VDM Metals

VDM® Alloy 617 B

Nicrofer 5520 Co B

Data Sheet **No. 4061**
February 2016 Revision 01

VDM® Alloy 617 B

Nicrofer 5520 Co B

VDM® Alloy 617 B is a nickel-chromium-cobalt-molybdenum alloy with excellent strength and creep properties. It was developed on the basis of Alloy 617, to meet the high demands of power plant technology for 700 °C power plants.

Designations and standards

Standard	Material designation
EN	2.4673 - NiCr23Co12Mo
ISO	NiCr22Co12Mo9
UNS	N06617

Table 1a – Designations and standards

Designations and standards

Product form	DIN	ASTM/ASME	VdTüV
Rod, bar	17744 17752	B 166/SB 166 B 564/SB 166	573
Sheet, plate	17744 17750	B 168/SB 168	

Table 1b – Designations and standards

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Co	S	Ti	Mo	Nb	P	Al	V	B
Min.	bal.	21		0.05			11		0.25	8			0.8		0.001
Max.		23	1.5	0.08	0.5	0.3	13	0.008	0.5	10	0.6	0.012	1.3	0.6	0.005

Table 2 – Chemical composition (wt.-%) according to VdTÜV data sheet 573

Physical Properties

Density	Melting range
8.4 g/cm³ (0.30 lb/in³)	1,330-1,380 °C (2,426-2,516 °F)

Temperature		Specific heat		Thermal conductivity		Electrical resistivity	Modulus of elasticity		Coefficient of thermal expansion	
°C	°F	J / (Kg · K)	Btu / (lb · °F)	W / (m · K)	Btu · in / (sq. ft · h F°)	μΩ · cm	GPa	10³ ksi	10^{-6} / K	10^{-6} / °F
20	68			11.7	81.1	122	212	30.7	12.09	6.72
100	212	474	0.113	13.1	90.8	125	206	29.9	12.55	6.97
200	392	494	0.118	14.9	103.3	126	200	29	13.13	7.29
300	572	511	0.122	16.7	115.8	127	194	28.1	13.43	7.46
400	762	528	0.126	18.7	129.7	128	188	27.3	13.72	7.62
500	932	544	0.13	20.7	143.5	129	181	26.3	14.09	7.83
600	1,112	584	0.139	23.5	162.9	131	173	25.1	14.62	8.12
700	1,292	663	0.158	27.7	192.1	133	166	24.1	15.33	8.52
800	1,472	658	0.157	27	187.2	134	157	22.8	16.02	8.9
900	1,652	662	0.158	27.2	188.6	135	149	21.6	16.6	9.22
1,000	1,832	664	0.159	28.5	197.6	138	139	20.2	17.09	9.49
1,100	2,012	681		30.7	212.9	141	129	18.7	17.64	9.8
1,200	2,192	701		32.3	223				18.22	10.12

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

Microstructural properties

The alloy obtains its strength both through solid solution strengthening (by Cr, Mo and Co) as well as by precipitation. The precipitation is caused by a combination of carbides (mainly chromium carbides) and γ' particles (Ni3 (Al, Ti)).

Mechanical properties

The following properties are applicable to VDM® Alloy 617 B in the solution annealed condition and indicated size ranges.

Temperature		Yield strength $R_{p\,0.2}$		Tensile strength R_m		Elongation A
°C	°F	MPa	ksi	MPa	ksi	%
20	68	300	43.5	700	101.5	35
100	212	270	39.2	650	94.3	
200	392	230	33.4	620	89.9	
300	572	220	31.9	600	87	
400	762	210	30.5	570	82.7	
500	932	200	29	540	78.3	
600	1,112	190	27.6	510	74	
700	1,292	185	26.8	400	58	
750	1,472	180	26.1	340	49.3	

Table 4 – Short-time properties of solution annealed VDM® Alloy 617 B at room temperature and elevated temperatures acc. to VdTÜV data sheet 573

Product form	Dimensions mm	Yield strength $R_{p\,0.2}$ MPa	Tensile strength R_m MPa	Elongation A %
Strip, sheet	≤ 6	≥ 350	≥ 750	≥ 35
	≤ 80	≥ 300	≥ 700	
Rod, bar	≤ 300	≥ 300	≥ 680	≥ 30

Table 5 – Min. mechanical properties at room temperature according to VdTÜV data sheet 573

Temperature		Creep rupture strength $R_m/10^4$ h		$R_m/10^5$ h	
°C	°F	MPa	ksi	MPa	ksi
600	1,112	331	48	265	38.4
610	1,130	317	45	249	36.1
620	1,148	303	43.9	233	33.8
630	1,166	289	41.9	218	31.6
640	1,184	274	39.7	202	29.3
650	1,202	259	37.6	187	27.1
660	1,220	244	35.4	172	24.9
670	1,238	229	33.2	158	22.9
680	1,256	214	31	145	21
690	1,274	199	28.9	132	19.1
700	1,292	185	26.8	119	17.3
710	1,310	171	24.8	108	15.7
720	1,328	158	22.9	97	14.1
730	1,346	145	21	87	12.6
740	1,364	132	19.1	77	11.2
750	1,382	121	17.5	69	10

Table 6 – Creep rupture strength of VDM® Alloy 617 B according to VdTÜV data sheet 573

Corrosion resistance

VDM® Alloy 617 B shows an excellent high-temperature corrosion resistance to oxidation and carburization under thermally constant and changing conditions up to 1,100 °C (2,012 °F). Because of these characteristics, combined with its exceptional strength, the alloy is suitable for high temperature applications.

Furthermore, the high proportion of nickel, chromium and molybdenum contributes to an excellent corrosion resistance of VDM® Alloy 617 B in a variety of aggressive media.

Applications

VDM® Alloy 617 B is specifically designed for use as a pipe and fitting material for steam generators in power plants with supercritical steam parameters (700 °C power plants).

Fabrication and heat treatment

VDM® Alloy 617 B 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 617 B. 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 con- trolled.

Heat treatments should be conducted in electric furnaces under vacuum or inert gas because of the precise tempera- ture control and freedom from contamination. Heat treatments in air or in gas-fired furnaces are acceptable though, if contaminants are at a low level, so that a neutral or slightly oxidizing furnace atmosphere can be adjusted. Fluctuating oxidizing and reducing furnace atmospheres should be avoided. Direct flame impingement needs to be avoided.

Hot working

VDM® Alloy 617 B may be hot-worked in the temperature range 1,200 to 950 °C (2,192 to 1,742 °F) with subsequent rapid cooling down in water or by using air. The workpieces should be placed in the furnace heated to hot working tem- perature in order to heat up. When the furnace has reached its temperature then again, the workpieces should be held for approximately 60 minutes per 100 mm thickness. Afterwards, the workpieces should be removed immediately and are hot formed within the temperature interval above. Reheating is required when temperatures fall below 950 °C (1,742 °F).

Heat treatment after hot working is recommended in order to achieve optimum fabrication properties (cold forming, machinability, weldability) and creep resistance.

Cold working

Cold working should be carried out on annealed material. VDM® Alloy 617 B has 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 resp. 5 % for applications above 900 °C (1,652 °F), the material should be solution annealed.

Heat treatment

Solution annealing should be carried out at temperatures between 1,150 and 1,200 °C (2,102 and 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 to achieve optimum material characteristics. Workpieces of less than 3 mm (0.12 in) thickness can be cooled down using air nozzles. For any thermal treatment the material should be charged into the heated annealing furnace. Please take note of the cleanliness requirements mentioned earlier under 'Heating'.

Solution annealed VDM® Alloy 617 B is prone to stress relaxation cracking after processing (welding, forming) in the temperature range of 550 to 780 °C (1,022 to 1,436 °F). Stabilizing annealing is therefore recommended, if a continu- ous operation (> 100 h) in the temperature range mentioned above is intended. The stabilizing annealing should be carried out after welding, since the heat-affected zones are particularly prone to stress relaxation cracking. Annealing should be carried out at 980 °C (1,796 °F) for 3 h. Heat up rate and cool down rate are uncritical and should not be too high to avoid disortion.

Descaling and pickling

Oxides of VDM® Alloy 617 B 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.

Particular attention should be paid to short pickling times (to avoid intercrystalline attacks), concentration and pickling temperatures. Before pickling in a nitric/hydrofluoric acid mixture, the surface oxide layer must be broken up by abrasive blasting or grinding or by pretreatment in a fused salt bath.

Machining
VDM® Alloy 617 B should be machined in the solution annealed condition. As the alloy is 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 expressed 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.

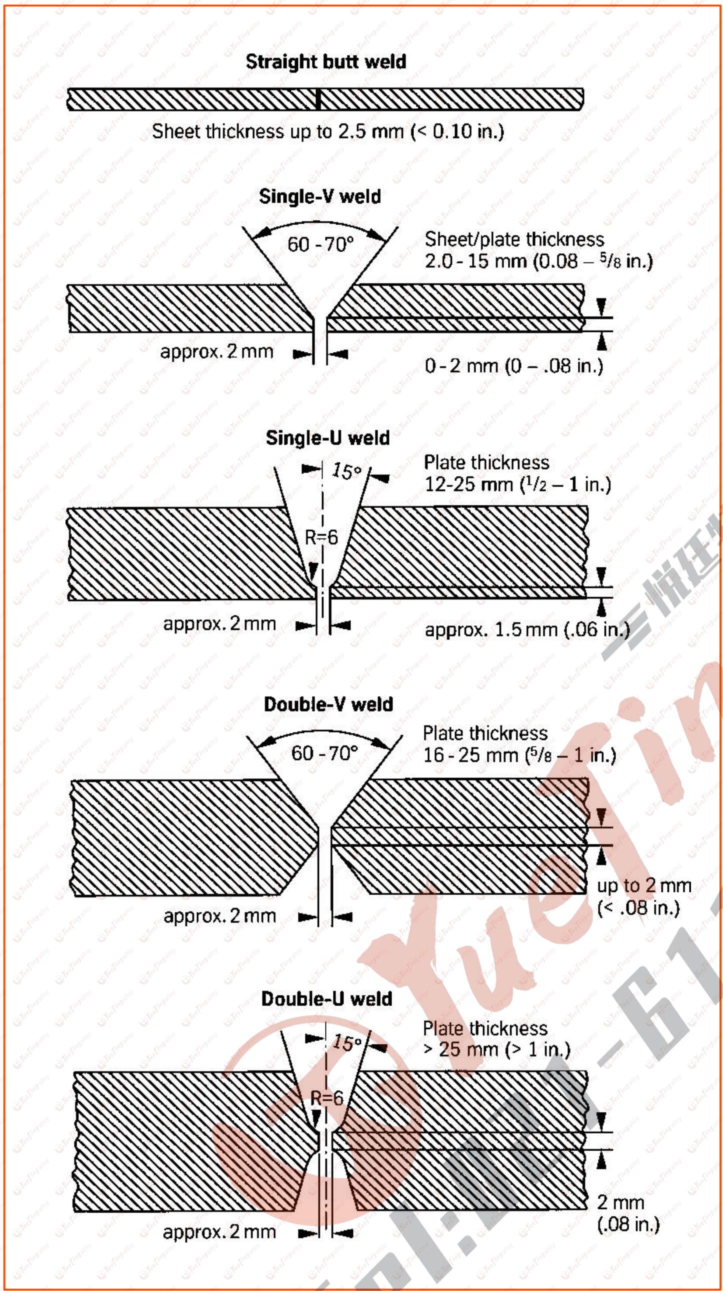

Figure 1 – Edge preparation for welding nickel alloys and special stainless steels

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

VDM® Alloy 617 B can be joined with similar and many other materials using the following procedures: TIG (WIG), GMAW (MIG/MAG) and plasma welding. For inert gas welding processes, the pulse technique should be used. For welding, VDM® Alloy 617 B should be in the solution annealed condition and be free from scale, grease and markings. When welding roots, sufficient protection of the root needs to be ensured with pure argon (Ar 4.6) so that the welding seam is free of oxides after welding. Root backing is also recommended for the first intermediate pass following the initial root pass and in some cases even for the second pass, depending on the weld set-up.

Any discoloration/heat tint should be removed preferably by brushing with a stainless steel wire brush while the weld metal is still hot.

Filler metal
The following filler materials are recommended:

Rods electrodes

VDM® FM 617 B (W.-Nr. 2.4627)
DIN EN ISO 18274: S Ni 6617 (NiCr22Co12Mo9) UNS N0617
AWS A5.14: ERNiCrCoMo-1

Welding parameters and influences
Care should be taken that the work is performed with a deliberately chosen, low heat input as indicated in Table 6 by way of example. The stringer bead technique is recommended. 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 mentioned under ‘Descaling and pickling’. Neither pre- nor postweld heat treatments are required.

Stabilizing annealing should be carried out on semi-finished products which were in use at temperatures between 600 and 650 °C (1,112 and 1,202 °F) before they are reused in this critical temperature range after repair welding.

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	15	I1	8-10
6	manual TIG	2-2.4		100-110	10	120-140	12	10-16	I1	8-10
8	manual TIG	2.4		100-110	11	130-140	12	10-16	I1	8-10
10	manual TIG	2.4		100-110	11	130-140	12	10-16	I1	8-10
3	autom. TIG	1.2	1,2			150	11	25	I1	12-14
5	autom. TIG	1.2	1,4			180	12	25	I1	12-14
2	autom. TIG HW	1				180	11	80	I1	12-14
10	autom. TIG HW	1.2				220	12	40	I1	12-14
4	Plasma[2]	1.2	1	180	25			30	I1	30
6	Plasma[2]	1.2	1	200-220	26			26	I1	30

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

[2] Recommended plasma gas Ar 4.6 / rate 3.0 to 3.5 l/min Section energy kJ/cm:
TIG, MIG/MAG max. 8; MMA max. 7; 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 617 B is available in the following standard semi-finished product forms:

Rod and bar

Delivery conditions: forged, rolled, drawn, heat treated, oxidized, 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	15-500 (0.59-19.69)	1,500-12,000 (59.06-472.44)
* Further dimensions on request		

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)	≤ 3,350
Hot rolled*	3-100 (0.12-3.94)	1,000-2,500 (39.37-98.43)	≤ 12,000 (472.44)	≤ 3,350
* 2 mm thickness on request				

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

Imprint

Date of publication
15 February 2016

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.