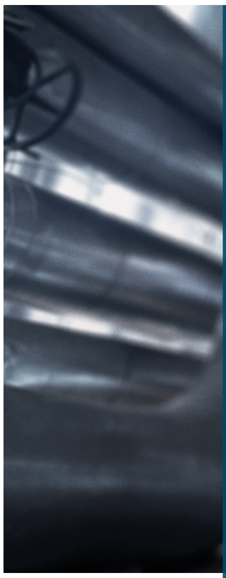

outokumpu
sustainable stainless steel

High performance steels and alloys for extremely corrosive environments

Outokumpu Ultra range datasheet

Ultra
Extremely corrosive environments

General characteristics and properties

The Ultra range consists of stainless steels and nickel base alloys meant for extremely corrosive environments (PRE > 27).

The Outokumpu Ultra range consists of high performance austenitic stainless steels and nickel base alloys that differ substantially from more conventional grades with regard to resistance to corrosion and, in some cases, also mechanical and physical properties. This is due to the high contents of mainly chromium, nickel, molybdenum and nitrogen. All grades have a fully austenitic microstructure in the quenched and annealed condition.

Ultra range grades have:

- Very good resistance to uniform corrosion
- Good to exceptionally good resistance to pitting and crevice corrosion
- Very good resistance to various types of stress corrosion cracking
- Very good ductility
- Good weldability
- Excellent formability

Chemical composition

Table 1

Ultra — Steels and alloys with PRE > 27, for extremely corrosive environments.

Outokumpu **Pro** family

Steel and alloy designations				Performance				Typical chemical composition, % by mass					
		ASTM			A [1]	$R_{p0.2}$	Grade						
Outokumpu name	EN	Type	UNS	PRE	%	MPa	family	C	Cr	Ni	Mo	N	Others
Key Ultra grades													
Ultra 904L	1.4539	904L	N08904	34	35	240	A	0.01	19.8	24.2	4.3	–	1.4Cu
Ultra 254 SMO	1.4547	–	S31254	43	35	320	A	0.01	20.0	18.0	6.1	0.20	Cu
Ultra Alloy 825	2.4858 [2]	–	N08825	33	30 [3]	241 [3]	A	0.01	23.0	39.0	3.2	–	1.7Cu, Ti, Al
Other Ultra grades													
Ultra 317L	(1.4438) [4]	317L	S31703	28	40 [5]	205 [5]	A	0.02	18.2	11.6	3.1	–	–
Ultra 725LN	1.4466	310MoLN2	S31050	34	40 [6]	250 [6]	A	0.01	25.0	22.3	2.1	0.12	–
Ultra 6XN	1.4529	–	N08926/ N08367	45	40 [6]	300 [6]	A	0.01	20.5	24.8	6.5	0.20	Cu
Ultra 654 SMO	1.4652	–	S32654	56	40	430	A	0.01	24.0	22.0	7.3	0.50	3.5Mn, Cu
Grades from other ranges for comparison													
Supra 316L/4404	1.4404	316L	S31603	24	40	240	A	0.02	17.2	10.1	2.1	–	–
Forta DX 2205	1.4462	2205	S32205	35	20	500	D	0.02	22.4	5.7	3.1	0.17	–
Forta SDX 2507	1.4410	2507	S32750	43	20	550	D	0.02	25.0	7.0	4.0	0.27	–

Grade family: A = austenitic, D = duplex. [1] Elongation reference varies between different standards, for coil the standard typically uses A_{80} – otherwise see footnote for specific grade. [2] Grade designation according to DIN 17750. [3] Min. values acc. to ASTM B424. [4] Quarto plate also available as EN 1.4438 with typical 14.2 % Ni. [5] Min values acc. to ASTM A-240 [6] Min. values for plate acc. to EN 10088-2.

PRE = %Cr + 3.3 x %Mo + 16 x %N. Values for $R_{p0.2}$ yield strength and for A_{80} elongation are according to EN 10088-2 min. values for cold rolled strip. Chemical compositions and PRE calculations are based on Outokumpu typical values. Please see values for other product forms at **steelfinder.outokumpu.com**

Key Ultra grades

Table 2

Outokumpu name	Typical applications	Product forms
Ultra 904L (EN 1.4539/UNS N08904) A high-nickel and molybdenum-alloyed austenitic stainless steel with very high corrosion resistance. Ultra 904L was originally developed for handling sulfuric acid at ambient temperatures, and is now used in a broad range of chemical industry applications.	• Chemical and petrochemical industry equipment such as pipes, heat exchangers, tanks, and reactor vessels • Sulfuric acid handling • Flanges and valves	• Cold rolled coil and sheet • Hot rolled coil and sheet • Quarto plate • Precision strip
Ultra 254 SMO (EN 1.4547/UNS S31254) A 6 % molybdenum and also nitrogen-alloyed austenitic stainless steel with extremely high resistance to both uniform and localized corrosion. This product was developed especially for oil and gas offshore platforms and the pulp and paper industry.	• Applications requiring resistance to chlorinated seawater • Flue gas cleaning • Bleaching equipment in the pulp and paper industry • Flanges and valves • Heat exchangers (plate and tubular)	• Cold rolled coil and sheet • Hot rolled coil and sheet • Quarto plate • Precision strip
Ultra Alloy 825 (EN 2.4858/ UNS N08825) Outokumpu Ultra Alloy 825 is a titanium stabilized austenitic nickel base alloy with an addition of copper. It has excellent resistance to stress corrosion cracking and very good resistance in oxidizing and reducing acids.	• Components in sour gas service • Offshore oil and gas piping systems • Equipment in petroleum refineries • Heating coils • Heat exchangers • Tanks • Chemical processing equipment	• Cold rolled coil and sheet • Hot rolled coil and sheet • Quarto plate

Other Ultra grades

Table 3

Outokumpu name	Typical applications	Product forms
Ultra 317L (EN 1.4438/UNS S31703) A molybdenum-alloyed austenitic stainless steel with higher corrosion resistance than Supra 316L/4404 – mainly used in the USA and in Asia.	• Chemical processing industry equipment • Oil and gas	• Cold rolled coil and sheet *) • Hot rolled coil and sheet *) • Quarto plate
Ultra 725LN (EN 1.4466/UNS S31050) Ultra 725LN is a type according to ASTM 310 material (high chromium and high nickel) that has been developed and optimized specifically for urea applications, which demand extremely high corrosion resistance. It has similar general pitting resistance as Ultra 904L.	• Fertilizer production	• Quarto plate
Ultra 6XN (EN 1.4529/UNS N08926/UNS N08367) A 6% molybdenum, high nickel and nitrogen-alloyed austenitic stainless steel with extremely high resistance to both uniform and localized corrosion.	• Applications requiring resistance to chlorinated seawater • Flue gas cleaning • Oil and gas	• Cold rolled coil and sheet • Hot rolled coil and sheet • Quarto plate
Ultra 654 SMO (EN 1.4652/UNS S32654) "The most corrosion resistant stainless steel in the world." A 7% molybdenum, very high nitrogen-alloyed austenitic stainless steel with high mechanical strength. A potentially lean alternative to traditional wet corrosion resistant nickel base alloys.	• Pressurized and erosive systems handling chlorinated seawater at elevated temperatures • Heat exchangers • Flue gas cleaning	• Cold rolled coil and sheet

*) Not available as EN 1.4438

Performance

Strength vs. Corrosion resistance

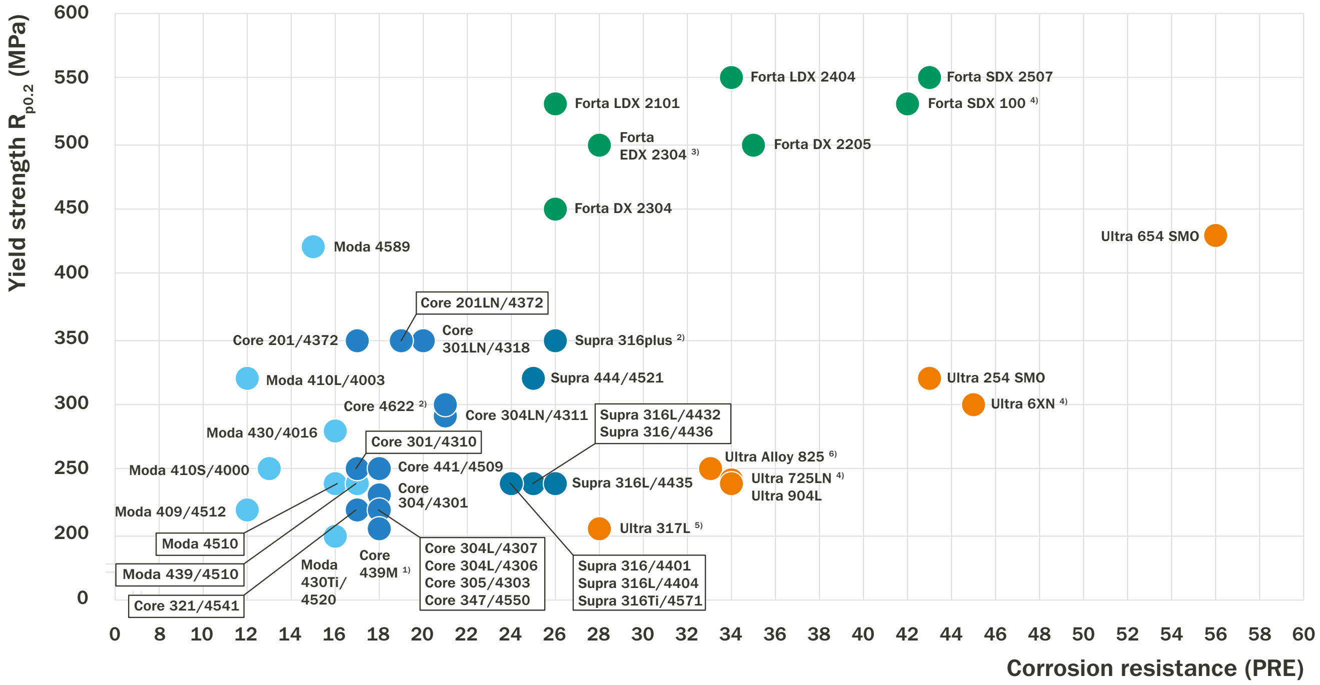

Fig. 1. Strength vs. Corrosion resistance.

Elongation vs. Corrosion resistance

Fig. 2. Elongation vs. corrosion resistance.

- Moda – Stainless steels for mildly corrosive environments (PRE ≤17)
- Core – Stainless steels for corrosive environments (PRE 17–22)
- Supra – Stainless steels for highly corrosive environments (PRE 22–26)
- Forta – Duplex stainless steels (PRE 26–43)
- Ultra – Stainless steels and nickel base alloys for extremely corrosive environments (PRE > 27)

PRE = %Cr + 3.3 x %Mo + 16 x %N.
Values for $R_{p0.2}$ yield strength and for A_{80} elongation are according to EN 10088-2 min. values for cold rolled strip. Chemical compositions and PRE calculations are based on Outokumpu typical values.

[1] Elongation reference varies between different standards, for coil the standard typically uses A_{80} – otherwise see footnote for specific grade.
[2] Min. values acc. to EN 10028-7.
[3] Outokumpu MDS-D35 for EDX 2304.
[4] Min. values for plate acc. to EN 10088-2.
[5] Min values acc. to ASTM A240.
[6] Min. values hot-rolled and cold-rolled acc. to ASTM B424.

Please see values for other product forms at **steelfinder.outokumpu.com**

Corrosion resistance

Stainless steels typically rely on their passivity for corrosion resistance. The stability of the passive film in different corrosive media is strongly dependent on the alloying content – elements like chromium, molybdenum and nitrogen are all well-known to promote passivity of stainless steels, the latter especially in chloride-bearing environments.

With this in mind, Ultra grades is expected to exhibit excellent performance in many environments that would simply be too aggressive for lower-alloyed materials. The high contents of chromium and molybdenum gives them excellent protection against uniform corrosion that might occur in acidic conditions. Most Ultra grades are also alloyed with nitrogen, giving them exceptional resistance to localized corrosion.

Uniform corrosion

The materials in the Ultra range generally have good to excellent resistance to most of the commonly encountered acids and other environments where uniform corrosion might be a risk. An affect of the high nickel content in many Ultra grades is the reduction of active corrosion rates compared to low-Ni grades, e.g. duplex stainless steels.

Sulfuric acid is one of the most commonly encountered acids and can be a challenging because of its changing characteristics across the concentration range. Grades such as Ultra 904L and Ultra Alloy 825 exhibits the best corrosion resistance when considering the whole concentration range as shown in Figure 3. However, at high concentrations lower alloyed grades such as Supra 316L/4404 and duplex grades can outperform Ultra grades. Chloride contamination can have a detrimental effect on the resistance of stainless steels as shown in Figure 4.

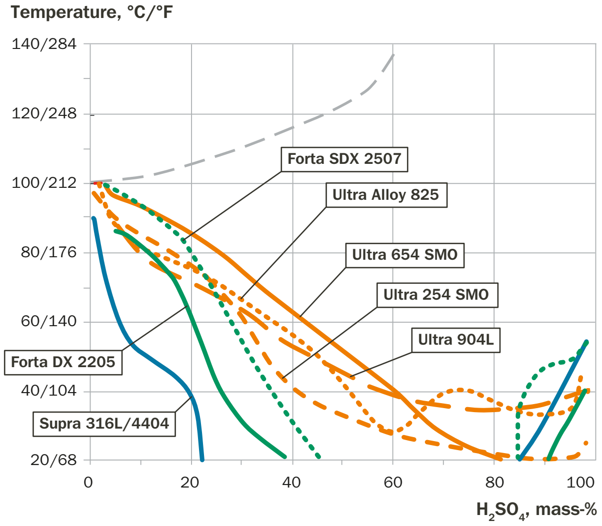

Fig. 3. Isocorrosion curves, 0.1 mm/year, in pure sulfuric acid.

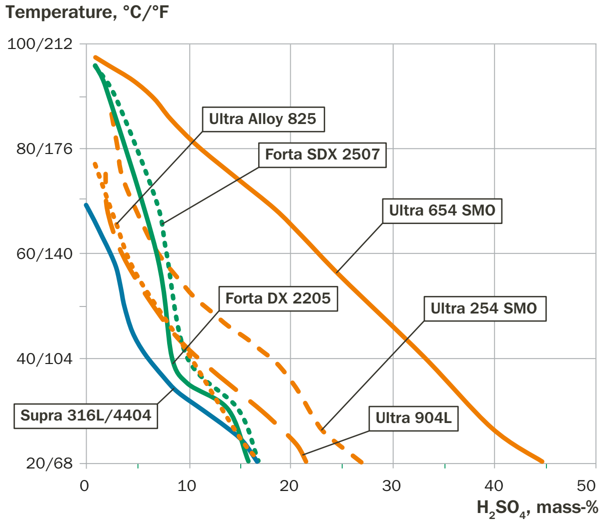

Fig. 4. Isocorrosion curves, 0.1 mm/year, in sulfuric acid containing 2000 ppm chlorides.

Uniform corrosion in wet process phosphoric acid *) at 60 °C

Table 4

Steel grade	Corrosion rate, mm/year
Ultra 254 SMO	0.05
Ultra 904L	1.2
Supra 316L/4404	>5

*) Composition: 54% P_2O_5, 0.06% HCl, 1.1% HF, 4.0% H_2SO_4, 0.27% Fe_2O_3, 0.17% Al_2O_3, 0.10% SiO_2, 0.20% CaO and 0.70% MgO.

Uniform corrosion in pickling acid *) at 25 °C

Table 5

Steel grade	Corrosion rate, mm/year
Ultra 654 SMO	0.06
Ultra 254 SMO	0.27
Ultra 904L	0.47
Supra 316L/4404	>6

*) Composition: 20% HNO_3 + 4% HF.

Corrosion rates in a fatty acid column for the distillation of tall oil at 235 °C

Table 6

Steel grade	Corrosion rate, mm/year
Ultra 254 SMO	0.01
Ultra 904L	0.06
Supra 316L/4404	0.88

Phosphoric acid produced according to the wet process (WPA) contains impurities of many kinds, of which some can have a strong negative influence on the corrosiveness of the acid. As shown in Table 4 the corrosion rate of Ultra 904L and Ultra 254 SMO is much lower than for standard austenitic grade Supra 316L/4404.

All stainless steels are sensitive to halide-based acids, such as hydrofluoric acid, hydrochloric acid and fluosilicic acid. While Ultra grades are no exception, they do indeed offer a significant advantage over standard grades like Supra 316L/4404, see Figures 5–7. The resistance typically increases with increasing alloying content, making Ultra 654 SMO the most resistant grade. This is also true for mixed acid, based on nitric acid and hydrofluoric acid, used for pickling (see Table 5).

Fractional distillation of tall oil often needs more corrosion resistant material than the Supra 316L/4404. Table 6 presents the results of exposing test coupons at a Swedish tall oil plant with the object of determining suitable material for woven packings of stainless steel. In this particular case, packings produced from about 20,000 km of 0.16 mm diameter Ultra 254 SMO wire were used.

In hot concentrated caustic solutions the corrosion resistance is mainly determined by the nickel content of the material, and Ultra 904L in particular can be a good alternative to more conventional stainless steels.

For more detailed information concerning the corrosion resistance of the different steels in other environments, see the Outokumpu Corrosion Handbook.

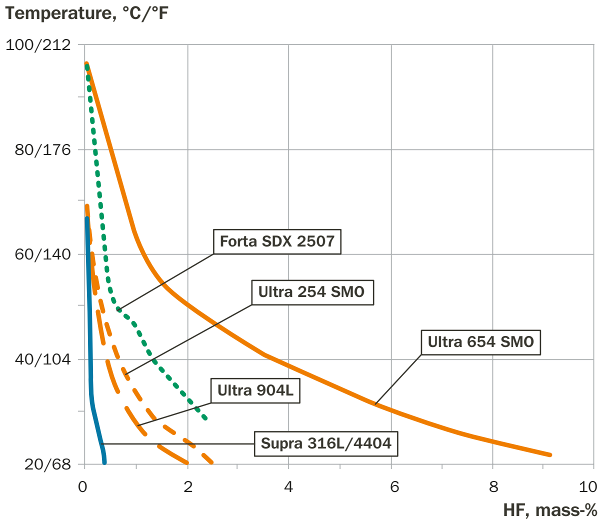

Fig. 5. Isocorrosion curves, 0.1 mm/year, in pure hydrofluoric acid.

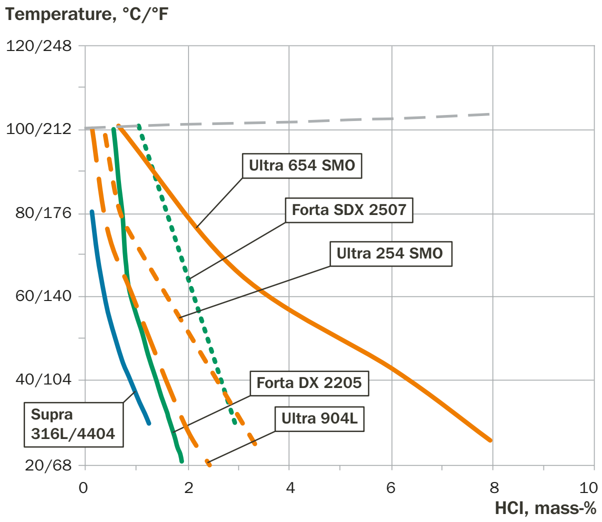

Fig. 6. Isocorrosion curves, 0.1 mm/year, in pure hydrochloric acid.

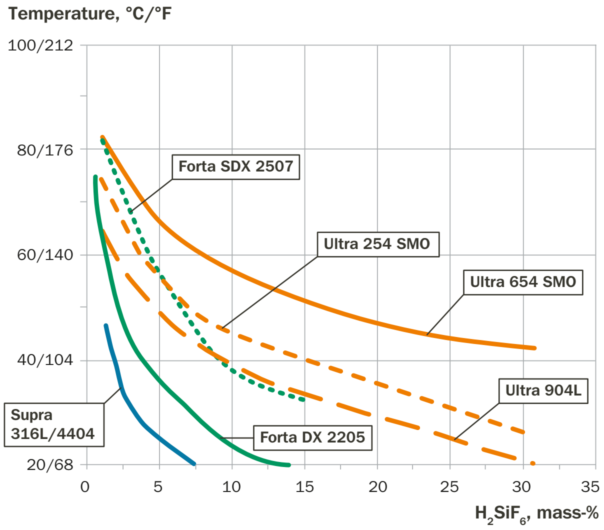

Fig. 7. Isocorrosion curves, 0.1 mm/year, in pure fluosilicic acid.

Pitting and crevice corrosion

Resistance to localized corrosion such as pitting and crevice corrosion is determined mainly by the chromium, molybdenum and nitrogen content in the material. This is often illustrated using the material specific pitting resistance equivalent (PRE), which can be calculated using the formula: PRE = %Cr + 3.3 x %Mo + 16 x %N. PRE values of Ultra range grades are presented in Table 7. The PRE value can be used for rough comparisons of different stainless steels.

A much more reliable means is to rank the steel according to the critical pitting temperature of the material (CPT). There are several different methods available to measure the CPT. Figure 8 shows the CPT, as measured according to ASTM G 150, in a 1 M NaCl solution (35,000 ppm or mg/l chloride ions). The CPT value for mill finish surface may vary between different product forms.

Ultra 6XN, and especially Ultra 654 SMO, have such a good resistance to pitting, that common test methods are not sufficiently aggressive to initiate any corrosion. A better measure of resistance is given by evaluating the results of various crevice corrosion tests (e.g. ASTM G48).

The crevice corrosion resistance of stainless steels can be evaluated by measuring the material specific critical crevice corrosion temperature (CCT). Typical CCT values according to ASTM G48 Method F can be found in Figure 9.

In narrow crevices the passive film may more easily be attacked and in unfavourable circumstances stainless steel can be subjected to crevice corrosion. Examples of such narrow crevices may be under gaskets in flange fittings, under seals in certain types of plate heat exchangers, or under strongly adherent deposits.

PRE values of the Ultra grades

Table 7

Steel grade	PRE
Key Ultra grades	
Ultra 904L	34
Ultra 254 SMO	43
Ultra Alloy 825	33
Other Ultra grades	
Ultra 317L	28
Ultra 725LN	34
Ultra 6XN	45
Ultra 654 SMO	56
Grades from other ranges for comparison	
Supra 316L/4404	24
Forta DX 2205	35
Forta SDX 2507	43

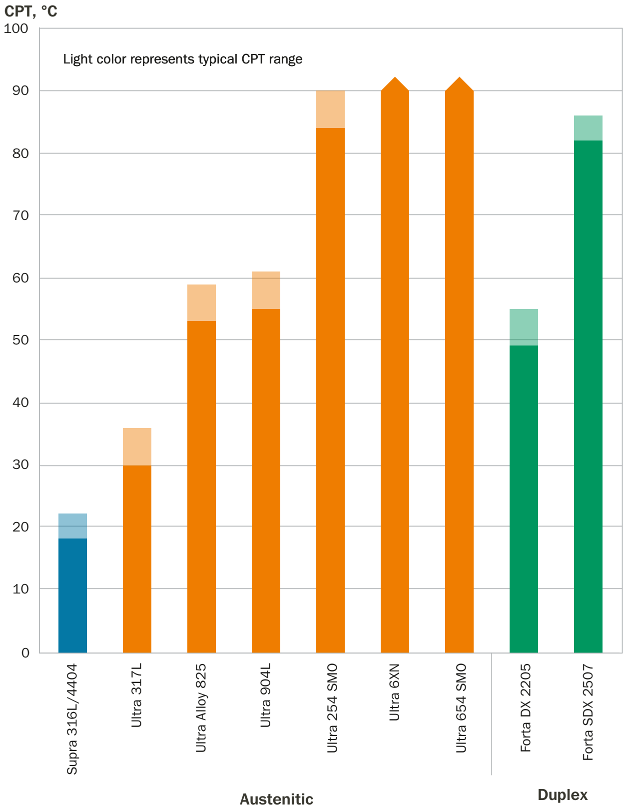

Fig. 8. Typical critical pitting corrosion temperatures (CPT) in 1 M NaCl measured according to ASTM G150 using the Avesta Cell. Test surfaces were wet ground to P320 grit. CPT varies with product form and surface finish.

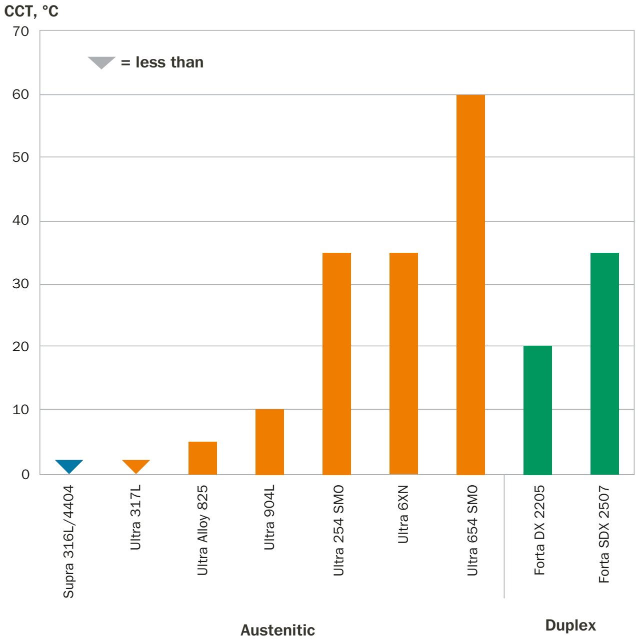

Fig. 9. Typical critical crevice corrosion temperature (CCT) according to ASTM G48 Method F. Test surfaces were dry ground to P120 grit. CCT varies with product form and surface finish.

Guide to material selection

Figure 10 illustrates to which approximate maximum temperatures Ultra 904L and Ultra 254 SMO can be used in aerated waters of varying chloride content. Ultra 317L has slightly higher resistance against pitting and crevice corrosion compared to grade
Supra 316L/4404. Ultra 6XN is in the same range as
Ultra 254 SMO but Ultra 654 SMO has much higher resistance compared to both these grades.

It should be underlined that the corrosion resistance of a material is also influenced by factors other than temperature and chloride content. Examples of such factors are weld defects, presence of oxide from welding, contamination of the steel surface by particles of non-alloyed or low-alloyed steel, microbial activity, pH, and chlorination of water. In demanding cases, such as crevices under the seals of plate heat exchangers or inside threaded connections, the lines for crevice corrosion will move to the left, i.e. the limit for chloride content/temperature is lower.

Seawater

The high performance austenitic stainless steels Ultra 254 SMO, Ultra 6XN and especially Ultra 654 SMO are excellent materials for seawater service.

Natural seawater contains living organisms, which very quickly form a biofilm on stainless steel. This film increases the corrosion potential of the steel and thus, the risk of pitting and crevice corrosion. The activity of the biofilm is temperature related. Different organisms are adapted to the natural water temperature of their habitat. Their activity varies between the different seas around the world. In cold seas, the natural water is most aggressive at 25–30 °C while the corresponding value in tropical seas is just above 30 °C. The biological activity ceases at higher temperatures.

In many seawater systems the water is chlorinated with either chlorine or hypochlorite solutions to reduce the risk of fouling. Both chlorine and hypochlorite are strong oxidizing agents and they cause the corrosion potential of the steel surface to exceed what is normal in non-chlorinated seawater, which in turn means increased risk of corrosion. In chlorinated seawater the aggressiveness increases as the temperature rises.

In crevice-free welded constructions Ultra 254 SMO may normally be used in chlorinated seawater with a chlorine content of up to 1 ppm at temperatures up to about 45 °C. Ultra 654 SMO should be used for flange joints, or the sealing surfaces should be overlay welded, e.g., using an ISO Ni Cr 25 Mo 16 type filler, if the temperature exceeds 30 °C. Higher chlorine content can be permitted if chlorination is intermittent.

Tests have indicated that Ultra 654 SMO can be used in plate heat exchangers with chlorinated seawater as cooling medium at temperatures up to at least 60 °C.

The risk of crevice corrosion in non-chlorinated seawater is considerably lower. Ultra 254 SMO has successfully been used in some fifty installations for desalination of seawater according to the reverse osmosis process. Ultra 654 SMO is resistant to pitting in natural boiling seawater.

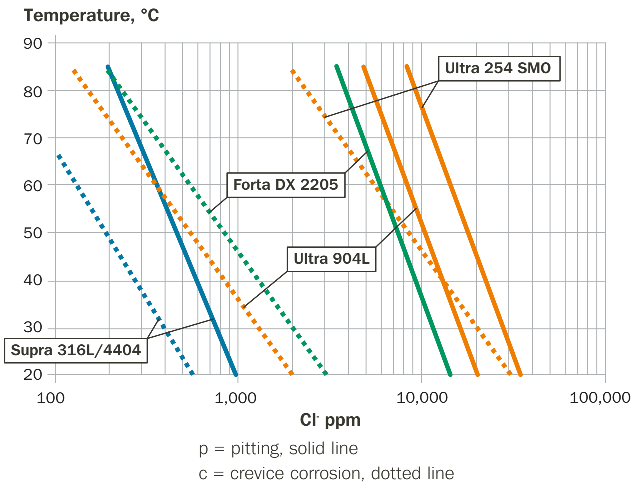

Fig. 10. Engineering diagram indicating the maximum temperature and chloride concentration allowed in slightly chlorinated (< 1 ppm) waters.

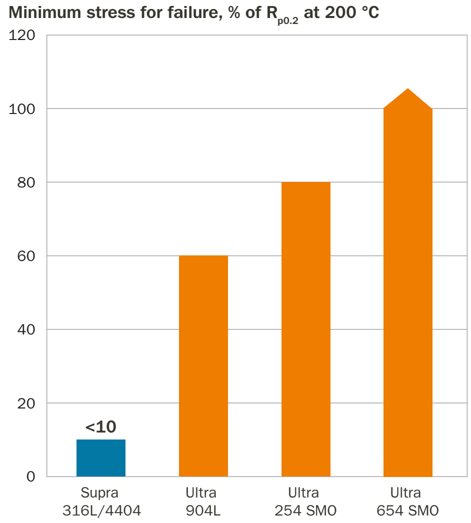

Fig. 11. Typical threshold stresses determined using the drop evaporation test.

Stress corrosion cracking

Stress corrosion cracking (SCC) is caused by the combined effect of mechanical stress and corrosive environment. Standard austenitic stainless steels such as Core 304L/4307 and Supra 316L/4404 are sensitive to stress corrosion cracking in chloride containing environments at elevated temperatures.

One way to improve the resistance to SCC is to increase above all the content of nickel and molybdenum. Therefore the high performance grades Ultra 904L, Ultra 254 SMO, Ultra 6XN, Ultra 654 SMO and Ultra Alloy 825 have very good resistance to SCC.

Different methods are used to rank stainless steel grades with regard to their resistance to SCC. The results can vary depending on testing method and environment. The resistance to stress corrosion cracking in a chloride solution under evaporative conditions can be determined according to the drop evaporation test method. Here a 0.1 M NaCl solution is allowed to slowly drip onto a heated specimen being subjected to tensile stress. By this method the threshold value is determined for the minimum relative stress resulting in rupture after 500 hours of testing. The threshold value is usually expressed as a percentage of the proof strength of the steel at 200 °C. Figure 11 shows the results of such a test, where high performance austenitic Ultra grades offer considerably better resistance to SCC than Supra 316L/4404.

Sulfide-induced stress corrosion cracking

Hydrogen sulfide can sometimes cause embrittlement of ferritic steels, and even of cold-worked duplex and austenitic steels. The sensitivity to cracking increases when the environment contains both hydrogen sulfide and chlorides. Such “sour” environments occur for example in the oil and gas industry.

Standard ISO 15156-3 (ANSI/NACE MR0175) provides requirements and recommendations for selection of corrosion resistant alloys for use in the oil and natural gas production in H_2S environments. It identifies materials that are resistant to cracking in a defined H_2S containing environment, but does not guarantee that the material selected using the standard will be immune from cracking under all service conditions.

High performance grades Ultra 904L, Ultra 254 SMO, Ultra 6XN, Ultra 654 SMO and Ultra Alloy 825 are included in ISO 15156-3 (ANSI/NACE MR0175). In accordance with this standard solution annealed Ultra 904L, Ultra 254 SMO, Ultra 6XN and Ultra 654 SMO are acceptable for use for any component or equipment up to 60 °C in sour environments. This is on condition that the partial pressure of hydrogen sulfide (pH_2S) does not exceed 1 bar (15 psi), or without restriction on temperature and pH_2S that the chloride concentration does not exceed 50 ppm. Moreover, solution annealed Ultra 254 SMO, Ultra 6XN and Ultra 654 SMO are acceptable for use up to 171 °C or pH_2S up to 7 bar (100 psi) if the chloride concentration does not exceed 5000 ppm. Ultra Alloy 825 can according to ISO 15156-3 be used without restrictions on temperature, pH_2S, chloride concentration or in situ pH in annealed condition. However, some combinations of individual parameters might not be acceptable. For cold worked Ultra Alloy 825 the temperature limit is 232 °C, providing that pH_2S does not exceed 2 bar (30 psi).

Intergranular corrosion

High performance austenitic stainless steels have such a low carbon content that the risk of conventional intergranular corrosion caused by chromium carbide precipitates in connection with welding is negligible. This means that welding can be performed without risk of intergranular corrosion.

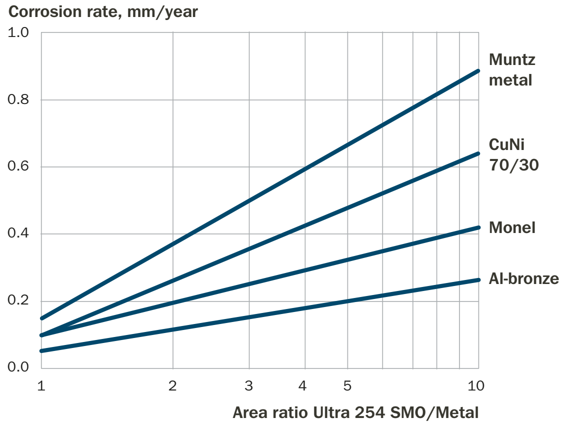

Fig. 12. Galvanic corrosion of copper alloys in contact with Ultra 254 SMO in slow moving seawater at ambient temperature.

Erosion corrosion

Unlike copper alloys, stainless steel generally offers very good resistance to impingement attack. This renders the need to limit the velocity of water redundant, e.g. in piping systems that convey seawater. Further, stainless steel is not sensitive to seawater that has been contaminated by sulfur compounds or ammonia.

In systems subjected to particles causing extreme wear, e.g., sand or salt crystals, the higher surface hardness of duplex stainless steels can in some cases be an advantage.

Galvanic corrosion

The high performance austenitic stainless steels Ultra 254 SMO, Ultra 6XN and Ultra 654 SMO are not affected by galvanic corrosion if they are connected to titanium in systems used for conveying seawater. However, the rate of corrosion for copper alloys is increased if they come into contact with most stainless steels (or with titanium). The intensity of corrosion is closely related to the surface area ratio between the stainless steel and the copper alloy, see Figure 12. The galvanic corrosion tests have been carried out with Ultra 254 SMO but the relation is the same for other high performance austenitic stainless steels. The galvanic effect is reduced somewhat if the seawater is chlorinated.

Fabrication

Forming

All Outokumpu high performance austenitic grades have very good formability properties and are suitable for all forming processes available for stainless steel. Depending on the chosen forming technique, the somewhat higher yield strength, and in some cases, lower fracture elongation of these grades compared to the most common standard austenitic grades can however impose small differences in forming behaviour such as increased springback. This can be compensated for, especially if the forming process is designed for the specific stainless steel grade. Moreover, an excellent interplay between the high yield strength, work hardening rate and elongation, make the high nitrogen containing grade Ultra 654 SMO well suited for light weight and cost-effective applications with complex shapes.

The impact of high strength varies for different forming techniques. Yet for all high performance austenitic grades the estimated forming forces will be higher than for the standard austenitic stainless steel grades. The higher yield strength of the high performance austenitic grades may also result in higher demands on the tool materials and the lubricant. However, both effects will be reduced if down gauging is possible.

For more information, see the Outokumpu Forming Handbook, available from our sales offices.
outokumpu.com/contacts

Cold forming

The high strength of the high nitrogen containing grade Ultra 654 SMO is clearly demonstrated when the stress-strain curves of high performance austenitic Ultra grades are compared with the standard austenitic grade Supra 316L/4404, see Figure 13. The deformation hardening rate is similar for all the austenitic grades presented in Figure 13.

The formability of Outokumpu's Ultra grades can be characterized in several ways. A sheet material's ability to withstand thinning during forming is demonstrated by the r-value in different tensile directions. The higher the r-value the better. Ultra 654 SMO shows excellent r-values as illustrated in Figure 14.

Figure 15 gives a relative comparison of the formability in plane strain condition between Ultra grades and the standard grade Supra 316L/4404. The ranking represents the most critical failure mode in sheet forming, especially in forming operations dominated by thinning (stretching). In pure drawing, all austenitic grades are comparable in that about the same limiting drawing ratio can be shown.

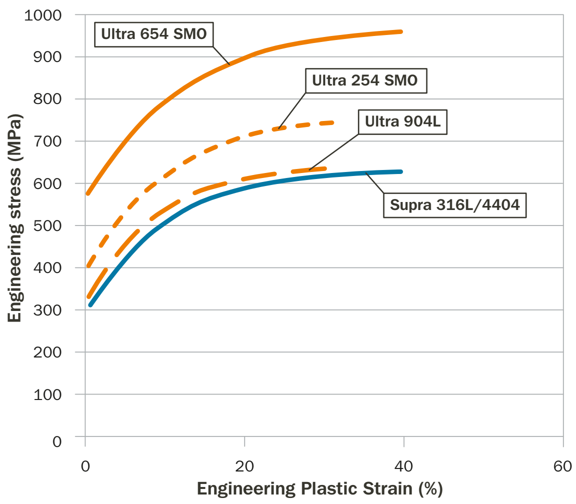

Fig. 13. Engineering stress-strain curves for high performance austenitic grades and standard austenitic grade Supra 316L/4404 (1.0 mm thick cold rolled).

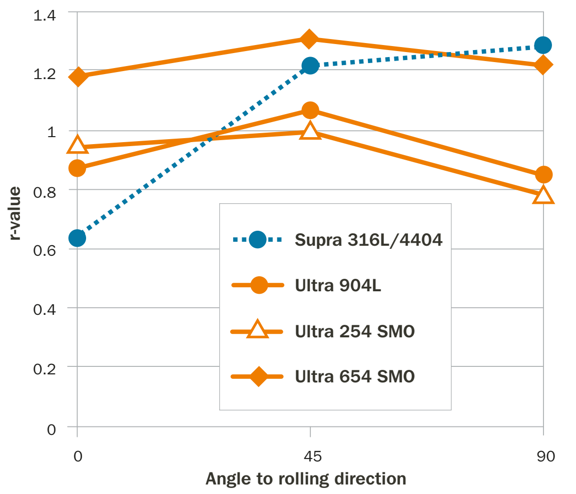

Fig. 14. r-values for high performance austenitic grades and standard austenitic grade Supra 316L/4404.

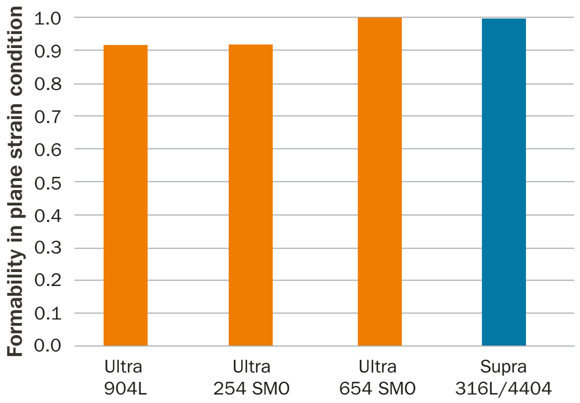

Fig. 15. Formability ranking of high performance austenitic grades in relation to standard austenitic grade Supra 316L/4404.

Typical temperatures, °C

Table 8

	Hot forming [1]	Solution annealing [1]	Pressure vessel approval
Ultra 904L	1150–850	1060–1140	-196 – +400
Ultra 254 SMO	1200–1000	1150–1200 [2]	-196 – +400
Ultra Alloy 825	1200–1000	1150–1200 [2]	-196 – +400
Ultra 317L	1250–850 [3]	1120–1160 [3]	-196 – +475
Ultra 725LN	1150–850	1070–1150	–
Ultra 6XN	1150–850	1120–1180	-196 – +400
Ultra 654 SMO	1200–1000	1150–1200	RT – +427 [4]

1) According to EN 10088-2: For corresponding EN grade numbers see Table 1.
2) Quenching with water at a thickness above 2 mm, below 2 mm an annealing temperature of 1120-1150°C and cooling with air/water can be used.
3) Outokumpu typical values.
4) ASME Code Case 2195-1

Welding consumables

Table 9

Steel grade	Welding consumables	
	Covered electrodes ISO 3581 ISO 14172	Wires ISO 14343 ISO 18274
Ultra 904L	20 25 5 Cu L	20 25 5 Cu L
Ultra 254 SMO	Ni Cr 21 Mo Fe Nb or Ni Cr 25 Mo 16 or P54 *)	Ni Cr 22 Mo 9 Nb
Ultra Alloy 825	Ni Cr 21 Mo Fe Nb or Ni Cr 22 Mo 9 Nb	Ni Cr 22 Mo 9 Nb
Ultra 317L	317L	317L
Ultra 725LN	25 22 2 N L	25 22 2 N L
Ultra 6XN	Ni Cr 21 Mo Fe Nb or Ni Cr 25 Mo 16 or P54 *)	Ni Cr 22 Mo 9 Nb
Ultra 654 SMO	Ni Cr 25 Mo 16	Ni Cr 25 Mo 16

*) voestalpine Böhler Welding designation. For use in certain oxidizing environments, e.g. chlorine dioxide stage in pulp bleaching plants, when welding Ultra 254 SMO and Ultra 6XN.

Hot forming

Suitable temperatures for hot forming of Ultra grades are shown in Table 8. Higher temperatures cause a deterioration in ductility and an increase in the formation of oxides (scaling). Normally hot working should be followed by solution annealing and quenching. However for Ultra 904L, if the hot forming is discontinued at a temperature above 1100 °C and the material is quenched directly thereafter, the material may be used without subsequent heat treatment. It is utterly important that the entire workpiece has been quenched from temperatures above 1100 °C.
In the case of partial heating or partial cooling below 1100 °C or if cooling has been too slow, hot working should always be followed by solution annealing and quenching.

Ultra 254 SMO and Ultra 654 SMO should be quenched at a temperature of at least 1150 °C after hot working to remove intermetallic phases formed during the hot working operation. These phases can also reoccur if the subsequent cooling process is too slow, resulting in reduced corrosion resistance.

Machining

Austenitic stainless steels work-harden quickly. This, together with their high toughness, means that they are often perceived as challenging from a machining perspective in operations such as turning, milling and drilling. This applies to an even greater extent to most highly alloyed steels and especially those that have a high nitrogen content, i.e. Ultra 254 SMO, Ultra 6XN and Ultra 654 SMO.

However, with the right choice of tools, tool settings and cutting speeds, these materials can be successfully machined. For further information see the Outokumpu Machining Guidelines for these grades.

Welding

All Ultra grades are well suited for welding and the methods used for welding conventional austenitic stainless steels can also be used on the Ultra range. However, due to their stable austenitic microstructure, they are somewhat more sensitive to hot cracking in connection with welding and generally welding should be performed using a low heat input.

On delivery, sheet, plate and other processed products have a homogeneous austenitic microstructure with an even distribution of alloying elements in the material. Solidification after partial smelting, e.g. by welding, causes redistribution of certain elements such as molybdenum, chromium and nickel. Segregation could remain in the cast structure of the weld which could impair the corrosion resistance in certain environments.

Segregation tendency is less evident in Ultra 904L and this steel is normally welded using a filler of the same composition as the base material and it can even be welded without filler. For Ultra 254 SMO, Ultra 6XN and Ultra 654 SMO, the variation for molybdenum in particular is so great that it must be compensated for by using fillers which have a higher content of molybdenum. EN ISO Ni Cr 21 Mo Fe Nb type of filler is normally used for welding Ultra 254 SMO and Ultra 6XN. ISO Ni Cr 25 Mo 16 type filler is recommended for the welding of Ultra 654 SMO.

The effect of segregation after welding can also be reduced by subsequent heat treatment and quench annealing, but such action is normally limited to uncomplicated geometries, e.g., pipes, pipe fittings and end pieces.

In the case of multi-run welding, the workpiece should be allowed to cool to 100 °C before welding the next run. This is the case for all Ultra grades.

In order to restore the stainless steel surface and achieve good corrosion resistance after welding, it is often necessary to perform a post fabrication treatment.

There are different methods available: Mechanical methods such as brushing, blasting and grinding as well as chemical methods, e.g. pickling. Which method to apply depends on not only what consequences the fabrication caused, i.e. what type of imperfections are to be removed, but also on requirements with regard to corrosion resistance, hygiene and aesthetic appearance.

For more information, see the Outokumpu Welding Handbook, available from our sales offices.
outokumpu.com/contacts

Mechanical properties

Mechanical properties at 20 °C, values according to EN 10088-2 [1)]

Table 10

Metric

Outokumpu name	Product form	Min. yield strength $R_{p0.2}$ [MPa]	Min. yield strength $R_{p1.0}$ [MPa]	Tensile strength R_m [MPa]	Min. elongation A [%] [2)]
Ultra 904L	Cold rolled	240	270	530–730	35
	Hot rolled	220	260	530–730	35
	Plate	220	260	520–720	35
Ultra 254 SMO	Cold rolled	320	350	650–850	35
	Hot rolled	300	340	650–850	35
	Plate	300	340	650–850	40
Ultra Alloy 825 [3)]	Cold rolled	240	–	590	30 [3)]
	Hot rolled	240	–	590	30 [3)]
	Plate	240	–	590	30 [3)]
Ultra 317L	Cold rolled	240	270	–	35
	Hot rolled	220	260	–	35
	Plate	220	260	520–720	40
Ultra 725LN	Cold rolled	–	–	–	–
	Hot rolled	–	–	–	–
	Plate	250	290	540–740	40
Ultra 6XN	Cold rolled [4)]	300	340	650–850	35
	Hot rolled [4)]	300	340	650–850	35
	Plate	300	340	650–850	40
Ultra 654 SMO	Cold rolled	430	470	750–1000	40
	Hot rolled	430	470	750–1000	40
	Plate	430	470	750–1000	40

[1)] For corresponding EN grade numbers see Table 1. [2)] Thickness < 3 mm: A_{80}, initial length = 80 mm Thickness ≥ 3 mm: A, initial length = $5.65\sqrt{S_0}$.
[3)] Values according to ISO 6208. [4)] Will be in new revision of 10088-2 by 2022/23.

Mechanical properties, values according to ASTM A240

Table 11

Outokumpu name	EN	ASTM UNS	Product form	Yield strength $R_{p0.2}$ [MPa]	Yield strength $R_{p0.2}$ [ksi]	Tensile strength R_m [MPa]	Tensile strength R_m [ksi]	Elongation A_{50} [%]
Ultra 904L	1.4539	N08904	Plate, Sheet and Strip	220	31	490	71	35
Ultra 254 SMO	1.4547	S31254	Sheet and Strip	310	45	690	100	35
			Plate	310	45	655	95	35
Ultra Alloy 825 [1)]	2.4858	N08825	Hot and Cold rolled Sheet and Plate	241 [2)]	35 [2)]	586	85	30
			Cold-Rolled Strip	241 [2)]	35 [2)]	586 [3)]	85 [3)]	30 [3)]
Ultra 317L	(1.4438) [4)]	S31703	Plate, Sheet and Strip	205	30	515	75	40
Ultra 725LN	1.4466	S31050	Plate, Sheet and Strip t ≤ 0.25 in. (6.35 mm)	270	39	580	84	25
			Plate, Sheet and Strip t > 0.25 in. (6.35 mm)	255	37	540	78	25
Ultra 6XN	1.4529	N08926	Plate, Sheet and Strip	295	43	650	94	35
	1.4529	N08367	Sheet and Strip	310	45	690	100	30
			Plate	310	45	655	95	30
Ultra 654 SMO	1.4652	S32654	Plate, Sheet and Strip	430	62	750	109	40

[1)] Values according to ASTM B424. [2)] Yield strength requirements do not apply to material under 0.020 in. (0.51 mm) in thickness. [3)] Not applicable for thicknesses under 0.010 in. (0.25 mm). [4)] Quarto plate also available as EN 1.4438 with typical 14.2 % Ni.

Mechanical properties at elevated temperatures, minimum values according to EN 10088-2

Table 12

Metric/Imperial							
Outokumpu name	**Mechanical properties [MPa/ksi]**		**100 °C/212 °F**	**200 °C/392 °F**	**300 °C/572 °F**	**400 °C/752 °F**	**500 °C/932 °F**
Ultra 904L	Proof strength	$R_{p0.2}$	205/30	175/25	145/21	125/18	110/16
	Proof strength	$R_{p1.0}$	235/34	205/30	175/25	155/22	140/20
	Tensile strength [1]	R_m	500/73	460/67	440/64	–	–
Ultra 254 SMO	Proof strength	$R_{p0.2}$	230/33	190/28	170/25	160/23	148/21
	Proof strength	$R_{p1.0}$	270/39	225/33	200/29	190/28	180/26
	Tensile strength [1]	R_m	615/89	560/81	525/76	510/74	495/72
Ultra 317L	Proof strength	$R_{p0.2}$	172/25	147/21	127/18	115/17	110/16
	Proof strength	$R_{p1.0}$	206/30	177/26	156/23	144/21	138/20
	Tensile strength [1]	R_m	430/62	390/57	380/55	–	–
Ultra 725LN	Proof strength	$R_{p0.2}$	195/28	160/23	140/20	–	–
	Proof strength	$R_{p1.0}$	225/33	190/28	170/25	–	–
	Tensile strength [1]	R_m	490/71	460/67	440/64	–	–
Ultra 6XN	Proof strength	$R_{p0.2}$	230/33	190/28	170/25	160/23	–
	Proof strength	$R_{p1.0}$	270/39	225/33	205/30	190/28	–
	Tensile strength [1]	R_m	550/80	520/75	480/70	–	–
Ultra 654 SMO	Proof strength	$R_{p0.2}$	350/51	315/46	300/44	295/43	280/41
	Proof strength	$R_{p1.0}$	390/57	355/51	335/49	330/48	310/45
	Tensile strength [2]	R_m	680/99	620/90	585/85	560/81	–

[1] Minimum values according to EN 10028-7. [2] Values given by Outokumpu.

Physical properties

Metric values according to EN 10088-1 [1)]

Table 13

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
Ultra 904L	8.0	195	15.8	12	450	1.00	No
Ultra 254 SMO	8.0	195	16.5	14	500	0.85	No
Ultra Alloy 825	8.1	195	14.1	10.5	440	1.12	No
Ultra 317L	8.0	200	16.0	14	500	0.85	No
Ultra 725LN	8.0	195	15.7	14	500	0.80	No
Ultra 6XN	8.1	195	15.8	12	450	1.00	No
Ultra 654 SMO	8.0	190	15.0	11 [2)]	500	0.78	No

[1)] For corresponding EN grade numbers see Table 1. [2)] Value given by Outokumpu.

Imperial values converted from Table 13

Table 14

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
Ultra 904L	0.289	28×10^6	8.8	6.9	0.108	39.37	No
Ultra 254 SMO	0.289	28×10^6	9.2	8.1	0.120	33.46	No
Ultra Alloy 825	0.292	28×10^6	7.8	6.1	0.105	44.09	No
Ultra 317L	0.289	29×10^6	8.9	8.1	0.120	33.46	No
Ultra 725LN	0.289	28×10^6	8.7	8.1	0.120	31.50	No
Ultra 6XN	0.292	28×10^6	8.8	6.9	0.108	39.37	No
Ultra 654 SMO	0.289	28×10^6	8.3	6.4	0.120	30.71	No

Products

Surface finishes on Ultra grades

The available surface finishes on our Ultra range are depending on the individual grade in combination with the selected thickness and width. Hot rolled Ultra grades (except for our cold band grade Ultra 654 SMO and our quarto plate grades Ultra 725LN and Ultra 3964) are offered with a 1D surface. Cold rolled Ultra grades can be produced with a 2E Pro or a 2E brushed finish. The addition Pro indicates that the coil was descaled by shot blasting resulting in a rough surface. The smoother finish 2E brushed which is descaled by brushing can be offered up to a thickness of 3 mm. In case an even smoother finish is required our Ultra 317L as well as our Ultra 904L can be produced with a bright annealed 2R/BA finish up to a thickness of 3.5 mm.

The surface finish 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 initiation. In general, the roughness of the hot rolled 1D surface is higher than on cold rolled surfaces.

For more information about the available surface finishes on each Ultra range grade in dependence of thickness and width please contact our Sales.

Standards, specifications and approvals

For a list of international standards by product, see **steelfinder.outokumpu.com**

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

Table 15

Product	Hot rolled quarto plate	Hot rolled coil and sheet	Cold rolled coil and sheet	Precision strip
Ultra 904L	✓	✓	✓	✓
Ultra 254 SMO	✓	✓	✓	✓
Ultra Alloy 825	✓	✓	✓	–
Ultra 317L	✓ [1)]	✓	✓	–
Ultra 725LN	✓	–	–	–
Ultra 6XN	✓	✓	✓	–
Ultra 654 SMO	–	–	✓	–

[1)] Also available as grade EN 1.4438 with typical 14.2 % Ni. See also outokumpu.com.

1563EN:8. December, 2024.

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	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	Superior machinability	Special surfaces

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