outokumpu
sustainable stainless steel



Supra
Highly corrosive environments

Supra 316plus®

EN 1.4420, ASTM UNS S31655

Outokumpu Supra range datasheet

General properties

With its high chromium and nitrogen content Supra 316plus® delivers high corrosion resistance, high strength, good formability, and excellent weldability, as well as good cost competitiveness against conventional Cr-Ni-Mo stainless steels. It is ideal for a variety of applications, including tanks, heat exchangers, water treatment, and piping, as well as in architectural applications such as indoor and outdoor facades.

Supra 316plus® is an austenitic Cr-Ni-Mo stainless steel with 21 wt.-% chromium and relatively low nickel and molybdenum content. Due to its high nitrogen content, it has increased mechanical strength and shows a high degree of work hardening on mechanical deformation. Also, thanks to its high chromium and nitrogen content, Supra 316plus® offers similar or better corrosion resistance than other austenitic Cr-Ni-Mo standard grades in many corrosive environments.

Supra 316plus® is used in applications where increased corrosion resistance and a combination of high mechanical strength and good formability is needed. Due to its tendency to work hardening, Supra 316plus® can absorb an increased amount of energy during deformation and provides improved wearing resistance. It can be delivered in the temper rolled condition with different strength levels. Due to the exceptional wide temperature usage range of Supra 316plus®, it is a very good alternative for both elevated and cryogenic use, including great properties against hydrogen embrittlement.

Typical applications

- Process and transport tanks
- Water treatment and pipes
- Heat exchangers
- Architectural applications
- Food and beverage industry
- Mining industry
- Process industry
- Chimney liners
- Cryogenic industry
- Hydrogen storage and transport

Products & dimensions

Cold rolled products, available dimensions (mm)

Table 1

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Max. width	Thickness	Max. width
2B	Cold rolled, heat treated, pickled, skin passed	0.20–6.00	2 000	0.20–6.00	2 000
2E	Cold rolled, heat treated, mechanically descaled	2.60–4.50	2 000	2.60–4.50	2 000
2K	Satin finish	0.70–4.00	1 500	0.70–4.00	1 500

Hot rolled coil products and quarto plates, available dimensions (mm)

Table 2

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Max. width	Thickness	Max. width
1D	Hot rolled, heat treated, pickled	3.50–12.00	2 000	3.20–12.00	2 000
1E	Hot rolled, heat treated, mech. desc.	2.60–4.50	1 524	2.60–4.50	2 000
1D	Quarto plate			6.00–50.00	3 200

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Chemical composition

The typical chemical composition for this grade is shown in the table below, together with the composition limits according to different standards.

The chemical composition is given as % by mass.

Table 3

	C	Cr	Ni	Mo	N
Typical	**0.02**	**20.3**	**8.6**	**0.7**	**0.19**
ASTM A240	≤0.030	19.5–21.5	8.0–9.5	0.50–1.50	0.14–0.25
EN 10028–7 EN 10088–2	≤0.030	19.5–21.5	8.0–9.5	0.50–1.50	0.14–0.25

Corrosion resistance

Supra 316plus® has excellent corrosion resistance in solutions of many halogen-free organic and inorganic compounds over a wide temperature and concentration range. It can withstand many organic and diluted mineral acids depending on the temperature and concentration of the solution. Supra 316plus® may suffer from uniform corrosion in strong mineral acids and hot strong alkaline solutions. Uniform corrosion testing has been performed according to ASTM G157, and the results show that the critical temperature (T_c) for Supra 316plus® generally is on a par with that of ASTM 316L/EN 1.4404 and ASTM 316L/EN 1.4432.

In aqueous solutions containing halogenides, e.g. chlorides or bromides, pitting and crevice corrosion may occur depending on the halogenide concentration, temperature, pH-value, concentration of oxidizing compounds, and crevice geometry, if applicable. Due to its high chromium and nitrogen content, the pitting and crevice corrosion resistance of Supra 316plus® is on the same level or even better than the corrosion resistance of the austenitic Cr-Ni-Mo standard grades ASTM 316L/EN 1.4404 and ASTM 316L/EN 1.4432, despite its lower molybdenum content. The presence of corrosion-inhibiting or accelerating compounds like transition metal ions or organic compounds may influence the corrosion behavior of Supra 316plus®, as well as ASTM 316L/EN 1.4404 and ASTM 316L/EN 1.4432.

In common with other standard austenitic stainless steels, Supra 316plus® is prone to chloride-induced stress corrosion cracking at temperatures above about 50 °C depending on the applied stress and the chloride concentration in the environment. Prior cold deformation of the structure under load increases the risk of stress corrosion cracking.

Supra 316plus® can be used for indoor and outdoor applications in urban and moderately corrosive industrial environments. In environments where the chloride contamination may be high, for instance in coastal areas, pitting and staining is possible. The best material performance is usually reached with the help of adequate design, correct post-weld treatment and regular cleaning during use (if applicable).

For more information on corrosion resistance, please refer to the Outokumpu Corrosion Handbook or contact our corrosion experts.

Pitting and crevice corrosion resistance

Table 4

	Pitting corrosion resistance			Crevice corrosion resistance
	PRE	**CPT ASTM G150**	**CPT ASTM G48 E**	**ASTM G48 F**
Supra 316plus®	26	31 ± 3 °C	27.5 °C	< 0 °C
ASTM 316L/EN 1.4404	24	20 ± 2 °C	20 °C	< 0 °C
ASTM 316L/EN 1.4432	25	27 ± 3 °C	25 °C	< 0 °C

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

Critical Pitting Corrosion Temperature (CPT) according to ASTM G 150 in a 1M NaCl solution (35,000 ppm or mg/l chloride ions), wet ground (320 grit) surface. Critical Pitting Corrosion Temperature (CPT) and Critical Crevice Corrosion Temperature (CCT) according to ASTM G48 methods E and F in a 6% $FeCl_3$ + 1% HCl solution, dry ground (120 grit) surface.

Uniform corrosion resistance – critical temperature as per ASTM G157

Table 5

Test solution	Critical temperature, T_c [°C]		
	Supra 316plus®	ASTM 316L / EN 1.4404	ASTM 316L/EN 1.4432
0.2% HCl	> 100 (bp)	> 100 (bp)	> 100 (bp)
1% HCl	30	30	40
10% H_2SO_4	35	40	40
10% H_2SO_4 + 0.33% NaCl	< 20	< 20	< 20
60% H_2SO_4	< 20	< 20	< 20
96% H_2SO_4	50	45	45
85% H_3PO_4	95	75	90
10% HNO_3	> 100 (bp)	> 100 (bp)	> 100 (bp)
65% HNO_3	100	90	95
50% NaOH	90	90	90

Critical temperature, according to ASTM G157, is the lowest temperature at which the corrosion rate exceeds 0.13 mm/year, samples with dry ground (120 grit) surface exposed for 96 hours.

Mechanical properties

The mechanical properties of the available products in the soft annealed condition at room temperature are shown in the table below. Moderate strengths can be reached at elevated temperatures (~550 °C/1 022 °F). Temperatures for excessive scaling are close to 850 °C/1 562 °F. This grade, along with other austenitic corrosion-resistant steels, exhibits very high ductility and high elongation to fracture. It is not susceptible to brittle fracture in the solution annealed condition.

Mechanical properties at room temperature (metric)

Table 6

	Standard	Product form [1]	Yield strength $R_{p0.2}$ [MPa]	Yield strength $R_{p1.0}$ [MPa]	Tensile strength R_m [MPa]	Elongation A [%]	Impact toughness KV min, tr.		Hardness HRC
							20 °C [J]	–196 °C [J]	
Supra 316plus®	EN 10028–7 EN 10088-2	C	≥ 350	≥ 380	650 – 850	≥ 35 [2]	≥ 60	≥ 60	–
		H	≥ 350	≥ 380	650 – 850	≥ 35 [2]	≥ 60	≥ 60	–
		P	≥ 320	≥ 350	630 – 830	≥ 40 [2]	≥ 60	≥ 60	–
	ASTM A240	C, H, P	≥ 310	–	≥ 635	≥ 35 [3]	–	–	≤ 100
EN 1.4404/ ASTM 316L	EN 10028–7 EN 10088-2	C	≥ 240	≥ 270	530 – 680	≥ 40 [2]	≥ 60	≥ 60	–
		H	≥ 220	≥ 260	530 – 680	≥ 40 [2]	≥ 60	≥ 60	–
		P	≥ 220	≥ 260	520 – 670	≥ 45 [2]	≥ 60	≥ 60	–
	ASTM A240	C, H, P	≥ 170	–	≥ 485	≥ 40 [3]	–	–	≤ 95

[1] Product forms: C = Cold rolled coil, H = Hot rolled coil, P = Quarto plate
[2] Thickness < 3 mm: A_{80} initial length = 80 mm. Thickness ≥ 3 mm initial lentgh = $5.65\sqrt{S_0}$
[3] Gauge length 2 in. or 50 mm

Mechanical properties at room temperature (imperial)

Table 7

	Standard	Product form [1]	Yield strength $R_{p0.2}$ [ksi]	Yield strength $R_{p1.0}$ [ksi]	Tensile strength R_m [ksi]	Elongation A [%]	Impact toughness KV min, tr.		Hardness HRC
							68 °F [ft–lb]	–320.8 °F [ft–lb]	
Supra 316plus®	EN 10028–7 EN 10088-2	C	≥ 51	≥ 55	94 – 123	≥ 35 [2]	≥ 44	≥ 44	–
		H	≥ 51	≥ 55	94 – 123	≥ 35 [2]	≥ 44	≥ 44	–
		P	≥ 46	≥ 51	91 – 120	≥ 40 [2]	≥ 44	≥ 44	–
	ASTM A240	C, H, P	≥ 45	–	≥ 92	≥ 35 [3]	–	–	≤ 100
EN 1.4404/ ASTM 316L	EN 10028–7 EN 10088-2	C	≥ 35	≥ 39	77 – 99	≥ 40 [2]	≥ 44	≥ 44	–
		H	≥ 32	≥ 38	77 – 99	≥ 40 [2]	≥ 44	≥ 44	–
		P	≥ 32	≥ 38	75 – 97	≥ 45 [2]	≥ 44	≥ 44	–
	ASTM A240	C, H, P	≥ 25	–	≥ 70	≥ 40 [3]	–	–	≤ 95

[1] Product forms: C = Cold rolled coil, H = Hot rolled coil, P = Quarto plate
[2] Thickness < 3 mm: A_{80} initial length = 80 mm. Thickness ≥ 3 mm initial lentgh = $5.65\sqrt{S_0}$
[3] Gauge length 2 in. or 50 mm

Mechanical properties at elevated temperatures, minimum values according to EN 10028-7 and and 10088-2.

Table 8

Temperature	Supra 316plus®			ASTM 316L/EN 1.4404		
	Yield strength $R_{p0.2}$ [MPa / ksi]	Yield strength $R_{p1.0}$ [MPa / ksi]	Tensile strength R_m [MPa / ksi]	Yield strength $R_{p0.2}$ [MPa / ksi]	Yield strength $R_{p1.0}$ [MPa / ksi]	Tensile strength R_m [MPa / ksi]
50 °C / 122 °F	280 / 41	320 / 46	615 / 89	200 / 29	237 / 34	486 / 70
100 °C / 212 °F	230 / 33	270 / 39	565 / 82	166 / 24	199 / 29	430 / 62
150 °C / 302°F	210 / 30	250 / 36	535 / 78	152 / 22	181 / 26	410 / 59
200 °C / 392 °F	190 / 28	225 / 33	505 / 73	137 / 20	167 / 24	390 / 57
250 °C / 482 °F	180 / 26	210 / 30	495 / 72	127 / 18	157 / 23	385 / 56
300 °C / 572 °F	170 / 25	195 / 28	480 / 70	118 / 17	145 / 21	380 / 55
350 °C / 662 °F	165 / 24	190 / 28	475 / 69	113 / 16	139 / 20	380 / 55
400 °C / 752 °F	160 / 23	185 / 27	465 / 67	108 / 16	135 / 20	380 / 55
450 °C / 842 °F	155 / 22	180 / 26	455 / 66	103 / 15	130 / 19	–
500 °C / 932 °F	150 / 22	170 / 25	455 / 66	100 / 15	128 / 19	360 / 52
550 °C / 1 022 °F	147 / 21	167 / 24	425 / 62	98 / 14	127 / 18	–

Mechanical properties at low temperatures, minimum values according to EN 10028-7

Table 9

	20 °C / 68 °F			
	Yield strength $R_{p0.2}$ [MPa/ksi]	Yield strength $R_{p1.0}$ [MPa/ksi]	Tensile strength R_m [MPa/ksi]	Elongation A [%]
Supra 316plus®	350 / 51	380 / 55	650 / 94	35
ASTM 316L/EN 1.4404	220 / 32	260 / 38	520 / 75	45
	-80 °C / -112 °F			
	Yield strength $R_{p0.2}$ [MPa/ksi]	Yield strength $R_{p1.0}$ [MPa/ksi]	Tensile strength R_m [MPa/ksi]	Elongation A [%]
Supra 316plus®	430 / 62	520 / 75	900 / 131	35
ASTM 316L/EN 1.4404	275 / 40	355 / 51	840 / 122	40
	-150 °C / -238 °F			
	Yield strength $R_{p0.2}$ [MPa/ksi]	Yield strength $R_{p1.0}$ [MPa/ksi]	Tensile strength R_m [MPa/ksi]	Elongation A [%]
Supra 316plus®	530 / 77	620 / 90	1 080 / 157	35
ASTM 316L/EN 1.4404	315 / 46	415 / 60	1 070 / 155	40
	-196 °C / -320.8 °F			
	Yield strength $R_{p0.2}$ [MPa/ksi]	Yield strength $R_{p1.0}$ [MPa/ksi]	Tensile strength R_m [MPa/ksi]	Elongation A [%]
Supra 316plus®	600 / 87	700 / 102	1 200 / 174	30
ASTM 316L/EN 1.4404	350 / 51	450 / 65	1 200 / 174	35

Enhanced mechanical properties

As shown in the graph below, Supra 316plus® offers a significantly improved yield strength ($R_{p0.2}$) of over 45% at room temperature compared with ASTM 316L/EN 1.4404 and ASTM 316Ti/EN 1.4571. While this gap in performance decreases with increasing temperature, even at 550 °C, Supra 316plus® offers superior yield strength.

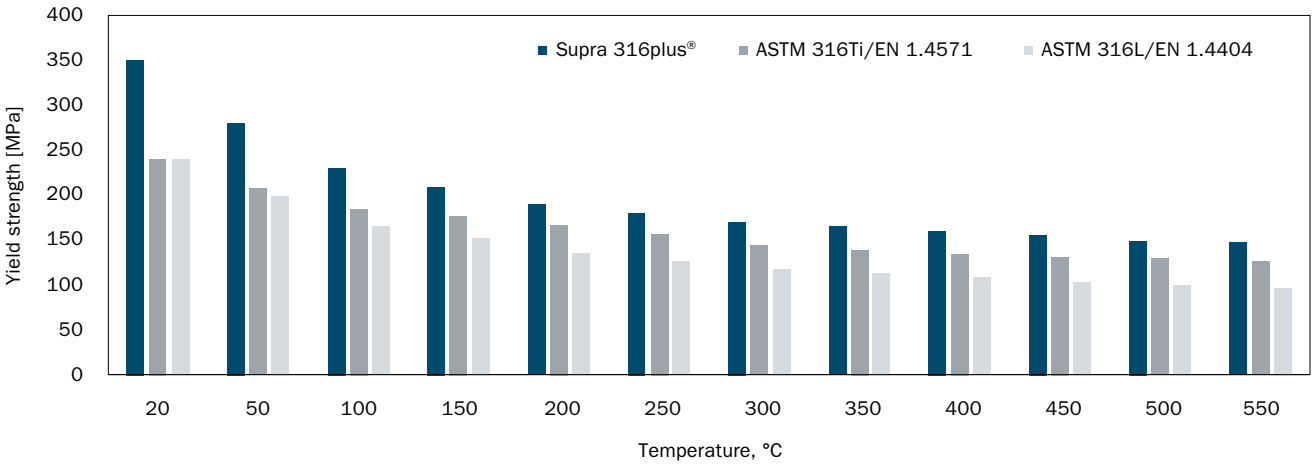
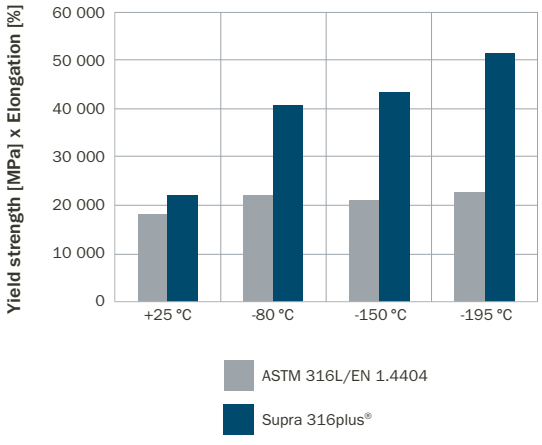


Fig. 1. Values from EN 10028-7 ($R_{p0.2}$).

Physical properties

The crystal structure of Supra 316plus® is austenitic, and therefore the material is non-ferromagnetic in the annealed condition. Analyze provides highly stable austenitic structure, which makes the Supra 316plus® highly resist towards martensite transformation and very good against Hydrogen embritlement. Supra 316plus® also offers important performance benefits at lower temperatures that make it ideally suited for arctic, liquid natural gas (LNG), Hydrogen and all other cryogenic applications. As shown in Figure 2, Supra 316plus® performs, in all tested temperatures, significantly better than ASTM 316L/EN 1.4404 in terms of its ability to absorb energy.



Source: VTT Technical Research Centre of Finland

Fig. 2. Supra 316plus® superior strength & ductility at cryogenic temperatures.

Table 10

Density at 20 °C	Modulus of elasticity at						Thermal expansion at					Thermal conductivity at 20 °C	Thermal capacity at 20 °C	Electrical resistivity at 20 °C
kg/dm³	[GPa]						[10⁻⁶/K]					[W/(m x K)]	[J/(kg x K)]	[Ω x mm²/m]
	20 °C	100 °C	200 °C	300 °C	400 °C	500 °C	100 °C	200 °C	300 °C	400 °C	500 °C			
7.9	200	194	186	177	169	160	16.0	16.5	17.0	17.5	18.0	15	500	0.73

Standards & approvals

Table 11

Standards and approvals	
EN 10088-2	Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes
EN 10028-7	Flat products made of steels for pressure purposes – Part 7: Stainless steels
EN 1993-1-4	Eurocode 3 – Design of steel structures – Part 1-4: Stainless steel structures
EN 1993-1-2	Eurocode 3 – Design of steel structures – Part 1-2: Structural fire design
PED Directive 2014/68/EU	European Pressure Equipment Directive
ASTM A240/A240M	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASME BPVC	UNS S31655 Austenitic Steel, alloy Plate, Sheet, and Strip Section VIII, Division 1
EN 10088-4	Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes (Only Avesta)
AD 2000-Merkblatt W2	Available Particular Material Appraisal (PMA) for AD 2000-Merkblatt W2 (Only Tornio)
Lloyd's Register approval	Certificate No: MD00/1165/0008/1. Steelmaking, Semi-Finished Products, Plates, Hot Rolled Coil and Coil
DNV-GL approval	Certificate No: AMMM00001DW. Steelmaking and Rolled Steel Products
ASTM A249/A249M	Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
ASTM A269/A269M	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A358/A358M	Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications
ASTM A554	Standard Specification for Welded Stainless Steel Mechanical Tubing
ASTM A312/S312M	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
NACE	NACE MR0103 / ISO 17945 and NACE MR0175/ISO 15156-1 / NACE MR0175/ISO 15156-3

Table 12

Standards and approvals in progress	
EN 10217-7	Welded steel tubes for pressure purposes – Technical delivery conditions – Part 7: Stainless steel tubes
EN 10088-4	Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes (for Tornio and German Mills)
EN 10095	Heat resisting steels and nickel alloys, Annex D
AISC 370	Specification for Structural Stainless Steel Buildings
ASCE 8	Specification for the Design of Cold-Formed Stainless Steel Structural Members
AD 2000-Merkblatt W2	Available Particular Material Appraisal (PMA) for AD 2000-Merkblatt W2 (for Swedish and German Mills)
API 650	Welded Tanks for Oil Storage
API 620	Design and Construction of Large, Welded, Low-pressure Storage Tanks

Fabrication

Supra 316plus® can be easily formed using all typical forming processes like folding, bending, drawing, etc.

Supra 316plus® has remarkably higher proof strength than the standard austenitic stainless steel grade ASTM 316L/EN 1.4404 in combination with the same degree of work hardening. The chemical composition enables the Erichsen Index and LDR (Limiting Drawing Ratio) to match those of well-known austenitic stainless steels like ASTM 304L/EN 1.4307 or ASTM 316L/EN 1.4404. These characteristics mean good deep drawability and excellent stretch-forming capabilities.

Welding

Supra 316plus® has excellent weldability and is suitable for the full range of all conventional welding methods (like MMA, MIG, MAG, TIG, SAW, LBW, or RSW). To ensure that the weld metal properties (e.g. strength, corrosion resistance) are equivalent to those of the parent metal, matching or slightly over-alloyed fillers should preferably be used. Austenitic 19 12 3 L (316L) filler metals can be used to match corrosion resistance and 22 09 NL type duplex welding consumables to match strength. Shielding gases should be Ar/He based or contain up to 3% nitrogen to minimize nitrogen drop. Typical heat input values for austenitic grades can be utilized. The high nitrogen content tends to restrict grain growth during the thermal cycle. Welds are not sensitized when normal welding procedures are followed.

Generally, post-weld heat treatment is not required. In special cases with high risks of stress corrosion cracking or fatigue, stress relief treatment may be considered.

In order to fully restore the corrosion resistance of the weld seam, the weld discoloration should be removed by pickling and passivation. More detailed information concerning welding procedures can be obtained from the Outokumpu Welding Handbook.

Contacts & Enquiries

Contact your nearest sales office

www.outokumpu.com/contacts

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Working towards a world that lasts 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 Mildly corrosive environments	Core Corrosive environments	Supra Highly corrosive environments	Forta Duplex & other high strength	Ultra Extremely corrosive environments	Dura High hardness	Therma High service temperatures	Prodec Superior machinability	Deco Special surfaces

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