Nicrofer® 5219 Nb – alloy 718

Material Data Sheet No. 4027
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High-temperature and corrosion-resistant alloy

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Nicrofer® 5219 Nb – alloy 718

Nicrofer 5219 Nb is a precipitation-hardenable nickel-chromium-iron alloy containing significant amounts of niobium and molybdenum as well as lesser amounts of aluminium and titanium. The alloy has good ductility in the annealed condition and high strength up to 700 °C (1300 °F). It can be delivered in the solution-annealed or precipitation-hardened condition.

Nicrofer 5219 Nb is characterized by

- good fabrication characteristics in the annealed condition
- good tensile, fatigue and creep-rupture strengths
- high-temperature strength up to 700 °C (1300 °F)
- good oxidation resistance up to 1000 °C (1830 °F)
- excellent mechanical properties in cryogenic environments
- excellent corrosion resistance at high and low temperatures and good resistance to stress-corrosion cracking and pitting corrosion
- good weldability by arc and resistance welding processes without susceptibility to post-weld cracking

Designations and standards

Country National standards	Material designation	Specification							
		Chemical composition	Tube and pipe seamless	 welded	Sheet and plate	Rod and bar	Strip	Welding Wire	Forgings
D	**W.-Nr. 2.4668** NiCr19Fe19Nb5Mo3								
DIN		17744	17751		17750	17752	17750	17753**	
WL		Parts 1 – 3			Part 1	Part 2	Part 1	Part 3	Part 2
F AFNOR	NC19FeNb				AIR 9165	AIR 9165			AIR 9165
UK BS	NA 51							2901 Part 5	
USA	UNS N07718								
ASTM		B 637			B 670*	B 637*	B 670*		B 637*
					SB 670	SB 637	SB 670		SB 637
ASME									
ASME Code Case						1993 (Sect. I) 2206 (Sect. VIII, Div.2)			1993 (Sec. I) 2206 (Sect. VIII,Div.2)
SAE AMS		5662	5589 5590		5596 5597	5662 5663 5664	5596 5597	5832	5662 5663 5664
NACE	Material listed in MR 0175								
ISO	NiCr19Nb5Mo3								

*For high-temperature service **Wire products, i.e., not specifically welding wire

Table 1 - Designations and standards.

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Cu	Mo	Co	Nb	Al	Ti	B	P	S	Pb	Se	Bi	Ta
min.	50.0	17.0	bal.					2.80		4.75	0.20	0.65							
max.	55.0	21.0		0.08	0.35	0.35	0.30	3.30	1.0	5.50	0.80	1.15	0.006	0.015	0.015	5 ppm	3 ppm	0.3 ppm	0.05

Table 2 – Chemical composition (wt.-%) according to ASTM and SAE AMS (Some compositional limits of other specifications may vary slightly).

	Ni	Cr	Fe	C	Mn	Si	Cu	Mo	Co	Nb	Al	Ti	B	P	S	Pb	Se	Bi	Sn
min.	50.0	17.0	bal.					2.80		4.87	0.40	0.80							to be repor-ted
max.	55.0	21.0		0.045	0.35	0.35	0.23	3.30	1.0	5.20	0.60	1.15	0.006	0.01	0.01	10 ppm	5 ppm	0.5 ppm	

Table 3 – Chemical composition (wt.-%) according to Schlumberger Operations Manual on 718 (120 – 140 ksi yield strength, 40 HRC) for products subjected to H_2S, CO_2 and Cl environments (Specification CMS-Z1 CGU.O).

The chemical compositional limits of some alloying elements are tighter for applications involving corrosive conditions. This applies primarily to the carbon and niobium contents and to some extent also to the aluminium and titanium contents as can be seen by comparing the compositional limits of the respective alloying constituents in Tables 2 and 3. The purpose for these tighter limits is to optimize the structure and mechanical properties of the material for the intended end use. Thus for high-temperature applications carbon and niobium contents near the upper ASTM specified limits yield material best suited for such applications whereas somewhat lower carbon and niobium contents result in microstructures more amenable to corrosive service.

ThyssenKrupp VDM utilizes tight internal compositional limits to ensure that material is always produced and supplied with optimum composition for the proposed application.

Physical properties

Density Melting range	8.2 g/cm³ 1260 – 1340 °C	0.30 lb/in.³ 2300 – 2440 °F
Permeability at 200 Oersted (15.9 kA/m) at 20 °C/68 °F	1.001	
Curie temperature: solution annealed solution annealed and precipitation hardened	 -195 °C -112 °C	 -320 °F -170 °F

Temperature (T)		Specific heat		Thermal conductivity		Electrical resistivity		Modulus of elasticity		Coefficient of thermal expansion between room temperature and T	
°C	°F	J/kg K	Btu/lb °F	W/mK	Btu in./ft² h °F	μ Ω cm	Ω circ mil/ft	kN/mm²	10³ ksi	10⁻⁶/K	10⁻⁶/°F
20	**68**	432	0.103	11.1	77	123	738	205	29.7		
93	**200**		0.105		84		745		29.0		7.0
100	212	440		12.2		124		199		12.6	
200	392	462		13.6		126		192		13.4	
204	**400**		0.110		95		758		27.8		7.5
300	572	488		15.2		128		187		13.8	
316	**600**		0.117		108		771		26.9		7.7
400	752	510		17.0		130		181		14.1	
427	**800**		0.124		122		782		26.1		7.9
500	932	540		18.9		131		175		14.4	
538	**1000**		0.131		137		791		24.9		8.1
600	1112	565		20.8		132		169		14.8	
649	**1200**		0.137		150		797		23.9		8.4
700	1292	595		22.4		133		161		15.4	
760	**1400**		0.145		165		802		22.5		8.8
800	1472	620		24.4		133		150		16.1	
871	**1600**		0.153		178		805		20.3		9.2
900	1652	650		26.1		134		136		16.8	
982	**1800**		0.161		192		807		17.5		
1000	1832	680		28.0		134		120			
1093	**2000**		0.170		205		807		14.5		
1100	2012	715				134		100			

Table 4 – Typical physical properties at room and elevated temperatures.

Mechanical properties

The following properties are applicable to Nicrofer 5219 Nb in the hot or cold formed, solution-annealed or solution-annealed and precipitation-hardened condition at the indicated size ranges. Specified properties of material outside these size ranges (see availability) with agreed properties are subject to special enquiry.

Product	Heat treatment process[1)]		Dimensions mm	in.	Tensile strength R_m N/mm²	ksi	0.2 % Yield strength $R_{p0.2}$ N/mm²	ksi	Elongation A_5 %	Reduct. of area Z %	Hardness Brinell[2)] HB	Grain size µm	Specification
Sheet, strip, plate	A	solution annealed 960 °C (1760 °F)	≤ 4.75	≤ 3/16	965	140	550	80	30		< 240	≤ 45	AMS 5596
			> 4.75	> 3/16	1035	150	725	105			< 260	≤ 90	
		+ precip. hard. 720/620 °C (1330/1150 °F)			1240	180	1035	150	12		> 350		
	C	solution annealed 1065 °C (1950 °F)			965	140	520	75	30		> 260	≤ 127	AMS 5597
		+ precip. hard. 760/650 °C (1400/1200 °F)			1240	180	1035	150	15		> 368		
Bars, forgings, rings	B	solution annealed 940 – 1000 °C (1720 – 1830 °F)	≤ 58 cm²	9 in.²							≤ 277	≤ 64	AMS 5662
			> 58 cm²	9 in.²								≤ 90	
		+ precip. hard. 720 – 760 °C/ 620 – 650 °C (1330 – 1400 °F/ 1150 – 1200 °F)		longit.	1275	185	1035	150	12	15	> 331		AMS 5663
			forg.	lg.-trsv.	1240	180			10	12			
			bars	trsv.	1240	180			6	8			
	C	solution annealed 1065 °C (1950 °F)									≤ 248	≤ 127	AMS 5664
		+ precip. hard. 760/650 °C (1400/1200 °F)	≤ 250	≤ 10	1240	180	1035	150			≥ 341		
			bars						10	12			
			forg. and rings						12	15			
Rod & bar	E	solution annealed 1021 – 1052 °C (1870 – 1925 °F)											
		+ precip. hard. 621 – 843 °C (1150 – 1550 °F)			655	95	552	80	20	35	≤ 363 (40 HRC max.)	ASTM 3 or finer	–
		or 774 – 802 °C (1425 – 1475 °F)			1034	150	862 – 1000	125 – 145	20	35			–
					1069	155	965 – 1034	140 – 150	17	25			–
Welding wire		stress relieved 960 °C (1760 °F)	≤ 4.75	≤ 3/16									AMS 5832

[1)] For exact conditions refer to Table 11.

[2)] According to NACE Standard MR 0175 wrought Nicrofer 5219 Nb is acceptable in each of the five following conditions: (1) solution annealed to 35 HRC maximum; (2) hot worked to 35 HRC maximum; (3) hot worked and aged to 35 HRC maximum; (4) solution annealed and aged to 40 HRC maximum; and (5) cast, solution annealed, and aged to 40 HRC maximum.

Table 5 – Minimum mechanical properties at room temperature according to AMS or specifications typical for oil & gas applications.

Rod size range diameter mm	inches	Tensile strength R_m N/mm²	ksi	0.2 % Yield strength $R_{p0.2}$ N/mm²	ksi	Elongation in 4 D A_5 %	Reduction of area %	Charpy V-Notch at -75 °F (-59 °C) ft-lbs	J	Hardness HB	HRC
≤ 50	≤ 2	1242		910		31	–		88	361	38
> 50 – ≤ 100	> 2 – ≤ 4	1233		914		30	–		95	356	37
>100 – ≤ 150	> 4 – ≤ 6	1221		924		29	–		95	354	37
>150	> 6	1206		923		28	–		82	358	38
Schlumberger Specification CMS-Z1 CGU.O requirements		1035 min.	150 min.	897 – 1001	130 – 145	20 min.	25 min.	30 min.	42 min.	298 – 363	32 – 40

Table 6 – Average mechanical property and hardness values of rods in the solution-annealed and precipitation-hardened condition of Nicrofer 5219 Nb production lots.

After precipitation hardening the product should have the following properties at elevated temperatures.

Product	Testing direction	Testing temp.	Dimensions mm	in.	Tensile strength R_m N/mm²	ksi	0.2 % Yield strength $R_{p0.2}$ N/mm²	ksi	Elonga-tion A_5 %	Reduct. of area Z %	Specifi-cation
Sheet, strip, plate		650 °C (1200 °F)	< 0.38	< 0.015	965	140	795	115	5		AMS 5596
			0.38 – ≤ 0.62	0.015 – ≤ 0.025							
			> 0.62	> 0.025	1000	145	825	120			
Bar	longit.	650 °C (1200 °F)			1000	145	860	125	12	15	AMS 5662 5663
	transv.				965	140			6	8	
Forgings	lg./trsv.								12	12	

Table 7 – Minimum mechanical properties of Nicrofer 5219 Nb at indicated temperature (precipitation-hardened condition).

Product	Testing direction	Testing temp.	Dimensions mm	in.	Constant load N/mm²	ksi	Time h	Elongation A_5 %	Specification
Sheet, strip, plate		650 °C (1200 °F)	< 0.38	< 0.015	655	95	23	–	AMS 5596
			0.38 – ≤ 0.62	0.015 – ≤ 0.025				4	
			> 0.62	> 0.025	690	100		4	
Bar	longit.	650 °C (1200 °F)			690	100	23	5	AMS 5662 5663
	transv.								
Forgings	lg./trsv.								

Table 8 – Minimum stress-rupture properties of Nicrofer 5219 Nb at indicated temperature (precipitation-hardened condition).

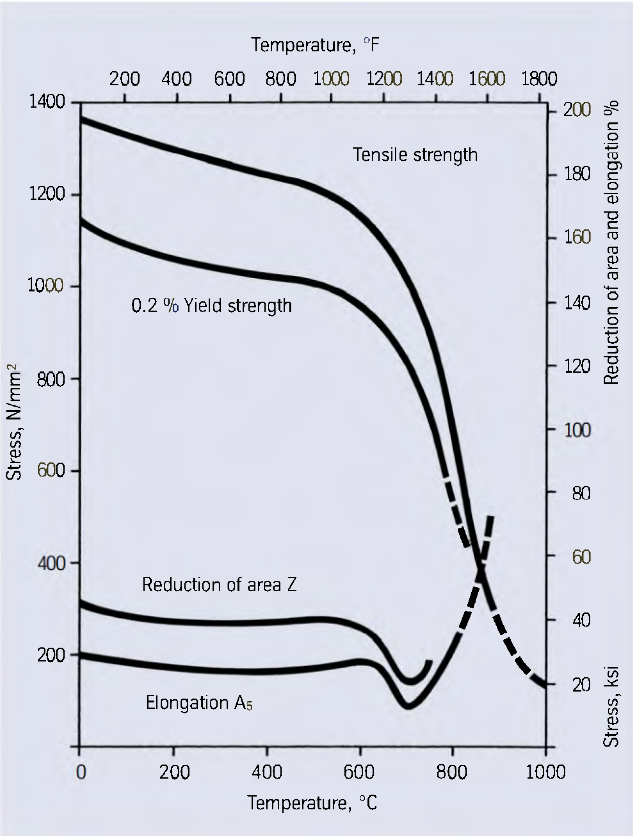


Fig. 1 – Typical short-time properties of solution-annealed and precipitation-hardened Nicrofer 5219 Nb sheet and plate at room and elevated temperatures.

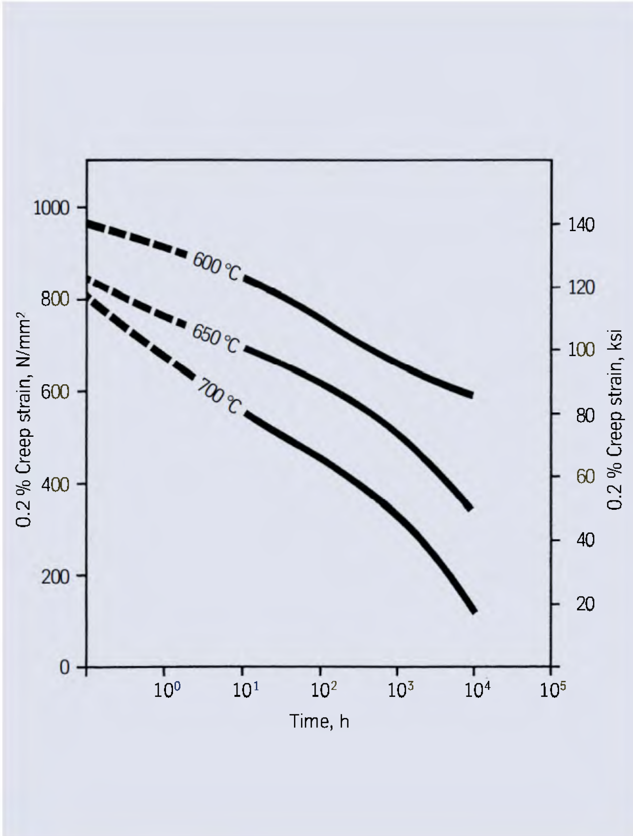


Fig. 2 – Typical 0.2 % creep-strain values of solution-annealed and pricipitation-hardened Nicrofer 5219 Nb at elevated temperatures.

Typical short- and long-time properties of solution-annealed and precipitation-hardened Nicrofer 5219 Nb at elevated temperatures are shown in Figures 1 to 3.

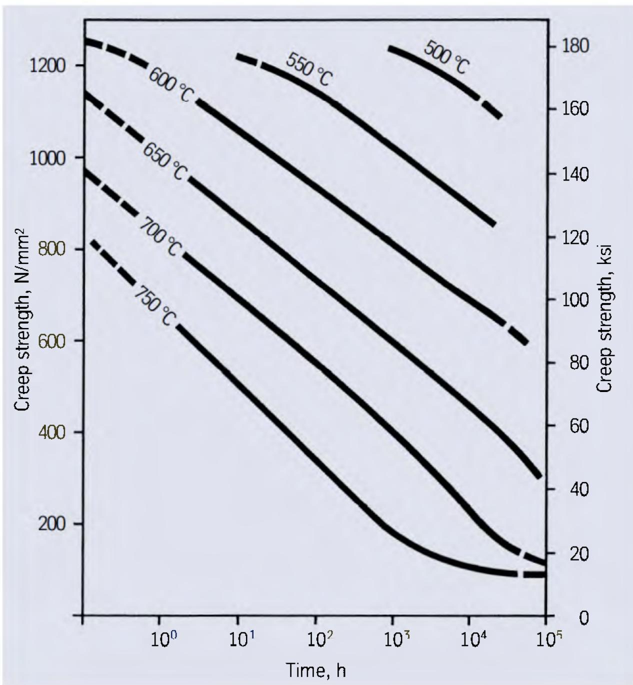


Fig. 3 – Typical creep-rupture strength of solution-annealed and precipitation-hardened Nicrofer 5219 Nb at elevated temperatures.

Charpy V-notch impact toughness
A typical oil & gas specification for alloy 718 rod and bar heat treated in accordance to Practice E (for details refer to Table 11) requires that the following minimum values for absorbed energy and lateral expansion are attained:

Charpy V-notch test at -75 °F (-59 °C) ft-lbs (J)	Lateral expansion, in. (mm)
Transverse (bar ≥ 3 in.): > 35 (47) average of 3 values > 30 (41) any single value Longitudinal (bar < 3 in.): > 52 (71) average of 3 values > 45 (61) any single value	> 0.015 (0.38)
Transverse or longitudinal: > 30 (41) average of 3 values > 25 (34) any single value	

Table 9 – Charpy V-notch impact toughness requirement for rod and bar heat treated to Practice E for H_2S service environments.

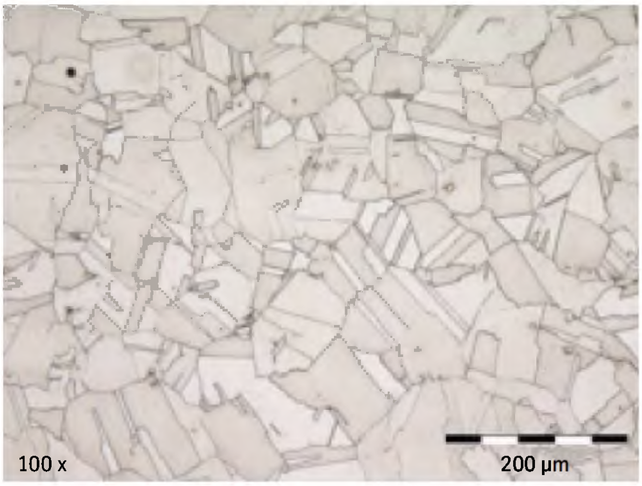
Bend Test
180 ° bend for sheet in the solution-annealed condition without cracking is obtained with a minimum bending radius equal to: sheet thickness (t) for t: < 1.27 mm (0.050 in.) or twice the sheet thickness (2 t) for t: 1.27 to 4.76 mm (0.050 to 0.187 in.)

Metallurgical structure
Nicrofer 5219 Nb – alloy 718 has an austenitic structure with a large number of phases which either have a characteristic morphology or will form in a specific temperature range such that tentative identification can be made if the thermal history is known. The phases normally found and their appearance as well as the temperatures at which they are formed are listed in Table 10.

Phase	Appearance	Occurrence
MC	Discrete particles	Forms on solidification; stable up to about 2200 °F (1205 °C).
Laves ([Fe,Cr]$_2$Nb) hexagonal	Round, island-like	Forms on solidification in high-niobium interdentritic areas; stable up to 2150 °F (1177 °C).
δ (Ni_3Nb) orthorhombic	acicular (needle-like) or globular	Forms on cooling during solidification in high-niobium areas and is stable up to 1850 °F (1010 °C) in wrought and 2050 °F (1120 °C) in cast material. It precipitates from 1550 to 1800 °F (845 – 980 °C) depending on the actual Nb-content of the alloy.
γ'' (Ni_3Nb, Al, Ti) body-centered-tetragonal	Disk-shaped	Forms during cooling or heat treatment at 1100 to 1700 °F (600 – 925 °C)* with precipitates becoming smaller at lower temperatures.
γ' (Ni_3Al, Nb) face-centered-cubic	Spheroidal	Forms during cooling or heat treatment in the 1150 to 1560 °F (620 – 850 °C)* range.
* according to ASM Specialty Handbook: Heat-Resistant Materials		

Table 10 – Nicrofer 5219 Nb – alloy 718 phases and their characteristics.

Nicrofer® 5219 Nb – alloy 718



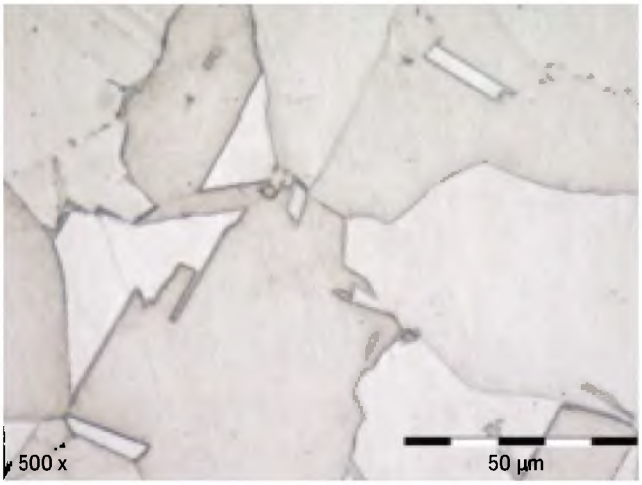


Fig. 4 – Typical microstructure of Nicrofer 5219 Nb 145 mm (5.7 in.) diameter rod solution-annealed at 1036 °C (1900 °F) for 1 h and water quenched. Etchant: HCl/HNO_3 according to ASTM A 604 (Kalling's No. 2)

Figure 4 illustrates the typical microstructure of solution-annealed Nicrofer 5219 Nb – alloy 718 at 100 X and 500 X magnification as exhibited by 145 mm (5.7 in.) diameter rod.

Figure 5 shows the phase stabilities of cast Nicrofer 5219 Nb – alloy 718 and typical heat treatments applied to material for corrosive service in oil and natural gas exploration and production particularly in "sour" (H_2S containing) environments.

Different levels of mechanical properties can be attained depending on the heat treatment conditions employed. The alloy's excellent mechanical strength results from precipitation-hardening by γ" which, as in other niobium bearing super-alloys, is also the reason for the alloy's resistance to strain-age cracking in the age-hardened condition. Further details are given under **'Heat treatment'**.

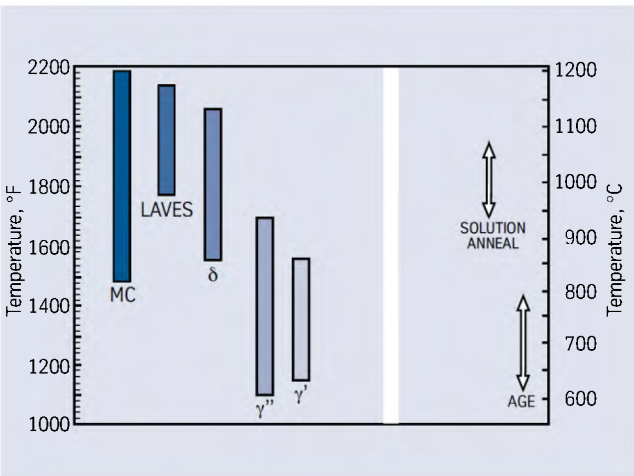


Fig. 5 – Phase stabilities of cast Nicrofer 5219 Nb – alloy 718 and temperature ranges of heat treatments commonly used in the fabrication of wrought products.

Corrosion resistance
The high chromium and molybdenum contents of Nicrofer 5219 Nb impart excellent resistance to uniform and localized corrosion, such as pitting in many media at both high and low temperatures. The chromium also enables it to withstand chloride-ion stress-corrosion cracking which makes it an excellent alloy for service in oil and sour gas (H_2S containing) environments as well as seawater.

Nicrofer 5219 Nb is generally only used for applications not exceeding 700 °C (1300 °F). However, oxidation resistance up to 1000 °C (1830 °F) is particularly high and comparable to that of other gamma-prime (γ') strengthened superalloys.

Applications
Due to its high-temperature strength up to 700 °C (1300 °F), excellent corrosion resistance and ease of fabrication Nicrofer 5219 Nb finds applications in many fields. Initially it was used as a turbine disk material in aircraft jet engines. Here resistance to creep and stress rupture was most important.

Because of its properties, fabricability and cost effectiveness it has since gained wider acceptance. To-day applications vary from highly stressed rotating and static components in gas turbines and rocket engines to high-strength bolting, springs and fasteners, components in nuclear reactors and space vehicles as well as high-temperature tooling for extrusion, of for example copper, and shearing. Another more recent important application involves pump shafts and other highly stressed well head and downhole components in off-shore and marine engineering. Particularly useful is the alloy for drilling equipment in sour (containing H_2S, CO_2 and chlorides) oil and gas wells.

Melt practice
Nicrofer 5219 Nb – alloy 718 is melted in a vacuum induction furnace (VIM) and cast as electrodes for remelting by the electro slag remelt (ESR) process.

Alternatively remelting can be done by the vacuum arc remelt (VAR) process.

For premium-quality for rotating parts in aerospace even triple melted material, i.e. VIM + ESR + VAR, is used.

Homogenization
The ESR ingots are homogenized prior to hot working by a controlled slow heating up to temperatures of 1180 °C (2155 °F) for up to 50 h to reduce the amount of Nb and Ti micro-segregations in the interdendritic regions of the cast structure, as well as to dissolve hexagonal Laves-phase (containing approx. 10 to 12 % Nb) and the needle-like orthorhombic Ni_3Nb δ-phase (containing approx. 8 to 10 % Nb).

Rapid heating up must be avoided as it causes incipient melting leading to the formation of a detrimental intergranular liquid phase according to the reaction:
Laves-phase $\rightarrow$ γ-phase + liquid.

Fabrication and heat treatment
Nicrofer 5219 Nb – alloy 718 can readily be hot- and cold worked and machined.

Heating
Workpieces must be clean and free from all kinds of contaminants before and during any heat treatment.

Nicrofer 5219 Nb – alloy 718 may become embrittled if heated in the presence of contaminants such as sulphur, phosphorus, lead and other low-melting-point metals. Sources of such contaminants include marking and temperature-indicating paints and crayons, lubricating grease, fluids and fuels.

Fuels must be as low in sulphur as possible. Natural gas should contain less than 0.1 wt.-% sulphur. Fuel oils with a sulphur content not exceeding 0.5 wt.-% are suitable.

Due to their close control of temperature and freedom from contamination, thermal treatments in electric furnaces under vacuum or an inert gas atmosphere are to be preferred. Treatments in an air atmosphere and alternatively in gas-fired furnaces are acceptable though, if contaminants are at low levels so that a neutral or slightly oxidizing furnace atmosphere is attained. A furnace atmosphere fluctuating between oxidizing and reducing must be avoided as well as direct flame impingement on the metal.

Hot working
Nicrofer 5219 Nb – alloy 718 may be hot worked (forged) above and below the δ-phase solvus temperature of 1877 °F (1025 °C) depending on the later application. Hot working is generally carried out immediately following homogenization and is followed by air cooling. Reductions during hot working should be uniform to avoid a duplex grain structure.

Cold working
Cold forming of Nicrofer 5219 Nb – alloy 718 should be done in the solution-annealed condition. Nicrofer 5219 Nb – alloy 718 has a much higher work-hardening rate than austenitic stainless steels. This should be taken into account when selecting forming equipment.

Heat treatment

Different solution and aging treatments are used to produce required properties. Long aging times are necessary to develop optimum mechanical properties in Nicrofer 5219 Nb, because the diffusion rate that controls formation of gamma double prime (γ") is relatively slow.

Typical heat treatment combinations (metal temperatures) are:

Process A
Fine grain structure gives the best combination of rupture life, notch rupture life and rupture ductility, and tensile, yield and fatigue strengths at room temperature.

Process B
Variation of process A with wider temperature ranges.

Process C
Special homogenizing treatment for heavy sections gives best ductility and impact strength, but with limited tensile values and tendency to notch brittleness.

During any heating operation the precautions outlined earlier regarding cleanliness must be observed.

Process D
Thermal treatment procedure for rods ≤ 215 mm (8.5 in.) diameter for service under corrosive conditions in oil and sour gas enviroments. This process yields material with a homogeneous grain size of ASTM 3 and finer and no precipitates of Laves- or needle-like δ-phase as typically shown in Fig 4.

Process E
Thermal treatment procedure for alloy 718 rod & bars for H_2S service.

Heat treatment process	Solution and re-solution annealing	Precipitation heat treatment
A	960 ± 15 °C (1760 ± 25 °F) for 30 min. to 1 h – AC or WC	720 ± 8 °C (1325 ± 15 °F) for 8 h; 2 h FC to 620 ± 8 ° C (1150 ± 15 °F), after holding for 8 h – AC
B	940 – 1000 °C (1725 – 1830 °F) for ≥ 1 h – AC or WC	720 – 760 °C (1325 – 1400 °F) for 8 h; 2 h FC to 620 – 650 °C (1150 – 1200 °F), after holding for 8 h – AC
C	1065 ± 15 °C (1950 ± 25 °F) for 30 min. to 2 h – AC or WC	760 ± 8 °C (1400 ± 15 °F) for 10 h; 2 h FC to 650 ± 8 °C (1200 ± 15 °F), after holding for 8 h – AC
D	1038 °C (1900 °F) for 1 h – WC	787 °C (1500 °F) for 6 h – AC
E	1021 – 1052 °C (1870 – 1925 °F) for 1 to 2 h – WC	Either 621 – 843 °C (1150 – 1550 °F) for 6 to 8 h – AC or 774 – 802 °C (1425 – 1475 °F) for 6 to 8 h – AC
AC-air cooling WC-water quenching FC-furnace cooling		

Table 11 – Commonly used thermal treatment procedures.

For any heat treatment (except for homogenizing) the material should be charged into the furnace at maximum working temperature. Also for any thermal treatment operation the precautions concerning cleanliness mentioned earlier under **'Heating'** must be observed.

Descaling and pickling

Oxides of Nicrofer 5219 Nb and discoloration adjacent to welds are more adherent than on stainless steels. Grinding with very fine abrasive belts or discs is recommended. Care should be taken to prevent tarnishing.

Before pickling which may be performed in a nitric/hydroflouric acid mixture with proper control of pickling time and temperature, the surface oxide layer must be broken up by abrasive blasting or by carefully performed grinding or by pretreatment in a fused salt bath.

Machining

Nicrofer 5219 Nb should be machined in the solution-treated condition. As the alloy exhibits a high work-hardening rate only low cutting speeds should be used compared with low-alloyed standard austenitic stainless steels. Tools should be engaged at all times. An adequate depth of cut is important in order to cut below the previously formed work-hardened zone.

Though machining is easier and gives longer tool life in the annealed condition, the alloy will have a better surface finish if machined in the age-hardened condition. Thus best results with the smoothest surface finish at final dimension are obtained by rough machining before age hardening and finishing after precipitation treatment in the aged condition. Machining Nicrofer 5219 Nb is more difficult than in the case of Nicrofer 4320 Ti (UNS N09925).

Welding

When welding nickel-base alloys and high-alloyed special stainless steels, the following instructions should be adhered to:

Workplace

The workplace should be in a separate location, well away from the areas where carbon steel fabrication takes place. Maximum cleanliness and avoidance of draughts are paramount.

Auxiliaries, clothing

Clean fine leather gloves and clean working clothes should be used.

Tools and machinery

Tools used for nickel-base alloys and stainless steels must not be used for other materials. Brushes should be made of stainless material. Fabricating and working machinery such as shears, presses or rollers should be fitted with means (felt, cardboard, plastic sheet) of avoiding contamination of the metal with ferrous particles, which can be pressed into the surface and thus lead to corrosion.

Cleaning

Cleaning of the base metal in the weld area (both sides) and of the filler metal (e. g. welding rod) should be carried out with acetone.

Trichlorethylene (TRI), perchlorethylene (PER), and carbon tetrachloride (TETRA) must not be used.

Edge preparation

This should preferably be done by mechanical means, i. e. turning, milling or planing; abrasive water jet or plasma cutting is also possible. However, in the latter case the cut edge (the face to be welded) must be finished off cleanly. Careful grinding without overheating is permissible.

Included angle

The different physical characteristics of nickel-base alloys and special stainless steels compared with carbon steel generally manifest themselves in a lower thermal conductivity and a higher rate of thermal expansion. This should be allowed for by means of, among other things, wider root gaps or openings (1 – 3 mm), while larger included angles (60 – 70°), as shown in Fig. 6, should be used for individual butt joints owing to the viscous nature of the molten weld metal and to counteract the pronounced shrinkage tendency.

Striking the arc

The arc should only be struck in the weld area, i. e. on the faces to be welded or on a run-out piece. Striking marks lead to corrosion.

Welding process

Nicrofer 5219 Nb can be joined to itself and to many other metals by conventional welding processes. These include GTAW (TIG), plasma arc, GMAW (MIG), plasma and electron beam welding. Pulsed arc welding is the preferred technique.

The precipitation-hardening alloy Nicrofer 5219 Nb is well suited to structures involving numerous welds in construction and under repair. Weld ductility, ease of fabrication, high strength and slow aging response are the main advantages of the alloy.

For welding, Nicrofer 5219 Nb should be free from scale, grease and markings. When welding the root, care should be taken to achieve best-quality root backing (argon 99.99), so that the weld is free from oxides after welding the root. Any heat tint should be removed preferably by brushing with a stainless steel wire brush while the weld metal is still hot.

Filler metal

For the gas-shielded welding processes, filler metal with the same composition as the base metal is recommended:

Bare electrodes: Nicrofer S 5219 – FM 718
W.-Nr. 2.4667
SG-NiCr19NbMoTi
AWS A5.14: ERNiFeCr-2
BS 2901 Part 5: NA 51

Welding parameters and influences (heat input)

Care should be taken that the work is performed with a deliberately chosen, low heat input as indicated in Table 13 by way of example. Use of the stringer bead technique should be aimed at. Interpass temperature should be kept below 100 °C (212 °F).

The welding parameters should be monitored as a matter of principle.

The heat input Q may be calculated as follows:

$$Q = \frac{U \times I \times 60}{v \times 1000} \text{ (kJ/cm)}$$

U = arc voltage, volts
I = welding current, amps
v = welding speed, cm/min.

Consultation with ThyssenKrupp VDM's Welding Laboratory is recommended.

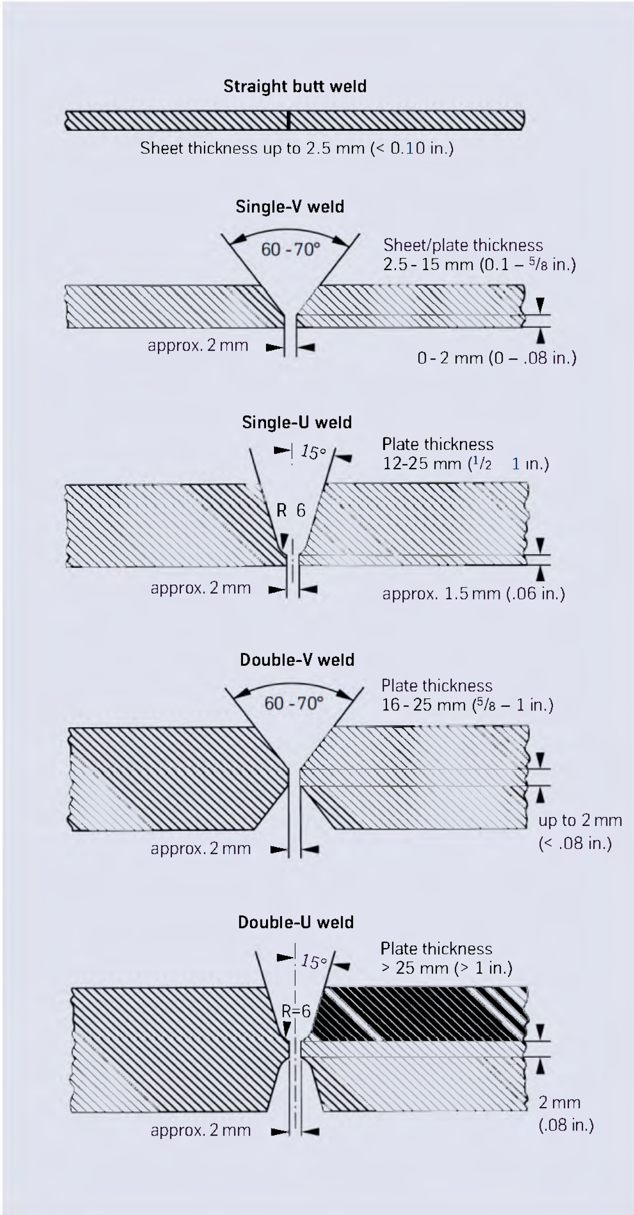


Fig. 6 – Edge preparation for welding of nickel-base alloys and special stainless steels.

Sheet/ plate thick-ness mm	Welding process	Filler metal Diameter mm	Speed m/min.	Welding parameters Root pass A	V	Intermediate and final passes A	V	Welding speed cm/min.	Flux/ shielding gas rate l/min.	Plasma-gas rate l/min.	Plasma-nozzle diameter mm
3.0	Manual GTAW	2.0		90	10	110 – 120	11	10 – 15	Ar W3[1] 8 – 10		
6.0	Manual GTAW	2.0 – 2.4		100 – 110	10	120 – 130	12	10 – 15	Ar W3[1] 8 – 10		
8.0	Manual GTAW	2.4		110 – 120	11	130 – 140	12	10 – 15	Ar W3[1] 8 – 10		
10.0	Manual GTAW	2.4		110 – 120	11	130 – 140	12	10 – 15	Ar W3[1] 8 – 10		
3.0	Autom. GTAW	1.2	0.5	manual		150	10	25	Ar W3[1] 15 – 20		
5.0	Autom. GTAW	1.2	0.5	manual		150	10	25	Ar W3[1] 15 – 20		
4.0	Plasma arc	1.2	0.5	165	25			25	Ar W3[1] 30	Ar W3[1] 3.0	3.2
6.0	Plasma arc	1.2	0.5	190 – 200	25			25	Ar W3[1] 30	Ar W3[1] 3.5	3.2
8.0	MIG GMAW	1.0	approx. 8	GTAW		130 – 140	23 – 27	24 – 30	argon 18 – 20		
10.0	MIG GMAW	1.2	approx. 5	GTAW		130 – 150	23 – 27	20 – 26	argon 18 – 20		

[1] Argon or argon + max. 3 % hydrogen
In all gas-shielded welding operations, ensure adequate back shielding.
These figures are only a guide and are intended to facilitate setting of the welding machines.

Table 12 – Welding parameters (guide values).

Welding process	Heat input per unit length kJ/cm
GTAW, manual, fully mechanised	max. 8
GMAW, manual, fully mechanised	max. 11
Plasma arc	max. 10

Table 13 – Heat input per unit length (guide values).

Postweld treatment
(brushing, pickling and thermal treatments)

Brushing with a stainless steel wire brush immediately after welding, i.e. while the metal is still hot generally results in removal of oxidation as a result of heat tint and produces the desired surface condition without additional pickling.

Pickling, if required or prescribed, however, would generally be the last operation performed on the weldment. Also refer to the information on **'Descaling and pickling'**.

Neither pre- nor postweld thermal treatments are required.

Nicrofer® 5219 Nb – alloy 718

Availability
Nicrofer 5219 Nb is available in the following standard product forms:

Sheet & plate
(for cut-to-length availability, refer to strip)

Conditions:
hot or cold rolled (hr, cr),
thermally treated and pickled

Thickness mm	hr / cr	Width[1] mm	Length[1] mm
1.10 – < 1.50	cr	2000	8000
1.50 – < 3.00	cr	2500	8000
3.00 – < 7.50	cr / hr	2500	8000
7.50 – ≤ 25.00	hr	2500	8000[2]
> 25.00[1]	hr	2500[2]	8000[2]

inches		inches	inches
0.043 – < 0.060	cr	80	320
0.060 – < 0.120	cr	100	320
0.120 – < 0.300	cr / hr	100	320
0.300 – ≤ 1.000	hr	100	320[2]
> 1.000[1]	hr	100[2]	320[2]

[1] other sizes subject to special enquiry
[2] depending on piece weight

Discs and rings
Conditions:
hot rolled or forged,
thermally treated,
pickled or machined

Product	Weight kg	Thickness mm	o. d.[1] mm	i. d.[1] mm
Disc	≤ 10000	≤ 300	≤ 3000	
Ring	≤ 3000	≤ 200	≤ 2500	on request

	lbs	inches	inches	inches
Disc	≤ 22000	≤ 12	≤ 120	
Ring	≤ 6600	≤ 8	≤ 100	on request

[1] other sizes subject to special enquiry

Rod & bar
Conditions:
forged, rolled, drawn,
thermally treated (solution annealed and age-hardened),
pickled, machined, peeled or ground

Product	Forged[1] mm	Rolled[1] mm	Drawn[1] mm
Rod (o. d.)	≤ 203	8 – 60	< 50
Bar, square (a)	40 – 175 (< 250)[2]	15 – 175	not standard

	inches	inches	inches
Rod (o. d.)	≤ 8	5/16 – 2 3/8	< 2
Bar, square (a)	1 5/8 – 7 (< 10)[2]	10/16 – 7	not standard

[1] other sizes and conditions subject to special enquiry
[2] forging stock (available only with chemical analysis certificate)

Forgings

Shapes other than discs, rings, rod and bar are subject to special enquiry. Flanges and hollow shafts may be available up to a piece weight of 2 t.

Strip[1]

Conditions:
cold rolled,
thermally treated and pickled or bright annealed

Thickness mm	Width[3] mm	Coil i. d. mm			
0.02 – ≤ 0.10	4 – 200[4]	300	400		
> 0.10 – ≤ 0.20	4 – 350[4]	300	400	500	
> 0.20 – ≤ 0.25	4 – 750		400	500	600
> 0.25 – ≤ 0.60	6 – 750		400	500	600
> 0.60 – ≤ 1.0	8 – 750		400	500	600
> 1.0 – ≤ 2.0	15 – 750		400	500	600
> 2.0 – ≤ 3.0 (≤ 3.5)[2]	25 – 750		400	500	600

inches	inches	inches			
0.0008 – ≤ 0.004	0.16 – 8[4]	12	16		
> 0.004 – ≤ 0.008	0.16 – 14[4]	12	16	20	
> 0.008 – ≤ 0.010	0.16 – 30		16	20	24
> 0.010 – ≤ 0.024	0.24 – 30		16	20	24
> 0.024 – ≤ 0.040	0.32 – 30		16	20	24
> 0.040 – ≤ 0.080	0.60 – 30		16	20	24
> 0.080 – ≤ 0.120 (≤ 0.140)[2]	1.0 – 30		16	20	24

[1] Cut-to-length available in lengths from 250 to 4000 mm (10 to 158 in.)
[2] Maximum thickness: bright annealed – 3 mm (0.120 in.); cold rolled only – 3.5 mm (0.140 in.)
[3] Wider widths subject to special enquiry. For semi-fabricated products to AMS specification requiring electro slag remelting (ESR) or vacuum arc remelting (VAR) the maximum width is 600 mm (24 in.)
[4] Wider widths up to 730 mm (29 in.) subject to special enquiry

Wire

Conditions:
bright drawn, 1/4 hard to hard,
bright annealed

Dimensions:
0.01 – 12.0 mm (0.0004 – 0.47 in.) diameter,
in coils, pay-off packs, on spools and spiders

Welding filler metals

Suitable welding rods and wire are available in standard sizes.

Seamless tube and pipe

Using ThyssenKrupp VDM cast materials seamless tubes and pipes are produced and available from DMV STAINLESS SAS, Tour Neptune, F-92086 Paris, La Défense Cedex (Fax: +33-1-4796 8141; Tel.: +33-1-4796 8140; E-mail: dmv-hq@dmv-stainless.com).

Welded tube and pipe

Welded tubes and pipes are obtainable from qualified manufacturers using ThyssenKrupp VDM semi-fabricated products.

As updates of data sheets are not automatically send out, when issued, ThyssenKrupp VDM recommends to ***request the latest edition of required data sheets either by phone +49 (0)2392 55-2493, by fax +49 (0)2392 55-2111 or by E-mail under info@tks-vdm.thyssenkrupp.com.***

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