

# Nicrofer® 3220 H/3220 HP – alloys 800 H/800 HP

Material Data Sheet No. 4029  
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## High-temperature alloys

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## Comparison of alloy variations

Nicrofer	3220 LC	3220	3220 H	3220 HP	
Werkstoff-Nr.	1.4558	1.4876	1.4876 <sup>2)</sup> 1.4958 <sup>3)</sup>	1.4959 <sup>3)</sup>	
EN DIN	(10216-5)	10095	10028-7, (10302)	10028-7, (10302)	
DIN*	–	–	17459*/17460*	17459*/17460*	
SEW	400	470	–	–	
VdTÜV Data Sheet	–	412	412/434	–	
UNS	–	N08800	N08810	N08811	
Temperature range of application	°C	≤ 500	≤ 600	600 – 950	700 – 1000
	°F	≤ 930	≤ 1110	1110 – 1740	1290 – 1830
Advantages	corrosion resistant	corrosion and heat resistant	resistant to oxidation, carburization, nitridation; good creep rupture properties		
Typical thermal treatment temperatures	°C	920 – 980	920 – 980	1150	1150 – 1200
	°F	1690 – 1800	1690 – 1800	2100	2100 – 2190
Grain size	µm	≤ 64	≤ 64	90 – 180	90 – 180
	ASTM No.	> 5	> 5	4 – 2	4 – 2
Carbon content	wt.-%	≤ 0.025	0.04 – 0.08	0.06 – 0.08	0.06 – 0.10
Al + Ti <sup>1)</sup>	wt.-%	≤ 1.0	≤ 1.0	≤ 0.7	≤ 1.2
Ductility		very good	good	good	reduced
<sup>1)</sup> VDM-Standard <sup>2)</sup> W.-Nr. reference in VdTÜV 412/434 <sup>3)</sup> W -Nr. reference in EN DIN 10028 – 7 * Specifications will be superseded by applicable provisional EN DIN specifications (xxxxx) = provisional specification					

Table 1 – Comparison of alloy variations.

### Characteristics of Nicrofer 3220 H – alloy 800 H

Nicrofer 3220 H is an austenitic high-strength solid-solution nickel-iron-chromium alloy with controlled levels of carbon, aluminium, titanium, silicon and manganese and controlled content of (Al + Ti).

The analysis is similar to that of Nicrofer 3220, but a special solution anneal treatment (with grain sizes  $\geq 90 \mu\text{m}$ / ASTM No. 4) gives significantly increased creep-rupture strength above 600 °C (1110 °F).

For services below 600 °C (1110 °F) the use of soft annealed Nicrofer 3220 is suggested.

#### Nicrofer 3220 H is characterized by:

- good creep-rupture properties at temperatures above 600 °C (1110 °F) without loss of ductility during long-term use at temperatures below 700 °C (1290 °F), due to limitation of (Ti + Al) content to max. 0.7 %
- good resistance to reducing, oxidizing and nitriding atmospheres and to atmospheres which alternate between reducing and oxidizing conditions
- metallurgical stability in long-term application at high temperatures

### Characteristics of Nicrofer 3220 HP – alloy 800 HP

Nicrofer 3220 HP is an austenitic high-strength solid-solution nickel-iron-chromium alloy with controlled levels of carbon, aluminium, titanium, silicon and manganese and increased content of (Al + Ti).

A special solution anneal treatment (with grain sizes  $\geq 90 \mu\text{m}$ / ASTM No. 4) gives highest creep-rupture strength above 700 °C (1290 °F) due to the precipitation of TiC.

Below 700 °C (1290 °F), gamma prime ( $\gamma'$ ) precipitates combined with loss of ductility.

#### Nicrofer 3220 HP is characterized by:

- excellent creep strength at temperature above 700 °C (1290 °F)
- However, for applications where frequent excursions to temperatures lower than 700 °C (1290 °F) during service cannot be excluded or parts of the material are permanently exposed to a temperature below 700 °C (1290 °F), the use of Nicrofer 3220 H is recommended.
- good resistance to reducing, oxidizing and nitriding atmospheres and to atmospheres which alternate between reducing and oxidizing conditions
  - metallurgical stability in long-term application at high temperatures

### Chemical composition

		Ni	Cr	Fe	C	Mn	Si	Cu	P	S	Al	Ti	Al + Ti
Nicrofer 3220 H – alloy 800 H	min.	30.0	19.0	bal.	0.06	0.5	0.2				0.20	0.20	
	max.	32.0	22.0		0.08	1.5	0.7	0.5	0.015	0.010	0.40	0.50	0.7
Nicrofer 3220 HP – alloy 800 HP	min.	30.0	19.0	bal.	0.06	0.5	0.2				0.30	0.30	
	max.	32.0	22.0		0.10	1.5	0.7	0.5	0.015	0.010	0.60	0.60	1.2

Table 2 – Chemical composition (wt.-%)

## Designations and standards

Country	Material designation	Specification							
		Chemical composition	Tube and pipe		Sheet and plate	Rod and bar	Strip	Wire	Forgings
			seamless	welded					
D	W.-Nr. 1.4958 X 5 NiCrAlTi 31-20	10028-7* (10216-5) (10302)	(10216-5)		10028-7 (10302)	(10307)	10028-7 (10302)	(10302)	
DIN VdTÜV									
F AFNOR									
UK BS	NA 15 (H)		3074		3072	3076	3073		
USA ASTM	UNS N08810		B 407	B 163 B 514/515	B 409	B 408	B 409		B 564
ASME			SB 407	SB 163/ 514/515	SB 409	SB 408	SB 409		SB 564
ASME code case section VIII, Div. 1			1983						

\* Specifications will be superseded by applicable provisional EN DIN specifications  
(xxxxx) = provisional specification

Table 3 – Designations and standards of *Nicrofer 3220 H – alloy 800 H*.

## Designations and standards

Country	Material designation	Specification							
		Chemical composition	Tube and pipe		Sheet and plate	Rod and bar	Strip	Wire	Forgings
			seamless	welded					
D	W.-Nr. 1.4959 X 8 NiCrAlTi 32-21	10028-7 (10216-5) (10302)	(10216-5)		10028-7 (10302)	(10302)	10028-7 (10302)	(10302)	
DIN VdTÜV									
F AFNOR									
UK BS									
USA ASTM ASME	UNS N08811		B 407	B 163	B 409	B 408	B 409		
			SB 407	SB 163	SB 409	SB 408	SB 409		

\* Specifications will be superseded by applicable provisional EN DIN specifications  
(xxxxx) = provisional specification

## Physical properties

Density	8.0 g/cm <sup>3</sup>	0.29 lb/in. <sup>3</sup>
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	$\frac{\text{J}}{\text{kg K}}$	$\frac{\text{Btu}}{\text{lb } ^\circ\text{F}}$	$\frac{\text{W}}{\text{mK}}$	$\frac{\text{Btu in.}}{\text{ft}^2 \text{ h } ^\circ\text{F}}$	$\mu \Omega \text{ cm}$	$\frac{\Omega \text{ circ mil}}{\text{ft}}$	$\frac{\text{kN}}{\text{mm}^2}$	10 <sup>3</sup> ksi	$\frac{10^{-6}}{\text{K}}$	$\frac{10^{-6}}{^\circ\text{F}}$
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	
649	1200		0.148		150		746		22.5		9.5
700	1292	633		22.7		125		151		17.4	
760	1400		0.155		166		760		21.2		9.8
800	1472	660		24.5		127		144		17.8	
871	1600		0.162		180		769		20.0		10.0
900	1652	685		26.8		128		136		18.2	
982	1800		0.169		197		775		18.9		10.4
1000	1832	715		29.0		129		127		18.8	

Table 5 – Typical physical properties at room and elevated temperatures.

**Mechanical properties**

The following properties are applicable to the solution-annealed condition and the indicated size ranges. Material outside these size ranges is 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		Tensile strength R <sub>m</sub>		Yield strength R <sub>p0.2</sub>		Yield strength R <sub>p1.0</sub>		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	%
RT	RT	500	72.5	170	24.5	200	29.0	transverse 30 longitudinal 35
93	200			141	20.4	161	23.3	
100	212	< 425 >		140	20.3	160	23.2	
200	392	< 400 >		115	16.7	135	19.6	
204	400			113	16.4	133	19.3	
300	572	< 390 >		95	13.8	115	16.7	
316	600			93	13.5	113	16.4	
400	752	< 380 >		85	12.3	105	15.2	
427	800			83	12.0	103	14.9	
500	932	< 360 >		80	11.6	100	14.5	
538	1000			77	11.2	97	14.1	
593	1100			75	10.9	95	13.8	
600	1112	< 300 >		75	10.9	95	13.8	

XXX ... according to VdTÜV data sheets 412 and 434 and converted (N/mm<sup>2</sup> × 0.145 = ksi) XXX ... values determined from graphs/diagrams < > informative only

\*Elongation values for strip products are normally determined based on an initial gauge length of 50 mm (2 in.).  
These values are lower, dependent on the alloy, than the corresponding A<sub>5</sub> values by an order of approx. 10%.

Table 6 – Minimum short-time mechanical properties of **Nicrofer 3220 H** at room and elevated temperatures according to VdTÜV data sheets 412 and 434.

**ISO V-notch impact toughness**

Average values at RT:      longitudinal      ≥ 150 J/cm<sup>2</sup>  
   transverse        ≥ 100 J/cm<sup>2</sup>

Temperature		VdTÜV 412		VdTÜV 434		Temperature		VdTÜV 412		VdTÜV 434	
°C	°F	N/mm <sup>2</sup>	ksi	N/mm <sup>2</sup>	ksi	°C	°F	N/mm <sup>2</sup>	ksi	N/mm <sup>2</sup>	ksi
600	1112	114	16.5	114	16.5	800	1472	19	2.8	24	3.5
650	1202	73	10.8	77	11.2	850	1562	10	1.5	16	2.3
700	1292	47	6.8	53	7.7	900	1652	4	0.58	10.5	1.5
750	1382	30	4.4	36	5.2	950	1742	–	–	7.0	1.0

For calculations for pressure vessels these values must be divided by the safety factor 1.5 (compare next table).

		Nicrofer 3220 H						Nicrofer 3220 HP	
According to		VdTÜV 412 <sup>1)</sup>		VdTÜV 434 <sup>1)</sup>		ASME UNS N08810		ASME UNS N08811	
(Al + Ti) %		≤ 0.7 <sup>2)</sup> resp. ≤ 1.0		≤ 0.7 <sup>2)</sup>		≤ 1.0		≤ 1.2	
Temperature °C	°F	N/mm <sup>2</sup>   ksi		N/mm <sup>2</sup>   ksi		N/mm <sup>2</sup>   ksi		N/mm <sup>2</sup>   ksi	
		593	1100		11.6		11.6	79.9	11.6
600	1112	76	11.0	76	11.0	76		84	
648	1200		7.2		7.5	51.0	7.4	57.2	8.3
650	1202	48.7	7.1	51.3	7.4	50		56	
700	1292	31.3	4.5	35.3	5.1	33.2		38.2	
704	1300		4.4		5.0	32.4	4.7	37.2	5.4
750	1382	20.0	2.9	24.0	3.5	22.2		24.4	
760	1400		2.7		3.2	20.7	3.0	23.4	3.4
800	1472	12.7	1.8	16.0	2.3	14.8		17.2	
815	1500		1.5		2.0	13.1	1.9	15.2	2.2
850	1562	6.7	0.97	10.2	1.6	10.2		11.7	
871	1600		0.72		1.3	8.3	1.2	9.7	1.4
898	1650		0.42		1.0	6.8	0.98	7.6	1.1
900	1652	2.7	0.39	7.0	1.0	6.8		7.5	
926	1700				0.80	5.0 <sup>3)</sup>	0.73 <sup>3)</sup>		
950	1742			4.7	0.68	4.4			
953	1750				(0.61)	4.3 <sup>3)</sup>	0.63 <sup>3)</sup>		
981	1800				(0.51)	3.5 <sup>3)</sup>	0.50 <sup>3)</sup>		
1000	1832								

<sup>1)</sup> values are: 10<sup>6</sup> hours creep-rupture strength (according to VdTÜV data sheet) divided by the safety factor 1.5  
 XXX ... original values of specification or converted (N/mm<sup>2</sup> x 0.145 = ksi)  
 XXX ... values determined from graphs/diagrams

<sup>2)</sup> for operating temperatures between 600 and 700 °C (1110 to 1290 °F)

<sup>3)</sup> for seamless pipe and tube ≤ 5 in. o.d. according to ASME code case 1983

Table 8 – Maximum allowable design stress values at elevated temperatures.

## Metallurgical structure

Nicrofer 3220 H/3220 HP are austenitic, solid solution alloys containing small amounts of precipitated titanium nitride and carbide, carbonitrides and chromium carbide.

During long-term exposure of Nicrofer 3220 H to temperatures below 700 °C (1290 °F)  $\gamma'$ -phase may be formed which lowers the ductility.

Nicrofer 3220 HP precipitates  $\gamma'$ -phase combined with a loss of ductility.

## Relaxation cracking susceptibility

Nicrofer 3220 H/3220 HP is susceptible to relaxation cracking if solution annealed material is exposed to service temperatures within the range of 550 – 750 °C (1020 – 1380 °F). A high degree of cold deformation and welding during fabrication enhances the susceptibility to relaxation cracking during subsequent service.

A stabilizing heat treatment at 980 °C (1800 °F) for 3 hrs of new material prior to fabrication and welding or prior to repair welding of material which has already been in service has been shown to alleviate susceptibility to relaxation cracking.

However, to ensure that susceptibility to relaxation cracking is entirely eliminated the welded component must be subjected to a post-weld heat treatment (PWHT) in addition to the already mentioned stabilizing heat treatment at 980 °C of the base material. If welding is carried out with matching Fe-base or Ni-base type 82 consumables a (local) PWHT at 875 °C (1610 °F) for 3 hrs suffices. If welding is carried out with Ni-base alloy 617 type consumables, however, a (local) PWHT again at 980 °C (1800 °F) for 3 hrs is essential. Heating and cooling rates for such heat treatments are not critical.

## Corrosion resistance

The high nickel and chromium contents of Nicrofer 3220 H and 3220 HP ensure excellent resistance to oxidation. The alloys are also very resistant to carburization, nitridation and oxidizing sulphur-bearing atmospheres.

The protective oxide film which is formed is adherent in both static and cyclic conditions of heating and cooling, and resistance to carburization is enhanced when a thin film of oxide is formed on the alloy through pre-oxidation prior to service.

Resistance to hydrogen is excellent and Nicrofer 3220 H and 3220 HP are standard materials used in the production of hydrogen in steam/hydrocarbon reforming processes.

## Applications

Due to high strength during long periods of service and resistance to carburization and nitridation, Nicrofer 3220 H and 3220 HP have found many applications in steam/hydrocarbon reforming for components such as: pigtails, headers/collectors/manifolds, transfer piping, catalyst tubes (in low-pressure processes) and quench-system piping.

Other applications are:

- ethylene pyrolysis tubing in convection and radiant sections – resistance to carburization and good mechanical properties
- ethylene dichloride cracking tubes – resistance to carburization and to dry hydrogen chloride and chlorine
- cracking tubes used in the production of acetic anhydride and ketene – high strength, resistance to both carburization and the formation of sigma phase
- components, e.g. heat exchangers, piping systems etc., in coal conversion plants
- steam generator tubing in helium cooled, high temperature reactor systems – high strength, resistance to helium and to steam

## Fabrication and heat treatment

Nicrofer 3220 H/3220 HP can readily be hot- and cold-worked and machined. Hot and cold working, however, require high-power machines, owing to the high strength of the materials.

## Heating

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

Nicrofer 3220 H/3220 HP may become impaired 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 and 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 3220 H/3220 HP may be hot-worked in the temperature range 1200 to 950 °C (2190 to 1740 °F), if deformation is 5% or greater. If the degree of hot deformation is less than 5%, as is generally the case with hot bending, a hot working temperature range between 1050 to 850 °C (1920 to 1560 °F) is recommended. Cooling after hot working should be by water quenching or rapid air cooling through the temperature range 760 to 540 °C (1400 to 1000 °F).

Solution annealing after hot working is required to ensure maximum creep resistance and optimum properties.

For hot working, the material may be charged into the furnace at the maximum working temperature of 1200 °C (2190 °F). After soaking for the required time the metal should be withdrawn immediately and worked within the specified temperature range. If the metal temperature falls below the minimum working temperature, it must be reheated.



### Cold working

For cold working the material should be in the solution-annealed condition. Nicrofer 3220 H/3220 HP have higher work-hardening rates than austenitic stainless steels. This should be taken into account when selecting forming equipment.

Interstage annealing may be necessary with high degrees of cold forming.

After cold working with more than 10% deformation, solution annealing is required.

Also note the information on 'Relaxation cracking susceptibility'.

### Heat treatment

Solution heat treatment should be carried out in the temperature range 1150 – 1200 °C (2100 – 2190 °F) for both alloy grades.

Water quenching is essential for maximum creep resistance. Under 1.5 mm (0.06 in.) thickness rapid air cooling is also suitable.

For stabilizing heat treatments to avoid relaxation cracking susceptibility of material exposed to service temperatures within the range of 550 – 750 °C (1200 – 1380 °F), following cold working and/or (repair) welding, refer to 'Relaxation cracking susceptibility'

For any thermal treatment the material should be charged into the furnace at temperature. Also for any thermal treatment operation the precautions concerning cleanliness mentioned earlier under 'Heating' must be observed.

### Descaling and pickling

High-temperature alloys develop a protective oxide layer in service. Pre-oxidation in air can produce increased corrosion resistance. Therefore on the basis of the end use the necessity of descaling should be checked.

Oxides of Nicrofer 3220 H/3220 HP 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/hydrofluoric acid mixture with proper control of pickling time and temperature, the surface oxide layer must be broken up by abrasive blasting, by carefully controlled grinding or by pretreatment in a fused salt bath.

### Machining

Nicrofer 3220 H/3220 HP should be machined in the heat-treated condition. As the alloys are prone to work-hardening, only low surface 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.

### Welding

When welding nickel-base alloys, the following instructions should be adhered to:

### Workplace

The workplace should be in a separate location, well away from 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 machines

Tools used for nickel-base alloys and stainless steels must not be used for other materials. Brushes should be made of stainless materials.

Fabricating and working machinery such as shears, presses or rollers should be fitted with means (felt, cardboard, plastic sheeting) 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 by turning, milling or planing; 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 permitted. Also a zone approximately 25 mm (1 in.) wide on each side of the joint should be ground to bright metal.

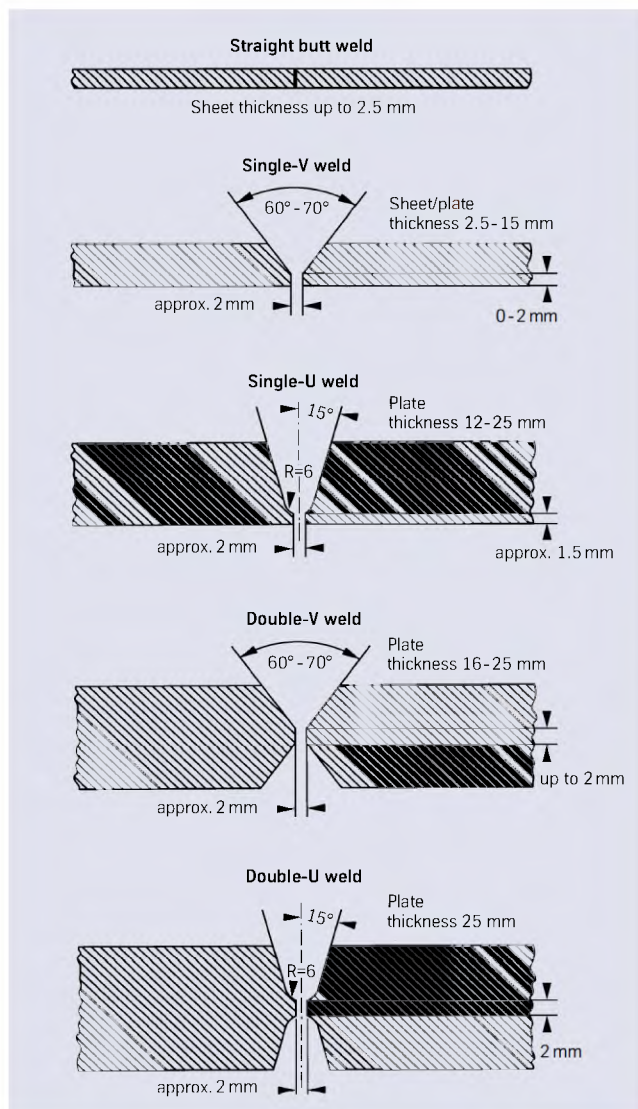


Fig. 1 – Edge preparation for welding of nickel-base alloys and special stainless steels.

### 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. 1, 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 of the arc

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

### Welding processes

Nicrofer 3220 H/3220 HP can be joined to itself and to many other metals by conventional welding processes. These include GTAW (TIG), plasma arc, GMAW (MIG/MAG) and SMAW (MMA). Pulsed arc welding is the preferred technique. For MAG welding the use of a multi-component shielding gas (Ar+He+H<sub>2</sub>+CO<sub>2</sub>) is recommended.

For welding, Nicrofer 3220 H/3220 HP should be in the solution-annealed condition and 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, matching material or the following filler metals are recommended:

Bare electrodes:	Werkstoff-Nr. ≈ 1.4850 SG-X15 NiCrNb3221
	or
	Nicrofer S 7020 – FM 82 Werkstoff-Nr. 2.4806 SG-NiCr20Nb UNS N06082 AWS A 5.14: ERNiCr-3
Covered electrodes:	Werkstoff-Nr. ≈ 1.4850 SG-X15 NiCrNb3221
	or
	Werkstoff-Nr. 2.4648 EL-NiCr19Nb AWS A 5.11: ≈ ENiCrFe-3

For applications at higher temperatures [above approx. 900 °C (1650 °F)] and where high creep-rupture properties are of prime consideration the following welding consumables are recommended. Weldments with these filler materials are resistant to scaling up to approx. 1100 °C (2012 °F) and are high temperature resistant up to approx. 1000 °C (1832 °F).

Bare electrode:	Nicrofer S 5520 – FM 617 Werkstoff-Nr. 2.4627 SG-NiCr22Co12Mo UNS N06617 AWS A 5.14: ERNiCrCoMo-1
Covered electrode:	Werkstoff-Nr. 2.4628 EL-NiCr21Co12Mo AWS A 5.11: ERNiCrCoMo-1

#### Welding parameters and influences

(heat input/energy input per unit length of weld)

Care should be taken that the work is performed with a deliberately chosen, low heat input as indicated in Table 10 by way of example. Use of the stringer bead technique should be aimed at. Interpass temperature should be kept below 120 °C (250 °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.

#### 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 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 normally required. Components utilizing plates with a thickness > 50 mm should, however, be subjected to a PWHT at not less than 850 °C to reduce residual stresses. Also to eliminate the risk of relaxation cracking of material exposed to service temperatures within the range of 550 – 750 °C (1020 – 1380 °F), following cold working and/or (repair) welding, the PWHT recommendations given under 'Relaxation cracking susceptibility' must be adhered to.

Sheet/ plate thick- ness mm	Welding process	Filler metal		Welding parameters				Welding speed	Flux/ shielding gas rate	Plasma- gas rate	Plasma- nozzle diameter
		Diameter	Speed	Root pass		Intermediate and final passes					
		mm	m/min.	A	V	A	V	cm/min.	l/min.	l/min.	mm
3.0	Manual GTAW	2.0		90	10	110 – 120	11	10 – 15	Ar W3 <sup>1)</sup> 8 – 10		
6.0	Manual GTAW	2.0 – 2.4		100 – 110	10	120 – 130	12	10 – 15	Ar W3 <sup>1)</sup> 8 – 10		
8.0	Manual GTAW	2.4		110 – 120	11	130 – 140	12	10 – 15	Ar W3 <sup>1)</sup> 8 – 10		
10.0	Manual GTAW	2.4		110 – 120	11	130 – 140	12	10 – 15	Ar W3 <sup>1)</sup> 8 – 10		
3.0	Autom. GTAW	1.2	0.5	manual		150	10	25	Ar W3 <sup>1)</sup> 15 – 20		
5.0	Autom. GTAW	1.2	0.5	manual		150	10	25	Ar W3 <sup>1)</sup> 15 – 20		
2.0	Hot wire GTAW	1.0	0.3			180	10	80	Ar W3 <sup>1)</sup> 15 – 20		
10.0	Hot wire GTAW	1.2	0.45	manual		250	12	40	Ar W3 <sup>1)</sup> 15 – 20		
4.0	Plasma arc	1.2	0.5	165	25			25	Ar W3 <sup>1)</sup> 30	Ar W3 <sup>1)</sup> 3.0	3.2
6.0	Plasma arc	1.2	0.5	190 – 200	25			25	Ar W3 <sup>1)</sup> 30	Ar W3 <sup>1)</sup> 3.5	3.2
8.0	MIG/MAG GMAW	1.0	approx. 8	GTAW		130 – 140	23 – 27	24 – 30	MAG <sup>2)</sup> MIG: argon 18 – 20		
10.0	MIG/MAG GMAW	1.2	approx. 5	GTAW		130 – 150	23 – 27	20 – 26	MAG <sup>2)</sup> MIG: argon 18 – 20		
6.0	SMAW	2.5		40 – 70	approx. 21	40 – 70	approx. 21				
8.0	SMAW	2.5 – 3.25		40 – 70	approx. 21	70 – 100	approx. 22				
16.0	SMAW	4.0				90 – 130	approx. 22				

<sup>1)</sup>Argon or argon + max. 3% hydrogen

<sup>2)</sup>For MAG welding the use of the shielding gas Cronigon He30S or Argomag-Ni, for example, is recommended.

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 9 – Welding parameters (guide values).

Welding process	Heat input per unit length kJ/cm	Welding process	Heat input per unit length kJ/cm
GTAW, manual, fully mechanised	max. 10	GMAW, MIG/MAG, manual, fully mechanised	max. 11
Hot wire GTAW	max. 6	SMAW, manual metal arc (MMA)	max. 7
Plasma arc	max. 10		

**Availability**

Nicrofer 3220 H/3220 HP are 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, oxidized, descaled or pickled

Thickness mm	hr / cr	Width <sup>1)</sup> mm	Length <sup>1)</sup> 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 <sup>2)</sup>
> 25.00 <sup>1)</sup>	hr	2500 <sup>2)</sup>	8000 <sup>2)</sup>

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 <sup>2)</sup>
> 1.000 <sup>1)</sup>	hr	100 <sup>2)</sup>	320 <sup>2)</sup>

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

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

**Discs and rings****Conditions:**

hot rolled or forged,  
thermally treated,  
oxidized, descaled or pickled or machined

Product	Weight kg	Thickness mm	O. D. <sup>1)</sup> mm	I. D. <sup>1)</sup> 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

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

**Rod & bar****Conditions:**

forged, rolled, drawn,  
thermally treated,  
oxidized, descaled or pickled, machined, peeled or ground

Product	Forged <sup>1)</sup> mm	Rolled <sup>1)</sup> mm	Drawn <sup>1)</sup> mm
Rod (o. d.)	≤ 600	8 – 100	12 – 65
Bar, square (a)	40 – 600	15 – 280	not standard
Bar, flat (a x b)	(40 – 80) x (200 – 600)	(5 – 20) x (120 – 600)	(10 – 20) x (30 – 80)
Bar, hexagonal (s)	40 – 80	13 – 41	≤ 50

	inches	inches	inches
Rod (o. d.)	≤ 24	<sup>5</sup> / <sub>16</sub> – 4	<sup>1</sup> / <sub>2</sub> – 2 <sup>1</sup> / <sub>2</sub>
Bar, square (a)	<sup>1</sup> / <sub>8</sub> – 24	<sup>10</sup> / <sub>16</sub> – 11	not standard
Bar, flat (a x b)	( <sup>1</sup> / <sub>8</sub> – <sup>3</sup> / <sub>8</sub> ) x (8 – 24)	( <sup>3</sup> / <sub>16</sub> – <sup>3</sup> / <sub>4</sub> ) x ( <sup>4</sup> / <sub>4</sub> – 24)	( <sup>3</sup> / <sub>8</sub> – <sup>3</sup> / <sub>4</sub> ) x ( <sup>1</sup> / <sub>4</sub> – <sup>3</sup> / <sub>8</sub> )
Bar, hexagonal (s)	<sup>1</sup> / <sub>8</sub> – <sup>3</sup> / <sub>8</sub>	<sup>1</sup> / <sub>2</sub> – <sup>1</sup> / <sub>8</sub>	≤ 2

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

### 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 10 t.

### Strip<sup>1)</sup>

Conditions:  
cold rolled,  
thermally treated and pickled or bright annealed<sup>2)</sup>

Thickness mm	Width <sup>3)</sup> mm	Coil I. D. mm			
		300	400	500	600
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	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	25 – 750		400	500	600

inches	inches	inches			
		12	16	20	24
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 – ≤ 0.040	0.32 – 30		16	20	24
> 0.040 – ≤ 0.080	0.60 – 30		16	20	24
> 0.080 – ≤ 0.120	1.0 – 30		16	20	24

<sup>1)</sup> Cut-to-length available in lengths from 250 to 4000 mm (10 to 158 in.)

<sup>2)</sup> Maximum thickness 3 mm (0.125 in.)

<sup>3)</sup> Wider widths subject to special enquiry

### Wire

Conditions:  
bright drawn,  $\frac{1}{4}$  hard to hard,  
bright annealed or oxidized

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, wire, strip electrodes and electrode core wire are available in all standard sizes.

### 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 Defence 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.

### Technical publications

The following publication concerning Nicrofer 3220 H/3220 HP is available:

H. van Wortel:  
Prevention of relaxation cracking by material selection and/or heat treatment;  
TNO Metals Research Institute, Nov. 2000

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