

# Nicrofer<sup>®</sup> 7216 LC – alloy 600 L

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**Corrosion-resistant and high-temperature alloy**



A company of  
ThyssenKrupp  
Stainless

**ThyssenKrupp VDM**

**QUEENSLAND AGENTS:**

Isolthermics Company Australia Pty Ltd

Phone 07 3806 5411

Fax 07 3806 5148

Email [info@isolthermics.com.au](mailto:info@isolthermics.com.au)

Web [www.isolthermics.com.au](http://www.isolthermics.com.au)



ThyssenKrupp

# Nicrofer® 7216 – alloy 600 L

Nicrofer 7216 LC is a special low-carbon version of Nicrofer 7216, with a carbon content limited to a maximum of 0.025%.

Nicrofer 7216 LC is characterized by:

- excellent resistance to intergranular corrosion
- virtual immunity to chloride-ion stress-corrosion cracking, even at elevated temperatures
- very good resistance to high-temperature corrosion in dry chlorine and hydrogen chloride.

## Designations and standards

Country	Material designation	Specification							
		Chemical composition	Tube and pipe		Sheet and plate	Rod and bar	Strip	Wire	Forgings
seamless	welded								
D DIN VdTÜV	W.-Nr. 2.4817 LC-NiCr15Fe	17742	17751		17750	17752	17750		17754
F AFNOR	NC 15 Fe*								
UK BS	NA 14*		3074		3072	3076	3073	3075	
USA ASTM	UNS N06600*		B 167	B 163 B 516/517	B 168	B 166	B 168		B 564
ASME			SB 167	SB 163 SB 516/517	SB 168	SB 166	SB 168		SB 564
ASME Code Case			1827	1827	1827	1827	1827		
ISO	LC-NiCr15Fe8								

\* When Nicrofer 7216 LC is required to AFNOR, BS or ASTM/ASME specifications the carbon content of 0.025 % maximum must be mentioned on the enquiry/order. Also the mechanical properties must be agreed upon as they will differ from those given in the relevant AFNOR, BS and ASTM/ASME specifications.

Table 1 – Designations and standards.

## Chemical composition

	Ni	Cr	FE	C	Mn	Si	Cu	P	S	Al	B	Ti
min.	72.0	14.0	6.0									
max.		17.0	10.0	0.025	1.0	0.5	0.5	0.015	0.010	0.3	0.006	0.3

For nuclear applications material with a limited cobalt content can be supplied on request.

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

## Physical properties

Density	8.4 g/cm <sup>3</sup>	0.30 lb/in. <sup>3</sup>
Melting range	1370 – 1425 °C	2500 – 2600 °F
Permeability at 20 °C / 68 °F (RT)	max 1.01	

Temperature (T)		Specific heat		Thermal conductivity		Electrical resistivity		Modulus of elasticity		Coefficient of thermal expansion between room temperature and T	
°C	°F	$\frac{\text{J}}{\text{kg K}}$	$\frac{\text{Btu}}{\text{lb } ^\circ\text{F}}$	$\frac{\text{W}}{\text{m K}}$	$\frac{\text{Btu in.}}{\text{ft}^2 \text{ h } ^\circ\text{F}}$	$\mu \Omega \text{ cm}$	$\frac{\Omega \text{ circ mil}}{\text{ft}}$	$\frac{\text{kN}}{\text{mm}^2}$	10 <sup>3</sup> ksi	$\frac{10^{-6}}{\text{K}}$	$\frac{10^{-6}}{^\circ\text{F}}$
0	32										
20	68	455	0.108	14.8	103	103	620	214	31.0		
93	200		0.112		109		626		30.5		7.5
100	212	475		15.8		104		209		13.7	
200	392	495		17.0		106		205		14.1	
204	400		0.118		118		638		29.7		7.8
300	572	508		18.4		107		200		14.4	
316	600		0.122		130		647		28.9		8.0
400	752	525		20.0		109		194		14.8	
427	800		0.126		143		650		27.8		8.3
500	932	550		22.0		111		187		15.1	
538	1000		0.132		160		674		26.7		8.4
600	1112	572		24.0		112		180		15.4	
649	1200		0.140		172		674		25.5		8.6
700	1292	602		25.7		112		172		15.8	
760	1400		0.146		186		674		24.2		8.7
800	1472	620		27.5		112		163		16.1	
871	1600		0.150		201		678		22.8		9.0
900	1652	630		29.4		113		153		16.4	
982	1800		0.151		215		683		21.0		9.3
1000	1832	635		31.2		114		143		16.9	

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

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## Mechanical properties

The following properties are applicable to Nicrofer 7216 LC in the annealed and solution-treated conditions and indicated size ranges.

Specified properties of material outside these size ranges are subject to special enquiry.

Sheet and plate	up to 50 mm	2 in.
Strip	up to 3 mm	0.12 in.
Rod, bar and forgings	up to 300 mm	12 in.
Tube	up to 250 mm	10 in.

Condition and form		Tensile strength		0.2% Yield strength		1.0% Yield strength		Elongation A <sub>5</sub> %	Brinell hardness HB
		N/mm <sup>2</sup>	ksi	N/mm <sup>2</sup>	ksi	N/mm <sup>2</sup>	ksi		
Annealed	sheet, plate, strip, tube	550	80	180	26.1	210	30.5	30	≤ 195
	rod and bar			170	24.7	200	29		
	forgings			–	–	–	–	35	
Solution-treated	sheet, plate, strip, tube	500	72.5	170	24.7	200	29	35	≤ 185
	rod and bar			160	23.2	190	27.6		
	forgings			–	–	–	–	–	

Table 4 – Minimum mechanical properties at room temperature of the indicated forms and dimensions.

Temperature		Tensile strength		0.2 % Yield strength		1.0% Yield strength		Elongation A <sub>5</sub> %
°C	°F	N/mm <sup>2</sup>	ksi	N/mm <sup>2</sup>	ksi	N/mm <sup>2</sup>	ksi	
93	200		77.1		22.0		26.4	45
100	212	530		150		180		
200	392	500		140		170		
204	400		72.4		20.3		24.6	
300	572	485		130		160		
316	600		69.9		18.7		22.9	
400	752	480		125		150		
427	800		69.3		18.0		21.5	

Table 5 – Minimum mechanical properties at elevated temperatures.

### Metallurgical structure

Nicrofer 7216 LC has a face-centered cubic structure.

### Corrosion resistance

Nicrofer 7216 LC is used mainly as a material resistant to aqueous corrosion at temperatures below about 450 °C (840 °F).

Its corrosion resistance is similar to that of Nicrofer 7216 and it is virtually immune to chloride-ion stress-corrosion cracking. The very low carbon content gives high resistance to intergranular corrosion.

High temperature corrosion resistance is similar to that of Nicrofer 7216 or Nicrofer 7216 H, which would be preferred for strength reasons.

### Applications

Typical applications are:

- pressurised-water-reactor steam-generator tube
- heat exchangers for sodium hydroxide
- component used in the manufacture of photographic materials and film processing
- oxychlorinator internals in vinyl chloride production
- strip for flight recorders

### Fabrication and heat treatment

Nicrofer 7216 LC is readily fabricated by usual industrial procedures.

#### Heating

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

Nicrofer 7216 LC 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 as 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<sup>3</sup> 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 oxidizing and must not fluctuate between oxidising and reducing. Flame impingement on the metal must be avoided.

#### Hot working

Nicrofer 7216 LC may be hot worked in the range 1200 to 870 °C (2200 to 1600 °F). The material may be charged into

the furnace at maximum working temperature. Cooling after hot working should be by water quenching or as fast as possible.

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

#### Cold working

Cold working should be carried out on annealed or solution-treated material. Nicrofer 7216 LC has a work-hardening rate similar to that of austenitic stainless steel and the forming equipment must be adapted accordingly.

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

After cold reductions of more than 15%, final annealing is required before use.

Due to the possibility of galling, dies should be of alloy tool steel, tungsten carbide or cast iron.

#### Heat treatment

Annealing should be carried out in the temperature range 920 to 980 °C (1700 to 1800 °F) followed by water quenching or rapid air cooling. The treatment is essential to ensure maximum corrosion resistance. High-temperature solution treatment is carried out at 1080 to 1150 °C (1970 to 2100 °F).

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

#### Descaling

Oxides of Nicrofer 7216 LC are more adherent than those of stainless steel. Both mechanical and chemical methods of descaling may be applied. Mechanical methods should be chosen which avoid contamination of the metal, or which produce an 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 7216 LC should be machined in the annealed condition. The alloy's high work-hardening rate should be considered; i.e. only low surface cutting speeds are possible compared with low-alloy standard austenitic stainless steels. Tools should be engaged at all times. Heavy feeds are important in getting below the workhardened 'skin'.

#### Joining

Nicrofer 7216 LC 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). Low heat input is necessary.

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Prior to welding, material should be in the heat-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.

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

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

The following welding products are recommended :

GTAW/GMAW Nicrofer S 7020	W.-Nr. 2.4806
	SG-NiCr20Nb AWS A 5.14 ERNiCr-3 BS 2901-NA 35
SMAW	W.-Nr. 2.4648
	EL-NiCr19Nb AWS A 5.11 ENiCrFe-3
	or
	W.-Nr. 2.4620
	EL-NiCr16FeMn AWS A 5.11 ENiCrFe-2

For optimum properties of the weld GTAW/GMAW is preferred.

## Availability

Nicrofer 7216 LC is available in all standard mill product forms:

## Sheet & plate

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

Conditions:

hot or cold rolled (hr, cr),

as rolled, annealed or solution-treated and pickled

Thickness mm	hr / cr	Width <sup>1)</sup> mm	Length <sup>2)</sup> 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 <sup>2)</sup>
≥ 20 <sup>1)</sup>	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 <sup>2)</sup>
≥ 3/4 <sup>1)</sup>	hr		

<sup>1)</sup> other sizes subject to special enquiry

<sup>2)</sup> depending on piece weight

## Discs and rings

Conditions:

hot rolled or forged,  
as formed, annealed or solution-treated,  
pickled or machined

Product	Weight kg	Thickness mm	o. d. <sup>1)</sup> mm	i. d. mm
Disc	≤ 10000	≤ 200	≤ 3000	
Ring	≤ 3000	≤ 200	≤ 2500	on request

	lb	inches	inches	inches
Disc	≤ 22000	≤ 8	≤ 120	
Ring	≤ 6600	≤ 8	≤ 100	on request

<sup>1)</sup> other sizes subject to special enquiry

## Rod & bar

Conditions:

forged, rolled, drawn,  
as formed, annealed or solution-treated,  
pickled, machined, peeled or ground

Product		forged <sup>1)</sup> mm	rolled <sup>1)</sup> mm	drawn <sup>1)</sup> mm
round	d	≤ 300	15 – 75	12 – 65
square	a	40 – 300	15 – 100	12 – 65
flat		40 – 80	5 – 20	10 – 20
		x	x	x
a x b		200 – 600	120 – 600	30 – 80
hexagon	s	40 – 80	13 – 50	12 – 60

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

<sup>1)</sup> other sizes subject to special enquiry

## Forgings

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

**Strip<sup>(1)</sup>**

Conditions:

cold rolled,

annealed and pickled

or bright annealed<sup>(2)</sup>

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
<sup>1)</sup> 0.06 – length available in coils from 500 to 3000 mm (20 to 120 in.)	0.25			16	20	24
<sup>2)</sup> 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, 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 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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Nicrofer<sup>®</sup>

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**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@tk-vdm.thyssenkrupp.com](mailto:info@tk-vdm.thyssenkrupp.com)

[www.thyssenkruppvdm.com](http://www.thyssenkruppvdm.com)

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