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Sanicro 29 for OCTG

(Tube and pipe, seamless)

Sanicro 29 is a high-alloy austenitic stainless steel (CRA) for OCTG downhole applications in particularly corrosive conditions. The grade is characterized by:

- Very good resistance to sulphide stress cracking and stress corrosion cracking (SCC) in H_2S environments
- Very high resistance to pitting and crevice corrosion
- Higher pitting resistance equivalent (PRE) than Sanicro 28 (UNS N08028)

Sanicro 29 is developed specifically for improved localized corrosion resistance where the environment contains high chloride concentrations, CO_2 and H_2S at high temperatures. Such an environment causes corrosion in lower alloyed materials. Sanicro 29 offers a cost effective solution to such corrosion problems over the more expensive nickel alloys.

STANDARDS

- ISO ISO 13680 27-31-4

Product standards

Seamless tubes for use as casing, tubing and coupling stock:	ISO 13680, PSL-1

Approvals

- NACE MR0175/ISO 15156 (Petroleum and natural gas industries - Materials for use in H_2S-containing environments in oil and gas production)

CHEMICAL COMPOSITION (NOMINAL) %

C	Si	Mn	P	S	Cr	Ni	Mo	Cu
max	max	max	max	max				
0.020	1.0	2.5	0.025	0.015	27	31.5	4.4	1.0

FORMS OF SUPPLY

Materials for oil and gas production
Cold worked seamless tube and pipe
For production tubing, casing, liner, and coupling stock for downhole oil and gas applications, Sanicro 29 is supplied cold worked with high strength properties. (Sanicro 29-110 ksi, -125 ksi)
Full details on sizes, finishes and mechanical properties are available on request.
Email: stmo.smt@sandvik.com

MECHANICAL PROPERTIES

At 20°C (68°F)

METRIC UNITS AND IMPERIAL UNITS

Grade	Proof strength		Tensile strength		Elong.	Hardness
	$R_{p0.2}$ a)		R_m		$A_{2"}$	HRC
	MPa	ksi	MPa	ksi	%	
			min	min	min	max
Sanicro 29-110	760 - 965	110 - 140	795	115	11	35
Sanicro 29-125	860 - 1035	125 - 150	895	130	10	37

1 MPa = 1 N/mm^2
a) $R_{p0.2}$ corresponds to 0.2% offset yield strength.

The PSL-2 requirements in ISO 13680 can be fulfilled for certain products. Further information is available on request. Email:stmo.smt@sandvik.com

At high temperatures
Sanicro 29 cold worked material also displays very good mechanical properties at higher temperatures.

METRIC UNITS IMPERIAL UNITS

Temperature, °C	De-rating factor*	Temperature, °F	De-rating factor*
20	1.00	68	1.00
50	0.94	100	0.97
100	0.91	200	0.92
150	0.87	300	0.87
200	0.86	400	0.86
250	0.86	500	0.85

* Approximate yield strength at temperature is achieved by multiplying the corresponding de-rating factor and yield strength at 20°C (68°F).

Impact strength
Due to its austenitic microstructure, Sanicro 29 has very good impact strength, both at room temperature and at lower temperatures. Tests have demonstrated that the steel readily fulfills the requirements in accordance with ISO 13680 (min. 40 J at -10°C (50°F)).

PHYSICAL PROPERTIES

Physical properties of cold worked Sanicro 29.
Density: 8.0 g/cm3, 0.29 lb/in3

Thermal conductivity
Metric units Imperial units

Temperature, °C	W/(m °C)	Temperature, °F	Btu/(ft h °F)
20	11	68	6
50	11	100	6.5
100	12	200	7
150	13	300	7.5
200	14	400	8
250	15	500	8.5
300	16	600	9

Specific heat capacity
Metric units Imperial units

Temperature, °C	J/kg °C	Temperature, °F	Btu/lb °F
20	460	68	0.11
50	465	100	0.11
100	480	200	0.11
150	490	300	0.12
200	495	400	0.12
250	505	500	0.12
300	515	600	0.12

Resistivity
Metric units Imperial units

Temperature, °C	μΩm	Temperature, °F	μΩin.
20	1.01	68	39.7
100	1.01	200	39.7
150	1.00	300	39.2
200	1.00	400	39.5
250	1.04	500	41.3
300	1.11	600	44.5

Thermal expansion, mean values in temperature ranges (×10-6)
Metric units Imperial units

Temperature, °C	Per °C	Temperature, °F	Per °F
30-50	13	86-100	7
30-100	14.5	86-200	8
30-150	15	86-300	8.5
30-200	15	86-400	8.5
30-250	15	86-500	8.5
30-300	15	86-600	8.5

Modulus of elasticity (×103)
Metric units Imperial units

Temperature, °C	MPa	Temperature, °F	ksi
20	195	68	28.3
100	190	200	27.6
200	182	400	26.3
300	174	600	25.1

Poisson's ratio
The Poisson's ratio for Sanicro 29 at room temperature is 0.30.

CORROSION RESISTANCE

Environments in sour wells, which commonly include high concentrations of hydrogen sulphide (H_2S), carbon dioxide (CO_2) and chlorides (Cl^-), are often very severe with respect to corrosion. However, the risk of corrosion attack can be significantly reduced by selecting a suitable material. In these environments, materials with high levels of nickel, chromium and molybdenum have proven to reduce the risk of corrosion. Sanicro 29 has been specifically designed to optimize the contents of these elements for sour service corrosion resistance.

Pitting corrosion

Sanicro 29 can withstand high temperatures in aggressive environments without pitting. A recognised method of ranking a material's susceptibility to localized corrosion is by means of the PRE number (Pitting Resistance Equivalent). This PRE number is based on the contents of chromium, molybdenum and nitrogen in the alloy according to the following formula:
PRE = %Cr + 3.3 × %Mo + 16 × %N

A PRE number is the relative measure of a material's ability of preventing pitting corrosion in chloride containing environments. Sanicro 29 has a minimum PRE number of 42, which confirms its high resistance to pitting corrosion when chlorides are present. For comparison, the minimum PRE number of Sanicro 28 is shown in the table below.

Alloy	PRE (minimum values)
Sanicro 29	42
Sanicro 28	38

Potentiostatic tests, based on ASTM G150, on cold worked Sanicro 29 in solutions with different chloride concentrations and pH values are presented in Figure 1 and Figure 2, respectively. In these tests the critical pitting temperature (CPT) is determined in

oxidizing conditions at the potential of +600 eV versus SCE. However, the conditions in wells are significantly less oxidizing, resulting in actual CPT values being higher than those presented in the figures. Figure 1 shows the CPT values as a function of chloride concentration. Also shown are results from similar measurements on Sanicro 28 demonstrating that Sanicro 29 performs better in such environments. In Figure 2, CPT values are presented as a function of pH.

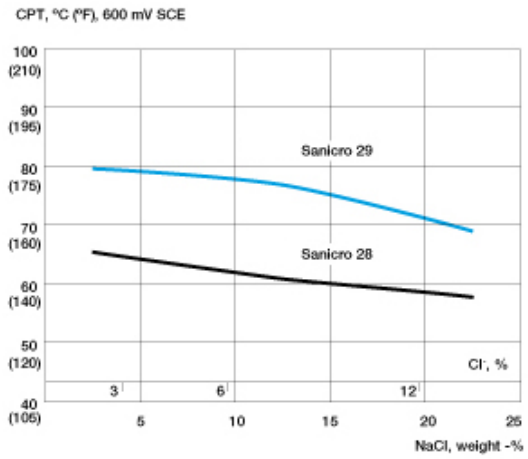

Figure 1. Critical pitting temperature (CPT) as a function of chloride concentrations for cold worked Sanicro 29 and Sanicro 28. The potential was +600 mV vs. SCE.

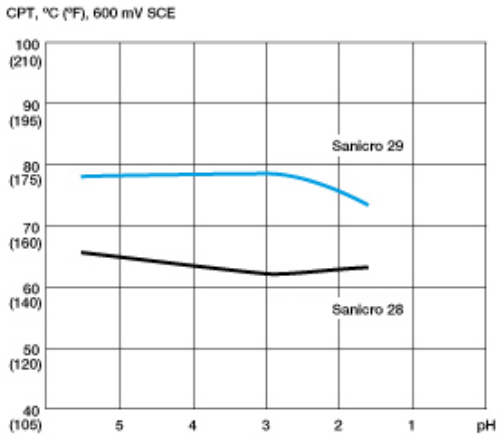

Figure 2. Critical pitting temperature (CPT) as a function of pH for cold worked Sanicro 29 and Sanicro 28 in a 3% Cl^- solution. The potential was +600 mV vs. SCE.

Stress corrosion cracking

Environmental assisted cracking, especially in the presence of hydrogen sulphide (H_2S), is one of the more serious forms of corrosion in sour environments. Failure of tubing as a result of environmental assisted cracking can occur rapidly without any warning. For that reason, the prevention of this form of corrosion must be considered when selecting tubing materials for sour wells.

Sanicro 29 possesses very good resistance to environmental assisted cracking in conditions where hydrogen sulphide is present together with chlorides.

Figure 3 presents the results of constant load tests, according to NACE TM0177-2005, at different temperatures and partial pressures of hydrogen sulphide. In some cases, the limitation are those of the test equipment and not the material.

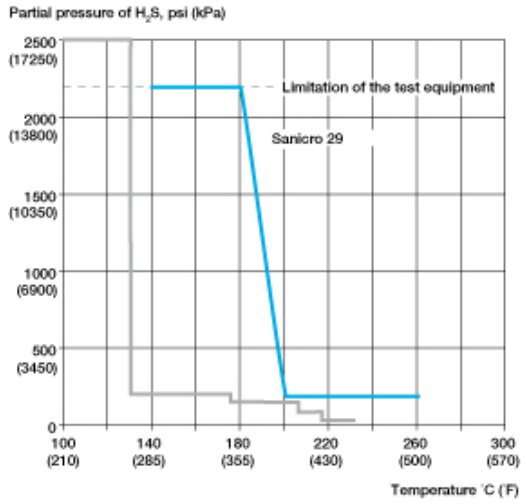

Figure 3: Constant load tests of cold worked Sanicro 29 at 100% of the actual yield strength. The concentration of NaCl in brine is 15% and the partial pressure of CO_2 is 1000 psi. The grey line represents the approved environments according to NACE MR0175/ISO 15156-3 for 4c type materials.

Stress corrosion cracking tests have also been performed in the presence of elemental sulfur. Cold worked Sanicro 29 tube with an $R_{p0.2}$ value of 910 MPa (132 ksi) has been tested. The tests were performed, according to NACE TM0177-2005, with tensile specimens stressed to 100% of the actual yield strength.

Temperature °C (°F)	pH_2S psi (MPa)	pCO_2, psi (MPa)	Chlorides (Cl^-) ppm	Elemental sulfur g/L	Stress corrosion cracking
140 (284)	2200 (15.2)	1000 (6.9)	91000	1	No
160 (320)	2200 (15.2)	1000 (6.9)	91000	1	No
170 (338)	2200 (15.2)	1000 (6.9)	91000	1	No
160 (320)	2200 (15.2)	1000 (6.9)	225000	1	No

HEAT TREATMENT

Tubes for downhole oil and gas applications are delivered in the high strength, cold worked condition. They are not annealed after cold working.

FABRICATION

Sanicro 29 tubes are supplied in the cold worked condition and are intended for use with threaded connections.

APPLICATIONS

Sanicro 29 is used for high strength downhole production tubing, casing, and liners in sour gas wells. This includes environments with high temperatures, high partial pressures of CO_2 and H_2S, and high chloride concentrations.

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.