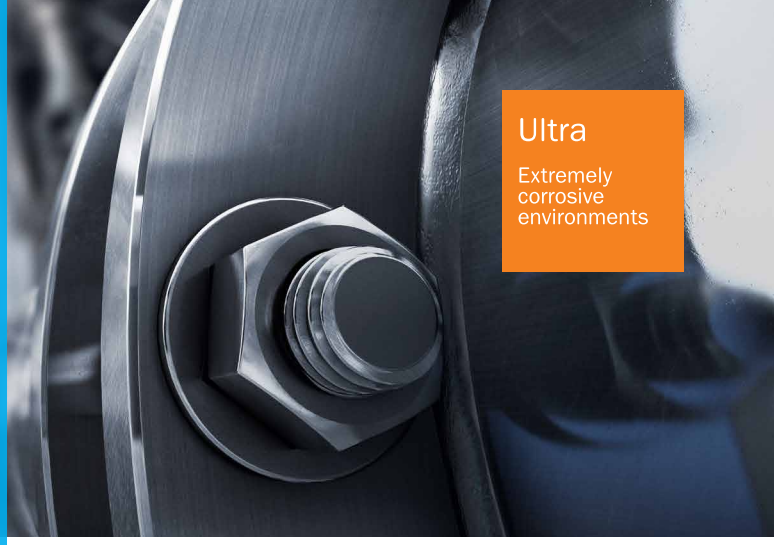
outokumpu
high performance stainless steel

Sanicro® 35 – Bridging the gap between stainless and Ni-based alloys

Outokumpu Ultra range datasheet



General characteristics and properties

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

Sanicro® 35 is a newly developed alloy combining the best features of a high performance austenitic stainless steel and nickel based alloys. This grade is our latest addition to the Ultra range, it has excellent corrosion resistance in combination with a high mechanical strength.

Sanicro® 35 in a nutshell:

- Excellent resistance to pitting and crevice corrosion
- Excellent resistance to stress corrosion cracking (SCC)
- High resistance to uniform corrosion in acid and caustic environments
- High resistance to erosion-corrosion
- Very high mechanical strength
- Good weldability using nickel based alloy consumables

Chemical composition

Table 1

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
Sanicro® 35 [2]	–	–	N08935	52	40	425	A	0.02	27.0	35.5	6.4	0.27	Cu
For comparison													
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
Forta SDX 2507	1.4410	–	S32750	43	20	550	D	0.02	25.0	7.0	4.0	0.27	–
Alloy 625 [3]	–	–	N06625	51	30 [4]	414 [4]	A	0.01	20–23	>58	8–10	–	Nb+Ta

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] Min. values hot-rolled and cold-rolled ≤ 6.35 mm acc. to ASTM B625. [3] Not produced by Outokumpu. [4] Values acc. to ASTM B443.

Sanicro® 35 is a trademark owned by Alleima AB and produced as plate and sheet by Outokumpu under a license agreement.

PRE = %Cr + 3.3 x %Mo + 16 x %N
Values for $R_{p0.2}$ yield strength and the A_{80} for 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**

Applications

Due to its extremely good pitting and crevice corrosion properties, Sanicro® 35 is particularly suitable for applications where seawater is used for cooling or heating. Sanicro® 35 also has a high resistance to uniform corrosion in acid environments, making it suitable for a variety of applications. It is an attractive material of choice for applications within the oil and gas industry where H_2S may be present, due to its high resistance to stress corrosion cracking.

Corrosion resistance

Uniform corrosion

Due to the combination of high contents of nickel, chromium and molybdenum, Sanicro® 35 has good resistance to many commonly found acids, such as sulfuric acid, nitric acid, phosphoric acid and organic acids.

Sanicro® 35 has better resistance in hydrochloric acid compared to stainless steels with a lower chromium and molybdenum content and can be useful in environments where moderate levels of hydrochloric acid is present. See Figure 1.

In low to intermediate concentrations of sulfuric acid, the resistance of Sanicro® 35 is similar to or better than Ultra 904L, see Figure 2. In chloride contaminated sulfuric acid, Sanicro® 35 can be expected to offer better resistance than Ultra 904L and Ultra 254 SMO, see Table 2. In addition, the active corrosion rates are typically lower than that for stainless steel alternatives, due to the high nickel content.

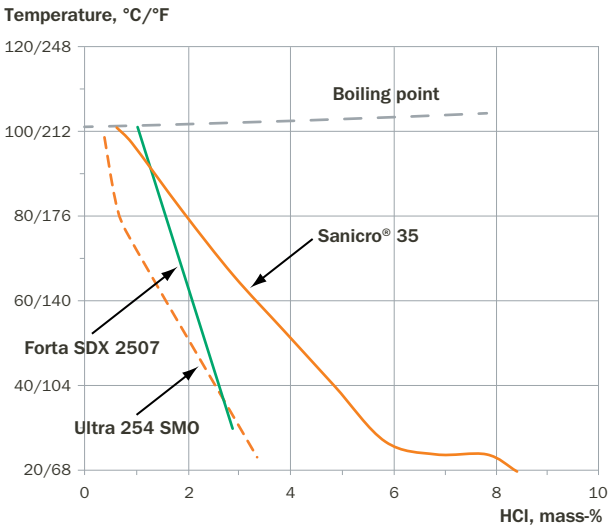


Fig. 1. Preliminary isocorrosion diagram for Sanicro® 35 in hydrochloric acid. The line represents a limit, below which the corrosion rate is expected to be lower than 0.1 mm/year. Other grades are included for comparison.

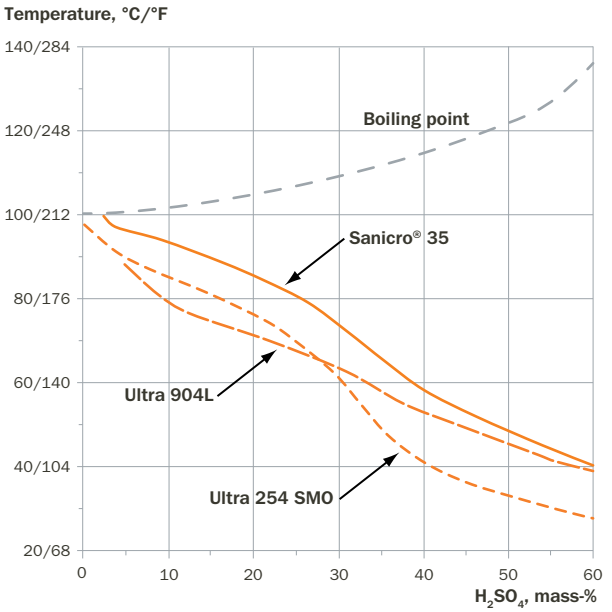


Fig. 2. Preliminary isocorrosion diagram for Sanicro® 35 in sulfuric acid. The line represents a limit, below which the corrosion rate is expected to be lower than 0.1 mm/year. Other grades are included for comparison.

Uniform corrosion rates (mm/year) after testing in 20 weight% sulfuric acid according to ISO 18069.

Table 2

Alloy designation	0 ppm chlorides			200 ppm chlorides		2,000 ppm chlorides
	60 °C	80 °C	100 °C	60 °C	80 °C	60 °C
Sanicro® 35	–	**0.00**	**1.92**	–	**0.00**	**0.00**
Ultra 904L	0.05	1.16	–	0.44	0.42	0.48
Ultra 254 SMO	0.15	1.40	–	0.59	2.34	0.84
Alloy 625	0.05	0.30	0.33	0.17	0.12	0.97

PRE, CPT and CCT data, typical values.

Table 3

Alloy designation	PRE	CPT [°C]		CCT [°C]
		ASTM G150 [1]	ASTM G48 E [2]	ASTM G48 F [2]
Sanicro® 35	52	>90	85	45
Ultra 904L	34	58 ± 3	40	10
Ultra 254 SMO	43	87 ± 3	65	35
Alloy 625	51	>90	90	25

[1] Wet ground surfaces, P320 grit.
[2] Dry ground surfaces, P120 grit.

Sanicro® 35 performs well in oxidizing acids, where the high chromium content is beneficial. Figure 3 shows the superior performance in nitric acid, compared to standard austenitic grades of type 304L and 316L.

Sanicro® 35 also has good resistance to uniform corrosion in alkaline environments, such as sodium and potassium hydroxide solutions. Tests performed at 120 °C showed corrosion rates below 0.1 mm/year in sodium hydroxide concentrations between 40 and 70%.

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 pitting resistance equivalent (PRE) for the material, which can be calculated using the formula: PRE = %Cr + 3.3 x %Mo + 16 x %N. Although the PRE typically exhibits good agreement with practical performance, it is only a theoretical approximation. A more reliable means to rank the alloys, based on laboratory testing, is by critical pitting temperatures (CPT) and critical crevice corrosion temperatures (CCT) of the material.

PRE, CPT and CCT data according to commonly used methods are listed in Table 3. The CPT value for Sanicro® 35 indicates a pitting resistance significantly higher than Ultra 254 SMO, and on a similar level as Alloy 625. Sanicro® 35 is resistant up to the maximum tested temperatures of 90°C in ASTM G150 and 85°C in ASTM G48 method E.

Stress corrosion cracking

Due to its high nickel content, Sanicro® 35 exhibits excellent resistance to chloride induced stress corrosion cracking (SCC). Resistance to cracking can be expected in many environments where type 316L and similar grades would be susceptible to SCC. Cracking may occur in the most extreme conditions, such as in the boiling 45% $MgCl_2$ U-bend test. Even then, Sanicro® 35 exhibits higher resistance than 6Mo grades such as Ultra 254 SMO. See Table 4.

The grade complies with NACE MR0175/ISO 15156-3 as a type 4a and 4c material, with significantly higher environmental limits than 6Mo grades like Ultra 254 SMO. Additionally, cold worked Sanicro® 35 (965 and 1,240 MPa) has been tested in a NACE MR0175/ISO 15156 Test Level VI environment according to NACE TM0198 with no indication of SCC.

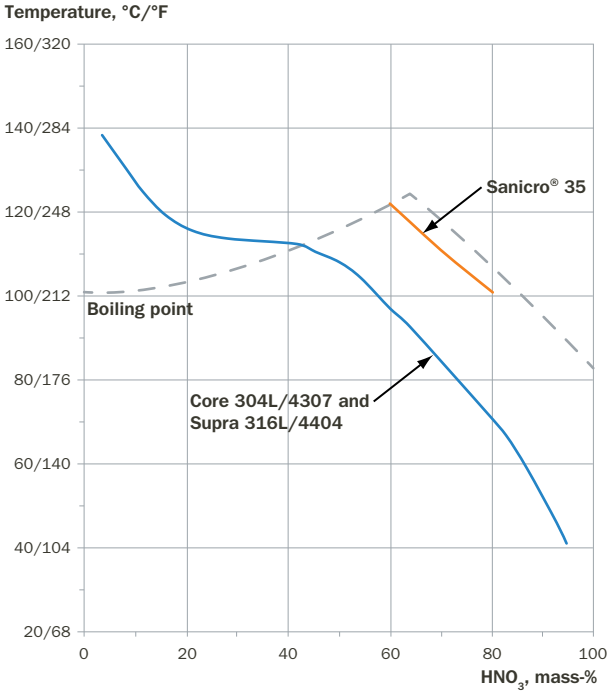


Fig. 3. Preliminary isocorrosion diagram for Sanicro® 35 in nitric acid. The line represents a limit, below which the corrosion rate is expected to be lower than 0.1 mm/year. Other grades are included for comparison.

Number of cracked U-bend samples after testing in 45% $MgCl_2$ at boiling conditions for 24 hours.

Table 4

Alloy designation	Cracked samples
Sanicro® 35	1/3
Ultra 254 SMO	3/3

Mechanical Properties

Table 5 shows the mechanical properties at room temperature for flat rolled products, data according to ASTM B625, EN 10088 and ASTM B443 when applicable. Table 6 indicates the mechanical values at elevated temperatures.

Mechanical properties at 20 °C

Table 5

Alloy designation	Product form	Min. yield strength $R_{p0.2}$ [MPa]	Min. yield strength $R_{p1.0}$ [MPa]	Tensile strength R_m [MPa]	Min. elongation A [%]
Sanicro® 35 [1]	Sheet	425	–	750	40
	Plate < 6.35 mm	425	–	750	40
	Plate ≥ 6.35 mm	350	–	700	40
Ultra 254 SMO [2]	Cold rolled	320	350	650–850	35
	Hot rolled	300	340	650–850	35
	Plate	300	340	650–850	40
Alloy 625 [3]	Cold rolled sheet /strip	414	–	827	30
	Cold rolled plate ≤ 9.5 mm	379	–	758	30
	Hot rolled sheet and plate ≤ 70 mm	379	–	758	30

Values according to
[1] ASTM B625
[2] EN 10088-2
[3] ASTM B443 (Grade 1 not produced by Outokumpu)

Mechanical properties at elevated temperatures

Table 6

Data valid for material t ≤ 6,35mm

Temperature °C	Min. yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Min. elongation A [%]
100	350	680	40
200	300	620	40
300	275	600	40
400	250	580	40

Physical properties

Table 7

Temperature °C	Density [kg/dm³]	Modulus of elasticity [GPa]	Coefficient of thermal expansion 30-T °C [10^{-6}/K]	Thermal conductivity [W/(m x K)]	Thermal capacity [J/(kg x K)]	Electrical resistivity [Ω x mm²/m]	Magnetizable
20	8.1	190	–	10.0	450	1.0	No
100	–	185	14.0	12.0	470	–	–
200	–	180	14.5	13.5	500	–	–
300	–	175	15.0	15.5	510	–	–
400	–	170	15.5	17.0	530	–	–

Fabrication

Forming

As Sanicro® 35 has a high mechanical strength the required force to start plastic deformation is higher than for many other stainless steels and nickel based alloys. Sanicro® 35 has an excellent formability as indicated by the high elongation value.

Welding

The weldability of Sanicro® 35 is good and welding is suitable using TIG (GTAW), MIG/MAG (GMAW), MMA (SMAW). For multi pass welding it is recommended to use TIG welding for the root pass. Welding should be undertaken with low heat input, maximum 1.2 kJ/mm, and an interpass temperature of maximum 100 °C.

Nickel based alloy UNS N06059 (ERNiCrMo-13, NiCr23Mo16) e.g. Avesta P16 is recommended as filler material. Use of filler material is recommended for this material. Autogenous welding should typically be avoided but if necessary, followed by appropriate and qualified post weld heat treatment.

Ar + 2 %N_2 is recommended as shielding gas with TIG welding to achieve the best combination of mechanical properties and corrosion resistance of the welded joints. Ar + 2 % N_2, Pure N_2 or N_2 + 5–10% H_2 can be used as backing gas provided that hydrogen addition is allowed according to given application standard.

For MIG/MAG welding Ar + 20–40% He + 1–3% CO_2 is recommended as shielding gas for optimal corrosion resistance and arc stability. Pure Ar can also be utilized.

Preheating and post-weld heat treatment are not necessary under normal circumstances. To maintain full corrosion resistance of the welded joint, welding must be followed by thorough cleaning to ensure the removal of all oxides and heat tint.

Welding of fully austenitic stainless steels and nickel based alloys often involves the risk of hot cracking in the welded joints if the weldment is under restraint. Due to the low level of impurities in Sanicro® 35, the risk of hot cracking is lower than for most nickel based alloys.

Joint type selection should be made according to recommendation for high alloyed austenitic stainless steels and nickel based alloys.

Products

Sanicro® 35 is available as cold rolled sheet and plate in thicknesses of 0.4–5.5 mm with a width of up to 1,350 mm.

Sanicro® 35 is available as hot rolled plate in thicknesses of 10–50 mm with a width of up to 2,000 mm.

Standards and Approvals

Sanicro® 35 as sheet and plate is included in ASTM B625 as UNS N08935.

Sheet, plate, bar and seamless tube and pipe are covered by the ASME Code Case 2982, Boiler and Pressure Vessel Code, Section VIII, Division I and II.

A process has been initiated for a pre-approval for Particular Material Appraisal (PMA), TÜV.

Seamless tube and pipe are included in ASTM B163. Compliance with NACE MR0175/ISO 15156-3:2015, (Petroleum, Petrochemical, and Natural Gas Industries - Materials for Use in H S-Containing Environments in Oil and Gas Production - Part 3: Cracking-Resistant CRAs (Corrosion-Resistant Alloys) and Other Alloys) for type 4a and type 4c materials. Compliance with ANSI/ NACE MR0103/ISO 17495-1:2016, (Petroleum, petrochemical and natural gas industries-Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments) for highly alloyed austenitic stainless steels and nickel alloys.

Sanicro® 35 as bar and wire products are included in ASTM B649 as UNS N08935 and these product forms are also intended to be included in the same code case as sheet and plate material.

Contacts and enquiries

Contact us

Our experts are ready to help you choose the best stainless steel product for your next project.

www.outokumpu.com/contact

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.

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	Improved machinability	Special surfaces

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