VDM Metals

A company of ACERINOX

Solutions for Welding Alloys

Welding Consumables

Materials for the future.

VDM Metals welding consumables

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The high-quality filler materials from VDM Metals are generally highly compatible with most of the standard welding processes. You will find example welding processes/parameters as well as additional information in the detailed descriptions that are provided for each welding material.

VDM Metals Welding Consumables

Our services at a glance

Filler materials and welding strips for various requirements:

- Corrosion-resistant alloys, e. g. VDM® FM 59, some of which have a high alloy content of molybdenum
- Alloys for high-temperature applications: for instance, VDM® FM 82
- Super alloys: for instance VDM® FM 617 B, some of which have a high alloy content of molybdenum and cobalt

Product forms:

- Wire electrodes and welding wire in diameters of 0.6 mm to 3.2 mm (0.024 in to 0.126 in)
- Welding rods in diameters from 1.6 mm to 4 mm (0.063 in to 0.157 in)
- Core wire in diameters from 2 mm to 5 mm (0.079 in to 0.197 in)
- Welding strip for weld cladding, mostly 0.5 mm (0.020 in) thick

Packaging forms:

- Wire on standardized spools, special spools or in various barrel types as well as strip in rings and rods in tubes

Quality standards:

- Narrow tolerance fluctuations in the alloying elements and in the dimensions
- Setting of optimized cast and helix values for trouble-free wire transport in automated welding processes
- Optimum preparation of raw stocks for clean and fault-free surfaces
- All quality-relevant processing steps are carried out by VDM Metals

Custom solutions for customers:

- New and ongoing development of alloys and material concepts by the R&D department working in close conjunction with our customers
- Extensive testing of the weldability of materials in VDM Metals' own Welding technology Center of Excellence

Sizes:

- Our welding consumables are available as well in imperial sizes from either mill production or inventory in the US and outside the US

General

General

Safety instructions and storage advice

Welding fumes and gases can be dangerous to health and can damage the lungs and other organs

Arc radiation can damage your eyes and burn your skin

Ensure adequate ventilation and extraction

Wear suitable eye, head, hand and body protection

Danger! Risk of fatal injury through electric shock

Read and observe the manufacturer' instructions, your employer's safety instructions and any available nationally published safety guidelines

Filler materials are to be stored in a dry and clean location – this applies especially to all filler materials with a nickel-iron basis and pure nickel

The additional letter "p" at MIGp, MAGp etc. indicates the application of the pulse arc method for the Gas Metal Arc Weld (GMAW) processes.

Explanation of the used icons

Corrosion resistant material

High-temperature material

Material for metallurgy

Material with physical peculiarities

Delivery forms and dimensions

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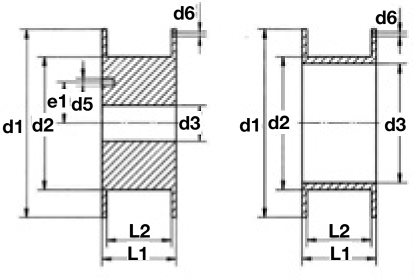
Delivery forms and dimensions

Spools



Spools acc. to DIN EN ISO 544

Dimensions stated in mm (inches) – all dimensions are nominal dimensions

Type	Model	d1	d2	d3	d5	e1	d6
Spool	SD 300	300 11.8	212 8.35	52 2.05	11 0.43	44.5 1.75	3 0.118
Spool	SD 350	350 13.8	212.5 8.37	52 2.05	11 0.43	44.5 1.75	3 0.118

Material
Our acrylonitrile butadiene styrene (ABS) spools are available in the color black.

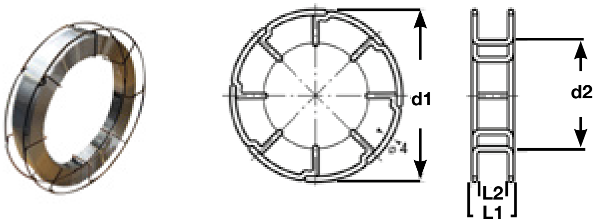
Tolerances
All of the measurements and weights provided are guide values; standard commercial tolerances and deviations are to be expected.

L1	L2	Weight in kg (lbs)	Material	Color	Wire Ø
103 4.06	85 3.35	15 33.1	ABS	black	0.8 – 1.6 0.031 – 0.063
103 4.06	89.9 3.54	27 59.5	ABS	black	0.8 – 1.6 0.031 – 0.063

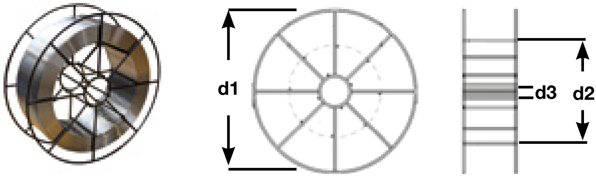
Delivery forms and dimensions

Basket coils

Basket coil



Basket toroidal coil



Spools acc. to DIN EN ISO 544

Dimensions stated in mm (inches) – all dimensions are nominal dimensions

Type	Model	d1	d2	d3
Basket coil	B 435/100	435 17.1	308 12.1	
Basket toroidal coil	BS 300	300 11.8	189 7.4	52 2.05

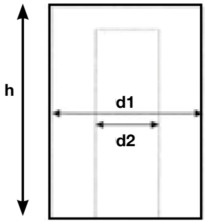
Tolerances
All of the measurements and weights provided are guide values; standard commercial tolerances and deviations are to be expected.

Please contact us if the packing size you need is not listed.

L1	L2	Weight in kg (lbs)	Material	Color	Wire Ø
100 3.94	92 3.62	30 66	Wire	coppered	0.8 – 3.2 0.031 – 0.126
100 3.94	92 3.62	15 33	Wire	black	0.8 – 1.6 0.031 – 0.063

Delivery forms and dimensions

Drums for welding wire



Drums for welding wire

Dimensions stated in mm (inches) – all dimensions are nominal dimensions

d1	d2	h	Capacity in kg (lbs)	Wire Ø	
525 20.7	300 11.8	785 30.9	max. 250 max. 551	≤ 1.2 ≤ 0.05	**
650 25.6	300 11.8	940 37.0	max. 450 max. 992	≤ 1.6 ≤ 0.06	*

Tolerances
All of the measurements and weights provided are guide values; standard commercial tolerances and deviations are to be expected.

* Drums with inspection glass with transport handles
** Drums with inspection glass and head with transport handles

Delivery forms and dimensions

Tubes for welding rods

Tubes for welding rods
Dimensions stated in mm (inches) –
all dimensions are nominal dimensions

d1	L1	Capacity in kg (lbs)
40	1034	5
1.57	40.7	11

Tolerances
All of the measurements and weights provided are guide values; standard commercial tolerances and deviations are to be expected.

Delivery forms and dimensions

Strip electrodes and strip for flux cored wire electrodes

We offer our binary nickel-iron alloys (Ni-Fe) as strips for cored wire electrodes or as strip electrodes. Various Ni contents are available.

We are happy to comply with your special requirements. Please contact us.

Typical dimensions (flux cored wire electrode):

Thickness:	0.2–0.4 mm (0.008–0.016 in)
Width:	8–10 mm (0.315–0.394 in)

Typical dimensions (strip electrode):

Thickness:	0.50 mm (0.020 in)
Width:	30–90 mm (1.18–3.54 in)

The following applies for all our alloys:
If you do not find the material you require in the tables or the product forms, please contact us. We refine existing materials together with our customers or develop new materials in line with special customer requirements.

Contact

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USA

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Filler Metals

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VDM® FM 31 Plus

B08034 (UNS) · 2.4692 (Werkstoff-Nr.)

VDM® FM 31 Plus, like VDM® FM 31, has a high chromium and moderate molybdenum content and is well suited for oxidizing media. VDM® FM 31 Plus also has a very stable austenite microstructure, even in welding-induced iron admixtures or when a PWHT is carried out. VDM® FM 31 Plus is therefore particularly suitable as a corrosion-resistant welding filler for deposition welding.

Designations & standards

ISO	S Ni 8034
AWS	-
VdTÜV	-

Typical chemical composition, values in %

Ni	Cr	Mo	N	Fe	Mn	C
Rest	26	6,5	0,2	30	2	max. 0,01

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi)	**Tensile strength** R_m (MPa) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
280 (40.6)	>650 (94.3)	30	>90 (66.4)

Applications

Welding filler for clad welding, for example in the field of thermal waste recycling.

Special notes for the welding process

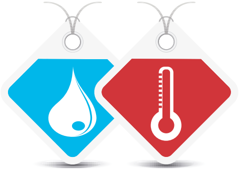
A low heat input and fast heat removal must be ensured. The component temperature during weld cladding should not exceed 150°C (302 °F). As a rule, water cooling is to be used to maintain the maximum component temperature. For the GMAW process, pulse welding is preferred.
No preheating or reheating is necessary to achieve the weld metal properties.

Exemplary welding techniques and –
parameters for single pipe cladding on 16Mo3 steel

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm / min)
MSGp (MIG / MAG) 131, 135	I1, Z-ArHeHC 30-2-0,05; Z-Ar-HeHC 30-2-0,12	16	210	200 79
Comment	*Consultation with VDM Metals recommended*			

VDM® FM 33

R20033 (UNS) · 1.4591 (Material No.)



VDM® FM 33 is a nickel-chromium-iron-molybdenum filler material that has been developed especially for welding VDM® Alloy 33. It possesses outstanding corrosion resistance in oxidizing acids and hot caustic soda and is used for corrosion-resistant weld cladding in large combustion plants.

Designations & standards

EN ISO 14343-A	S Z 33 32 1 Cu N L
AWS A5.9	ER33-31
VdTÜV	Data sheet no. 07528

Typical chemical composition, values in %

Fe	Ni	Cr	Mo	Cu	N	C
Bal.	31	33	1.5	0.8	0.4	< 0.015

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 400 (> 58.0)	> 730 (> 106)	> 25	> 90 (> 66.4)

Applications

Filler material for the welding of VDM® Alloy 33. Also suitable for weld claddings of boiler tubes and tube walls in power plants.

Special notes for the welding process

A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 120 °C (248 °F). No preheating or reheating is required to achieve the weld metal properties. Due to the increased nitrogen content, the alloy should be processed using thin weld runs (small amounts of weld metal, multiple pass technique) to avoid gas effusion.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 5 % H_2	≈ 10	70–140	11–16 4.33–6.30
Comment	*Root welding up to 100 A*			
v-TIG 141, 145	I1, R1 max. 5 % H_2	11–12	150–180	20–30 7.87–11.8
Plasma (PAW) 15	I1, R1 max. 5 % H_2	≈ 25	180–220	25–30 9.84–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM 36 M

1.3990 (Material No.)

VDM® FM 36 M is a Fe-Ni filler material for welding VDM® Alloy 36 with a very low thermal expansion. Thanks to its alloy additives, it exhibits good welding behavior.

Typical chemical composition, values in %

Fe	Ni	Nb	Mn	Ti	C
Bal.	36	1.5	0.5	1	0.3

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 350 (> 50.8)	> 500 (> 72.5)	> 20	> 47 (> 34.7)

Applications
Filler material for the welding of VDM® Alloy 36 especially for CFRP mold construction applications. VDM® FM 36 M is not suitable for use in low-temperature applications (see VDM® FM 36 LT). VDM® FM 36 M possesses considerably improved welding characteristics compared with VDM® FM 36.

Special notes for the welding process

VDM® FM 36 M should ideally be worked using the TIG (or plasma) process. It can, however, also be welded using the MIGp process. The interpass temperature should not exceed 130 °C (266 °F). The stringer bead technique is recommended even in exigencies. Magnetization of the material can have an effect on the arc.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 5 % H_2	9–10	70–140	≈ 15 ≈ 5.91
Comment	*Root welding at 70 A to 100 A*			
v-TIG 141, 145	I1, R1 max. 5 % H_2	10–15	150–200	20–25 7.87–9.84
MIGp 131	I3-ArHe 30	25–30	150–180	20–30 7.87–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			

Please note that this filler material requires special protection against humidity.

VDM® FM 36 LT

VDM® FM 36 LT is a Fe-Ni filler material for welding VDM® Alloy 36. Its alloy additives make it particularly suitable for low-temperature applications in which a reduced coefficient of thermal expansion combined with increased microstructural stability of the weld metal is required.

Designations & standards

VdTÜV	Data sheet no. 11218

Typical chemical composition, values in %

Fe	Ni	Cr	C	Mn	Al	Co
Bal.	36	1.4	0.02	1	1.4	1.6

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	**Tensile strength** R_m (MPa) (Ksi) (Ksi)		**Elongation** A_5 (%)		**ISO V-notch impact strength** (J) (ft-lbs)
> 270 (> 39.2)	WIG	WP*	WIG	WP*	> 120 (> 88.5)
	> 440 > 63.8	> 410 > 59.5	> 30	> 25	

*) Deviation from base material requirements

Applications

Filler material for the welding of VDM® Alloy 36 especially for low-temperature applications. The filler material VDM® FM 36 LT is characterized by its high weld metal strength at low temperatures and its improved workability.

Special notes for the welding process

VDM® FM 36 LT should ideally be worked using the TIG (or plasma) process. The interpass temperature should not exceed 130 °C (266 °F).The stringer bead technique is recommended. Magnetization of the material can have an effect on the arc. The flow properties of the molten metal can be optimized by using a hydrogen-containing shielding gas (max. 5 %) during welding.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas according to ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 5 % H_2	9–10	70–140	≈ 15 ≈ 5.91
Comment	*Root welding at 70 A to 100 A*			
v-TIG 141, 145	I1, R1 max. 5 % H_2	10–15	150–200	20–25 7.87–9.84
Plasma (PAW) 15	R1 max. 5 % H_2	≈ 25	≈ 230	25–30 9.84–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

Please note that this filler material requires special protection against humidity.

VDM FM 52i®

N06056 (UNS)

VDM FM 52i® is a nickel-chromium filler material with good workability and a low tendency to crack that is ideal for seam welding homogeneous and similar materials. In particular, this material has been developed for weld cladding and welding in Ni-Cr-Fe components in the reactor coolant systems of nuclear power plants.
It is characterized by high resistance to stress corrosion cracking in this environment.

Designations & standards

AWS A5.14	ERNiCrFe-15
ASME	Code Case 2142-4

Typical chemical composition, values in %

Ni	Cr	Fe	Nb	Mn	C
Bal.	27	2.6	2.3	3	0.04

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 240 (> 34.8)	> 580 (> 84.1)	> 20	> 50 (> 36.9)

Applications
Filler material for welding VDM® Alloy 690. Particularly suitable also for weld cladding on carbon steel due to its excellent corrosion properties, especially its resistance to stress-corrosion cracking, and good weldability.

Special notes for the welding process

The newly developed VDM FM 52i® exhibits significantly improved welding characteristics compared with the standard filler material FM 52 and stands out due to its high resistance to hot cracking during welding. Other welding processes are currently being tested. The component or interpass temperature should not exceed 100 °C (212 °F).

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141	I1	11–15	90–150	10–15 3.94–5.91
Comment	*Root welding at 90 A to 110 A*			
v-TIG 141	I1	10–15	150–200	20–30 7.87–11.8
MIGp 131	I3-ArHe30	≈ 32	≈ 150	20 7.87

VDM® FM 55

W82002 (UNS) • (2.4560 Material No.)

VDM® 55 is used for cast iron cold welding, e.g. for repairs and for joinging large structural elements made of grey cast iron.

Designations & standards

AWS A5.15	ENiFe-CI

Typical chemical composition, values in %

Ni	Fe	C	Mn	Si
59,5	Rest	0,1	0,8	0,16

Please note that this filler material requires special protection against humidity.

VDM® FM 59

N06059 (UNS) · 2.4607 (Material No.)

VDM® FM 59 is a nickel-chromium-molybdenum filler material with a low carbon content for the over-alloyed seam welding of high-performance alloys in the area of wet chemistry. It possesses exceptionally high stability in hot acid and chloride-containing media and is frequently used in the chemical industry and environmental technologies.

Designations & standards

ISO 18274	S Ni 6059, NiCr23Mo16
AWS A5.14	ERNiCrMo-13, ABS
VdTÜV	Data sheet no. 06013, 06014

Typical chemical composition, values in %

Ni	Cr	Mo	Fe	C
Bal.	22.5	16	0.5	< 0.01

Mechanical properties at ambient temperature

(in condition "U" – unannealed)

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 450 (> 65.3)	> 720 (> 104)	> 35	> 70 (> 51.6)

Applications

Filler material for the welding of VDM® Alloy 59, VDM® Alloy C-4, VDM® Alloy C-276, VDM® Alloy 22, VDM® Alloy 31, VDM Alloy 31 Plus® and VDM® Alloy 926. Additional material combinations and fields of application are available on request.

Special notes for the welding process

VDM® FM 59 exhibits an exceptional weldability and a high resistance to sensitization. A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or reheating is required to achieve the weld metal properties. If required, the weld can be solution annealed after welding to optimize the corrosion resistance. This brings the mechanical and technological values into line with those of the base material VDM® Alloy 59.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–12	90–140	11–16 4.33–6.30
Comment	*Root welding up to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	≈ 12	150–180	25 9.84
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	11–12	180–220	40–80 15.7–31.5
MSGp (MIG/MAG) 131, 135	I1, I3-ArHe 30, Z-ArHeHC 30/2/0.05 Z-ArHeHc 30 / 2 / 0,12	23–27	130–150	24–30 9.45–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 %	≈ 25	200–220	≈ 26 ≈ 10.2
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM 60

N04060 (UNS) · 2.4377 (Material No.)

VDM® FM 60 is a cupronickel filler material for seam welding VDM® Alloy 400. It possesses good corrosion resistance in brine and alkaline salt solutions and is frequently used in offshore installations, ship building and the chemical industry.

Designations & standards

ISO 18274	S Ni 4060, NiCu30Mn3Ti
AWS A5.14	ERNiCu-7, ABS
VdTÜV	Data sheet no. 01545, 01547

Typical chemical composition, values in %

Ni	**Cu**	**Mn**	**Fe**	**Ti**
Bal.	29	3.2	1	2.4

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 200 (> 29)	> 460 (> 66.7)	> 30	> 100 (> 73.8)

Applications

Filler material for the welding of VDM® Alloy 400, VDM® Alloy K-500 as well as steels that have been roll clad or explosive clad in these Ni-Cu alloys. Also suitable for weld cladding on carbon steel; if required, using a buffer layer of VDM® FM 61.

Special notes for the welding process

A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or reheating is required to achieve the weld metal properties. The welding process should be particularly carefully screened using shielding gas. VDM® FM 60 is also suitable for the submerged arc process.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	≈ 11	90–140	10–15 3.94–5.91
Comment	*Root welding up to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	≈10	≈ 150	≈ 25 ≈ 9.84
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	11–12	180–220	40–80 15.7–31.5
MIG 131	R1 max. 3 % H_2	23–27	130–150	20–30 7.87–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	R1 max. 3 % H_2 (Shielding gas & Plasma gas)	≈ 25	165–200	25 9.84
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM 61

N02061 (UNS) · 2.4155 (Material No.)

VDM® FM 61 is a pure nickel filler material with a titanium additive for seam welding nickel and weld cladding on steel, frequently as a buffer layer. Due to its high corrosion resistance in saline solutions and alkalis, it is often used in the chemical industry.

Designations & standards

ISO 18274	S Ni 2061, S Ni 2061B, NiTi 3
AWS A5.14	ERNi–1, ABS
VdTÜV	Data sheet no. 00948, 00949

Typical chemical composition, values in %

Ni	Ti
95	3.3

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 200 (> 29)	> 410 (> 59.5)	> 25	> 100 (> 73.8)

Applications
Filler material for the welding of VDM® Alloy 205, VDM® Alloy 201, VDM® Alloy 200, nickel manganese and pure nickel roll-clad or explosive-clad steels. Also usable for weld cladding on carbon steel.

Special notes for the welding process

A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or reheating is required to achieve the weld metal properties. The welding process should be particularly carefully screened using shielding gas. VDM® FM 61 is also suitable for the submerged arc process.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–12	90–140	11–16 4.33–6.30
Comment	*Root welding up to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	11–12	150–180	20–30 7.87–11.8
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	11–12	180–220	40–80 15.7–31.5
MSGp (MIG/MAG) 131, 135	I1, I3-ArHe 30, Z-ArHeHC 30/2/0.05	23–27	130–150	25–30 9.84–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	180–220	25–30 9.84–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

Please note that this filler material requires special protection against humidity.

VDM® FM 65 Ni

N08065 (UNS) · 2.4858 (Material No.)

VDM® FM 65 Ni is a nickel-chromium-molybdenum filler material for wet corrosion- and acid gas applications. It is used primarily for the corrosion resistant weld cladding of pipes and valves for the oil and gas industry.

Designations & standards

AWS A5.14	ERNiFeCr-1

Typical chemical composition, values in %

Ni	Fe	Cr	Mo	Cu	Ti	Mn	C
Bal.	27	22.5	3.2	2	0.8	< 1	< 0.02

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
–	550[1)] (79.8[1)])	–	–

[1)] typical acc. to AWS 5.14

Applications
Filler material for the welding of VDM® Alloy 825 and other Ni-Fe-Cr-Mo-Cu alloys with similar compositions. Particularly suitable for weld cladding on carbon steel due to its excellent corrosion properties and good weldability; however, usually in conjunction with a buffer layer of VDM® FM 61.

Special notes for the welding process

Special attention must be paid to low heat input and fast heat removal. The interpass temperature should not exceed 120 °C (248 °F). No preheating or reheating is required to achieve the weld metal properties. ISO 14175: R1 with max. 3 % H_2 is particularly suitable for use as a shielding gas for homogeneous welds. Pure argon (I1) is usually used for weld cladding.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–11	90–120	10–15 3.94–5.91
Comment	*Root welding at approx. 90 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	11–12	≈ 150	≈ 25 ≈ 9.84
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	11–12	180–250	40–80 15.7–31.5
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	165–200	≈ 25 ≈ 9.84
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM 67

C71581 (UNS) · 2.0837 (Material No.)

VDM® FM 67 is a cupronickel filler material for seam welding cupronickel materials and the weld cladding of cupronickel materials on steel. It possesses good corrosion resistance in brine and is therefore frequently used in marine engineering.

Designations & standards

ISO 24373	S Cu 7158, CuNi30Mn1FeTi
AWS A5.7	ERCuNi, ABS
VdTÜV	Data sheet no. 01622, 01623

Typical chemical composition, values in %

Cu	Ni	Mn	Fe	Ti	C
Bal.	31	0.7	0.6	0.4	< 0.05

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 200 (> 29)	> 360 (> 52.2)	> 30	> 80 (> 59.0)

Applications

Filler material for the welding of VDM® Alloy CuNi 70-30, VDM® Alloy CuNi 80-20, VDM® Alloy CuNi 90-10 and steels that are roll clad or explosive clad with these Cu-Ni alloys. Also suitable for weld cladding on carbon steel, whereby a buffer layer of VDM® FM 61 or, in some cases, also of VDM® FM 60 should be used.

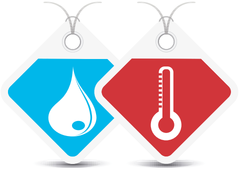
Special notes for the welding process
A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 120 °C (248 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or PWHT is required to achieve the weld metal properties.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–11	90–120	10–15 3.94–5.91
Comment	*Root welding at approx. 90 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	11–12	≈ 150	≈ 25 ≈ 9.84
MSGp (MIG/MAG) 131, 135	I1, I3-ArHe 30, Z-ArHeHC 30/2/0.05	23–27	130–150	25–30 9.84–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	165–200	≈ 25 ≈ 9.84
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM 82

N06082 (UNS) · 2.4806 (Material No.)



VDM® FM 82 is a versatile nickel-chromium filler material for the joint welding of high-temperature and heat-resistant chromium-nickel steels and nickel alloys. It is frequently used in industrial oven construction and for steam generators.

Designations & standards

ISO 18274	S Ni 6082, NiCr20Mn3Nb
AWS A5.14	ERNiCr-3, SAE AMS 5836, ABS
VdTÜV	Data sheet no. 00880, 00881

Typical chemical composition, values in %

Ni	Cr	Mn	Nb	Fe	Ti
Bal.	21	3.2	2.5	1	0.4

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 420 (> 60.9)	> 640 (> 92.8)	> 30	> 200 (> 148)

Applications
Filler material for the welding of VDM® Alloy 600/600 H and VDM® Alloy 800/800 H/800 HP. Creep values for homogeneous welds with VDM® Alloy 600/600 H are available. Additional material combinations and fields of application available on request.

Special notes for the welding process

A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or reheating is required to achieve the weld metal properties. The material can also be processed using the submerged arc process.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–12	90–140	11–16 4.33–6.30
Comment	*Root welding up to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	11–12	150–180	20–30 7.87–11.8
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	11–12	180–220	40–80 15.7–31.5
MSGp (MIG/MAG) 131, 135	I1, I3-ArHe 30, Z-ArHeHC 30/2/0.05	23–27	130–150	25–30 9.84–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	180–220	25–30 9.84–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM FM 602 CA®

N06025 (UNS) · 2.4649 (Material No.)

VDM FM 602 CA® is a nickel-chromium-aluminum filler material with excellent high-temperature stability and oxidation stability of more than 1,000 °C (1,832 °F) and a high resistance to carburization and metal dusting. The main areas of application are syngas applications and high temperature applications up to 1,200 °C (2,192 °F).

Designations & standards

ISO 18274	S Ni 6025, NiCr25Fe10AlY
AWS A5.14	ERNiCrFe-12
VdTÜV	Data sheet no. 09444, 09445

Typical chemical composition, values in %

Ni	Cr	Fe	Al	C	Y	Zr
63	25	10	2.1	0.2	0.1	0.05

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 300 (> 43.5)	> 650 (> 94.3)	> 25	> 50 (> 36.9)

Applications
Filler material for the welding of VDM® Alloy 601 and VDM Alloy 602 CA®.

Special notes for the welding process

To optimize the hot crack resistance of the material VDM FM 602 CA®, shielding gases with a nitrogen content of 2 % to 5 % must be used during arc welding. Because of the aluminium burn-off when using a submerged arc process, the weld metal must be covered with a double layer with the help of a TIG process. The interpass temperature should not exceed 120 °C (248 °F).

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141	N2 (max. 2 % N_2)	11–15	90–150	10–15 3.94–5.91
Comment	*Root welding at 90 A to 110 A*			
v-TIG 141	N2 (max. 2 % N_2)	10–15	150–250	20–30 7.87–11.8
MSGp (MAG) 135	Z-ArHeNC 10-5-0.05	23–27	160–180	25–35 9.84–13.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	N2 (max. 2 % N_2)	≈ 25	≈ 180	25–30 9.84–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM 617

N06617 (UNS) · 2.4627 (Material No.)

VDM® FM 617 is a highly heat-resistant nickel-chromium-cobalt filler material for seam welding in high-temperature applications. It is primarily used in the power plant technology and industrial oven construction.

Designations & standards

ISO 18274	S Ni 6617, NiCr22Co12Mo9
AWS A5.14	ERNiCrCoMo-1
VdTÜV	Data sheet no. 05458, 05459

Typical chemical composition, values in %

Ni	Cr	Co	Mo	Al	Fe	Ti	C
Bal.	22	11	8.5	1.3	0.5	0.3	0.1

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
450 (65.3)	750 (108.8)	30	120 (88.5)

Applications

Filler material for the welding of VDM® Alloy 617, VDM® Alloy 601, VDM® Alloy 800 H, VDM® Alloy 800 HP, as well as in conjunction with various high-temperature cast alloys such as HK-40 (material no. 1.4848). Creep values for homogeneous welds with VDM® Alloy 617 up to 1,050 °C (1,922 °F) are available.

Special notes for the welding process

A low heat input and fast heat removal must be ensured. The stringer bead technique is recommended. The interpass temperature should not exceed 120 °C (248 °F). No preheating is required to achieve the weld metal characteristics.The appearance of tension relaxation cracks in the deployment temperature range of 550 °C to 780 °C (1,022 °F to 1,436 °F) when making homogeneous joins can be countered by carrying out a stabilizing anneal after welding at 980 °C (1,796 °F) for 3 hours.The burn-off of Ti and Al during welding should be avoided (this applies particularly to submerged arc welding).

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	≈11	110–140	14–16 5.51–6.30
Comment	*Root welding at 90 A to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	≈ 11	150–180	20–30 7.87–11.8
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	≈ 12	180–250	40–80 15.7–31.5
MSGp (MIG/MAG) 131, 135	I1, Z-ArHeHC 10-5-0.05	23–27	130–150	24–30 9.45–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	180–220	26–30 10.2–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			
Submerged (SAW) 121		≈ 28	240–280	45–55 17.7–21.7

VDM® FM 617 B

N06617 (UNS) · 2.4627 (Material No.)

VDM® FM 617 B was developed with the aim of providing enhanced weldability and increased creep rupture strength compared with FM 617. Its field of application is in highly stressed pipes and fittings for coal-fired power stations with extremely high steam temperatures.

Designations & standards

ISO 18274	S Ni 6617, NiCr22Co12Mo9
AWS A5.14	ERNiCrCoMo-1
VdTÜV	Data sheet 11465

Typical chemical composition, values in %

Ni	Cr	Co	Mo	Al	Fe	Ti	B
Bal.	22	11	8.5	1.3	0.5	0.3	0.002

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 450 (> 65.3)	> 750 (> 109)	> 30	> 100 (> 73.8)

Applications

Welding filler for welding the base material of the same type, especially for applications in the creep range up to approx. 750 °C (1,382 °F). The creep rupture values of the pure weld metal reach or exceed the values of the base material VDM® Alloy 617.

Special notes for the welding process

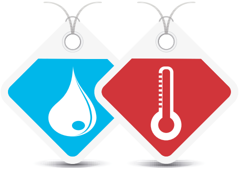
A low heat input and fast heat removal must be ensured. The stringer bead technique is recommended.The interpass temperature should not exceed 100 °C (212 °F). To minimize the thermal stress during welding, the use of a mechanized TIG narrow gap welding process is recommended for increasing work piece thickness. No preheating is required to achieve the weld metal characteristics.The appearance of tension relaxation cracks in the deployment temperature range of 550 °C to 780 °C (1,022 °F to 1,436 °F) when making homogeneous joins can be countered by carrying out a stabilizing anneal after welding at 980 °C (1,796 °F) for 3 hours.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, T145	I1, R1 max. 5 % H_2	≈ 11	110–140	14–16 5.51–6.30
Comment	*Root welding at 90 A to 110 A*			
v-TIG 141, 145	I1, R1 max. 5 % H_2	≈ 11	150–180	20–30 7.87–11.8
Comment	*Consultation with VDM Metals recommended*			

VDM® FM 622

N06022 (UNS) · 2.4635 (Material No.)



VDM® FM 622 is a nickel-chromium-molybdenum filler material with a low carbon content for the seam welding of homogeneous alloys in the area of wet corrosion applications. It is also used for the corrosion-resistant weld cladding of steam generator pipes for various fuels.

Designations & standards

ISO 18274	S Ni 6022, NiCr21Mo13Fe4W3
AWS A5.14	ERNiCrMo-10
VdTÜV	Data sheet no. 11245, 11246

Typical chemical composition, values in %

Ni	Cr	Fe	C	Mo	Others
Bal.	22	2.5	< 0.01	14	W 3.3; Al 0.1

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 310 (> 44.9)	> 690 (> 100)	> 30	> 70 (> 51.6)

Applications

Filler material for the welding of VDM® Alloy C-4, VDM® Alloy C-276 and VDM® Alloy C-22 together, as well as for dissimilar material joints with suitable high- and low-alloyed steels. Particularly suitable also for weld cladding on carbon steel due to its excellent corrosion properties and good weldability.

Special notes for the welding process

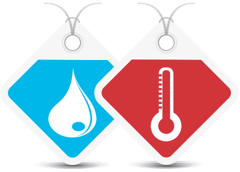
A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or reheating is required to achieve the weld metal properties.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 2 % H_2	10–12	90–140	11–16 4.33–6.30
Comment	*Root welding up to 110 A*			
v-TIG 141, 145	I1, R1 max. 2 % H_2	11–12	150–180	20–30 7.87–11.8
v-TIG HW 141 H, 145 H	I1, R1 max. 2 % H_2	11–12	180–220	40–80 15.7–31.5
MSGp (MAG) 135	Z-ArHeHC, 30/2/0.05	23–27	130–150	25–30 9.84–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 2 % H_2	≈ 25	180–220	25–30 9.84–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM 625

N06625 (UNS) · 2.4831 (Material No.)



VDM® FM 625 is a versatile nickel-chromium-molybdenum filler material for seam welding homogeneous alloys in wet-corrosion and high-temperature applications. It is also used for corrosion-resistant weld cladding in piping and fittings in oil production and steam generator pipes.

Designations & standards

ISO 18274	S Ni 6625, S Ni 6625B, NiCr22Mo9Nb
AWS A5.14	ERNiCrMo-3, ABS
VdTÜV	Data sheet no. 03453, 03454

Typical chemical composition, values in %

Ni	Cr	Mo	Nb	Fe	C
Bal.	22	9	3.5	< 0.7	< 0.1

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 460 (> 65.7)	> 720* (> 104)*	> 30	> 100 (> 73.8)

* (> 760 typically) (> 110.2 typically)

Applications

Filler material for the welding of VDM® Alloy 625, VDM® Alloy 825, VDM® Alloy 20 and VDM® Alloy 926. Additional material combinations and fields of application available on request.

Special notes for the welding process

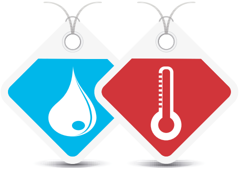
Ensure low heat input and rapid heat dissipation. The interlayer temperature should not exceed 150 °C. (302 °F) For the MSG process, impulse welding is preferably used. No preheating or reheating is required to achieve the weld metal properties. If the submerged arc process is used, the wire diameter should not exceed 1.6 mm (0.039 in).

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–12	90–140	11–16 4.33–6.30
Comment	*Root welding at 90 A to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	≈ 12	150–180	≈ 25 ≈ 9.84
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	11–12	180–220	40–80 15.7–31.5
MSGp (MIG/MAG) 131, 135	I1, I3-ArHe-30, Z-ArHeHC 30-2-0.05 Z-ArHeHC 30-2-0,12	23–27	130–150	24–30 9.45–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	165–200	≈ 26 ≈ 10.2
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			
Submerged (SAW) 121		≈ 28	240–280	45–55 17.7–21.7

VDM® FM 660

N06660 (UNS)



VDM® FM 660 has a similar material concept to FM 625, but VDM® FM 660 uses the alloy element tungsten instead of niobium. Compared with FM 625, VDM® FM 660 offers improved weldability, higher welding material ductility and a higher thermal stability, in particular in case of post heat treatment of the substrate materials.

Designations & standards

ISO	S Ni 6660, NiCr22Mo10W3
AWS	ERNiCrMo-20
VdTÜV	Data sheet no. 19468

Typical chemical composition, values in %

Ni	**Cr**	**Mo**	**W**	**Fe**	**C**
Other	22	9	3.5	Max. 0.7	Max. 0.1

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi)	Tensile strength R_m (MPa) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
420 60.9	690 100	40	180 132.7

Applications

Welding filler for weld cladding in the area of wet-corrosion and high-temperature corrosion protection, including for thermal waste management among other applications. VDM® FM 660 can also be used for seam welding of Alloy 625 with P275NH – P355NH, for example.

Special notes for the welding process

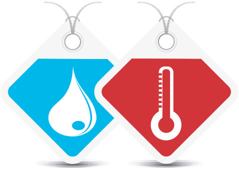
A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method.
No preheating or reheating is required to achieve the weld metal properties.

Example welding processes and
parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	Shielding gas as per ISO 14175	Welding parameters		
		U (V)	I (A)	V (cm / min)
v-WIG 141	I1	ca. 17	150–230	≈ 25 ≈ 9.84
v-WIG-HD 141 H	I1	11–12	180–220	40–80 15.7-31.5
MSGp (MIG) 131	I1	25–30	140–200	30–45 11.8-17,7
Comment	*Consultation with VDM Metals recommended*			

VDM® FM 699 XA

N06699 (UNS) · 2.4842 (Material No.)



VDM® FM 699 XA contains around 29 % chromium plus 2.1 % aluminum and is highly resistant to metal dusting in carburizing and reducing atmospheres. In addition, the chromium and aluminum content is also responsible for the high resistance in oxidizing atmospheres at elevated temperatures. The aluminum content increases also the materials high temperature strength by the precipitation of the γ' phase at temperatures up to about 800 °C.

Designations & standards

ISO 18274	S Ni 6699; NiCr29Al
VdTÜV	Data sheet no. 19891

Typical chemical composition, values in %

Ni	**Fe**	**Cr**	**Al**	**Zr**	**C**
68	≤ 2.5	29	2.1	0.05	0.02

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi)	Tensile strength R_m (MPa) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
240 (35)	610* (88)	30	70

** typical according to ISO 18274*

Applications

VDM® FM 699 XA is used for welding nickel-chromium alloy having UNS number N06699 to itself, to steels and to weld overlay steels. Welds made with this composition are particularly resistant to metal dusting in chemical and petrochemical applications.

Special notes for the welding process

Special attention must be paid to low heat input and fast heat removal. The interpass temperature (IPT) shall not exceed 100 °C (212 °F). A preheating of the material before starting the weld process is normally not required. In order to achieve optimal creep strength of weld joints in the temperature range of about 600 to 650 °C, a PWHT at 1100 °C for 40 minutes could be applied. For further information, please contact VDM Metals.
The purity of the argon shielding and backing gas should be 99.996 % (Ar 4.6) or better. For the best corrosion performance, especially in applications in atmospheres similar to syngas (carbon activity larger than one and low oxygen partial pressure), at temperature between 400 °C to 800 °C, heat tints shall be thoroughly removed by grinding the weld seam and the HAZ using fine abrasive belts or grinding discs.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175 (AWS 5.32 SG-A)**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG (root layer)	I1 (SG-A)	10–12	105–125	4–7 1.6–2.8
m-TIG	I1 (SG-A)	11–14	125–190	7–15 2.8–5.9
mech.-TIG	I1 (SG-A)	15	205	12–14 4.7–5.5

VDM® FM 718

N07718 (UNS) · 2.4667 (Material No.)

VDM® FM 718 is a nickel-chromium-iron-molybdenum filler material for seam welding of the basic material VDM® Alloy 718 in a wide range of demanding applications.
Based on its properties and good workability, VDM® FM 718 is used for seam welding and repair welding in stationary gas turbines, automotive applications, fastening elements and in pipework for the chemical processing industry.

Designations & standards

ISO	S Ni 7718, NiCr19Nb5Mo3
AWS	ERNiFeCr-2
VdTÜV	–

Typical chemical composition, values in %

Ni	Cr	Mo	Nb	Ti	C
Rest	19	3,1	5	0,9	max. 0,1

Mechanical properties at ambient temperature

Yield strength* $R_{p\,0.2}$ (MPa)	**Tensile strength*** R_m (MPa)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
≈ 900 (130.5)	≈ 1140 (165.3)		

**) after 2-stage hardening: Level 1: 8h at 720°C (1,328 °F) + level 2: 8h at 620°C (1,148 °F)*

Applications

Welding filler for seam welding of the homogeneous, high-strength nickel alloy VDM® Alloy 718. VDM® FM 718 is also increasingly being used in the area of (wire-based) 3D printing/the WAAM process, for example.

Special notes for the welding process

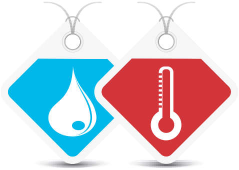
A low heat input and fast heat removal must be ensured.
The interpass temperature should not exceed 120 °C (248 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating is required to achieve the weld metal characteristics.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm / min)
v-WIG 141	I1	ca. 13	160–200	≈ 25 ≈ 9.84
MSGp (MIG) 131	I1	25–30	140–200	30–45 11.8–17.7
Comment	*Consultation with VDM Metals recommended*			

VDM® FM 780

2.4960 (Material No.)



VDM® FM 780 is a new-developed age-hardenable nickel-cobalt-chromium alloy. Hardenability is achieved by means of admixtures of niobium, titanium and aluminum. The VDM® FM 780 is characterized by higher application temperature (potentially up to 750 °C) compared to FM 718 and high temperature oxidation resistance. The mechanical strength of the weld metal as well as the ductility are superior to FM 718.

Designations & standards

ISO 18274	S Ni Z NiCr18Co25Nb5Mo3Al2

Nominal chemical composition values in %

Ni	Co	Cr	Nb	Mo	Fe	Al	Ti
43	25.0	18.0	5.0	3.0	<3.0	2.0	0.3

Mechanical properties* at ambient temperature, as-welded

Yield strength $R_{p\,0.2}$ (MPa) (Ksi)	Tensile strength R_m (MPa) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J)
700 (101)	950 (138)	30	70

** Note, that the values can vary in either direction depending on the welding task (WAAM or joint welding)*

Applications

VDM® FM 780 can be used for many demanding applications. Originally, it was developed for static and rotating components in aircraft turbines such as housings, mounting elements and turbine disks. The material can also be used for static and rotating components in stationary gas turbines, rocket drives and space craft, motor vehicle turbo chargers, mounting elements and for heat-resistant tools in forgeries, extruders and separating shearers. Opposite to many other super-alloys, VDM® FM 780 can be processed by Wire Arc Additive Manufacturing (WAAM).

Special notes for the welding process

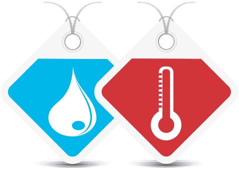
Special attention must be paid to low heat input and fast heat removal. The interpass temperature (IPT) shall not exceed 100 °C (250 °F). No preheating is required to achieve the weld metal properties.

Example welding processes and parameters for weldings in position 1G (1.20 mm wire)

Welding process as per ISO 4063	**Shielding gas as per ISO 14175 (AWS 5.32 SG-A)**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
GMAW	I1 (SG-A)	25	130	70 127.5

VDM® FM 825 CTP

N08827 (UNS) · 2.4861 (Material No.)



VDM® FM 825 CTP is a further development of the standard FM 825 (FM 65 Ni 8065 / Ni 8125). Opposite to standard FM 825, VDM® FM 825 CTP is highly hot cracking resistant during welding. VDM® FM 825 CTP is therefore especially suitable for overlay welding using (hot wire & cold wire) TIG or GMAW. Furthermore, VDM® FM 825 CTP is characterized by a significantly higher pitting and crevice corrosion resistance compared to standard FM 825.

Designations & standards

ISO 18274	S Ni 8827; NiFe30Cr22Mo6

Typical chemical composition values in %, as-welded

Ni	Fe	Cr	Mo	Cu	Ti	Mn
40	22	22	6	2	–	0.9

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi)	Tensile strength R_m (MPa) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J)
240 (35)	590 (85)	30	180

Applications

VDM® FM 825 CTP is used for welding the matching base material alloy UNS N08827 (VDM® Alloy 825 CTP), invented for applications like offshore piping, seawater-cooled heat exchangers, control lines or capillary tubing. Since VDM® FM 825 CTP is high resistant to pitting and crevice corrosion as well as chloride-induced stress corrosion cracking in combination with a high hot cracking resistance, VDM® FM 825 CTP is especially suitable for weld cladding of carbon steel pipes, bends, fittings, flanges, valves etc. for the oil and gas or the chemical industry.

Special notes for the welding process

Special attention must be paid to low heat input and fast heat removal. The interpass temperature (IPT) must not exceed 120 °C (250 °F). No preheating or post weld heat treatment (PHWT) is required to achieve the weld metal properties.

Example welding processes
and parameters for weldings in position 1G (2.4 mm rod, 1.20 mm wire)

Welding process as per ISO 4063	Shielding gas as per ISO 14175 (AWS 5.32 SG-A)	Welding parameters		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG (root layer)	I1 (SG-A)	11	90	6–8 2.3–3.1
m-TIG	I1 (SG-A)	12.5	130	9–14 3.5–5.5
mech.-TIG	I1 (SG-A)	13.5	210	13.5 5.3
GMAW	I1 (SG-A)	30	210	40 15.7

VDM® FM 2120

N06058 (UNS) · 2.4700 (Material No.)

VDM® FM 2120 is a nickel-chromium-molybdenum filler material with a low carbon content and controlled nitrogen addition for the over-alloyed seam welding of high-performance alloys in the area of wet chemistry. It offers extremely high corrosion resistance in both reducing and oxidizing conditions, in hot, acid, and chloride-containing media and excellent resistance to mineral acids such as sulfuric acid and hydrochloric acid. VDM® FM 2120 is frequently used in extremely corrosive media in the chemical industry and environmental engineering.

Designations & standards

ISO	S Ni 6058, NiCr21Mo20
AWS	ERNiCrMo-19
VdTÜV	Data sheet no. 18965, 18953, 18954

Typical chemical composition, values in %

Ni	**Cr**	**Mo**	**Fe**	**N**	**C**
Other	21	19.5	0.1	Max. 1.5	Max. 0.01

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi)	Tensile strength R_m (MPa) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact str**ength (J) (ft-lbs)
360 (52.2)	760 (110)	40	90* (66.4*)

**) Multi-layer welds with ISO V notch impact toughness > 50 J*

Applications

Welding filler for the welding of VDM® Alloy 2120 MoN. Additional material combinations and fields of application available on request.

Special notes for the welding process

A low heat input and fast heat removal must be ensured.
The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or reheating is required to achieve the weld metal properties.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm / min)
m-WIG 141	I1	9–12	90–160	10–16 3.94-6.30
Comment	*Root welding at 80 A to 110 A*			
v-WIG 141	I1	ca. 12	150–180	≈ 25 ≈ 9.84
v-WIG-HD 141 H	I1	11–12	180–220	25–60 9.84-23.6
MSGp (MIG / MAG) 131, 135	I1, Z-ArHeHC 30-2-0,05; Z-Ar-HeHC 30-2-0,12	25–30	130–200	30-45 11.8-17.7
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			
Comment	Consultation with VDM Metals recommended			

VDM® FM B-2

N10665 (UNS) · 2.4615 (Material No.)

VDM® FM B-2 is a nickel-molybdenum filler material that has been developed especially for welding VDM® Alloy B-2. It possesses outstanding corrosion resistance in reducing acids.

Designations & standards

ISO 18274	S Ni 1066, NiMo28
AWS A5.14	ERNiMo-7
VdTÜV	Data sheet no. 07736, 07737

Typical chemical composition, values in %

Ni	**Mo**	**Fe**	**Cr**	**C**
Bal.	28	1.7	0.7	< 0.02

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 480 (> 69.6)	> 760 (> 110)	> 30	> 80 (> 59)

Applications

Filler material for the welding of VDM® Alloy B-2. Suitable for weld cladding on carbon steel.

Special notes for the welding process

VDM® FM B-2 exhibits outstanding weldability. A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 120 °C (248 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or PWHT is required to achieve the weld metal properties.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–12	90–140	11–16 4.33–6.30
Comment	*Root welding up to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	≈ 12	150–180	≈ 25 ≈ 9.84
MSGp (MIG/MAG) 131, 135	I1, M12, ArHeC 50-2	23–27	130–150	24–30 9.44–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	200–220	≈ 26 ≈ 10.2
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM C-4

N06455 (UNS) · 2.4611 (Material No.)

VDM® FM C-4 is a nickel-chromium-molybdenum filler material with a low carbon content for seam welding homogeneous alloys in wet corrosion applications. It is frequently used in the chemical industry for applications involving hydrochloric acid.

Designations & standards

ISO 18274	S Ni 6455, NiCr16Mo16Ti
AWS A5.14	ERNiCrMo-7
VdTÜV	Data sheet no. 04588, 04589

Typical chemical composition, values in %

Ni	Cr	Mo	Fe	Ti	W	C
Bal.	16	16	1	0.3	0.5	< 0.01

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 400 (> 58)	> 700 (> 101)	> 30	> 90 (> 66.4)

Applications

Filler material for the welding of VDM® Alloy C-4. Particularly suitable also for weld cladding on carbon steel due to its excellent corrosion properties and good welding characteristics.

Special notes for the welding process

A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 150 °C (302 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or PWHT is required to achieve the weld metal properties.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141	I1	10–12	90–140	11–16 4.33–6.30
Comment	*Root welding up to 110 A*			
v-TIG 141	I1	11–12	150–180	20–30 7.87–11.8
MSGp (MIG) 131	I1	23–27	130–150	25–30 9.84–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1	≈ 25	180–220	25–30 9.84–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

VDM® FM C-263

N07263 (UNS) · (2.4650 Material No.)

VDM® FM C-263 is a nickel-chromium-cobalt filler material that has been developed especially for the homogeneous welding of superalloy VDM® Alloy C-263. The addition of titanium means that the weld metal can be age hardened and thus achieves excellent creep resistance.

Designations & standards

ISO 18274	S Ni 7263, NiCr20Co20Mo6Ti2
VdTÜV	Data sheet 11451

Typical chemical composition, values in %

Ni	Cr	Co	Mo	Ti	Al	Fe	C	Al+Ti
Bal.	20	20	5.8	2.1	0.5	< 0.7	0.06	2.4–2.8

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)		Tensile strength R_m (MPa) (Ksi) (Ksi)		**Elongation** A_5 (%)		**ISO V-notch impact strength** (J) (ft-lbs)	
U	> 450 (> 65.3)	U	> 760 (> 110)	U	> 25	U	> 120 (> 88.5)
A	> 570 (> 82.7)	A	> 920 (> 133)	A	> 15	A	> 50 (> 36.9)

Condition “U” = unannealed
Condition “A” = aged hardened 4h at 800 °C (1472 °F)

Applications

Filler material for welding VDM® Alloy C-263.

Special notes for the welding process

A low heat input and fast heat removal must be ensured.
The stringer bead technique is recommended. The interpass temperature should not exceed 100 °C (212 °F). No preheating is required to achieve good weld metal characteristics. If required, the alloy can be age hardened at 800 °C (1,472 °F)/4 hrs. The alloy is not prone to cracking as a result of the age hardening. Before welding, the material should be in a solution-annealed state. The burn-off of Ti and Al during welding should be avoided.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	≈ 11	110–140	14–16 5.51–6.30
Comment	*Root welding at 90 A to 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	≈ 11	150–180	20–30 7.87–11.8
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	180–220	26–30 10.2–11.8
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			
Comment	Consultation with VDM Metals recommended			

VDM® FM C-276

N10276 (UNS) · 2.4886 (Material No.)

VDM® FM C-276 is a nickel-chromium-molybdenum filler material with a low carbon content for seam welding homogeneous alloys in wet corrosion applications. It is widely used in the chemical industry and environmental technologies.

Designations & standards

ISO 18274	S Ni 6276, NiCr15Mo16Fe6W4
AWS A5.14	ERNiCrMo-4, ABS
VdTÜV	Data sheet no. 05582, 05583

Typical chemical composition, values in %

Ni	Cr	Mo	Fe	W	Mn	V	C
Bal.	16	16.5	6	3.5	0.5	0.2	< 0.01

Mechanical properties at ambient temperature

Yield strength $R_{p\,0.2}$ (MPa) (Ksi) (Ksi)	Tensile strength R_m (MPa) (Ksi) (Ksi)	**Elongation** A_5 (%)	**ISO V-notch impact strength** (J) (ft-lbs)
> 450 (> 65.3)	> 750 (> 109)	> 30	> 90 (> 66.4)

Applications
Filler metal for welding VDM® Alloy C-276 and for mixed joints with suitable high- and low-alloy steels. Due to excellent corrosion properties suitable for clad welding on carbon steel. The material VDM® FM C-276 can also be used for submerged arc welding in the field of liquefied natural gas (LNG).

Special notes for the welding process

A low heat input and fast heat removal must be ensured. The interpass temperature should not exceed 120 °C (248 °F). When using the gas-shielded metal-arc process, pulsed welding is the preferable method. No preheating or reheating is required to achieve the weld metal properties.

Example welding processes and parameters for homogeneous seam welding in Position 1G

Welding process as per ISO 4063	**Shielding gas as per ISO 14175**	**Welding parameters**		
		U (V)	I (A)	V (cm/min) (in/min)
m-TIG 141, 145	I1, R1 max. 3 % H_2	10–11	90–120	10–15 3.94–5.91
Comment	*Root welding at 110 A*			
v-TIG 141, 145	I1, R1 max. 3 % H_2	11–12	≈ 150	≈ 25 ≈ 9.84
v-TIG HW 141 H, 145 H	I1, R1 max. 3 % H_2	10–12	180–250	40–80 15.7–31.5
MSGp (MIG/MAG) 131, 135	I1, R1 max. 3 % H_2	23–27	130–150	20–30 7.87–11.8
Comment	*from approx. 8 mm (0.315 in) work piece thickness*			
Plasma (PAW) 15	I1, R1 max. 3 % H_2	≈ 25	165–200	≈ 25 ≈ 9.84
Comment	*up to approx. 8 mm (0.315 in) work piece thickness*			

Core Wire

VDM® CW 55

W82002 (UNS) · (2.4560 Material No.)

VDM® CW 55 is used for the production of coated nickel-iron stick electrodes. The filler material is used for so-called cast iron cold welding, e. g. for repairs and for joining large structural elements made of grey cast iron.

Designations & standards

AWS A5.15	ENiFe-CI

Typical chemical composition, values in %

Ni	Fe	C	Mn	Si	Cu + beil. Ag	Al
59.5	39	0.007	0.8	0.16	0.04	0.05

Others	P	S
	<0.01	<0.005

Please note that this filler material requires special protection against humidity.

VDM® CW 60

N04060 (UNS) • (2.4377 Material No.)

VDM® CW 60 is used for the production of coated stick electrodes as per material no. 2.4377. The filler material is used for the joint welding of nickel-copper materials and for corrosion resistant weld cladding on steel. It is used for salt solutions and alkalis in the chemical industry and in marine engineering.

Designations & standards

AWS (A5.14)	(ERNiCu-7)

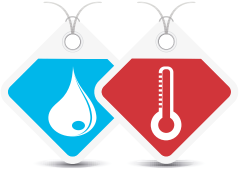
Typical chemical composition, values in %

Ni	Ti	Fe	C	Mn	Si	Cu	Al
64	2.3	1	0,01	3.2	0.1	29	0.1

Others	P	S
	<0.01	<0.005

VDM® CW 182

N06082 (UNS) • (2.4620, 2.4648 Material No.)



VDM® CW 182 is used for the production of coated electrodes as per material no. 2.4648 or 2.4807. It is a widely used nickel-chromium filler material for the joint welding of high-temperature and heat-resistant chromium-nickel steels and nickel alloys, also together with carbon steels, as well as low-temperature nickel steels. It is used in cryogenic engineering as well as for industrial oven construction and steam generators.

Designations & standards

AWS (A5.14)	(ERNiCr-3)

Typical chemical composition, values in %

Ni	Cr	Fe	C	Mn	Si	Cu	Mo
73	19.5	1.5	0.006	3.2	0.15	0.01	0.01

Ti	Nb
0.4	1.8

Others

P	S
<0.01	<0.005

VDM® CW Nickel

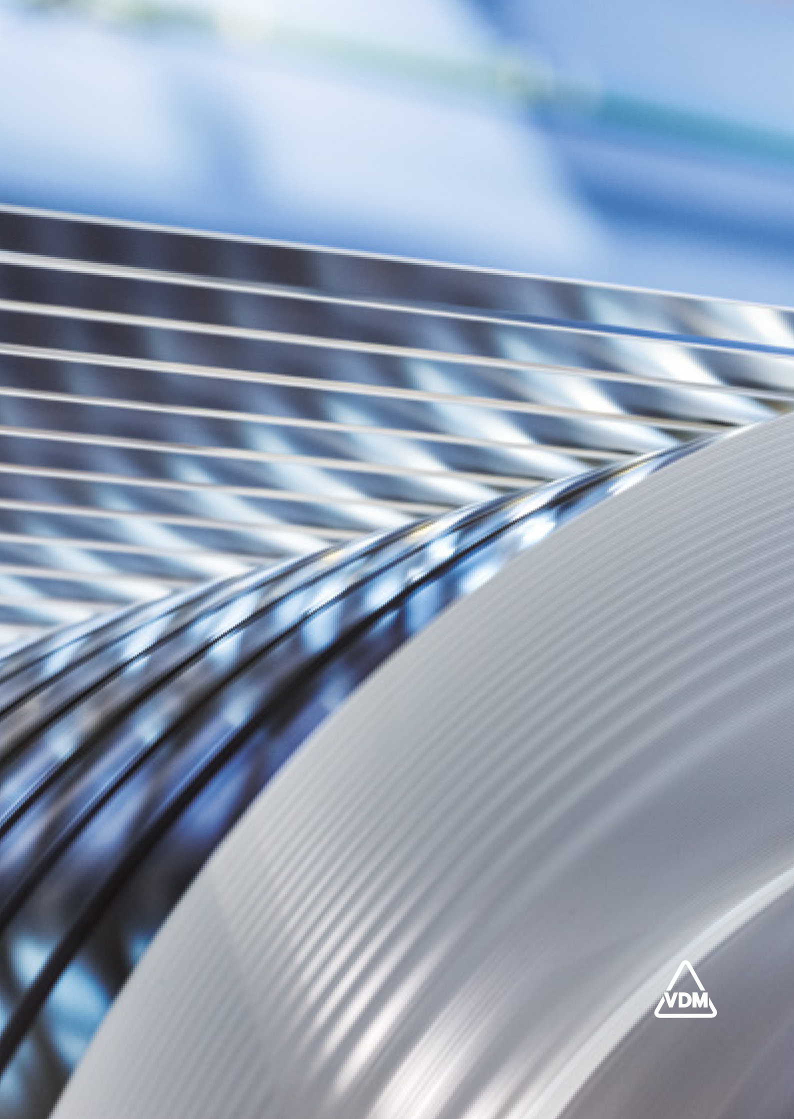
N02200 (UNS) · 2.4066 (Material No.)

VDM® CW Nickel is used for the production of coated stick electrodes with a core of commercially pure nickel. Typically, these coated stick electrodes are used for joint and repair welds of cast iron especially in order to meet highest demands on ductility and machinability.

Typical chemical composition, values in %

	DIN
Nickel	99.6

∑ Elements not listed < 0.5


VDM

Strip electrodes and Strip for flux cored wire

VDM® WS 52i

N06056 (UNS)

VDM® WS 52i is a nickel-chromium welding filler with good workability and a low tendency to crack that is ideal for seam welding homogeneous materials.
In particular, this material was developed for weld cladding and welding in Ni-Cr-Fe components in the reactor coolant systems of nuclear power plants.

Designations & standards

AWS A5.14	EQNiCrFe-15
ASME	Code Case 2142-4

Typical chemical composition, values in %

Ni	Cr	Fe	Nb	Mn	C
Rest	27	2.6	2.3	3	0.04

Special notes for the welding process:
The newly developed VDM® WS 52i exhibits significantly improved welding characteristics in comparison with other welding fillers, such as FM 52, and stands out due to its high resistance to hot cracking during welding. The strip is generally applied via electroslag welding (ESW).

VDM® WS 59

N06059 (UNS) · 2.4607 (Material No.)

VDM® WS 59 is a nickel-chromium-molybdenum filler material with a low carbon content for wet corrosion-resistant weld cladding on steel. It possesses exceptionally high stability in hot acid and chloride-containing media and is frequently used in the chemical industry and environmental technologies.

Designations & standards

ISO 18274	Ni 6059
AWS A5.14	EQNiCrMo-13

Typical chemical composition, values in %

Ni	Cr	Fe	C	Mn	Si	Cu	Al
60	22.5	0.7	< 0.01	0.2	0.02	0.02	0.25

Mo	Co	Others	P	S
16	0.02		0.005	0.002

VDM® WS 82

N06082 (UNS) · 2.4806 (Material No.)

VDM® WS 82 is a chromium-nickel filler material for corrosion- and heat-resistant weld cladding. It possesses good resistance to alkaline salt solutions as well as high-temperature oxidation and chlorination. The main areas of use are in the chemical industry, oven construction and nuclear energy.

Designations & standards

ISO 18274	Ni 6082
AWS A5.14	EQNiCr-3

Typical chemical composition, values in %

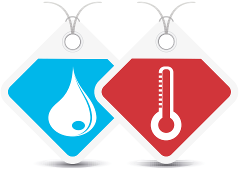
Ni	Cr	Fe	C	Mn	Si	Cu	Ti
73	20.5	0.3	0.006	3.2	0.06	0.01	0.3

Nb
2.6

Others	P	S
	0.005	0.002

VDM® WS 625

N06625 (UNS) · 2.4831 (Material No.)



VDM® WS 625 is a nickel-chromium-molybdenum filler material for wet corrosion- and heat-resistant applications. It is mainly used for corrosion-resistant weld cladding in acid gas applications, e. g. piping and valves for the oil and gas industry and for the corrosion protection of boiler tubes in waste-to-energy plants.

Designations & standards

ISO 18274	Ni 6625
AWS A5.14	EQNiCrMo-3

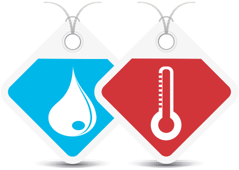
Typical chemical composition, values in %

Ni	Cr	Fe	C	Mn	Si	Cu	Mo
65	22	0.3	0.015	0.013	0.06	0.01	8.5

Al	Ti	Nb			Others	P	S
0.11	0.22	3.5				0.005	0.002

VDM® WS 625 HS

N06625 (UNS) · 2.4831 (Material No.)



VDM® WS 625 HS is a nickel-chromium-molybdenum filler material designed as a strip for electroslag weld cladding, especially at high speeds. It is mainly used on unalloyed or low-alloyed steel to achieve higher corrosion resistance to wet corrosion or at higher temperatures. Example applications include acid gas treatment plants and acid gas lines, for slug catchers in oil production and in intake gas separators.

Designations & standards

ISO 18274	Ni 6625
AWS A5.14	EQNiCrMo-3

Typical chemical composition, values in %

Ni	Cr	Fe	C	Mn	Si	Cu	Mo
65	22	0.3	0.015	0.015	0.07	0.01	8.8

Al	Ti	Nb	Others P	Others S
0.11	0.22	3.7	0.005	0.002

VDM® WS 8020

(N06076 UNS) · 2.4639 (Material No.)

VDM® WS 8020 is a chromium-nickel filler material for heat-resistant weld cladding. It has good resistance to high-temperature oxidation and chlorination. Its main areas of use are in the chemical industry and oven construction. Titanium and Carbon contents deviate from the standards due to requirements in the field of core wire.

Designations & standards

AWS A5.14	EQNiCr-6 (exc. C; Ti)

Typical chemical composition, values in %

Ni	Cr	Fe	C	Si	Ti
79	20.5	0.15	0.008	0.08	0.01

VDM® WS C-276

N10276 (UNS) · 2.4886 (Material No.)

VDM® WS C-276 is a nickel-chromium-molybdenum filler material with a low carbon content for wet corrosion-resistant weld cladding on steel. It is widely used in the chemical industry and environmental technologies.

Designations & standards

ISO 18274	Ni 6276
AWS A5.14	EQNiCrMo-4

Typical chemical composition, values in %

Ni	Cr	Fe	C	Mn	Si	Cu	Mo
58	16	6	0.004	0.5	0.02	0.03	15.5

Co			Others	P	S	V	W
0.2				0.005	0.002	0.15	3.4

Process descriptions

Process descriptions

Basic rules and preparatory work

Welding technology is becoming increasingly important in the construction of apparatus and plants as their safety, reliability and longevity is significantly affected by the quality of their welded joints. Because of this, the following basic rules of welding are to be followed, especially when nickel alloys and super austenitic stainless steels are being processed for demanding applications.

- In the selection of the filler material, the basic principle is: always use over-alloyed or at least similar filler metal for welding.
- Nickel alloys and special stainless steels should be welded in a soft-annealed or solution-annealed state.
- Before welding, the mill scale should be removed by sanding or blasting and pickling, at least in the area around the weld.
- The edges for a butt joint should be prepared as shown in Fig. 1.
- Both the seam edges as well as the upper and lower surface of the sheet must be clean, free of grease, markings and paint residue for a distance of at least 25 mm from the edge. The cleaning should be carried out without the use of the sulphur- or chloride-based agents.

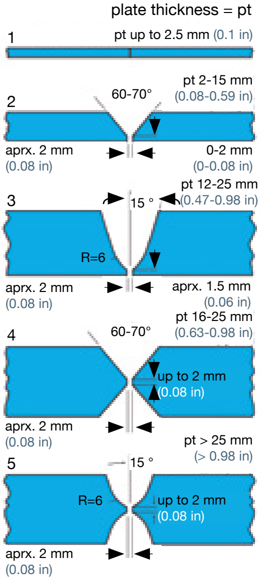
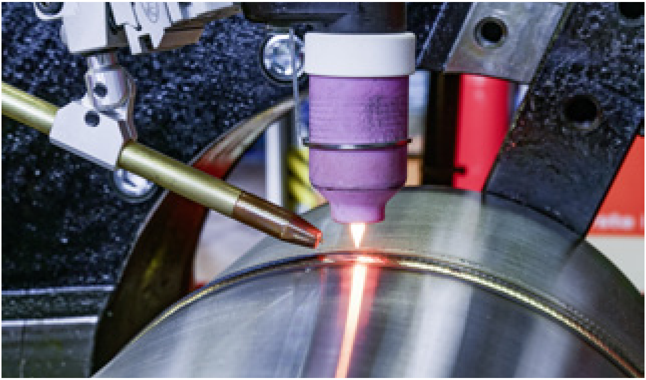


Fig. 1

1 Straight butt weld
2 Single-V weld
3 Single-U weld
4 Double-V weld
5 Double-U weld



- Pore-forming gases such as nitrogen and oxygen must be kept away from the joint. (Except for filler metals VDM(R) FM 602 CA)
- The reaction of the weld pool with oxydizing gases has to be avoided as well as the loss of alloying elements with high affinity to oxygen.
- The recommended filler materials are listed in chapters 03–05.
- A selection of the suitable welding processes is given in chapter 06.
- Discolorations should be removed after welding, for instance by brushing using a stainless steel brush.

When welding nickel alloys and high-alloyed special stainless steels, special attention is to be paid to the following:

- The reduced heat conductivity and high rate of thermal expansion of these alloys compared with stainless or carbon steels.
- The danger of hot cracking due to sulphur absorption.
- Influences from precipitations, especially with hardened materials.

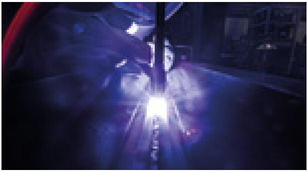
Generally speaking, most of the currently known fusion welding processes for nickel alloys and high-alloyed special stainless steels are suitable, whereby the welding parameters need to be customized for the special requirements of these materials. Details can be found in the chapter “Welding nickel alloys and high-alloyed special stainless steels” in the textbook “Nickel alloys and high-alloyed special stainless steels” (4th edition, 2012; expert Verlag, ISBN 978-3-8169-2751-8).

When welding two different materials, the filler material must also meet the following requirements:

- High solubility of the elements iron, nickel and chromium without the creation of mixzones that are brittle or susceptible to cracking (formation of intermetallic phases, strong carbon diffusion).
- The coefficient of thermal expansion should lie between that of the alloys to be joined.
- Corrosion resistance, stability and elasticity should be at least equal to that of the weakest alloy. It is desirable to use filler materials whose properties coincide at least with those of the higher value alloy in the join.

Preparatory work

The specified design of the structural component needs to be checked to see whether it is suitable for welding in terms of the combination of materials, arrangement of the seams and the weld positions. If cold forming of around 10–15 % (by deep-drawing, trimming or bending) is necessary before welding, a further heat treatment of the work piece may be required. The weld edges need to be prepared before welding. The type of preparation will depend on the material and dimensions as well as the welding technique selected. It should be carried out using a mechanical treatment such as planing, milling or turning. Abrasive water jet cutting and plasma/laser cutting are also possible. When using mechanical methods, it is important to remember that machining nickel and nickel alloys is considerably more difficult than machining steel. The cutting speeds and service life of the tools used are far below the values that are usual for steel (empirical value: 1:10).



To ensure trouble-free machining of nickel alloys, the following points must be considered:

- Maximum rigidity of tool and work piece must be maintained as well as the sharpness of the tools (smooth surface and sharp edges) to ensure a clean cut.
- To support the cutting edge, the lip angle should not be any larger than necessary.
- As much material as possible should be left on the tip of roughing tools.
- An adequate supply of sulphur-free cutting oil.
- Compared with steel, the cutting speed should be reduced. The cutting depth should be large rather than too small to undercut work-hardened areas on the surface.
- As much space as possible should be left for swarf from cutting and scraping tools.

The weld preparation of nickel alloys generally differs from those of mild steels. The larger joint angle is normally necessary due to the higher viscosity of the melt and higher shrinkage reaction of the material during cooling. Typical seam preparations are shown in Fig. 1 (Page 88).

Process descriptions

Joint welding and weld cladding processes

Welding process

The fusion welding of high-alloyed special stainless steels, nickel- and cobalt-based alloys is the state of the art these days. The standard processes are:

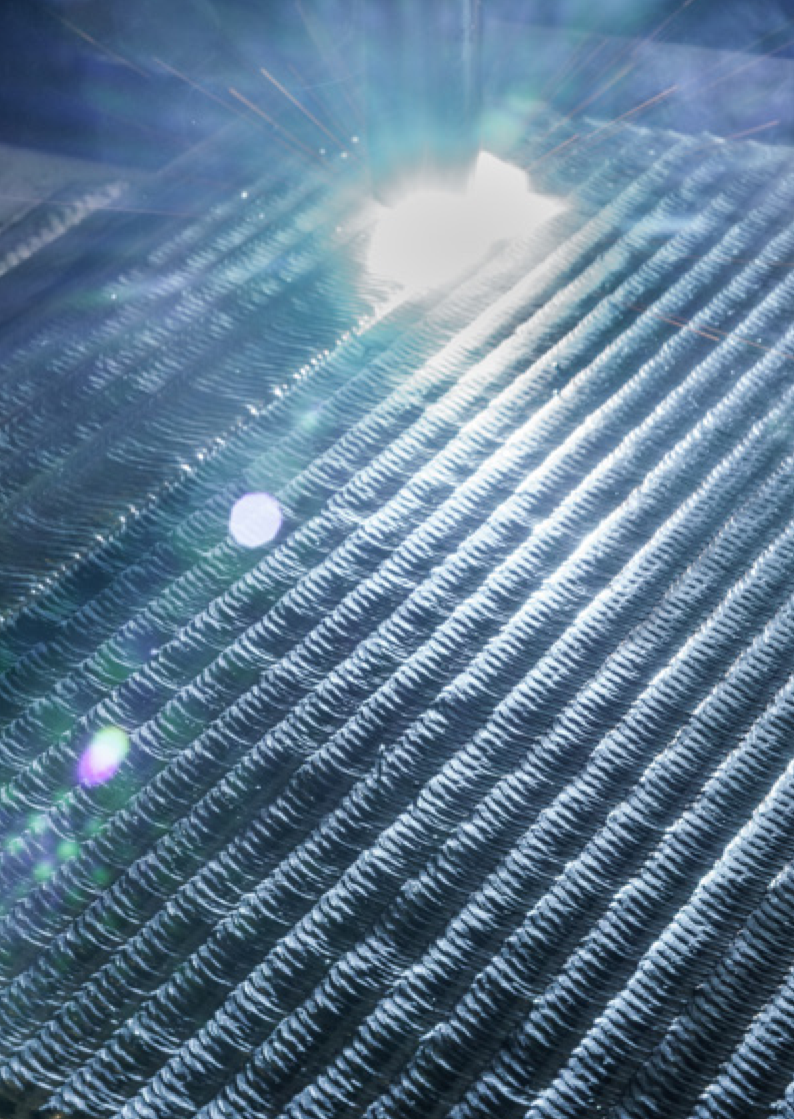
- Tungsten inert-gas welding (TIG)
- Tungsten inert-gas hot-wire welding (TIG HW)
- Tungsten plasma arc welding (PAW)
- Metal inert-gas welding and metal active-gas welding (MIG/MAG)
- MAG tandem welding
- Submerged arc welding (SAW)
- Laser welding
- Electron beam welding

These processes have been tried and tested in the fields of process engineering, in chemical and petrochemical apparatus and plant engineering, industrial oven construction and also in environmental and energy technology. MAG welding, unlike with carbon steel, generally uses shielding gases with an especially low percentage of CO_2 of less than 0.12 %.

The most common weld cladding processes are:

- Tungsten inert-gas weld cladding (TIG),
- Tungsten inert-gas hot-wire welding (TIG HW),
- Gas-shielded metal-arc weld cladding (MIG/MAG) (+ heat-reduced variants),
- Submerged arc welding (SAW) with wire or strip,
- Electroslag weld cladding (ES) with strip,
- Twin, hybrid or tandem technologies can be used to increase productivity

All of these methods are commercially attractive because of their high surface power and their low dilution with the substrate material. Optimal application of a qualified welding technique and fillers makes it possible to practically achieve the corrosion resistance of a parent material that corresponds to the filler. Alongside pure argon, a number of different gas mixtures can be used that, in most cases, improve profitability and quality.



Process descriptions

Joint welding

Welding solid materials

A comprehensive scope of applications combined with good weldability: these are the key functional characteristics of nickel alloys and high-alloyed special stainless steels in solid form. The filler material, welding process and welding technique must be selected in accordance with the respective material-specific requirements or adapted to it.

This is because the quality of the weld produced should be comparable with the mechanical and technological parameters, the high-temperature resistance level, creep resistance, corrosion properties, etc. of the base material (sheet & platematerial or piping metal or piping). This requirement is not to be taken for granted. In structural composition, welded joints are rather to be categorized as areas with a cast structure. Compared to wrought materials with comparable nominal compositions, changes to the properties can arise. If the welding recommendations are heeded, however, secure and outstanding-quality welded joints can be produced.

Welding clad materials

Generally speaking, the same rules apply for clad materials as for solid materials. Clad steels are construction materials that are of economic interest when various demands have to be coped with simultaneously; for example, high mechanical stress in a corrosive environment.

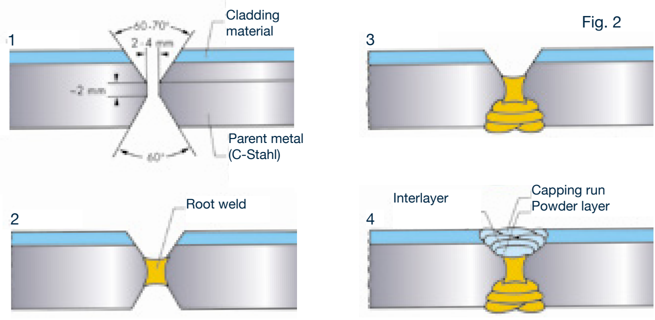
Usually, a low-alloyed steel that has been adapted to the requirements is used as support material and construction material, while a comparatively thin cladding layer of nickel alloy is used as a corrosion inhibitor. The manufacture of cladded materials is usually carried out using a roll cladding or explosive cladding process. The minimum thickness of the cladding layer will only be under 2 mm (0.079 in) in exceptional cases. Ideally, a layer or cladding thickness of 3 mm (0.118 in) should be used as the lower the thickness the greater the problems during welding.

Seam preparation is of fundamental importance. Here, adherence to DIN EN ISO 9692-4 (Recommendations for joint preparation – Part 4: Clad steels) is recommended.

The welding of the support material is usually carried out using a TIG or gas-shielded metal-arc welding process. At higher deposition rates and equally good joint quality, it is also possible to use the submerged arc/MAG tandem weld process. The prerequisite for a good result is precise alignment of the metal sheets or components to be welded. This ensures uniformity of cladding on the areas being welded. A horizontal welding position is recommended as this produces the best results in terms of minimizing dilution, heat input, etc. In practice, however, it is sometimes also necessary to execute vertical and transverse welds. Also in these cases satisfactory results will be achieved – even under building site conditions – if well-trained welders who have been certified according to ISO 9606-1 resp. ISO 9606-4 or ISO 14732 carry out the welding.

Various factors are relevant for the necessary number of weld layers or weld runs, in particular the expected corrosion exposure in this zone. The composition of the weld should, as far as possible, correspond to that of the cladding material which results in the requirement for a lower dilution with the base material. The stringer bead technique is suitable for this, i.e.

Fig. 2



1 Weld preparation

2 Welding of the root weld on the cladding side using TIG process

3 Welding the carbon steel parent material

4 Welding of a buffer layer, interlayers and two capping runs

the application of several thin runs/layers using a wire diameter that is as thin as possible. The layer thickness of 1.5–2.0 mm (0.059–0.079 in) also allows working with cover strips. The welding work can be carried out manually, partially or fully automatically using a TIG process with cold wire feed. The TIG hot wire process offers economic and qualitative benefits compared with the cold wire process.

Wallpapering

In addition to processing explosive-, roll- and well-clad sheet, the so-called wallpapering process is often used, especially during refurbishment work. Wallpapering involves applying thin-walled sheet and strip cladding or shrouding in thickness ranges of 1.5 to 2.5 mm (0.059 to 0.098 in) onto areas that are at risk from corrosion. This technique offers a number of benefits if a subsequent lining or panel is required, e. g. during repair or refurbishment work on large volume building components in flue gas desulphurization plants.

Various practice-tested options are available for carrying out lining work. As a rule, a practical, safely controllable and, not least, economical method for carrying out wallpapering should be chosen. Here, in addition to the selected technology, the welding process employed will play an important role. It must be possible to achieve a single-pass, dense, top-quality and always reproducible weld – generally fillet welding – regardless of the position.

The possibility of employing a mechanized welding process should be examined and the use of a filler material is absolutely necessary. The techniques illustrated in Figs. 3 – 6 can all be safely controlled by using fully mechanized welding processes. When working on large-format sheets, it is absolutely necessary to create a secure joint between shroud and support material using plug welds – on the surface of the sheet (see Fig. 6). The number of plug welds per unit of area can vary and must be determined on a case-by-case basis. Technical and quality assurance guidelines for handling and installing nickel alloy and stainless steel linings in air pollution control and other process equipment is described in detail in NACE Standard RP 0292.

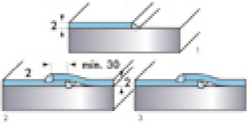


Fig. 3

Wallpapering using TIG cold wire or TIG hot wire welding process “without root”, overlapping.

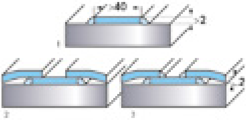


Fig. 5

Wallpapering using TIG cold wire or TIG hot wire welding process “on roots” (grid).

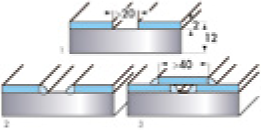


Fig. 4

Wallpapering using TIG cold wire or TIG hot wire welding process “with covering strip”.

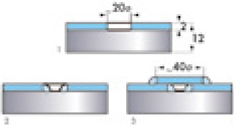
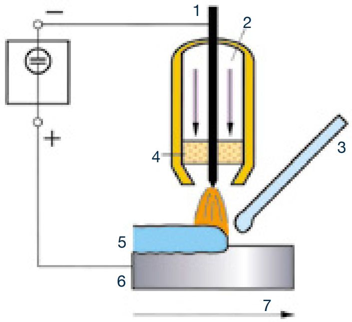


Fig. 6

Manual or fully mechanized TIG plug weld with cover.

Process descriptions – Joint welding

Tungsten inert-gas welding (TIG)



1 Tungsten electrode
2 Argon or helium (mix)
3 Filler material
4 Gas lens
5 Weld metal
6 Parent material
7 Weld progression

This process guarantees maximum weld metal quality. It allows welding with low heat input, especially when working with filler material (cold wire). With the help of the melting welding rod, the bath temperature can be favorably influenced.

The process is particularly well-suited for welding thin to medium sheets and also for welding root passes on thicker sheets. Inert or reducing gases are suitable as shielding gases. Flashing off of alloying elements is not to be expected.

Technical prerequisites

- A power source (direct current)
- Tungsten electrodes (preferably thorium-free): 1.6 – 2 – 2.4 – 3.2 – 5 mm (0.063 – 0.079 – 0.094 – 0.126 – 0.197 in) diameter, as sharp as possible, negative polarity. More information can be found in ISO 6848.
- Shielding gas: argon or argon with hydrogen content of up to max. 5 %.

Processing instructions

All work pieces should be free of contaminants (especially anything containing sulphur).

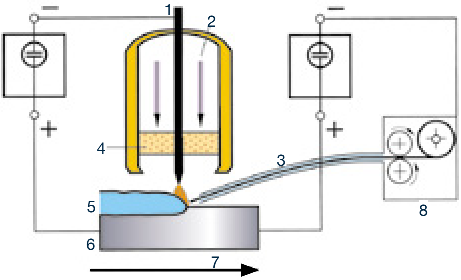
Ignition and stopping of the electric arc should be carried out using a run-on/run-off plate.

Example welding parameters

Sheet metal gauge		**3 mm** **0.118 in**	**6 mm** **0.236 in**	**8 mm** **0.315 in**	**10 mm** **0.394 in**
Root pass	A	90	100–110	110–120	110–120
	V	10	10	11	11
Filling and capping run	A	110–112	120–140	130–140	130–140
	V	11	12	12	12
Joint form		V 70 °	V 70 °	V 70 °	V 70 °
Filler material	mm Ø in Ø	2.0 0.079	2.0–2.4 0.079–0.094	2.4 0.094	2.4 0.094
Welding speed	cm/min in/min	10–15 (manuel) – 20–30 (mechanized) 3.94–5.91 – 7.87–11.8			
Shielding gas quantity	l/min ft³/min	8–10 0.282–0.353			
Energy per unit length	kJ/cm kJ/in	≤ 8 ≤ 20.3			

Process descriptions – Joint welding

Tungsten inert-gas hot-wire welding (TIG HW)



1 Tungsten electrode
2 Argon or helium (mix)
3 Filler material
4 Gas lens
5 Weld metal
6 Parent material
7 Weld progression
8 Wire feed

Like the TIG process, the hot-wire (TIG HW) process also delivers high quality welds in weld cladding and joint welds. The TIG arc is used to melt the parent material while a wire feed system continuously transports the filler material to the arc/molten pool. The filler wire – usually 0.8–1.2 mm (0.0315–0.047) in diameter – is connected to a dedicated power source via a contact tube and is thus preheated through conductive heating.

One factor that is of fundamental importance for an optimal TIG HW weld is the angle of attack of the contact tube. This should ideally be at an inclination of 20°–40° to the work piece/the horizontal. The length of the free wire end should not exceed 15 mm (0.591 in) at a weld wire diameter of 0.8 mm (0.0315 in) as the wire otherwise can flash off due to resistance heating before being dipped in the molten pool.

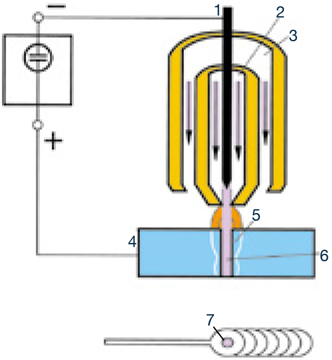
Technical prerequisites

- A power source (direct current)
- Tungsten electrodes (preferably thorium-free), negative polarity
- Shielding gas: argon or argon with a hydrogen content of up to max. 5 %
- A power source (alternating current) for heating the hot wire.

To prevent oxidation of the hot wire, the contact tube can be equipped with a shielding gas supply. The welding speed is between approx. 25–40 cm (9.84–15.7 in), possibly higher depending on the conditions.

The weld result is particularly favorable thanks to the increased output, reduced warpage, narrower heat-affected zones, better join, lower risk of hot cracking and lower dilution with the parent material.

Tungsten plasma arc welding (PAW)



1 Tungsten electrode
2 Plasma gas
3 Shielding gas
4 Parent material
5 Weld metal
6 Leaking plasma
7 Keyhole

This process differs from TIG welding in that the electric arc is held between the tungsten electrode and the work piece within the welding nozzle and that this arc remains strongly focused thanks to the plasma column.

This focusing technology makes it possible to achieve a very narrow weld profile. The plasma keyhole process can be safely and economically used for sheet metal gauges of up to around 8 mm (0.31 in).

An I-joint is sufficient for joint preparation. It is possible to work with filler material. The weld profile is very uniform. Top-quality welded joints can be achieved in which the flashing off of alloying elements is not likely. The process is therefore useful for materials which are highly susceptible to corrosion stresses.

Technical prerequisites

- A power source (direct current)
- Tungsten electrodes (preferably thorium-free): 1.6–2–2.4–3.2–5 mm (5.25–6.56–7.87–10.5–16.4 in) diameter, as sharp as possible, negative polarity
- Suitable shielding and plasma gas

Processing instruction

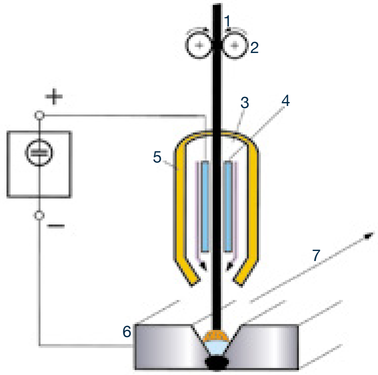
All work pieces should be free of contaminants (especially anything containing sulphur).

Example welding parameters

Sheet metal gauge		4 mm 0.157 in	6 mm 0.236 in
Welding current	A	≈ 180	≈ 200–220
	V	≈ 25	≈ 26
Plasma nozzle	mm Ø in Ø	3.2 0.126	3.2 0.126
Filler material	mm Ø in Ø	1.2 0.047	1.2 0.047
Wire feed	m/min in/min	≈ 1 ≈ 39.4	≈ 1 ≈ 39.4
Welding speed	cm/min in/min	30 11.8	30 11.8
Shielding gas quantity	l/min ft^3/min	30 1.06	30 1.06
Plasma gas quantity	l/min ft^3/min	3.0 0.106	3.5 0.124
Energy per unit length	kJ/cm kJ/in	≤ 10 ≤ 25.4	

Process descriptions – Joint welding

Metal inert-gas welding (MIG) and metal active-gas welding (MAG)



1 Wire electrode
2 Wire transport rolls
3 Shielding gas
4 Contact tube
5 Gas nozzle
6 Parent material
7 Weld progression

In this process, the heat source is provided by the electric arc burning under shielding gas between the continuously fed melting filler material (wire electrode) and the parent material. Inert gases or active gas-containing gas mixtures are used as shielding gas. The option of overlaying the welding power (basic power) current pulses with an adjustable frequency offers the benefit that in addition to the reliable welding of thin cross-sections it is also possible to work with a relatively low heat input. Consequently, this process is also suitable for materials that are exposed to great corrosion stresses.

Technical prerequisites

- Pulsed power source with adjustable welding parameters
- Inert or corresponding MAG shielding gas with a predefined CO_2 content
- A wire electrode

Processing instructions

All work pieces should be free of contaminants (especially anything containing sulphur).

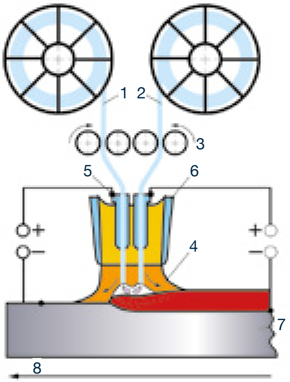
Ignition and stopping of the electric arc should be carried out using a run-off plate.

Example welding parameters

Sheet metal gauge		8 mm 0.315 in	10 mm 0.394 in	16 mm 0.630 in
Root pass	TIG			
Filling and capping run	A	≈ 130–140	≈ 130–150	≈ 150
	V	23–27	23–27	24–28
Joint form		V 70 °	V 70 °	V 70 °
Filler material	mm Ø in Ø	1.2 0.047	1.2 0.047	1.6 0.063
Wire feed	m/min ft/min	≈ 6 ≈ 19.7	≈ 6 ≈ 19.7	≈ 6 ≈ 19.7
Welding speed	cm/min in/min	MIG: ≈ 25–30 (MIG: ≈ 9.84-11.8) MAG: ≈ 40–45 (MAG: ≈ 15.7-17.7)		
Argon quantity	l/min ft³/min	18–20 0.635-0.706		
Energy per unit length	kJ/cm kJ/in	≤ 8 ≤ 20.3		
Pulse frequency	Hz	≈ 100		

Process descriptions – Joint welding

MAG tandem welding



1 Wire electrode 1
2 Wire electrode 2
3 Wire transport rolls
4 Shielding gas
5 Contact tube
6 Gas nozzle
7 Parent material
8 Weld progression

MAG tandem welding involves two welding torches combined in a single shielding gas nozzle. Two largely independent pulse current sources of the same construction type are used to operate the electric arcs. The welding parameters of the two electric arcs can be the same, but also quite different. The quality of the wire electrodes must be laid out so that an interference-free welding process can be maintained.

As two wire electrodes can be melted simultaneously, this provides a significantly higher deposition rate than in the MIG/MAG welding process. And also delivers a faster welding speed of over 1 m/min (3.28 ft/min). This leads to an extraordinarily low-cost heat management during the process.

Technical prerequisites

- 2 pulsed power sources
- 2 wire transport feeds
- 1 torch
- Inert or corresponding MAG shielding gas with a predefined CO_2 content
- 2 wire electrodes

Processing instructions

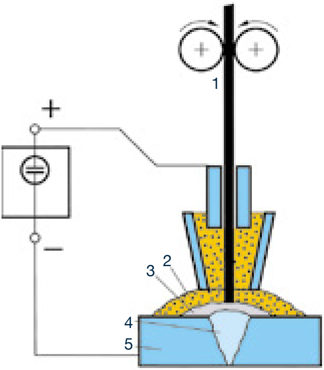
See MIG/MAG joint welding.

Example welding parameters

Sheet metal gauge		10 mm 0.394 in	16 mm 0.630 in
Weld pool backup	TIG		
Filling and capping run	A	140–160	160–180
	V	24–27	28–30
Joint form		V 70 °	V 70 °
Filler material	mm Ø in Ø	2 × 1.2 0.079 × 0.047	2 × 1.2 0.079 × 0.047
Wire feed	m/min ft/min	≈ 6 ≈ 19.7	≈ 7 ≈ 23.0
Welding speed	cm/min ft/min	≈ 100 ≈ 3.28	
Shielding gas quantity (mixed gas with active components)	l/min ft^3/min	18–20 0.635–0.706	
Energy per unit length	kj/cm kJ/in	≤ 5 ≤ 12.7	
Pulse frequency	l/min ft^3/min	≈ 100 ≈ 3.53	

Process descriptions – Joint welding

Submerged arc welding (SAW)



1 Wire electrode
2 Welding flux
3 Slag
4 Weld metal
5 Parent material

Submerged arc welding (SAW) is one of the covered arc welding processes. The electric arc burns in a gap under a blanket of liquid slag formed from the welding flux. This slag then reacts with the molten pool. This reaction leads to the desired changes in the composition of the weld joint.

The characteristic features of this process are the continuity of the welding operation, the high deposition rate and the quality of the join.

Technical prerequisites

- Submerged arc power source (direct current)
- Welding flux with targeted composition and tested quality
- Cold-drawn wire electrodes with standardized analyses, on spools, positive polarity

Processing instructions

All work pieces should be free of contaminants (especially anything containing sulphur). A run-off plate should be used for the ignition of the electric arc.

Example welding parameters

Sheet metal gauge		**12 mm** **0.472 in**	**20 mm** **0.787 in**
Weld pool backup	TIG		
Filling and capping run	A	250	250
	V	28	28
Joint form		V 70 °	V 70 °
Filler material	mm Ø in Ø	1.6 0.063	1.6 0.063
Welding speed	cm/min ft/min	44–55 1.44–1.80	44–55 1.44–1.80
Flux (in consultation with supplier)		highly alkaline	highly alkaline
Energy per unit length	kJ/cm kJ/in	≤ 10 ≤ 25.4	≤ 10 ≤ 25.4

Process descriptions

Weld cladding

Weld cladding with strip and wire electrodes has a firm place in the oil and gas industry as well as in the construction of chemical apparatus and plants. As only the surfaces are susceptible to corrosion, unalloyed or low-alloyed steels can be provided with highly effective corrosion protection by means of weld cladding of corrosion-resistant materials. Weld cladding is a thoroughly viable alternative to explosive cladding and, in some cases, also to roll cladding. The prerequisite is, however, that the components can be water-cooled during the welding process or that it is a thick-walled construction – e. g. tube plate for steam generators, pressure equipment for nuclear reactors, tube sheet for heat exchangers, etc. – whose weld-cladded surfaces are exposed to corrosion, wear, cavitation or high temperatures and scaling (depending on usage). Major demands are made on the prospective welding process.

Generally, processes with a low weld penetration are preferred, i.e. a low dilution with the carrier material and an as high as possible deposition rate on uniformly finely scaled surfaces with smooth edges. All known arc-welding and, to a certain extent, beam welding processes more or less fulfil the basic requirements and have thus become standard, although with varying degrees of success. GTA hot wire weld cladding is a welding process that is of interest for small surfaces and components that are difficult to access. The cleanliness requirements on the work pieces to be processed, the working environment, the work equipment and the qualification of the personnel are, as with seam welding, of considerable importance for high-quality results.

Process descriptions

Wire Arc Additive Manufacturing (WAAM)

Additive manufacturing (AM), that is creating components layer by layer with the help of computer-aided processes, is considered a key technology in modern production technology. This method can produce components virtually overnight, anywhere in the world, that can be used for prototyping, as replacement parts at distant locations or for cost-effective small series, for example. It also gives engineers and processors the freedom to realize new component geometries and optimize the shaping of materials with almost no manufacturing limitations.

The wire arc additive manufacturing variant, or WAAM for short, plays a major role: By means of arc welding, welding wire is melted layer by layer, ultimately generating a body or component "made of pure weld metal". The WAAM process places extremely high requirements on welding wires: They have to allow for consistently perfect processing over a period of hours, days or even weeks. The metallurgy of the primary material and the quality of the welding wire have to meet maximum requirements and remain as constant as possible across batches. The benefit of VDM Metals

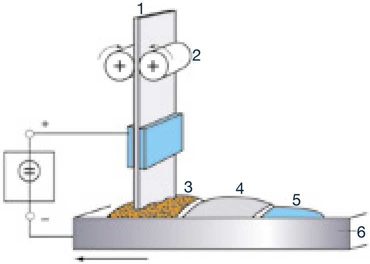
is that all quality-related processing steps, from melting to the finished welding wire, all come from a single source: VDM Metals.

As one of the first manufacturers in Europe, for decades VDM Metals has worked with nickel-based welding fillers, be it in developing innovative materials, improving existing ones or optimizing welding wire properties, for example for deposition welding. The increasing industrial processing of WAAM has prompted VDM Metals to further expand its expertise in the area of welding and welding wire.

But welding wire and its workability are not the only important aspects when it comes to WAAM – often there are material aspects that have to be considered, such as annealing after welding. Our application technology and R&D departments are prepared to assist customers, applying our material expertise to develop the best possible solutions.

Process descriptions – Weld cladding

Submerged arc welding (SAW)



1 Strip electrode
2 Strip feed
3 Powder fill
4 Slag
5 Weld metal
6 Carrier material

In weld cladding by submerged arc welding, in contrast to seam welding, the material to be applied is preferably fed in as a strip electrode. Otherwise, the process descriptions provided in the chapter "Submerged arc welding" apply.

Technical prerequisites

- Submerged arc power source (direct current)
- Welding flux with targeted composition and tested quality

Welding material

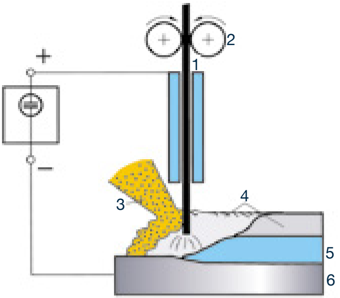
Cold-rolled strip in standardized analysis, standard dimension 90 x 0.5 mm, 60 x 0.5 mm or 30 x 0.5 mm (3.54 x 0.02 in, 2.36 x 0.02 in or 1.18 x 0.02 in), strip electrode in positive polarity. Because of the higher deposition rate, automatic strip cladding requires current intensity up to approx. 700 A at voltages around 30 V. Welding speeds of approx. 12 cm/min (4.7 in/min) are usual.

Processing instructions

All work pieces should be free of contaminants (especially anything containing sulphur). A run-on plate should be used for the ignition of the electric arc.

Process descriptions – Weld cladding

Electroslag welding (ES)



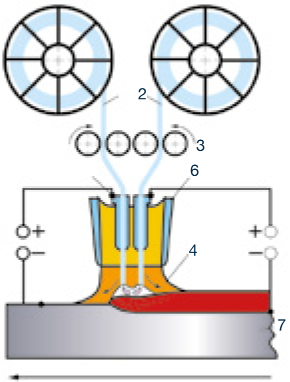
1 Welding strip
2 Strip feed
3 Powder fill
4 Slag
5 Weld metal
6 Carrier material

Electroslag weld cladding is similar to the submerged arc weld cladding process. However, the heat required for welding is not provided by an arc, but by passing electrical current through melted electroslag. An electric arc is only used at the beginning of the process until a sufficient amount of electroslag is melted. After this, because of the rising amount of slag, the larger contact surface with the backing and the rising slag temperature, the electrical resistance of the slag falls until the arc finally goes out. The weld heat during the actual welding process is then only produced by conductive heating caused by current transfer through the liquid slag. The temperature of the slag at this point is approx. 2000 °C (3632 °F).

Technical prerequisites
- Welding material and processing instructions comparable to submerged arc weld cladding.
- ES flux

Process descriptions – Weld cladding

MAG tandem welding



1 Wire electrode 1
2 Wire electrode 2
3 Wire feed roles
4 Shielding gas
5 Contact tube
6 Gas nozzle
7 Basis material
8 Weld progression

MAG tandem weld cladding involves two welding torches combined in a single shielding gas nozzle. Also, two largely independent pulse current sources of the same construction type are used to operate the electric arc. The welding parameters of the two electric arcs can be the same, but also quite different. The quality of the wire electrodes must be laid out so that an interference-free welding process can be maintained at wire speeds of up to 15 m/min (49.2 ft/min). As two wire electrodes can be melted simultaneously, this provides a significantly higher deposition rate than in the MIG welding process and also delivers a faster welding speed: a welding speed of over 1 m/min (3.28 ft/min).

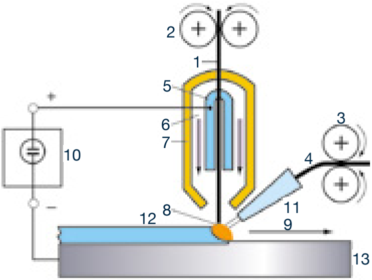
This leads to an extraordinarily low-cost heat management during the process.

Example welding parameters

Carrier material		Boiler plate H II, plate thickness 50 mm (1.97 in)
Wire electrode		VDM® FM 59, 2 x 10 mm (0.078 x 0.394 in)
Shielding gas		MAG shielding gas with a predefined CO_2 content
Wire feed 1./2. wire electrode	m/min ft/min	≈ 12/10 ≈ 39.4/32.8
Impulse current 1./2. wire electrode	V	50/50
Pulse duration 1./2. wire electrode	ms	1.0/1.0
Base current 1./2. wire electrode	A	140/140
Pulse frequency	Hz	110/110
Welding speed	cm/min in/min	120 47.2
Current intensity 1./2. wire electrode	A	≈ 180/170
Voltage 1./2. Wire electrode	V	≈ 33/35
Energy per unit length	kj/cm kJ/in	6 ≤ 15.2
Deposition rate	kg/h lbs/h	9 19.8
Bead interval	mm (in)	4.5 (0.177)
Interpass temperature	°C (°F)	< 150 (< 302)

Process descriptions – Weld cladding

Gas-shielded metal-arc welding MIG/MAG



1 Wire electrode
Ø 1.2–1.6 mm
(Ø 0.047–0.063 in)
2 Wire feed rollers
3 Separate wire feed
Ø 1.2 mm (Ø 0.047 in)
for cold wire
4 cold wire
5 Contact nozzle
6 Shielding gas
7 Shielding gas nozzle
8 Arc
9 Direction of welding
10 Power Supply
11 Cold wire nozzle
12 Weld metal
13 Substrate

In MIG/MAG weld cladding, the same process is followed as in MIG/MAG joint welding, except that the wire electrodes can be woven during welding. In addition, it is also possible, by using a current-free, so-called cold wire, to increase the deposition rate and achieve better heat management for the welding process.

Technical prerequisites

- A pulse current source
- Inert or corresponding MAG shielding gas with a pre-defined CO_2 percentage
- A wire electrode

VDM Metals – our service portfolio

VDM Metals – our service portfolio

VDM Metals at a glance

VDM Metals is one of the world's leading manufacturers of high-performance metallic materials. For many decades, we have been developing nickel and zirconium alloys as well as high alloyed special stainless steels for use in particularly demanding environments and processes.

As major innovator in this field, VDM Metals has its finger on the pulse. The company has its own division for the production of high alloyed powder materials for additive manufacturing. Working closely with its customers, VDM Metals develops tailored solutions, for example for welding fillers, for WAAM processes and for powder alloys. Supported by its technical competence center for welding, the company helps its customers with regard to welding fillers and their use.

At VDM Metals, all important production steps are carried out in-house. Our materials are melted in our arc or induction furnaces at the Unna plant and then subjected to a vacuum treatment. A ladle furnace takes over the metallurgical post-treatment. As an alternative to the conventional technology of open ore melting, a vacuum induction melting furnace is also available.
Homogeneity and purity of the materials can be increased by remelting in our electro-slag and vacuum arc remelting plants. The slabs, billets

and electrodes produced in Unna are used as raw stock for plates, strips, rods and wires. After hot forming, the metal is further processed into finished wire in the form of fine, coarse and profile wires at our production facilities in Werdohl. Welding fillers are an another important constituent of our wire production. In addition to core wires for bar electrodes, rods and welding wires for TIG welding and wire electrodes for GMAW welding are produced here. In addition, we also produce wires for a wide range of applications, such as heating conductor and resistance wires, starting and braking resistors, power supply, contact and tubular pins, anode buttons or spark plug wires.

All VDM Metals materials are subjected to strict quality controls. At a very early stage, we made the implementation of quality assurance measures one of our most important management principles and developed it further into a comprehensive quality management system which includes inspections during production. Today, VDM Metals is a manufacturer and developer certified by a number of organizations.

VDM Metals – our service portfolio

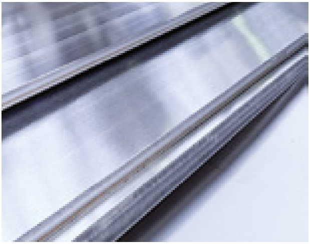
Service Centers

Our Service Centers offer our customers sheet metal and the corresponding filler materials – fast, flexible and all from a single source.

In these times of lean management and just-in-time production, the reliability and reaction times of suppliers are becoming ever more important for the competitiveness of your company. Our Service Centers in Europe, Asia and Australia are equipped to deal with your needs punctually, flexibly and at short notice.

The services provided by our Service Centers comply with the very highest demands for quality and reliability. We offer tailored service packages – from application-oriented material selection to short-term delivery, regardless of where in the world you need your materials. As our Service Centers are closely networked, our employees at each location always have an overview of all stock and can thus prepare the best-possible offer for you.

In the area of filler materials, we have permanent stock of numerous materials in the form of solid wire and welding rods. We can deliver our solid wire on basket coils (15 kg/33 lbs) or in barrels (250 kg/450 kg/551lbs/992 lbs). We also supply welding rods for TIG welding in quivers (5 kg/11 lbs). Other formats are also available on demand.



Our filler wire offers optimized cast and helix values for problem-free wire feed in automated welding processes. The filler materials exhibit extremely tight alloying tolerances. Each delivery is accompanied by a test report as per DIN EN 10204-3.1 – we will also be happy to provide an inspection certificate 3.2 for all classifications (TÜV, LRS, GL, DNV, AWS, …).

In addition to filler materials, the VDM Metals' Service Centers also carry an extensive portfolio of corrosion- and heat-resistant nickel and titanium alloys in the following product forms:

- sheet/plate
- rod/bar
- strip
- billet

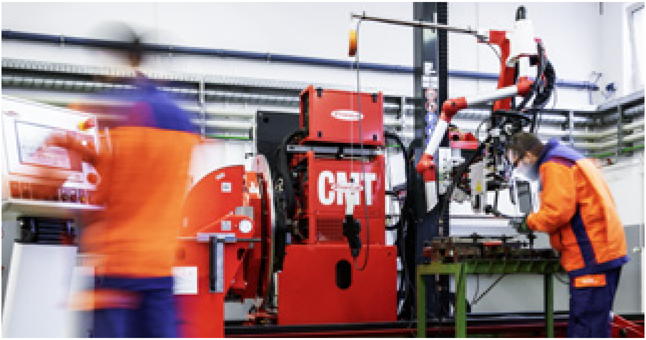
Our experienced sales teams will guide you through every step of the process: from initial advice to delivery.

If you need further materials and dimensions, we offer you the possibility of custom producing these especially for you. These will then be packaged, stored as required in the Service Center and dispatched in partial shipments. In this way, we are able to offer you on-time fulfillment of your special requirements. You can also use the welding consumables 24/7 in our online shop: www.vdm-metals.com/shop

Contact
servicecenter.vdm@vdm-metals.com

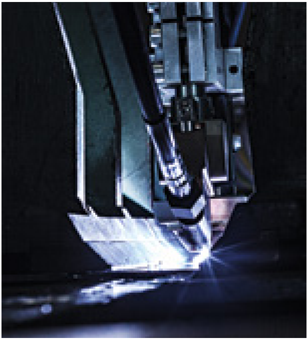
VDM Metals – our service portfolio

Welding technology Center of Excellence



VDM Metals' Welding technology Center of Excellence is equipped with cutting-edge systems and process technologies. A team of qualified welding metallurgists, welding engineering specialists and welders are on hand to answer our customers' welding-related queries during complex projects from the planning stage to the commissioning of plants. The focuses of our work are:

- The ongoing development and optimization of filler materials
- Advice regarding technical issues in welding and service for difficult applications
- The investigation of new welding techniques to improve the economic viability of processing nickel materials and high-alloyed special stainless steels
- Welding of test specimens for practice-oriented use in operational plants
- Providing expert welding advice during special assignments, e. g.

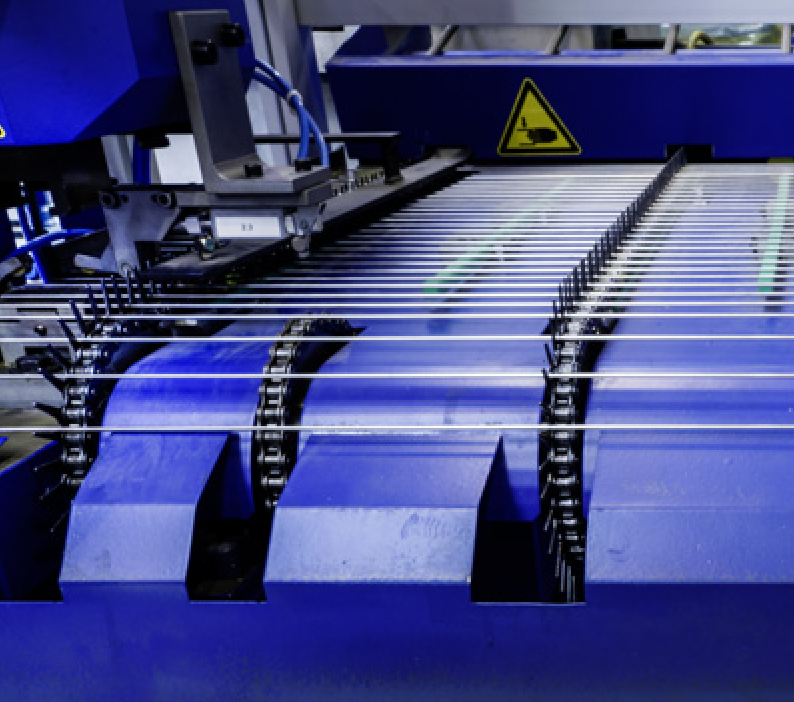


when welding plated materials or cladding with thin sheets using the "wallpapering" method

- As part of the VDM Metals' Research and Development division, our Welding technology Center of Excellence has access to our entire infrastructure, e. g. optical and electron microscopes for metallographic examinations, mechanical technological material testing processes and also the corrosion laboratory. In addition, our customers also benefit from our comprehensive stock of samples that are available in a wide variety of sizes for test welding semi-finished products made of standard and special materials.

Contact

tks.vdm@vdm-metals.com



Visitors

As a dealer or customer, you have probably asked yourself what process steps VDM Metals‘ wire production and the manufacture of welding consumables involve. You are welcome to make an appointment with us for a factory tour of the welding wire production in Werdohl.

Contact
Phone +49 (0) 2392 55-0

VDM Metals – our service portfolio

Apparatus and plant construction

Chemicals, petrochemicals, energy and environmental technologies, aerospace, offshore and marine engineering – hardly any material would be possible without the associated joining technology. A significant amount of the research and development work at VDM Metals is therefore devoted to welding technology. It constitutes a realm of knowledge and experience that must be provided to users along with the materials themselves.

Welding technology includes the welding suitability of the basis materials, the development and testing of suitable filler materials as well as the testing of new welding techniques and their transferability to welding other high-performance materials.

Glossary

Glossary

AWS classification

American Welding Society

AWS classification	VDM Metals designation
(ERNiCu-7)	VDM® CW 60
ENiFe-CI	VDM® CW 55
(ERNiCr-3)	VDM® CW 182
EQNiCr-3	VDM® WS 82
(EQNiCr-6)	VDM® WS 8020
EQNiCrMo-3	VDM® WS 625 / VDM® WS 625 HS
EQNiCrMo-4	VDM® WS C-276
EQNiCrMo-13	VDM® WS 59
EQNiCrFe-15	VDM® WS 52i
ER33-31	VDM® FM 33
ERCuNi	VDM® FM 67
ERNi-1	VDM® FM 61
ERNiCr-3	VDM® FM 82
ERNiCrCoMo-1	VDM® FM 617
ERNiCrCoMo-1	VDM® FM 617 B

American Welding Society

AWS classification	VDM Metals designation
ERNiCrFe-12	VDM FM 602 CA®
ERNiCrFe-15	VDM FM 52i®
ERNiCrMo-3	VDM® FM 625
ERNiCrMo-4	VDM® FM C-276
ERNiCrMo-7	VDM® FM C-4
ERNiCrMo-10	VDM® FM 622
ERNiCrMo-13	VDM® FM 59
ERNiCrMo-19	VDM® FM 2120
ERNiCrMo-20	VDM® FM 660
ERNiCu-7	VDM® FM 60
ENiFe-CI	VDM® FM 55
ERNiFeCr-1	VDM® FM 65 Ni
ERNiFeCr-2	VDM® FM 718
ERNiMo-7	VDM® FM B-2

Glossary

UNS designation

Unified Numbering System

UNS designation	VDM Metals designation
B08034	VDM® FM 31 Plus
C71581	VDM® FM 67
N02061	VDM® FM 61
N02200	VDM® CW Nickel
N04060	VDM® FM 60 / VDM® CW 60
N06022	VDM® FM 622
N06025	VDM® FM 602 CA
N06056	VDM FM 52i® / VDM® WS 52i
N06058	VDM® FM 2120
N06059	VDM® FM 59 / VDM® WS 59
(N06076)	VDM® WS 8020
N06082	VDM® CW 182 / VDM® WS 82
N06455	VDM® FM C-4

Unified Numbering System

UNS designation	VDM Metals designation
N06617	VDM® FM 617 / VDM® FM 617 B
N06625	VDM® FM 625
N06625	VDM® WS 625 / VDM® WS 625 HS
N06660	VDM® FM 660
N06699	VDM® FM 699 XA
N07263	VDM® FM C-263
N07718	VDM® FM 718
N08065	VDM® FM 65 Ni
N08827	VDM® FM 825 CTP
N10276	VDM® FM C-276 / VDM® WS C-276
N10665	VDM® FM B-2
R20033	VDM® FM 33
W82002	VDM® CW 55 / VDM® FM 55

Glossary

DIN EN ISO numerical designation

DIN EN ISO

Numerical designation	VDM Metals designation
B Ni 6059	VDM® WS 59
B Ni 6082	VDM® WS 82
B Ni 6276	VDM® WS C-276
B Ni 6625	VDM® WS 625 / VDM® WS 625 HS
S Cu 7158	VDM® FM 67
S Ni 1066	VDM® FM B-2
S NI 2061	VDM® FM 61
S Ni 4060	VDM® FM 60
S Ni 6022	VDM® FM 622
S Ni 6025	VDM FM 602 CA®
S Ni 6058	VDM® FM 2120
S Ni 6059	VDM® FM 59
S Ni 6082	VDM® FM 82
S Ni 6276	VDM® FM C-276
S Ni 6455	VDM® FM C-4
S Ni 6617	VDM® FM 617 / VDM® FM 617 B
S Ni 6625	VDM® FM 625
S Ni 6660	VDM® FM 660
S Ni 6699	VDM® FM 699 XA
S Ni 7263	VDM® FM C-263
S Ni 7718	VDM® FM 718
S Ni 8827	VDM® FM 825 CTP
S Ni Z NiCr18Co25Nb5Mo3Al2	VDM® FM 780

Glossary

Material number

DIN EN

Material number	VDM Metals designation
1.3990	VDM® FM 36 M
1.4562	VDM® FM 31
1.4591	VDM® FM 33
2.0837	VDM® FM 67
2.4066	VDM® CW Nickel
2.4155	VDM® FM 61
2.4377	VDM® FM 60
(2.4366)	VDM® CW 60
(2.4560)	VDM® CW 55
2.4607	VDM® FM 59 / VDM® WS 59
2.4611	VDM® FM C-4
2.4615	VDM® FM B-2
(2.4620, 2.4648)	VDM® CW 182
2.4627	VDM® FM 617 / VDM® FM 617 B
2.4635	VDM® FM 622
2.4639	VDM® WS 8020
2.4649	VDM FM 602 CA®
2.4650	VDM® FM C-263
2.4667	VDM® FM 718
2.4692	VDM® FM 31 Plus
2.4700	VDM® FM 2120
2.4806	VDM® FM 82 / VDM® WS 82
2.4831	VDM® FM 625 / VDM® WS 625

Glossary

Material number

DIN EN

Material number	VDM Metals designation
2.4842	VDM® FM 699 XA
2.4858	VDM® FM 65 Ni
2.4861	VDM® FM 825 CTP
2.4886	VDM® FM C-276 / VDM® WS C-276
2.4960	VDM® FM 780

Glossary

Conversion of different basic units

Heat transfer

Source	Target	
1 J/m	0.0254	J/in

Strength

Source	Target	
1 N	7.2330	lb*ft/s^2
	0.225	lbf
	10^5	g*cm/s^2
	0.10197	kgf
	$1.00361*10^{-4}$	ton force (long) UK

Density

Source	Target	
1 kg/m^3	0.0624	lb/ft^3
	$3.6127*10^{-5}$	lb/in^3
	$8.345*10^{-3}$	lb/USgal
	0.001	g/cm^3

Flow rate

Source	Target	
1 l/min	2.1189	ft^3/h
	0.0353	ft^3/min
	15.850	gal/h
	0.2642	gal/min

Melting rate

Source	Target	
1 kg/h	2.2046	lb/h
	0.0367	lb/min

Heat capacity

Source	Target	
1 kJ/kg	0.4299	Btu/lb
	0.2389	cal/g

Glossary

Conversion of different basic units

Length

Source	Target	
1 m	3.2808	foot
	39.37	inch
	1.0936	yard
1 mm	0.03937	inch
	39.37	mil.

Energy / Work

Source	Target	
1 J	0.2388	cal
	$1*10^{7}$	erg
	$9.478*10^{-4}$	Btu
	0.738	ft*lbf
	$3.73*10^{-7}$	PS*h
	$2.78*10^{-7}$	kWh

Plain

Source	Target	
1 mm^2	0.00155	inch^2
1 m^2	10.7639	ft^2
	1.196	yd^2
1 km^2	0.3861	mile^2

Mass

Source	Target	
1 kg	2.20465	pound (lb)
	$9.84*10^{-4}$	ton, long (UK)
	0.0011	ton, short (US)
	35.274	ounce (oz)

Temperature

Source	Difference	Absolute
1 °C	1.8 °F	(°F - 32)/1.8
	1.8 °R	°R/1.8 - 273.15
	1 K	K - 273.15

Performance

Source	Target	
1 W	0.7376	ft*lbf/s
	0,.00136	PS
	3.4121	BTU/h

Glossary

Conversion of different basic units

Pressure

Source	Target	
1 N/mm^2	1	MN/m^2, MPa
	0.145	ksi
	7500.615	Torr (l mmHg)
1 N/m^2	1.45*10^{-4}	lbf/in^2 (psi)
	7.25*10^{-8}	tonf/in^2 (US)
	1*10^{-5}	bar

Volume

Source	Target	
1 m^3	35.3147	ft^3
	61023.74	in^3
	1.3080	yd^3
	219.9792	gal (UK)
	264.1721	gal (US)
	1000	Liter

Heat conductivity

Source	Target	
1 W/(m.K)	0.5778	BTU/h ft °F

Notch impact strength

Source	Target	
1 J/cm^2	0.1020	kgm/cm^2
	4.7613	ft*lb/in^2

Notes

Notes

Disclaimer

1. General
VDM Metals makes all reasonable efforts to ensure that the information and data contained in this brochure are accurate.

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