Nicrofer® 4722 Co – alloy X

Material Data Sheet No. 4016
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High-temperature alloy

A company of ThyssenKrupp Stainless

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Nicrofer® 4722 Co – alloy X

The high-temperature alloy Nicrofer 4722 Co is a matrix stiffened nickel-chromium-molybdenum-iron alloy with cobalt and tungsten additions.

Nicrofer 4722 Co is characterized by:

- excellent oxidation resistance up to 1200 °C (2190 °F)
- high-temperature strength
- good formability and weldability
- good resistance to stress corrosion cracking

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 WL	W.-Nr. 2.4665 NiCr22Fe18Mo				Teil 1	Teil 2	Teil 1	Teil 3	Teil 2
F AFNOR	NC22FeD				AIR 9165	AIR 9165			AIR 9165
UK BS					HR 204	HR 6	HR 204	2901 NA 40	HR 6
USA ASTM ASME ASME Code Case AMS	UNS N06002		B 622 SB 622 5587	B 619, 626 SB 619, 626 5588	B 435 SB 435 5536	B 572 SB 572 5754	B 435 SB 435 5536	 5798	 5754
ISO	NiCr21Fe18Mo9								

Table 1 – Designations and standards.

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Co	Mo	Al	W	P	S	B
min.	bal.	20.5	17.0	0.05			0.5	8.0		0.2			
max.		23.5	20.0	0.15	1.0	1.0	2.5	10.0	0.10	1.0	0.015	0.010	0.005

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

Physical properties

Density	8.3 g/cm³	0.30 lb/in.³
Melting range	1260 – 1355 °C	2300 – 2470 °F
Permeability at 20 °C/68 °F (RT)	≤ 1.002	

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
0	32										
20	68	435	0.104	11.3	78	115	692	205	29.7		
93	200		0.105		87		704		29.1		7.5
100	212	440		12.7		117		201		13.6	
200	392	460		14.5		119		195		13.9	
204	400		0.110		101		716		28.1		7.7
300	572	485		16.2		121		189		14.3	
316	600		0.117		114		731		27.3		8.0
400	752	510		17.9		123		182		14.6	
427	800		0.123		127		743		26.1		8.2
500	932	540		19.5		125		176		14.9	
538	1000		0.131		139		758		25.1		8.4
600	1112	570		21.2		127		168		15.2	
649	1200		0.140		153		758		23.8		8.6
700	1292	605		22.8		127		161		15.6	
760	1400		0.148		166		758		22.6		8.8
800	1472	640		24.6		127		153		15.9	
871	1600		0.159		180		770		21.3		9.0
900	1652	675		26.4		128		145		16.3	
982	1800		0.170		193		776		19.7		9.2
1000	1832	715		28.2		129		135		16.7	

Table 3 – Typical physical properties at room temperature or as indicated.

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Mechanical properties

The following properties are applicable to Nicrofer 4722 Co in the solution-treated condition and the indicated size ranges. Acceptance of properties of material outside these size ranges is subject to special enquiry.

Form	Dimension N/mm²	Dimension ksi	Tensile strength N/mm²	Tensile strength ksi	Yield strength 0.2 % $R_{p0.2}$ N/mm²	Yield strength 0.2 % $R_{p0.2}$ ksi	Yield strength 1.0 % $R_{p1.0}$ N/mm²	Yield strength 1.0 % $R_{p1.0}$ ksi	Elongation A_5 %	Brinell hardness HB
Sheet, strip	≤ 4.75	≤ 3/16	725	105	310	45			30	
Plate	> 4.75	> 3/16	690	100	275	40				
Tube, pipe	≤ 90	≤ 3 1/2	690	100	275	40			35	
Rod, bar	≤ 100	≤ 4	660	95	240	35				

Table 4 – Minimum mechanical properties at room temperature, according to ASTM, AMS and BS.

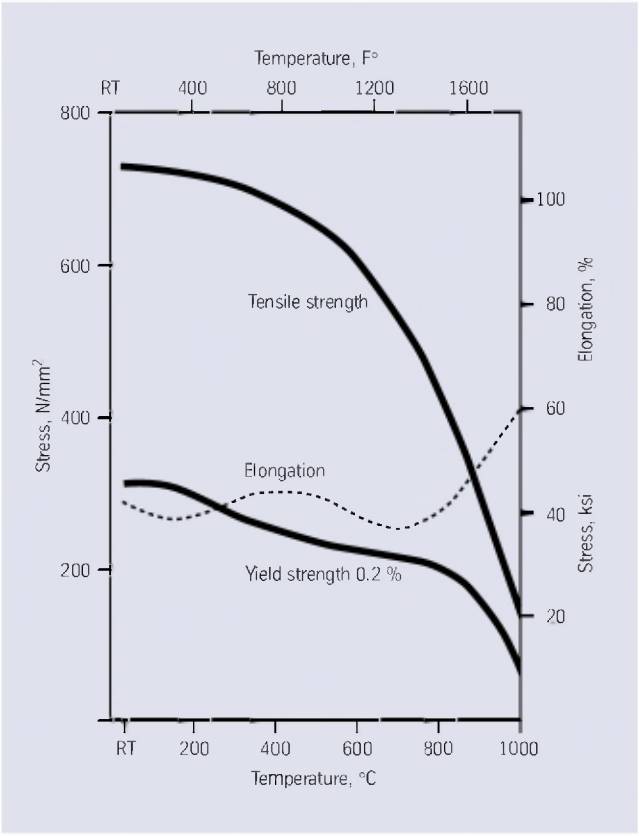

Fig. 1 – Typical short-time mechanical properties at room and elevated temperatures.

Stress-rupture requirements at 815 °C (1500 °F)

Stress: 110 N/mm² (16 ksi)
Time: min. 23 hrs
Elongation: min. 8 %

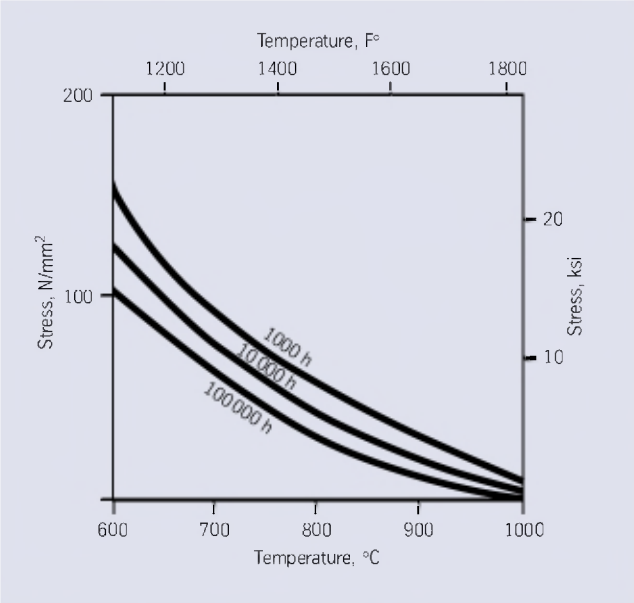

Fig. 2 – Typical creep-strain properties of Nicrofer 4722 Co (solution-treated).

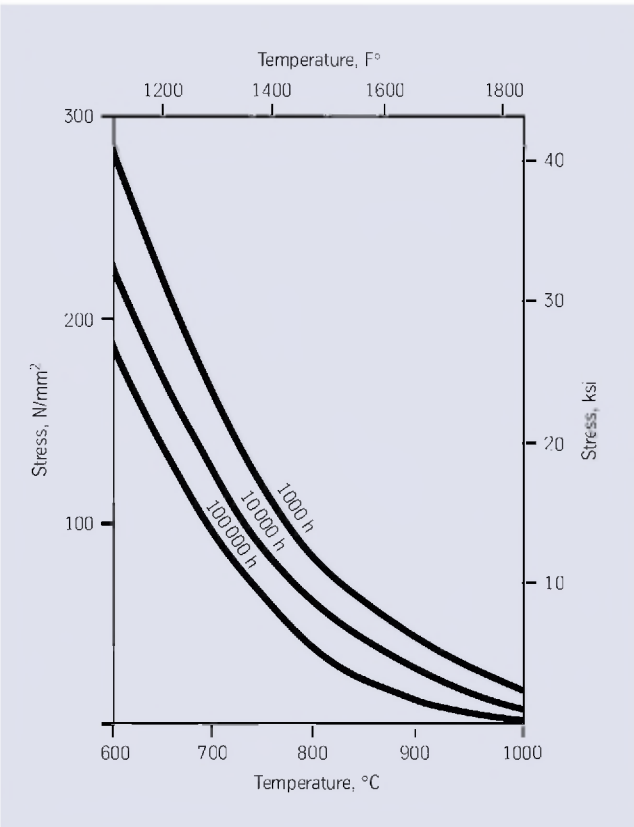

Fig. 3 – Typical creep-rupture properties of Nicrofer 4722 Co (solution-treated).

Temperature °C	°F	Maximum allowable stress N/mm² 1)	1) 2)	ksi	2)
	100			23.3	23.3
	200			20.9	23.3
100		143	161		
	300			19.2	23.3
200		124	158		
	400			17.8	22.9
	500			16.5	22.3
300		109	148		
	600			15.6	21.1
	700			15.0	20.3
400		102	138		
	800			14.7	19.8
	900			14.5	19.6
500		100	135		
	1000			14.3	19.3
	1100			14.2	17.5
600		97	117		
	1200			11.6	11.3
700		55	55		
	1300			7.7	7.7
	1400			4.8	4.8
800		25	25		
	1500			3.0	3.0
	1600			1.7	1.7
900	(1650)	8.3	8.3	1.2	1.2

1) values determined by interpolaton 2) conditional stress values (see below)

Table 5 – Maximum allowable stress values in tension according to ASME UNF-23.3, SB 435.

The higher conditional stress values of up to 90 % of the yield strength at temperature may be used for applications in which slightly greater deformation is acceptable. These stresses may result in dimensional changes due to permanent strain and are not recommended for flanges of gasketed joints.

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Metallurgical structure
Nicrofer 4722 Co has a face centered cubic structure. The excellent mechanical strength at high temperatures results from solid solution hardening and precipitated primary and secondary carbides.

Corrosion resistance
Nicrofer 4722 Co shows excellent oxidation resistance up to 1200 °C (2190 °F) and can also be used in neutral as well as in reducing atmospheres. Nicrofer 4722 Co is resistant in carburizing and nitriding atmospheres.

Applications
Due to its corrosion resistance in various atmospheres up to very high temperatures, and excellent high-temperature strength, Nicrofer 4722 Co finds wide application in high-temperature service.

Typical applications are:
- components for industrial and aircraft gas turbines (combustion chambers, honeycombs, housings etc.)
- industrial furnace parts, support rolls, grids, wire belts and radiant tubes
- pigtails in petrochemical furnaces
- high temperature gas cooled nuclear reactors

Fabrication and heat treatment
Nicrofer 4722 Co is easily hot or cold formed and machined by common industrial processes. Hot and cold working, however, require high-power machines, owing to the high strength of the material.

The weldability of Nicrofer 4722 Co is excellent. Joining can be performed by all conventional welding processes.

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

Nicrofer 4722 Co 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/m³ maximum of sulphur. Fuel oils containing no more than 0.5 % by mass sulphur are satisfactory.

Electric furnaces are desirable due to close control of temperature and freedom from contamination. Gas-fired furnaces are acceptable if impurities are at low levels.

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

Hot working
Nicrofer 4722 Co may be hot-worked in the range 1200 to 1000 °C (2190 to 1830 °F). Solution treatment is required after hot working to ensure maximum creep resistance.

For hot working, the material may be charged into the furnace at maximum working temperature. After soaking for the required time the metal should be withdrawn immediately and worked within the specified range. If the metal temperature falls below the minimum working temperature, it must be reheated.

Cold working
Cold working should be carried out on solution-treated material. Nicrofer 4722 Co has a much higher work-hardening rate than austenitic stainless steel and the forming equipment must be designed accordingly.

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

After cold reductions of more than 10 %, more than 5 % for applications at temperatures higher than 900 °C (1650 °F) final solution treatment is required.

Heat treatment
Solution treatment should be carried out in the temperature range 1160 to 1190 °C (2120 to 2175 °F), preferably at about 1175 °C (2150 °F). Water quenching is essential for maximum creep resistance. Below 1.5 mm (0.06 in.) thickness rapid air cooling is practicable.

Stress-relief annealing may be performed at temperatures up to 870 °C (1600 °F).

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

Descaling
Oxides of Nicrofer 4722 Co and discoloration adjacent to welds, are more adherent than on stainless steels. Grinding with very fine abrasive belts or discs is recommended.

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

Machining
Nicrofer 4722 Co should be machined in the solution-treated condition. The alloys high work-hardening rate should be considered, i.e. only low surface cutting speeds are possible compared with low-alloy standard austenitic stainless steel. Tools should be engaged at all times. Heavy feeds are important in getting below the work-hardened 'skin'.

Joining

Nicrofer 4722 Co can be welded by all conventional processes, including gas tungsten-arc (GTAW/TIG), gas metal-arc (GMAW/MIG) and shielded metal-arc welding (SMAW/MMA). Pulsed arc welding is the preferred technique.

Prior to welding, material should be in the solution-treated 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.

Low heat input is necessary. Interpass temperature should not exceed 100 °C (210 °F).

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

The following welding products are recommended:

GTAW/GMAW	Nicrofer S 4722	W.-Nr. 2.4613 SG-NiCr21Fe18Mo AWS A5.14 ERNiCrMo-2
SMAW		AWS A5.11 ENiCrMo-2

Availability

Nicrofer 4722 Co is available in the following standard mill product forms.

Sheet and plate

(for cut-to-length availability, refer to strip)

Conditions:
hot or cold rolled (hr, cr),
solution treated or precipitation hardened and pickled

Thickness mm	hr / cr	Width* mm	Length* mm
1.20 – < 1.50	cr	2000	6000
≥ 1.50 – < 6.0	cr	2400	8000
≥ 6.0 – < 10.0	cr	2400	8000
≥ 6.0 – < 10.0	hr	2400	8000
≥ 10.0 – < 20.0	hr	2400	5000**
> 20.0*	hr		

inches		inches	inches
0.047 – < 0.060	cr	80	240
≥ 0.060 – < 1/4	cr	96	320
≥ 1/4 – < 3/8	cr	96	320
≥ 1/4 – < 3/8	hr	96	320
≥ 3/8 – < 3/4	hr	96	200**
≥ 3/4*	hr		

*other sizes subject to special enquiry
**depending on piece weight

Discs and rings

Conditions:
hot rolled or forged,
solution treated,
pickled or machined

Product	Weight kg	Thickness mm	o. d.* mm	i. d.* mm
Disc	≤ 4000	≤ 300	≤ 2000	–
Ring	≤ 3000	≤ 200	≤ 2500	on request

	lb	inches	inches	inches
Disc	≤ 8800	≤ 12	≤ 80	–
Ring	≤ 6600	≤ 8	≤ 100	on request

*other sizes subject to special enquiry

Rod and bar

Conditions:
forged, rolled, drawn,
solution treated,
pickled, machined, peeled or ground

Product	forged* mm	rolled* mm	drawn* mm
round d	≤ 200	15 – 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
hexagonal s	40 – 80	13 – 50	12 – 60

	inches	inches	inches
round d	≤ 8	5/8 – 3	1/2 – 2 1/2
square a	1 5/8 – 12	5/8 – 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
hexagonal s	1 5/8 – 3 1/8	1/2 – 2	1/2 – 2 3/8

*other sizes subject to special enquiry

Forgings

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

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Strip*
Conditions:
cold rolled,
solution treated and pickled or bright annealed**

Thickness mm	Width mm	Coil i. d. mm				
0.04 – ≤ 0.10	30 – 120	100	300			
> 0.10 – ≤ 0.20	4 – 200		300	400		
> 0.20 – ≤ 0.25	4 – 400		300	400		
> 0.25 – ≤ 0.60	5 – 635		300	400		
> 0.60 – ≤ 1.0	8 – 635			400	500	
> 1.0 – ≤ 2.0	15 – 635			400	500	600
> 2.0 – 3.0	25 – 635			400	500	600

inches	inches	inches				
0.0016 – ≤ 0.004	1.20 – 5	4	12			
> 0.004 – ≤ 0.008	0.16 – 8		12	16		
> 0.008 – ≤ 0.010	0.16 – 16		12	16		
> 0.010 – ≤ 0.024	0.20 – 25		12	16		
> 0.024 – ≤ 0.04	0.32 – 25			16	20	
> 0.04 – ≤ 0.08	0.60 – 25			16	20	24
> 0.08 – 0.12	1.0 – 25			16	20	24

*cut-to-length available in lengths from 500 to 3000 mm (20 to 120 in.)
**maximum thickness 3.0 mm (1/8 in.)

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

Dimensions:
0.01 – 12.7 mm (0.0004 – 1/2 in.) diameter
in coils, pail-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.

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