

Standard Cr-Ni-Mo Stainless Steels

STEEL GRADES

AvestaPolarit	EN	ASTM
4404	1.4404	316L
4401	1.4401	316
4406	1.4406	316LN
4571	1.4571	316Ti
4432	1.4432	316L
4436	1.4436	316
4435	1.4435	316L
4429	1.4429	316LN

CHARACTERISTIC PROPERTIES

- All-purpose grades
- Enhanced corrosion resistance compared to standard Cr-Ni grades
- Excellent formability
- Excellent weldability
- Excellent impact strength

CHEMICAL COMPOSITION

AvestaPolarit steel name	International steel no.		Typical composition, %							National steel designations, superseded by EN			
	EN	ASTM	C	N	Cr	Ni	Mo	Other	BS	DIN	NF	SS	
4404	1.4404	316L	0.02	0.04	17.2	10.2	2.1	-	316S11	1.4404	Z3 CND 17-11-02	2348	
4401	1.4401	316	0.02	0.04	17.2	10.2	2.1	-	316S31	1.4401	Z7 CND 17-11-02	2347	
4406	1.4406	316LN	0.02	0.14	17.2	10.3	2.1	-	316S61	1.4406	Z3 CND 17-11 Az	-	
4571	1.4571	316Ti	0.04	0.01	16.8	10.9	2.1	Ti	320S31	1.4571	Z6 CNDT 17-12	2350	
4432	1.4432	316L	0.02	0.05	16.9	10.7	2.6	-	316S13	-	Z3 CND 17-12-03	2353	
4436	1.4436	316	0.02	0.05	16.9	10.7	2.6	-	316S33	1.4436	Z7 CND 18-12-03	2343	
4435	1.4435	316L	0.02	0.06	17.3	12.6	2.6	-	316S13	1.4435	Z3 CND 18-14-03	2353	
4429	1.4429	316LN	0.02	0.14	17.3	12.5	2.6	-	316S63	1.4429	Z3 CND 17-12 Az	2375	
4301	1.4301	304	0.04	0.05	18.1	8.3	-	-	304S31	1.4301	Z7 CN 18-09	2333	
904L	1.4539	904L	0.01	0.06	20	25	4.3	1.5 Cu	904S13	1.4539	Z2 NCDU 25-20	2562	
254 SMO®	1.4547	S31254	0.01	0.20	20	18	6.1	Cu	-	1.4547	-	2378	
SAF 2304®	1.4362	S32304	0.02	0.10	23	4.8	0.3	-	-	1.4362	Z3 CN 23-04 Az	2327	
2205	1.4462	S32205*	0.02	0.17	22	5.7	3.1	-	318S13	1.4462	Z3 CND 22-05 Az	2377	

*also available as S31803

SAF 2304® is produced under licence from AB Sandvik Steel

GENERAL CHARACTERISTICS

These grades are molybdenum-containing austenitic stainless steels intended to provide improved corrosion resistance relative to the standard Cr-Ni steel grades used in corrosive process environments.

The addition of molybdenum provides improved resistance to pitting and crevice corrosion in environments containing chlorides or other halides.

These grades are used in applications for handling the wide range of chemicals used by process industries, e.g. pulp and paper, textile, food and beverages, pharmaceutical, medical, and in the manufacture of other chemical processing equipment. These grades are supplied with a wide range of functional and aesthetic surfaces. Non-titanium-stabilised grades generally have a better surface finish than titanium-stabilised grades.

Given their fully austenitic structure, these grades are non-magnetic in the annealed condition but may become slightly magnetic as a result of cold working or welding.

CHEMICAL COMPOSITION

The chemical composition of specific steel grades may vary slightly between different national standards.

The required standard will be fully met as specified on the order.

MECHANICAL PROPERTIES

AvestaPolarit has used the European Standard EN 10088 where applicable. The permitted design values may vary between product forms, see the specification in question for the correct value.

The values in Table 2 refer to hot rolled plate/cold rolled strip and sheet. For hot rolled strip, the proof strength corresponds to that of hot rolled plate, and the tensile strength and elongation to that of cold rolled strip.

Mechanical Properties

Table 2. Hot rolled plate/cold rolled strip and sheet, minimum values at 20°C

Steel grade	Proof strength		Tensile strength R _m MPa	Elongation A ₅ %	Hardness HB (typical)	Impact value KV J
	R _{p0.2} MPa	R _{p1.0} MPa				
4404	220/240	260/270	520/530	45/40	165	60
4401	220/240	260/270	520/530	45/40	160	60
4406	280/300	320/330	580/580	40/40	–	60
4571	220/240	260/270	520/540	40/40	165	60
4432	220/240	260/270	520/550	45/40	165	60
4436	220/240	260/270	530/550	40/40	165	60
4435	220/240	260/270	520/550	45/40	165	60
4429	280/300	320/330	580/580	40/35	–	60

Tensile properties at elevated temperatures

Table 3a. Proof strength R_{p0.2}, MPa, minimum values

Steel grade	Temperature, °C				
	100	200	300	400	500
4404	177	147	127	115	110
4401	166	137	118	108	100
4406	211	167	145	135	128
4571	185	167	145	135	129
4432	177	147	127	115	110
4436	166	137	118	108	100
4435	165	137	119	108	100
4429	211	167	145	135	129

Table 3b. Proof strength R_{p1.0}, MPa, minimum values

Steel grade	Temperature, °C				
	100	200	300	400	500
4404	211	177	156	144	139
4401	199	167	145	135	128
4406	246	198	175	164	158
4571	218	196	175	164	158
4432	211	177	156	144	139
4436	199	167	145	135	128
4435	200	165	145	135	128
4429	246	198	175	164	158

Table 3c. Tensile strength R_m , MPa, minimum values

Steel grade	Temperature, °C				
	100	200	300	400	500
4404	430	390	380	–	–
4401	430	390	380	380	360
4406	520	460	440	–	–
4571	440	390	375	375	360
4432	460	420	410	410	390
4436	430	390	380	380	360
4435	420	380	370	–	–
4429	520	460	440	435	430

Mechanical properties at low temperatures

Table 4. Minimum values

Steel grade	Temp. °C	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	A_5 %
4404*	–80	275	355	840	40
4404*	–196	350	450	1200	35
4406**	–80	380	450	800	35
4406**	–196	600	700	1150	30

Values from EN 10028-7

* 4401, 4571, 4432, 4436 and 4435 have approximately the same values as 4404

**4429 has approximately the same values as 4406.

PHYSICAL PROPERTIES

The physical properties are the same for all steel grades in this group.

Data according to EN 10088.

Table 5. Physical properties, typical values at 20°C

Density	kg/dm ³	8.0
Modulus of elasticity	GPa	200
Poissons ratio		0.3
Thermal conductivity	W/m°C	15
Heat capacity	J/kg°C	500
Electrical resistivity	$\mu\Omega\text{m}$	0.75

Physical properties at elevated temperatures

Table 6a. Linear expansion ($RT \rightarrow T$) $\times 10^{-6}/^\circ\text{C}$

Steel grade	Temperature, °C				
	100	200	300	400	500
4571	16.5	17.5	18.0	18.5	19.0
Non-Ti-stabilised grades	16.0	16.5	17.0	17.5	18.0

Table 6b. Modulus of elasticity, GPa

Steel grade	Temperature, °C				
	100	200	300	400	500
All grades	194	186	179	172	165

CORROSION RESISTANCE

The Cr-Ni-Mo standard stainless steels have a versatile corrosion resistance and are suitable for a wide range of applications. The grades with molybdenum content of 2.6 per cent (4432, 4436, 4435, 4429) have somewhat enhanced corrosion resistance compared to the grades with molybdenum content of 2.1 per cent (4404, 4401, 4406, 4571). A brief description of their resistance to different types of corrosion follows below. For a more detailed description of their corrosion resistance properties in different environments, please refer to the AvestaPolarit Corrosion Handbook.

Uniform corrosion

Uniform corrosion is characterised by a uniform attack on the steel surface that has come into contact with a corrosive medium. The corrosion resistance is generally considered good if the corrosion rate is less than 0.1 mm/year.

This group of Cr-Ni-Mo grades have a good resistance in many organic and inorganic chemicals. An example of an isocorrosion diagram is shown in figure 1.

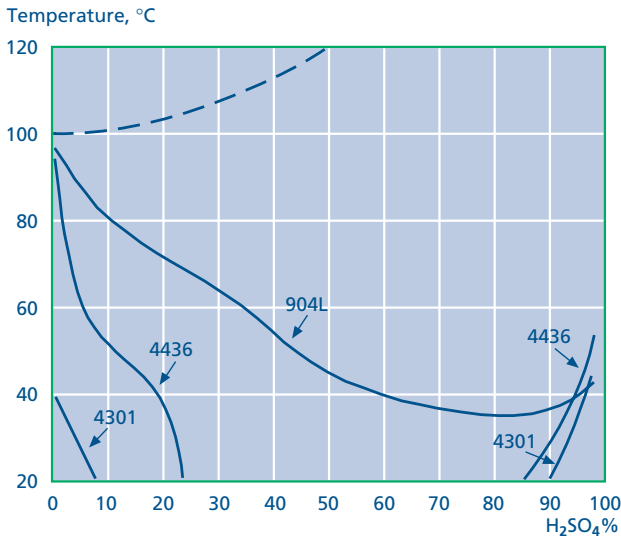


Fig. 1. Isocorrosion diagram for 4301, 4436 and 904L in stagnant sulphuric acid. The curves represent a corrosion rate of 0.1 mm/y. The dashed line represents the boiling point.

Pitting and crevice corrosion

The resistance to pitting and crevice corrosion can be enhanced by increasing the content of chromium, molybdenum and nitrogen. These grades have a significantly better resistance to these types of localised corrosion than the standard Cr-Ni grades.

For better resistance, higher alloyed grades such as 2205 and 254 SMO® are recommended (see Figure 2).

Figure 3 shows up to which approximate temperatures stainless steel can be used in oxygen-saturated solutions of varying chloride content. There is an additional risk for stress corrosion cracking at temperatures above 50°C.

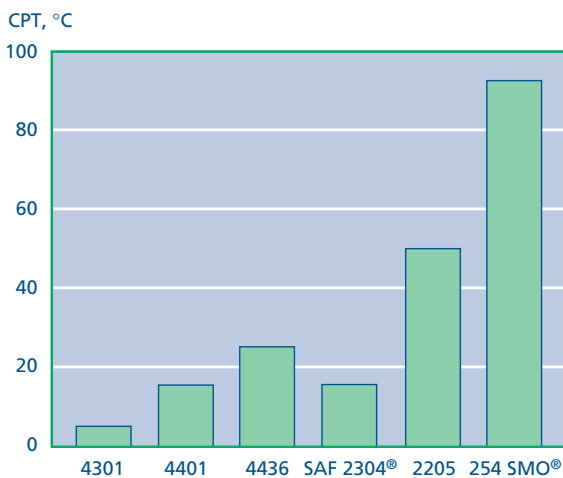


Fig. 2. Critical pitting temperatures (CPT) in 1M NaCl according to ASTM G150 using the Avesta Cell. Typical values.

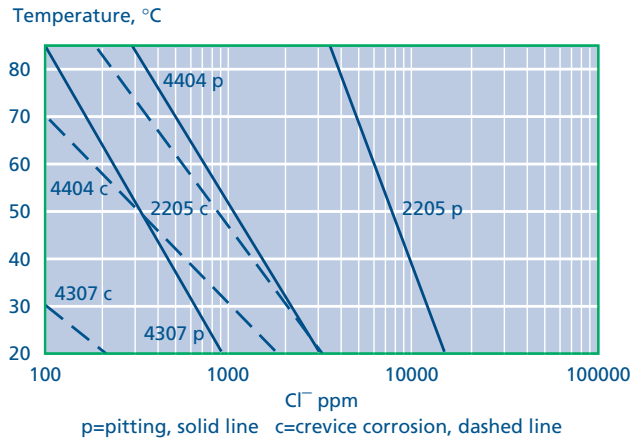


Fig. 3. Risk of pitting and crevice corrosion on conventional stainless steel in water of different chloride content or temperature.

Stress corrosion cracking

These austenitic grades – like the standard Cr-Ni steels – are susceptible to stress corrosion cracking (SCC). Critical service conditions, i.e. applications subjected to combinations of tensile stresses, temperatures above about 50°C and certain solutions, especially those containing chlorides, should be avoided.

For applications demanding high resistance to SCC, the duplex grades 2205 and SAF 2304® are more suitable.

Stress corrosion cracking may also occur in hot alkaline solutions (above 110°C).

Intergranular corrosion

Intergranular corrosion is not a common problem for modern stainless steels since the carbon content is generally kept at a low level.

Operations that increase the risk for intergranular corrosion are welding of heavy gauges, heat treatment operations within the critical temperature interval (550 – 850°C) and slow cooling after heat treatment or hot forming. Ti-stabilised steels and steels with low carbon content (0.02%) have better resistance towards intergranular corrosion after such operation conditions.

FABRICATION

Hot forming

Hot working can be carried out in the 850 – 1150°C range. For maximum corrosion resistance, forgings should be annealed at 1070°C and rapidly cooled in air or water after hot working operations.

Cold forming

These grades can be readily formed and fabricated by a full range of cold working operations. They can be used in heading, drawing and bending. Any cold working operations will increase the strength and hardness of the material (see Figure 4). For more information on deep drawing, see "Guide for deep drawing stainless steel".

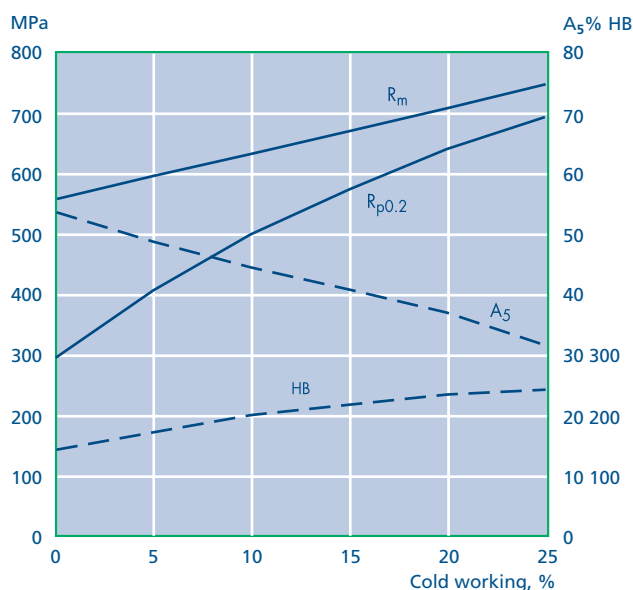


Fig. 4. 4301 work-hardening at cold working

Heat treatment

Annealing

Quench annealing should be performed at 1030 – 1110°C and followed by rapid cooling in water or air. For Ti-stabilised grades, annealing temperatures above 1070°C may impair the resistance to intergranular corrosion.

Ti-stabilised grades may also be given a stabilising treatment at lower temperatures. However, temperatures below 980°C 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, but may also be performed at lower temperatures. Please contact AvestaPolarit for further information.

Hardening

These grades cannot be hardened by heat treatment. However, they can be hardened by cold working.

Machining

These austenitic grades are more difficult to machine than ordinary carbon steels but are still comparatively easy to machine compared to more highly alloyed stainless grades. Unless modified for improved machinability, they require higher cutting forces than carbon steels, show resistance to chip breaking and a high tendency to built-up edge formation. The best machining results are obtained by using high-power equipment, sharp tooling and a rigid set-up.

The machinability of these grades in relation to other stainless steels is indicated by the machinability index in Figure 5. This index, which rises with increased machinability, is based on a compounded evaluation of test data from several different machining operations. It gives an indication of the machinability of different stainless steel grades in relation to that of grade 4436. It should be noted that it does not describe the relative difficulty of machining with cemented carbide and high speed steel tools. Nitrogen alloyed stainless steels are more difficult to machine.

Better machinability performance is given by PRODEC® versions, which have been modified for improved machinability. PRODEC® is available as hot rolled plate and bar in 4401, 4404, 4436 and 4432.

For more information, see "Machining Guidelines", available from AvestaPolarit on request.



Fig. 5. Relative machinability for some stainless steel grades.

Welding

These grades can be readily welded by a full range of conventional welding methods such as:

- Shielded metal arc welding (SMAW)
- Gas tungsten arc welding, TIG (GTAW)
- Gas metal arc welding, MIG (GMAW)
- Flux-cored arc welding (FCW)
- Plasma arc welding (PAW)
- Submerged arc welding (SAW)

The following welding filler metals from AvestaPolarit Welding are recommended:

4404	316L/SKR
4401	316L/SKR
4406	316L/SKR
4571	318/SKINb, 316L/SKR
4432	316L/SKR
4436	316L/SKR
4435	316L/SKR
4429	316L/SKR

Other filler metals with a molybdenum content higher than that of the base metal may also be used. For further information, see the brochures "STAINLESS STEELS – Their properties and their suitability for welding", Info. No. 9473, and "HANDBOOK for the pickling and cleaning of stainless steel", Info. No. 270101GB.

PRODUCTS

- Hot rolled plate, sheets and strip
- Cold rolled plate, sheet and coil
- Cold rolled narrow strip
- Welded tube and pipe
- Bar
- Rod
- Billet
- Welding consumables

MATERIAL STANDARDS

EN 10088-1	Stainless steels – List of stainless steels (Not for ordering)
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 10028-7	Flat products for pressure purposes – Stainless steels
EN 10272	Stainless steel bars for pressure purposes
ASTM A240/ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate, sheet and strip for pressure vessels
ASTM A479/ASME SA-479	Stainless steel bars for boilers/pressure vessels
ASTM A666/ASME SA-666	Austenitic stainless steel sheet, strip, plate, bar for structural and architectural applications

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