Alleima

SAF™ 2906

Tube and pipe, seamless

Datasheet

SAF™ 2906 is a high-alloy duplex (austenitic-ferritic) stainless steel with excellent corrosion resistance in caustic environments and environments with chlorides. SAF™ 2906 characteristics:

- Excellent resistance to caustic environments, also in the presence of contaminants such as chlorides
- Excellent resistance to intergranular corrosion
- Excellent resistance to pitting and crevice corrosion
- High resistance to stress corrosion cracking (SCC)
- Good weldability
- Very high strength. The proof strength is about three times as high as for conventional austenitic stainless steels.

Standards

- UNS: S32906
- EN Number: 1.4477

Product standards

- Seamless tube and pipe: ASTM A789, A790
- Bar steel: ASTM A479
- Plate: ASTM A240

Approvals

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- Approved by the American Society of Mechanical Engineers (ASME) for use in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, div. 1 and 2.
- PED (Pressure Equipment Directive) PED 2014/68/EU and AD2000 Merkblatt W2: Particular Material Appraisal (PMA), Austenitic-ferritic steel SAF™ 2906.

Chemical composition (nominal)

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	N
≤0.030	0.3	1.0	≤0.030	≤0.015	29	7	2.3	≤0.80	0.35

Applications

Typical applications for SAF™ 2906 are:

- Caustic soda production: the material is suitable for use in piping systems from the cells up to the evaporation plant. It is also an excellent choice for very aggressive conditions, such as the evaporator tubes, in both diaphragm and membrane process.
- Alumina production: heat exchanger tubes and piping in the digestion of alumina
- Environments where high resistance to pitting and crevice corrosion is required

Corrosion resistance

Caustic environment

SAF™ 2906 has, owing to its high chromium content, a very good resistance in caustic environments. For pure caustic soda, the performance of SAF™ 2906 can be observed in the iso-corrosion diagram (0.1 mm/year), see Figure 1. In the production of caustic soda, however, impurities in the form of chlorides and chlorates are present. Usually, in the caustic soda manufacturing process Ni200 or high nickel alloys are used, especially in critical equipment such as the evaporators.

Results of corrosion tests in sodium hydroxide (NaOH) containing different amounts of sodium chloride (NaCl) and sodium chlorate ($NaClO_3$), similar to the content found in the evaporation plants of diaphragm and membrane processes, are presented in Table 1, 2 and Figure 2. The results clearly indicate the good performance of SAF™ 2906 in caustic environments.

Table 1. Performance in caustic environments - Diaphragm process

Grade	Environment	Temperature, °C (°F)	Corrosion rate mm/year
SAF™ 2906	10% NaOH, 2% NaCl, 800 ppm ClO_3^-	100 (212)	< 0.01
		Boiling	< 0.01

Table 1. Performance in caustic environments - Diaphragm process

Grade	Environment	Temperature, °C (°F)	Corrosion rate mm/year
	50% NaOH, 7% NaCl, 800 ppm ClO_3^-	100 (212)	< 0.01
		Boiling	0.016
Sanicro® 28	10% NaOH, 2% NaCl, 800 ppm ClO_3^-	100 (212)	< 0.01
		Boiling	< 0.01
	50% NaOH, 7% NaCl, 800 ppm ClO_3^-	100 (212)	< 0.01
		Boiling	0.34
Ni200	10% NaOH, 2% NaCl, 800 ppm ClO_3^-	100 (212)	< 0.01
		Boiling	< 0.01
	50% NaOH, 7% NaCl, 800 ppm ClO_3^-	100 (212)	< 0.01
		Boiling	0.15

Table 2. Performance in caustic environments - Membrane process

Grade	Environment	Temperature	Corrosion rate mm/year
SAF™ 2906	32%NaOH + 30 ppm Cl^- + 20 ppm $NaClO_3$	Boiling	< 0.01
	50%NaOH + 30 ppm Cl^- + 20 ppm $NaClO_3$	Boiling	< 0.01
Ni200	32%NaOH + 30 ppm Cl^- + 20 ppm $NaClO_3$	Boiling	< 0.01
	50%NaOH + 30 ppm Cl^- + 20 ppm $NaClO_3$	Boiling	< 0.01

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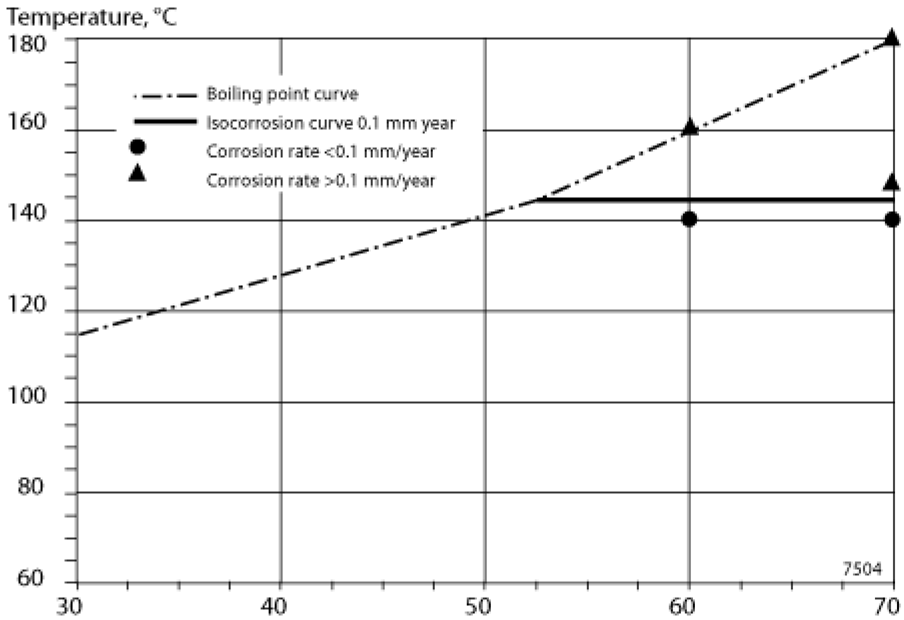
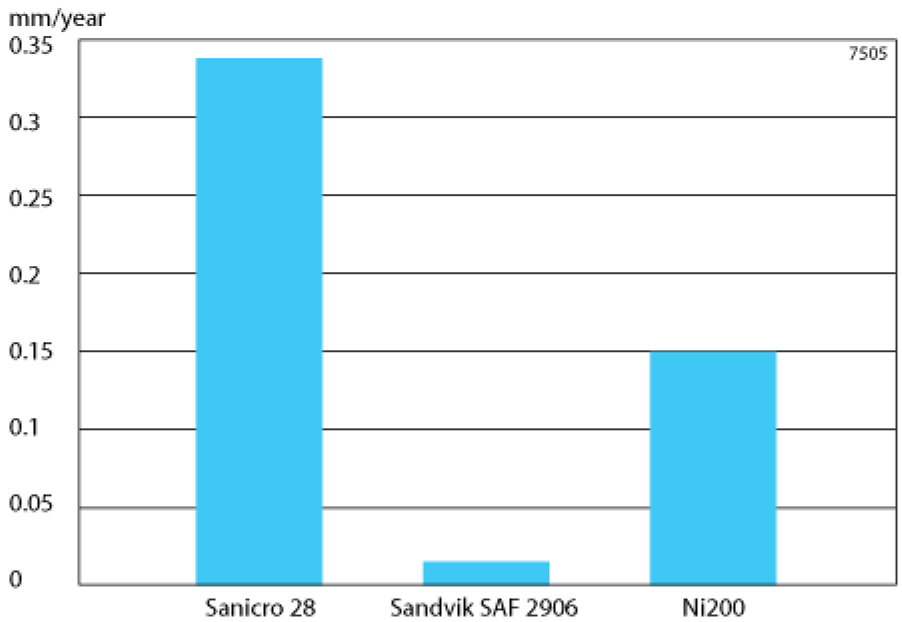


Figure 1. Iso- corrosion diagram for SAF 2906 in pure NaOH, naturally aerated solution.



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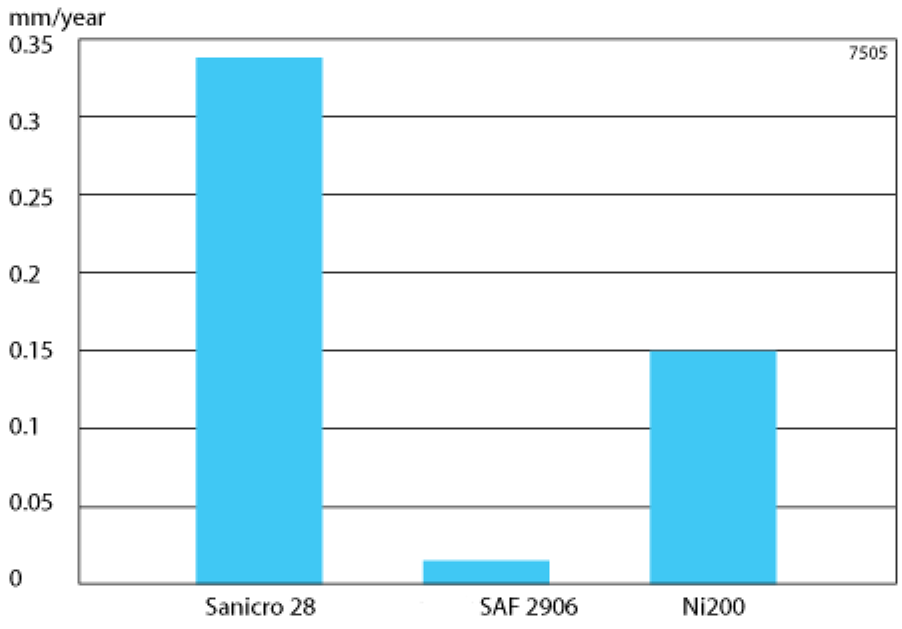


Figure 2. Corrosion rates in a mixture of 50% NaOH, 7% NaCl, 800 ppm ClO_3^-, boiling solution.

Pitting and crevice corrosion

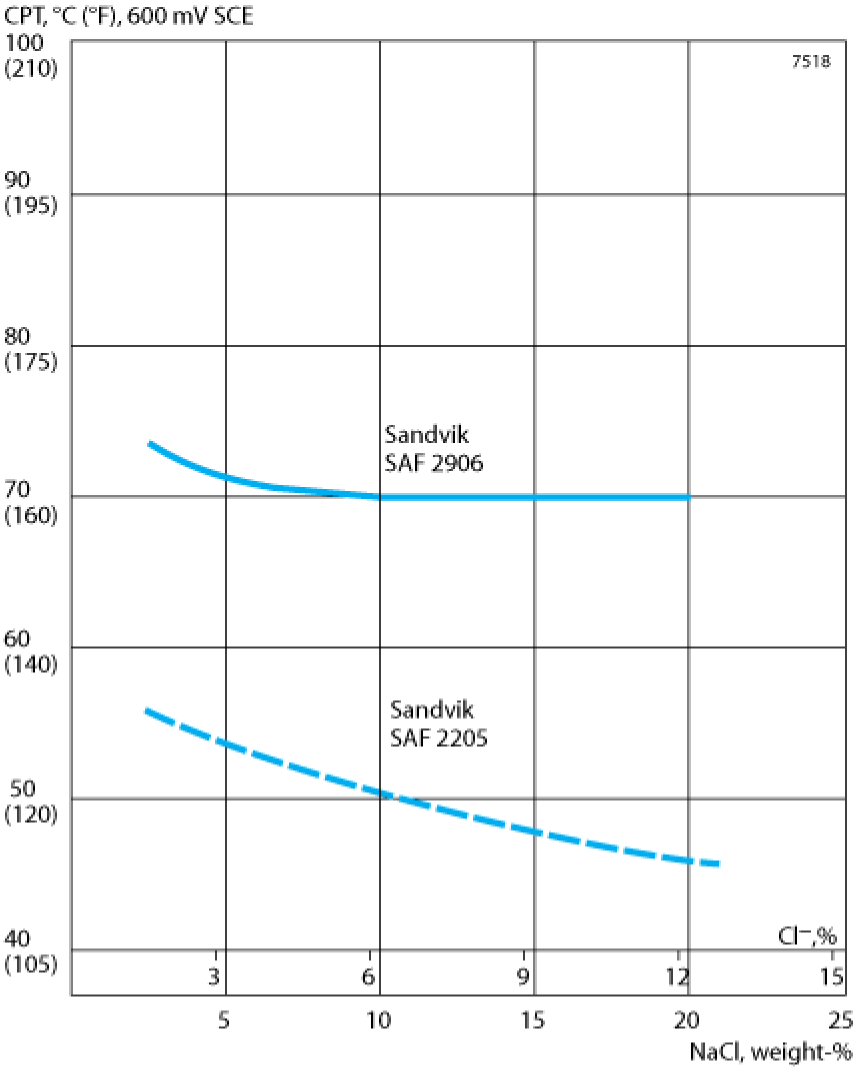
SAF™ 2906 has a carefully balanced composition with a high chromium and nitrogen content and a moderate amount of molybdenum. This gives the material a high resistance to localized corrosion caused by chlorides. The PRE number (Pitting Resistance Equivalent) is an index for comparing pitting corrosion resistance.

The PRE is defined as, in weight-PRE = %Cr + 3.3 x %Mo + 16 x %N
A very severe test for pitting or crevice corrosion is the ASTM G48 test, i.e. immersion in 6% $FeCl_3$. Results for pitting test according to modified method A and crevice corrosion testing according to method B, are presented in Table 3. The crevice corrosion test was performed with a crevice specified in the MTI-2 procedure, where an artificial crevice is mounted on the sample with a torque of 0.28 Nm. The critical pitting temperature (CPT) and the critical crevice temperature (CCT) are the temperatures where pitting or crevice corrosion starts to develop on the material.

Table 3. PRE, CPT and CCT values

Grade	PRE (min.)	CPT, °C (°F)	CCT, °C (°F)
SAF™ 2906	41.5	75 (167)	42.5 (109)
SAF™ 2507	42.5	80 (176)	50 (122)
SAF™ 2205	35	30 (86)	18 (64)
ASTM 316L	26	<10 (50)	<10 (50)

Potentiostatic tests in solutions with different chloride contents are reported in Figure 3. Figure 4 shows the effect of increased acidity. In both cases the applied high potential, 600 mV SCE, corresponds to very harsh conditions, thus resulting in conservative data with a lower critical temperature compared with most practical situations.


CPT, °C (°F), 600 mV SCE
100
(210)
90
(195)
80
(175)
70
(160)
60
(140)
50
(120)
40
(105)
7518
Sandvik
SAF 2906
Sandvik
SAF 2205
Cl⁻,%
3
6
9
12
15
5
10
15
20
25
NaCl, weight-%

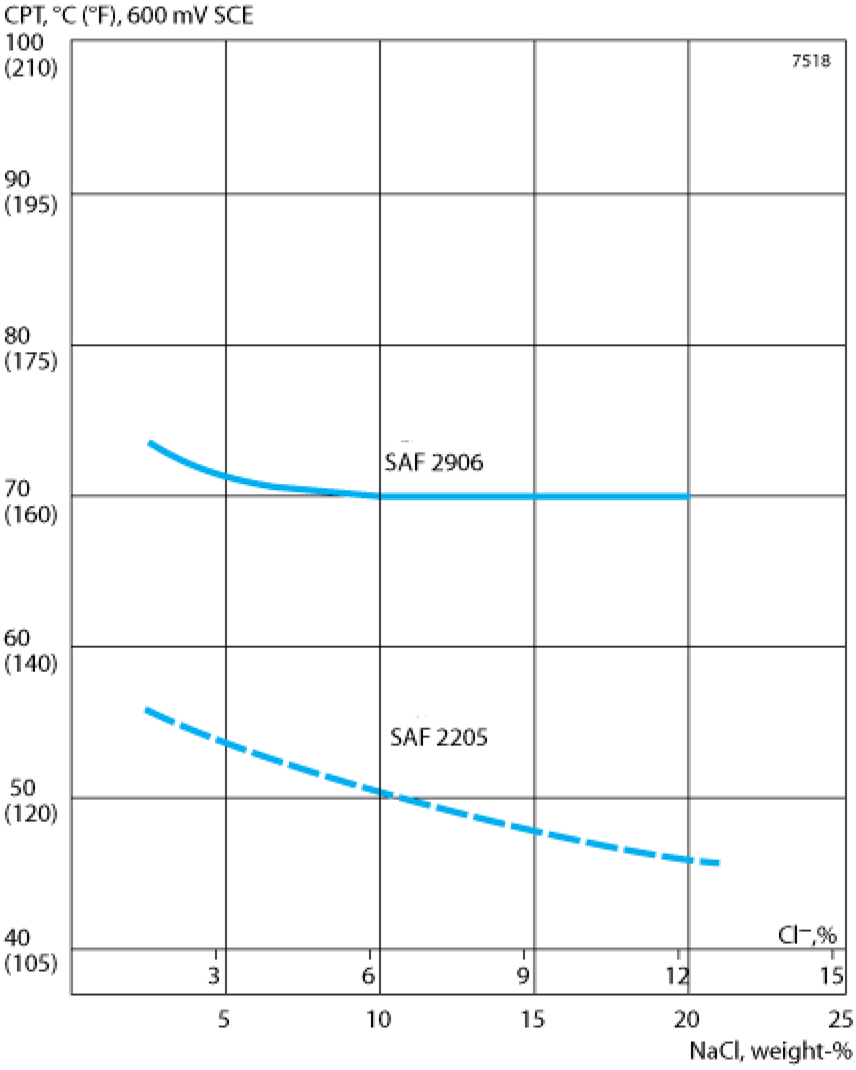
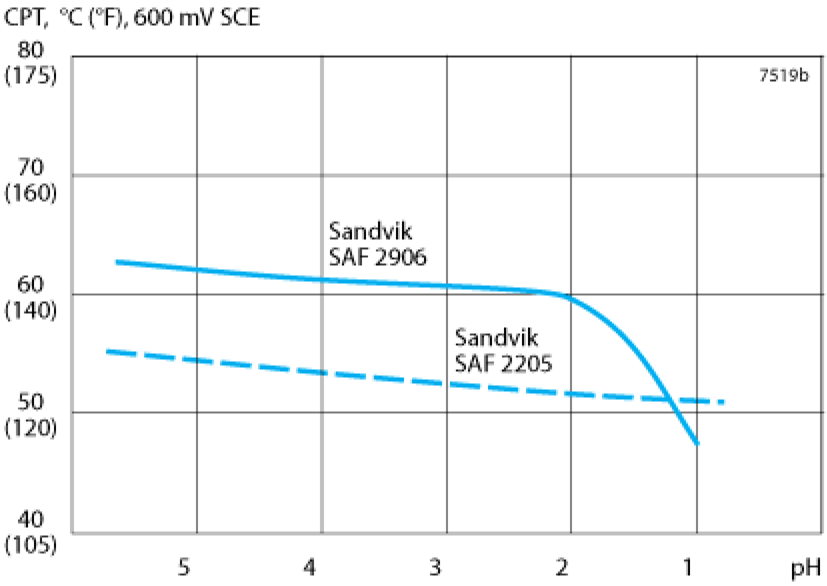


Figure 3. Critical pitting temperature (CPT) at varying concentrations of sodium chloride, from 3 to 25% (potentiostatic determination at +600 mV SCE with surface ground to 600 grit paper).



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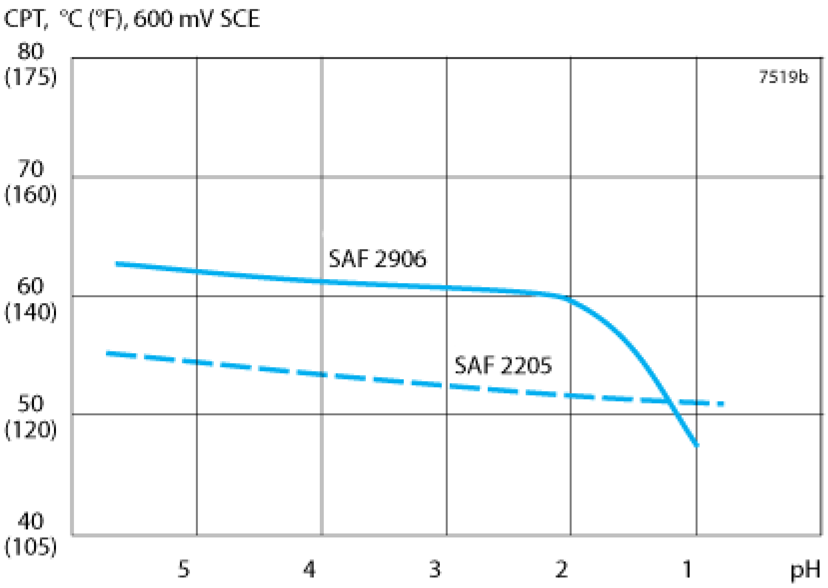
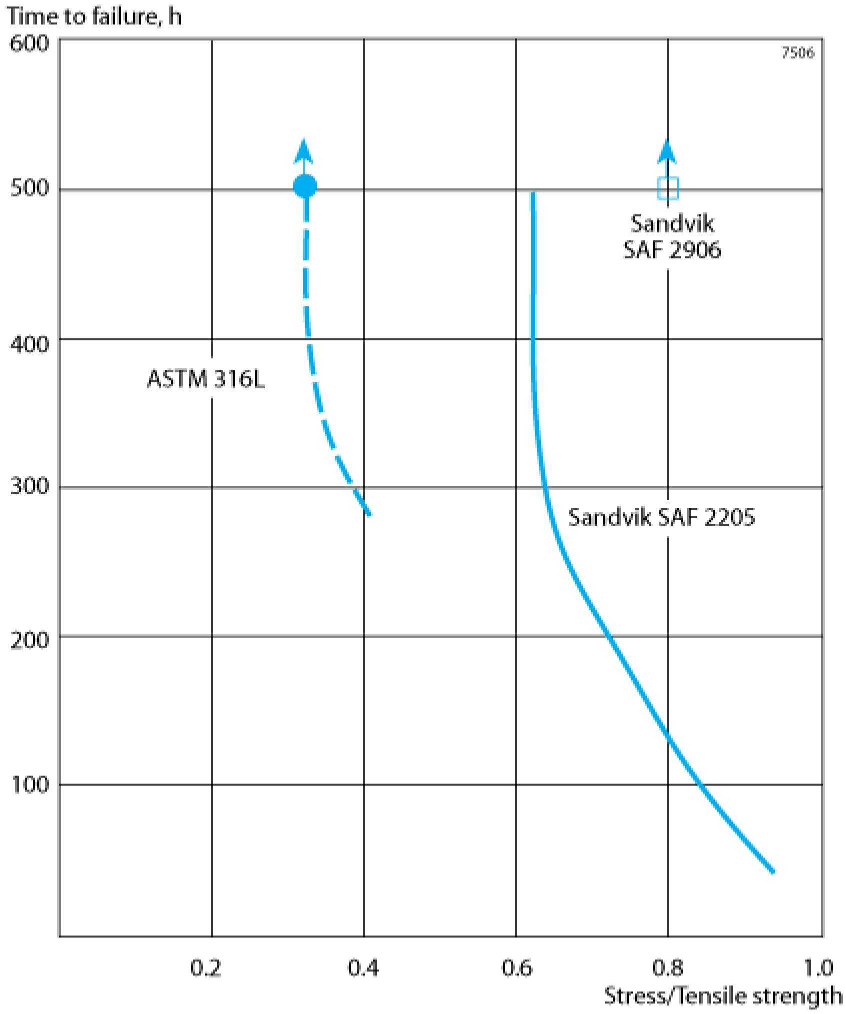


Figure 4. *Critical pitting temperature (CPT) in 3% NaCl with varying pH (potentiostatic determination at +600 mV SCE with surface ground to 600 grit paper).*

Stress corrosion cracking (SCC)

SAF™ 2906 has excellent resistance to chloride induced stress corrosion cracking (SCC). The resistance of various alloys to stress corrosion cracking (SCC) determined by constant load testing in aerated 40% $CaCl_2$, pH 1.5, at 100°C (210°F), (modified ASTM G36 method) is shown in Figure 5.


Time to failure, h
600
500
400
300
200
100
7506
Sandvik
SAF 2906
ASTM 316L
Sandvik SAF 2205
0.2
0.4
0.6
0.8
1.0
Stress/Tensile strength

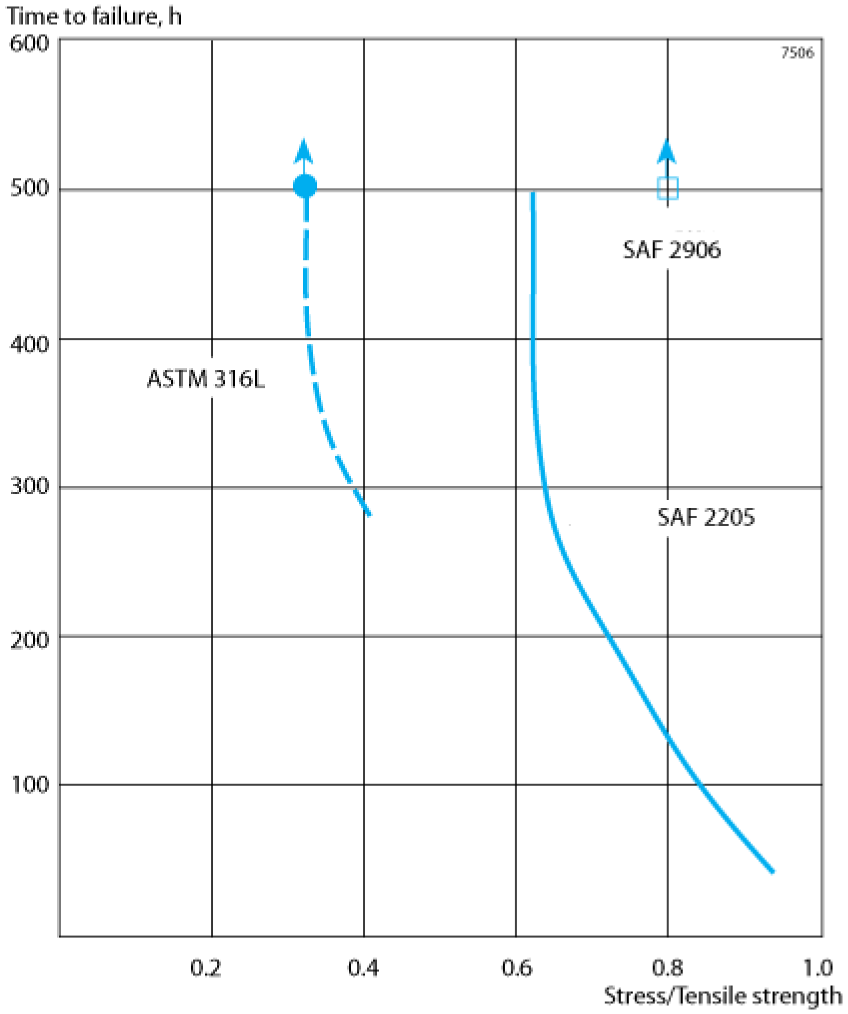


Figure 5. Constant load testing of SAF™ 2906 and some other alloys in 40% $CaCl_2$, pH 1.5, at 100°C (212°F). Time to failure vs. applied stress in percentage of tensile strength is shown. Filled symbol: cracking, unfilled symbol: no cracking.

Nitric acid

Due to its balance of chromium and molybdenum, SAF™ 2906 presents good resistance to nitric acid. The iso-corrosion diagram, see Figure 6, shows the performance of the material compared to SAlleima2RE10, a high purity austenitic grade widely used for nitric acid.

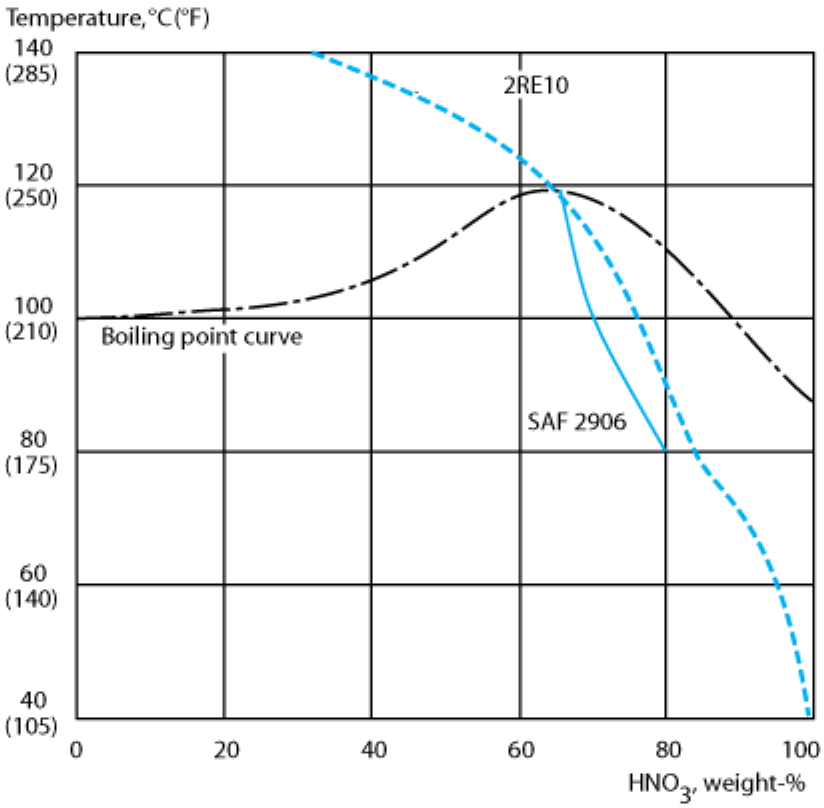


Figure 6. Iso- corrosion diagram for SAF™ 2906 and Alleima® 2RE10 in a naturally aerated, stagnant solution of nitric acid. The curves represent a corrosion rate of 0.1 mm/year.

Fabrication

Bending

The force needed for bending SAF™ 2906 is higher than that for standard austenitic stainless steels which is a natural consequence of the higher yield strength.

Expanding

Compared with austenitic stainless steels, SAF™ 2906 has a higher proof and tensile strength. This must be kept in mind when expanding tubes into tubesheets. Normal 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 tubesheet joints should be welded to ensure a leak free joint.

Machining

Being a dual phase material (austenitic-ferritic) SAF™ 2906 will present a different wear picture from that of a single phase material like Alleima® 2RE69. The cutting speed must therefore be lower than that recommended for austenitic grades. Further information is available on request.

Forms of supply

Seamless tube and pipe

SAF™ 2906 can be supplied as seamless tube and pipe. Tubes can be supplied straight or U-bent.

Other forms of supply:

- Fittings and flanges
- Plate, sheet and strip
- Bar steel
- Forged products

Heat treatment

The tubes are normally delivered in the heat treated condition. If additional heat treatment is needed after further processing, the following is recommended.

Solution annealing

1040-1080°C (1900-1980°F), rapid cooling in air or water.

Mechanical properties

The following figures apply to material in the solution annealed condition. If SAF™ 2906 is exposed for prolonged periods to temperature ranges exceeding 280°C (540°F), the microstructure changes, which results in a reduction in toughness. This does not necessarily affect the behavior of the material at the operating temperature. The listed values are guaranteed for tube and pipe.

At 20°C (68°F)

Wall thickness	Proof strength		Tensile strength		Elong.
	$R_{p0.2}$ [a)]		R_m		A [b)]
mm	MPa	ksi	MPa	ksi	%

	min	min.	min.	min.	min.
<10	650	94	800	116	25
≥10	550	80	750	109	25

1 MPa = 1 N/mm^2
a) $R_{p0.2}$ corresponds to 0.2% offset offset yield strength.
b) Based on $L_0 = 5.65 \sqrt{S_0}$ where L_0 is the original gauge length and S_0 the original cross-section area.

At high temperatures

Metric units

Temperature	Wall thickness	Proof strength	Tensile strength,	Elong
		$R_{p0.2}$	R_m	A
°C	mm	MPa	MPa	%
		min.	min.	min
100	<10	550	750	25
	≥10	500	730	25
200	<10	470	720	25
	≥10	430	700	25
300	<10	450	710	25
	≥10	410	690	25

Imperial units

Temperature	Wall thickness	Proof strength	Tensile strength	Elong
		$R_{p0.2}$	R_m	A
°F	in.	ksi	ksi	%
		min.	min.	min.
200	<0.4	80	109	25
	≥0.4	73	106	25
400	<0.4	68	104	25
	≥0.4	62	101	25
600	<0.4	65	103	25
	≥0.4	59	100	25

Recommended design values for SAF™ 2906(UNS S32906) recommended according to ASME Code Case 2295-3

Temperature	Stress

		Tube wall thickness <10 mm		Tube wall thickness >10 mm	
°F	°C	ksi	MPa	ksi	MPa
100	38	33.1	228	31.1	214
200	93	33.1	228	31.1	214
300	149	31.5	217	29.6	204
400	204	30.6	210	28.7	197
500	260	30.1	207	28.3	195
600	316	30.1	207	28.3	195

Impact strength

SAF™ 2906 possesses a good impact strength. The ductility to brittle transition temperature is approximately -100°C (-150°F). Figure 7 shows the typical impact energy for SAF™ 2906.

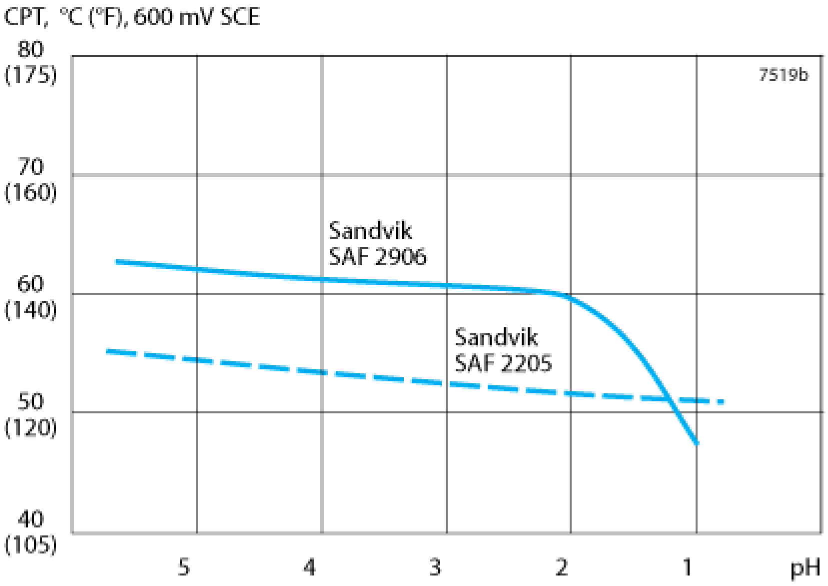


Figure 7. Typical impact energy curve for SAF™ 2906 using half size (5 x 10 mm) Charpy V specimens (average of 3 at each temperature).

Physical properties

Density: 7.7 g/cm^3, 0.28 lb/in^3

Thermal conductivity

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h°F

20	13	68	7
100	14	200	8
200	16	400	9
300	18	600	10
400	19	800	11

Specific heat capacity

Temperature, °C	J/kg °C	Temperature, °F	Btu/ft h°F
20	470	68	0.11
100	500	200	0.12
200	530	400	0.13
300	560	600	0.14
400	600	800	0.14

Thermal expansion

Mean values in temperature ranges (x10^{-6}) SAF™ 2906 has a coefficient of thermal expansion close to that of carbon steel. This gives SAF™ 2906 definite design advantages over austenitic stainless steels. The values given in the table are average values in the temperature ranges.

Metric units, x10^{-6}/°C

Temperature, °C	30-100	30-200	30-300	30-400
SAF™ 2906	11.5	12.0	12.5	12.5
Carbon steel	12.5	13.0	13.5	14.0
ASTM 316L	16.5	17.0	17.5	18.0

Imperial units, x10^{-6}/°F

Temperature, °F	86-200	86-400	86-600	86-800
SAF™ 2906	6.5	7.0	7.0	7.0

Carbon steel	7.0	7.0	7.5	8.0
ASTM 316L	9.5	9.5	10.0	10.0

Resistivity

Temperature, °C	μΩm	Temperature, °F	μΩinch
20	0.81	68	31.9

Modulus of elasticity, x10^3

Temperature, °C	MPa	Temperature, °F	ksi
20	200	68	29.0
100	194	200	28.2
200	186	400	26.9
300	180	600	26.0

Welding

The weldability of SAF™ 2906 is good. Welding must be carried out without preheating and subsequent heat treatment is normally not necessary. Suitable method of fusion welding is gas tungsten arc welding GTAW/TIG with shielding gas of Ar+2% N_2. For tube to tubesheet welding, it is recommended to use Ar+3% N_2 as shielding gas to have proper weld metal structure.

For SAF™ 2906, heat input of 0.2-1.5 kJ/mm and interpass temperature of <150°C (300°F) are recommended.

Recommended filler metals

GTAW/TIG welding

Exaton 29.8.2.L wire or strip electrodes are recommended for overlay welding of tubesheets and high-pressure vessels in cases where corrosion resistance, equal to that of SAF™ 2906, is required.

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 Alleima materials.