

VDM Metals

A company of ACERINOX

VDM® Alloy 690
Nicrofer 6030

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VDM® Alloy 690 is a nickel-chromium-iron alloy with approx. 30 % of chromium, which is particularly suitable for use in oxidising media.

VDM® Alloy 690 is characterised by:

- very good resistance to fluoride containing hot nitric acid,
- good resistance to stress corrosion cracking caused by alkalis,
- excellent resistance to stress corrosion cracking caused by media containing chloride and polythionic acids,
- excellent resistance to many aggressive aqueous media or in the primary and secondary loops of nuclear reactors,
- good resistance to oxidation, sulphidation and metal dusting in hot gases and
- good mechanical properties at room temperature and high temperature, paired with high ductility.

Designations and standards

Standard	Material designation
EN	2.4642 - NiCr29Fe
ISO	NiCr29Fe9
UNS	N06690
AFNOR	NC30Fe

Product form	DIN	ISO	ASME	ASTM
Sheet, plate	17742	6208	SB 168	B 168
	17750	9722		
Strip	17742		SB 168	B 168
	17750			
Rod, bar	17742		SB 166	B 166
	17752		SB 564	B 564
Wire	17753			

Table 1 – Designations and standards

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Cu	S
Min.	58	27	7					
Max.		31	11	0.05	0.5	0.5	0.5	0.015

Table 2 – Chemical composition (%)

Physical properties

Density	Melting range	Relative magnetic permeability at 20 °C (68 °F)
8.2 g/cm ³	1,390 to 1,410 °C	1.01 (max.)

Temperature		Specific heat		Thermal conductivity		Electrical resistivity	Modulus of elasticity		Coefficient of thermal expansion	
°C	°F	$\frac{J}{kg \cdot K}$	$\frac{Btu}{lb \cdot F^\circ}$	$\frac{W}{m \cdot K}$	$\frac{Btu \cdot in}{sq. ft \cdot h \cdot F^\circ}$	$\mu\Omega \cdot cm$	GPa	103 ksi	$\frac{10^{-6}}{K}$	$\frac{10^{-6}}{F^\circ}$
20	68					116	212	30.8		
100	212	496	0.118	13.9	96.4	117	206	29.9	13.7	7.6
200	392	521	0.124	15.8	109.6	120	201	29.2	14.2	7.9
300	572	538	0.128	17.6	122.1	122	195	28.3	14.6	8.1
400	752	555	0.133	19.5	135.3	124	189	27.4	14.9	8.3
500	932	573	0.137	21.5	149.2	125	182	26.4	15.4	8.6
600	1,112	620	0.148	24.4	169.3	125	175	25.4	16	8.9
700	1,292	654	0.156	26.7	185.2	125	167	24.2	16.5	9.2
800	1,472	663	0.158	27.1	188.0	125	155	22.5	16.9	9.4
900	1,652	677	0.162	28.4	197.0	126	152	22.0	17.3	9.6
1,000	1,832	684	0.163	29.6	205.4	127	143	20.7	17.7	9.8
1,100	2,012	695	0.166	30.9	214.4				18.2	10.1
1,200	2,192	705	0.168	32.3	224.1				18.6	10.3

Table 3 – Typical physical properties

Metallurgical structure

VDM® Alloy 690 has a cubic face-centred structure.

Mechanical properties

The following mechanical properties apply to VDM® Alloy 690 in the solution-annealed condition and in the stated semi-fabricated forms and dimensions.

Temperature		Yield strength R _{p 0.2}		Tensile strength R _m		Elongation A
°C	°F	MPa	ksi	MPa	ksi	%
20	68	240	34.8	590	85.6	30
100	212	236	34.2	580	84.1	45
200	392	228	33.1	550	79.8	45
300	572	220	31.9	520	75.4	45
400	752	216	31.3	500	72.5	45
500	932	210	30.5	490	71.1	45
600	1,112	200	29	470	68.2	45
700	1,292	156	22.6			
800	1,472	120	17.4			

Table 4 – Short-term properties of solution-annealed VDM® Alloy 690 at elevated temperatures (yield strength in acc. w. DIN 10302, typical values for tensile strength and elongation)

Product	Yield strength		Tensile strength		Elongation
	R _{p0.2}		R _m		A
	MPa	ksi	MPa	ksi	%
Sheet, strip	> 240	> 34.8	> 586	> 85	> 30
Bar, billet	> 240	> 34.8	> 586	> 85	> 30

Table 5a – Minimum values at room temperatures in acc. w. ASTM B166 or B168

Product and condition	Dimensions	Yield strength		Tensile strength		Elongation
		R _{p0.2}		R _m		A
		MPa	ksi	MPa	ksi	%
Sheet, strip Hard	> 6.4	> 620	> 89.9	> 860	> 124.7	> 2
Rounds Cold worked	< 12.7	> 620	> 89.9	> 825	> 119.7	> 7
	12.7-25.4	> 585	> 84.8	> 760	> 110.2	> 10
	25.4-63.5	> 550	> 79.8	> 725	> 105.2	> 12
Squares, hexagons and rectangles Cold worked	< 6.4	> 550	> 79.8	> 690	> 100.1	> 5
	6.4-12.7	> 480	> 69.6	> 655	> 95	> 7

Table 5b – Minimum values at room temperatures in acc. w. ASTM B166 or B168 for various product forms, size ranges and processing status

Temperature		Creep Values			
		Rp 1.0/10 ⁴ h	Rp 1.0/10 ⁵ h	Rm /10 ⁴ h	Rm /10 ⁵ h
		MPa	MPa	MPa	MPa
700	1,292	42	30	56	39
750	1,382	30	19.3	41	30
800	1,472	20	12	30	21
850	1,562	12.8	7.6	21.5	14.4
900	1,652	8.2	4.8	15.4	10
950	1,742	5.3	3	10.9	7
1,000	1,832	3.4	1.9	7.7	4.8
1,050	1,922	2.2	1.2	5.4	3.4

Table 6 – Typical creep properties of solution-annealed VDM® Alloy 690

Corrosion resistance

VDM® Alloy 690 is resistant to a wide range of corrosive media and atmospheres. The high chromium content makes the material particularly suitable for strongly oxidising conditions. The high chromium content also confers resistance to high-temperature corrosion in gases having an oxidising and sulphidising effect. Due to its high nickel content, VDM® Alloy 690 is exceptionally resistant to stress corrosion cracking which can occur in the primary water loops of nuclear power stations. The material also shows good resistance in mixtures of nitric and hydrofluoric acid. It demonstrates remarkable behaviour in concentrated (98.5 %) sulphuric acid at temperatures of up to 150 °C (300 °F).

Applications

Thanks to its excellent resistance to wet and high-temperature corrosion, and its good mechanical properties, VDM® Alloy 690 is suitable for a wide range of applications.

Typical applications include:

- treatment of radioactive waste,
- components in boilers and steam generators in pressurised water reactors,
- production of alkali metal sulphates using Mannheim furnaces,
- fittings in combustion units for crude oil (oil ash corrosion) and
- glass and silicate production.

Fabrication and heat treatment

VDM® Alloy 690 can be processed using standard industrial production techniques.

Heating

Workpieces must be clean and free of any contaminants before and during heat treatment. Sulphur, phosphorus, lead and other low-melting-point metals can lead to damage when heat treating VDM® Alloy 690. This type of contamination is also contained in marking and temperature display paints or crayons, and also in lubricating grease, oils, fuels and similar materials.

Fuels should contain as little sulphur as possible. Natural gas should contain less than 0.1 % by weight of sulphur. Heating oil with a sulphur content of maximum 0.5 % by weight is also suitable.

Electric furnaces are to be preferred due to precise temperature control and freedom from contamination due to fuel. The furnace atmosphere should be set between neutral and slightly oxidising, and should not change between oxidising and reducing. Direct flame impingement needs to be avoided.

Hot working

VDM® Alloy 690 can be hot worked at a temperature range of between 1,230 and 900 °C (2,250 and 1,650 °F) with subsequent rapid cooling down in water or by using air nozzles. The workpieces should be placed in the furnace heated to hot working temperature in order to heat up. Once the temperature has equalised, a retention time of 60 minutes for each 100 mm of workpiece thickness is recommended. After this, the workpieces should be removed immediately and formed during the stated temperature window. If the material temperature falls below the minimum hot working temperature, the workpiece must be reheated. Heat treatment after hot working is recommended in order to achieve optimum properties and corrosion resistance.

Cold working

Cold working should be carried out on annealed material. VDM® Alloy 690 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 forming processes. Intermediate annealing may be necessary for high degrees of cold working deformation. Before use, heat treatment is required after cold working with more than 10 % deformation.

Heat treatment

Solution annealing should be carried out at temperatures between 1,020 and 1,070 °C (1,870 to 1,960 °F). If use in a high-temperature range with increased creep resistance is intended, the solution annealing temperature should be raised to between 1,080 and 1,150 °C (1,980 to 2,100 °F).

Water quenching should be carried out on workpiece thicknesses over 1.5 mm so that the optimum corrosion resistance of the material can be reached. Workpieces of less than 1.5 mm thickness can be cooled using air nozzles.

If use in pressurised water reactors is intended, a subsequent heat treatment of around 10 hours at between 700 and 740 °C is necessary in order to ensure that carbides are segregated specifically at grain boundaries.

The cleanliness requirements must be followed for any form of heat treatment.

Descaling and pickling

Oxides of VDM® Alloy 690 and discolorations in the area around welding seams are more adherent than on stainless steels. Grinding using extremely fine abrasive belts or grinding discs is recommended. It is imperative that grinding burn is avoided. Before pickling – which may be performed in a hydrofluoric acid mixture – the surface oxide layer must be broken up by abrasive blasting, by carefully performed grinding or by pre-treatment in a fused salt bath. The pickling baths used should be carefully monitored with regard to concentration and temperature, since pickling for too long can damage the material surface due to intercrystalline corrosion.

Machining

VDM® Alloy 690 should preferably be machined in the annealed condition. Since the material exhibits a considerable work hardening rate, low cutting speeds should be used and the tool should remain continuously in contact. An adequate cutting depth is important in order to cut below the 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.

Welding information

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

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 which 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 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 permissible.

Ignition

The arc may only be struck in the weld area, e.g. along the seam flanks or a shoe, 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 behaviour must be taken into account using larger root gaps or web spacings (1 to 3 mm), whereas due to the viscous weld metal in comparison with standard austenites and the shrinkage tendency, angles of aperture of between 60 and 70 degrees are to be provided for butt welds as shown in Figure 1.

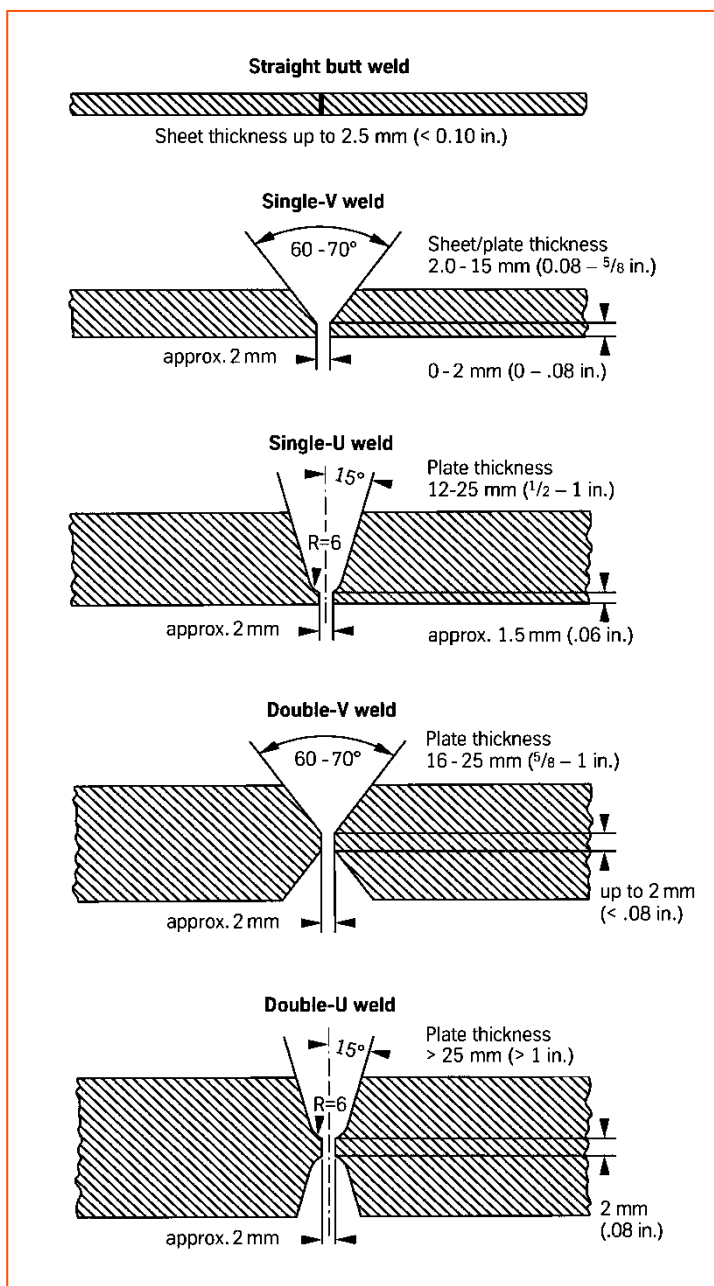


Figure 1 – Seam preparation for welding nickel alloys and special stainless steels

Cleaning

Cleaning of the basic 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 690 should be in solution-annealed condition for welding, and should be free of scale, grease and markings. VDM® Alloy 690 can be welded using TIG and plasma welding processes. 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 and, in certain cases depending on the welded construction, also for the second intermediate root pass. Any discolouration/heat tint should be removed, preferably using a stainless steel brush, while the welding seam is still hot from the welding heat.

Filler metal

The following filler materials are recommended:

When welding VDM® Alloy 690, VDM® FM 52 can be used as filler material. VDM® FM 52 is available in varying product forms on request. An improved variation on VDM® FM 52 is provided by VDM FM 52i®, since this stands out due to its particularly high hot crack resistance during welding. VDM FM 52i® is available in the following product forms:

TIG rod, welding wire, wire electrode,
and welding strip*)

Coated rod electrodes

VDM FM 52i®
ASME CODE Case 2142-4
UNS N06056
AWS A5.14: ERNiCrFe-15 (electrode rod)

VDM FM 52i®
UNS W86056 (proposed)
AWS A5.11: ENiCrFe-15

*) recommendations for welding powder on request

Welding parameters and influences

It must be ensured that work is carried out using targeted heat application and low heat input as shown in Table 7 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:

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

U = arc voltage, volts

I = welding current, amperes

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 specified, should generally be the last operation in the welding process. Information under "Descaling and pickling" should be referred to. Heat treatments are not required either before or after welding.

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

Thickness (mm)	Welding technique	Filler material		Root pass ¹⁾		Intermediate and final passes		Welding speed (cm/min)	Shielding gas	
		Diameter (mm)	Speed (m/min)	I in (A)	U in (V)	I in (A)	U in (V)		Type	Rate (l/min)
3	m-TIG	2		90	10	110-120	11	15	I1, R1 at max. 3% H2	8-10
6	m-TIG	2-2.4		100-110	10	120-140	12	10-16	I1, R1 at max. 3% H2	8-10
8	m-TIG	2.4		100-110	11	130-140	12	10-16	I1, R1 at max. 3% H2	8-10
10	m-TIG	2.4		100-110	11	130-140	12	10-16	I1, R1 at max. 3% H2	8-10
3	v-TIG	1.2	1.2	90	10	150	11	25	I1, R1 at max. 3% H2	15-20
5	v-TIG	1.2	1.4	100-110	11	180	12	25	I1, R1 at max. 3% H2	15-20
2	v-TIG HD	1		90	10	180	11	80	I1, R1 at max. 3% H2	15-20
10	v-TIG HD	1.2		100-110	11	220	12	40	I1, R1 at max. 3% H2	15-20
4	Plasma ²⁾	1.2	1	180	25			30	I1, R1 at max. 3% H2	30
6	Plasma ²⁾	1.2	1	200-220	25			26	I1, R1 at max. 3% H2	30

¹⁾ Root pass: It must be ensured that there is sufficient root protection, for example using Ar 4.6, for all inert gas welding processes.

²⁾ Plasma: recommended plasma gas Ar 4.6 / plasma quantity 3.0-3.5 l/min

Section energy kJ/cm: TIG, MIG/MAG manual, mechanised max. 8; e-manual 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 690 is available in the following standard semi-finished product forms:

Sheet and plate

Delivery condition: Delivery conditions: hot or cold rolled, thermally treated, descaled or pickled

Condition	Thickness mm (in)	Width mm (in)	Length mm (in)	Piece weight Kg (lb)
Cold rolled	1-7 (0.04 – 0.28)	1.000-2.500 (39-98)	< 5.500 (< 217)	<3.350 (< 132)
Hot rolled	3-100 (0.12 – 0.39)	1.000-2.500 (39-98)	< 12.000 (< 472)	< 3.350 (< 132)

Strip

Delivery condition: cold rolled, thermally treated and pickled or bright annealed

Thickness mm (in)	Width mm (in)	Coil - inside diameter mm (in)			
0.025-0.15 (0.001-0.006)	4-230 (0.16-9.06)	300 (11.8)	400 (15.7)	500 (19.7)	
0.15-0.25 (0.006-0.01)	4-720 (0.16-28.3)	300 (11.8)	400 (15.7)	500 (19.7)	
0.25-0.6 (0.01-0.02)	6-750 (0.24-29.5)		400 (15.7)	500 (19.7)	600 (23.6)
0.6-1 (0.02-0.04)	8-750 (0.31-29.5)		400 (15.7)	500 (19.7)	600 (23.6)
1-2 (0.04-0.08)	15-750 (0.6-29.5)		400 (15.7)	500 (19.7)	600 (23.6)
2-3 (0.08-0.12)	25-750 (1.0-29.5)		400 (15.7)	500 (19.7)	600 (23.6)

Rod and bar

Delivery condition: forged, rolled, drawn, thermally treated, oxidised, descaled or pickled, machined, peeled or ground

Dimensions*	Outside diameter mm (in)	Length mm (in)
General dimensions	6-800* (0.24-31.5)	1.500-12.000 (59.1-472)
Material specific dimensions	22-300 (0.9-11.8)	1.500-12.000 (59.1-472)

* Further dimensions on request

Wire

Delivery condition: 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 (0.2-0.7)

Other shapes and dimensions such as circular blanks, rings, seamless or longitudinal-welded tubing and forgings can be requested.

Legal notice

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