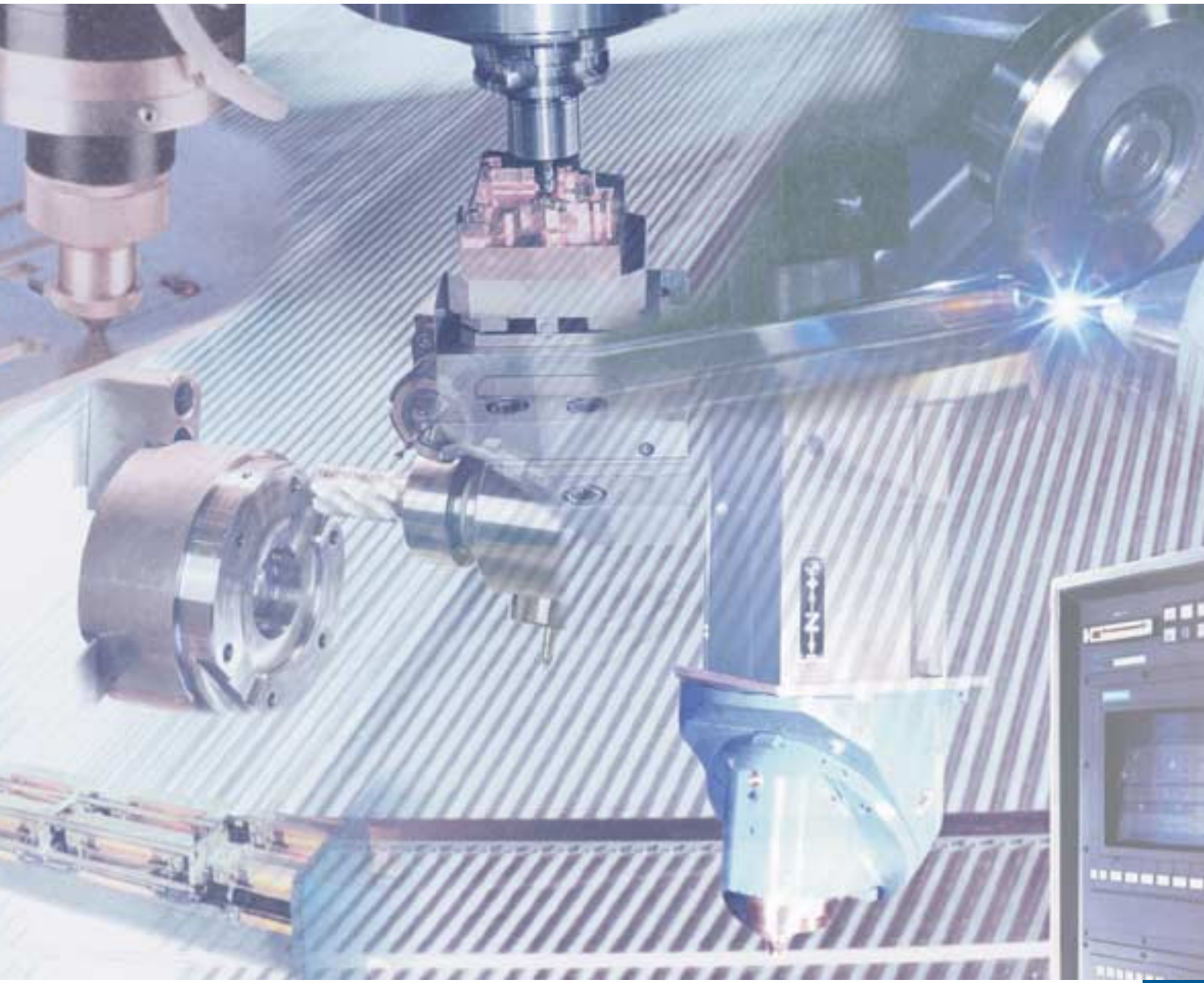
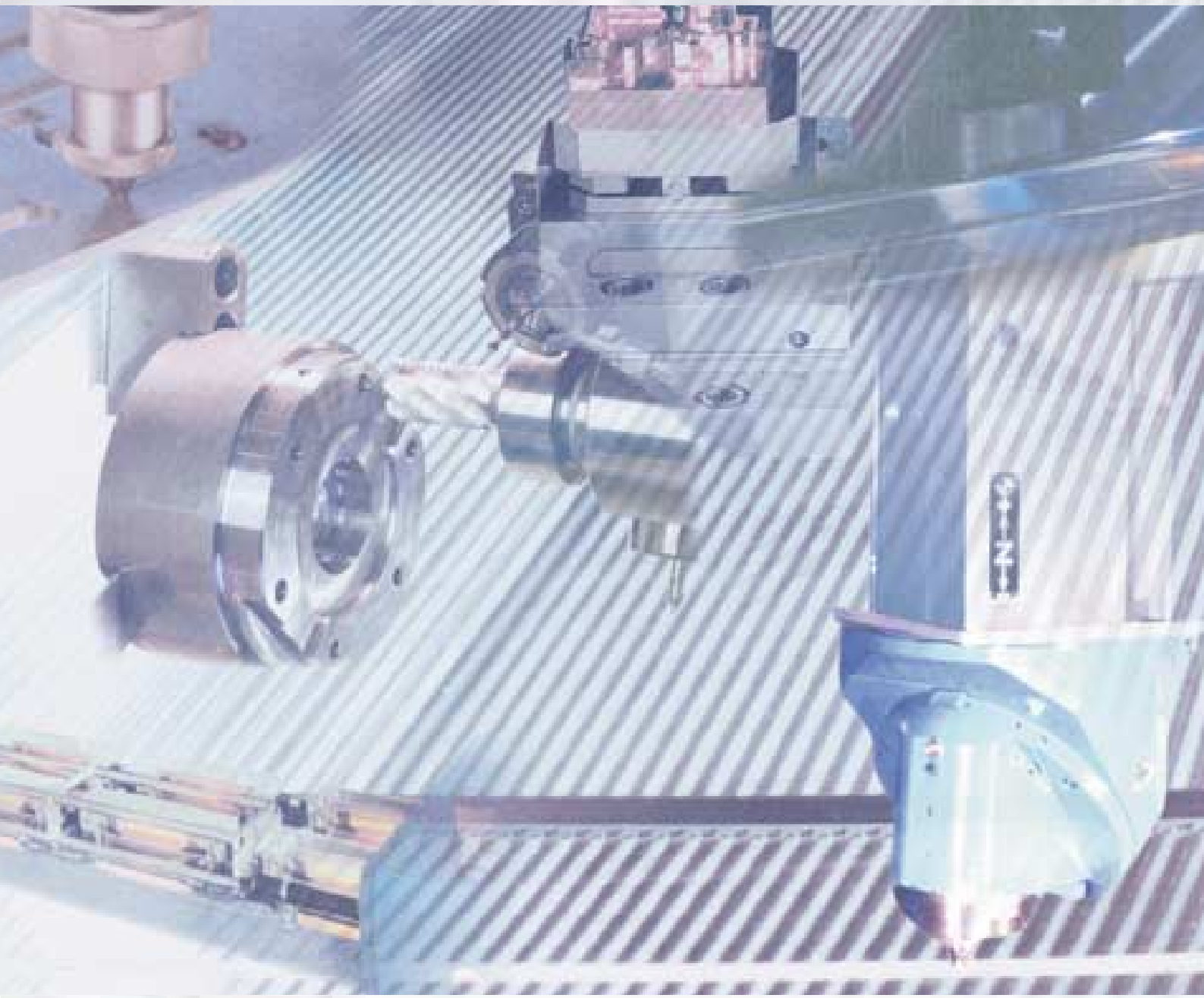
High-performance materials from Krupp VDM for production and automation technology: tools and molds.



A company of
Krupp Thyssen
Stainless

Krupp VDM

ThyssenKrupp



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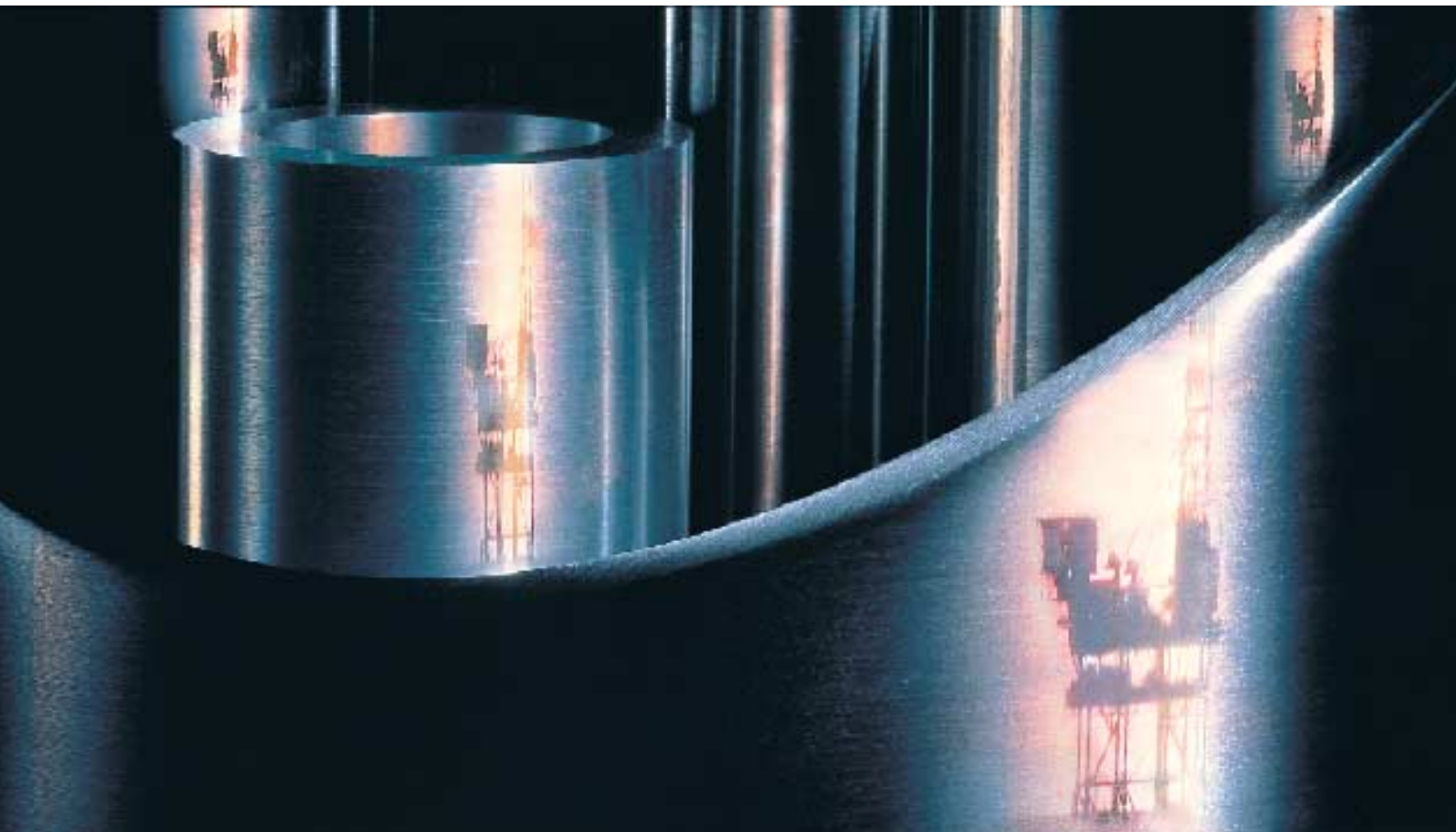
Krupp VDM GmbH
High-performance materials for special applications and processes.

Krupp VDM GmbH is a company of Krupp Thyssen Stainless GmbH. For many decades it has developed high-performance materials for especially demanding applications and processes. Today, Krupp VDM is among the leading producers of nickel-based alloys and high-alloy special materials. The production program includes sheet and plate, rod and bar, forgings, strip, wire and materials for tube and pipe production.

Krupp VDM supplies all-round packages for chemicals and petrochemicals, energy and environmental engineering, offshore and marine engineering, the automotive industry, aerospace, electronics and electrical engineering.

The company is based in Werdohl and has further production facilities in Altena, Unna and Werdohl-Bärenstein. It has a division in the U.S.A. named Precision Rolled Products, Inc., which produces high-temperature materials for the aviation industry at plants in Reno and Florham Park. The four Krupp VDM plants with their worldwide sales organization and the plants of Precision Rolled Products together employ more than 1,800 people. To ensure optimal cooperation with customers in the industrial engineering, electrical and electronic sectors and the automotive industry Krupp VDM has built up a network of advisory and sales offices, marketing companies, representatives and authorized stockholders and distributors.



Unna plant
Melting and refining.

All Krupp VDM alloys have their origin in the company´s ultra-modern melting plant at Unna near Dortmund. The Unna plant is equipped for melting and ladle treatment of high-nickel superalloys, high-alloy special stainless steels and copper-nickel alloys.

The scanning electron microscope in the metallographic laboratory at our Altena plant supports the latest technology in microstructure analysis.

Melting processes
The duplex melting process of electric-arc primary melting followed by VOD refining was specially developed by Krupp VDM for the production of nickel alloys and high-alloy special stainless steels.

A 30-tonne arc furnace as well as three 16-tonne induction furnaces are available for primary melting, alloying and refining.

Secondary metallurgical treatments and fine adjustment of chemical composition are performed in the VOD facility. The operation takes place in a vacuum vessel using argon or nitrogen as stirring gas. Carefully controlled pressure reduction enables the carbon content to be reduced below 0.005 per cent. Hydrogen and nitrogen contents are simultaneously reduced to extremly low residual values. Metallurgical treatment follows in a ladle furnace.

Remelting
Certain materials for special applications require exceptionally high purity with segregation levels reduced to an absolute minimum. To this end, electrodes produced at the Unna plant are refined by electroslag or vacuum-arc remelting.

Casting
After a final check of the chemical composition, the molten metal is released for casting. The majority of heats are cast by bottom pouring into ingot molds, with an argon shield to protect the metal stream from oxygen and nitrogen pick-up.

Quality assurance and control
By means of systematic quality checks, a continuous record is created for every heat. Such records are based on a comprehensive program of quality - assurance measures, such as chemical analyses, ultrasonic tests and surface inspection at defined production steps. Only when all results have been found satisfactory is material released for the next stage of processing. Quality assurance personnel are free to make any decision required in pursuit of their responsibilities and are totally independent of the production departments.

With the new ESR (Electro-Slag-Remelting) plant at Unna, materials can be remelted in a protective atmosphere.

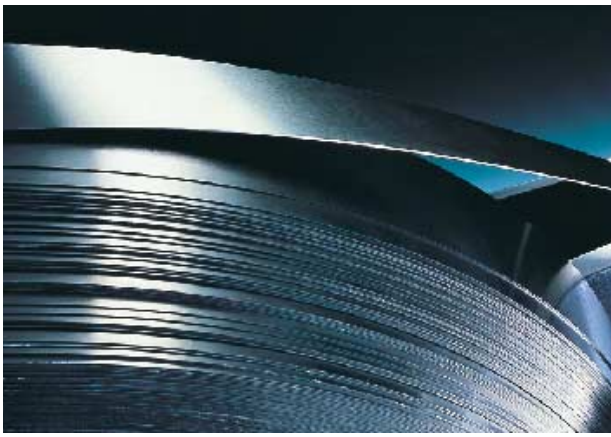
Our performance spectrum
Product forms.

Sheet and plate
Sheet and plate in all their forms and variants are standard in our manufacturing program. The production center for hot- and cold-rolled sheet and plate is our Altena plant. Slab is the starting point, carefully ground then sawn or plasma-cut to length prior to hot rolling.

Cold rolling is performed on a computer-controlled six-roll Sendzimir cold rolling mill, the world´s largest single-sheet reversing mill for widths up to 2,500 mm. Even difficult-to-deform materials can be processed to exceptionally large sheets using these methods, to tight tolerances and outstanding surface quality. Computer control is used at all stages of intermediate and final treatment, making it possible to meet even exceptional requirements quickly and easily.

Cut-outs and drilled holes are made to customers´ precise specifications. Flat products clad by explosive and roll-bonding processes are produced by associated companies.

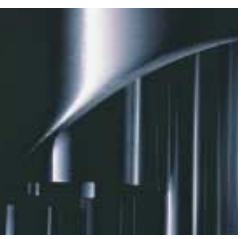
Rod and bar, forgings
Rod, bar and forged materials are produced from cast and remelted ingots by hot rolling or forging. The special products range includes hammer forgings produced in varied shapes and sizes to customers´ drawings, then finished to final dimensions.



Seamless and welded tubes
Seamless and longitudinally welded tubes made from Krupp VDM high-performance alloys are produced and marketed via a network of national and international alliances. In the field of seamless tubing, we have an internationally distinguished associate in DMV Stainless BV.

Strip
Strip is produced in our Werdohl plant from rolled ingots or continuously cast slabs. The nickel and special alloys are rolled to their final dimensions on four different cold-rolling lines. Maximum strip width is 800 mm. Final product thickness varies between 0.02 and 4.5 mm.

Wire
Wire rod, heavy-gauge wire, fine-gauge wire, flat wire and rods are produced in our Bärenstein plant. Welding filler metals are available as wire electrodes, welding wire, welding rods and core wire.



Time to market
Application engineering.

In a period of rapidly advancing technology, materials selection can be a particularly difficult task. Krupp VDM´s Application Engineering Department, a proven team of highly qualified engineers, metallurgists and technicians, with state-of-the-art equipment and access to the latest technology, is an important aid to decision-making and provides a link between customer and supplier. As expert consultants to the industrial plant construction sector, they have accompanied numerous projects from planning stage to start-up.

Krupp VDM´s application engineers are totally familiar with industries and technologies such as:

- chemicals and petrochemicals
- power generation and pollution control
- oil and gas production
- marine engineering
- aerospace engineering
- production technology
- automotive industry
- electrical and electronic engineering

The Application Engineering Department offers unrivaled experience in one of the widest ranges of high-performance materials. With related know-how in application profiles and fabrication techniques, the department provides optimized material concepts for specific applications. At the same time, accumulated in-depth knowledge of market trends and their evaluation helps to guide the company´s own product development.

In the welding labortory at Altena, the base material's suitability for welding is examined, welding materials are developed and tested, and new processes are screened for their transferability to Krupp VDM high-performance materials.

Trade that spans borders

The Krupp VDM group is European number one and world number two in nickel-base alloys; US subsidiary Precision Rolled Products ensures the group´s strategic presence in the classic aerospace market.

Krupp VDM works closely with customers to ensure that all products give the best possible service. This concern starts as early as process design, comprising individual, jointly drafted, materials conceps. It extends to VDM´s broadly spread network of consulting and marketing offices in each of the world´s industrial and technological regions.

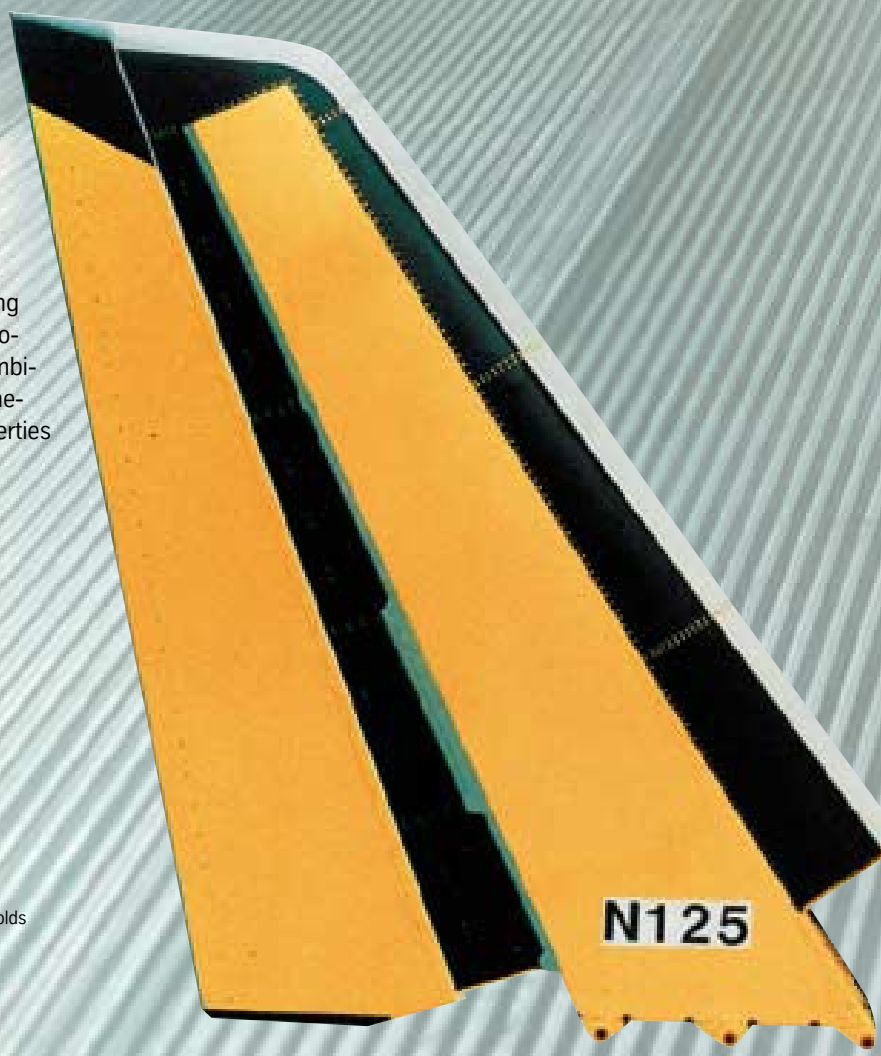
Our Technical Marketing and Sales Departments maintain a close relationship with customers, characterized by continuous interchange of ideas with scientists, engineers, metallurgists and technicians. We need their help in devising new materials and products that will succeed around the world. This exchange of ideas is documen ted through our worldwide net work of branches and marketing agencies. In collaboration with our international associates, we ensure that a large number of products are always in stock and thus easily and quickly available.

In this way, we are represented not only as a company but also by our products, whether in Germany, Europe or overseas. Our customers appreciate the benefits of short logistical routes, concepts that span all borders and fast solutions to their problems. This is how we´ve made a name for ourselves around the world, as the right people to talk to when high performance is required.

We present our creative ideas at many of the world´s most important national and international fairs and exhibitions, at company presentations and symposia. Intensive dialog is a vital channel of communications for both our customers and ourselves.

High-performance alloys for production and automation technology

"Highest precision at highest speed – highest flexibility at lowest costs".
To meet the challenges of the "Factory of the Future", production systems, tools and molds, controlling and measuring devices and other components with a specific combination of mechanical, chemical and physical properties are needed.



Sheet made of Pernifer 36 for molds for production of the rudder unit for the Airbus A330-200.

Materials with low coefficient of thermal expansion: Pernifer alloys

Pernifer alloys are needed in all applications where deviations of dimension or distance due to thermal expansion cannot be tolerated or where differences in thermal expansion may cause mechanical or electrical stresses. Typical applications of Pernifer alloys are components of laser welding machines, measuring devices in tool machines, applications in piezo-technology and microsystems and molds for production of large components made of carbon-fiber reinforced plastic, including aircraft and helicopter parts.

Pernifer alloys with thermal expansion coefficients similar to glass or ceramics are commer cially available. Pernifer 36 (NiFe36) has the lowest coefficient of thermal expansion of all Fe-Ni alloys. Its thermal expansion remains low up to about 260°C (500°F). The temperature range can be expanded to 300°C (572°F) by using Pernifer 42 (FeNi42) or even to 450°C (842°F) by using the nickel-cobalt-iron alloy Pernifer 2918.

If necessary, the thermal expansion coefficient can be adapted to customers requirements by treatment or changes in alloy composition. Typical thermal expansion coefficients of common materials in comparison to those of Pernifer alloys are shown in Fig. 1.

Materials with soft-magnetic behavior: Magnifer alloys

Soft-magnetic alloys - Magnifer alloys - are used in a variety of electronic and electrotechnical applications. Due to its high saturation induction in combination with a low coercive force, Magnifer 50 is used for magnetic valves.

Frames made of Pernifer 36
for laser machine manufacturing.

Material	Coefficient of thermal expansion (10^{-6}/K) between room temperature and 100°C (212°C)
Carbon-fiber reinforced plastic	-0.8 - 34.0
Granite	3.0 - 8.0
Aluminium	23.8
Silica glass	0.5
Glass	8.0
Stainless stee l (1.4301)	16.0
High-alloyed stainless steel (1.4876)	14.4
Carbon steel	11.1
Pernifer 36	1.2
Pernifer 42	5.3
Pernifer 2918	6.1

Coefficient of thermal expansion for various materials

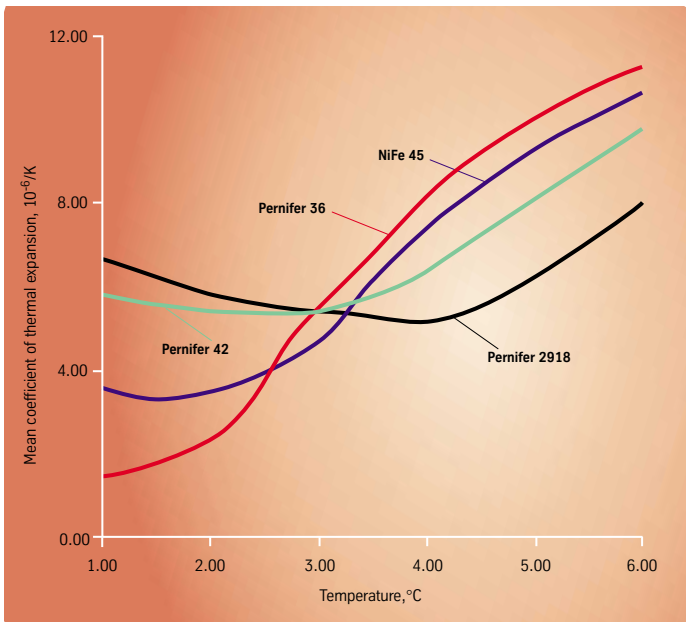


Fig. 1 - Coefficient of thermal expansion for Pernifer alloys

Magnifer 50 can also be used for magnetic shieldings. However, if a very high initial permeability is required, Magnifer 7904 may also be used. Magnifer 7904 also has a very low coercive force.

Other soft magnetic alloys with adapted magnetic properties are obtainable upon request.

Corrosion-resistant alloys: Cronifer and Nicrofer

Reactor vessels, piping systems and components in chemical and petrochemical plants, in marine applications, in oil & gas production and in transportation of chemicals are subject to corrosive attack by a variety of organic and inorganic substances. KruppVDM offers a wide range of corrosion resistant high alloyed stainless steels and nickel base alloys that withstand corrosion by chloride-contaminated water, seawater and brine, inorganic and organic acids and pharmaceuticals.

Turned and molded parts made of nickel-base alloys

The corrosion resistance generally increases with increasing concentrations of nickel, chromium and molybdenum. Application ranges of Cronifer 1925 hMo-alloy 926, Nicrofer 3127 hMo-alloy 31 and Nicrofer 5923hMo-alloy 59 in chloride-contaminated acids are shown in Fig. 2.

High-temperature, high-strength alloys: Nicrofer

Hot corrosive gases and deposits are encountered by furnace walls and components in high temperature processes. Nicrofer 3220 H-alloy 800 H offers excellent resistance to oxidation by hot air and to carburization by carbon-containing gases up to temperatures of about 1000 °C (1832°F). If the temperature exceeds 1000°C or if the environment contains nitrogen, ammonia, chlorine or fluorine in substantial amounts, especially in the absence of oxygen, Nicrofer 7216 H -alloy 600 H may be used. Depending on the gas composition, alloy 600 H is usable up to about 1100°C (2012°F). Nicrofer 6025 HT-alloy 602 CA is usable up to 1200°C (2192°F) due to its high concentration of aluminum, which enables the formation of a protective alumina scale.

The age-hardenable superalloys Nicrofer 5219 Nb-alloy 718 and Nicrofer 7520 TI-alloy 80 A are used where high mechanical strength and surface hardness is a must. Typical examples for alloy 718 are knives and other cutting tools, bolts, springs and extruders, turbine and engine components. Alloy 718 keeps its high strength and hardness up to temperatures of about 700°C (1292°F). Alloy 718 shows reasonable resistance to high temperature corrosion and high resistance to aqueous corrosion at ambient temperatures. The strength and toughness of alloy 718 at cryogenic temperatures are outstanding.

Alloy 80 A is also used for gas turbine and engine components, bolts and springs. Its high resistance to high temperature corrosion makes this alloy also a suitable choice for high temperature molds. The excellent mechanical properties of alloy 80 A remain up to about 850°C (1562°F).

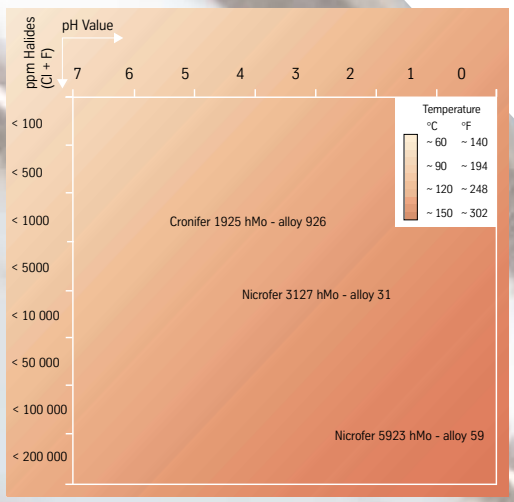


Fig. 2 - Application of nickel alloys and stainless steels in chloride (fluoride) contaminated acid (H_2SO_4)

Notes for use

The following tables have been prepared to assist in selecting Krupp VDM high-performance alloys which are most suitable for specific applications.

When placing an order, specifications (ASTM, BS, DIN etc.) laid down by the custumer will become an integral part of the contract.

Specifications and designations
The listed product forms are available according to given standards. Standards in brackets indicate a deviation in the Krupp VDM data from those specified in the standard.

Chemical composition
When an element is reported as the “balance” of a composition, this only means that this element predominates, other elements may be present in minimal amounts.

Mechanical properties
Mechanical properties are typical, except those reported as minimum (“min”).

The given data are generally applicable to sheet products.

For properties applicable to other product forms, refer to respective data sheets available on request or contact Krupp VDM.

Creep properties
The values correspond to the best-fit curve fitted to the scatterband of results. Minimum values are approximately 20% below the listed averages.

All data and information are as accurate and as complete as possible at the time of going to press. However, the values reported are not intended for specification purposes.

For more extensive data the relevant individual data sheets or standards should be consulted.

For the very latest information please contact the Application Engineering Department of Krupp VDM.

Low expansion alloys
Iron-nickel
Iron-nickel-cobalt

		Pernifer 36 – alloy 36				Pernifer 42				Pernifer 2918			
Designations and specifications													
USA	Designation, UNS	K93600/93601				K94100				K94610			
	ASTM (B)	388/A 658				–				F 15			
GB	Designation, BS	–				–				–			
	BS	–				–				–			
F	AFNOR	Fe-Ni 36				–				Fe-Ni 29 Co 17			
D	Designation	Ni 36				Ni 42				NiCo 2918			
	Werkstoff-Nr.	1.3912				1.3917				1.3981			
	DIN	–				–				–			
	SEW	385				385				385			
	VdTÜV data sheet	–				–				–			
Chemical composition (%)													
Nickel		35 – 37				41 – 43				28 – 29.5			
Chromium		max. 0.2				–				–			
Iron		balance				balance				balance			
Cobalt		max. 0.5				max. 0.02				17 – 18			
Manganese		max. 0.35				max. 0.7				max. 0.3			
Silicon		max. 0.2				max. 0.2				max. 0.2			
Carbon		max. 0.03				max. 0.5				max. 0.03			
Mechanical properties (N/mm², %)													
Temperature (°C)		**Rp 0.2**	**Rp 1.0**	**Rm**	**A_5**	**Rp 0.2**	**Rp 1.0**	**Rm**	**A_5**	**Rp 0.2**	**Rp 1.0**	**Rm**	**A_5**
20		270	–	490	40	–	–	–	–	370	–	530	30
100		180	–	435	45	–	–	–	–	260	–	430	40
200		115	–	430	45	–	–	–	–	200	–	405	40
300		95	–	410	50	–	–	–	–	140	–	395	45
400		90	–	350	55	–	–	–	–	110	–	350	50
500		90	–	290	60	–	–	–	–	100	–	280	55
600		75	–	210	70	–	–	–	–	90	–	200	60
Physical properties at room temperature or as indicated													
Density	g/cm³	8.1				8.2				8.3			
Specific heat	J/kg K	515				500				500			
Thermal conductivity	W/m K	12.8				15				17.5			
Electrical resistivity	µ Ω cm	76				66				49			
Thermal expansion	10^{-6}/K												
20 – 100°C		0.8 – 1.4				5.3				5.9 – 6.3			
20 – 150°C		1.2 – 1.9				–				–			
20 – 200°C		1.6 – 2.5				5.2				5.3 – 5.8			
20 – 300°C		4.4 – 5.5				6.3				4.9 – 5.4			
20 – 400°C		7.4 – 8.4				6.3				4.5 – 5.2			
20 – 500°C		8.9 – 9.7				8.1				5.9 – 6.4			
20 – 600°C		10.0 – 10.7				9.6				7.5 – 8.0			
Modulus of elasticity	kN/mm²	133				148				160			
Fabrication characteristics													
Formability		Yes				Yes				Yes			
Weldability		Yes				Yes				Yes			
Welding products													
Filler wire		matching or Nicrofer S 7020 – FM 82				matching or Nicrofer S 7020 – FM 82				matching			
Covered electrode		2.4648				1182							
		EL-NiCr19Nb											
		AWS ENiCrFe-3											
Material characteristics													
		Iron-nickel alloy with extremely low coefficient of thermal expansion from cryogenic temperatures to about 260°C (500°F).				Iron-nickel alloy with low coefficient of thermal expansion up to about 300°C (572°F).				Iron-nickel-cobalt alloy with low coefficient of thermal expansion from –100 to 450°C (–150 to 840°F).			
Typical applications													
		Laser technology, tools and molds, measuring devices.				Al_2O_3/ceramic seals, X-ray tubes.				Hybrid packages, ceramic and hard glass seals, X-ray tubes.			

Soft-magnetic alloys
Nickel-iron

		Magnifer 50				Magnifer 7904			
Designations and specifications									
USA	Designation, UNS	–				–			
	ASTM	–				A753 – 97 (Alloy 4)			
GB	Designation, BS	–				–			
	BS	–				–			
F	AFNOR	–				–			
D	Designation	Ni 48				NiFe15 Mo			
	Werkstoff-Nr.	1.3922				2.4545			
	DIN	17745				17745			
	SEW	–				–			
	VdTÜV data sheet	–				–			
Chemical composition (%)									
Nickel		47.0 – 48.5				79.5 – 81.0			
Iron		balance				balance			
Carbon		max. 0.05				max. 0.05			
Manganese		0.3 – 0.5				max. 0.8			
Silicon		max. 0.3				max. 0.5			
Molybdenum		–				4.0 – 5.0			
Aluminum		max. 0.02				–			
Mechanical properties (N/mm², %)									
		Rp 0.2	**Rm**	**A_5**	**HV_5**	**Rp 0.2**	**Rm**	**A_5**	**HV_5**
cold rolled		700	750	4	220	900	1100	4	335
soft annealed		230	510	40	130	260	630	40	130–170
Magnetic properties									
		Grade	Permeability (min)		Coercive force	Grade	Permeability (min)		Coercive force
			μ_4	μ_{max}	A/m		μ_4	μ_{max}	A/m
		MF 3	4000	50000	≤ 8	MP 130	130.000	260.000	≤ 1
		MF 6	6000	70000	≤ 8	MP 160	160.000	300.000	–
		MF 10	10000	80000	≤ 5	MP 200	200.000	350.000	–
		MH 8	–	–	≤ 8	MP 220	220.000	375.000	–
		MG 6	6000	70000	–	MP 240	240.000	400.000	–
		MG 10	10000	80000	–	MP 280	280.000	400.000	–
Physical properties at room temperature or as indicated									
Saturation induction	T	1.55				0.8			
Curie temperature	°C	470				410			
Saturation magnetostriction	10^{-6}	+ 25				+ 1			
Density	g/cm³	8.2				8.7			
Thermal conductivity	W/mK	15				32			
Electrical resistivity	μ Ω cm	45				55			
Mean coefficient of thermal expansion	10^{-6}/K								
20 – 100°C		9.3				12			
20 – 200°C		9.0				12.8			
20 – 300°C		8.7				13			
20 – 400°C		8.9				13.6			
20 – 500°C		9.3				14.3			
Fabrication characteristics									
Melting temperature		1445				1450			
Formability		yes				yes			
Weldability		yes				yes			
Material characteristics									
		High saturation induction, low coercive force.				High initial permeability, very low coercive force.			
Typical applications									
		Shieldings, magnetic valves, stepping motors.				Shieldings, stepping motors, magnetic valves.			

Corrosion-resistant alloys
Iron-nickel-chromium-molybdenum
Nickel-chromium-molybdenum

		Cronifer 1925 hMo – alloy 926		Nicrofer 3127 hMo – alloy 31		Nicrofer 5923 hMo – alloy 59	
Designations and specifications		**Sheet/strip**	**Rod/bar**	**Sheet/strip**	**Rod/bar**	**Sheet/strip**	**Rod/bar**
USA	Designation, UNS	N08926		N08031		N06059	
	ASTM (B) ASME (SB)	625	472/649	625	649	575	574
GB	Designation, BS	–	–	–		–	–
	BS	–	–	–		–	–
F	AFNOR			–		–	
D	Designation	X 1 NiCrMoCuN 25 20 6		X 1 NiCrMoCu 32 28 7		NiCr23Mo16Al	
	Werkstoff-Nr.	1.4529		1.4562		2.4605	
	DIN	–	–	–		–	–
	VdTÜV data sheet	502	502			505	–
Chemical composition (%)							
Nickel		24.5 – 25.5		30 – 32		balance	
Chromium		20 – 21		26 – 28		22 – 24	
Molybdenum		6 – 6.8		6 - 7		15 – 16.5	
Iron		balance		balance		max. 1	
Carbon		max. 0.020		max. 0.015		max. 0.01	
Others		N: 0.18 – 0.20	Cu: 0.8 – 1.0	N: 0.15 – 0.25		Al: 0.1 – 0.4	
Mechanical properties (N/mm², %)							
Temperature (°C)		**Rp 0.2**	**Rp 1.0** **Rm** **A_5**	**Rp 0.2**	**Rp 1.0** **Rm** **A_5**	**Rp 0.2**	**Rp 1.0** **Rm** **A_5**
20		min. 300	min. 340 min. 650 min. 40	min. 280	min. 310 min. 650 50	min. 340	min. 380 min. 690 min. 40
100		min. 230	min. 270 min. 610 –	min. 210	min. 240 630 50	min. 290	min. 330 650 50
200		min. 190	min. 230 min. 560 –	min. 180	min. 210 580 50	min. 250	min. 290 615 50
300		min. 170	min. 205 min. 525 –	min. 165	min. 195 530 50	min. 220	min. 260 580 50
400		min. 160	min. 190 min. 510 –	min. 150	min. 180 500 50	min. 190	min. 230 545 50
500		min. 120	min. 150 – –	min. 135	min. 165 470 50	–	– – –
Physical properties at room temperature or as indicated							
Density	g/cm³	8.1		8.1		8.6	
Specific heat	J/kg K	415		452		414	
Thermal conductivity	W/m K	12.0		11.7		10.4	
Electrical resistivity	µ Ω cm	96		103		126	
Thermal expansion	10^{-6}/K						
20 – 300°C		16.1		15.1		12.5	
Modulus of elasticity	kN/mm²	193		198		210	
Fabrication characteristics							
Formability		good		good		good	
Weldability		good		good		good	
Welding products							
Filler wire		Nicrofer S 6020 – FM 625/S 5923 – FM 59		Nicrofer S 3127 – FM 31 or S 5923 – FM 59		Nicrofer S 5923 – FM 59	
Covered electrode		2.4621	2.4609	1.4562 or	2.4609	2.4609	
		EL-NiCr20Mo9Nb	EL-NiCr22Mo16	XlNiCrMoCu 32 28 7	EL-NiCr22Mo16	EL-NiCr22Mo16	
		AWS ENiCrMo-3					
Material characteristics							
		High-alloyed stainless steel with increased molybdenum content. Excellent resistance to pitting, crevice corrosion and stress-corrosion cracking in chloride-contaminated water, seawater, and a wide range of chemicals.		Austenitic low-carbon, high-molybdenum iron-nickel-chromium alloy with copper and nitrogen additions. Excellent resistance to pitting, crevice corrosion and stress-corrosion cracking. Outstanding resistance to oxidizing media. Particularly resistant to sulfuric acid solutions, even when contaminated, and to phosphoric acid.		Nickel-chromium-molybdenum superalloy with outstanding corrosion resistance to a wide range of organic and anorganic chemicals.	
Typical applications							
		Marine applications, chemical and petrochemical process industry, oil and gas production, tunnels, chloride-contaminated air and water.		Pulp and paper industry. Components in flue-gas desulfurization plants of fossil-fired power stations. Marine and offshore engineering, chemical and petrochemical process industry, oil and gas production.		Chemical and pharmaceutical industry, flue-gas desulfurization plants, marine applications.	

High-temperature, high-strength alloys
Iron-nickel-chromium
Nickel-chromium-iron

		Nicrofer 3220 H – alloy 800 H		Nicrofer 7216 H – alloy 600 H		Nicrofer 6025 HT – alloy 602 CA	
Designations and specifications		**Sheet/strip**	**Rod/bar**	**Sheet/strip**	**Rod/bar**	**Sheet/strip**	**Rod/bar**
USA	Designation, UNS	N08810		N06600		N06025	
	ASTM (B) ASME (SB)	409	408	–	–	168	166
GB	Designation, BS	NA 15 (H)	NA 15 (H)	–	–	–	–
	BS	3072/3073	3076	–	–	–	–
F	AFNOR	–	–	–	–	–	–
D	Designation	X 5 NiCrAlTi 3120		NiCr15Fe		NiCr25FeAlY	
	Werkstoff-Nr.	1.4958 (1.4876[1])		2.4816		2.4633	
	DIN	17460	17460	17742/17750	17742/17752	–	–
	VdTÜV data sheet	412[1]/434	412[1]/434	305	305	–	–
Chemical composition (%)							
Nickel		30 – 32		min. 72		balance	
Chromium		19 – 22		14 – 17		24 – 26	
Iron		balance		6 – 10		8 – 11	
Carbon		0.06 – 0.08		0.05 – 0.08		0.1 – 0.2	
Titanium		0.2 – 0.4		max. 0.3		0.5 – 0.25	
Aluminum		0.2 – 0.5		max. 0.3		1.8 – 2.4	
Others				Cu: max. 0.5, Si: max. 0.5		Y: 0.05 – 0.12, Zr: 0.01 – 0.10	
Mechanical properties (N/mm², %)							
Temperature (°C)		**Rp 0.2**	**Rp 1.0** **Rm** **A_5**	**Rp 0.2**	**Rp 1.0** **Rm** **A_5**	**Rp 0.2**	**Rp 1.0** **Rm** **A_5**
20		min. 170	min. 200 min. 450 min. 35	min. 180	– min. 500 min. 35	min. 270	min. 310 min. 675 min. 30
100		min. 140	min. 160 425 –	min. 170	– 480 –	min. 240	min. 280 min. 650 min. 30
200		min. 115	min. 135 400 –	min. 160	– 460 –	min. 220	min. 260 min. 625 min. 30
300		min. 95	min. 115 390 –	min. 150	– 445 –	min. 200	min. 240 min. 600 min. 30
400		min. 85	min. 105 380 –	min. 150	– 440 –	min. 190	min. 225 min. 580 min. 30
500		min. 80	min. 100 360 –	–	– – –	min. 180	min. 210 min. 560 min. 30
600		min. 75	min. 95 300 –	–	– – –	min. 175	min. 205 min. 520 min. 30
700		–	– – –	–	– – –	min. 170	min. 200 min. 420 min. 30
Creep properties (N/mm²)							
Temperature (°C)		**Rp 1.0/10⁴**	**Rm/10⁴** **Rp 1.0/10⁵** **Rm/10⁵**	**Rp 1.0/10⁴**	**Rm/10⁴** **Rp 1.0/10⁵** **Rm/10⁵**	**Rp 1.0/10⁴**	**Rm/10⁴** **Rp 1.0/10⁵** **Rm/10⁵**
600		–	152 – 114	91	138 66 97	185	120 215 140 (650°C)
700		–	75 – 53	43	63 28 42	132	85 155 100
800		–	37 – 24	18	29 12 17.1	32	16.5 42 20
900		–	17 – 10.5	8	13 4 7	13	7.5 18 9.7
1000		–	11.5 – 7	–	– – –	5.8	3.4 9 4.5
1100		–	– – –	–	– – –	2.2	1.0 4.4 2.1
Physical properties at room temperature or as indicated							
Density	g/cm³	8.0		8.4		8.4	
Specific heat	J/kg K	455		455		420	
Thermal conductivity	W/m K	11.6		14.8		13.4	
Electrical resistivity	µ Ω cm	98		103		122	
Thermal expansion	10^{-6}/K						
20 – 300°C		15.8		14.4		13.1	
Modulus of elasticity	kN/mm²	198		214		212	
Fabrication characteristics							
Formability		good		good		satisfactory	
Weldability		satisfactory		good		satisfactory	
Welding products							
Filler wire		Nicrofer S 7020 – FM 82/S 6020 – FM 625		Nicrofer S 7020 – FM 82/S 6020 – FM 625		Nicrofer S 6025 – FM 602	
Covered electrode		2.4648	2.4621	2.4648	2.4621	UTP 6225 Al	
		EL-NiCr19Nb	EL-NiCr20Mo9Nb	EL-NiCr19Nb	EL-NiCr20Mo9Nb		
		AWS ENiCrFe-3	AWS ENiCrMo-3	AWS ENiCrFe-3	AWS ENiCrMo-3		
Material characteristics							
		High strength and high resistance to high temperature corrosion up to about 1000°C (1832°F).		High resistance to oxidation and outstanding resistance to nitrogen.		Outstanding resistance to oxidation at high temperatures, even under cyclic conditions up to a temperature of 1200°C (2192°F). Good corrosion resistance in carburizing environments.	
Typical applications							
[1] Solution-annealed, age-hardened		Furnaces and furnace components up to a temperature of about 1000°C (1832°F).		Furnaces and furnace components up to a temperature of about max. 1100°C (2012°F).		Furnaces and furnace components up to a temperature of max. 1100°C (2012°F). Components in highly carburizing environments.	

High-temperature, high-strength alloys
Nickel-chromium-iron
Nickel-chromium

		Nicrofer 5219 Nb – alloy 718		Nicrofer 7520 Ti – alloy 80 A
Designations and specifications		**Sheet/strip**	**Rod/bar**	**Rod/bar**
USA	Designation, UNS	N07718		N07080
	ASTM (B) ASME (SB)	670	–	637
GB	Designation, BS	–	–	NA 20
	BS	–	–	3076 – 2HR1/2HR601
F	AFNOR	NC 19 FeNb		NC 20 TA
D	Designation	NiCr19NbMo		NiCr20TiAl
	Werkstoff-Nr.	2.4668		2.4952
	DIN	–	–	17742/17754 (WL 2.4631)
	VdTÜV data sheet	–	–	–
Chemical composition (%)				
Nickel		50 – 55		balance
Chromium		17 – 21		19 – 21
Iron		balance		max. 1
Carbon		0.02 – 0.08		0.04 – 0.09
Titanium		0.7 – 1.15		2 – 2.6
Aluminum		0.3 – 0.7		1.1 – 1.7
Others		Mo: 2.8 – 3.3 Nb: 4.8 – 5.5		Co: max. 2
Mechanical properties (N/mm², %)				

Temperature (°C)	**Rp 0.2**[1]	**Rp 1.0**	**Rm**[1]	**A_5**[1]	**Rp 0.2**[1]	**Rp 1.0**	**Rm**[1]	**A_5**[1]
20	min. 1035	–	min. 1240	min. 12	min. 620	–	min. 1000	min. 20
100	1060	–	–	–	750	–	1070	30
200	1040	–	–	–	740	–	1050	30
300	1020	–	–	–	720	–	1020	30
400	1000	–	–	–	710	–	1000	30
500	980	–	–	–	710	–	990	30
600	950	–	–	–	700	–	930	20
700	–	–	–	–	690	–	800	15
800	–	–	–	–	500	–	590	15

Physical properties at room temperature or as indicated			
Density	g/cm³	8.2	8.2
Specific heat	J/kg K	432	450
Thermal conductivity	W/m K	11.1	10.9
Electrical resistivity	µ Ω cm	123	123
Thermal expansion	10^{-6}/K		
20 – 300°C		13.8	13.7
Modulus of elasticity	kN/mm²	205	225
Fabrication characteristics			
Formability		good	annealed: good
Weldability		annealed: possible	–
		age-hardened: not applicable	
Welding products			
Filler wire		Nicrofer S 5219 – FM 718	Nicrofer S 7020 – FM 82
Covered electrode		–	2.4648
			EL-NiCr19Nb AWS ENiCrFe-3
Material characteristics			
		Age-hardenable nickel base superalloy. Excellent corrosion resistance at high and low temperatures. High mechanical strength up to 700°C (1292°F). Excellent toughness at cryogenic temperatures.	Nickel-chromium alloy, age-hardenable through aluminum and titanium additions. High mechanical strength up to 815°C (1480°F)
Typical applications			
[1] Solution-annealed, age-hardened		Components in gas turbines, engines. Bolts, molds and springs for liquid metals. Cutting tools for use at high and very low temperatures.	Gas turbine and automotive components. Bolts, valves and molds for glass-forming.

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Manufacturing program:
Ingots, billets and bar products made of high-temperature alloys (nickel and cobalt-base alloys) titanium and specialty steels in form of flats, rounds and shapes

Plants:
Reno, Nevada – bar production

Florham Park, New Jersey – melting plant and billet production

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