SANDVIK

SANDVIK 2RE10
TUBE AND PIPE, SEAMLESS

DATASHEET

Sandvik 2RE10 is an austenitic stainless steel with extremely low carbon and impurity contents. The grade is characterized by:

- Excellent resistance to corrosion in nitric acid
- Excellent resistance to intergranular corrosion
- Good resistance to pitting
- Good weldability

STANDARDS

- UNS: S31002
- EN Number: 1.4335
- W.Nr.: 1.4335*
- DIN: X 1 CrNi 2521*

* Obsolete. Replaced by EN.

Product standards

- ASTM A213 and A312
- EN 10216-5
- SEW 400 (Feb 1991)

Sandvik 2RE10 conforms to EN no. 1.4335, but actual composition specified for EN no. 1.4335 allows considerable higher maximum levels of C, Si, P, S and Mo. High levels of these elements increase the potential for corrosion and have therefore been kept as low as possible in Sandvik 2RE10.

Approvals

- ASME Code Case 2591. Section VIII, Division 1.

CHEMICAL COMPOSITION (NOMINAL) %

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo
≤0.015	≤0.15	1.8	≤0.020	≤0.005	24.5	20	≤0.10

FORMS OF SUPPLY

Tube and pipe are supplied in dimensions up to 80 mm (3.15 in.) outside diameter in the solution annealed and white-pickled or in the bright annealed condition.

Other forms of supply

– Welding wire and wireelectrodes
– Covered electrodes
– Sheet and plate
– Bar steel (grade Sandvik2RE69)

MECHANICAL PROPERTIES

Metric units, at 20°C

Proof strength		Tensile strength	Elong.	Hardness
$R_{p0.2}$[a)]	$R_{p1.0}$[a)]	R_m	A[b)]	
MPa	MPa	MPa	%	Vickers
				approx.
≥205	≥210	≥500-670	≥35[c)]	155

1 MPa = 1 N/mm2

Imperial units, at 68°F

Proof strength		Tensile strength	Elong.	Hardness
$R_{p0.2}$[a)]	$R_{p1.0}$[a)]	R_m	A2"	
ksi	ksi	ksi	%	Vickers
				approx.
≥30	≥31	≥73-98	≥35[c)]	155

a) $R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset yield strength respectively.
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.
c) EN 10216-5 with min 45% can be fulfilled

Impact strength

Due to its austenitic microstructure, Sandvik 2RE10 has very good impact strength both at room temperature and at cryogenic temperatures.

Tests have demonstrated that the steel fulfils requirements according to the European standards EN 13445-2 (UFPV-2) ((min. 60 J (44 ft-lb) at -270°C (-455°F)) and EN 10216-5 (min. 60 J (44 ft-lb) at -196°C (-320°F).

At high temperatures

Metric units

Temperature	Proof strength		Tensile strength
	$R_{p0.2}$	$R_{p1.0}$	R_m
°C	MPa	MPa	MPa
	min.	min.	min.
50	195	225	485
100	180	210	470
150	170	200	455
200	160	190	440
250	150	180	430
300	145	170	420
350	140	165	415

Metric units

Temperature	Proof strength		Tensile strength
	$R_{p0.2}$	$R_{p1.0}$	R_m
°C	MPa	MPa	MPa
	min.	min.	min.
400	135	160	410

Imperial units

Temperature	Proof strength		Tensile strength
	$R_{p0.2}$	$R_{p1.0}$	R_m
°F	ksi	ksi	ksi
	min.	min.	min.
200	36.4	30.8	68.5
400	23.1	27.4	63.7
600	20.8	24.4	60.7
700	20.0	23.6	59.9

PHYSICAL PROPERTIES

Density: 7.9 g/cm^3, 0.29 lb/in^3

Thermal conductivity

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h °F
20	13	68	7.5
100	15	200	8.5
200	17	400	10
300	19	600	11.5
400	21	800	12.5
500	23	1000	13.5
600	25	1200	14.5
700	26	1300	15

Specific heat capacity

Temperature, °C	J/kg °C	Temperature, °F	Btu/lb °F
20	470	68	0.11
100	495	200	0.12
200	530	400	0.13
300	555	600	0.13
400	580	800	0.14
500	600	1000	0.15
600	615	1200	0.15
700	630	1300	0.15

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Thermal expansion[1)]

Temperature, °C	Per °C	Temperature, °F	Per °F
30-100	15.5	86-200	8.5
30-200	16.5	86-400	9
30-300	17	86-600	9.5
30-400	17	86-800	9.5
30-500	17.5	86-1000	9.5
30-600	17.5	86-1200	10
30-700	18	86-1400	10

1) Mean values in temperature ranges ($x10^{-6}$)

Resistivity

Temperature, °C	µΩm	Temperature, °F	µΩin.
20	0.84	68	33.1
100	0.90	200	35.2
200	0.98	400	35.6
300	1.07	600	42.3
400	1.10	800	43.7
500	1.14	1000	45.5
600	1.18	1200	46.8
700	1.20	1400	47.7
800	1.22	1600	48.3
900	1.23	1800	48.7
1000	1.24	-	-

Modulus of elasticity[1)]

Temperature, °C	MPa	Temperature, °F	ksi
20	195	68	28.3
100	190	200	27.6
200	182	400	26.4
300	174	600	25.1
400	166	800	23.8
500	158	1000	22.5

1) ($x10^{3}$)

CORROSION RESISTANCE

General corrosion

Sandvik 2RE10 was developed to combat corrosion problems in nitric acid service. Thanks to its high chromium and low impurity contents it has considerably better resistance to nitric acid than steels of type ASTM 304L, as illustrated by the isocorrosion diagram, figure 1. In such applications Sandvik 2RE10 is far superior to ASTM 304L, ASTM 321 and ASTM 329. The corrosion rates of these grades in 65% nitric acid (Huey test) are compared in figure 2.

Sandvik 3R12 is the Sandvik version of ASTM 304L. Results are presented from tests of solution annealed

material (the delivery condition) and also material in a sensitized (650°C (1202°F) for 1 h condition. ASTM 329 was sensitized at 650°C (1202°F) for only 5 min.

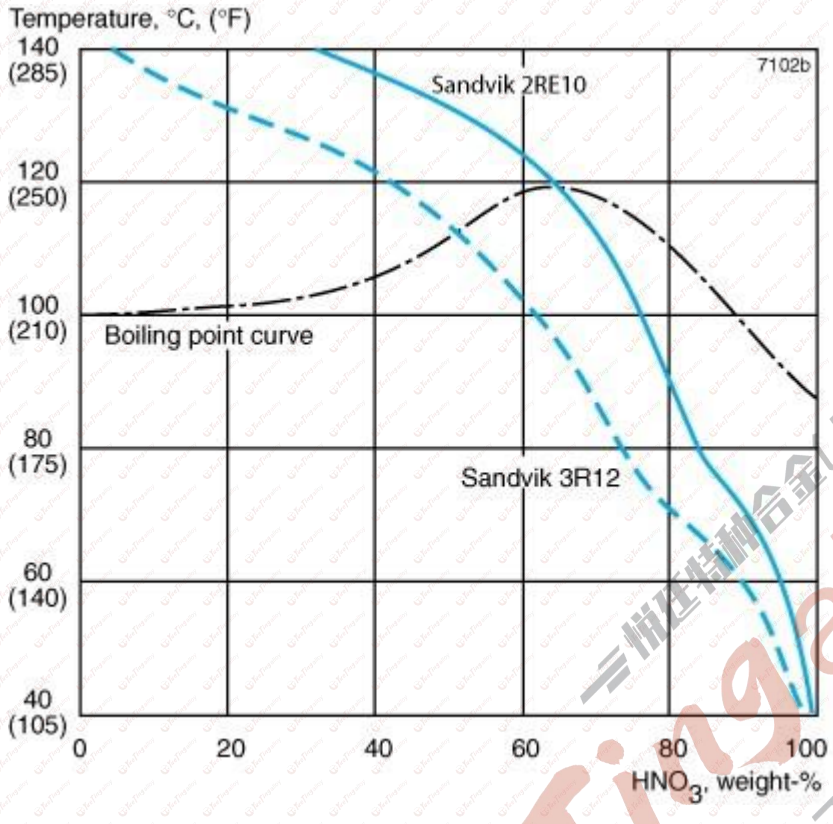

Figure 1. Isocorrosion diagram for Sandvik 2RE10 and 3R12 (ASTM 304L) in a naturally aerated, stagnant solution of nitric acid. The curves represent a corrosion rate of 0.1 mm/year (4 mpy).

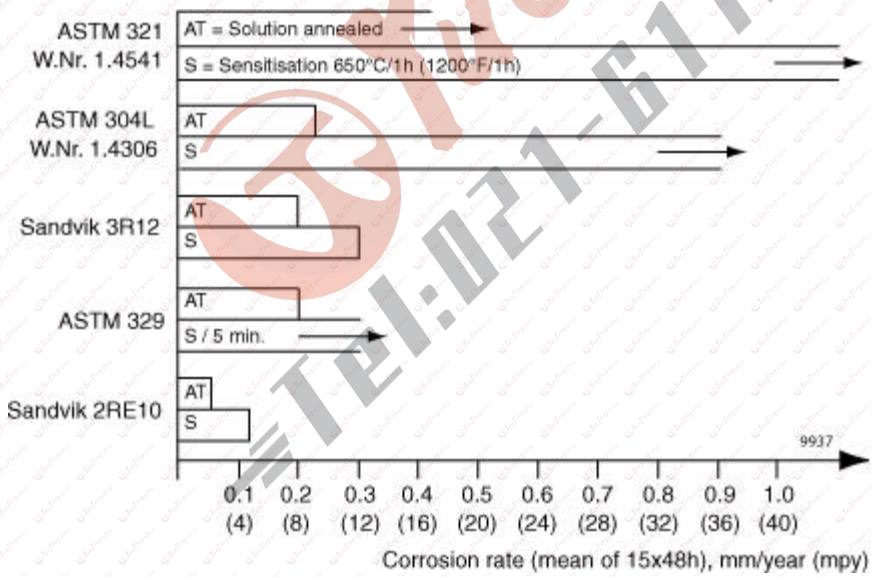

Figure 2. Huey test results for different stainless steels (average values).
 Arrows denote accelerated attack for each period, which indicates material will not perform satisfactorily in service.

Stress corrosion cracking (SCC)

The higher nickel content makes Sandvik 2RE10 slightly more resistant to stress corrosion cracking (SCC) than

conventional austenitic stainless steels, such as ASTM 304L.

Intergranular corrosion

Sandvik 2RE10 is highly resistant to intergranular corrosion even after long-term sensitization. Figure 3 shows the results of Huey testing (boiling in 65% nitric acid for 5x48 h) sensitized specimens of Sandvik 2RE10 and a steel of type ASTM 304L. The low tendency for sensitization is an advantage in complicated welding operations.

In delivery testing, by means of the Huey test, the guaranteed maximum corrosion rate for Sandvik 2RE10 is 0.12 mm/year (5 mpy) in the solution annealed condition, and 0.20 mm/year (8 mpy) after sensitization at 675°C (1250°F). Even lower values can be guaranteed by agreement in certain cases. Figure 3 demonstrates that sensitization does not increase the corrosion rate greatly in Huey testing, whereas the corrosion rate for ASTM 304L increases significantly.

Pitting corrosion

Sandvik 2RE10 has considerably higher pitting corrosion resistance than ASTM 304L and is also superior to ASTM 329, as illustrated by figure 4.

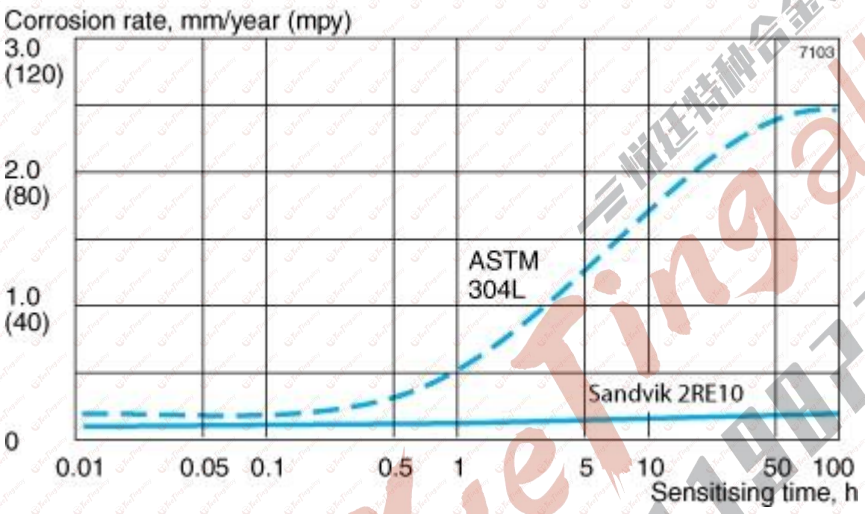

Figure 3. Corrosion curves for Sandvik 2RE10 and AISI 304L obtained from Huey testing after sensitization at 675°C (1250°F).

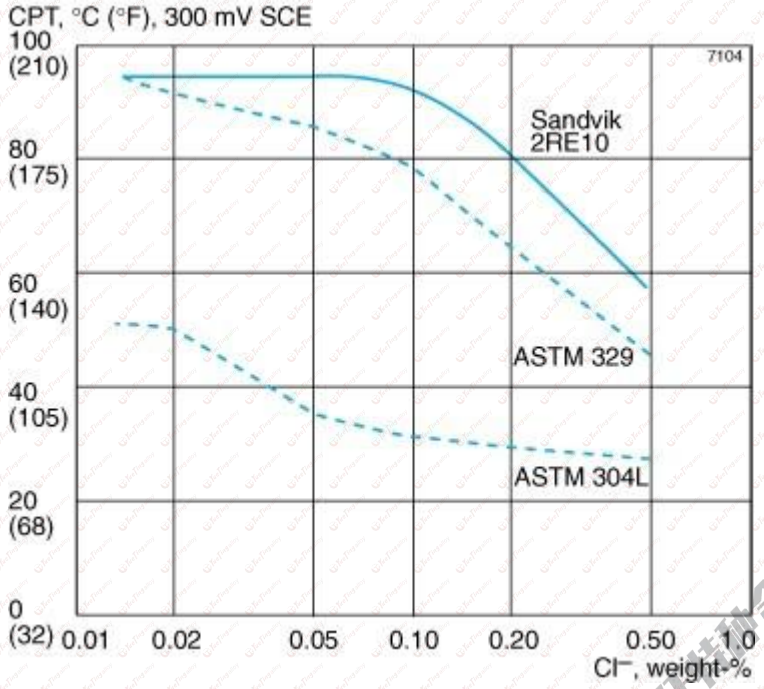

Figure 4. Critical pitting temperature (CPT) for Sandvik 2RE10, ASTM 304L and ASTM 329 in neutral chloride solutions (potentiostatic determination at
 +300 mV SCE).

HEAT TREATMENT

Tubes are delivered in the heat treated condition. If another heat treatment is needed, due to further processing, the following is recommended.

Stress relieving

850–950°C (1560–1740°F), 10–15 minutes, rapid cooling in air. Alternatively 1000–1050°C (1830–1920°F), about 1 minute, rapid cooling in air.

Solution annealing

1000–1100°C (1830–2010°F), 5–20 minutes, rapid cooling in air or water.

WELDING

The weldability of Sandvik 2RE10 is good. Suitable methods of fusion welding are manual metal-arc welding (MMA/SMAW) and gas-shielded arc welding, with the TIG/GTAW method as first choice.

In common with all fully austenitic stainless steels, Sandvik 2RE10 has low thermal conductivity and high thermal expansion. Welding plans should therefore be carefully selected in advance, so that distortions of the welded joint are minimized. If residual stresses are a concern, solution annealing can be performed after welding.

For Sandvik 2RE10, heat-input of <1.0 kJ/mm and interpass temperature of <100°C (210°F) are recommended. A string bead welding technique should be used.

Recommended filler metals

TIG/GTAW or MIG/GMAW welding

25.20.L (e.g. Exaton 25.20.L)

ISO 14343 S 25 22 2 N L (e.g. Exaton 25.22.2.LMn)

MMA/SMAW welding

ISO 3581 E 25 22 2 N L B (e.g. Exaton 25.22.2.LMnB)

ISO 14343 S 25 22 2 N L wire or strip electrodes are recommended for overlay welding of tube sheets and high-pressure vessels in cases where corrosion resistance, equal to that of Sandvik 2RE10, is required.

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BENDING

The excellent formability of Sandvik 2RE10 permits cold bending to very small bending radii. Cold working does not impair resistance to general and intergranular corrosion. Annealing is not normally necessary after cold bending. If, however, tubes have been cold worked and are to be used under conditions where stress corrosion cracking (SCC) is liable to occur, stress relieving is recommended. See under 'Heat treatment'.

APPLICATIONS

Sandvik 2RE10 is very suitable for heat exchanger tube and pipe in processes that treat nitric acid, for example, the manufacture of nitric acid, acrylic fibres, ammonium nitrate and the reprocessing of nuclear reactor fuel. Extensive practical experience in such applications has confirmed the superiority of Sandvik 2RE10 over standard steels such as ASTM 304L and ASTM 329.

Tail gas preheaters

The main reason for highly corrosive conditions in tail gas preheaters is that droplets of nitric acid are entrained in the tail gas from the absorption tower. When this gas enters the heater, the droplets settle on the hot tube wall and start boiling. The temperature of the heating medium, usually hot process gas or steam, can be very high. In this type of condition, ASTM 304L tends to have a short service life. Tubes and tube sheets manufactured in Sandvik 2RE10 are recommended for a long service life

Cooler/condensers

In cooler/condensers, corrosion is normally encountered at the inlet end, where the first condensate is formed. If reboiling of the first condensate occurs, the corrosive conditions become very severe, leading to the kind of attack illustrated in figure 5. This typical corrosion problem can be detected easily. By upgrading to Sandvik 2RE10 the service life will be substantially longer than, for example, ASTM 304L.

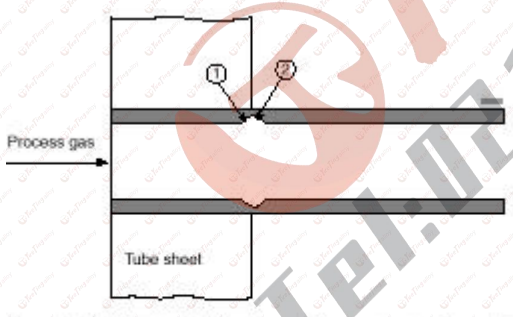

Figure 5. Illustration of hot dew point corrosion in nitric acid cooler/condensers.
1 = first condensate formed – 120–130°C (250–270°F).
2 =Reboiling – corrosion increases with increasing gas inlet temperature

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