

Ultra 654 SMO

EN 1.4652, ASTM UNS S32654

General characteristics

7% Mo, very high N alloyed austenitic grade. The most corrosion resistant stainless steel in the world. High mechanical strength. Useful for e.g. pressurized and erosive systems handling chlorinated sea water at higher temperatures, plate heat exchangers and flue gas cleaning applications.

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 austenitic stainless steels have good weldability and excellent formability. Outokumpu manufactures a number of steels of this type and 654 SMO[®] is the most highly alloyed of them. In some applications, 654 SMO[®] can compete with Ni-base alloys and Titanium.

Typical applications

- Pressurized and erosive systems handling chlorinated sea water at higher temperatures
- Plate heat exchangers
- Flue gas cleaning
- Process equipment in chemical industry
- Bleaching equipment in the pulp and paper industry
- Desalination
- Hydrometallurgy
- Food and beverage
- Pharmaceuticals

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	0.50-3.00	36-950	0.50-3.00	400-950

Chemical composition

The typical Outokumpu composition as well as the demands in some standards are given below

The chemical composition is given as % by weight.

	C	Mn	Cr	Ni	Mo	N	Other
Typical	0.01	3.5	24.0	22.0	7.3	0.50	Cu:0.50
ASME II A SA-240	≤0.020	2.0-4.0	24.0-25.0	21.0-23.0	7.0-8.0	0.45-0.55	Cu:0.30-0.60
ASTM A240	≤0.020	2.0-4.0	24.0-25.0	21.0-23.0	7.0-8.0	0.45-0.55	Cu:0.30-0.60
EN 10088-2	≤0.020	2.0-4.0	23.0-25.0	21.0-23.0	7.0-8.0	0.45-0.55	Cu:0.30-0.60
EN 10088-3	≤0.020	2.00-4.00	23.0-25.0	21.0-23.0	7.0-8.0	0.45-0.55	Cu:0.30-0.60
IS 6911	≤0.020	2.00-4.00	24.0-25.0	21.0-23.0	7.0-8.0	0.45-0.55	Cu:0.30-0.60

Corrosion resistance

Uniform corrosion

The high content of alloying elements gives the steels 904L, 254 SMO® and 4565 exceptionally good resistance to uniform corrosion.

904L was originally developed to withstand environments involving dilute sulphuric acid and it is one of the few stainless steels that at temperatures of up to 35°C provides full resistance in such environments within the entire range of concentration, from 0 to 100%. 904L also offers good resistance to a number of other inorganic acids, e.g., phosphoric acid, as well as most organic acids. Acids and acid solutions containing halide ions can, however, be very aggressive and the corrosion resistance of 904L may be insufficient. Examples of such acids are hydrochloric acid, hydrofluoric acid, chloride contaminated sulphuric acid, phosphoric acid produced according to the wet process (WPA) at elevated temperatures, and also pickling acid based on nitric acid and hydrofluoric acid mixtures. In these cases 254 SMO® and 4565 are preferable and in certain cases they can be an alternative to other considerably more expensive alloys.

Pitting and Crevice corrosion

Resistance to pitting corrosion (and also crevice corrosion) is determined mainly by the content of chromium, molybdenum and nitrogen in the material. This is often illustrated using the pitting resistance equivalent (PRE) for the material, which can be calculated using the formula: $PRE = \%Cr + 3.3 \times \%Mo + 16 \times \%N$. The PRE value can be used for rough comparisons of different materials.

A much more reliable means, however, 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 and ASTM G 150 is one method that uses the Avesta Cell with a 1M NaCl solution (35,000 ppm or mg/l chloride ions). CPT-values are shown in the table below. Grades 4565 and 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.

In narrow crevices the passive film may more easily be damaged 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 hard adherent deposits. Crevice corrosion occurs in the same environments as pitting. Higher contents of chromium, molybdenum or nitrogen enhance the corrosion resistance of the steel. Typical critical crevice corrosion temperature (CCT) according to ASTM G48 Method F are shown in the table below. (Test surfaces dry ground to 120 mesh.) CCT varies with product form and surface finish. The actual value of mill finish surface may differ between product forms.

Stress Corrosion Cracking

Conventional stainless steels such as 4307 and 4404 are sensitive to stress corrosion cracking (SCC) under certain conditions, 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
56	>90	60

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

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 strength and elongation of 904L are similar to those for conventional austenitic stainless steels. The addition of nitrogen in 254 SMO[®], 654 SMO[®] and 4565 gives higher proof strength and tensile strength. Despite the greater strength of these steels, the possibilities for cold as well as hot forming are very good.

Cold rolled coil and sheet	R _{p0.2} MPa	R _{p1.0} MPa	R _m MPa	Elongation ¹⁾ %	Impact strength J	Rockwell	HB	HV
ASME II A SA-240	≥ 430		≥ 750				≤ 250	
ASTM A240	≥ 430		≥ 750				≤ 250	
EN 10088-2	≥ 430	≥ 470	750 - 1000	≥ 40				
IS 6911	≥ 430		≥ 750				≤ 250	

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)								
EN 10088-2	≥ 430	≤ 470	750 - 1000	≥ 40				
IS 6911	≥ 430		≥ 750				≤ 250	

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)	460	490	860	60			200	
EN 10088-2	≥ 430	≥ 470	750 - 1000	≥ 40				
IS 6911	≥ 430		≥ 750				≤ 250	

¹⁾Elongation according to EN standard:

A₈₀ for thickness below 3 mm.

A for thickness = 3 mm.

Elongation according to ASTM standard A₂^{*} or A₅₀.

Physical properties

The typical values of some physical properties are given in the table below.

Density	Modulus of elasticity	Thermal exp. at 100 °C	Thermal conductivity	Thermal capacity	Electrical resistance	Magnetizable
kg/dm ³	GPa	10 ⁻⁶ /°C	W/m°C	J/kg°C	μΩm	
8.0	190	15	11	500	0.78	No

Fabrication

The high performance austenitic stainless steels cold-harden considerably faster than conventional austenitic grades. This, together with the initial high strength, makes it necessary to apply high forming forces. The spring back for grades 254 SMO[®] and 4565 is also greater than for conventional austenitic steels. In complicated cold-forming operations, intermediate annealing of the material may sometimes be necessary, especially if the workpiece is welded. 654 SMO[®] has a better performance than the other superaustenitic grades.

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. 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. 254 SMO[®], 4565 and 654 SMO[®]. However, with the right choice of tools, tool settings and cutting speeds, these materials can be successfully machined. For further information contact Outokumpu.

Welding

654 SMO[®] should be welded with over-alloyed Ni-base filler to overcome molybdenum segregation. If autogenous welding is performed and no post weld heat treatment is used, the weld will have a reduced corrosion resistance. High-energy methods (>1.5kJ/mm) such as submerged arc welding should be used with some care. MAG welding may require modern pulse equipment and the use of special shielding gases containing Ar, He and O₂/CO₂.

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

Standards & approvals

Some standards are given in the table below.

Standard	Designation
ASME SA-240M Code Sect. II. Part A	UNS S32654

ASTM A240/A240M	UNS S32654
EN 10088-2	1.4652
EN 10088-3	1.4652
IS 6911, AMENDMENT NO. 2	ISS 326

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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