Nicrofer® 3220 LC/3220 – alloys 800 L/800

Material Data Sheet No. 4028
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ThyssenKrupp VDM GmbH
Plettenberger Straße 2
58791 Werdohl
Postfach 18 20
58778 Werdohl
Telefon: +49 2392 55-0
Telefax: +49 2392 55-2217
E-Mail: vdm@thyssenkrupp.com
www.thyssenkruppvdm.com

Comparison of alloying variations

Temperature range of application	°C	≤ 500	≤ 600	700 – 950	700 – 1000
	°F	≤ 930	≤ 1110	1290 – 1740	1290 – 1830
Advantages		corrosion resistant	corrosion and heat resistant	resistant to oxidation, carburisation, nitriding, good creep rupture properties	
Typical heat treatment at		920 – 980 °C 1690 – 1800 °F	920 – 980 °C 1690 – 1800 °F	1150 °C 2100 °F	1150 – 1200 °C 2100 – 2190 °F
Grain size	µm ASTM	≤ 64 > No. 5	≤ 64 > No. 5	90 – 180 4 – 2	90 – 180 4 – 2
Carbon content	%	≤ 0.025	0.04 – 0.08	0.06 – 0.08	0.06 – 0.10
Ti+Al[1]	%	≤ 1.0	≤ 1.0	≤ 0.7	≤ 1.2
Ductility		very good	good	good	reduced
Nicrofer®		**3220 LC**	**3220**	**3220 H**	**3220 HT**
Werkstoff-Nr.		**1.4558**	**1.4876**	**1.4876**[2] **1.4958**[3]	**1.4959**
DIN		–	17460	17459/17460	17459/17460
SEW		400	470	–	–
VdTÜV – Data Sheet		–	412	434	–
UNS		(N08800)	N08800	N08810	N08811

[1] VDM-Standard
[2] VdTÜV – Data Sheet, edition 01.84 with former W.-Nr. 1.4876
[3] W.-Nr. according to DIN

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Characteristics of Nicrofer® 3220 LC – alloy 800 L

Nicrofer 3220 LC is the fully austenitic low-carbon version of Nicrofer 3220, a nickel-iron-chromium alloy.
It is available with cobalt content restricted to a maximum of 0.01%.

Nicrofer 3220 LC is characterised by:

- outstanding corrosion resistance in aqueous media at extremely high temperatures up to 500 °C (930 °F)
- good resistance to stress-corrosion cracking
- good workability

Characteristics of Nicrofer® 3220 – alloy 800

Nicrofer 3220 is an austenitic, high-strength solid-solution nickel-iron-chromium alloy with controlled levels of carbon, aluminium, titanium, silicon and manganese.

Nicrofer 3220 is characterised by:

- good corrosion and heat resistance
- good mechanical properties at sub-zero, room and elevated temperatures up to 600 °C (1110 °F)
- good resistance to oxidising, reducing and nitriding conditions
- good workability

In the range where resistance to wet corrosion is the main requirement, the low-carbon version Nicrofer 3220 LC is preferred.

Chemical composition (%)

		Ni	Cr	Fe	C	Mn	Si	Cu	Al	Ti	Al+Ti	P	S
Nicrofer 3220 LC – alloy 800 L	min	32.0	20.0	bal.		0.5	0.2		0.15	0.35			
	max	34.0	22.0		0.025	1.0	0.5	0.5	0.40	0.60	0.7	0.015	0.010
Nicrofer 3220 – alloy 800	min	30.0	19.0	bal.	0.04	0.5	0.2		0.20	0.20			
	max	32.0	21.5		0.08	1.0	0.6	0.5	0.40	0.50	0.7	0.015	0.010

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Designation and standards of Nicrofer® 3220 LC – alloy 800 L

Country / National standards	Material designation	Specification							
		Chemical composition	Tube and pipe		Sheet and plate	Rod and bar	Strip	Wire	Forgings
			seamless	welded					
France AFNOR									
Germany	**W.-Nr. 1.4558** X2 NiCrAlTi 32 20								
SEW		400	400	400	400	400	400	400	400
VdTÜV									
United Kingdom									
BS	NA 15*		3074		3072	3076	3073	3075	
USA	(N08800)*								
ASTM			B 407	B 163 B 514/515	B 409	B 408	B 409		B 564
ASME									
AMS									
ISO									

* When Nicrofer 3220 LC is required to BS or ASTM/ASME specifications the carbon content of 0.025% maximum must be stated on the enquiry/order. The mechanical properties of Nicrofer 3220 LC are then valid and differ from those stated in the listed BS and ASTM/ASME specifications.

Designation and standards of Nicrofer® 3220 – alloy 800 (annealed)

Country / National standards	Material designation	Specification							
		Chemical composition	Tube and pipe		Sheet and plate	Rod and bar	Strip	Wire	Forgings
			seamless	welded					
France AFNOR	Z8NC32.21								
Germany	**W.-Nr. 1.4876** X10 NiCrAlTi 32 20								
SEW		470	470	470	470	470	470	470	470
VdTÜV		412	412		412	412	412		412
United Kingdom									
BS	NA 15		3074		3072	3076	3073	3075	
USA	UNS N08800								
ASTM			B 407	B 163 B 514/515	B 409	B 408	B 409		B 564
ASME			SB 407	SB 163 SB 514/515	SB 409	SB 408	SB 409		SB 564
AMS					5871	5766	5871		
ISO	FeNi32Cr21AlTi								

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Physical properties

Typical physical properties at room and elevated temperatures.

Density	8.0 g/cm³	0.29 lb/in³
Melting range	1350–1400 °C	2460–2550 °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	µΩ cm	Ω circ mil / ft	kN/mm²	10³ ksi	10⁻⁶/K	10⁻⁶ / °F
0	32										
20	**68**	455	0.108	11.6	80	98	590	198	28.7		
93	**200**		0.112		89		610		28.1		8.0
100	212	472		13.0		102		193		14.4	
200	392	500		15.0		107		187		15.2	
204	**400**		0.119		104		644		27.1		8.4
300	572	525		16.2		112		180		15.8	
316	**600**		0.126		114		677		25.5		8.8
400	752	550		17.8		116		173		16.2	
427	**800**		0.132		126		704		24.8		9.0
500	932	577		19.2		119		166		16.6	
538	**1000**		0.140		138		722		23.6		9.3
600	1112	605		21.0		122		158		17.0	

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Mechanical properties

The following properties are applicable in the soft-annealed condition and the indicated size ranges. Specified properties of materials outside these size ranges are subject to special enquiry. The values are valid for longitudinal and transverse specimens.

Sheet and strip	up to 3 mm	up to 1/8 in
Sheet and plate	up to 50 mm	up to 2 in
Tube	up to 200 mm dia./ 40 mm wall thickness	up to 8 in dia./ 1 1/2 in wall thick.
Rod, bar, forgings	up to 250 mm	up to 10 in

Temperature		Nicrofer® 3220 LC				Nicrofer® 3220			
		Tensile strength	0.2% Yield strength	1.0% Yield strength	Elong. A_5	Tensile strength	0.2% Yield strength	1.0% Yield strength	Elong. A_5
°C	°F	N/mm²	N/mm²	N/mm²	%	N/mm²	N/mm²	N/mm²	%
RT	RT	450	180	210	35	500	210	240	35
100	212		155	185			185	205	
200	392		140	170			160	180	
300	572		130	160			145	165	
400	752		120	150			130	150	
500	932		100	130			125	145	
600	1112		–	–			115	135	
		according to SEW 400				according to VdTÜV 412			
°C	°F	ksi	ksi	ksi	%	ksi	ksi	ksi	%
RT	**RT**	65.3	26.1	30.5	35	72.5	30.5	34.8	35
93	**200**		22.5	26.8			27.1	30.2	
204	**400**		20.3	24.7			23.2	26.1	
315	**600**		18.6	22.9			20.7	23.6	
426	**800**		16.7	21.0			18.9	22.0	
538	**1000**		(12.8)	(17.4)			17.5	20.6	
593	**1100**		–	–			16.8	19.7	

Table 5 – Minimum mechanical properties at room and elevated temperatures.

ISO-V notch

Average value at RT:

longitudinal ≥ 105 J/cm² (Nicrofer 3220 LC)
transverse ≥ 150 J/cm² (Nicrofer 3220)

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Metallurgical structures

Nicrofer 3220 LC has a face-centred cubic structure. The very low carbon content and the increased Ti: C ratio promote a stabilised structure and maximum resistance to sensitisation and intergranular attack.

Low annealing temperature of about 950 °C (1740 °F) provides fine grain structure.

Nicrofer 3220 is an austenitic, solid solution alloy with face-centred cubic structure. In the mill-annealed condition with final annealing at about 950 °C (1740 °F) the formed TiC is not redissolved. Only a small amount of carbon remains to precipitate as chromium carbide. The low annealing temperature ensures fine grain structure, resulting in high tensile and yield strengths.

Corrosion resistance

Nicrofer 3220 LC is resistant to many corrosive media. In aqueous corrosive conditions its high nickel content, however, gives good resistance to stress-corrosion cracking.

The higher chromium content gives better resistance to pitting and crevice corrosion.

The alloy shows very good resistance to nitric and organic acids, but has only limited resistance to sulphuric and hydrochloric acids.

With the exception of halides, where pitting can occur, good resistance is also shown to oxidising and non oxidising salts. Resistance is also good in fresh water and steam and mixtures of steam, air and carbon dioxide.

Nicrofer 3220 is resistant to many corrosive media. In aqueous corrosive conditions its resistance may be compared to that of austenitic stainless steels. The high nickel content, however, gives good resistance to stress-corrosion cracking. The higher chromium content gives better pitting and crevice corrosion resistance.

The alloy shows very good resistance to nitric and organic acids, but has only limited resistance to sulphuric and hydrochloric acids.

With the exception of halides, where pitting can occur, good resistance is also shown to oxidising and non-oxidising salts. Resistance is also good in fresh water and steam and mixtures of steam, air and carbon dioxide.

At elevated temperatures, excellent resistance is shown to oxidising and carburising atmospheres and to conditions where alternating oxidising and carburising atmospheres occur. Resistance to hydrogen, nitrogen and sulphurous atmospheres is also good. In the latter case resistance is better under oxidising than under reducing conditions.

Applications

- Nitric acid coolers – resistance to nitric acid conditions
- steam super-heater tubing – good mechanical strength and resistance to steam etc
- heating element sheathing – good mechanical strength

For service up to about 500 °C (930 °F) the alloy is supplied in the annealed conditions.

- Heating element sheathing – good mechanical strength
- acetic anhydride cracking tubes – resistance to process conditions

For service up to about 600 °C (1110 °F) the alloy is supplied in the annealed condition. For service at higher temperatures Nicrofer 3220 H in the solution-annealed condition is recommended. See data sheet no. 4029.

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Availability

Nicrofer 3220 LC and 3220 are available in all standard mill products forms.

Sheet and plate

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

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

Thickness mm			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*		hr		

inches			inches	inches
0.043	< 0.060	cr	80	240
≥ 0.060	< 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

Disc and ring

Conditions:
hot rolled or forged,
annealed
pickled or machined

Product	Weight kg	Thickness mm	O D* mm	I D mm
Disc	≤ 10000	≤ 300	≤ 3000	–
Ring	≤ 3000	≤ 200	≤ 2500	on request
	lb	inches	inches	inches
Disc	≤ 22000	≤ 12	≤ 120	–
Ring	≤ 6600	≤ 8	≤ 100	on request

* other sizes subject to special enquiry.

Rod and bar

Conditions:
forged, rolled, drawn,
annealed
pickled, machined, peeled or ground

Product		forged* mm	rolled* mm	drawn* mm
round	d	≤ 350	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	≤ 14	5/16 – 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
hexagon	s	1 – 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, annealed 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 (⅛ in)

Wire

Conditions:
bright drawn, ¼ hard to hard
bright annealed

Dimensions:
0.01 – 12.7 mm (0.0004 – ½ in) diameter
in coils, pay-off packs, on spools and spiders.

Seamless tube and pipe

Conditions:
cold rolled, cold drawn,
bright annealed or annealed and pickled

Outside diameter	12 – 219	mm	½ – 8⅝ in.
Wall thickness	0.5 – 20	mm	0.02 – 0.80 in.
Length max	26	m*	85 ft*

*depending on tube size

Conditions:
hot extruded,
annealed and pickled

Outside diameter	70 – 219	mm	2¼ – 8⅝ in.
Wall thickness	5 – 40	mm	0.20 – 1⅝ in.
Length max	17.5	m*	57 ft*

*depending on tube size

Seam-welded tube and pipe (from strip)

Conditions:
as seam-welded, annealed and pickled
or bright annealed

Outside diameter	12 – 114	mm	½ – 4½ in.
Wall thickness	0.5 – 4.0	mm	0.02 – 0.16 in.
Length max	26	m*	85 ft*

*depending on condition

Seam-welded tube and pipe (from sheet and plate)

Conditions:
as seam-welded or
annealed and pickled

Outside diameter	114 – 1500	mm	4½ – 60 in.
Wall thickness	3 – 15	mm	⅛ – ⅝ in.
Length max	6	m	20 ft

Technical publications

The following publication concerning Nicrofer 3220 LC / 3220 may be obtained from Krupp VDM GmbH:

VDM Report No. 15: "Krupp VDM AG's high temperature alloys and their use in furnace construction".

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Fabrication and heat treatment

Nicrofer 3220 LC and 3220 are readily fabricated by usual industrial procedures. Hot and cold working, however, require high-power machines owing to the high strength of the materials.

Both Nicrofer 3220 LC and 3220 are readily welded. 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 3220 LC and 3220 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 of 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 oxidising and must not fluctuate between oxidising and reducing. Flame impingement on the metal must be avoided.

Hot working

Nicrofer 3220 LC and 3220 may be hot-worked in the range 1200 to 900 °C (2190 to 1650 °F). Cooling should be by water quenching or as fast as possible through the range 760 to 540 °C (1400 to 1000 °F). Hot bending is carried out in the range 1150 to 1000 °C (2100 to 1830 °F).

The material may be charged in the furnace at the maximum working temperature of 1200 °C (2190 °F).

When the furnace has returned to temperature, the material should be soaked for 60 minutes per 100 mm (4 in) of thickness. 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.

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

Cold working

Cold working should be carried out on annealed material. Nicrofer 3220 LC and 3220 have higher work-hardening rates than 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 10%, final soft annealing is required before use.

Heat treatment

Soft annealing should be carried out in the temperature range 920 to 980 °C (1690 to 1800 °F), preferably at about 950 °C (1740 °F). Water quenching is essential for maximum corrosion resistance. Under about 1.5 mm (0.06 in) thickness rapid air cooling is practicable.

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

Descaling

Oxides of Nicrofer 3220 LC and 3220 and discoloration adjacent to welds are more adherent than those of stainless steels. Both mechanical and chemical methods of descaling may be applied. Mechanical methods should be chosen which avoid contamination of the metal, or which produce a highly-deformed surface layer.

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 3220 LC and 3220 should be machined in the annealed condition. The alloys high work-hardening rates 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 3220 LC and 3220 can be welded by all conventional processes, including gas tungsten-arc (GTAW/TIG), gas metal-arc (GMAW/MIG), plasma, submerged-arc and shielded metal-arc welding (SMAW/MMA).

Prior to welding, material should be in the annealed condition, clean and free from scale, grease, marking paints, etc.

Low heat input is necessary. The 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/GMAW	Nicrofer S 7020	W.-Nr. 2.4806 SG-NiCr20Nb AWS A 5.14 ER NiCr-3 BS 2901-NA 35
SMAW		W.-Nr. 2.4648 EL-NiCr19Nb AWS A 5.11 E NiCrFe-3

For Nicrofer 3220 LC only electrodes which do not result in carbon and silicon pick-up, or which keep it to a minimum, should be preferred.

For optimum corrosion resistance, argon-arc welding (GTAW) is preferred. GMAW as well as SMAW welding, using a matching filler metal, are also applicable.

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We reserve the right to make alterations, especially where necessitated by technical developments or changes in availability.
The information contained in this data sheet, which in any case provides no guarantee of particular characteristics, has been compiled to the best of our knowledge but is given without any obligation on our part.

Our liability is determined solely by the individual contract terms, in particular by our general conditions of sale.

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ThyssenKrupp VDM GmbH
Plettenberger Straße 2
58791 Werdohl
Postfach 18 20
58778 Werdohl
Telefon: +49 2392 55-0
Telefax: +49 2392 55-2217
E-Mail: vdm@thyssenkrupp.com
www.thyssenkruppvdm.com