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Sandvik 4C54

(Tube and pipe, seamless)

Sandvik 4C54 is a ferritic, heat resisting, stainless chromium steel, characterized by:

- Extremely good resistance to reducing sulphurous gases
- Very good resistance to oxidation in air
- Good resistance to oil-ash corrosion
- Good resistance to molten copper, lead and tin

This steel can be used at temperatures up to 1100°C (2010°F). However, allowance should be made for low creep strength at the highest temperatures in order to avoid distortion due to the mass of the steel.

STANDARDS

- ASTM 446-1
- UNS S44600
- EN number 1.4749
- W.Nr. 1.4749
- DIN X 18 CrN 28
- SS 2322

Product standards

- ASTM A268
- EN 10297-2
- EN 10095
- SS 14 23 22

CHEMICAL COMPOSITION (NOMINAL) %

C max	Si	Mn	P max	S max	Cr	N
0.20	0.5	0.8	0.030	0.015	26.5	0.2

FORMS OF SUPPLY

Seamless tube and pipe - finishes and dimensions
Seamless tube and pipe in Sandvik 4C54 is supplied in dimensions up to 125 mm outside diameter in the solution annealed and white pickled condition or in the bright annealed condition.

Stock sizes
Sandvik 4C54 is stocked in sizes ranging from outside diameter 3/8" to 3" outside diameter. Additional data concerning sizes and finishes is available on request from your nearest Sandvik office.

MECHANICAL PROPERTIES

At 20°C (68°F)

METRIC UNITS

Proof strength		Tensile strength	Elong.		Hardness Vickers.
$R_{p0.2}$ 1)	$R_{p1.0}$ 1)	R_m	A 2)	$A_{2"}$	
MPa	MPa	MPa	%	%	
min.	min.		min.	min.	approx.
280	320	500-700	20	18	190

IMPERIAL UNITS

Proof strength		Tensile strength	Elong.		Hardness Vickers.
$R_{p0.2}$ 1)	$R_{p1.0}$ 1)	R_m	A 2)	$A_{2"}$	
ksi	ksi	ksi	%	%	
min.	min.		min.	min.	approx.
41	46	73-102	20	18	190

1 MPa = 1 N/mm^2
1) $R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset and 1.0% offset yield strength, respectively.
2) Based on L_0 = 5.65 ÖS_0, where L_0 is the original gauge length and S_0 the original cross-sectional area.

At high temperatures

METRIC UNITS

Temperature	Proof strength		Tensile strength	Creep rupture strength	
°C	$R_{p0.2}$ 1)	$R_{p1.0}$ 1)	R_m	10 000 h	100 000 h
	MPa	MPa	MPa	MPa	MPa
	min.	min.		approx.	approx.
100	235	280	450		
200	215	260	430		
300	200	250	430		
400	185	245	430		
500	175	240	375		
525	165	230	335		
550	150	200	290		
600				38	29
700				10	7
800				4.8	3.3
900				3.4	2.5
1000				1.9	1.6

IMPERIAL UNITS

Temperature	Proof strength		Tensile strength	Creep rupture strength	
°C	$R_{p0.2}$ 1)	$R_{p1.0}$ 1)	R_m	10 000 h	100 000 h
	ksi	ksi	ksi	ksi	ksi
	min.	min.		approx.	approx.
200	34.4	40.9	66.7		
400	31.0	37.7	62.3		
600	28.7	36.1	62.3		
800	26.8	35.5	62.2		
1000	22.9	31.9	46.0		
1100				5.9	4.4
1300				1.4	0.99
1500				0.69	0.47
1800				0.32	0.26

Since Sandvik 4C54 has very large creep rupture elongation, often more than 100%, and little resistance to creep, it is necessary to allow for considerable creep deformation long before rupture occurs. At normal service temperatures, i.e. over 700 °C (1290 °F), even the dead weight of the tubes can cause stresses leading to large deformations.

Careful attention must be given, therefore to the way in which tubes are supported. Sandvik 4C54, in common with other ferritic chromium steels, is less tough than austenitic stainless steels in the as delivered condition. The transition temperature of Sandvik 4C54 is around 100-150 °C (210-300 °F). After a period of operation, toughness at room temperature can decrease further. For this reason, large impact and similar stresses should be avoided during repairs.

The graph in Fig. 1 can be used to determine the temperature above which, design calculations should be based on creep rupture strength rather than proof strength.

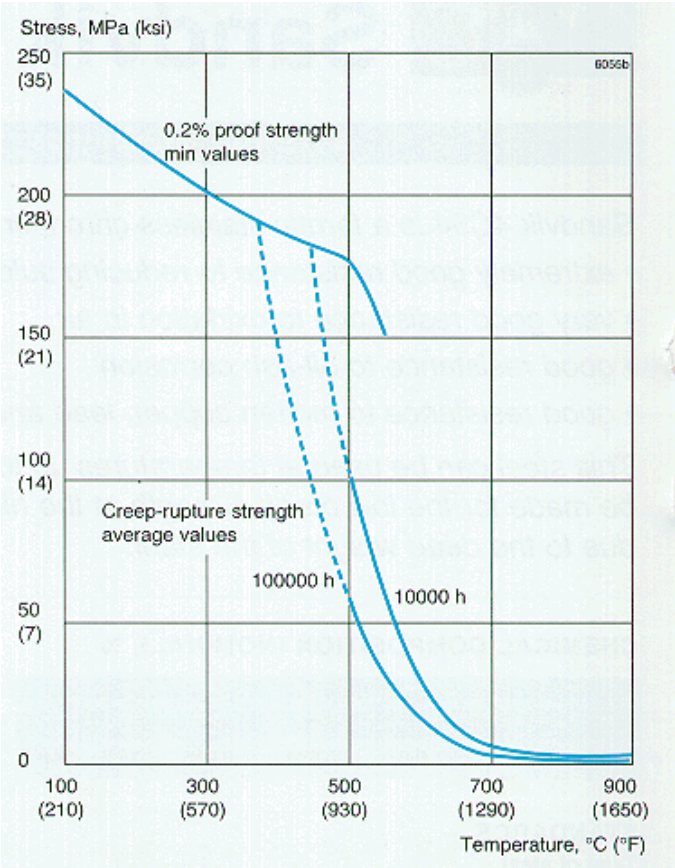

Figure 1. 0.2% proof strength and creep rupture stress at 10 000h and 100 000h.

PHYSICAL PROPERTIES

Density: 7.6 g/cm^3, 0.27 lb/in^3

THERMAL CONDUCTIVITY

Temperature, °C	W/(m °C)	Temperature, °F	Btu/(ft h °F)
20	20	68	11.5
100	21	200	12.5
200	22	400	12.5
300	23	600	13
400	2	800	13.5
500	24	1000	14.5
600	25	1200	14
700	26	1400	14.5
800	27	1600	15.5
900	28	1800	17
1000	30	2000	19
1100	34		

SPECIFIC HEAT CAPACITY

Temperature, °C	J/(kg °C)	Temperature, °F	Btu/(lb °F)
20	475	68	0.11
100	520	200	0.12
200	555	400	0.13
300	595	600	0.14
400	625	800	0.16
500	710	1000	0.18
600	795	1200	0.18
700	720	1400	0.17
800	695	1600	0.16
900	680	1800	0.17
1000	715	2000	0.18
1100	760		

THERMAL EXPANSION [1)]

Temperature, °C	Per °C	Temperature, °F	Per °F
30-100	10	86-200	5.5
30-200	10	86-400	5.5
30-300	10.5	86-600	6
30-400	11	86-800	6
30-500	11	86-1000	6
30-600	11.5	86-1200	6.5
30-700	11.5	86-1400	6.5
30-800	12	86-1600	7
30-900	13	86-1800	7.5
30-1000	13.5		

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

RESISTIVITY

Temperature, °C	μΩm	Temperature, °F	μΩin.
20	0.69	68	27.0
100	0.75	200	29.5
200	0.84	400	33.2
300	0.92	600	36.8
400	1.00	800	40.2
500	1.08	1000	43.3
600	1.14	1200	45.8
700	1.19	1400	47.7
800	1.22	1600	48.9
900	1.24	1800	49.1
1000	1.25		

MODULUS OF ELASTICITY [1)]

Temperature, °C	MPa	Temperature, °F	ksi
20	195	68	28.5
200	190	400	27.5
400	180	800	25.5
600	145	1200	20.5
800	125	1400	18.5
1000	120	1800	17.5

1) x 10^3

CORROSION RESISTANCE

Air
Sandvik 4C54 is highly resistant to oxidation, both at constant and at cyclically varying temperatures (see Fig. 2). The service temperature in air should not exceed about 1100°C (2010°F).

Isothermal oxidation at 1100°C (2010°F) for 1000h results in a weight loss of about 0.25 g/m^2 h after removal of the oxide layer.

Cyclic oxidation at 1100°C (2010°F) for 5 x 24 h, with cooling to room temperature every 24 hours, gives a weight loss of less than 1.5 g /m^2 h after removal of the oxide layer.

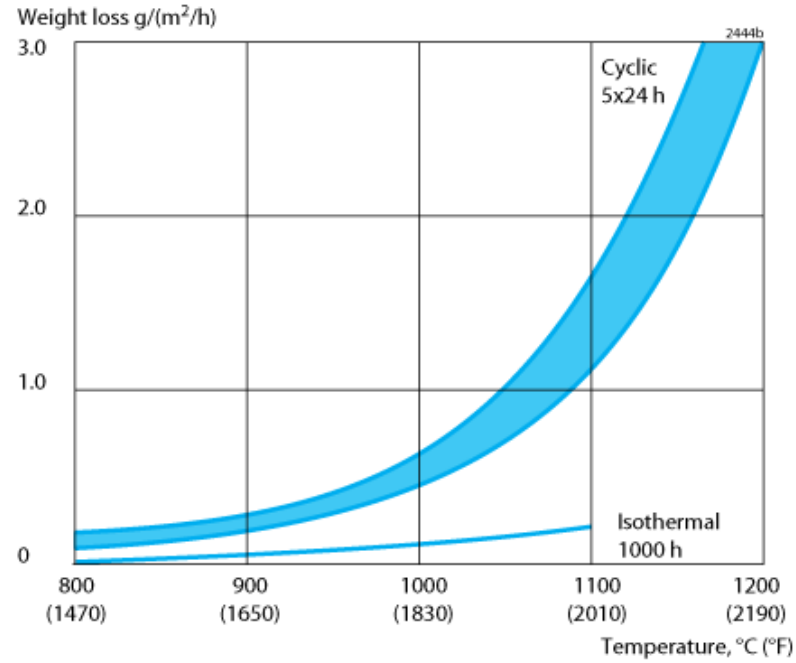

Figure 2. Oxidation in air resulting from cyclic exposure for 5 x 24 h with cooling to room temperature every 24 hours and isothermal exposure for 1000 h (1 g/m²h) = approx. 1 mm/year.

Hot corrosion / sulphidation

Owing to its high chromium content and the absence of nickel, Sandvik 4C54 has very good resistance in sulphidizing gases and salts. The steel has relatively good resistance to slags containing vanadium pentoxide and sodium sulphate, for example, which are extremely aggressive at temperatures above 600°C (1110°F). The results of a corrosion test in combustion gases from heavy oil show that Sandvik 4C54 possesses better resistance than 50Cr50Ni alloy and austenitic high temperature steels in such environments (see Fig. 3).

In other sulphurous flue gases, especially where the oxygen pressure is low (reducing atmosphere), Sandvik 4C54 possesses considerably better resistance than the austenitic steels. In laboratory tests simulating combustion in a fluidized bed, where the oxygen pressure varies between low and high, Sandvik 4C54 exhibits very good resistance. See Fig. 4.

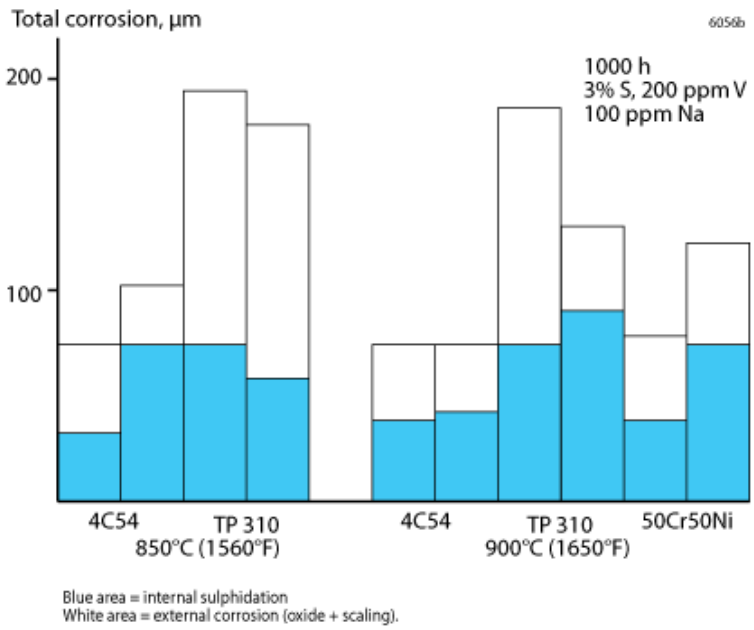

Fig. 3. Corrosion test in combustion gases from heavy oil for Sandvik 4C54, TP 310 and a 50Cr50Ni alloy. Two tests (bars) per grade.

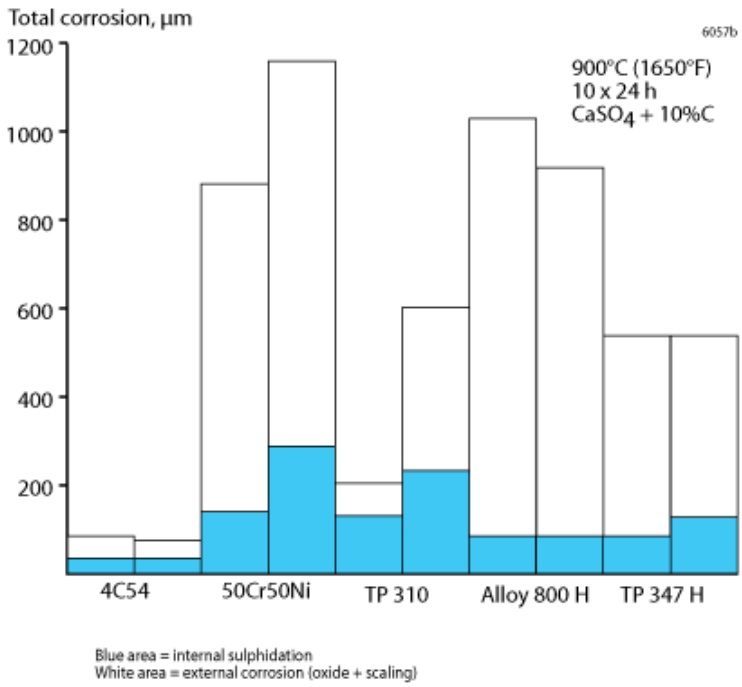

Figure. 4. Results from simulated fluidzed bed combustion. Two tests (bars) per grade.

Nitrogen pick up
Nitrogen pick up can occur in gas mixtures with low oxygen concentrations and high concentrations of nitrogen, cracked ammonia or mixtures of nitrogen and hydrogen. It leads to embrittlement and reduced oxidation resistance. Sandvik 4C54 is more sensitive than austenitic steels to environments where nitrogen pick up can occur.

Carburizing atmosphere
When a material comes into contact with hot gases containing hydrocarbons and carbon monoxide, carburization can occur. The extent of carburization depends on the composition of the material and of the gas.

The relatively high chromium content of Sandvik 4C54 promotes the formation of a protective oxide layer on the surface of the material, providing some protection against carburization.

However, because Sandvik 4C54 is ferritic, carburization occurs quickly, if the oxide layer cracks or, if the oxygen content is too low to form a protective oxide layer. For this reason, the material does not possess the same resistance as the austenitic steels, for example, Sandvik 253MA or Sanicro 31HT.

Metal and salt baths
The ferritic structure of Sandvik 4C54 gives it good resistance in baths of molten copper. It also possesses good resistance in other molten metals, such as lead, tin, bearing metals, brass and magnesium. In these metals, it is a good idea to use replaceable sleeves of ceramic material or graphite, since corrosion is heaviest at the surface of the metal bath. In salt baths for heat treatment etc., such as cyanide and neutral salt baths, austenitic alloys with a high nickel content should be selected instead (e.g. Sanicro 31HT).

HEAT TREATMENT

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

Stress relieving
800-850°C (1470-1560°F), 15-30 minutes, rapid cooling in air.

Annealing
800-900°C (1470-1650°F), 30-60 minutes, rapid cooling in air.

STRUCTURAL STABILITY

Temperatures of about 400-550°C (750-1020°F) should be avoided for even short periods of time, whether the steel is in service or merely being held at that temperature, since severe embrittlement, known as 475 °C (887°F). embrittlement, can occur. This is noticeable after the tubes have cooled to room temperature. However, the steel can be restored to its original condition by short term heating at a temperature above 600°C (1110°F). Embrittlement can also occur as a result of sigma phase formation after prolonged service at 550-750°C (1020-1380°F).

WELDING

Suitable fusion welding methods are manual metal-arc welding with covered electrodes or gas shielded arc welding, preferably using the TIG and MIG methods. The welding zone should be preheated to 200-300°C (390-570°F). No post-weld heat treatment is necessary, where Sandvik 4C54 is used in structures that operate for prolonged periods at high temperature. For other structures and where heat treatment is considered appropriate, due to design considerations, annealing as described above is recommended.

For gas shielded arc welding(MIG or TIG), Sandvik 29.9, Sandvik 25.20.C or Sanicro 72HP can be used. For manual metal-arc welding (MMA), the corresponding electrodes are Sandvik 29.9.R, Sandvik 25.20.B and Sanicro 71.

In severe environments of reducing sulphurous atmosphere, where nickel containing filler metals have an inferior corrosion resistance, Sandvik 4C54 (not a standard filler metal grade) is suggested. In these circumstances, please contact us for advice/recommendations.

BENDING

Due to their limitations in ductility at low temperatures, caution must be taken when performing bending of ferritic steels, such as Sandvik 4C54.

Hot worked tubes should preferably be hot bent, but they can be bent cold, depending on bending radius, diameter, bending equipment, etc. Please contact Sandvik for more information.
Hot bending is carried out at 1000-800°C (1830-1470°F) and should be followed by annealing, see the Heat treatment section, for details.
For cold bending, cold worked tubes are recommended. Annealing is usually not necessary after cold bending.

When straightening or bending tubes that have already been in service, we recommend the following:

Tubes that have been in service at 400-550°C (750-1020°F):
Heat for a brief period to a temperature above 600°C (1110°F), cool in air, followed by preheating to 200-400°C (390-750°F).

Tubes that have been in service above 550°C (1020°F):
Preheat to 200-400°C (390-750°F).

APPLICATIONS

Sandvik 4C54 should be chosen mainly for service at temperatures above 700°C (1290°F) where the excellent resistance of the material to slag corrosion and sulphidizing gases is particularly advantageous.

Typical applications for Sandvik 4C54 are:

- Recuperators in the metallurgical and glass industries
- Thermocouple protection tubes
- Sootblower tubes
- Injection nozzles
- Muffle tubes in continous wire annealing furnaces

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.