VDM Metals

VDM® Alloy 718 CTP

Nicrofer 5219 Nb

Material Data Sheet No. 4127

September 2017

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VDM® Alloy 718 CTP is an age-hardenable nickel-chromium-iron-molybdenum alloy. The age hardening is achieved by specific additions of niobium, titanium and aluminum. It can be delivered in the solution-annealed or in different age-hardened conditions. The standard Alloy 718 CTP version has a minimum yield strength of 120 ksi and can be ordered with the material designation 120K. A further variant of Alloy 718 CTP has a minimum yield strength of 150 ksi and can be ordered with the material designation 150K.

VDM® Alloy 718 CTP is characterized by:

- Good processing properties in the solution-annealed condition
- Good mechanical short and long-term properties, and excellent fatigue strength in the age-hardened condition
- Excellent mechanical properties in low temperatures
- Excellent resistance to stress corrosion cracking and pitting in chloride-containing media
- Excellent resistance to stress corrosion cracking and sulfide stress cracking in sour (H_2S-containing) oilfield environments

Depending on the use conditions, narrower analysis limits apply to certain alloy elements. This is true in particular for carbon and niobium, but to lesser extent also for aluminum and titanium. The purpose of this limitation is to optimize the structure and mechanical properties with regard to the intended use. VDM® Alloy 718 CTP is characterized by limited levels of carbon and niobium.

Additional information can be found in the material data sheet of the VDM® Alloy 718.

Designations

Standard	Material designation
EN	2.4668 - NiCr19Fe19Nb5Mo3
ISO	NiCr19Nb5Mo3
UNS	N07718
AFNOR	NC19FeNb
BS	NA 51

Table 1a – Designations

Standards

Product form	DIN	DIN EN	ISO	ASTM	NACE	Others
Rod, bar					MR 0175 / ISO 15156*	API 6ACRA*
Sheet, plate	17750			B 670		
Strip	17744 17750	10302	6208	B 670		
Wire	17744 17753					

* Ballot for inclusion of the 150K variant of Alloy 718 CTP in NACE MR 0175/ISO15156 and API6ACRA is pending.

Table 1b – Standards

Chemical composition

	Ni	Fe	C	Mn	Si	Cu	Al	Ti	P	S	Pb	Cr	Mo	Co	B	Se	Bi	Nb + Ta
Min.	50.0	balance					0.40	0.80				17.0	2.80					4.87
Max.	55.0		0.045	0.35	0.35	0.23	0.60	1.15	0.010	0.010	0.0010	21.0	3.30	1.00	0.0060	0.0005	0.00005	5.20

Table 2 – Chemical composition (%) according to API Standard 6ACRA, UNS number N07718

Physical properties

Density	Melting range	Relative magnetic permeability at 20 °C (68 °F)	Curie temperature
8.26 g/cm^3 at 20 °C (68 °F)	1,270-1,340 °C (2,318-2,444 °F)	1.001 (Maximum)	-195 °C (383 °F) (solution-annealed) -112 °C (233.6 °F) (solution-annealed and age-hardened)

Temperature		Specific heat capacity		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	10^3 ksi	10^{-6} / K	10^{-6} / °F
20	68	460	0,110	11.1	77.0	116	203	29.4		
100	212	462	0,110	11.9	82.6	118	199	28.9	14.2	7.89
200	392	476	0,114	13.4	93.0	121	192	27.8	14.3	7.94
300	572	494	0,118	15.2	105.5	123	186	27.0	14.3	7.94
400	762	511	0,122	17.2	119.3	125	179	26.0	14.4	8.00
500	932	521	0,124	19.0	131.8	127	172	24.9	14.6	8.11
600	1,112	539	0,129	20.8	144.3	128	165	23.9	15.0	8.33
700	1,292	613	0,146	24.5	170.0	129	158	22.9	15.4	8.56
800	1,472	617	0,147	24.4	169.3	130	150	21.8	16.6	9.22
900	1,652	626	0,150	25.1	174.1	131	142	20.6	17.2	9.56
1,000	1,832	635	0,152	25.7	178.3	131	134	19.4	17.6	9.78
1,100	2,012	637	0,152	27.0	187.3		125	18.1		
1,200	2,192	662	0,158	28.8	199.8		121	17.5		

Table 3 – Typical physical properties at room and increased temperatures

Microstructural properties

VDM® Alloy 718 CTP has an austenitic microstructure with multiple phases. By means of different heat treatments, graduated mechanical properties of the material can be reached. The excellent mechanical properties of VDM® Alloy 718 CTP result from the γ‘‘-formation during the precipitation hardening. Depending on the precipitation hardening temperature the size of the γ‘‘-particles vary which leads to different strength properties. More information can be found in the “Heat treatment” chapter.

Mechanical properties

The following mechanical properties of VDM® Alloy 718 CTP apply to hot or cold-formed material in the age-hardened condition in the specified dimensions. Material with specified properties outside of the listed dimensions ranges (see “Availability” chapter) must be requested separately.

Material designation	**Temperature**		**Yield strength $R_{p\,0.2}$**		**Tensile strength R_m**		**Elongation A**	**Reduction of area Z**
	°C	**°F**	**MPa**	**ksi**	**MPa**	**ksi**	**%**	**%**
120K	-196	-320.8	1,138	165.1	1,606	233.9	28	34
	-100	-148	1,049	152.1	1,400	203.1	27	45
	20	68	962	139.5	1,256	182.2	29	43
	100	212	931	135.0	1,231	178.5	26	38
	150	302	913	132.4	1,211	175.6	24	42
	200	392	901	130.7	1,196	173.5	23.5	38
150K	175	347	1040	150.9	1237	179.5	21	40
	205	401	1039	150.6	1237	179.4	22	39

Table 4 – Typical mechanical properties of age-hardened VDM® Alloy 718 CTP, material designations 120K and 150K

Material designation	**Product form**	**Dimensions**		**Yield strength $R_{p\,0.2}$**		**Tensile strength R_m**		**Elongation A**	**Reduction of area Z**
		mm	**in**	**MPa**	**ksi**	**MPa**	**ksi**	**%**	**%**
120K	Round bar	≤ 254	≤ 10	827-1,000	120-145	≥ 1,034	≥ 150	≥ 20	≥ 35
	Round bar	≥ 254	≥ 10	827-1,000	120-145	≥ 1,034	≥ 150	≥ 20	≥ 25
150K	Round bar	≤ 254	≤ 10	≥ 1034	≥ 150	≥ 1241	≥ 180	≥ 20	≥ 35
	Round bar	≥ 254	≥ 10	≥ 1034	≥ 150	≥ 1241	≥ 180	≥ 20	≥ 25

Table 5 – Mechanical properties at ambient temperature of age-hardened VDM® Alloy 718 CTP, material designations 120K and 150K

Charpy V-notch impact toughness

Material Designation	QTC Cross Section Thickness		Orientation	Minimum Average		Minimum Single		Lateral Expansion	
	mm	in		J	ft·lbs	J	ft·lbs	mm	in
120K	< 76	< 3	Longitudinal	68	50	61	45	0.38	0.015
	≥ 76-254	≥ 3-10	Transverse	47	35	41	30	0.38	0.015
	> 254	> 10	Transverse	41	30	37	27	0.38	0.015
150K	< 76	< 3	Longitudinal	68	50	61	45	0.38	0.015
	≥ 76-254	≥ 3-10	Transverse	47	35	41	30	0.38	0.015
	> 254	> 10	Transverse	41	30	37	27	0.38	0.015

Table 6 – Impact testing shall be performed on a set of three specimens and all tests at or below -60 °C (-75 °F).

Hardness Rockwell HRC

Material Designation	Hardness	
	HRC	
	min	max
120K	32	40*
150K	32	45

Table 7 – Hardness according to NACE MR 0175/ISO15156*

Corrosion resistance

As a result of the high chromium and molybdenum concentrations, VDM® Alloy 718 CTP has very good general corrosion resistance and pitting corrosion resistance in many environments. By virtue of its high nickel content, VDM® Alloy 718 CTP also has good resistance against stress corrosion.

Applications

Due to its excellent corrosion resistance and its good workability, VDM® Alloy 718 CTP is versatile in use in the oil and gas industry, in the offshore industry and in marine engineering. The alloy has proven itself well, especially for oilfield completion equipment in very demanding environments containing H_2S, CO_2, and high chlorides. The alloy has also proven itself for highly stressed oilfield components.

Fabrication and heat treatment

VDM® Alloy 718 CTP can be easily processed by both hot and cold forming 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 lead to damage when heat-treating VDM® Alloy 718 CTP. This type of contamination is also contained in marking and temperature display paints or pens, and also in lubricating grease, oils, fuels and similar materials. Fuels must have as low a sulfur content 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 temperature 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 718 CTP can be hot-worked at a temperature range of between 1,120 and 900 °C (2,048 and 1,652 °F). It should be done evenly in order to receive a homogeneous microstructure. The subsequent deformation should be at least 20% and be implemented below 960 °C (1,760 °F) to achieve an optimal toughness. The cooling down should preferably take place in water.

Cold forming

The workpieces should be in the solution-annealed condition for cold working. VDM® Alloy 718 CPT has a significantly higher work hardening than 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. To achieve a high strength, a combination of cold forming with subsequent age hardening is an option.

Heat treatment

Various solution-annealing and aging conditions are combined in order to obtain the different required material properties. Since the diffusion rate crucial for the formation of the γ"-phase is relatively low, long age hardening times are required to achieve the optimal mechanical quality values for VDM® Alloy 718 CTP. The material must be placed in a furnace that has been heated up to the maximum annealing temperature before any heat treatment. 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. The cleanliness requirements listed under the "Heating" chapter must be observed.

Heat treatment for VDM® Alloy 718 CTP 120K reference API standard 6ACRA for use under H_2S-containing media:

- Solution annealing: 1-2.5 hours at 1,021-1,052 °C (1,870-1,925 °F), cooling down in water
- Age hardening: 6-8 hours at 774-802 °C (1,425-1,475 °F), cooling down in air or faster

Heat treatment for VDM® Alloy 718 CTP 150K according to NACE MR0175/ISO15156*:

- Solution annealing: 1-2.5 hours at 1,021-1,052 °C (1,870-1,925 °F), cooling down in water
- Age hardening: min. 8 hours at 700-750 °C (1,292-1,382 °F), furnace cool to 600-650 °C (1,112-1,202 °F) and hold for additional 8 hours minimum, air cool

*Ballot for inclusion of Alloy 718 CTP 150K is pending.

Descaling and pickling

Oxides from VDM® Alloy 718 CPT and discolorations in the area around welds have better bonding than in 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 removed by abrasive blasting or fine grinding, or pre-treated in molten salts. The pickling baths used should be carefully monitored with regard to concentration and temperature.

Machining
The mechanical processing of VDM® Alloy 718 CTP should take place in a solution-annealed condition. For reasons of the increased tendency to work hardening in comparison with low-alloy austenitic stainless steels, a lower cutting speed should be selected and the cutting tool should stay engaged at all times. An adequate chip depth is important in order to cut below a previously formed work-hardened zone. Optimum heat dissipation through the use of large quantities of suitable, preferably aqueous, lubricants has considerable influence on a stable machining process. Although the material in the solution-annealed condition is easier to process and the strain on tools is less, better surface quality is achieved in the age-hardened condition. The best results in terms of the surface quality of the finished product are achieved, however, by pre-treatment before age hardening and finishing after age hardening.

Welding information

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

Workplace
A separate workplace should be provided which is clearly separated from the areas where carbon steel is processed. 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. This can ultimately lead to corrosion.

Edge preparation
Weld seam preparation should preferably be carried out using mechanical methods such as lathing, milling or planing. 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, and not on the component surface. Scaling areas are areas in which corrosion more easily occurs.

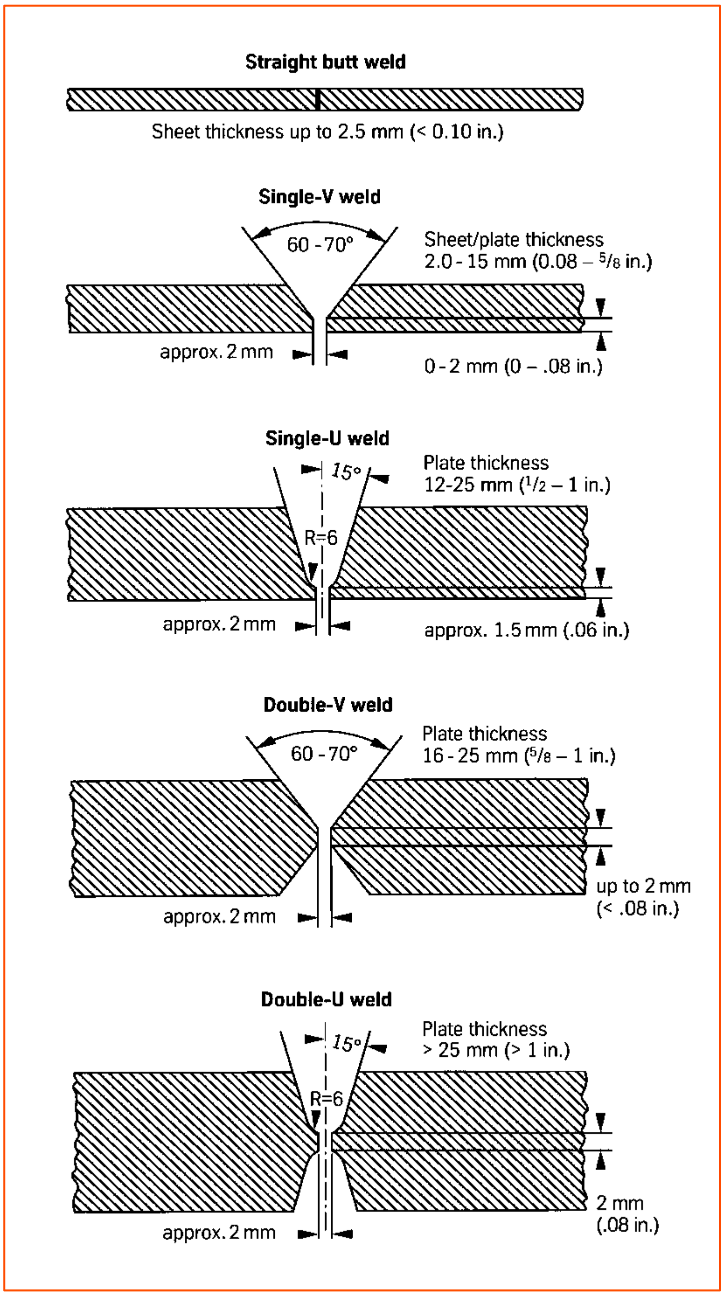

Figure 1 – Seam preparation for welding nickel alloys and special stainless steels

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 austenites) and the tendency to shrink, opening angles of 60 to 70° – as shown in figure 1 – have to be provided for butt welds.

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 parameters and influences

It must be ensured that work is carried out using targeted heat application and low heat input. The stringer bead technique is recommended. The interpass temperature should not exceed 100 °C (212 °F). A continuous monitoring of the welding parameters is in principle required.

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/minute

Welding technique
VDM® Alloy 718 CTP can be welded with a number of different welding processes. Wherever metal inert gas welding process is used, impulse technology is preferable. The material should be in its solution-annealed condition for welding, and should be free of scale, grease and markings. When welding the root and possibly the first filler beads, care should be taken to achieve best quality root protection (e.g. argon 4.6), so that the welding edge is free from oxides after welding the root. Any temper colors must be removed, preferably using a stainless steel brush, while the welding seam is still hot.

Welding filler
The following welding consumable is recommended:

VDM® FM 718 W.-no. 2.4667
AWS A5.14: ERNiFeCr-2
ISO 18274

The use of bar electrodes in sleeves is possible.

Post-treatment
During optimum implementation of the work, brushing directly after welding, in other words, in a hot condition, without additional pickling results in the required surface condition, i.e. discolorations can be removed completely. Once the welding work is finished, age hardening can be conducted if desired (see the section “Heat treatment”). Pickling, if required or specified, should generally be the last operation in the welding process. The information contained in the section entitled "Descaling and pickling" must be observed.

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	2.0	-	90	10	110-120	11	15	I1, R1 mit max. 3% H_2	8-10
6	manual TIG	2.0-2.4	-	100-110	10	120-140	12	14-16	I1, R1 mit max. 3% H_2	8-10
8	manual TIG	2.4	-	100-110	11	130-140	12	14-16	I1, R1 mit max. 3% H_2	8-10
10	manual TIG	2.4	-	100-110	11	130-140	12	14-16	I1, R1 mit max. 3% H_2	8-10
3	autom. TIG [2)]	1.2	1.2	-	-	150	11	25	I1, R1 mit max. 3% H_2	12-14
5	autom. TIG [2)]	1.2	1.4	-	-	180	12	25	I1, R1 mit max. 3% H_2	12-14
2	autom. TIG HD[2)]	1.0	-	-	-	180	11	80	I1, R1 mit max. 3% H_2	12-14
10	autom. TIG HD[2)]	1.2	-	-	-	220	12	40	I1, R1 mit max. 3% H_2	12-14
4	Plasma[3)]	1.2	1.0	180	25	-	-	30	I1, R1 mit max. 3% H_2	30
6	Plasma[3)]	1.2	1.0	200-220	26	-	-	26	I1, R1 mit max. 3% H_2	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)] 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

Section energy kJ/cm:
autom. TIG HD max. 6; TIG, GMAW manual, automated 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 718 CTP is available in the following standard semi-finished forms:

Rod and bar

Delivery condition: Forged, rolled, drawn, heat treated (solution-annealed or age-hardened), oxidized, descaled or pickled, turned, peeled, ground or polished.

Dimensions	Outside diameter mm (in)	Length mm (in)
General dimensions	6-800 (0.24-31.50)	1,500-12,000 (59.06-472.44)
Material specific dimensions	10-350 (0,39-13,78)	1,500-12,000 (59.06-472.44)

Sheet and plate

Delivery condition: Hot or cold rolled, heat-treated, descaled or pickled.

Condition	Thickness mm (in)	Width mm (in)	Length mm (in)	Piece weight Kg (lb)
Cold rolled	1.1-7 (0.04-0.28)	≤ 2,000 (78.74)	≤ 5,500 (216.54)	≤ 1,100 (2,425)
Hot rolled*	3-8 (0.12-0.31)	≤ 2,500 (98.43)	≤ 5,500 (216.54)	≤ 1,100 (2,425)
Hot rolled	8-50 (0.31-1.97)	≤ 2,500 (98.43)	≤ 8,000 (314.96)	≤ 1,100 (2,425)

Sheets can be manufactured considering the minimum and maximum dimensions
* 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			
0.025-0.15 (0.001-0.006)	4-230 (0.16-9.06)	300	400	500	–
0.15-0.25 (0.006-0.01)	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

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

Wire

Delivery condition: Drawn bright, 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 available on request.

Legal notice

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