

# Sandvik SAF 2507

## (Plate and sheet)

Sandvik SAF 2507 is a super-duplex (austenitic-ferritic) stainless steel for service in highly corrosive conditions. It is characterized by:

- Excellent resistance to stress corrosion cracking (SCC) in chloride-bearing environments
- Excellent resistance to pitting and crevice corrosion
- High resistance to general corrosion
- Very high mechanical strength
- Physical properties that offer design advantages
- High resistance to erosion corrosion and corrosion fatigue
- Good weldability

### STANDARDS

- UNS S32750
- EN number 1.4410\*
- EN name X 2 CrNiMoN 25-7-4\*
- SS 2328

### Product standards

Plate, sheet and strip: ASTM A240/480, EN 10088\*-2

### Approvals

- Approved by the American Society of Mechanical Engineers (ASME) for use in accordance with ASME Boiler and Pressure Vessel Code, section VIII, div. I.
- ASME B31.3 Chemical Plant and Petroleum Refinery piping.
- VdTÜV-Werkstoffblatt 508
- NACE MR 0175 (Sulphide stress cracking resistant material for oil field equipment)
- NGS 1609 Nordic rules for application of the non-standard steel SAF 2507 manufactured by AB Sandvik Steel.

### CHEMICAL COMPOSITION (NOMINAL) %

C	Si	Mn	P	S	Cr	Ni	Mo	Others
max.	max.	max.	max.	max.				
0.030	0.8	1.2	0.035	0.02	24.0-26.0	6.0-8.0	3.0-5.0	N=0.24-.032 Cu=0.5max

### FORMS OF SUPPLY

Plate and sheet are delivered in the solution annealed and pickled condition.

The size ranges available are given below

#### Plate sheet and coil

Sandvik SAF 2507 plate, sheet are stocked in a wide range of sizes according to ASTM. Details of our stock program are given below:

#### Sandvik Australia's Stock Program

##### Plate (HR-No 1 Finish)

Thickness Range - 5mm - 40mm  
Widths - 2000mm

##### Sheet (CR-2B Finish)

Thickness Range - 3mm,4mm  
Widths - 2000mm,  
Lengths - 3000mm, 6000mm

### MECHANICAL PROPERTIES

The following figures apply to material in the solution annealed condition. More detailed information can be supplied on request.

At 20°C (68°F)

**METRIC UNITS**

Proof strength		Tensile strength	Elong.		Hardness
R <sub>p0.2</sub> <sup>a</sup>	R <sub>p1.0</sub> <sup>a</sup>	R <sub>m</sub>	A <sup>b</sup>	A <sub>2</sub> "	Brinell
MPa	MPa	MPa	%	%	
min.	min.		min.	min.	max.
550	640	800-1000	25	15	310

1 MPa = 1 N/mm<sup>2</sup>

a) R<sub>p0.2</sub> and R<sub>p1.0</sub> correspond to 0.2% offset and 1.0% offset yield strength, respectively.

b) Based on  $L_0 = 5.65 \sqrt{S_0}$  where L<sub>0</sub> is the original gauge length and S<sub>0</sub> the original cross-section area.

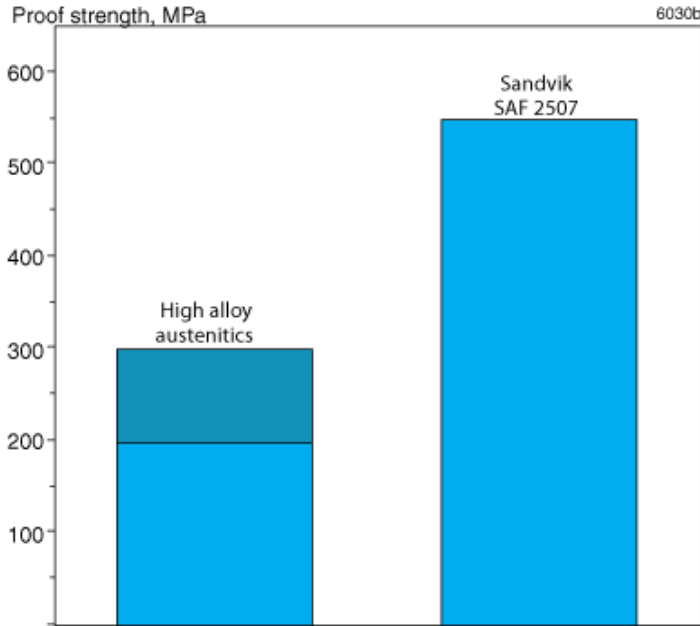


Figure 1. Comparison of minimum proof strength, 0.2% offset, off Sandvik SAF 2507 and high alloy austenitic grades, for material in the solution annealed condition.

**At high temperatures**

If Sandvik SAF 2507 is exposed for prolonged periods to temperatures exceeding 250°C (480°F), the microstructure changes which results in a reduction in impact strength. This effect does not necessarily affect the behaviour of the material at the operating temperature. For example, heat exchanger tubes may be used at higher temperatures without any problems. Contact Sandvik for advice.

For pressure vessel applications, 250°C (480°F) is required as maximum according to VdTÜV-Wb 508 and NGS 1609.

**Tube and pipe with wall thickness max. 20 mm (0.79 in.)**

**METRIC UNITS**

Temperature °C	Proof Strength		Tensile strength
	R <sub>p0.2</sub>	R <sub>p1.0</sub>	R <sub>m</sub>
	MPa	MPa	MPa
	min.	min.	min.
100	480	530	710
150	445	485	685
200	420	450	665
250	405	435	650
300	395	425	645
350	395	425	645
400	395	425	645

**IMPERIAL UNITS**

Temperature °F	Proof Strength		Tensile strength
	R <sub>p0.2</sub>	R <sub>p1.0</sub>	R <sub>m</sub>
	ksi	ksi	ksi
	min.	min.	min.
200	70	78	105
300	65	70	99
400	61	65	96
500	59	63	94
600	57	61	94
700	57	61	94
800	57	61	93

**Impact strength**

Sandvik SAF 2507 possesses good impact strength. The ductile brittle transition temperature is below -50°C (-58°F). The impact strength of welded Sandvik SAF 2507 is also good, although the values are lower than the base metal. The impact strength if gas-shielded arc weldments is minimum 27 J (20 ft lb) at a temperature of -50°C (-58°F).

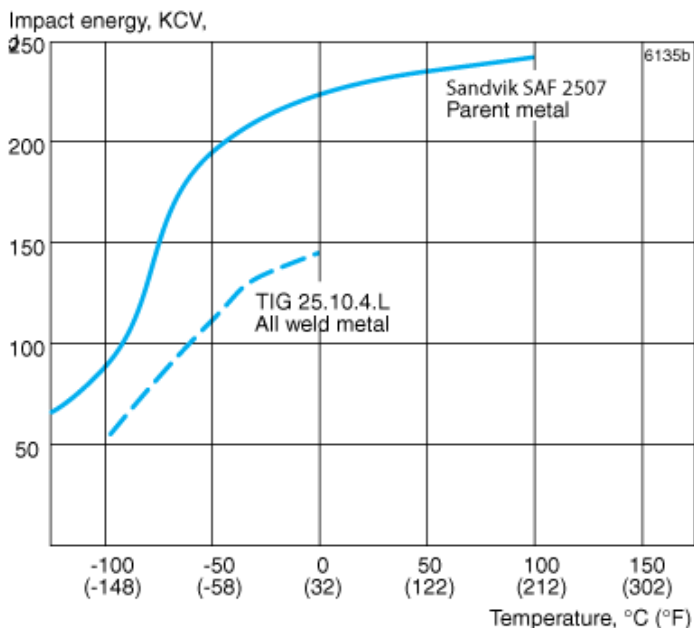


Figure 2. Typical impact energy curves for Sandvik SAF 2507 using standard Charpy V specimens (average of 3 at each temp.).

Parent metal samples taken in the longitudinal direction from 260x12 mm hot extruded and solution annealed (1075°C/1965°F) tube. All weld metal samples from Sandvik 25.10.4.L TIG wire.

According to ASME B31.3 the following design values are recommended for UNS S32750 (Sandvik SAF 2507):

Temperature		Stress	
°F	°C	ksi	MPa
100	38	38.7	265
200	93	35.0	240
300	149	33.1	230
400	204	31.9	220
500	260	31.4	215
600	316	31.2	215

### PHYSICAL PROPERTIES

Density: 7.8 g/cm<sup>3</sup>, 028 lb/in<sup>3</sup>

#### Specific heat capacity

#### METRIC UNITS, IMPERIAL UNITS

Temperature °C	J/(Kg °C)	Temperature °F	Btu/(lb °F)
20	480	68	0.12
100	500	200	0.12
200	530	400	0.13
300	550	600	0.13
400	580	800	0.14

#### Thermal conductivity

#### METRIC UNITS <sup>1)</sup>

Temperature °C	20	100	200	300	400
Sandvik SAF 2507	14	15	16	18	20
ASTM 316L	14	15	17	18	20

1) W/(m °C)

#### IMPERIAL UNITS <sup>1)</sup>

Temperature °F	68	200	400	600	800
Sandvik SAF 2507	8	9	9	10	12
ASTM 316L	8	9	10	10	12

1) Btu/(ft h °F)

#### Thermal expansion

Sandvik SAF 2507 has a coefficient of thermal expansion close to that of carbon steel. This gives Sandvik SAF 2507 definite design advantages over austenitic stainless steels in equipment comprising of both carbon steel and stainless steel. The values given below are average values in the temperature ranges.

#### METRIC UNITS <sup>1)</sup>

Temperature °C	30-100	30-200	30-300	30-400
Sandvik SAF 2507	13.5	14.0	14.0	14.5
Carbon Steel	12.5	13.0	13.5	14.0
ASTM 316L	16.5	17.0	17.5	18

1) x10<sup>-6</sup>/°C

## IMPERIAL UNITS <sup>1)</sup>

Temperature, °F	86-200	86-400	86-600	86-800
Sandvik SAF 2507	7.5	7.5	8.0	8.0
Carbon Steel	6.8	7.0	7.5	7.8
ASTM 316L	9.0	9.5	10.0	10.0

1)  $\times 10^{-6}/^{\circ}\text{F}$

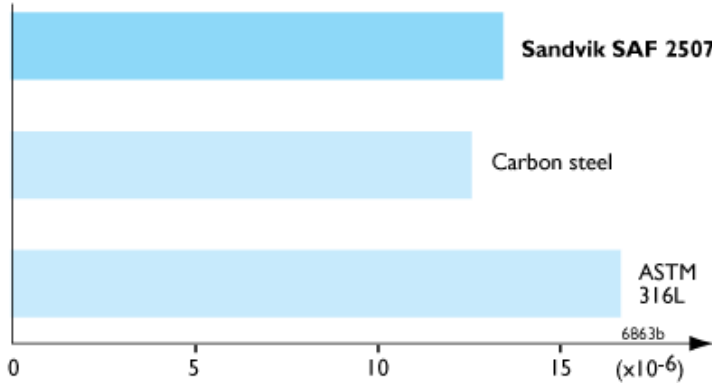


Figure 3. Thermal expansion, per°C (30-100°C, 86-210°F).

## Modulus of elasticity, ( $\times 10^3$ )

### METRIC UNITS, IMPERIAL UNITS

Temperature °C	MPa	Temperature °F	ksi
20	200	68	29.0
100	194	200	28.2
200	186	400	27.0
300	180	600	26.2

## CORROSION RESISTANCE

### General corrosion

Sandvik SAF 2507 is highly resistant to corrosion by organic acids, e.g. formic and acetic acid, see Fig. 4, and pure formic acid, see Fig. 5. Also in contaminated acid Sandvik SAF 2507 remains resistant. Fig. 6 and 7 show results from tests of Sandvik SAF 2507 and various stainless steels and Ni-base alloys in acetic acid contaminated with chlorides which frequently are present in processes in practise.

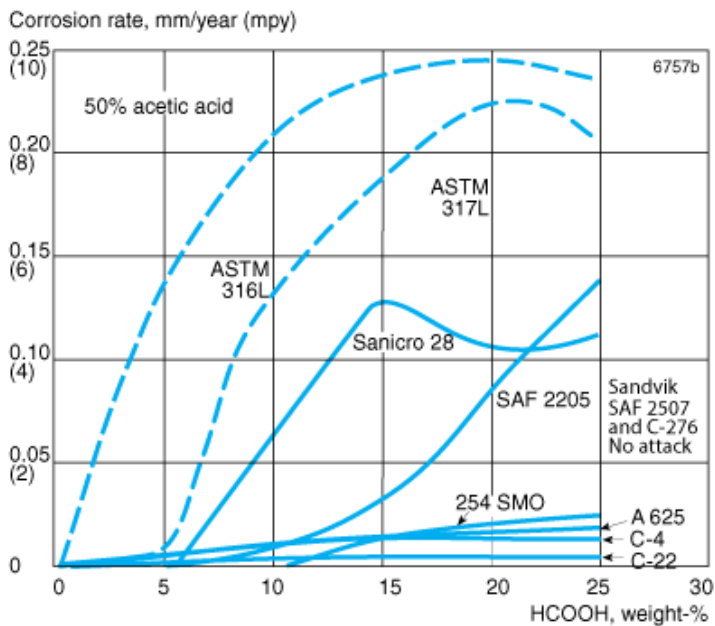


Figure 4. Corrosion rate of various alloys in boiling mixtures of 50% acetic acid and varying proportions of formic acid. Test time 1+3+3 days.

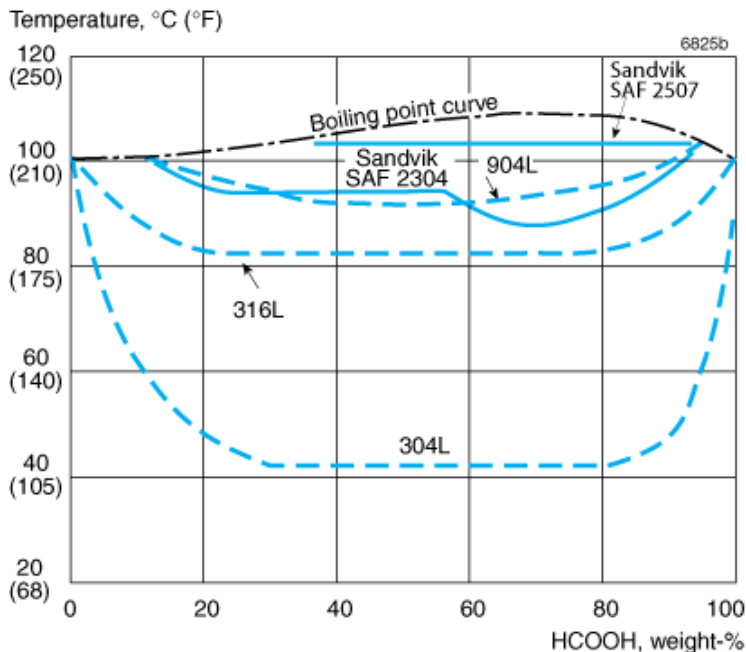


Figure 5. Isocorrosion diagram in formic acid. The curves represent a corrosion rate of 0.1 mm/year (4 mpy) in stagnant test solution.

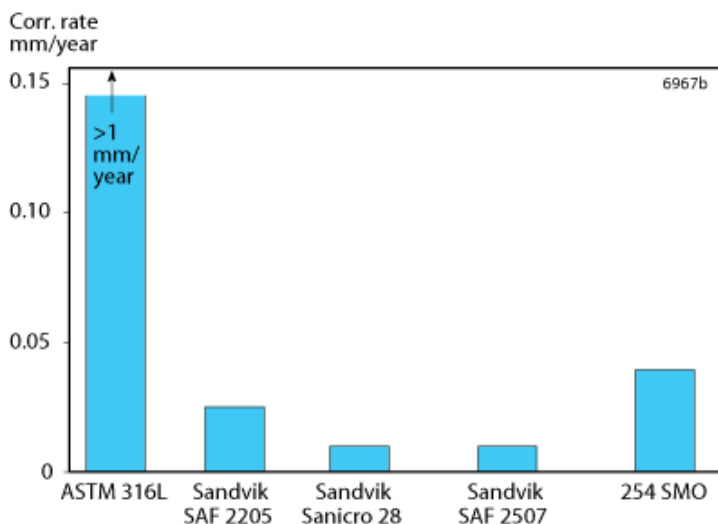


Figure 6. Corrosion rate of various alloys in 80% acetic acid with 2000 ppm chlorides at 90°C (195 °F).

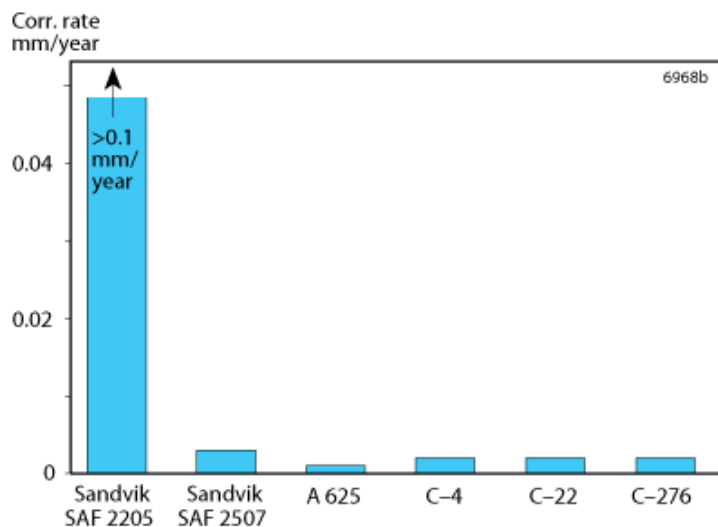


Figure 7. Corrosion rate various alloys in concentrated acetic acid with 200 ppm chlorides.

Practical experience with Sandvik SAF 2507 in organic acids, e.g. in terephthalic acid plants, has shown that this alloy is highly resistant to this type of environment. The alloy is therefore a competitive alternative to high alloyed austenitics and nickelbase alloys in applications where standard austenitic stainless steels corrode at a high rate.

Resistance to inorganic acids is comparable to, or even better than that of high alloy austenitic stainless steels in certain concentration ranges.

Figures 8 to 10 show isocorrosion diagrams for sulphuric acid, sulphuric acid contaminated with 2000 ppm chloride ions, and hydrochloric acid, respectively.

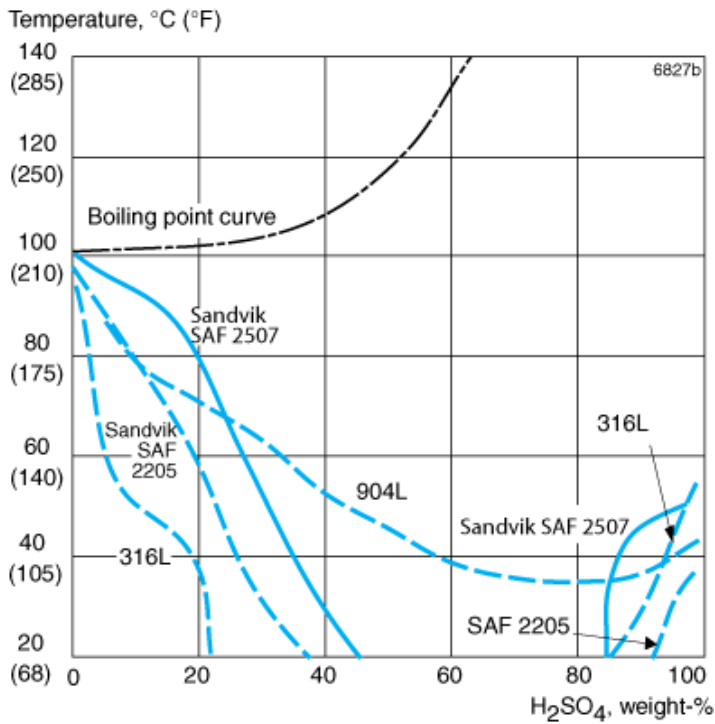


Figure 8. Isocorrosion diagram in sulphuric acid. The curves represent a corrosion rate of 0.1 mm/year (4 mpy) in stagnant test solution.

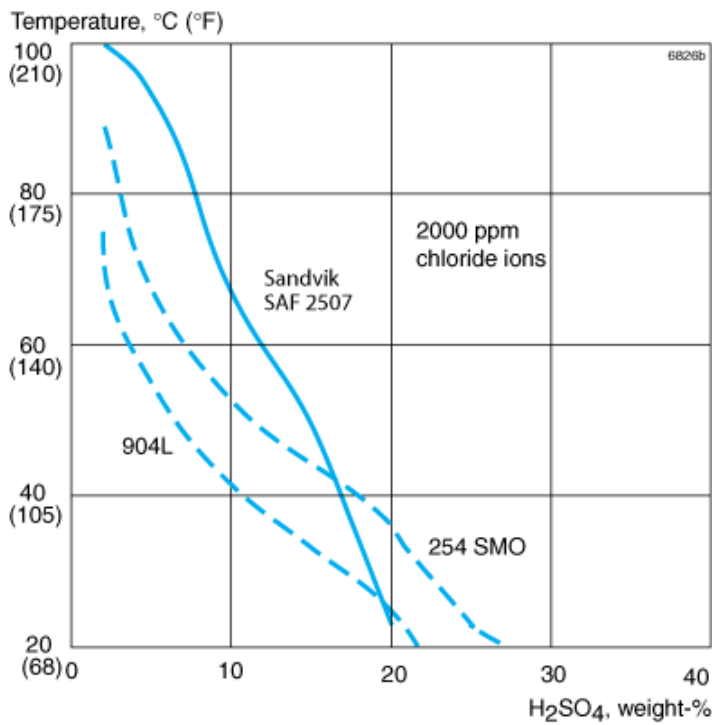


Figure 9. Isocorrosion diagram, 0.1 mm/year (4 mpy) in sulphuric acid containing 2000 ppm chloride ions.

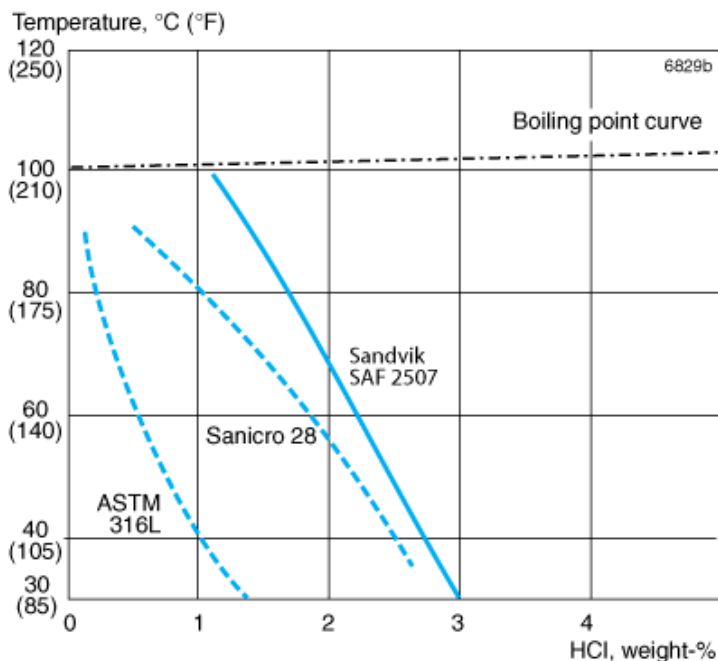


Figure 10. Isocorrosion diagram in hydrochloric acid. The curves represent acorrosion rate of 0.1 mm/year (4 mpy) in stagnant test solution.

#### Pitting and crevice corrosion

The pitting and crevice corrosion resistance of a stainless steel is primarily determined by the content of chromium, molybdenum and nitrogen. An index for comparing the resistance to pitting in chloride environments is the PRE number (Pitting Resistance Equivalent).

The PRE is defined as, in weight-%  
 $PRE = \%Cr + 3.3 \times \%Mo + 16 \times \%N$

For duplex stainless steels the pitting corrosion resistance is dependent on the PRE-value in both the ferrite phase and the austenite phase, so that the phase with the lowest PRE-value will be limiting for the actual pitting corrosion resistance. In Sandvik SAF 2507 the PRE-value is equal in both phases, which has been achieved by a careful balancing of the elements.

The minimum PRE-value for Sandvik SAF 2507 is 41. This is significantly higher than e.g. the PRE-values for other duplex stainless steels of the 25Cr type which are not 'super-duplex'. As an example UNS S31260 25Cr3Mo0.2N has a minimum PRE-value of 33.

One of the most severe pitting and crevice corrosion tests applied to stainless steel is ASTM G48, i.e. exposure to 6% FeCl<sub>3</sub> with and without crevices (method A and B respectively). In a modified version of the ASTM G48 PrA test, the sample is exposed for periods of 24 hours. When pits are detected together with a substantial weight loss (>5 mg), the test is interrupted. Otherwise the temperature is increased 5 °C (45 °F) and the test is continued with the same sample. Figure 11 shows critical pitting and crevice temperatures (CPT and CCT) from this test.

Potentiostatic tests in solutions with different chloride contents are reported in figure 12. Figure 13 shows the effect of increased acidity. In both cases the applied potential is 600 mV vs SCE, a very high value compared with that which could be expected in natural unchlorinated seawater, thus resulting in lower critical temperatures compared with most practical service conditions.



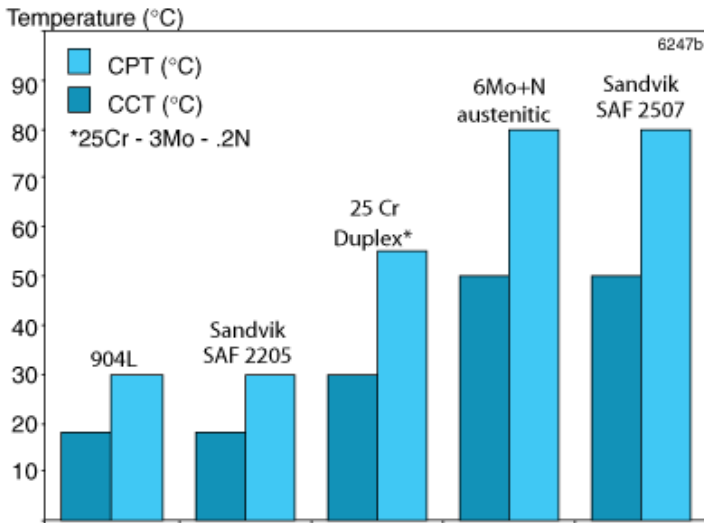


Figure 11. Critical pitting and crevice temperatures in 6% FeCl<sub>3</sub>, 24h (similar to ASTM 648).

The scatter band for Sandvik SAF 2507 and 6Mo+N illustrates the fact that both alloys have similar resistance to pitting, and CPT-values are within the range shown in the figure.

Tests were performed in natural sea water to determine the critical crevice corrosion temperature of samples with an applied potential of 150 mV vs SCE. The temperature was raised by 4°C (40°F) steps every 24 hours until crevice corrosion occurred and the results are shown in the following table.

Alloy	CCT (°C)
Sandvik SAF 2507	64
6Mo+N	61

In these tests the propagation rates of initiated crevice corrosion attacks, at 15-50°C (59-122°F) and an applied potential of 150 mV vs SCE were also determined. These were found to be about ten times lower for Sandvik SAF 2507 than for the 6Mo+N alloy.

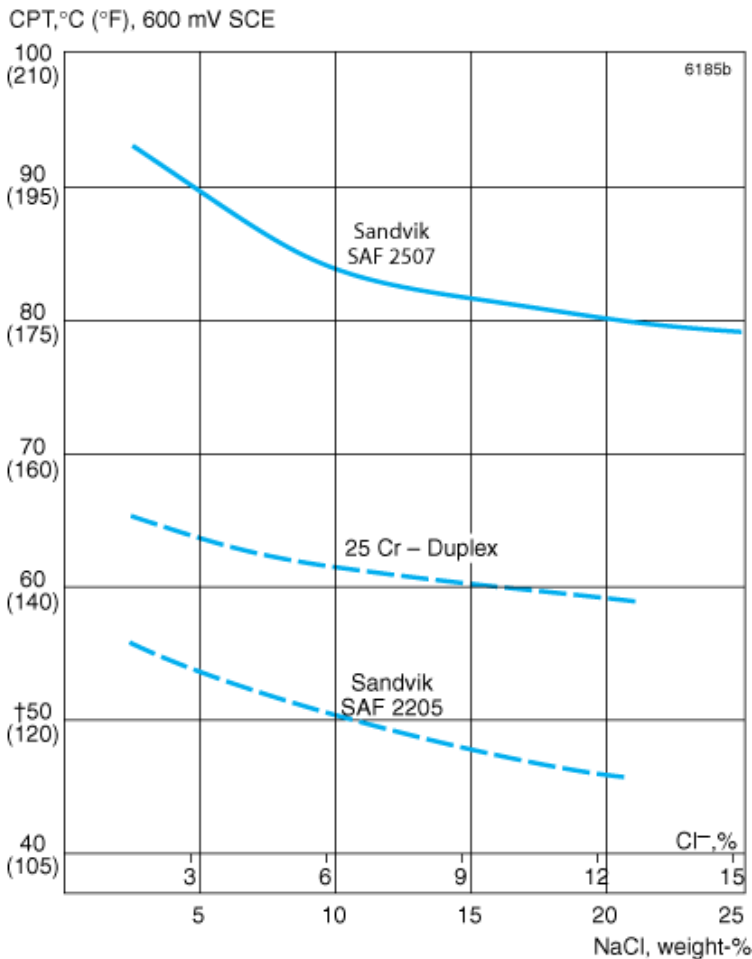


Figure 12. Critical pitting temperatures (CPT) at varying concentrations of sodium chloride, from 3 to 25% (potentiostatic determination at +600 mV SCE with surface ground to 600 grit paper).

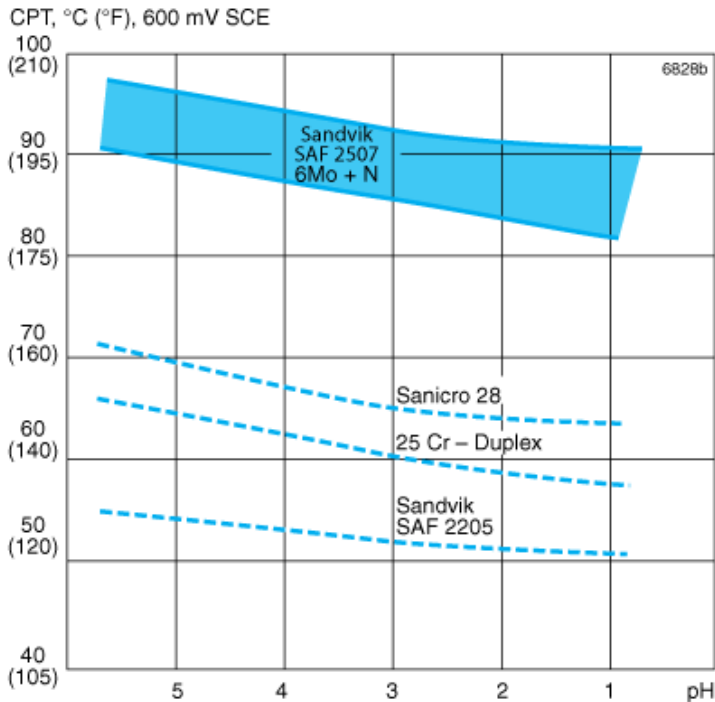


Figure 13. Critical pitting temperatures (CPT) in 3% NaCl with varying pH (potentiostatic determination at +600 mV SCE with surface ground to 600 grit paper).

The corrosion resistance of Sandvik SAF 2507 in oxidising chloride solutions is illustrated by critical pitting temperatures (CPT) determined in 'Green death' -solution (1% FeCl<sub>3</sub> + 1% CuCl<sub>2</sub> + 11% H<sub>2</sub>SO<sub>4</sub> + 1.2% HCl) and in 'Yellow death' -solution (0.1 % Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> + 4% NaCl + 0.01 M HCl). The table below shows CPT-values for different alloys in these solutions. It is clear that the values for Sandvik SAF 2507 are on the same level as those for the nickel-base alloy UNS N06625. The tests have shown a good correlation with the ranking of alloys for use as reheater tubes in flue gas desulphurisation systems.

Critical pitting temperature (CPT) determined in different test solutions.

Alloy	Critical pitting temperature (CPT), °C 'Green death'	'Yellow death'
Sandvik SAF 2507	72.5	>90
6Mo+N	70	>90
UNS N06625	67.5	>90
ASTM 316	<25	20

**Stress corrosion cracking**

Sandvik SAF 2507 has excellent resistance to chloride induced stress corrosion cracking.

The SCC resistance of Sandvik SAF 2507 in chloride solutions at high temperatures is illustrated in figure 14. There are no signs of SCC up to 1000 ppm Cl<sup>-</sup>/300°C (570°F) and 10000 ppm Cl<sup>-</sup>/250°C (480°F).

Sandvik SAF 2507 U-bend specimens exposed for 1000 hours in hot brine (108°C/226°F, 25% NaCl) showed no cracking.

The threshold stress for Sandvik SAF 2507 in 40% CaCl<sub>2</sub> at 100°C (210°F) and pH = 6.5 is above 90% of the tensile strength for both parent metal and welded joints. (TIG-welded with Sandvik 25.10.4.L or MMA-welded with Sandvik 25.10.4.LR).

Figure 15 shows the result of testing in 40% CaCl<sub>2</sub> at 100°C (210°F) acidified to pH = 1.5. Acidifying of the standard test solution to pH = 1.5 lowers the threshold stress for Sandvik SAF 2205 but not for Sandvik SAF 2507. This is true for both parent metal and welded joints.

The threshold stress for both parent metal and welded joints of Sandvik SAF 2507 in boiling 45% MgCl<sub>2</sub>, 155°C (311°F) (ASTM G36) is approximately 50% of the proof strength.

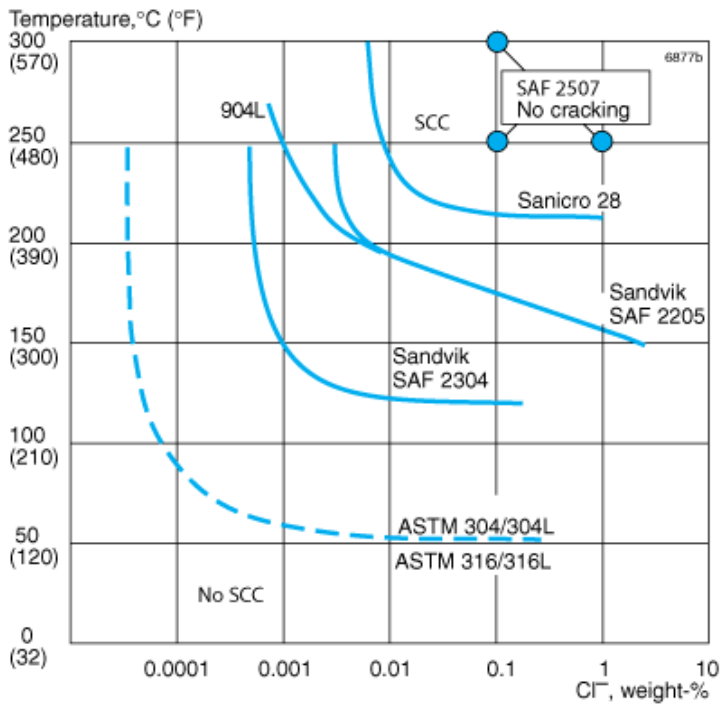


Figure 14. SCC resistance in oxygen-bearing (abt. 8 ppm) neutral chloride solutions. Testing time 1000 hours. Applied stress equal to proof strength at testing temperature.

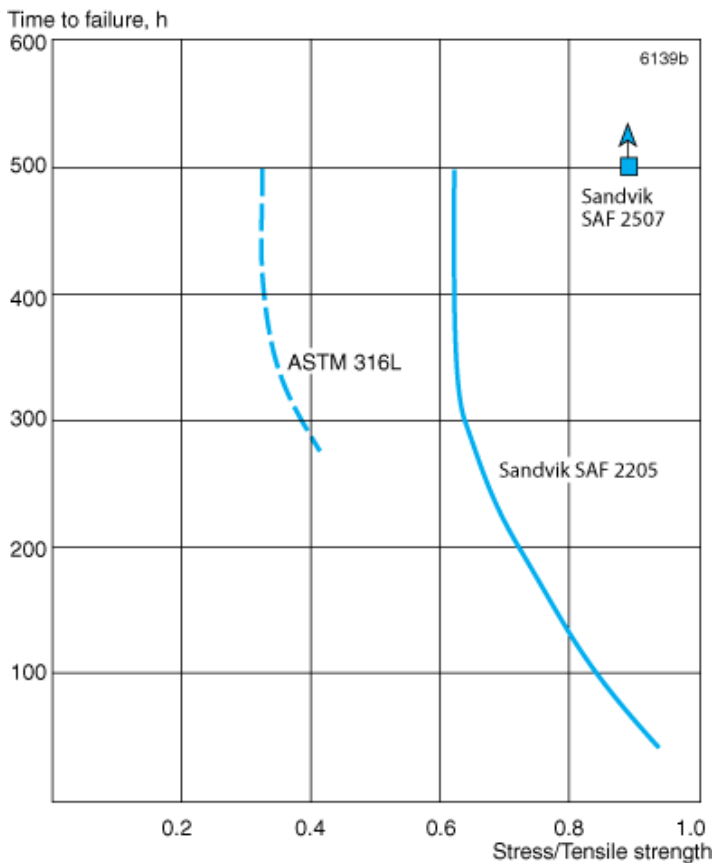


Figure 15. Results of SCC tests with constant load in 40% CaCl<sub>2</sub>, pH=1.5, at 100°C (210°F) with aerated test solution.

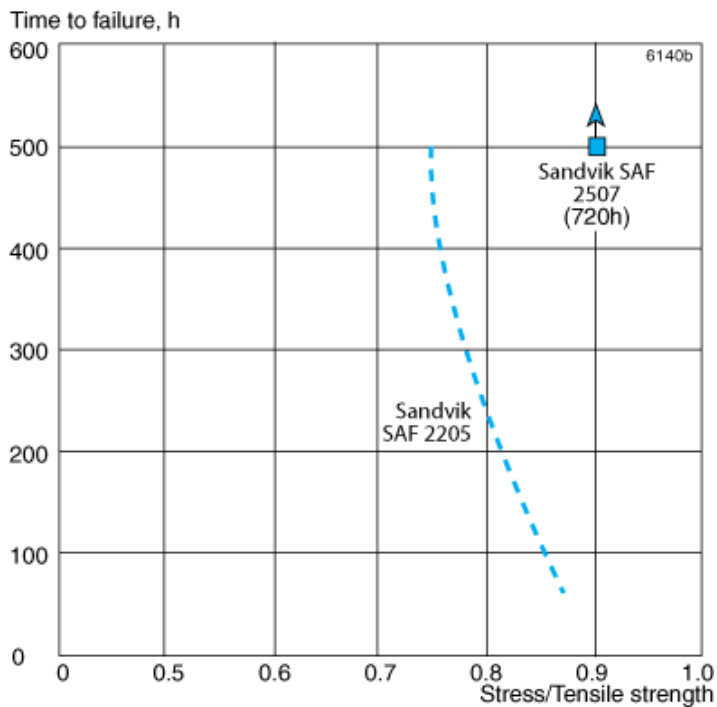


Figure 16. Constant-load SCC tests in NACE-solution at room temperature (NACE TM 0177).

Figure 16 shows the results of SCC tests at room temperature in NACE solution (5% sodium chloride and 0.5% acetic acid saturated with hydrogen sulphide). No cracking occurred on Sandvik SAF 2507 irrespective of the applied stress.

In aqueous solutions containing hydrogen sulphide and chlorides, stress corrosion cracking can also occur on stainless steels at temperatures below 60°C (140°F). The corrosivity of such solutions is affected by acidity and chloride content. In direct contrast to the case with ordinary chloride-induced stress corrosion cracking, ferritic stainless steels are more sensitive to this type of stress corrosion cracking than austenitic steels.

In accordance with NACE MR 0175 solution annealed wrought duplex stainless steel UNS S32750 (Sandvik SAF 2507) is acceptable for use at temperatures up to 450°F (232°C) in sour environments, if the partial pressure of hydrogen sulphide does not exceed 1.5 psi (0.10 bar), and its hardness is not greater than HRC 32.

#### Intergranular corrosion

Sandvik SAF 2507 is a member of the family of modern duplex stainless steels whose chemical composition is balanced to give quick reformation of austenite in the high temperature heat affected zone in the weld. This results in a microstructure that gives the material a good resistance to intergranular corrosion. Testing according to ASTM A262 Practice E (Strauss test) constitutes no problem for Sandvik SAF 2507 which passes without reservations.

#### Erosion corrosion

The mechanical properties combined with the corrosion resistance give Sandvik SAF 2507 good resistance to erosion corrosion. Testing in sand containing media has shown that Sandvik SAF 2507 has an erosion corrosion resistance better than corresponding austenitic stainless steels. Figure 17 below shows the relative mass loss rate of the duplex Sandvik SAF 2507, Sandvik SAF 2205 and an austenitic 6Mo+N type steel after exposure to synthetic seawater (ASTM D-1141) containing 0.025-0.25% silica sand at a velocity of 8.9–29.3 m/s (average of all tests is shown).

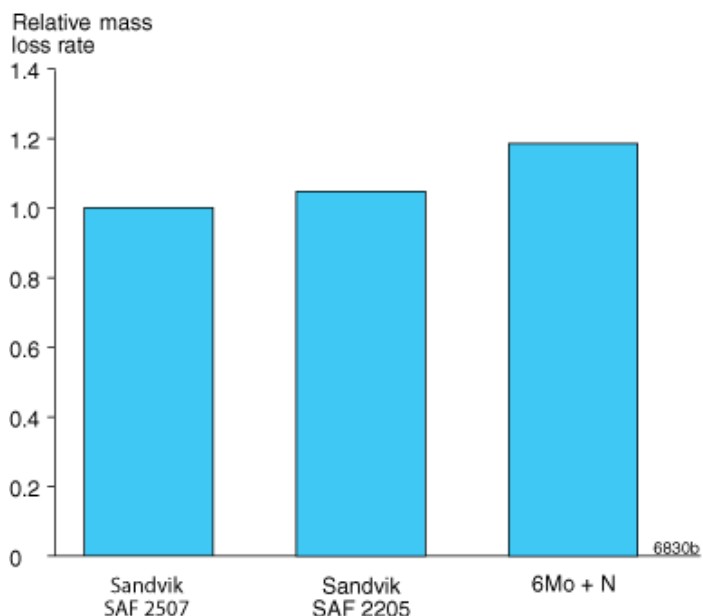


Figure 17. Relative mass loss rate after testing of the resistance against erosion corrosion.

#### **Corrosion fatigue**

Duplex stainless steels which have a high tensile strength usually also have a high fatigue limit, and high resistance to both fatigue and corrosion fatigue. The high fatigue strength of Sandvik SAF 2507 can be explained by its good mechanical properties, and its high resistance to corrosion fatigue has been proven by fatigue testing in corrosive media.

#### **HEAT TREATMENT**

Plate and sheet are normally delivered in heat treated condition. If additional heat treatment is needed after further processing the following is recommended.

##### **Solution annealing**

1050-1125°C (1920-2060°F), rapid cooling in air or water.

#### **WELDING**

The weldability of Sandvik SAF 2507 is good. Suitable welding methods are manual metal-arc welding with covered electrodes or gas-shielded arc welding. Welding should be undertaken within the heat input range of 0.2-1.5 kJ/mm and with an interpass temperature of maximum 150°C (300°F).

Preheating or post-weld heat treatment is not necessary.

Matching filler metals are recommended in order to obtain a weld metal with optimum corrosion resistance and mechanical properties. For gas-shielded arc welding use Sandvik 25.10.4.L, and for manual metal-arc welding the covered electrode Sandvik 25.10.4.LR.

#### **FABRICATION**

##### **Bending**

The starting force needed for bending is slightly higher for Sandvik SAF 2507 than for standard austenitic stainless steels (ASTM 304L and 316L).

If the service conditions are on the limit of the stress corrosion resistance of Sandvik SAF 2507 heat treatment is recommended after cold bending. For pressure vessel applications in Germany and the Nordic countries heat treatment may be required after cold deformation in accordance with VdTÜV-Wb 508 and NGS 1609. Heat treatment should be carried out by solution annealing or resistance annealing.

Hot bending is carried out at 1125-1025°C (2060-1880°F) and should be followed by solution annealing.

##### **Expanding**

Compared to austenitic stainless steels, Sandvik SAF 2507 has a higher proof and tensile strength. This must be kept in mind when expanding tubes into tube-sheets. Normal expanding methods can be used, but the expansion requires higher initial force and should be undertaken in a one-step operation. As a general rule, tube to tube-sheet joints should be welded if the service conditions include a high chloride concentration, thus limiting the risk for crevice corrosion.

##### **Machining**

Being a two-phase material (austenitic-ferritic) Sandvik SAF 2507 will present a different wear picture from that of single-phase steels of type AISI 304L.

The cutting speed must therefore be lower than that recommended for ASTM 304L. It is recommended that a tougher insert grade is used than when machining austenitic stainless steels, e.g. ASTM 304L.

## APPLICATIONS

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Sandvik SAF 2507 is a duplex stainless steel especially designed for service in aggressive chloride-containing environments. Typical applications are:

### Typical applications: Sandvik SAF 2507

<b>Oil and gas industry</b>	Chloride containing environments such as seawater handling and process systems. Hydraulic and process fluid tubes in umbilicals
<b>Seawater cooling</b>	Tubing for heat exchangers in refineries, chemical industries, process industries, and other industries using seawater or chlorinated seawater as coolant
<b>Salt evaporation industry</b>	Evaporator-tubing for production of corrosive salts, e.g. chlorides, sulphates and carbonates
<b>Desalination plants</b>	Pressure vessels for reverse osmosis units, tube and pipe for seawater transport, heat exchanger tubing
<b>Geothermal wells</b>	Heat exchangers in geothermal exploitation units, systems exposed to geothermal or high-salinity brines, tubing and casing for production
<b>Refineries and petrochemical plants</b>	Tubes and pipes where the process environment contains a high amount of chlorides, or is contaminated with hydrochloric acid
<b>Pulp and paper industry</b>	Material for chloride-containing bleaching environments
<b>Chemical industry</b>	In organic acid plants, also when process solution is contaminated with e.g. chlorides
<b>Mechanical components requiring high strength</b>	

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Propeller shafts and other products subjected to high mechanical load in seawater and other chloride-containing environments.

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<b>Desulphurisation units</b>	As reheater tubes in flue gas desulphurisation systems. The good mechanical and corrosion properties make Sandvik SAF 2507 an economical choice in many applications by reducing the life cycle cost of the equipment.
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#### DISCLAIMER:

Recommendations are for guidance only, and the suitability of a material for a specific application can be confirmed only when we know the actual service conditions. Continuous development may necessitate changes in technical data without notice. This datasheet is only valid for Sandvik materials.