								
Core 304/4301	1.4301	304	S30400	C	30	–	75	40
				H	30	–	75	40
				P	30	–	75	40
				R*	42	48	87	–
Core 304L/4307	1.4307	304L	S30403	C	25	–	70	40
				H	25	–	70	40
				P	25	–	70	40
				R*	41	46	84	–
Alternatives								
Core 304LN/4311	1.4311	304LN	S30453	C	30	–	75	40
				H	30	–	75	40
				P	30	–	75	40
				R*	46	52	93	–
Core 304L/4306	1.4306	304L	S30403	C*	37	41	85	–
				H*	37	46	84	–
				P*	35	39	84	–
				R*	41	46	84	–
Core 305/4303	1.4303	305	S30500	C	25	–	70	40
				H	25	–	70	40
				P	25	–	70	40
Core 321/4541	1.4541	321	S32100	C	30	–	75	40
				H	30	–	75	40
				P	30	–	75	40
				R*	36	42	83	–
Core 347/4550	1.4550	347	S34700	C	30	–	75	40
				H	30	–	75	40
				P	30	–	75	40
				R*	36	41	84	–
Core 301LN/4318	1.4318	301LN	S30153	C	35	–	80	45
				H	35	–	80	45
				P	35	–	80	45
Core 301/4310	1.4310	301	S30100	C	30	–	75	40
				H	30	–	75	40
				P	30	–	75	40
				R*	44	48	116	–
Low-nickel stainless steel								
Core 201/4372	1.4372	201	S20100	C	30	–	75	40
				H	45	–	–	40
				P	54	59	102	–
Core 201LN/4372	1.4372	201LN	S20153	C	45	–	95	45
				H	45	–	95	45
				P	45	–	95	45
Nickel-free stainless steels								
Core 441/4509	1.4509	–	S43940	C	36	–	62	18
				H*	30	–	75	18
Core 439M	–	439M	S43932	C	30	–	60	22
Core 4622	1.4622	–	S44330	C	30	–	56	22
				H	30	–	56	22
Core 434/4113	1.4113	434	S43400	C	35	–	65	22
				H	35	–	65	22
				P	35	–	65	22

Note: Values according to ASTM A240 unless marked otherwise.

*Outokumpu typical values.

A_{50} initial length = 50 mm

Product forms: cold rolled coil and sheet (C), hot rolled coil and sheet (H), quarto plate (P), wire rod (R). More product forms may be available than are shown in table.

For more information, please see steelfinder.yttzhj.com

Mechanical properties of Core range austenitics

The strength of the austenitic steels in the Core range increases with increasing levels of carbon, nitrogen and, to a certain extent, molybdenum and manganese. Austenitic steels exhibit very high ductility; they have a high elongation to fracture. These steels are very tough, a property that extends to cryogenic temperatures.

Outokumpu uses the European Standard EN 10088 where applicable. The permitted design values may vary between product forms; see the relevant specification for the correct value.

Mechanical properties at elevated temperatures

An elevated temperature is usually defined as being up to 500–600 °C/930–1110 °F, with high temperature being in excess of this. Core range austenitic stainless steels possess useful elevated and high temperature strength and oxidation resistance. The highest elevated temperature strength among these steels is exhibited by the nitrogen-alloyed steels and those containing titanium or niobium. Most products are approved for pressure vessel applications, with pressure vessel codes giving design values for temperatures up to 400 °C/750 °F. For applications such as heaters, catalytic converters, and furnaces – where pressure is not a factor – austenitic corrosion-resistant stainless steels can be used up to approximately 800 °C /1470 °F, depending on specific circumstances.

Structural fire resistance

The performance requirements of a stainless steel structure that may be subjected to accidental fire loading are similar to those of carbon steel. Core range austenitic stainless steels generally retain a higher proportion of their room temperature strength than carbon steels above temperatures of about 550 °C/1020 °F, and a higher proportion of their stiffness at all temperatures.

The behavior of stainless steel differs from that of most other metals at fire temperatures in that its mechanical properties (mainly modulus of elasticity and proof strength) are maintained comparatively well up to temperatures corresponding to a 30-minute standard fire. The temperature of unprotected stainless steel after a 30-minute standard fire is 800–830 °C/1470–1520 °F depending on the thickness of the material. There are significant differences in the values of the effective yield strengths used in structural design between stainless steel grades.
Where mechanical resistance in the case of fire is required, the structure should be designed and constructed in such a way that it maintains its load-bearing function during the relevant fire exposure. EN 1993-1-2 “Eurocode 3 – Design of steel structures – Part 1-2: General rules – Structural fire design”, 2010 AISC Specification for Structural Steel Buildings (AISC, 2010c) and Euro Inox “Design Manual for Structural Stainless Steel” (2006) give further guidance on fire design for stainless steels.

Mechanical properties at cryogenic temperatures

Core range austenitic stainless steels are not susceptible to brittle fracture in the solution-annealed condition. Due to their high impact toughness at very low temperatures, they are suitable for cryogenic applications.

Physical properties

Metric							
Outokumpu name	Density [kg/dm³]	Modulus of elasticity at 20 °C [GPa]	Coefficient of thermal expansion 20–100 °C [10^{-6} / K]	Thermal conductivity at 20 °C [W/(m x K)]	Thermal capacity at 20 °C [J/(kg x K)]	Electrical resistivity at 20 °C [Ω x mm² / m]	Magnetizable
Key products							
Core 304/4301	7.9	200	16.0	15	500	0.73	No
Core 304L/4307	7.9	200	16.0	15	500	0.73	No
Alternatives							
Core 304LN/4311	7.9	200	16.0	15	500	0.73	No
Core 304L/4306	7.9	200	16.0	15	500	0.73	No
Core 305/4303	7.9	200	16.0	15	500	0.73	No
Core 321/4541	7.9	200	16.0	15	500	0.73	No
Core 347/4550	7.9	200	16.0	15	500	0.73	No
Core 301LN/4318	7.9	200	16.0	15	500	0.73	No
Core 301/4310	7.9	200	16.0	15	500	0.73	No
Low-nickel stainless steel							
Core 201/4372	7.8	200	–	15	–	0.70	No
Core 201LN/4372	7.8	200	–	15	–	0.70	No
Nickel-free stainless steels							
Core 441/4509	7.7	220	10.0	25	460	0.60	Yes
Core 439M*	7.7	220	10.0	25	460	0.60	Yes
Core 4622*	7.7	220	10.0	21	460	0.65	Yes
Core 434/4113	7.7	220	10.0	25	460	0.70	Yes

Values according to EN 10088-1.
*Outokumpu tested values.

Imperial							
Outokumpu name	Density [lbm/in³]	Modulus of elasticity [psi]	Coefficient of thermal expansion 68-212 °F [µin / (in x °F)]	Thermal conductivity [Btu/(hr x ft x °F)]	Thermal capacity [Btu/(lbm x °F)]	Electrical resistivity [µΩ x in]	Magnetizable
Key products							
Core 304/4301	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Core 304L/4307	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Alternatives							
Core 304LN/4311	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Core 304L/4306	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Core 305/4303	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Core 321/4541	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Core 347/4550	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Core 301LN/4318	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Core 301/4310	0.285	29 x 10^6	8.9	8.7	0.120	28.74	No
Low-nickel stainless steel							
Core 201/4372	0.282	29 x 10^6	–	8.7	–	27.56	No
Core 201LN/4372	0.282	29 x 10^6	–	8.7	–	27.56	No
Nickel-free stainless steels							
Core 441/4509	0.278	32 x 10^6	5.6	14.5	0.110	23.62	Yes
Core 439M*	0.278	32 x 10^6	5.6	14.5	0.110	23.62	Yes
Core 4622*	0.278	32 x 10^6	5.6	12.1	0.110	25.59	Yes
Core 434/4113	0.278	32 x 10^6	5.6	14.5	0.110	27.56	Yes

Values according to EN 10088-1.
*Outokumpu tested values.

Fabrication

Core range austenitics

Formability

Core range austenitic stainless steels can be readily formed by all cold forming methods and share common forming properties:

- Excellent stretch formability
- High work-hardening rate
- Average strain ratio r of approximately 1

In the low-nickel alloyed products, the austenite is metastable. In metastable steels, the austenite may partially transform to hard martensite during cold forming. The martensitic transformation increases the work-hardening rate of these steels, which results in higher resistance to thinning in stretch forming operations and increases the final strength of the fabricated part. Therefore, metastable austenitic stainless steels exhibit the best stretch formability of all common sheet metals.

The stability of the austenite decreases with lower alloying element content; more martensite is formed during cold forming. In addition to the chemical composition, the martensite transformation depends on the forming temperature. At about 150 °C/300 °F no martensite is formed even for the most unstable grades. It follows that the formability of metastable austenitic stainless steels can be modified by selective heating of the piece being worked.

The most unstable products – such as Core 301/4310 and Core 301LN/4318 – are susceptible to delayed cracking after severe deep drawing operations. The delayed cracking phenomenon is related to the high martensite content developed during forming. Therefore, the risk of delayed cracking can be reduced by selecting more stable products.

For very demanding deep drawing applications and for multiple-step forming operations, stable grades with higher nickel content are preferable. These stable grades are designed to minimize martensite formation, but do retain their work hardening capacity in the subsequent forming steps. Stable grades can also result in slightly reduced tool wear, lower elastic springback, and better dimensional tolerances.

Hot forming

Hot forming can be carried out in the 850–1150 °C/1550–2100 °F range. For maximum corrosion resistance, forgings should be annealed at 1070 °C/1950 °F and rapidly cooled in air or water after hot forming operations. Slow cooling may have adverse effects on the ductility and corrosion properties of the product.

Heat treatment

Solution annealing should be performed at 1000–1100°C/1830–2010 °F and followed by rapid cooling in water or air. For titanium-stabilized grades, annealing temperatures above 1070 °C/ 1950 °F may impair the resistance to intergranular corrosion. Titanium-stabilized grades may also be given a stabilizing treatment at lower temperatures. However, temperatures below 980 °C/1790 °F should only be used after due consideration of the intended service environment. In applications where high residual stresses cannot be accepted, stress relief treatment may be necessary. This can be performed by annealing as outlined above.

Machinability

Due to their high toughness and work-hardening behavior, austenitic steels are more difficult to machine than carbon steels but are still comparatively easy to machine compared to more highly alloyed stainless steel grades. They require higher cutting forces than carbon steels, show resistance to chip breaking, and have a high tendency to built-up edge formation. The best machining results are obtained by using high-power equipment, sharp tooling, and a rigid setup.

Better machinability performance is given by the Prodec range variants, which have been modified for improved machinability. For more information please see the Prodec range data sheet. See also the Outokumpu Machining Guidelines.

Welding

Core range austenitic stainless steels have excellent weldability and are suitable for the full range of conventional welding methods except oxyacetylene. In thin sections, autogenous welding may be used. In thicker sections, products with lower carbon content are preferred. To ensure that the weld metal properties (e.g. strength and corrosion resistance) are equivalent to those of the parent metal, matching or slightly over-alloyed fillers are preferable. In some cases, however, a differing composition may improve weldability or structural stability.

Austenitic steels have about 50% higher thermal expansion and lower heat conductivity compared to ferritic and duplex steels. This means that larger deformation and higher shrinkage stresses may result from welding.

Generally, post-weld heat treatment is not required. In special cases where there is a high risk of stress corrosion cracking or fatigue, stress relief treatment may be considered. In order to fully restore the corrosion resistance of the weld, the weld oxides should be removed by e.g. pickling.

More detailed information about welding procedures can be obtained from the Outokumpu Welding Handbook, available from our sales offices.

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Core range ferritics

Formability

Core range products can be readily cold formed by all standard processes. Their forming properties are similar to those of low-alloyed carbon steels. Their deep drawability is comparable to that of deep drawing quality carbon steels. The stabilized product Core 441/4509 is particularly suitable for deep drawing.

An indicator of deep drawability is the limiting drawing ratio (LDR), which is the ratio of the maximum blank diameter to the cup diameter. Good deep drawability is characterized by a high LDR value. The LDR depends on the thickness of the sheet.

The drawability of a material can be described with the average plastic strain ratio r and the planar anisotropy Δr values. The value of planar anisotropy indicates the amount of uneven elongation in a deep drawing operation and is generally referred to as earing. A low earing tendency is characterized by a Δr value close to 0. The height of the ears can be 5–10% of the height of the cup, depending on the grade, thickness, and grain size.

Roping is characterized by surface undulations parallel to the rolling direction of the sheet. Roping can be avoided by selecting a titanium-stabilized product such as Core 4622.

The stretchability of Core range ferritics is comparable to that of low-alloyed carbon steels.

The minimum bending radius for Outokumpu ferritic products equals the sheet thickness. For sheets thinner than 1 mm/0.04 in, a bending radius of half the sheet thickness may be used. Sharp bends should be positioned perpendicular to the rolling direction.

The ductility of ferritic stainless steels usually decreases when the temperature falls below room temperature. Demanding cold forming operations should therefore be carried out with room-temperature material.

Machining

Core range ferritics are relatively easy to machine. Their machining characteristics are similar to those of low-alloyed carbon steels with a tensile strength of 500 MPa. Consequently,
the guidelines regarding the machining parameters and tools given for low-alloyed carbon steels can be used.

Welding

Core range ferritic stainless steels are readily weldable with conventional welding methods, including:

- Shielded metal arc welding (SMAW, MMA)
- Gas tungsten arc welding (GTAW, TIG)
- Gas metal arc welding (GMAW, MIG/MAG)
- Plasma arc welding (PAW)
- Laser welding
- Resistance welding
- High frequency welding (HF)

Weldability

Low interstitial levels and added stabilizers have made enormous improvements to the welding characteristics of ferritic stainless steels. In addition, due to their lower thermal expansion and higher thermal conductivity, distortion and buckling is much lower during welding compared to austenitic or duplex stainless steels.

The microstructures of ferritics diverge quite a lot depending on the chemical composition of a particular product, mostly due to the effects of chromium, carbon, nitrogen, titanium, and niobium. Low and medium-chromium unstabilized stainless steels usually consist of a mixture of austenite and ferrite at elevated temperatures during welding, and subsequently transform into martensite and ferrite during cooling.

Dual stabilization (titanium + niobium) notably improves the weldability characteristics. Titanium stabilization improves autogenously welded joints by refining the grain structure in the weld metal.
On the other hand, niobium effectively restricts the grain coarsening in the heat-affected zone (HAZ). Although the significance of grain-coarsening embrittlement has somewhat diminished over the years, the use of a low heat input is still compulsory for ferritic grades to produce satisfactory welds.

Welding naturally increases the grain size in the HAZ, but fortunately the carbide and nitride precipitates restrict the grain coarsening in a similar manner to that of austenite in unstabilized grades. Stabilization prevents chromium carbide precipitation, which could otherwise lead to sensitization embrittlement. Consequently, the stabilized grades are practically immune to intergranular corrosion in the as-welded condition.

Filler metals

Standard austenitic filler metals are normally used due to their availability, excellent toughness, and good corrosion resistance. Ferritic fillers are preferred under thermal stresses, in sour environments, or in situations where stress corrosion cracking could occur. Toughness is limited when using ferritic filler metals, although high service temperatures can tolerate the issue. Ferritic fillers should only be used for single-pass welds due to the increased risk of grain growth in the weld metal.

Shielding gases

Shielding gases for ferritic grades are usually argon-based with an additional 1–2% O_2/CO_2. Helium is sometimes used alongside argon when higher welding speeds are preferred. Due to the limited dissolution of interstitials in ferrite, higher additions of oxygen or carbon dioxide should be avoided. Nitrogen or hydrogen gases should not be used when welding ferritics. Nitrogen increases the interstitial content of the weld metal and adjacent HAZ, while hydrogen promotes hydrogen-induced cracking (cold cracking), which is a common problem with all ferritic grades.

Post-fabrication treatments

Welding reduces the resistance to localized corrosion, and therefore various surface-cleaning methods are preferred. Mechanical cleaning such as brushing or grinding gives some improvement, but the best results are usually obtained with chemical cleaning methods like pickling pastes or baths. As mentioned previously, post-weld heat treatment can be used for improving the mechanical and corrosion properties of some products.

For low-interstitial or stabilized ferritic stainless steels, post- weld heat treatment is generally unnecessary and often undesirable; however, a low-temperature heat treatment (e.g. a few hours at 200 °C/390 °F) can be effective in restoring the ductility of hydrogen-embrittled regions.

For more information, see the Outokumpu Welding Handbook, available from our sales offices.

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Surface finishes

A wide variety of surface finishes are available for Core range products. Many are produced at the mill, and other surface finishes can be applied later during processing either at a service center or after fabrication.

Core range finishes include 1D, 2B, 2E, and rolled finishes. Deco range offers Deco BA/2R, polished (#3 and #4), brushed, and patterned finishes. 2H finishes are available in the Forta range. The surface finish also plays an important role in influencing the corrosion resistance of the stainless steel, especially in the case of atmospheric corrosion or where splashing is common. A smooth surface finish increases the resistance to corrosion.

In general, the roughness of the hot rolled 1D surface is higher than cold rolled surfaces. The bright annealed surface (Deco 2R/BA) is highly reflective and very smooth compared to the cold rolled, annealed, pickled, and skin-passed (2B) surface.

More information about surface finishes can be found in the Deco range brochure.

Standards and approvals

The most commonly used international product standards are given in the table below. For a full list of standards by product, see **steelfinder.yttzhj.com**

Standards	
Flat products	
EN ISO 18286	Hot-rolled stainless steel plates – Tolerances on dimensions and shape
EN 10051	Hot-rolled steel strip.
EN 10088-1	Stainless steels – list of stainless steels
ISO 15510	Stainless steels – chemical composition
EN ISO 9445	Cold-rolled stainless narrow strip, wide strip, plate/sheet and cut lengths.
ASTM A 480	General requirements for flat-rolled stainless and heat resisting steel
ASTM A 959	Harmonized standard grade compositions for wrought stainless steels
ASME IID	Materials – Physical properties tables
Flat and long products	
EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10088-2	Stainless steels – sheet/plate and strip for general purposes
EN 10088-3	Stainless steels – semi-finished products, bars, rods sections for general purposes
EN 10088-4	Technical delivery conditions for sheet/plate and strip
EN 10095	Heat resisting steels and nickel alloys
EN 10151	Stainless steel strip for springs
EN 10217-7	Welded steel tubes for pressure purposes – Stainless steel tubes
EN 10296-2	Welded circular steel tubes for mechanical and general engineering purposes – Stainless Steel tubes
EN 10302	Creep resisting steels, nickel and cobalt alloys
ASTM A 167	Stainless and heat-resisting Cr-Ni steel plate, sheet, and strip
ASTM A 176	Stainless and heat-resisting Cr steel plate, sheet, and strip
ASTM A182/ ASME SA-182	Stainless steel and heat resisting steel bars and shapes
ASTM A 240	Cr and Cr-Ni stainless steel plate, sheet and strip for pressure vessels
ASTM A276	Stainless steel and heat-resisting steel rod and wire for cold heading and forging
ASTM A479/ ASME SA-479	General requirements for stainless and heat resistant steel wire and wire rod
ASTM A 666	Austenitic stainless steel sheet, strip, plate, bar for structural and architectural applications
ASME IIA	Materials. Part A – Ferrous Material Specifications
Eurocode 3 / EN 1993-1-4	Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels

Certificates and approvals

Outokumpu meets the most common certifications and approvals, including:

- AD 2000 Merkblatt
- Approval of Material Manufacturers
- Factory Production Control Certificate
- ISO 9001
- ISO 14001
- ISO 50001
- ISO/TS 16949
- NORSOK
- OHSAS 18001
- Pressure Equipment Directive (PED)

For a list of certificates and approvals by mill, see
yttzhj.com/certificates

Contacts and enquiries

Contact us

Our experts are ready to help you choose the best stainless steel product for your next project.

yttzhj.com/contacts

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Working towards forever.

We work with our customers and partners to create long lasting solutions for the tools of modern life and the world's most critical problems: clean energy, clean water, and efficient infrastructure. Because we believe in a world that lasts forever.

outokumpu classic

outokumpu pro

Moda	Core	Supra	Forta	Ultra	Dura	Therma	Prodec	Deco
Mildly corrosive environments	Corrosive environments	Highly corrosive environments	Duplex & other high strength	Extremely corrosive environments	High hardness	High service temperatures	Improved machinability	Special surfaces

outokumpu
high performance stainless steel