SANDVIK 3R60™
TUBE AND PIPE, SEAMLESS

DATASHEET

Sandvik 3R60™ is an austenitic chromium-nickel steel with minimum 2.5% molybdenum and a low carbon content.

Sandvik 3R60™ is also available in a variant for the urea industry, Sandvik 3R60™ Urea Grade.

STANDARDS

- ASTM: TP316L, TP316
- UNS: S31603, S31600
- EN Number: 1.4435, 1.4436
- EN Name: X 2 CrNiMo 18-14-3, X 3 CrNiMo 17-13-3
- W.Nr.: 1.4435, 1.4436
- DIN: X 2 CrNiMo 18 14 3, X 5 CrNiMo 17 13 3
- SS: 2353, 2343
- AFNOR: Z 2 CND 17.13
- BS: 316S13
- JIS: SUS316LTP, 316TP, SUS316LTB, 316TB

Product standards

- ASTM A213, A269 and A312
- JIS G3459
- JIS G3463
- EN 10216-5
- BS 3605, 3606
- DIN 17456, 17458
- NFA 49-117*, 49-217*
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* Mo content 2.00-2.40%

CHEMICAL COMPOSITION (NOMINAL) %

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo
≤0.030	0.4	1.7	≤0.040	≤0.015	17.5	13	2.6

FORMS OF SUPPLY

Seamless tube and pipe- Finishes and dimensions

Seamless tube and pipe in Sandvik 3R60™ is supplied in dimensions up to 260 mm outside diameter in the solution annealed and white-pickled condition or solution annealed in a bright-annealing process.

Other forms of supply

We can also deliver other product forms from stock in a grade corresponding to ASTM 316L mainly:

- Welded tube and pipe
- Fittings and flanges
- Bar steel
- Filler metal for welding

Sizes in stock

Seamless tube is stocked in a wide range of sizes according to ISO. Heat exchanger and instrumentation tubes are also stocked in BWG-and SWG-sizes. Hollow bar is stocked in a large number of sizes as SANMAC 316L (see data sheet S-1840-ENG). Details of our manufacturing programme are given in catalogue S-110-ENG.

MECHANICAL PROPERTIES

For tube and pipe with wall thickness greater than 10 mm (0.4 in.) the proof strength may fall short of the stated values by about 10 MPa (1.4 ksi).

At 20°C

Metric units

Proof strength		Tensile strength	Elong.		Hardness
$R_{p0.2}$[a]	$R_{p1.0}$[a]	R_m	A[b]	A2"	
MPa	MPa	MPa	%	%	HRB
≥220	≥250	515-690	≥40[c]	≥35	≤80

At 68°F

Imperial units

Proof strength		Tensile strength	Elong.		Hardness
$R_{p0.2}$[a]	$R_{p1.0}$[a]	R_m	A[b]	A2"	
ksi	ksi	ksi	%	%	HRB
≥32	≥36	75-100	≥40[c]	≥35	≤80

1 MPa = 1 N/mm2

a) $R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset and 1.0% 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) NFA 49-117, 49-217 with min 45% can be fulfilled on request.

Impact strength

Due to its austenitic microstructure, Sandvik 3R60 has very good impact strength both at room temperature and at cryogenic temperatures.

Tests have demonstrated that the steel fulfils the 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	
	$R_{p0.2}$	$R_{p1.0}$

°C	MPa	MPa
	min.	min.
50	200	230
100	180	215
150	165	195
200	150	180
250	140	170
300	135	160
350	130	155
400	125	150
450	120	145
500	120	145
550	115	140
600	110	135

Imperial units

Temperature	Proof strength	
	$R_{p0.2}$	$R_{p1.0}$
°F	ksi	ksi
	min.	min.
200	26	31
400	21	26
600	19	23
800	18	21
1000	17	20

Creep-rupture strength (ISO-values)

Temperature		10 000 h		100 000 h	
°C	°F	MPa	ksi	MPa	ksi
		approx.	approx.	approx.	approx.
550	1020	255	37.0	177	25.7
575	1065	214	31.0	137	19.9
600	1110	172	24.9	108	15.7
625	1155	137	19.9	86	12.5
650	1200	108	15.7	64	9.3
675	1245	83	12.0	46	6.7
700	1290	64	9.3	33	4.8
725	1335	49	7.1	25	3.6
750	1380	37	5.4	18	2.6

PHYSICAL PROPERTIES

Density: 8.0 g/cm^3, 0.29 lb/in^3

Thermal conductivity

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h °F
20	14	68	8
100	15	200	8.5
200	17	400	10
300	18	600	10.5
400	20	800	11.5
500	21	1000	12.5
600	23	1100	13

Specific heat capacity

Temperature, °C	J/kg °C	Temperature, °F	Btu/lb °F
20	485	68	0.11
100	500	200	0.12
200	515	400	0.12
300	525	600	0.13
400	540	800	0.13
500	555	1000	0.13
600	575	1100	0.14

Thermal expansion [1)]

Temperature, °C	Per °C	Temperature, °F	Per °F
30-100	16.5	86-200	9.5
30-200	17	86-400	9.5
30-300	17.5	86-600	10
30-400	18	86-800	10
30-500	18	86-1000	10
30-600	18.5	86-1200	10.5
30-700	18.5	86-1400	10.5

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

Modulus of elasticity [1)]

Temperature, °C	MPa	Temperature, °F	ksi
20	200	68	29.0
100	194	200	28.2
200	186	400	26.9
300	179	600	25.8
400	172	800	24.7
500	165	1000	23.5

1) ($x10^3$)

CORROSION RESISTANCE

Sandvik 3R60™ has good resistance in:

- Organic acids at high concentrations and moderate temperatures
- Inorganic acids, e.g. phosphoric and sulfuric acids, at moderate concentrations and temperatures. The steel can also be used in sulfuric acid of concentrations above 90% at low temperature.
- Salt solutions, e.g. sulfates, sulfides and sulfites
- Caustic environments

Stress corrosion cracking

Austenitic steels are susceptible to stress corrosion cracking. This may occur at temperatures above about 60°C (140°F) if the steel is subjected to tensile stresses and at the same time comes into contact with certain solutions, particularly those containing chlorides. Such service conditions should therefore be avoided. Conditions when plants are shut down must also be considered, as the condensates which are then formed can develop conditions that lead to both stress corrosion cracking and pitting.

In applications demanding high resistance to stress corrosion cracking, austenitic-ferritic steels, such as Sandvik SAF 2304® or SAF 2205™ are recommended. See data sheets S-1871-ENG and S-1874-ENG.

Intergranular corrosion

Sandvik 3R60™ has a low carbon content and therefore better resistance to intergranular corrosion than steels of type AISI 316. The TTC-diagram, Figure 1, shows the result of corrosion testing for 24 hours in boiling Strauss solution (12% sulfuric acid, 6% copper sulphate). The resistance to grain boundary attack is much better for AISI 316L than for AISI 316. This is an advantage in complicated welding operations.

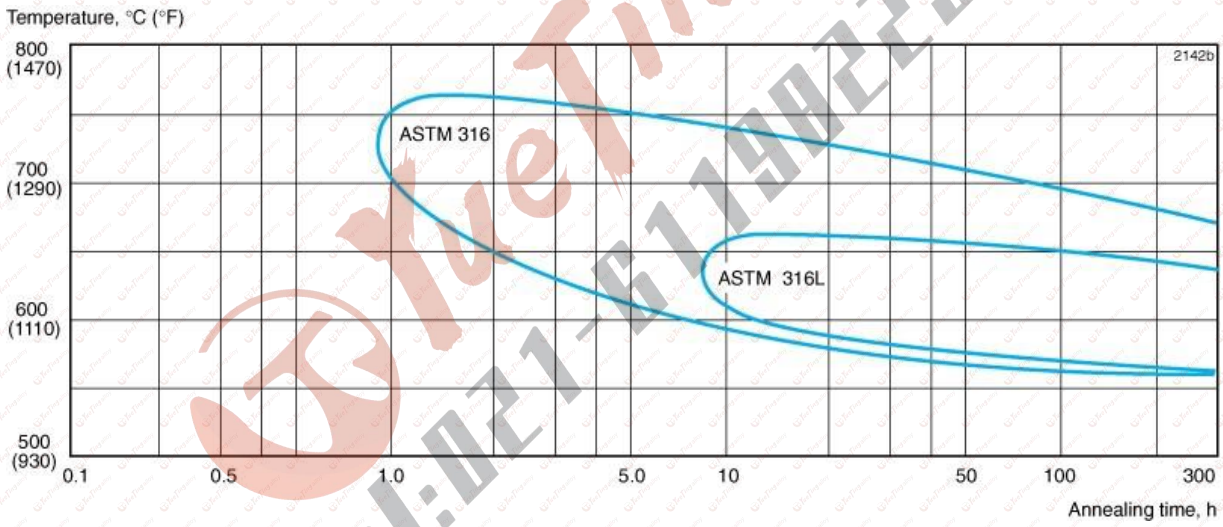

Figure 1. TTC-diagram for Sandvik 3R60 (AISI 316L) and AISI 316.

Pitting and crevice corrosion

Resistance to these types of corrosion improves with increasing molybdenum content. Sandvik 3R60™, containing about 2.6% Mo, has substantially higher resistance to attack than these steels of type AISI 304 and also better resistance than ordinary AISI 316/316L steels with 2.1% Mo.

Gas corrosion

Sandvik 3R60™ can be uses in

- Air up to 850°C (1560°F)
- Steam up to 750°C (1380°F)

Creep behavior should also be taken into account when using the steel in the creep range.

In flue gases containing sulfur, the corrosion resistance is reduced. In such environments the steel can be used at temperatures up to 600-750 °C (1100-1380 °F) depending on service conditions. Factors to consider are whether the atmosphere is oxidizing or reducing, i.e. the oxygen content, and whether impurities such as sodium and vanadium are present.

HEAT TREATMENT

Tubes are delivered in heat treated condition. If additional heat treatment is needed after further processing the following is recommended.

Stress relieving

850-950°C (1560-1740°F), cooling in air

Solution annealing

1000-1100°C (1830-2010°F), followed by rapid cooling in air or water.

WELDING

The weldability of Sandvik 3R60™ is good. Welding must be carried out without preheating and subsequent heat treatment is normally not required. 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.

For Sandvik 3R60™, heat input of <2.0 kJ/mm and interpass temperature of <150°C (300°F) are recommended.

Recommended filler metals

TIG/GTAW or MIG/GMAW welding

ISO 14343 S 19 12 3 L /AWS A5.9 ER316L (e.g. Exaton 19.12.3.L)

MMA/SMAW welding

ISO 3581 E 19 12 3 L R /AWS A5.4 E316L-17 (e.g. Exaton 19.12.3.LR)

ISO 14343 S 19 12 3 L /AWS A5.9 ER316L (e.g. Exaton 19.12.3.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 3R60™, is required.

BENDING

Annealing after cold bending is not normally necessary, but this point must be decided with regard to the degree of bending and the operating conditions. Heat treatment, if any, should take the form of stress relieving or solution annealing, see under Heat treatment.

Hot bending is carried out at 1100-850°C (2010-1560°F) and should be followed by solution annealing.

APPLICATIONS

Sandvik 3R60™ is used for a wide range of industrial applications where steels of type ASTM 304 and 304L have insufficient corrosion resistance. Typical examples are: heat exchangers, condensers, pipelines, cooling and heating coils in the chemical, petrochemical, pulp and paper and food industries.

Datasheet updated 8/26/2019 9:24:05 AM (supersedes all previous editions)