VDM Metals

A company of ACERINOX

VDM® Alloy 925
Nicrofer 4320 Ti

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VDM® Alloy 925

Nicrofer 4320 Ti

VDM® Alloy 925 (Nicrofer 4320 Ti) is a γ'-phase precipitation-hardenable austenitic nickel-iron-chromium alloy containing molybdenum, copper, titanium and aluminum. It exhibits high strength at temperatures up to approx. 1,020 °F (550 °C) and shows excellent corrosion resistance including resistance to sulfidic stress cracking (SSC) under H_2S containing sour gas conditions. It is used for surface and down-hole applications in sour gas wells and in oil production.

Designations

Standard	Material designation
EN	2.4852 - NiCr20FeMo3TiCuAl
UNS	N09925

Table 1 – Designations

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Mo	Cu	Ti	Al	Nb	P	S
Min.	42	19.5	22				2.5	1.5	1.9	0.1			
Max.	46	22.5		0.03	1	0.5	3.5	3.0	2.4	0.5	0.5	0.03	0.03

Table 2 – Chemical composition (wt.-%)

Physical Properties

Density	Melting range	Relative magnetic permeability at 20 °C (68 °F)
8.1 g/cm^3 (0.292 lb/in^3)	1,300-1,366 °C (2,392-2,490 °F)	1.001

Temperature		Specific heat		Thermal conductivity		Modulus of elasticity		Coefficient of thermal expansion	
°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	10^3 ksi	$\frac{10^{-6}}{K}$	$\frac{10^{-6}}{°F}$
20	68	435	0.104	12.0	83	199	28.9		
93	200		0.109			195	28.3		7.8
100	212	456		12.9	89			13.2	
200	392	486		14.3	99			14.2	
204	400	485	0.116			188	27.3	14.6	8.1
300	572	507		15.9	110			14.7	
316	600		0.122			182	26.4	14.9	8.4
400	762	532		17.4	121			15.0	
427	800	540	0.129			175	25.4	15.2	8.5
500	932	561		19.3	134			15.3	
538	1000		0.136			168	24.2		8.7
600	1112	586		22.2	154			15.7	
649	1200	598	0.143			160	23.2		9
700	1292	611		24.0	167			16.3	
760	1400		0.150			150	21.8		9.5
800	1472	641		28.2	196			17.2	
871	1600	657	0.157			139	20.2		
900	1,652	666		27.2	192				

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

Microstructural properties

Metallurgical structure

VDM® Alloy 925 (Nicrofer 4320 Ti) is a precipitation-hardenable austenitic Ni-Fe-Cr alloy with additions of titanium and aluminum. Precipitation hardening, which is carried out in a dual step thermal treatment to ensure only formation of γ'-phase and to avoid particularly formation of brittle phases such as σ-phase, considerably increases the alloy's hardness and tensile strength. Prolonged exposure to higher temperatures causes detrimental phases to form. Fig. 1 shows the time-temperature-transformation (TTT) diagram for VDM® Alloy 925 material in the initially solution-annealed condition.

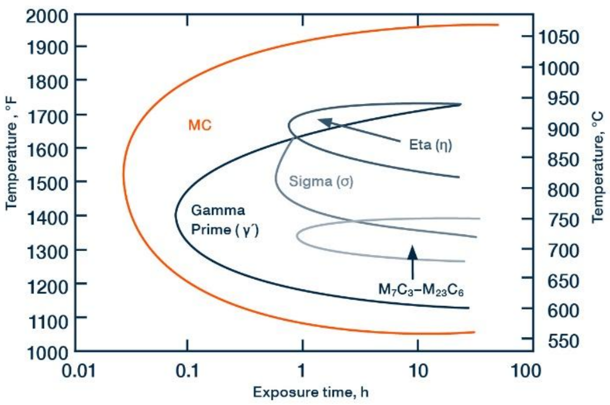

Fig. 1 – Time-temperature-transformation diagram for solution annealed VDM® Alloy 925 material

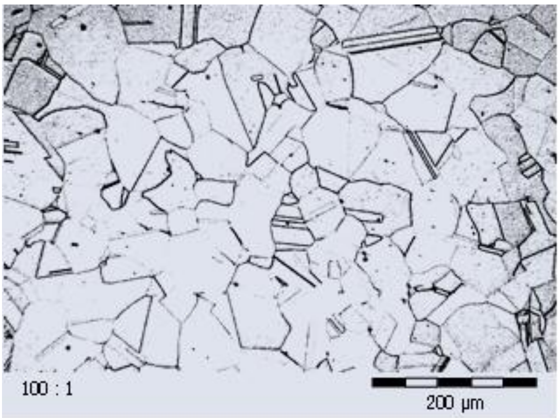

Fig. 2 – Typical microstructure of solution-annealed VDM® Alloy 925 214 mm (8.5 in.) diameter rod.

Mechanical properties

The following properties are applicable to VDM® Alloy 925 at room temperature and elevated temperatures in the indicated size ranges.

Temperature		Yield strength $R_{p\ 0.2}$		Tensile strength R_m		Elongation A
°C	°F	MPa	ksi	MPa	ksi	%
20	68	734	106.2	1092	164.3	27

Table 4 – Minimum short-time mechanical properties at room temperature for VDM® Alloy 925

ISO V-notch impact values

Average values at room temperature a_k: ≥110 J/cm^2

Rockwell Hardness HRC

Average values at room temperature 31 (Acceptable in the solution-annealed and aged condition to 35 HRC maximum according to NACE standard MR0175)

Corrosion resistance

The high chromium content as well as molybdenum and copper contents make VDM® Alloy 925 very resistant to all forms of corrosion in a variety of chemical media under both reducing and oxidizing conditions. Due to its high nickel Content VDM® Alloy 925 also exhibits virtual immunity to chloride-induced stress-corrosion cracking. Particularly useful is VDM® Alloy 925 in oil and sour gas environments as well as seawater.

Critical pitting and crevice corrosion temperatures (CPT and CCT) of VDM® Alloy 925 determined in accordance to ASTM G48, Methods C and D respectively, indicated the respective values to be similar for both materials in the solution-annealed as well as in the solution-annealed and age-hardened condition as shown in Fig. 3.

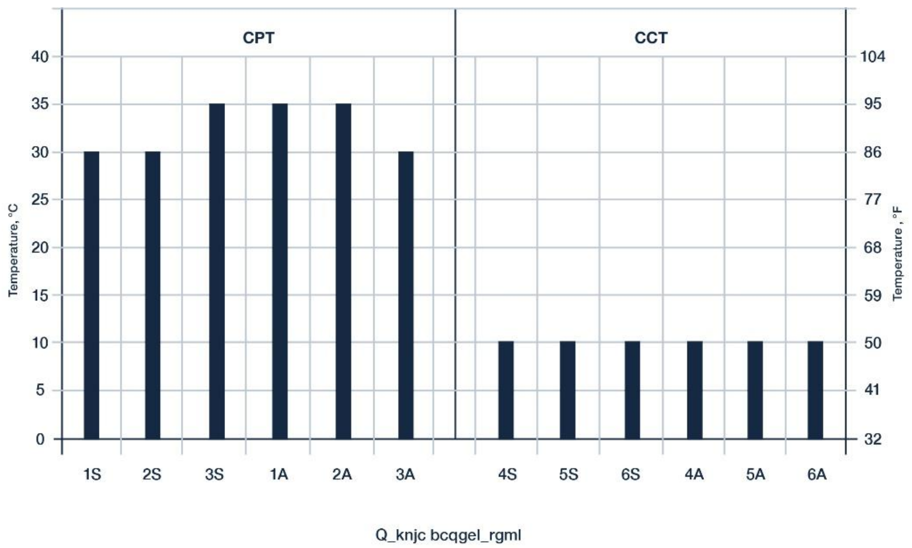

Fig. 3 – Critical pitting (CPT) and crevice corrosion (CCT) temperatures of VDM® Alloy 925 in the solution-annealed (S) and solution-annealed and age-hardened (A) condition.

Table 5 lists CPT and CCT together with Pitting Resistance Equivalent (PRE) values for VDM® Alloy 925 and various other similar alloys for comparison.

Material	Material No.	**CPT** (ASTM G48 Method C and D)	**CCT** (ASTM G48 Method C and D)	**PREN (pitting resistance equivalent number)[1)]**
VDM® Alloy 925	2.4852	30	<10	29
VDM® Alloy 825	2.4858	30	<5	33
VDM® Alloy 625	2.4856	77.5	57.5	51
VDM® Alloy 926	1.4529	72.5	47.5	47
VDM® Alloy 31	1.4562	85	65	54

[1)] PREN = 1 (% Cr) + 3,3 (% Mo) + 20 (% N)

Table 5 – Critical pitting temperature (CPT) and critical crevice temperature (CCT) of VDM® Alloy 925 and other alloys used in the oil & gas industr

C-Ring tests performed according to NACE Standard TM 0177, Method C in various test solutions and different periods of exposure varying from 30 to 61 days showed no sensitivity for VDM® Alloy 925 to stress-corrosion-cracking (SCC) in H2S environments.

Applications

VDM® Alloy 925 finds application in oil and natural gas exploration and production particularly in “sour” (H2S containing) environments.
Typical applications are:

- tool joints,
- completion tools,
- hangers and packers
- down-hole and surface gas-well components
- pump shafting and similar high-strength hardware particularly in marine environments and others containing both chlorides and sulfides.

Fabrication and heat treatment

VDM® Alloy 925 can readily be hot- and cold worked and machined.

Heating
Workpieces must be clean and free from all kinds of contaminants before and during any heat treatment. VDM® Alloy 925 may become embrittled 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, 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
VDM® Alloy 925 may be hot worked (forged) in the temperature range 1050 to 920 °C (1920 to 1680 °F), followed by air cooling.
Hot rolling should be carried out at temperatures ≥ 950 °C (≥ 1740 °F).
For heating up, workpieces may be charged into the furnace at maximum working temperature. When the furnace has returned to temperature, the workpieces should be soaked for 60 minutes per 100 mm (4 in.) of thickness. At the end of this period it should be withdraw immediately and worked within the above temperature range. If the metal temperature falls below the minimum hot working temperature, it must be reheated.

Cold working
Cold forming of VDM® Alloy 925 is preferably done in the solution-annealed condition prior to age-hardening. VDM® Alloy 925 has a higher work-hardening rate than austenitic stainless steels. This should be taken into account when selecting forming equipment.

Heat treatment
Solution heat treatment should be carried out in the temperature range 980 – 1040 °C (1800 – 1900 °F) for 2 h followed by water quenching. For age hardening the following two step precipitation treatment process is used: 740 °C (1365 °F) for 6 h followed by furnace cooling to 621 °C (1150 °F) at which temperature the material is held for a further 6 h before air cooling to room temperature. This thermal treatment results in a structure with a homogeneous and uniformly distributed grain size.
For any thermal treatment the material should be charged into the furnace at maximum working temperature. Also for any thermal treatment operation the precautions concerning cleanliness mentioned earlier under ’Heating’ must be observed.

Descaling and pickling
Oxides of VDM® Alloy 925 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 or by carefully performed grinding or by pretreatment in a fused salt bath.

Machining
VDM® Alloy 925 can be machined in the solution-annealed or age-hardened condition. As the alloy exhibits a high work-hardening rate only low 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.
Best results with the smoothest surface finish at final dimension are obtained by rough machining before age hardening and finishing after precipitation treatment in the aged condition.
VDM® Alloy 925 is more easily machined than Nicrofer 5219 Nb – VDM® Alloy 718 (UNS N07718).

Availability

VDM® Alloy 925 is available in the following standard semi-finished product forms:

Rod and bar
Delivery conditions: forged, rolled, drawn, heat treated, descaled resp. pickled, machined, peeled or ground

Dimensions*	**Outside diameter mm (in)**
General dimensions (forged, round)	≤250 (≤10)
General dimensions (forged, square)	40-175 (1.125-7)
General dimensions (rolled, round)	8-60 (0.3125-2.375)
General dimensions (rolled, square)	15-175 (0.625-7)
General dimensions (drawn, round)	12-50 (0.5-2)
General dimensions (drawn, square)	not standard

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Disclaimer

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