VDM Metals

VDM® Alloy 800 H/HP
Nicrofer 3220 H/HP

Data Sheet No. 4129   Revision 03
February 2019

VDM® Alloy 800 H/HP

Nicrofer 3220 H/HP

VDM® Alloy 800 H is an austenitic, heat resistant iron-nickel -chromium alloy with controlled levels of carbon, aluminum and titanium.

The analysis of VDM® Alloy 800 H is identical to that of VDM® Alloy 800. A special solution annealing results in a grain sizes ≥ 90 µm (ASTM No. 4), which increases the creep rupture strength above 600 °C (1,112 °F) significantly.

VDM® Alloy 800 H is characterized by:

- good creep rupture strength at temperatures above 600 °C (1,112 °F)
- good resistance in oxidizing, nitriding and carburizing conditions
- metallurgical stability in long-term use at high temperatures

VDM® Alloy 800 HP is an austenitic nickel-iron-chromium alloy with increased content of (Al + Ti), compared to VDM® Alloy 800 H.

A special solution annealing results in a grain sizes ≥ 90 µm (ASTM No. 4) and highest creep rupture strength above 700 °C (1,290 °F) due to titanium carbide precipitation. Below 700 °C (1,290 °F), γ´ precipitates combined with a loss of ductility.

VDM® Alloy 800 HP is characterized by:

- excellent creep rupture strength at temperatures above 700 °C (1,290 °F)
- good resistance to reducing, oxidizing and nitriding atmospheres and to atmospheres which alternate between reducing and oxidizing conditions
- metallurgical stability in long-term use at high temperatures

If the repeated lowering of operating temperatures below 700 °C (1,290 °F) cannot be ruled out, or the operating temperature is permanently below 700 °C (1,290 °F), the use of VDM® Alloy 800 H is recommended. At temperatures below 600 °C (1,112 °F), soft annealed VDM® Alloy 800 is generally used.

Designations and standards

Standard	Material designation	
	VDM® Alloy 800 H	**VDM® Alloy 800 HP**
EN	1.4876 - X10NiCrAlTi32-20[1)] 1.4958 - X5NiCrAlTi31-20[2)]	1.4959 - X8NiCrAlTi32-21[2)]
ISO	FeNi32Cr21AlTi-HC	FeNi32Cr21AlTi-HT
UNS	N08810	N08811
AFNOR		Fe-Ni29Cr17
NA	15 (H)	

1) VdTÜV data sheet 412, version 01.84 with old W.-No. 1.4876

2) W.-No. according to DIN EN 10302

Table 1a – Designations and standards

Designations and standards

Product form	DIN	DIN EN	ISO	ASTM	ASME	VdTÜV	SEW	Others
Sheet, plate		10028-7 10095[1)] 10302		A 240 B 409	SA 240 SB 409	412 434[1)]		ASME Code Case 1325[1)] NACE MR 0175/ISO 15156
Strip		10028-7 10088-1 10095 10302	6208	A 240 B 409	SA 240 SB 409	412 434[1)]	470	SAE AMS 5871[2)]
Rod, bar		10095[1)] 10302		B 408 B 564	SB 408 SB 564	412 434[1)]	470	

[1)] only valid for VDM® Alloy 800 H

[2)] only valid for VDM® Alloy 800 HP

Tabelle 1b – Designations and standards

Chemical composition

VDM® Alloy 800 H

	Ni	Cr	Fe	C	Mn	Si	Cu	Al	Ti	P	S	(Al + Ti)
Min.	30	19	43	0,06	0,5	0,2		0,2	0,2			
Max.	32	21	50	0,1	1	0,6	0,5	0,6	0,6	0,015	0,01	0,7

Table 2b – Chemical composition (wt.-%) of VDM® Alloy 800 H

VDM® Alloy 800 HP

	Ni	Cr	Fe	C	Mn	Si	Cu	Al	Ti	P	S	(Al + Ti)
Min.	30	19	43	0,06	0,5	0,2		0,2	0,3			0,85
Max.	32	22	50	0,1	1	0,6	0,5	0,6	0,6	0,015	0,01	1,2

Table 2b – Chemical composition (wt.-%) of VDM® Alloy 800 HP

Physical properties

Density	Melting range	Relative magnetic permeability at 20 °C (68 °F)
8.0 g/cm³ (0.29 lb/in³) at 20 °C (68 °F)	1,350-1,400 °C (2,462-2,552 °F)	1.01

Temperature		Specific heat		Thermal conductivity		Electrical resistivity	Modulus of elasticity		Coefficient of thermal expansion	
°C	°F	K/(Kg · K)	Btu/(lb · °F)	W/(m · K)	Btu · in/(sq. ft · h · °F)	µΩ · cm	GPa	10^3 ksi	10^{-6}/K	10^{-6}/°F
20	68	443	0.106	12.4	86	101	194	28.1	14	7.78
100	212	457	0.109	13.7	95.1	104	189	27.4	14.08	7.82
200	392	474	0.113	15.3	106.2	108	183	26.5	14.6	8.11
300	572	492	0.118	17	117.9	112	177	25.7	14.92	8.28
400	762	512	0.122	18.9	131.1	115	170	24.7	15.2	8.44
500	932	548	0.131	21.4	148.5	118	163	23.6	15.49	8.61
600	1,112	578	0.138	23.6	163.7	120	156	22.6	15.87	8.82
700	1,292	588	0.140	24.7	171.4	122	149	21.6	16.42	9.12
800	1,472	598	0.143	25.8	179	124	141	20.5	16.98	9.43
900	1,652	602	0.144	26.7	185.2	126	134	19.4	17.36	9.64
1,000	1,832	613	0.146	28	194.3	127	127	18.4	17.76	9.87
1,100	2,012	628	0.150	29.6	205.4	128	120	17.4	18.27	10.15
1,200	2,192	634	0.151	30.6	212.3	129	113	16.4	18.74	10.41

Table 3 – Typical physical properties of VDM® Alloy 800 Hat room temperature and elevated temperatures

Microstructural properties

VDM® Alloy 800, VDM® Alloy 800 H and VDM® Alloy 800 HP are austenitic solid solution alloys which precipitate carbides and γ' phase during high temperature ageing.

Mechanical properties

The following properties are applicable to VDM® Alloy 800 H and VDM® Alloy 800 HP in the annealed condition in the following size ranges:

- Sheet, plate up to 50 mm (1.97 in)
- Strip up to 3 mm (0.12 in)
- Rod, bar and forgings up to 250 mm (9.84 in)

For larger dimensions, the properties are to be agreed separately. The values are valid for longitudinal and transverse samples.

Temperature		**Yield strength** $R_{p\ 0.2}$		**Tensile strength** R_m		**Elongation** A
°C	**°F**	**MPa**	**ksi**	**MPa**	**ksi**	**%**
20	68	170	24.7	450-700	65.3-101.5	Longit. 35 Transverse 30
100	212	140	20.3	425[1)]	61.6	
200	392	115	16.7	400[1)]	58	
300	572	95	13.8	390[1)]	56.6	
400	762	85	12.3	380[1)]	55.1	
500	932	80	11.6	360[1)]	52.2	
600	1,112	75	10.9	300[1)]	43.5	

[1)] Average, for information only

Table 4 – Mechanical short-time properties of solution annealed VDM® Alloy 800 H and VDM® Alloy 800 HP at room temperature and elevated temperatures; min. values according to VdTÜV data sheet 412

Product form	**Dimensions** mm	**Yield strength** $R_{p\ 0.2}$ MPa	**Tensile strength** R_m MPa	**Elongation** A %
Sheet, plate, strip	≤ 50	≥ 170	450-700	≥ 30
Rod, bar	≤ 160	≥ 170	450-700	≥ 30
Forging	≤ 250	≥ 170	450-700	≥ 30

Table 5 – Mechanical properties at room temperature according to according to VdTÜV data sheet 412

ISO V-notch impact toughness

Average values at room temperature, longit.: 150 J/cm^2

Average values at room temperature, transverse: 100 J/cm^2

Temperature		Creep strength $R_m/10^5$ h			
		UNS N08810[1)]	UNS N08811[1)]	VdTÜV 412	VdTÜV 434
°C	°F	MPa	MPa	MPa	MPa
600	1,112	114		114	77
650	1,202	75		73	53
700	1,292	50	57	47	36
750	1,382	33	37	30	24
800	1,472	22	26	19	16
850	1,562	15	18	10	10.5
900	1,652	10	11	4	7
950	1,742		7		

[1)] VDM Metals calculation, based on ASME Code Case 1987; for 950 °C (1,742 °F) based on ASME Code Case 1988

Table 6 – $R_m/10^5$ h creep rupture strength

Corrosion resistance

The high nickel and chromium contents in VDM® Alloy 800 H and VDM® Alloy 800 HP ensure excellent resistance to oxidation. The alloys are also highly resistant to carburizing, nitriding and oxidation in sulphurous atmospheres. The protective oxide layer is adherent under static and cyclic thermal stress. Both materials are particularly resistant to carburization if a thin oxide film was formed by pre-oxidation.

The resistance to hydrogen embrittlement of VDM® Alloy 800 H and 800 HP is excellent, so that the alloys can be used in the production of hydrogen and steam/hydrocarbon reformers.

Applications

VDM® Alloy 800H and Alloy 800 HP have a wide range of applications in areas of elevated temperatures in furnace construction, in the chemical industry, in environmental protection equipment, in the automotive industry and in power plants. Typical applications include furnace muffles, containers, bins, holders in various heat treatment plants and burner components.

Because of their resistance to carburization and nitriding, the alloys are furthermore used in the areas of:

- steam/hydrocarbon reformers
- ethylene pyrolysis
- Equipment for acetic anhydride and ketone production.

Fabrication and heat treatment

VDM® Alloy 800 H and Alloy 800 HP can readily be hot- and cold-worked and machined.

Heating

Workpieces must be clean and free of any contaminants before and during heat treatment. Sulfur, phosphor, lead and other low-melting-point metals can lead to damages when heat treating VDM® Alloy 800 H and Alloy 800 HP. Sources of such contaminants include marking and temperature-indicating paints and crayons, lubricating grease and fluids, and fuels. Heat treatments can be carried out in gas fired, oil fired or electric furnaces in air, under vacuum or inert gas atmosphere. Fuels should contain as little sulfur as possible. Natural gas should contain less than 0.1 wt.-% of sulfur. Heating oil with a sulfur content of maximum 0.5 wt.-% is also suitable with a slightly oxidizing atmosphere. Reducing or changing furnace atmosphere should be avoided, as well as direct flame impingement. The temperature should be precisely controlled.

Hot working

VDM® Alloy 800 H and Alloy 800 HP may be hot-worked in the temperature range 1,200 to 900 °C (2,192 to 1,650 °F) with subsequent rapid cooling down in water or by using air. In particular the temperature range from 760 to 540 °C (1,400 to 1,004 °F) must be passed quickly. Hot bending is carried out at 1,150 to 1,000 °C (2,102 to 1,832 °F). The furnace should be heated up to maximum working temperature (1,200 °C/2,192 °F) before workpieces are inserted into the preheated furnace. The holding time is about 60 minutes per 100 mm thickness. After the hot forming a solution heat treatment is recommended in order to achieve optimum creep strength.

Cold working

Cold working should be carried out on annealed material. VDM® Alloy 800 H and Alloy 800 HP have a higher work hardening rate than austenitic stainless steels. This must be taken into account during design and selection of forming tools and equipment and during the planning of the forming processes. Intermediate annealing may be necessary at high degrees of cold working deformation.

After cold working with more than 10 % deformation the material should be solution annealed.

Heat treatment

Solution heat treatment should be carried out at the following temperatures:

- VDM® Alloy 800 H: 1,150 °C (2,102 °F)
- VDM® Alloy 800 HP: 1,150 bis 1,200 °C (2,102 to 2,192 °F)

The retention time during annealing depends on the workpiece thickness and can be calculated as follows:

- For thicknesses d ≤ 10 mm (0.4 in) the retention time is t = d • 3 min/mm
- For thicknesses d = 10 to 20 mm (0.4 to 0.8 in) the retention time is t = 30 min + (d - 10 mm) • 2 min/mm
- For thicknesses d > 20 mm (0.8 in) the retention time is t = 50 min + (d - 20 mm) • 1 min/mm

The retention time starts when the annealing temperature is reached. Longer retention times are less critical than too short retention times.

Water quenching should be carried out rapidly if the material should be further fabricated after solution annealing. Workpieces of less than 3 mm (0.12 in) thickness can be cooled down using air nozzles. If the solution annealing is the last fabrication step, the material can be cooled down more slowly in order to avoid material distortion.

Solution annealed VDM® Alloy 800 H and 800 HP are prone to stress relaxation cracks in the temperature range of 550 and 750 °C and should therefore be subjected to stabilizing annealing when a continuous operation (> 100 h) in the mentioned temperature range is intended. The stabilizing annealing temperature depends on the welding material and should be determined with VDM Metals’ Technical Customer Support. If possible, the stabilizing annealing should be carried out when all welding work is completed, because the heat-affected zones of the welds are particularly susceptible to cracking. Heating rates are critical and should not be too high to avoid disortion.

The cleanliness requirements listed under ‘Heating’ must be complied with.

Descaling and pickling
High temperature alloys develop a protective oxide layer in service. Therefore the necessity of descaling should be checked during the order process. Oxides of VDM® Alloy 800 H and 800 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 should preferably carried out in nitric hydrofluoric acid, oxide and scale layers have to be disrupted by blasting or treated in oxidizing salt melts. The pickling baths used must carefully be monitored regarding the concentration and temperatures; through too long pickling times, the material surface may be damaged by intergranular corrosion.

Machining
VDM® Alloy 800 H and 800 HP should be machined in the solution annealed condition. As the alloys are prone to work-hardening, low cutting speeds and appropriate feed rates should be used and the tool should be engaged at all times. Sufficient chip depths are important to get below the work-hardened surface layer.

Due to the high temperature loads on the cutting edge during machining, large amounts of cooling lubricants should be used. Water-based emulsions, as they are also used for construction and stainless steels, are suitable for instance.

Welding

When welding nickel-base alloys and special stainless steels, the following instructions should be adhered to:

Workplace
A separately-located workplace, which is specifically separated from areas in which carbon steels are being processed, should be used. Maximum cleanliness is required, and draughts should be avoided during inert gas welding.

Auxiliary equipment and clothing
Clean fine leather gloves and clean working clothes should be used.

Tools and machines
Tools used for other materials must not be used for nickel-base alloys and stainless steels. Brushes should be made of stainless materials. Processing and machining equipment such as shears, punches or rollers must be fitted with means (felt, cardboard, films) in order to avoid material contamination with ferrous particles, which can be pressed into the surface of the material and thus lead to corrosion.

Welding edge preparation

Welding edge preparation should preferably be carried out using mechanical methods such as lathing, milling or planing. Abrasive waterjet cutting or plasma cutting is also suitable. In the latter case, however, the cut edge (seam flank) must be cleanly re-worked. Careful grinding without overheating is also acceptable.

Ignition

The arc may only be struck in the weld area, e.g. along the seam flanks or outlets, and should not be carried out on the workpiece surface. Arc striking areas are prone to corrosion.

Included angle

The different physical characteristics of nickel alloys and special stainless steels are generally reflected through lower thermal conductivity and higher thermal expansion in comparison with carbon steel. This should be allowed for by means of, among other things, wider root gaps or openings (1-3 mm; 0.04-1.2 in), 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.

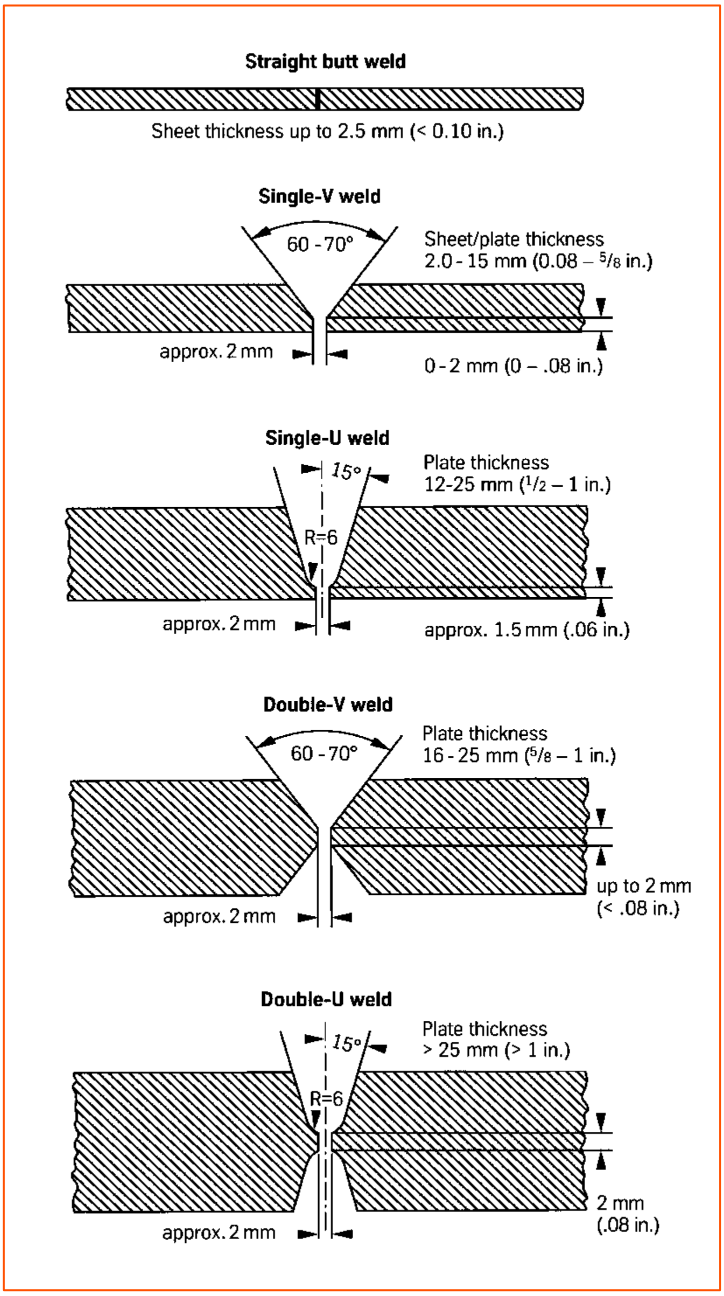

Figure 1 – Edge preparation for welding nickel alloys and special stainless steels

Cleaning

Cleaning of the base material in the seam area (both sides) and the filler material (e.g. welding rod) should be carried out using Acetone.

Welding process

For welding, VDM® Alloy 800 H and 800 HP should be in the annealed condition and be free from scale, grease and markings. VDM® Alloy 800 H and 800 HP can be welded using the following procedures: GTAW (TIG), GTAW (TIG) hot wire, plasma, SMAW (MMA), GMAW (MIG/MAG) and submerged arc welding.

Filler metal

The following filler materials are recommended:

VDM® FM 82 (W.-Nr. 2.4806)
DIN EN ISO 18274: S Ni 6082 (SG/UP-NiCr 20 Nb)
AWS A 5.14: ERNiCr-3

The use of covered electrodes is possible.

Welding parameters and influences

Care should be taken that the work is performed with a deliberately chosen, low heat input as indicated in Table 7 by way of example. The stringer bead technique is recommended. In this context attention should also be drawn to the correct selection of wire and electrode diameters. The corresponding section energies are exemplified in Table 7 below. The interpass temperature should not exceed 120 °C (248 °F). The welding parameters should be monitored as a matter of principle.

The heat input Q may be calculated as follows:

$$Q=\frac{U \cdot I \cdot 60}{v \cdot 1.000}\ \left(\frac{kJ}{cm}\right)$$

U = arc voltage, volts
I = welding current, amps
v = welding speed, cm/min.

Post-weld treatment

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. Please also refer to the information on ‘Descaling and pickling’. Neither pre- nor postweld heat treatments are required.

Thickness	Welding technique	Filler material		Root pass[1]		Intermediate and final passes		Welding speed	Shielding gas	
(mm)		Diameter (mm)	Speed (m/min)	I in (A)	U in (V)	I in (A)	U in (V)	(cm/min)	Type	Rate (l/min)
3	manual TIG	2	–	90	10	110-120	11	10-15	I1, R1 mit max. 3% H2	8-10
6	manual TIG	2-2,4	–	100-110	10	120-130	12	10-15	I1, R1 mit max. 3% H2	8-10
8	manual TIG	2,4	–	110-120	11	130-140	12	10-15	I1, R1 mit max. 2% H2	8-10
3	autom. TIG HD[2]	0,8-1,2	1-2,5	-	-	150	10	25	I1, R1 mit max. 2% H2	15-20
5	autom. TIG HD[2]	0,8-1,2	1-2,5	-	–	150	10	25	I1, R1 mit max. 2% H2	15-20
6	Plasma[3]	1,0-1,2	1	165	25	-	–	25	I1, R1 mit max. 2% H2	30
8	Plasma[3]	1,0-1,2	1	190-200	25	-	–	30	I1, R1 mit max. 2% H2	30
8	GMAW[4]	1	8	-	-	140-160	25-28	25-30	I1, R1 mit max. 2% H2	18-20
≥ 10	GMAW[4]	1,2	5	–	–	150	23-27		I1, R1 mit max. 2% H2	18-20
≥ 12	Submerged arc welding	1,6	-	–	–	250	28	44-55	-	-

[1] It must be ensured that there is sufficient root protection, for example using Ar 4.6, for all inert gas welding processes.

[2] The root pass should be welded manually (see manual TIG).

[3] Recommended plasma gas Ar 4.6 / rate 3.0 to 3.5 l/min

[4] For MAG welding the use of multicomponent inert gases is recommended.

Section energy kJ/cm:
autom. TIG HD max. 6, TIG, GMAW manual, autom. max. 8; Plasma max. 10

Figures are for guidance only and are intended to facilitate setting of the welding machines.

Table 7 – Welding parameters

Availability

VDM® Alloy 800 H and HP are available in the following standard semi-finished product forms:

Sheet and plate

Delivery conditions: hot or cold rolled, heat treated, descaled resp. pickled

Condition	Thickness mm (in)	Width mm (in)	Length mm (in)	Piece weight kg
Cold rolled	1-7 (0.04-0.28)	1,000-2,500 (39.37-98.43)	≤ 5,500 (216.54)	–
Hot rolled*	3-80 (0.12-3.15)	≤ 2,500 (39.37-98.43)	≤ 12,000 (472.44)	≤ 2,250

* 2 mm thickness on request

Strip

Delivery conditions: cold rolled, heat treated, pickled or bright annealed

Thickness mm (in)	Width mm (in)	Coil - inside diameter mm			
0.02-0.15 (0.0008-0.0059)	4-230 (0.16-9.06)	300	400	500	–
0.15-0.25 (0.0059-0.01)	4-720 (0.16-28.34)	300	400	500	–
0.25-0.6 (0.01-0.024)	6-750 (0.24-29.5)	–	400	500	600
0.6-1 (0.024-0.04)	8-750 (0.32-29.5)	–	400	500	600
1-2 (0.04-0.08)	15-750 (0.6-29.5)	–	400	500	600
2-3 (0.08-0.12)	25-750 (0.98-29.5)	–	400	500	600

Rod and bar

Delivery conditions: forged, rolled, drawn, heat treated, oxidised, descaled resp. pickled, machined, peeled, ground or polished

Dimensions*	Outside diameter mm (in)	Length mm (in)
General dimensions	6-800 (0.24-31.5)	1,500-12,000 (59.06-472.44)
Material specific dimensions	12-500 (0.47-19.69)	1,500-12,000 (59.06-472.44)

* Further dimensions on request

Wire

Delivery conditions: bright drawn, ¼ hard to hard, bright annealed in rings, containers, on spools and spiders

Drawn mm (in)	Hot rolled mm (in)
0.16-10 (0.006-0.4)	5.5-19 (0.22-0.75)

Other shapes and dimensions such as circular blanks, rings, seamless or longitudinal welded tubes and pipes or forgings are subject to special enquiry.

Technical publications

K. Drefahl, K. H. Matucha, F. Hofmann: Determination and Valuation of Extrapolation Parameters for Creep-Stressed Nickel-Based High Temperature Materials, CORROSION 86, Paper No. 376, NACE International Houston, Texas, 1986.

V. Coppolecchia, J. Bryant, F. Hofmann, K. Drefahl: Loss of Creep Ductility in Alloy 800 H with High Levels of Titanium and Aluminium, in Performance of High Temperature Materials, ASM International,1987, S. 201 – 208.

U. Brill, U. Heubner, K. Drefahl, H.-J. Henrich:
Zeitstandwerte von Hochtemperaturwerkstoffen,Ingenieur-Werkstoffe 3 (1991) No. 4, S. 59 – 62.
U. Heubner, J. Klöwer et al.: "Nickelwerkstoffe und hochlegierte Sonderedelstähle", 5. Auflage, Expert Verlag, Renningen-Malmsheim, 2012.

Imprint

Date of publication
4 October 2018

Publisher
VDM Metals GmbH
Plettenberger Straße 2
58791 Werdohl
Germany

Disclaimer

All information contained in this data sheet are based on the results of research and development work carried out by VDM Metals GmbH, and the data contained in the specifications and standards listed available at the time of printing. The information does not represent a guarantee of specific properties. VDM Metals reserves the right to change information without notice. All information contained in this data sheet is compiled to the best of our knowledge and is provided without liability. Deliveries and services are subject exclusively to the relevant contractual conditions and the General Terms and Conditions issued by VDM Metals GmbH. Use of the latest version of this data sheet is the responsibility of the customer.

VDM Metals GmbH
Plettenberger Straße 2
58791 Werdohl
Germany

Tel +49 (0)2392 55 0
Fax +49 (0)2392 55 22 17

vdm@vdm-metals.com
www.vdm-metals.com