Nicrofer® 3718/3718 So* – alloy DS*

Material Data Sheet No. 4002
August 1997 Edition

High-temperature alloys

A company of ThyssenKrupp Stainless

ThyssenKrupp VDM

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Nicrofer® 3718/3718 So* – alloy DS*

Nicrofer 3718 and 3718 So* are nickel-iron-chromium solid-solution alloys with the addition of approximately 2% silicon.

Nicrofer 3718 and 3718 So* are characterized by:

- good oxidation and scale resistance
- excellent resistance to carburisation and to alternating carburising and oxidising atmospheres
- good mechanical properties with high strength at elevated temperatures.

Designations and standards

Country National standards	Material designation	Specification							
		Chemical composition	Tube and pipe		Sheet and plate	Rod and bar	Strip	Wire	Forgings
			seamless	welded					
D SEW	**W.-Nr. 1.4864** X12NiCrSi36-16 **W.-Nr. 1.4862** X8NiCrSi38-18* **W.-Nr. 1.4864**	470	310/470	310/470	310/470	310/470	310/470	310/470	310/470
F AFNOR	Z12NCS35.16 Z12NCS37.18*								
UK BS	NA 17*		3074		3072	3076	3073	3075	
USA	N08330	is the corresponding material. Differences from previously mentioned SEW, AFNOR, BS are mainly in the contents of Si = 0.75 – 1.50%, Pb ≤ 0.005% and Sn ≤ 0.025%							
ISO									

Table 1 – Designations and standards.

Chemical composition

Alloy		Ni	Cr	Fe	C	Mn	Si	Cu	Ti	P	S
Nicrofer 3718	min	34.0	15.0	bal			1.0				
	max	37.0	17.0		0.15	2.0	2.0		0.20	0.040	0.020
Nicrofer 3718 So*	min	35.0	17.0	bal		0.8	1.9				
	max	39.0	19.0		0.10	1.5	2.5	0.50	0.20	0.030	0.030

Table 2 – Chemical composition (wt.-%).

Physical properties

Density	8.0 g/cm³	0.29 lb/in.³
Melting range	1330 – 1400 °C	2430 – 2550 °F
Permeability at 20 °C/68 °F (RT)	1.01	

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 / m K	Btu in. / ft² h °F	µ Ω cm	Ω circ mil / ft	kN / mm²	10³ ksi	10⁻⁶ / K	10⁻⁶ / °F
– 100	– 148	394						201		13.6	
– 73	**– 100**		0.102						28.8		
0	32	467	0.112					196	28.4		
20	**68**	472	0.113	11.4	79	104	623	194	28.2		
93	**200**		0.120		89		640		27.4		8.3
100	212	501		12.8		107		189		15.1	
200	392	525		14.6		111		183		15.7	
204	**400**		0.126		102		665		26.6		8.7
300	572	532		16.3		114		177		16.2	
316	**600**		0.128		115		688		25.5		9.0
400	752	555		17.9		117		170		16.6	
427	**800**		0.134		127		706		24.4		9.3
500	932	582		19.5		119		163		17.0	
538	**1000**		0.142		140		723		23.2		9.5
600	1112	604		21.0		122		156		17.4	
649	**1200**		0.145		151		736		22.1		9.8
700	1292	610		22.6		123		149		17.7	
760	**1400**		0.146		164		748		20.9		10.0
800	1472	609		24.1		125		141		18.0	
871	**1600**		0.146		174		760		19.8		10.1
900	1652	615		25.6		127		134		18.3	
982	**1800**		0.152		187		766		18.7		10.3
1000	1832	641		27.0		129		127		18.6	

Table 3 – Typical physical properties at room and elevated temperatures.

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Mechanical properties
The following mechanical properties are applicable to Nicrofer 3718/3718 So* in the annealed and solution treated condition.

Temperature T		0.2% Yield strength		1.0% Yield strength		Tensile strength Rm		Elongation A5	Hardness Brinell
°C	°F	N/mm²	ksi	N/mm²	ksi	N/mm²	ksi	min %	HB max
20	**68**	285	41.3	310	45.0	650	94.3	30	210
93	**200**		39.1		42.8		92.1		
100	212	265		290		630		30	
200	392	240		265		615		30	
204	**400**		34.8		38.4		89.2		
300	572	220		250		605		30	
316	**600**		31.2		35.5		87.0		
400	752	210		235		590		30	
427	**800**		29.7		33.4		84.1		
500	932	200		225		555		30	
538	**1000**		29.0		31.9		76.9		
600	1112	195		215		480		30	
649	**1200**		27.6		29.7		60.9		
700	1292	175		190		340		30	
760	**1400**		21.8		23.2		37.0		
800	1472	135		145		210		30	
871	**1600**		14.5		16.7		20.3		
900	1652	85		100		120			
982	**1800**		7.3		8.7		13.0		
1000	1832	48		55		80			

Table 4 – Typical short-time properties at room and elevated temperatures, annealed at 1020 °C (1870 °F).

Temperature T		Creep strength Rp 1.0/10⁴ h		Rp 1.0/10⁵ h		Creep rupture strength Rm/10⁴ h		Rm/10⁵ h	
°C	°F	N/mm²	ksi	N/mm²	ksi	N/mm²	ksi	N/mm²	ksi
600	1112	80		40		125		75	
649	**1200**		7.7		3.6		10.3		6.2
700	1292	35		14		45		25	
760	**1400**		3.1		1.0		4.1		2.0
800	1472	15		4		20		7	
871	**1600**		1.1		0.22		1.6		0.52
900	1652	5		1.5		8		3	
982	**1800**								0.23
1000	1832	(3)				(4)		1.5	

Table 5 – Typical creep properties at elevated temperatures, solution treated at 1150 °C (2100 °F).

Metallurgical structure
Nicrofer 3718 and 3718 So* are solid solution alloys with small amounts of precipitated titanium nitride and carbide as well as carbonitrides in the austenitic matrix.

Corrosion resistance
The nickel-chromium-iron alloys Nicrofer 3718 and 3718 So* containing about 2% silicon are general-purpose heat-resisting materials. They have good oxidation resistance up to about 1000 °C (1850 °F), particularly under cyclic conditions of heating and cooling. They also have excellent resistance to carburisation and are widely used in industry under such conditions. Their resistance to nitrogen-containing atmospheres where oxygen content is low makes them suitable for environments such as cracked ammonia.

Due to its higher chromium and silicon contents, Nicrofer 3718 So* is in every respect superior to the standard alloy Nicrofer 3718.

Oxidation
Nicrofer 3718 and 3718 So* have good oxidation resistance and resist scale formation up to about 1000 °C (1850 °F). Any scale which is formed is tightly adherent, particularly under cyclic conditions of heating and cooling.

Carburisation
The alloys have excellent resistance to carburisation and are therefore widely used in industry under carburising conditions. In an alternating carburising and oxidising atmosphere, excellent resistance is shown to the phenomenon known as “green rot”.

Nitriding
Nicrofer 3718 and 3718 So* have good resistance to nitrogen-containing atmospheres where the oxygen content is low, i.e. in cracked ammonia.

Sulphidation
Resistance to sulphidation is better under oxidising than under reducing condition. Sulphide scale has a tendency to flake and spall and does not have the protective action of an oxide scale.

It must be repeated that, due to its higher chromium and silicon contents, Nicrofer 3718 So* alloy is in every respect superior to the standard Nicrofer 3718 grade.

Applications
Nicrofer 3718 and 3718 So* find wide application in high-temperature processes:
- fans operating at high temperatures in carburising furnaces – resisting carburisation
- boxes and baskets used in carburising – resisting carburisation and showing weight savings when compared with cast boxes
- hangers, hooks and conveyor chains used to carry vitreous-enamelled components during firing – resisting oxide spalling so that oxide does not fall on the enamel
- combustion tubes – resisting oxidation to carburisation and alternating oxidising and carburising conditions
- jigs and fixtures used in furnace brazing and wire mesh belts to carry components in heat-treatment processes
- thermocouple sheaths – resisting carburisation and nitriding
- flare-stack tips – resisting alternating conditions
- components handling cracked ammonia

Fabrication and heat treatment
Nicrofer 3718 and 3718 So* are formed by established commercial hot and cold working techniques and are joined to themselves or many other metals by common welding processes such as manual metal-arc and TIG.

Heating
It is very important that the workpiece be clean and free from any contaminant before and during heating.

Nicrofer 3718 and 3718 So* may become embrittled if heated in the presence of contaminants such as sulphur, phosphorus, lead and other low-melting-point metals. Sources of contamination include marking and temperature-indicating paints and crayons, lubricating grease and fluids, and fuels. Fuels must be low in sulphur; e.g. natural and liquefied petroleum gases should contain less than 0.1% by mass, and town gas 0.25 g/m^3 maximum, of sulphur. Fuel oils containing no more than 0.5% by mass of sulphur are satisfactory.

The furnace atmosphere should be neutral to slightly oxidising and must not fluctuate between oxidising and reducing. Flame impingement on the metal must be avoided.

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Hot working
Nicrofer 3718 and 3718 So* may be hot-worked in the range 1150 to 950 °C (2100 to 1740 °F). Cooling should be by water quenching or as fast as possible.

Annealing is recommended after hot working to ensure maximum corrosion resistance and optimum structure.

The material may be charged into the furnace at maximum working temperature.

Cold working
Cold working should be carried out on annealed material. Nicrofer 3718 and 3718 So* have a similar work-hardening rate compared to austenitic stainless steel and the forming equipment must be adapted accordingly.

When cold working is performed, interstage annealing may become necessary.

After cold reduction of more than 15%, final annealing is required before use, in so far as the creep-strength is important.

Bending property and formability is given even with oxidised sheets. Nevertheless the bending radius should be 3 times sheet thickness.

Heat treatment
Annealing should be carried out in the temperature range 1020 to 1120 °C (1870 to 2050 °F).
Water quenching is essential for maximum creep resistance.

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

Descaling
High-temperature alloys form a protecting oxide layer in service. Therefore the necessity of descaling should be checked.

Oxides of Nicrofer 3718 and 3718 So* and discoloration adjacent to welds, are more adherent than on stainless steels. Grinding with very fine abrasive belts or discs is recommended.

If pickling is necessary – as usual with high-temperature alloys – pickling time must be as short as possible.

Before pickling in a nitric/hydrofluoric acid mixture, oxides must be broken up by grit-blasting, fine grinding or by pre-treatment in a fused salt bath.

Machining
Nicrofer 3718 and 3718 So* should be machined in the annealed condition. As the alloys are susceptible to work-hardening, a low cutting speed should be used and tools should be engaged at all times. Heavy feeds are important in getting below the work-hardened ‘skin’.

Advice on welding
When welding nickel 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 is worked. Maximum cleanliness, partitions, and avoidance of draughts are required.

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

Tools and machinery
The tools should be used only for nickel alloys and stainless steels; 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 surface of the metal with ferrous material.

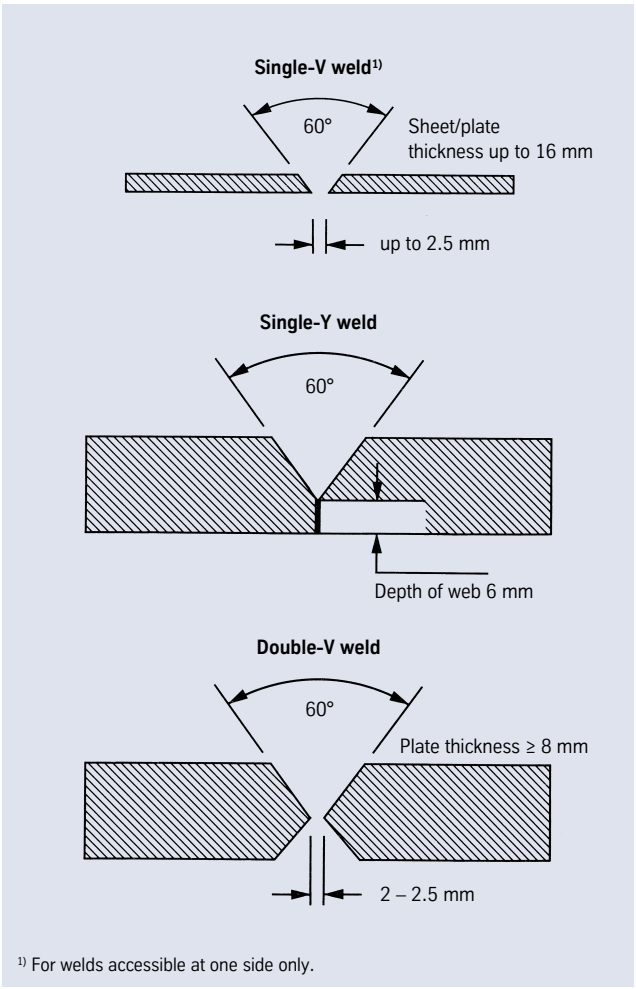
Cleaning
Cleaning of the base metal in the weld area (both sides) and of the filler metal (e.g. welding rod) should be carried out with ACETONE.

Trichloroethylene (TRI), perchloroethylene (PER), or carbon tetrachloride (TETRA) must **not** be used.

Edge preparation
Preferably by mechanical means, i.e. turning, milling or planing; plasma cutting is also possible. However, in the latter case the cut edge (the face to be welded) must be cleanly finished. Careful grinding without overheating is permissible.

Included angle
The different physical behaviour of nickel alloys and special stainless steels compared with carbon steel generally manifests itself in a lower thermal conductivity and a higher rate of thermal expansion.

For welding of Nicrofer 3718/3718 So* it should be allowed for by means of, among other things, wider root gaps or openings 1 – 3 mm, while an included angle of 60° is obligatory due to the low viscosity of the weld metal and the low shrinkage.



1) For welds accessible at one side only.

Fig. 1 – Edge preparation for welding of Nicrofer 3718/3718 So (exemplary).*

Striking the arc
The arc should only be struck in the weld area, e.g. on the faces to be welded or on a run-off-strip, not on the surface of the metal. Strike marks lead to corrosion.

Postweld treatment (pickling and brushing)
Pickling, if required or prescribed, is generally the last operation performed on the weldment. In such a case, the work should be carried out by specialized firms. Consultation with our specialists is strongly recommended. If the workmanship is of the highest quality, brushing immediately after welding, i.e. while the metal is still hot, can often produce the desired surface condition, i.e. heat tints can be completely removed.

Only fine grinding with clean belts or wheels should be considered, and where possible should be followed by pickling/passivation.

Joining
Nicrofer 3718 and 3718 So* can be welded by GTAW, plasma arc and SMAW processes.

Prior to welding, material should be in the annealed condition, clean and free from scale, grease, marking paints etc. A zone approximately 25 mm (1 in) wide on each side of the joint should be ground to bright metal.

Interpass temperature should not exceed 150 °C (300 °F).

Neither pre- nor post-weld heat treatment is required.

The following welding products are recommended:

GTAW/ Plasma arc	Nicrofer S 7020	W.-Nr. 2.4806 SG-NiCr20Nb AWS A 5.14 ERNiCr-3
SMAW		W.-Nr. 2.4648 EL-NiCr19Nb AWS A 5.11 ENiCrFe-3

For optimum corrosion resistance argon-arc welding, i.e. GTAW is preferred.

Nicrofer 3718 and 3718 So* can be welded to a variety of dissimilar metals. In general, the electrodes and filler metals referred to above are used.

Welding parameters and influences (heat input)
Care should be taken to ensure that the work is performed with a low heat input (see table 6). Attention is also drawn to correct selection of the wire and stick electrode diameters. The welding parameters should be monitored as a matter of principle.

Sheet/ plate thick-ness mm	Welding process	Filler metal dia-meter mm	Welding parameters Root pass A	V	Intermediate and final passes A	V	Welding speed cm/min	Heat input per unit length kJ/cm	Plasma-gas/ rate l/min
2.0	Manual GTAW	2.0	70	9			approx. 12	max. 8	Ar 99.99 8
6.0	Manual GTAW	2.0–2.4	90	10	110	11	approx. 12	max. 10	Ar 99.99 8
12.0	Manual GTAW	2.4	100	10	110	11	approx. 12	max. 10	Ar 99.99 8
4.0	Plasma arc	1.0–1.2	165	25			approx. 25	max. 12	Ar 99.99 3
6.0	Plasma arc	1.0–1.2	190–200	25			approx. 25	max. 12	Ar 99.99 3.5
8.0	SMAW Manual GTAW	2.5–3.25 2.4	90	10	60–80	approx. 24	approx. 25	max. 6.5	
12.0	SMAWnd Manual GTAW	2.5–3.25 2.4	90	10	60–80	approx. 24	approx. 25	max. 6.5	

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 6 – Welding parameters (guide values)

Availability
Nicrofer 3718 and 3718 So* are available in all standard mill product forms.

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

Conditions:
hot or cold rolled (hr, cr),
heat treated and oxidised or descaled

Thickness mm		hr/cr	Width* mm	Length* mm
1.10	< 1.50	cr	2000	6000
≥ 1.50	< 6.0	cr	2500	8000
≥ 6.0	< 10.0	cr	2500	8000
≥ 6.0	< 10.0	hr	2500	8000
≥ 10.0	< 20.0	hr	3000	8000
≥ 20.0*		hr		

inches		hr/cr	inches	inches
0.043	< 1/16	cr	80	240
≥ 1/16	< 1/4	cr	100	320
≥ 1/4	< 3/8	cr	100	320
≥ 1/4	< 3/8	hr	100	320
≥ 3/8	< 3/4	hr	120	320
≥ 3/4*		hr		

* other sizes subject to special enquiry

Forgings
Shapes other than discs, rings, rod and bar are subject to special enquiry.

Discs and rings
Conditions:
hot rolled or forged,
heat treated and oxidised or descaled
or machined

Product	Weight kg	Thickness mm	O D* mm	I D* mm
Disc	≤ 4000	≤ 300	≤ 3000	–
Ring	≤ 3000	≤ 200	≤ 2500	on request

	lb	inches	inches	inches
Disc	≤ 8800	≤ 12	≤ 120	–
Ring	≤ 6600	≤ 8	≤ 100	on request

* other sizes subject to special enquiry

Rod and bar
Conditions:
forged, rolled, drawn,
heat treated and oxidised or descaled,
machined, peeled or ground

Product		forged* mm	rolled* mm	drawn* mm
round	d	≤ 300	8 – 75	12 – 65
square	a	40 – 300	15 – 100	12 – 65
flat a x b		40 – 80 x 200 – 600	5 – 20 x 120 – 600	10 – 20 x 30 – 80
hexagon	s	25 – 80	13 – 50	12 – 60

		inches	inches	inches
round	d	≤ 12	0.32 – 3	1/2 – 2 1/2
square	a	1 5/8 – 12	0.60 – 4	1/2 – 2 1/2
flat a x b		1 5/8 – 3 1/8 x 8 – 24	3/16 – 3/4 x 5 – 24	3/8 – 3/4 x 1 1/4 – 3 1/8
hexagon	s	1 – 3 1/8	1/2 – 2	1/2 – 2 3/8

* other sizes subject to special enquiry

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Strip*
Conditions:
cold rolled,
heat treated and oxidised or descaled
or bright annealed**

Thickness mm	Width mm	Coil I D mm			
0.04 ≤ 0.10	4 – 200	300	400		
> 0.10 ≤ 0.20	4 – 350	300	400	500	
> 0.20 ≤ 0.25	4 – 750		400	500	600
> 0.25 ≤ 0.60	5 – 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	25 – 750		400	500	600

inches	inches	inches			
0.0016 ≤ 0.004	0.16 – 8	12	16		
> 0.004 ≤ 0.008	0.16 – 14	12	16	20	
> 0.008 ≤ 0.010	0.16 – 30		16	20	24
> 0.010 ≤ 0.024	0.20 – 30		16	20	24
> 0.024 ≤ 0.04	0.32 – 30		16	20	24
> 0.04 ≤ 0.08	0.60 – 30		16	20	24
> 0.08 – 0.12	1.0 – 30		16	20	24

* cut-to-length available in lengths from 500 to 3000 mm (20 to 120 in)
** maximum thickness 3.0 mm (⅛ in)

Wire
Conditions:
bright drawn, ¼ hard to hard
bright annealed

Dimensions:
0.01 – 12.7 mm (0.004 – ½ in) diameter
in coils, pay-off packs, on spools and spiders

Seamless tube and pipe
Using ThyssenKrupp VDM cast materials seamless tubes and pipes are produced and available from DMV STAINLESS Int. Sales, Tour Neptune, F-92086 Paris, La Défense Cedex (Fax: +33-1-4796 8126; Tel.: +33-1-4796 8128).

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

August 1997 Edition.

This edition supersedes material data sheet no. 4002, dated April 1989.

ThyssenKrupp VDM GmbH
Plettenberger Strasse 2
58791 Werdohl
P.O. Box 18 20
58778 Werdohl
Germany
Phone: +49 (23 92) 55 - 0
Fax: +49 (23 92) 55 - 22 17
E-Mail: info@tks-vdm.thyssenkrupp.com
www.thyssenkruppvdm.com