SAFUREX®
TUBE AND PIPE, SEAMLESS

DATASHEET

Safurex® is a high-alloy duplex (austenitic-ferritic) stainless steel developed to withstand the corrosive environments present in the Stamicarbon urea process. The grade is characterized by:

- Good corrosion resistance to carbamate solutions both with oxygen and with little or no oxygen
- Excellent resistance to intergranular corrosion
- Excellent resistance to pitting and crevice corrosion
- High resistance to stress corrosion cracking (SCC)
- Good weldability

STANDARDS

- UNS: S32906
- EN Number: 1.4477

Product standards

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

Approvals

- ASME Code Case 2295-3
- Stamicarbon specification 18005AA-BE 06/MS.50
- PMA 1326W113330-4 Latest revision

APPLICATIONS

Safurex® high-alloy duplex steel is suitable for the following applications in urea plants:

- Stripper tubes
- Pool condenser tubes
- Pool reactor tubes
- Carbamate condenser tubes
- Ferrules in strippers
- High-pressure piping
- Scrubbers
- Lining
- Overlay welding
- Reactor trays

Datasheet updated 9/9/2019 9:44:48 AM (supersedes all previous editions)

– High-pressure valves

FORMS OF SUPPLY

Seamless tube and pipe

Safurex® can be supplied as straight or U-bent tubing. The size range is up to OD 457 mm (18.1 in.).

The tubes are supplied in the solution annealed and white pickled condition or in the bright-annealed condition.

Other forms of supply:

– Fittings
– Flanges
– Plate
– Round bar
– Forgings
–

CORROSION RESISTANCE

Urea carbamate found in the high-pressure urea process is very aggressive and corrosion problems in form of intergranular or/and general corrosion are found when an inferior material is applied.

Variations in corrosion properties have been found especially on ASTM 316L type materials for urea applications (e.g. Sandvik 3R60 Urea Grade). The Huey test has been included as material test for Sandvik 3R60 U.G. and Sandvik 2RE69 to verify a low general corrosion rate and a low intergranular attack. Past experience has showed that a high corrosion rate in service corresponds to a high corrosion rate in the Huey test.

Under normal service conditions in the Stamicarbon urea process the chloride concentration in the boiler water is extremely low and no chloride induced corrosion will appear. If the chloride concentration is unintentionally increased, stress corrosion cracking (SCC) can occur on austenitic stainless steels like Sandvik 3R60 U.G. and Sandvik 2RE69. The risk for SCC increases with increasing chloride concentration, stresses and temperature.

At the prevailing conditions even small concentrations in the range 10–50 ppm may be sufficient to cause SCC. Austenitic-ferritic (duplex) grades have in general a much improved resistance to SCC (see Figure 1). Pitting and crevice corrosion are formed at much higher chloride concentrations, which are unlikely to appear in service. Safurex has superior resistance to pitting and crevice corrosion compared to Sandvik 3R60 U.G. and Sandvik 2RE69.

Stress corrosion cracking (SCC)

Safurex® high-alloy duplex steel 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 1.

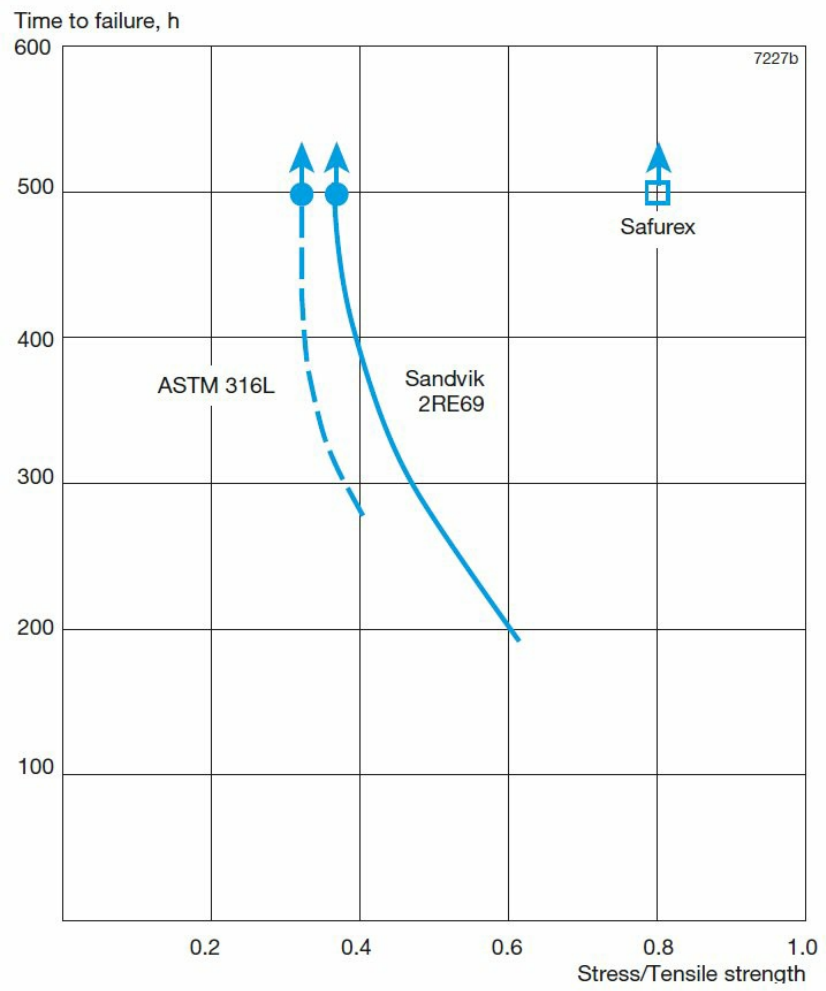

Figure 1. Constant load testing of Safurex and some other alloys in 40% CaCl₂, pH 1.5 at 100°C (210°F). Time to failure vs. applied stress in percentage of tensile strength is shown.

Intergranular corrosion

Safurex® has, owing to its high content of important alloying elements, excellent resistance to intergranular corrosion.

The resistance to intergranular corrosion is often studied by means of either Huey testing (ASTM A262 practice C, 5x48 h in boiling HNO_3) or Streicher testing (ASTM A262 practice B, 120 h in boiling H_2SO_4 + $FeSO_4$). For Safurex®, the Streicher test is a more relevant test method. In the table below, some results from this test are presented. Regarding Huey testing, Safurex® meets the same requirements as Sandvik 2RE69 according to specifications from Stamicarbon.

Streicher test results for Safurex

Typical mm/year	Maximum mm/year	Selective attack µm
0.18	0.78	<70

Pitting and crevice corrosion

Safurex® high-alloy duplex steel has a carefully balanced composition with a high content of chromium and nitrogen and a moderate amount of molybdenum. This enables a very high resistance to localized corrosion, such as pitting and crevice corrosion.

One of the most severe pitting and crevice corrosion tests applied to stainless steel is ASTM G48, i.e. immersion

in 6% $FeCl_3$. When pits are detected following a 24 hours exposure, together with a substantial weight loss (>5 mg), the test is interrupted. Otherwise the temperature is increased 5°C (9°F) and the test is continued with the same sample.

In the table below, Safurex® is compared with some other grades used in the urea process with regard to pitting resistance equivalent (PRE) and the critical pitting temperature (CPT) determined by ASTM G48A.

Critical pitting temperature (CPT) acc. to ASTM G48A for Safurex® and some other urea grades

Grade	CPT, °C	CPT, °F
Safurex	75	167
Sandvik 2RE69	45	113
Sandvik 3R60 U.G.	<10	<50

Potentiostatic tests in solutions with different chloride contents are reported in Figure 2. 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.

Critical crevice corrosion temperature (CCT) was determined with the MTI-2 procedure which is immersion in 6% $FeCl_3$, 12 crevices on each side of the test coupon and a torque of 0.28 Nm. Duplicate samples were immersed for 24 hours. The CCT for Safurex® was approximately 40°C (100°F).

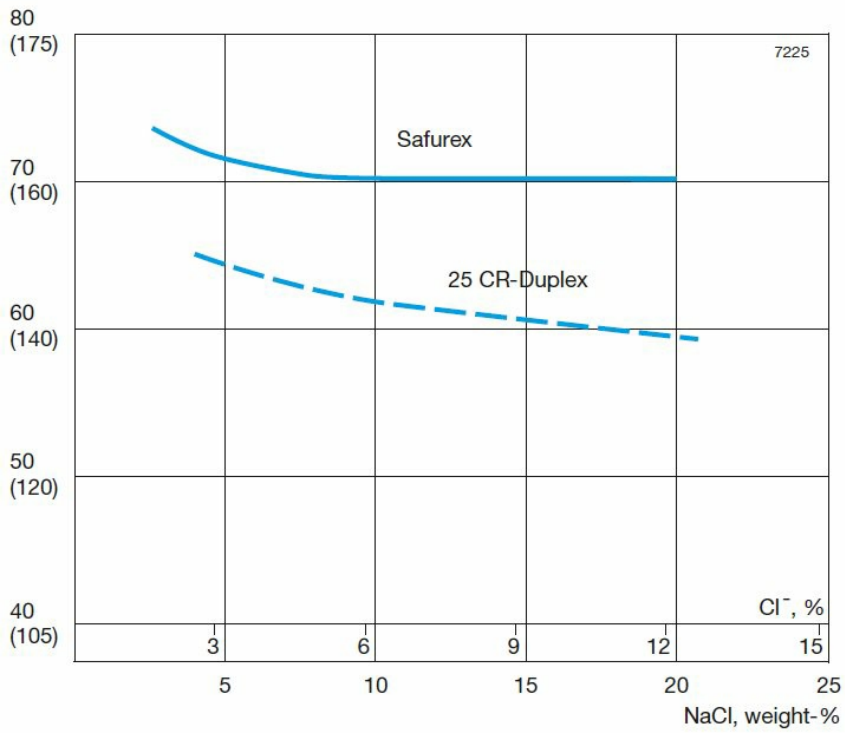

Figure 2. Critical pitting temperature (CPT) at varying concentrations of sodium chloride (NaCl), from 3 to 25% (potentiostatic determination at +600 mV SCE with surface ground to 600 grit paper).

FABRICATION

Bending

The force needed for bending Safurex® high-alloy duplex steel is higher than that for standard austenitic stainless steels which is a natural consequence of the grade's higher proof strength.

Expanding

Compared with austenitic stainless steels, Safurex 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) Safurex® will present a different wear picture from that of a single phase material like Sandvik 2RE69. The cutting speed must therefore be lower than that recommended for austenitic grades. Contact us for further information.

MECHANICAL PROPERTIES

The mechanical properties are determined for heat exchanger tubes. If Safurex® 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 valid 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/mm²
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
	10-15	500	730	25
	>15	470	700	25
200	<10	470	720	25
	10-15	430	700	25
	>15	400	650	25
300	<10	450	710	25
	10-15	410	690	25
	>15	360	630	25

Imperial units

Temperature	Wall thickness	Proof strength	Tensile strength	Elong.

		$R_{p0.2}$	R_m	A
°F	inch	ksi	ksi	%
		min.	min.	min.
200	<0.4	80	109	25
	0.4-0.59	73	106	25
	>0.59	69	102	25
400	<0.4	68	104	25
	0.4-0.59	62	101	25
	>0.59	58	94	25
600	<0.4	65	103	25
	0.4-0.59	59	100	25
	>0.59	51	91	25

Recommended design values for Safurex® (UNS S32906) according to ASME Code Case 2295-3

Temperature		Stress			
		Tube wall thickness <0.4 in. (10 mm)		Tube wall thickness >0.4 in. (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

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/lb °F
20	470	68	0.11
100	500	200	0.12
200	530	400	0.13
300	560	600	0.14

Specific heat capacity

Temperature, °C	J/kg °C	Temperature, °F	Btu/lb °F
400	600	800	0.14

Thermal expansion

Safurex® high-alloy duplex steel has a coefficient of thermal expansion close to that of carbon steel. This gives Safurex® definitive design advantages over austenitic stainless steels. The values given in the tables are average values in the temperature ranges.

Metric units, (x10^{-6}/°C)

Material	Temperature, °C			
	30–100	30–200	30–300	30–400
Safurex	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)

Material	Temperature, °F			
	86–200	86–400	86–600	86–800
Safurex	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	µΩin.
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 Sandvik Safurex® 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 Sandvik Safurex®, 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

Safurex® / 29.8.2.L

Safurex® / 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 Sandvik Safurex®, is required.

Datasheet updated 9/9/2019 9:44:48 AM (supersedes all previous editions)