SANICRO® 69
TUBE AND PIPE, SEAMLESS

DATASHEET

Sanicro® 69 is an austenitic nickel-chromium-iron alloy used primarily for steam generators in nuclear power plants (PWR). For this application it is used in the 'thermally treated' condition. This treatment results in chromium carbide precipitation at the grain boundaries but no significant chromium depletion. The grade has good structure stability and good weldability.

For the steam generator application the material is characterized by:

- Extremely high resistance against stress corrosion cracking in primary side PWR water conditions
- Improved pitting corrosion resistance in chloride containing solutions compared with Alloy 600

Sanicro® 69 is also characterized by:

- Good corrosion resistance in caustic environments
- Excellent performance in nitric acid solutions

STANDARDS

- UNS: N06690
- W.Nr.: 2.4642
- AFNOR: NC 30FE (RCCM)

Products standards
Seamless condenser and heat exchanger tubes: ASTM B163
Seamless tube and pipe: ASTM B167

Approvals
ASME Boiler and Pressure Vessel Code Case N-20 and N-474.
AFCEN RCCM M4105

For steam generator applications Sanicro® 69 is delivered to the most stringent individual specifications in order to assure maximum reliable performance in nuclear power plants.

CHEMICAL COMPOSITION (NOMINAL) %

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Fe
0.02	≤0.5	≤0.5	≤0.020	≤0.015	30	60	10

Normally the Co-content is max 0.05%. Lower contents can be specified after agreement.

FORMS OF SUPPLY

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Seamless tube and pipe are supplied in the size range from 1/4" O.D. (6.35 mm) to 4" O.D. (101.6 mm) in wall thickness from 0.030" (0.9 mm) to 1" (25.4 mm).

Tube and pipe are delivered in the solution annealed and pickled condition.

PWR steam generator tubes are delivered in the bright annealed and thermally treated condition. The thermal treatment involves a treatment in vacuum furnace at about 720°C (1330°F) for normally 10 hours.

MECHANICAL PROPERTIES

The following two tables give general nominal values.
At 20°C (68°F)

Proof strength $R_{p0.2}$[a] MPa	ksi	Tensile strength R_m MPa	ksi	Elongation A[b] %	Hardness Vickers approx.
≥240	≥35	≥585	≥85	≥30	160

1 MPa = 1N/mm²
a)$R_{p0.2}$ corresponds to 0.2% offset yield strength.
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.
At high temperatures

Temperature		Proof strength		Tensile Strength	
°C	°F	$R_{p0.2}$		R_m	
		MPa	ksi	MPa	ksi
		min.	min.	min.	min.
100	210	220	31.9	550	79.8
200	390	190	27.5	510	74.0
300	570	187	27.1	495	71.8
400	750	184	26.7	490	71.1
500	930	180	26.1	480	69.6
600	1110	175	25.4	440	63.8
700	1290	150	21.8	340	49.3

For steam generator tubing in the thermally treated condition the following higher proof strength values can be guaranteed.

Temperature		Proof strength	
°C	°F	$R_{p0.2}$	
		MPa	ksi
20	68	280	40.6
100	210	260	37.7
200	390	240	34.8
350	660	210	30.5

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Impact strength
Since Sanicro® 69 is a fully austenitic alloy it possesses good toughness down to -196°C (-320°F)

PHYSICAL PROPERTIES

Density: 8.12 g/cm³; 0.293 lb/in³

Thermally Treated condition

Specific heat capacity

Temperature, °C	J/(kg °C)	Temperature, °F	Btu/(lb °F)
23	460	73	0.11
100	480	200	0.11
200	495	400	0.12
300	505	600	0.12
400	510	800	0.12
500	520	1000	0.13
600	580	1100	0.14

Thermal conductivity

Temperature, °C	W/(m °C)	Temperature, °F	Btu/(ft h°F)
23	11	73	6.5
100	13	200	7.5
200	14	400	8.5
300	16	600	9.5
400	18	800	10.5
500	19	1000	11.5
600	23	1100	13

Resistivity

Temperature, °C	µΩm	Temperature, °F	µΩin.
20	1.11	68	43.7
100	1.14	200	44.9
200	1.18	400	46.5
300	1.22	600	48.0
400	1.24	800	48.8

Thermal expansion [1)]

Temperature, °C	Per °C	Temperature, °F	Per °F
30-100	13.5	86-200	7.5
30-200	14	86-400	8
30-300	14.5	86-600	8
30-400	15	86-800	8.5
30-500	15.5	86-1000	8.5
30-600	15.5	86-1200	9

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

Modulus of elasticity 1)

Temperature, °C	MPa	Temperature, °F	ksi
20	210	68	30.5
100	206	200	30.0
200	201	400	29.1
300	195	600	28.1
400	189	800	27.1
500	182	1000	26.0
600	174	1200	24.8

1) ($x10^3$)

CORROSION RESISTANCE

Stress corrosion cracking

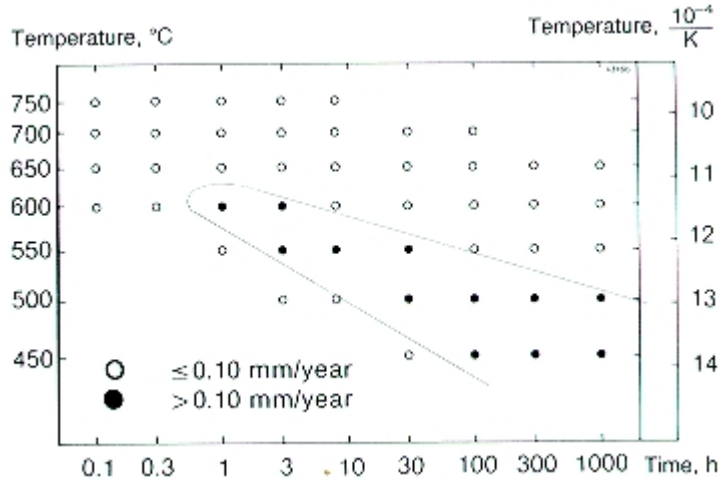
The thermally treated condition of Sanicro® 69 is developed specifically to resist stress corrosion cracking in steam generator environment at nuclear power plants. This has been confirmed by laboratory stress corrosion cracking tests in pure water (less than 5 ppm oxygen, 4-5 ppm hydrogen added) at 365°C (690°F).

No stress corrosion cracking was developed in Sanicro® 69 during the entire test period of 33 000 hours. Alloy 600 started to crack after 200 hours.

Intergranular corrosion

Sanicro® 69 has good resistance to intergranular corrosion in both the thermally treated condition and the solution annealed condition. Typical corrosion rates in the Huey test (65% HNO_3, 5 x 48h, ASTM A262 Practice C) are 0.06 mm/year (2.4 mpy).

The figure below shows a TTS diagram for a heat of Sanicro® 69 with 0.03% carbon tested in the Huey test. The initial material was annealed at 1040°C (1900°F), 20 min/WQ.



As can be seen there is a very narrow area where Sanicro® 69 shows some tendency for sensitization.

General corrosion

Sanicro® 69 and Alloy C-276 have been corrosion tested in 20% HNO_3+ 4%HF at 65 °C (150 °F). Sanicro® 69 had a corrosion rate of 0.625 mm/year (24.6 mpy) while Alloy C-276 suffered a corrosion rate of 23.7 mm/year (933 mpy).

HEAT TREATMENT

For steam generator application the tubes are delivered in the thermally treated conditions. This means exposure at about 720°C (1330°F) for normally 10 hours. Prior to the thermal treatment the tubes are solution annealed at approximately 1100 °C (2010°F) for some minutes.

For other applications the tubes are delivered in the solution annealed condition. If additional solution annealing is necessary after further processing the following procedure is recommended:

1050-1150°C (1920-2100°F), 1-10 minutes, rapid cooling in air or water.

WELDING

Sanicro® 69 has good weldability. Suitable welding methods are manual metal-arc welding with covered electrodes and gas shielded arc welding, such as TIG and MIG. Strip overlay welding of tube sheets can be made using ESW. Preheating and post-weld heat treatment are normally not necessary.

This type of nickel-base materials have increased risk of hot cracking compared to standard stainless steels. Therefore welding should be performed with low heat input and with low dilution from the base material to reduce the risk of hot cracking. It is also important to keep the joint surfaces and the welding material as clean as possible, for the same reason. These measures are especially important when the weldment is under constraints.

Since Sanicro® 69 has low thermal conductivity and high thermal expansion, a low heat input is also important for reducing the deformation and residual stresses in the welded joint.

As filler metal for TIG and MIG welding Sanicro® 68HP is recommended. For manual metal-arc welding, covered electrode Sanicro 69 is the first choice. For strip overlay welding Sanicro® 69HP is recommended.

FABRICATION

Bending

The excellent formability of Sanicro® 69 permits cold-bending to very small bending radii. Annealing is normally not necessary after cold-bending owing to the high stress corrosion cracking resistance for Sanicro® 69.

Expanding

Sanicro® 69 is expanded into tube sheets in the same way as standard austenitic stainless steels.

APPLICATIONS

- Steam generators in nuclear power plants.
- Units in contact with nitric acid at elevated temperatures.
- Equipment requiring high resistance to oxidation, carburization and nitriding.
- Units exposed to caustic solutions at high temperature.

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