VDM Metals

A company of ACERINOX

VDM Alloy 31 Plus®

Nicrofer 3426 hMo

Material Data Sheet No. 4063 Revision 05

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VDM Alloy 31 Plus® is a Nickel-Iron-Chromium-Molybdenum alloy with a controlled addition of nitrogen. For an improved metallurgical stability the alloy has an optimized nickel content compared to VDM® Alloy 31.

VDM Alloy 31 Plus® is characterized by:

- high corrosion resistance similar to VDM® Alloy 31
- improved lower solution annealing temperature
- excellent corrosion resistance to sulfuric acids
- excellent corrosion resistance to phosphoric acids
- ease of working and processing
- good weldability
- approval for pressure vessels according to ASME Code Section VIII Div 1; Section VIII Div 2, Class 1 applications

Designations

Standard	Material designation
D	2.4692
ISO	NiFeCr27Mo6CuN
UNS	N08034

Standards

Product form	ASTM	VdTUEV	Others
Strip	B 625	583	ASME Code Case 2991*
Sheet and plate	B 625	583	ASME Code Case 2991*
Rod and bar	B 581 B 649		ASME Code Case 2991*
Wire	B 649		
Forging	B 564		ASME Code Case 2991*
*Valid for Solution Annealed alloy			

Table 1 – Designations and standards

Chemical composition

	Ni	Cr	Fe	S	Si	Mn	P	Mo	Cu	N	C	Al
Min.	33,5	26.0	balance			1.0		6.0	0.5	0.10		
Max.	35,0	27.0		0.01	0.1	4.0	0.02	7.0	1.5	0.25	0.01	0.30

Table 2 – Chemical composition (%)

Physical properties

Density	Melting range	Relative magnetic permeability at 20 °C (68 °F)
8.08 g/cm^3 (0.292 lbs/in^3) at 20 °C (68 °F)	1,350-1,370 °C (2,460-2,500 °F)	1.001

Temperature		Specific heat capacity		Thermal conductivity		Modulus of elasticity		Average linear expansion coefficient	
°C	°F	$\frac{J}{Kg \cdot K}$	$\frac{Btu}{lb \cdot °F}$	$\frac{W}{m \cdot K}$	$\frac{Btu \cdot in}{sq.\,ft \cdot h \cdot °F}$	GPa	10^6 psi	$\frac{10^{-6}}{K}$	$\frac{10^{-6}}{°F}$
20	68	431 1)	0.103 1)	10.3 1)	5.95 1)	199	28.9	14.3 1)	7.94 1)
100	212	447	0.107	11.6	6.70	195	28.3	14.8 1)	8.22 1)
200	392	468	0.112	13.4	7.74	189	27.4	15.4	8.56
300	572	480	0.115	14.9	8.61	181	26.3	16.0	8.89
400	752	488	0.117	16.3	9.42	174	25.2	16.3	9.06
500	932	488	0.117	17.6	10.17	168	24.4	16.3	9.06

1) Extrapolated

Table 3 – Typical physical properties of VDM Alloy 31 Plus® at room temperature and elevated temperatures

Microstructural properties

VDM Alloy 31 Plus® has a face-centered cubic structure. The nitrogen and nickel content reduces the tendency for precipitation of intermetallic phases and stabilizes the austenitic microstructure.

Mechanical properties

The data for the 0.2 % yield strength $R_{p0.2}$, 1.0 % yield strength $R_{p1.0}$, elongation at fracture A_5, A_{80} and notch impact toughness KV_2 are minimum values. They apply for the solution-annealed and quenched condition independent of the sampling location and the sample position for the sample direction longitudinal (l) and transverse (q).

Temperature		Yield strength $R_{p\,0.2}$		Yield strength $Rp_{\,1.0}$		Tensile strength R_m		Elongation A
°C	°F	MPa	ksi	MPa	ksi	MPa	ksi	%
20	68	280	40.6	310	45	650 to 850	94.3 to 123	40
100	212	210	30.5	240	34.8			
200	392	180	26.1	210	30.5			
300	572	165	23.9	195	28.3			
400	762	150	21.8	180	26.1			
500	932	135	19.6	165	23.9			

Table 4 – Mechanical short-term properties at room and elevated temperatures for the product form plate, plate thickness ≤ 30mm (minimum value)

ISO V-notch impact energy

Average value, room temperature: ≥ 150 J

Average value, -196 °C (-320.8 °F): ≥ 110 J

Cut axis perpendicular to the surface, sheet thickness ≤ 30 mm average value from 3 samples. The minimum average value may only fall below by a single value, namely no more than 30%. These values only apply for normal samples according to DIN EN ISO 148-1. For undersized samples according to DIN EN ISO 148-1, the minimum values indicated for the notch impact toughness linear to the sample cross-section in the gap must be reduced. For undersized samples < 5 mm according to DIN EN ISO 148-1, the values for the individual case must be agreed separately with the manufacturer. The values also apply for the heat affected zone in welded joints.

Corrosion resistance

The material is resistant to inter-crystalline corrosion in the delivery condition and when welded according to the test procedure according to ASTM-G 28, Method A. The corrosion rate determined via the mass loss according to ASTM-G 28, Method A (test period 24 hours), is maximum 0.5 mm/a (0.020 mpy) in the delivery condition and when welded. A very good resistance is also provided against crevice corrosion and pitting. The corrosion resistance is comparable with the material VDM® Alloy 31.

Fields of application

Typical fields of application for VDM Alloy 31 Plus® are:

- Chemical processes with sulfuric acid
- Treatment of sulfuric acids from waste
- Components for flue gas desulfurization plants
- Clad tanks
- Plants for the production of phosphoric acid via the wet digestion process
- Ocean water and brackish water applications
- Evaporation and crystallization of salts
- Pickling plants for sulfuric acid and for nitric-hydrofluoric acid
- Hydrometallurgy, e.g. digestion of laterite ores in the HPAL process
- Fine chemicals, special chemicals and organic acids
- Components for the cellulose and paper industry
- Marine scrubber / ship diesel scrubber
- Longitudinal welded tubes for waste to energy

Fabrication and heat treatment

VDM Alloy 31 Plus® can be easily formed both hot and cold and can also be machined.

Heating
It is important that the workpieces are clean and free of any contaminants before and during heat treatment. Sulfur, phosphorus, lead and other low-melting-point metals can result in damage during the heat treatment of the material. This type of contamination is also contained in marking and temperature-indicating paints or pens as well as in lubricating grease, oils, fuels and similar materials. The sulfur content of fuels must be as low as possible. Natural gas should contain less than 0.1% by weight of sulfur. Heating oil with a maximum sulfur content of 0.5% by weight is also suitable. Electric furnaces are to be preferred due to precise temperature control and lack of contaminants due to fuel. The furnace atmosphere should be set between neutral and slightly oxidizing and should not change between oxidizing and reducing. The workpieces must not come in direct contact with flames.

Hot forming
VDM Alloy 31 Plus® should be hot-formed in a temperature range of 1,200 to 1,050 °C (2,192 to 1,922 °F) with subsequent rapid cooling in water or in air. For heating up, workpieces should be placed in a furnace that has been heated up to the maximum hot-forming temperature (solution annealing temperature). Once the furnace has reached its temperature again, the workpieces should remain in the furnace for around 60 minutes per 100 mm (3.94 in) of thickness. After this, they should be removed from the furnace immediately and formed within the temperature range stated above, with reheating necessary once the temperature reaches 1,050 °C (1,922 °F). Heat treatment after hot forming is recommended in order to achieve optimal properties.

Cold forming
The workpieces should be in the annealed condition for cold forming. VDM Alloy 31 Plus® has a significantly higher work hardening rate than other widely used austenitic stainless steels. This must be taken into account during the design and selection of forming tools and equipment and during the planning of forming processes. Intermediate annealing is necessary for major cold forming work. For cold forming of > 15%, a final solution annealing must be conducted.

Heat treatment
Solution annealing should take place at temperatures between 1,140 and 1,170 °C (2,084 and 2,138 °F). The retention time during annealing depends on the semi-finished product thickness and can be calculated as follows:

- For thickness d ≤ 10 mm (0.39 in), the retention time is t = d * 3 min/mm
- For thickness d = 10 to 20 mm (0.39 to 0.79 in), the retention time is t = 30 min + (d – 10 mm) * 2 min/mm
- For thickness d > 20 mm (0.79 in), the retention time is t = 50 min + (d – 20 mm) * 1 min/mm

The retention time commences with material temperature equalization; longer times are generally considerably less critical than retention times that are too short.

For maximum corrosion resistance, the workpieces must be quickly cooled from the annealing temperature particularly through the range of 1,100 to 500 °C (2,012 to 932 °F) with a cooling rate of >150 °C/min (>302 °F/min). The material must be placed in a furnace that has been heated up to the maximum annealing temperature before any heat treatment. The cleanliness requirements listed under "Heating" must be observed. For strip products, the heat treatment can be performed in a continuous furnace at a speed and temperature that is adapted to the strip thickness.

Descaling and pickling
Oxides formed on VDM Alloy 31 Plus® and discoloration adjacent to welds are more adherent than on stainless steels. Grinding using extremely fine abrasive belts or grinding discs is recommended. It is imperative that grinding burns be avoided. Before pickling in nitric-hydrofluoric acid mixtures, the oxide layers should be disrupted by abrasive blasting or

fine grinding, or pre-treated in in a fused salt bath. The pickling baths used should be carefully monitored with regard to concentration and temperature.

Machining
VDM Alloy 31 Plus® should be machined in the heat-treated condition. Because of the considerably elevated tendency toward work hardening in comparison with low-alloy austenitic stainless steels, a low cutting speed and a feed level that is not too high should be selected and the cutting tool should be engaged at all times. An adequate depth of cut is important in order to cut below the previously formed strain-hardened zone. Optimum heat dissipation through the use of large quantities of suitable, preferably aqueous, lubricants has considerable influence on a stable machining process.

Welding information

When welding nickel alloys and special stainless steels, the following information should be taken into account:

Safety
The safety recommendations of the manufacturer of welding consumables have to be taken into consideration especially to avoid dust and smoke exposure.

Workplace
A separately located workplace, which is specifically separated from areas in which C-steel is being processed, must be provided. Maximum cleanliness is required, and drafts should be avoided during gas-shielded welding.

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

Tools and machines
Tools that have been used for other materials may not be used for nickel alloys and stainless steels. Only stainless steel brushes may be used. Processing and treatment machines such as shears, punches or rollers must be fitted (felt, cardboard, films) so that the workpiece surfaces cannot be damaged by the pressing in of iron particles through such equipment, as this can lead to corrosion.

Edge preparation
Welding seam preparation should preferably be carried out using mechanical methods through lathing, milling or planning. Abrasive waterjet cutting or plasma cutting is also possible. In the latter case, however, the cut edge (seam flank) must be cleanly reworked. Careful grinding without overheating is also permissible.

Striking the arc

The arc should only be struck in the seam area, such as on the weld edges or on an outlet piece (extension tab), and not on the component surface. Arc strikes are areas in which corrosion more easily occurs.

Included angle

Compared to C-steels, nickel alloys and special stainless steels exhibit lower heat conductivity and greater heat expansion. These properties must be taken into account by larger root openings or root gaps (1 to 3 mm, 0.039 to 0.118 in). Due to the viscosity of the welding material (compared to standard austenitic stainless steels) and the tendency to shrink, opening angles of 60 to 70° – as shown in Figure 5 – have to be provided for butt welds.

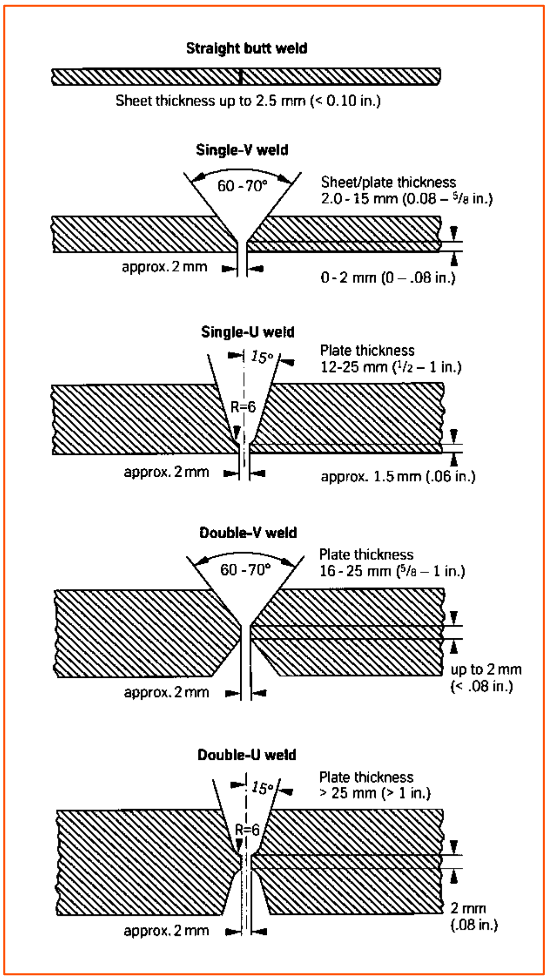

Figure 1 – Seam preparation for welding nickel alloys and special stainless steels

Cleaning

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

Welding technique

VDM Alloy 31 Plus® can be welded in most applications with VDM® FM 59 using conventional processes. This includes TIG and MAG welding. Pulsed arc welding is preferred for gas-shielded welding processes. For welding, VDM Alloy 31 Plus® should be in a solution-annealed condition and free of scale, grease and markings. When welding the root, care should be taken to achieve best quality root protection using pure argon, purity 99.99% or better so that the welding edge is free of oxides after welding the root. Root protection is also recommended for the first and, in certain cases depending on the welded construction, also for the second intermediate layer weld after root welding. Any tempering colors must be removed while the welding edge is still hot, preferably using a stainless steel brush.

Welding filler

The use of the following fillers is recommended for gas-shielded welding methods:

Welding rods and wire electrodes:

VDM® FM 59 (material no. 2.4607)
UNS N06059 AWS A5.14: ERNiCrMo-13
DIN EN ISO 18274: S Ni 6059 (NiCr23Mo16)
It is recommended to contact the manufacture for application in strongly oxidizing media.

Welding parameters and influences

It must be ensured that work is carried out using targeted heat application and low heat input as listed in Table 6 as an example. The stringer bead technique is recommended. The interpass temperature should not exceed 120 °C (248 °F). In principle, checking of welding parameters is necessary.

Heat input Q can 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 strength, amperes
v = welding speed, cm/min

Post-treatment

For the optimal performance of the work, insert the brush immediately after welding, i.e., while still warm, without additional pickling to the desired surface condition, i.e., discoloration can be removed completely. Pickling, if required, should generally be the last operation in the welding process. Information contained in the section entitled "Descaling and pickling" must be observed. Heat treatments are normally not required before or after welding.

Thickness	**Welding technique**	**Filler material**	**Intermediate and final passes**		**Welding speed**	**Shielding gas**	
mm (in)		**Diameter (mm)**	**I in (A)**	**U in (V)**	**(cm/min)**	**Type**	**Rate (l/min)**
8 (0.314)	v- TIG	1.2 (0.047)	150-170	11	19	I1	8-13
25 (0.984)	TIG	1.2 (0.047)	190-210	23-25	24,5	I1	12-16

Table 5 – Welding parameters

Availability

VDM Alloy 31 Plus® is available in the following standard semi-finished forms:

Sheet

Delivery condition: Hot- or cold-rolled, heat-treated, de-scaled or pickled

Condition	Thickness mm (in)	Width mm (in)	Length mm (in)	Piece weight Kg (lb)
Cold rolled	1-7 (0.04-0.28)	≤ 2,500 (98.43)	≤ 12,500 (492.13)	
Hot rolled*	3-30 (0.118-1.181)	≤ 2,500 (98.43)	≤ 12,500 (492.13)	≤ 1,650 (3,637.63)

* 2 mm (0.08 in) thickness on request

Strip

Delivery condition: Cold-rolled, heat-treated, pickled or bright annealed

Thickness mm (in)	Width mm (in)	Coil - inside diameter mm (in)			
0.03-0.15 (0.00118-0.006)	4-230 (0.16-9.06)	300 (11.811)	400 (15.748)	500 (19.685)	–
0.15-0.25 (0.006-0.01)	4-720 (0.16-28.34)	300 (11.811)	400 (15.748)	500 (19.685)	–
0.25-0.6 (0.01-0.024)	6-750 (0.24-29.5)	–	400 (15.748)	500 (19.685)	600 (23.622)
0.6-1 (0.024-0.0393)	8-750 (0.32-29.5)	–	400 (15.748)	500 (19.685)	600 (23.622)
1-2 (0.0393-0.0787)	15-750 (0.6-29.5)	–	400 (15.748)	500 (19.685)	600 (23.622)
2-3 (0.078-0.118)	25-750 (0.98-29.5)	–	400 (15.748)	500 (19.685)	600 (23.622)

Rolled sheet – separated from the coil – are available in lengths from 250 to 4,000 mm (9.84 to 157.48 in).

Other shapes and dimensions (such as rods, wires, discs, rings, seamless or longitudinally welded pipes and forgings) can be requested.

Publications

The following technical literature has been published about the material VDM Alloy 31 Plus®:

H. Alves, R. Behrens, F. Winter: "UNS N08031 and UNS N08031 Plus, multipurpose alloys for the chemical process industry and related applications", CORROSION 2016, Paper No. 7563, NACE International, Vancouver, British Columbia, 2016.

H. Alves, R. Behrens, L. Paul: "Evolution of Nickel Base Alloys – Modification to Traditional Alloys for Specific Applications", CORROSION 2014, Paper No. 4317, NACE International, San Antonio, Texas, 2014.

R. Behrens, F. Stenner, H. Alves: "New developed 6-Mo super-austenitic stainless steel with low sigma solvus temperature and high resistance to localised corrosion", CORROSION 2013, Paper No. 2228, NACE International, Orlando, Florida, 2013.

H. Alves, R. Behrens, F. Winter: “UNS N08031 and UNS N08031 Plus, multipurpose alloys for the chemical process industry and related applications”, NACE Corrosion 2016, Paper No. 7563.

D. Niespodziany, Dr. Alves, Dr. Behrens, Dr. Wolf: “Characterization of novel high performance material UNS N08034”, NACE CORROSION 2019, Nashville, 24.-28.03.2019, Paper No. 13156.

Legal notice

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