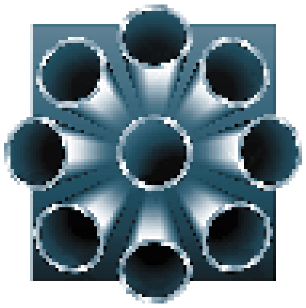

Seamless tube

Sandvik 4C54

SANDVIK Steel

S-1735-ENG November 1998 • Cancels all previous editions

Sandvik 4C54 is a ferritic stainless chromium steel, characterised 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 the low creep strength at the highest temperatures in order to avoid distortion due to the dead weight of the steel.

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

STANDARDS

Type of steel

- ASTM TP446-1
- AISI 446-1
- UNS S44600
- EN 1.4749[a)]
- W.-Nr. 1.4749
- SS 2322
- DIN X 18 CrN 28

Product standards

- ASTM A268
- EN 10095[a)]
- SS 14 23 22

FORMS OF SUPPLY, FINISHES AND DIMENSIONS

Seamless tube and pipe in 4C54 is supplied in dimensions up to 125 mm outside diameter in the annealed condition, but are also available white-pickled condition after annealing.

SIZES IN STOCK

4C54 is stocked in a number of sizes. Detailed information on size range and tolerances is provided in tube catalogue S-110-ENG.

MECHANICAL PROPERTIES

At 20°C (68°F)

Metric units

Proof strength $R_{p0.2}$ [b)] MPa min.	$R_{p1.0}$ [b)] MPa min.	Tensile strength R_m MPa	Elong. A [c)] % min.	$A_{2"}$ % min.	Hardness Vickers approx.
275	320	500–700	20	18	190

Imperial units

Proof strength $R_{p0.2}$ [b)] ksi min.	$R_{p1.0}$ [b)] ksi min.	Tensile strength R_m ksi	Elong. A [c)] % min.	$A_{2"}$ % min.	Hardness Vickers approx.
40	46	73-102	20	18	190

1 MPa = 1 N/mm²

a) *Heat resisting steels and nickel alloys. Technical delivery conditions for sheet/plate, strip, bars, rods and sections.*

b) *$R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset and 1.0% offset yield strength, respectively.*

c) *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 °C	Proof strength $R_{p0.2}$ MPa min.	$R_{p1.0}$ MPa min.	Tensile strength R_m MPa min.	Creep-rupture strength 10 000 h MPa approx.	100 000 h MPa approx.
100	235	280	450		
200	215	260	430		
300	200	250	430		
400	185	245	430		
500	175	240	375	100	55
525	165	230	335	77	43
550	150	200	290	59	33
575				46	26
600				35	20
625				25	14
650				18	10
675				13	7.0
700				9.5	5.0
725				7.6	4.0
750				6.2	3.3
775				5.0	2.7
800				4.3	2.3
825				3.4	1.9
850				2.8	1.5
875				2.3	1.2
900				1.9	1.0

Imperial units

Temperature °F	Proof strength $R_{p0.2}$ ksi min.	$R_{p1.0}$ ksi min.	Tensile strength R_m ksi min.	Creep-rupture strength 10 000 h ksi approx.	100 000 h ksi 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	9.7	5.5
1050				7.3	4.1
1100				5.5	3.0
1150				3.9	2.2
1200				2.6	1.5
1250				1.9	1.01
1300				1.35	0.71
1350				1.04	0.58
1400				0.83	0.46
1450				0.67	0.38
1500				0.54	0.33
1550				0.43	0.28
1600				0.36	0.20
1650				0.28	0.16
1700				0.26	0.14

Since 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 therefore be given to the way in which the tubes are supported. 4C54, in common with other ferritic chromium steels, are less tough than austenitic stainless steels in the as-delivered condition. The transition temperature of 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 stresses and the like should be avoided during repairs. The graph in figure 1 can be used to determine the temperature above which design calculations should be based on creep-rupture strength rather than proof strength.

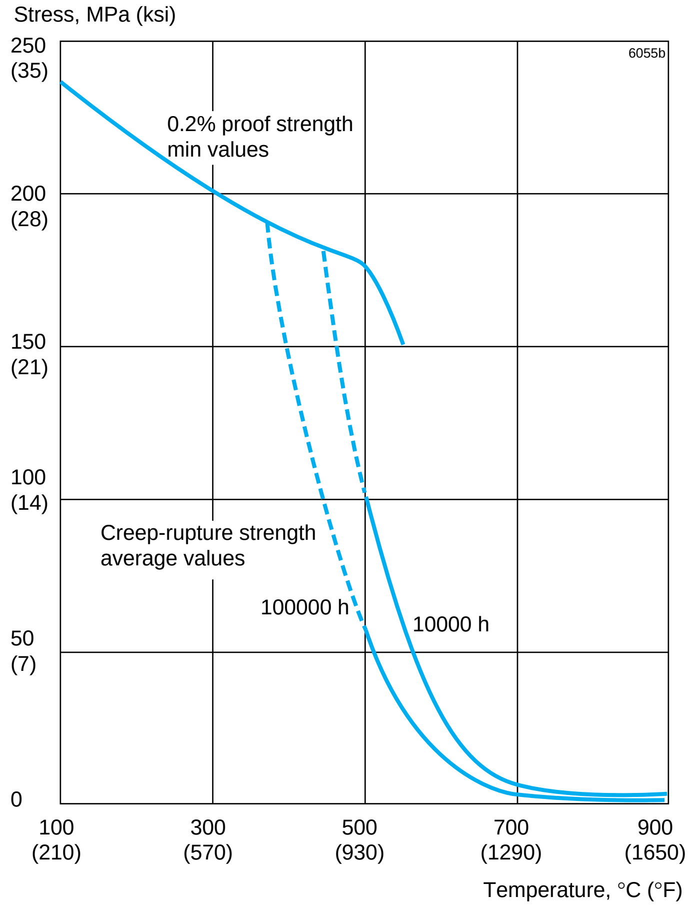

Figure 1 0.2% proof strength and creep-rupture stress at10 000h and 100 000h.

PHYSICAL PROPERTIES

Density, 7.6 g/cm³, 0.27 lb/in³

Thermal conductivity

Temperature °C	W/m °C	Temperature °F	Btu/ft h °F
20	17	68	10
100	21	200	12
200	22.5	400	13
300	23	600	13.5
400	23.5	800	13.5
500	24	1000	14
600	25	1200	14.5
700	26	1400	15.5
800	27	1600	16 [a)]
900	27.5 [a)]	1800	16 [a)]
1000	28 [a)]		

[a)] *Extrapolated value*

Specific heat capacity

Temperature °C	J/kg °C	Temperature °F	Btu/lb °F
20	460	68	0.11
100	500	200	0.12
200	540	400	0.13
300	560	600	0.13
400	580	800	0.14
500	595	1000	0.14
600	610	1200	0.15
700	630	1400	0.15
800	650	1600	0.16
900	660	1800	0.16 [a]
1000	670 [a]		

[a] *Extrapolated value*

Thermal expansion, mean values in temperature ranges ($x10^{-6}$)

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		

Modulus of elasticity, ($x10^{3}$)

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

CORROSION RESISTANCE

Air

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

Isothermal oxidation at 1100°C (2010°F) for 1000 h 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.

Hot corrosion / sulphidation

Owing to its high chromium content and the absence of nickel, 4C54 has very good resistance in sulphidising gases and salts. The steel has a 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 4C54 possesses better resistance than 50Cr50Ni and austenitic high-temperature steels in such environments (see figure 3).

In other sulphurous flue gases, especially where the oxygen pressure is low (reducing atmosphere), 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, 4C54 exhibits very good resistance (see figure 4).

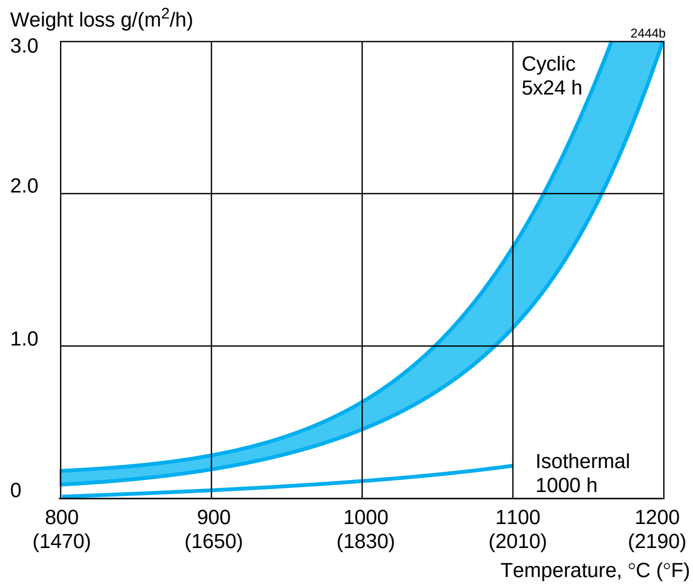

Figure 2 Oxidation in air resulting from cyclic exposure for 5 x 24 h with cooling to room temperature every 24 hours and isothermal exposure for 1000 h (1 g/m^2 h) = approx. 1 mm/year.

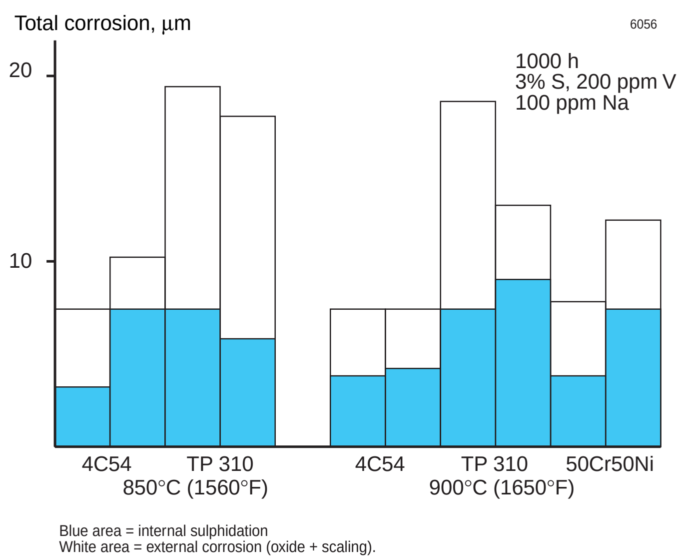

Figure 3 Corrosion test in combustion gases from heavy oil for 4C54, TP 310 and a 50Cr50Ni alloy. Two tests (bars) per grade.

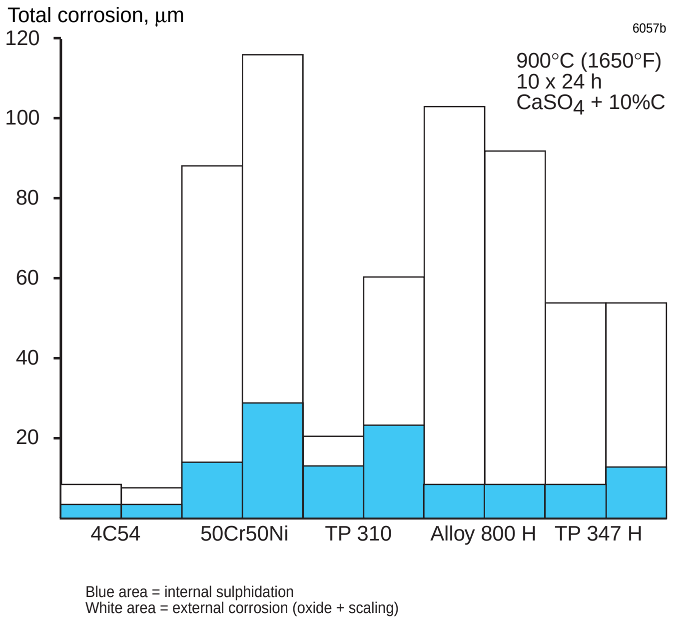

Figure 4 Results from simulated fluidized bed combustion. Two tests (bars) per grade.

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. Nitrogen pick-up leads to embrittlement and reduced oxidation resistance. 4C54 is more sensitive than austenitic steels in environments where nitrogen pick-up can occur.

Carburising atmosphere

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

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

However, because 4C54 is ferritic, carburisation 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 253MA or Sandvik Sanicro 31HT.

Metal and salt baths

The ferritic structure of 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 baths and neutral salt baths, austenitic alloys with a high nickel content should be chosen instead, e.g. Sandvik Sanicro 31HT.

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° embrittlement, can take place. This is noticeable after the tubes have cooled to room temperature. However, the steel can be restored to its original condition by brief 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).

HEAT TREATMENT

The tubes are delivered in heat treated condition. If additional 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.

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 postweld heat treatment is necessary where 4C54 is used in structures that operate for prolonged periods at high temperatures. 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 Sandvik 4C54 (not a standard wire electrode) is recommended. In cases where there is risk of cracking due to inherent welding stresses the wire electrodes Sandvik 29.9, 25.20.C and Sanicro 72 can be used.

For manual metal-arc welding the covered electrodes Sandvik 29.9.R, 25.20.B and Sanicro 71 are recommended. In this case, however, allowance must be made for lower corrosion resistance in a reducing, sulphurous atmosphere.

BENDING

When 4C54 tubes are to be bent cold, we recommend the use of cold-worked tubes. Annealing is not normally necessary after cold bending.

Hot-worked tubes should preferably be bent hot, but they can be bent cold if the bending radius is greater than 5 times the diameter.

Hot bending is carried out at 1000-800°C (1830-1470°F) and should be followed by annealing.

When straightening or bending tubes that have already been in service, the following recommendations should be observed:

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

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

APPLICATIONS

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

Typical applications for 4C54 are:

- recuperators within the metallurgical and glass industries
- thermocouple protection tubes
- sootblower tubes
- injection nozzles

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.

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