

# 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 topitting
- 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) %

Strate.	С	Stelling S	Jedin 3	Si	Straffing of	eri Steatin	S. Feelman	Skaline.	Mn	Staff B	Stall and	Steffe 3	S	Stall.	Challen and	Staffer and	Cr	Staff.	Ni 🤲	STraffer.	Мо	Stalin Sta
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## **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 Sandvik 2RE69)

## **MECHANICAL PROPERTIES**

# Metric units, at 20°C

STRAT!	Proof strength	Station Station Station Station	Tensile strength	Elong. Hardness
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Jife Ti	MPa	MPa	MPa MPa	% Vickers
(Jifrel)		State State State State		approx.
STATE	≥205	≥210	≥500-670	≥35∘) 155

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

#### Imperial units, at 68°F

Proof stren	gth	Tensile strength	Elong.	Hardness
Rp0.2a)	Rp1.0a)	Rm	A2"	The state of the state of the state of the state of
ksi	ksi	ksi	%	Vickers
	The state of the s			approx.
≥30	≥31	≥73-98	≥35∘)	155

## 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

Temperatur	e Proof strength			Tensile	strength	Program.						
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50	195	225	res <sup>pert</sup> Street	485	Tree Street	Sterio Indiana	Str.	Gleen.	STATE OF THE PARTY	Sterior	Str.	3
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350	140	165	and the first	415	- Kelingher - Kelingher	Kellingson	- Katuani	Testino"	of Tenting!	The fire	For Teatings	

a) Rp0.2 and Rp1.0 correspond to 0.2% offset yield strength respectively. b) Based on L0 =  $5.65\sqrt{S0}$ , where L0 is the original gauge length and S0 the original cross-section area.

c) EN 10216-5 with min 45% can be fulfilled

# Metric units

Temperature	Proofstren	gth	Tensile strength	
ate and and are are	Rp0.2	Rp1.0	Rm	ger Stein Stein Stein Stein Stein Stein Stein
°C ,	MPa	MPa	MPa	the the state of t
The state of the s	min,	min.	min.	The the things the the things the the things the the things the th
400	135	160	410	The hand the

# Imperial units

Temperature	Proof strength		Tensile strength
	Rp0.2	Rp1.0	Rm
Form State of the	ksi ma	ksi	ksi
the state of the s	min.s.	min.	min
200	36.4	30.8	68.5
400 300 3000 3000 3000 3000 3000 3000	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/cm3, 0.29 lb/in3

# Thermal conductivity

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h°F
20 m gain gain gain gain gain gain gain gain	13	68	7.5
100° 30° 30° 30° 30° 30° 30° 30° 30° 30°	15	200	8.5 pm 3 pm
200 / / / / /	17	400	John 10 profession graphers graphers graphers graphers
300 300 300 300 300 300 300 300 300 300	19	600	34 11,5 34 34 34 34 34 34 34 34
400	21	800	3 <sup>6</sup> 12.5 3 <sup>6</sup> 3 <sup>6</sup> 3 <sup>6</sup> 3 <sup>6</sup> 3 <sup>6</sup>
500	23	1000	3 <sup>1</sup> 13.5 3 <sup>1</sup> 3 <sup>1</sup> 3 <sup>1</sup> 3 <sup>1</sup>
600	25	1200	14.5
700	26	1300	15

# Specific heat capacity

Temperature, °C	J/kg ℃	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/	/ J 0.15
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700 300 3000 3000 3000 3000 30	630	1300 8 8 8 8 8 8	o.15 of state of

#### Thermal expansion1)

Temperature, °C	Per °C	Temperature, ℉	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		86-1200	10
30-700	34 Martin 34 Mar	86-1400	10 , , ,

<sup>1)</sup> Mean values in temperature ranges (x10-6)

### Resistivity

Temperature, °C	μΩm	Temperature, °F	μΩin.
20 / / / / /	0.84	68	33.1
100 get get get get get	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		Attended to the state of the st

# Modulus of elasticity1)

Temperature, °C	MPa	Tempe	erat	ure,	°F	eri Sterfrasë	ol Skeings	er Stattana	or Status	or Station	. Stark	si	or Status	of Straffinguest St
20 / / /	195	68	Straffing of	or Street	of tellor	Staling!	Strafna'	Skellus .	Sheffing	States	of telling.	Stellas .	an Skelings	28.3
100	190	200	3 tra franci	Skefter	States	Skeling	3kafna'	Shafras	3 he from	Skeling	States	Skalina	Skaling!	27.6
200	182	400	Straffen.	Street too	Steller	The last	The Tree	The Ind	Shellen.	of Steeling.	Steller	Skelm'	Skelles.	26.4
300	174	600	Stelling.	STeether .	Station	Green and a	3 Keiling	Great me	Steller.	Station	Steller	Stales .	Skeling	25.1
400	166	800	Stellar.	Steel and	Status.	Steilmer of see	Stales.	Stellar.	Stellar.	STATE OF	Status.	Steiner	Stellar.	23.8
500	158	1000	Steller.	Steller	Steller A	Steller	Steller.	Shelm	Stratus	STAR STAR	Steller.	Sterior .	Skelen Stelen	22.5

<sup>1) (</sup>x10<sub>3</sub>)

# **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.

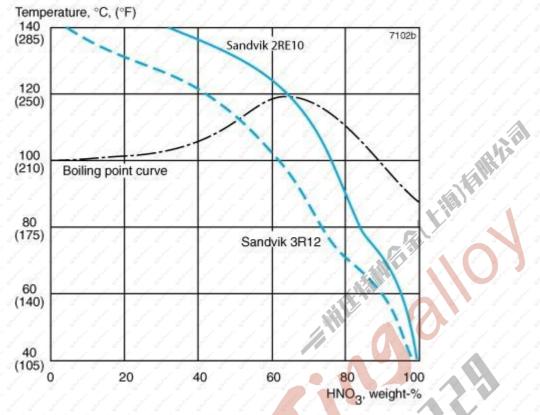
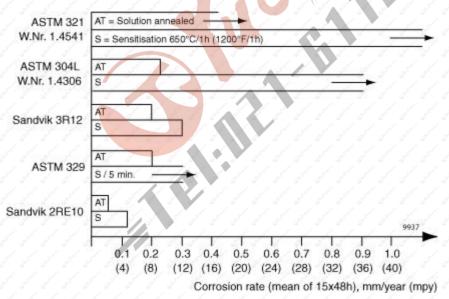


Figure 1. Isocorrosion diagram for Sandvik 2RE10 and 3R12 (ASTM 304L) in a naturally aerated, stagnant solution of nitric acid. The curves represent a corrosion rate of 0.1 mm/year (4 mpy).



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.

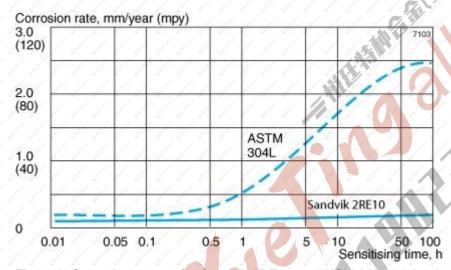


Figure 3. Corrosion curves for Sandvik 2RE10 and AISI 304L obtained from Huey testing after sensitization at 675°C (1250°F).

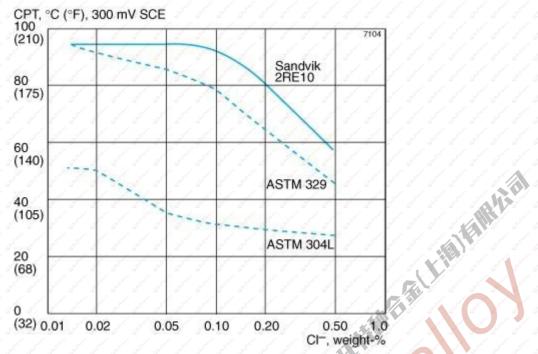


Figure 4. Critical pitting temperature (CPT) for Sandvik 2RE10, ASTM 304L and ASTM 329 in neutral chloride solutions (potentiostatic determination at <a href="https://example.com/scale-ref]/br/s-4300 mV SCE).

#### 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.

#### **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.

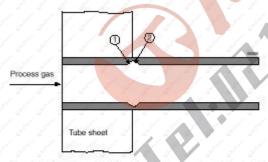


Figure 5. Illustration of hot dew point corrosion in nitric acid cooler/condensors.

- 1 = first condensate formed 120 130°C (250-270°F).
- 2 =Reboiling corrosion increases with increasing gas inlet temperrature.

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.

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