outokumpu
high performance stainless steel

Ultra 904L

EN 1.4539, ASTM UNS N08904

General characteristics

High Ni and Mo austenitic grade with very high resistance to corrosion. Commonly used in chemical and petrochemical industry for handling medium concentrated sulphuric acid.

High performance austenitic stainless steels differ substantially from more conventional grades with regard to resistance to corrosion and, in some cases, also mechanical and physical properties. This is mainly due to the high contents of chromium, nickel, molybdenum and nitrogen. High performance austentic stainless steels have good weldability and excellent formability. Outokumpu manufactures a number of steels of this type: 904L, 254 SMO® ,4565 and 654 SMO®. Grade 4529 can also be delivered if specified.

Typical applications

- Process equipment in chemical industry
- Petrochemical industry
- Bleaching equipment in the pulp and paper industry
- Flue gas cleaning
- Desalination
- Seawater handling
- Hydrometallurgy
- Food and beverage
- Pharmaceuticals
- Heat exchangers

Products & dimensions

Cold rolled products, available dimensions (mm)

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Width	Thickness	Width
2E	Cold rolled, heat treated, mech. desc. pickled	0.40-6.00	36-2040	0.40-6.00	300-2040
2H	Work hardened	1.90-2.10	400-1500		
2R	Cold rolled, bright annealed	0.05-3.00	3-1250	0.40-3.00	350-1250

Continous hot rolled products, available dimensions (mm)

Surface finish		Coil / Strip		Plate / Sheet	
		Thickness	Width	Thickness	Width
1D	Hot rolled, heat treated, pickled	6.00-10.00	96-2040	6.00-10.00	300-2040

Quarto plate products, available dimensions (mm)

Surface finish	Coil / Strip		Plate / Sheet	
	Thickness	Width	Thickness	Width

1D	Hot rolled, heat treated, pickled			7.00-60.00	400-3000
1G	Ground			12.00-19.99	400-3000

Chemical composition

The typical chemical composition for this grade is given in the table below, together with composition limits given for this grade according to different standards. The required standard will be fully met as specified on the order.

The chemical composition is given as % by weight.

	C	Mn	Cr	Ni	Mo	N	Other
Typical	**0.01**		**19.8**	**24.2**	**4.3**		**Cu:1.4**
ASME II A SA-240	≤0.020	≤2.00	19.00-23.00	23.0-28.0	4.00-5.00	≤0.10	Cu:1.0-2.0
ASTM A240	≤0.020	≤2.00	19.0-23.0	23.0-28.0	4.0-5.0	≤0.10	Cu:1.0-2.0
EN 10028-7	≤0.020	≤2.00	19.0-21.0	24.0-26.0	4.0-5.0	≤0.15	Cu:1.20-2.00
EN 10088-2	≤0.020	≤2.0	19.0-21.0	24.0-26.0	4.0-5.0	≤0.15	Cu:1.2-2.0
EN 10088-3	≤0.020	≤2.00	19.0-21.0	24.0-26.0	4.0-5.0	≤0.15	Cu:1.20-2.00
EN 10088-4	≤0.020	≤2.0	19.0-21.0	24.0-26.0	4.0-5.0	≤0.15	Cu:1.2-2.0
IS 6911	≤0.020	≤2.00	19.0-23.0	23.0-28.0	4.0-5.0	≤0.10	Cu:1.00-2.00

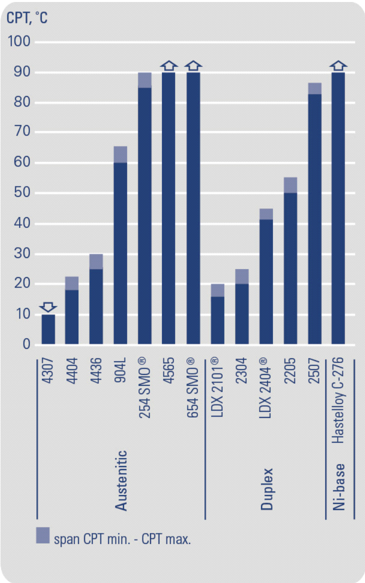
Corrosion resistance

Uniform corrosion

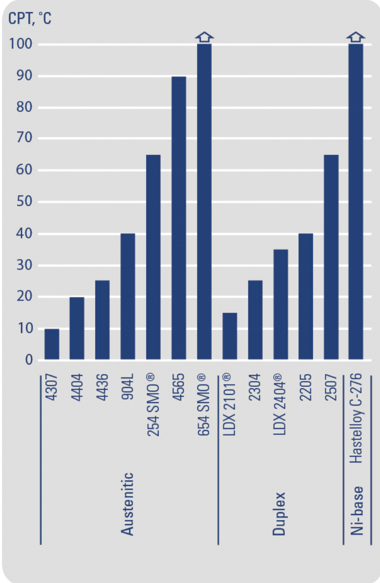
Uniform corrosion occurs when all, or at least a large section, of the passive layer is destroyed. This typically occurs in acids or in hot alkaline solutions. The influence of the alloy composition on the resistance to uniform corrosion may vary significantly between different environments; chromium is essential for ensuring the passivity of stainless steels, nickel helps reduce the corrosion rate of depassivated steel, molybdenum enhances passivity (except for strongly oxidising environments, such as warm concentrated nitric acid) and copper has a positive effect in the presence of reducing acids such as dilute sulphuric acid. In an environment with constant temperature and chemical composition, uniform corrosion occurs at a steady rate. This rate is often expressed as a loss of thickness per unit time, e.g. mm/y. Stainless steels are normally considered to be resistant to uniform corrosion in environments in which the corrosion rate does not exceed 0.1 mm/y. Impurities may drastically affect the corrosivity of acid solutions. For guidance on materials selection in a large number of environments capable of causing uniform corrosion, the tables and iso-corrosion diagrams in Outokumpu Corrosion Handbook may be consulted.

Pitting and Crevice corrosion

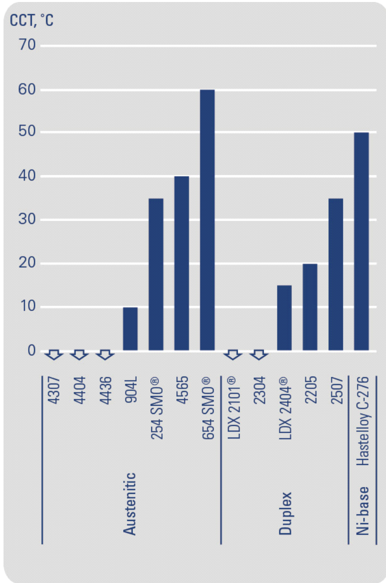
Chloride ions in a neutral or acidic environment facilitate local breakdown of the passive layer. As a result, pitting and crevice corrosion can propagate at a high rate, causing corrosion failure in a short time. Since the attack is small and may be covered by corrosion products or hidden in a crevice, it often remains undiscovered until perforation or leakage occurs.
Resistance to pitting corrosion is determined mainly by the content of chromium, molybdenum and nitrogen in the stainless steel. This is often illustrated using the pitting resistance equivalent (PRE) for the material, which can be calculated using the formula: PRE = %Cr + 3.3 x %Mo + 16 x %N. The PRE value can be used for rough comparisons of different materials. A more reliable means, however, is to rank the steel according to the critical pitting temperature (CPT) of the material. There are several different methods available, for example ASTM G 150 that uses the Avesta Cell with a 1M NaCl solution (35 000 ppm or mg/l chloride ions). The CPT-values are shown in the table below. Higher contents of chromium, molybdenum and nitrogen also enhance the crevice corrosion resistance of the stainless steel. Typical values of the critical crevice corrosion temperature (CCT) in 6% $FeCl_3$ + 1% HCl according to ASTM G48 Method F are included in the table below. The CPT and CCT values vary with product form and surface finish, the values given are for ground surfaces. Both ASTM G150 and G48 are methods for ranking the relative pitting or crevice corrosion resistance for the different stainless steels but they do not give the maximum temperature for using these alloys in real service environments.



CPT according to ASTM G150. Wet ground to 120 grit



CPT according to ASTM G48E. Dry ground to 120 grit



CCT according to ASTM G48F. Dry ground to 120 grit

Stress Corrosion Cracking

Conventional stainless steels such as 4307 and 4404 are sensitive to stress corrosion cracking (SCC) under certain onditions, i.e. a special environment in combination with tensile stress in the material and often also an elevated temperature. Resistance to SCC increases with the increased content of above all nickel and molybdenum. This implies that the high performance austenitic steels 904L, 254 SMO®, 654 SMO®and 4565 have very good resistance to SCC.

Pitting corrosion resistance		Crevice corrosion resistance
PRE	CPT	CCT
34	58±3	10

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

CPT Corrosion Pitting Temperature as measured in the Avesta Cell (ASTM G 150), in a 1M NaCl solution (35,000 ppm or mg/l chloride ions).

CCT Critical Crevice Corrosion Temperature is the critical crevice corrosion temperature which is obtained by laboratory tests according to ASTM G 48 Method F

Mechanical properties

The mechanical properties of the available products are given in the table below.

Cold rolled coil and sheet	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 1 mm)	**340**	**375**	**655**	**55**				
ASME II A SA-240	≥ 220		≥ 490			≤ 90HRB		
ASTM A240	≥ 220		≥ 490					
EN 10028-7	≥ 240	≥ 270	530 - 730	≥ 35				
EN 10088-2	≥ 240	≥ 270	530 - 730	≥ 35				
EN 10088-4	≥ 240	≥ 270	530 - 730	≥ 35				
IS 6911	≥ 220		≥ 490			≤ 90HRB		

Hot rolled coil and sheet	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 4 mm)								

ASME II A SA-240	≥ 220		≥ 490			≤ 90HRB		
ASTM A240	≥ 220		≥ 490					
EN 10028-7	≥ 240	≥ 270	530 - 730	≥ 35				
EN 10088-2	≥ 240	≥ 270	530 - 730	≥ 35				
EN 10088-4	≥ 240	≥ 270	530 - 730	≥ 35				
IS 6911	≥ 220		≥ 490			≤ 90HRB		

Hot rolled quarto plate	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
Typical (thickness 15 mm)	**260**	**285**	**600**	**50**			**155**	
ASME II A SA-240	≥ 220		≥ 490			≤ 90HRB		
ASTM A240	≥ 220		≥ 490			≤ 90HRB		
EN 10028-7	≥ 220	≥ 260	520 - 720	≥ 35				
EN 10088-2	≥ 220	≥ 260	520 - 720	≥ 35				
EN 10088-4	≥ 220	≥ 260	520 - 720	≥ 35				
IS 6911	≥ 220		≥ 490			≤ 90HRB		

Wire rod	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	Elongation[1)] %	Impact strength J	Rockwell	HB	HV
Typical	**260**	**300**	**600**	**50**				

[1)]Elongation according to EN standard:
A_{80} for thickness below 3 mm.
A for thickness = 3 mm.
Elongation according to ASTM standard $A_{2"}$ or A_{50}.

Physical properties

The physical properties at room temperature are shown in the table below. Data according to EN10088 or EN10095.

Density kg/dm^3	Modulus of elasticity GPa	Thermal exp. at 100 °C 10^{-6}/°C	Thermal conductivity W/m°C	Thermal capacity J/kg°C	Electrical resistance µΩm	Magnetizable
8.0	195	15,8	12	450	1.0	No

Fabrication

Machining

Austenitic stainless steels work harden quickly and this, together with their toughness, means that they are often perceived as problematic from a machining perspective, e.g. n operations such as turning, milling and drilling. However, with the right choice of tools, tool settings and cutting speeds, these materials can be sucessfully machined. For further information contact Outokumpu.

Welding

All the highly alloyed austenitic steels are well suited for welding and the methods used for welding conventional austenitic steels can also be used on 904L. However, due to the stable austenitic structure, it is 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 structure with an even distribution of alloying elements in the material. Solidification after partial remelting, e.g. by welding, causes redistribution of certain elements such as molybdenum, chromium and nickel. These variations, segregation, remain in the cast structure of the weld and can impair the material’s corrosion resistance in certain environments.

More information

A number of publications regarding this steel grade are available for downloading from our publications system. The downloads can be found under Products/Useful Tools Online/Publications. Below are a few publications that might be of interest.

High Performance Austenitic Stainless Steel - 904L. 254 SMO®. 4529. 4565. 654 SMO®
Material data sheet presenting the properties for Outokumpu Stainless most corrosion resistant alloys.

Acom 2010 Ed:4
Acom chronicle 1980-2010
J. Gunnarsson
Superaustenitic stainless steels in demanding environments
M. Liljas. C. Canderyd. R. Pettersson. M. Willför
Lean duplex - the first decade of service experience
E. Alfonsson
80 years with duplex steels - a historic review and prospects for the future
M. Liljas
30 years with acom (index) - in order
30 years with acom (index) - by subject

Acom 2007 Ed:4
Stainless Steels for Flue Gas Cleaning - laboratory trials. field tests and service experience.
B. Beckers. A. Bergquist. C.-O. A. Olsson. M. Snis. and E. Torsner. Outokumpu Stainless AB

Acom 2003 Ed: 1
In-Plant Corrosion Testing in Ozone Bleaching Environments
Pekka Pohjanne and Marko Siltala

Acom 2003 Ed:4
Stainless steels for SWRO plants high-pressure piping. properties and experience MSF chambers of solid duplex stainless steel

Acom 2007 Ed:3
Stainless Steel for Hydrometallurgy Plants
J. Olsson

Standards & approvals

Outokumpu produce and certify materials to most international and national standards. Work is continuously on-going to get the different grades approved for relevant standards. The most commonly used international product standards are given in the table below.

Standard	Designation
ASME SA-240M Code Sect. II. Part A	UNS N08904 / 904L
ASTM A240/A240M	UNS N08904 / 904L
EN 10028-7, PED 2014/68/EU	1.4539
EN 10088-2	1.4539
EN 10088-3	1.4539
EN 10088-4	1.4539
IS 6911, AMENDMENT NO. 2	ISS 904L

Contacts & Enquiries

Contact your nearest sales office

www.outokumpu.com/contacts

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.

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