Nicrofer® 6030 – alloy 690

Material Data Sheet No. 4038
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Corrosion-resistant alloy

A company of ThyssenKrupp Stainless

ThyssenKrupp VDM

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ThyssenKrupp

Nicrofer® 6030 – alloy 690

Nicrofer 6030 is a nickel-chromium-iron alloy with approximately 30 % of chromium which is particularly suitable for service in oxidizing media.

Nicrofer 6030 is characterized by:

- very good resistance to fluoride-contaminated, hot nitric acid
- good resistance to caustic cracking
- excellent resistance to stress-corrosion cracking in chloride media, in polythionic acids or in the primary circuits of nuclear reactors
- excellent resistance to many corrosive aqueous media
- good resistance to oxidation and sulfidation in high temperature gaseous environments
- high mechanical properties at both room and elevated temperatures together with good ductility

Designations and standards

Country National standards	Material designation	Specification							
		Chemical composition	Tube and pipe		Sheet and plate	Rod and bar	Strip	Wire	Forgings
			seamless	welded					
D DIN VdTÜV	W.-Nr. 2.4642 NiCr29Fe								
F AFNOR	NC 30 Fe								
UK BS									
USA ASTM ASME ASME Code Case	UNS N06690		B 163* B 167 B 829 SB 163* SB 167 SB 829 2083, N-525		B 168 SB 168 N-525	B 166 SB 166 N-525	B 168 SB 168 N-525	B 166 SB 166 N-525	B 564 SB 564
ISO	NiCr29Fe9								
*Tubes only									

Table 1 – Designations and standards.

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Cu	S
min.	58.0	27.0	7.0					
max.		31.0	11.0	0.05	0.5	0.5	0.5	0.015

Table 2 – Chemical composition (wt.-%) according to ASTM.

Physical properties

Density	8.2 g/cm³	0.296 lb/in.³
Melting range	1345 – 1375 °C	2450 – 2510 °F
Permeability at 20 °C / 68 °F	1.001	

Temperature (T)		Specific heat		Thermal conductivity		Electrical resistivity		Modulus of elasticity		Coefficient of thermal expansion between room temperature and T	
°C	°F	J / kg K	Btu / lb °F	W / m K	Btu in. / ft² h °F	µ Ω cm	Ω circ mil / ft	kN / mm²	10^3 ksi	10^{-6} / K	10^{-6} / °F
0	32										
20	68	450	0.108	12.0	83	115	692	215	31.2		
93	200		0.112		96		698		30.3		7.8
100	212	470		14.0		116		208		14.1	
200	392	500		16.0		118		201		14.3	
204	400		0.120		112		710		29.1		8.0
300	572	525		18.0		120		195		14.5	
316	600		0.127		126		724		28.1		8.1
400	752	550		19.5		121.5		189		14.8	
427	800		0.134		139		734		27.1		8.3
500	932	580		21.4		122.5		182		15.2	
538	1000		0.140		153		740		26.0		8.6
600	1112	605		23.3		123.5		175		15.7	
649	1200		0.148		167		745		24.8		8.9
700	1292	630		25.0		124		167		16.2	
760	1400		0.155		180		750		23.5		9.1
800	1472	655		26.6		125		160		16.6	
871	1600		0.161		192		755		22.3		9.4
900	1652	685		28.2		126		152		17.0	
982	1800		0.170		205		763		21.0		9.6
1000	1832	715		29.7		127		143		17.3	
1093	2000		0.176		209		772				9.7
1100	2012	740		30.3		128.5				17.6	

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

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Mechanical properties

The following properties are applicable to Nicrofer 6030 in the specified condition and indicated size ranges. Specified properties of material outside these size ranges are subject to special enquiry.

Product	Tensile strength R_m N/mm²	ksi	Yield strength $R_{p0.2}$ N/mm²	ksi	Elongation A_{50} %
Sheet, plate, strip Rod, bar	586[1]	85	240	35	30[1]

[1] Not applicable for thickness under 0.25 mm (0.010 in.).

Table 4 – Minimum mechanical properties in the soft-annealed condition at room temperature according to ASTM.

Product and condition	Dimensions or o.d. mm	inches	Tensile strength R_m N/mm²	ksi	Yield strength, $R_{p0.2}$ N/mm²	ksi	Elongation A_{50} %
Sheet, strip hard	< 6.4	< 1/4	860[1]	125	620	90	2[1]
Rounds cold worked	< 12.7	< 1/2	825	120	620	90	7[2]
	12.7 – 25.4	1/2 – 1	760	110	585	85	10
	> 25.4 – 63.5	> 1 – 2 1/2	725	105	550	80	12
Squares, hexagons and rectangles cold worked	≤ 6.4	≤ 1/4	690	100	550	80	5[2]
	> 6.4 – 12.7	> 1/4 – 1/2	655	95	480	70	7

[1] Not applicable for thickness under 0.25 mm (0.010 in.)
[2] Not applicable to diameters or cross sections under 2.4 mm (3/32 in.)

Table 5 – Minimum mechanical properties at room temperature for various conditions and size ranges according to ASTM.

Temperature		Tensile strength R_m		Yield strength $R_{p0.2}$		Yield strength $R_{p1.0}$		Elongation A_5
°C	°F	N/mm²	ksi	N/mm²	ksi	N/mm²	ksi	%
93	200		84		38		42	45
100	212	580		260		290		45
200	392	550		220		260		45
204	400		80		32		38	45
300	572	520		200		240		45
316	600		74		28		33	45
400	752	500		180		220		45
427	800		72		25		30	45
500	932	490		170		200		45
538	1000		70		24		29	45
600	1112	470		160		190		45

Table 6 – Typical short-time mechanical properties at elevated temperatures.

Temperature		Creep values							
		N/mm²				ksi			
°C	°F	$R_{m/10^4h}$	$R_{p1.0/10^4h}$	$R_{m/10^5h}$	$R_{p1.0/10^5h}$	$R_{m/10^4h}$	$R_{p1.0/10^4h}$	$R_{m/10^5h}$	$R_{p1.0/10^5h}$
500	932	260							
538	1000					20.7		14.6	
600	1112	105		70					
649	1200					11.3		7.5	
700	1292	55		36					
760	1400					3.5	2.5	5.4	3.6
800	1472	29	19.1	19	11.5				
871	1600					1.6	0.8	2.5	1.5
900	1652	14	7.8	9	4.5				
982	1800					0.7		1.1	
1000	1832	6.7	3.1	3.5	–				

Table 7 – Typical creep properties in the solution-annealed condition.

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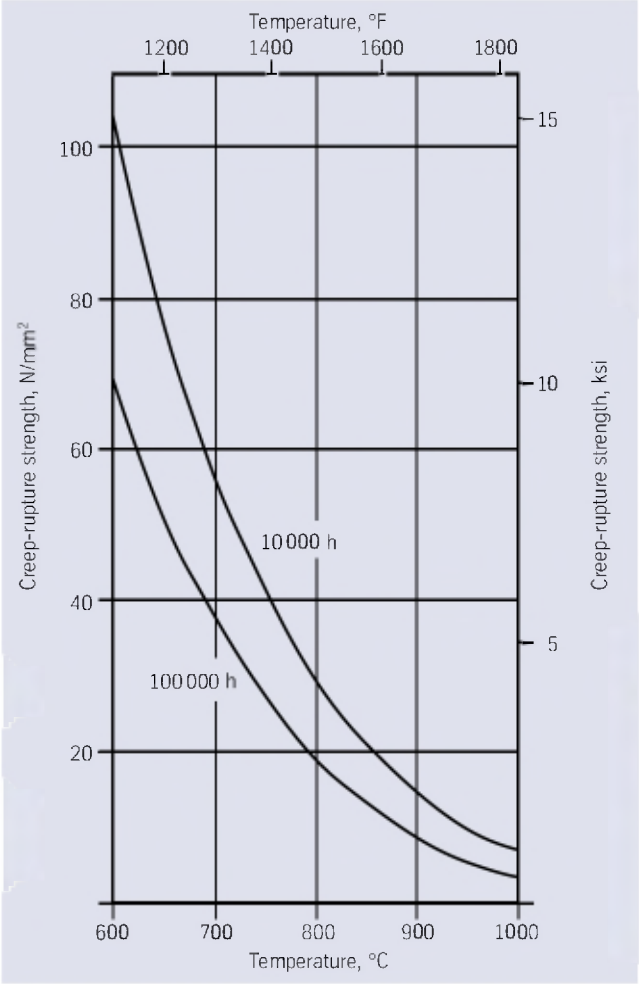

Fig. 1 – Typical creep-rupture properties in the solution-annealed condition.

Temperature °C	°F	Maximum allowable stress values N/mm² 1)	1) 2)	ksi	2)
38	100			21.3	21.3
93	200			21.1	21.3
100	212	146	147		
149	300			19.9	21.0
200	392	132	142		
204	400			19.1	20.6
260	500			18.5	20.2
300	572	127	139		
316	600			18.4	20.0
371	700			18.4	19.9
400	752	127	137		
427	800			18.4	19.8

Notes:
1) metric values determined by interpolation
2) Due to the relatively low yield strength of this material, the higher stress values were established at temperatures where the short-time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The higher stress values exceed 66 2/3 %, but do not exceed 90 % of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. The higher stress values are not recommended for flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

Table 8 – Maximum allowable stress values in tension according to ASME UNF-23.3, SB 167, SB 168

Metallurgical structure

Nicrofer 6030 has a single-phase face-centered-cubic structure with a high degree of metallurgical stability.

Corrosion resistance

Nicrofer 6030 is resistant to a wide range corrosive media and atmospheres. The high chromium content makes the alloy particularly suitable for service in strongly oxidizing conditions.

The high chromium content also confers resistance to high temperature corrosion in oxidizing and sulphidizing atmospheres.

Nicrofer 6030 exhibits excellent resistance to stress-corrosion cracking in the primary circuits of nuclear power plants. The alloy is also suitable for service in mixtures of nitric and hydrofluoric acid.

It demonstrates remarkable behaviour in concentrated (98.5 %) sulphuric acid, even at temperatures up to 150 °C (300 °F).

Applications

The excellent resistance both to wet corrosion and to high-temperature corrosion, combined with good mechanical properties makes Nicrofer 6030 suitable for a wide range of applications.

Typical applications include:

- processing of radioactive waste
- steam-generator internals in pressurized water reactors (PWR)
- production of alkali-metal sulfates (Mannheim furnace)
- components in furnaces fired with heavy fuel oil (fuel-ash corrosion)
- glass and silicate production

Fabrication and heat treatment

Nicrofer 6030 can readily be hot- and cold worked and machined.

Heating

Workpieces must be clean and free from all kinds of contaminants before and during any heat treatment.

Nicrofer 6030 may become embrittled if heated in the presence of contaminants such as sulphur, phosphorus, lead and other low-melting-point metals. Sources of such contaminants include marking and temperature-indicating paints and crayons, lubricating grease, fluids and fuels.

Fuels must be as low in sulphur as possible. Natural gas should contain less than 0.1 wt.-% sulphur. Fuel oils with a sulphur content not exceeding 0.5 wt.-% are suitable.

Due to their close control of temperature and freedom from contamination, thermal treatments in electric furnaces under vacuum or an inert gas atmosphere are to be preferred. Treatments in an air atmosphere and alternatively in gas-fired furnaces are acceptable though, if contaminants are at low levels so that a neutral or slightly oxidizing furnace atmosphere is attained. A furnace atmosphere fluctuating between oxidizing and reducing must be avoided as well as direct flame impingement on the metal.

Hot working

Nicrofer 6030 may be hot-worked in the temperature range 1230 to 900 °C (2250 to 1650 °F), followed by water quenching or rapid air cooling.

For heating up, workpieces may be charged into the furnace at maximum working temperature. When the furnace has returned to temperature, the workpieces should be soaked for 60 minutes per 100 mm (4 in.) of thickness. At the end of this period it should be withdraw immediately and worked within the above temperature range. If the metal temperature falls below the minimum hot working temperature, it must be reheated.

Heat treatment after hot working is recommended in order to achieve optimum properties and to ensure maximum corrosion resistance.

Cold working

For cold working the material should be in the annealed condition. Nicrofer 6030 has a higher work-hardening rate than austenitic stainless steels. This should be taken into account when selecting forming equipment.

Interstage annealing may be necessary with high degrees of cold forming. After cold working with more than 10 % deformation soft or solution annealing is required before use.

Heat treatment

Soft annealing of Nicrofer 6030 should be carried out in the temperature range 1020 to 1070 °C (1870 to 1960 °F), preferably at about 1040 °C (1900 °F).

Solution annealing for improved creep strength is carried out at 1080 to 1150 °C (1980 to 2100 °F). Water quenching or rapid air cooling is recommended for thicknesses above about 1.5 mm (0.06 in.) and is essential for maximum corrosion resistance.

Stress-relief annealing may be performed at 700 to 750 °C (1300 to 1400 °F).

For any thermal treatment the material should be charged into the furnace at maximum working temperature. Also for any thermal treatment operation the precautions concerning cleanliness mentioned earlier under 'Heating' must be observed.

Descaling and pickling

Oxides of Nicrofer 6030 and discoloration adjacent to welds are more adherent than on stainless steels. Grinding with very fine abrasive belts or discs is recommended. Care should be taken to prevent tarnishing.

Before pickling which may be performed in a nitric/hydrofluoric acid mixture with proper control of pickling time and temperature, the surface oxide layer must be broken up by abrasive blasting or by carefully performed grinding or by pretreatment in a fused salt bath.

Machining

Nicrofer 6030 should be machined in the heat-treated condition. As the alloy exhibits a high work-hardening rate only low cutting speeds should be used compared with low-alloyed standard austenitic stainless steels. Tools should be engaged at all times. An adequate depth of cut is important in order to cut below the previously formed work-hardened zone.

Welding

When welding nickel-base alloys and high-alloyed special stainless steels, the following instructions should be adhered to:

Workplace

The workplace should be in a separate location, well away from the areas where carbon steel fabrication takes place. Maximum cleanliness and avoidance of draughts are paramount.

Auxiliaries, clothing

Clean fine leather gloves and clean working clothes should be used.

Tools and machinery

Tools used for nickel-base alloys and stainless steels must not be used for other materials. Brushes should be made of stainless material. Fabricating and working machinery such as shears, presses or rollers should be fitted with means (felt, cardboard, plastic sheet) of avoiding contamination of the metal with ferrous particles, which can be pressed into the surface of the material and thus lead to corrosion.

Cleaning

Cleaning of the base metal in the weld area (both sides) and of the filler metal (e. g. welding rod) should be carried out with acetone.

Trichlorethylene (TRI), perchlorethylene (PER), and carbon tetrachloride (TETRA) must not be used.

Edge preparation

This should preferably be done by mechanical means, i. e. turning, milling or planing; abrasive water jet or plasma cutting is also possible. However, in the latter case the cut edge (the face to be welded) must be finished off cleanly. Careful grinding without overheating is permissible.

Included angle

The different physical characteristics of nickel-base alloys and special stainless steels compared with carbon steel generally manifest themselves in a lower thermal conductivity and a higher rate of thermal expansion. This should be allowed for by means of, among other things, wider root gaps or openings (1 – 3 mm), while larger included angles (60 – 70°), as shown in Fig. 2, should be used for individual butt joints owing to the viscous nature of the molten weld metal and to counteract the pronounced shrinkage tendency.

Striking the arc

The arc should only be struck in the weld area, i. e. on the faces to be welded or on a run-out piece. Striking marks lead to corrosion.

Welding process

Nicrofer 6030 can be joined to itself and to many other metals by most conventional welding processes. These include GTAW (TIG), plasma arc and SMAW (MMA). Pulsed arc welding is the preferred technique.

For welding, Nicrofer 6030 should be in the annealed condition and be free from scale, grease and markings. When welding the root, care should be taken to achieve best-quality root backing (argon 99.99), so that the weld is free from oxides after welding the root. Root backing is also recommended for the first intermediate pass following the initial root pass and in some cases even for the second pass depending on the weld set-up. Any heat tint should be removed preferably by brushing with a stainless steel wire brush while the weld metal is still hot.

Filler metal

For the gas-shielded welding processes, the following filler metals are recommended:

Bare electrodes:

Nicrofer S 6030 – FM 690
W.-Nr. 2.4642
SG-NiCr23Mo16
AWS A5.14: ERNiCrMo-13

or

Nicrofer S 7020 – FM 82
W.-Nr. 2.4806
SG-NiCr20Nb
AWS A5.14: ERNiCr-3

Nicrofer S 6030 – FM 690 is preferred as weldments with Nicrofer S 7020 are less corrosion resistant.

Welding parameters and influences (heat input)

Care should be taken that the work is performed with a deliberately chosen, low heat input as indicated in Table 10 by way of example. Use of the stringer bead technique should be aimed at. Interpass temperature should be kept below 150 °C (300 °F).

The welding parameters should be monitored as a matter of principle.

The heat input Q may be calculated as follows:

$$Q = \frac{U \times I \times 60}{v \times 1000}\ (kJ/cm)$$

U = arc voltage, volts
I = welding current, amps
v = welding speed, cm/min.

Consultation with ThyssenKrupp VDM's Welding Laboratory is recommended.

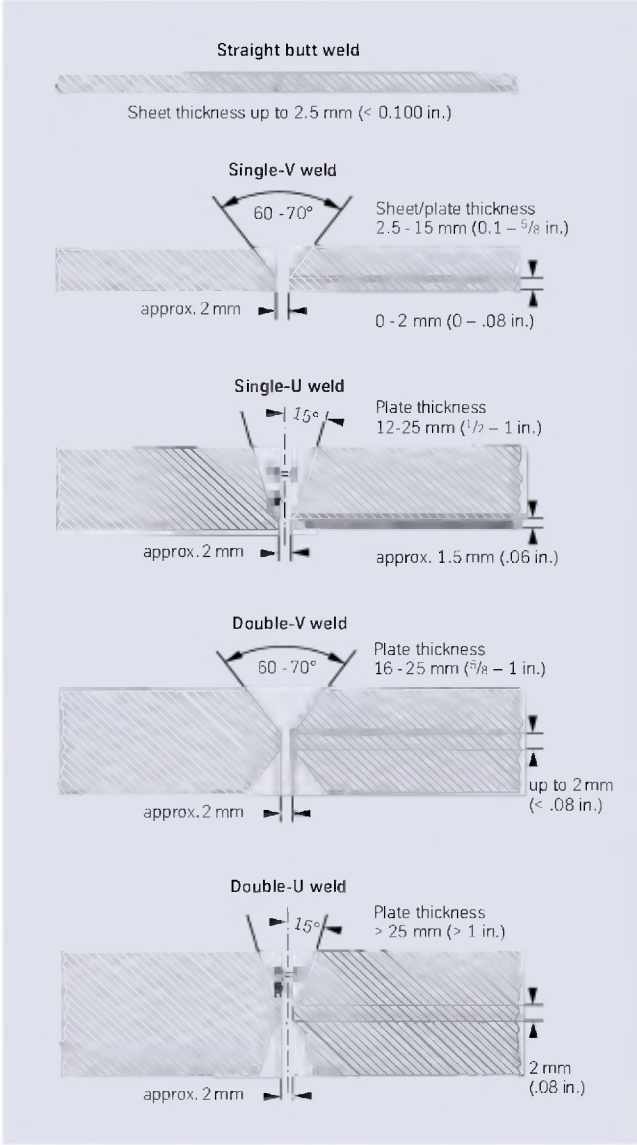

Fig. 2 – Edge preparation for welding of nickel alloys and special stainless steels.

Sheet/ plate thick-ness mm	Welding process	Filler metal Diameter mm	Speed m/min.	Welding parameters Root pass A	V	Intermediate and final passes A	V	Welding speed cm/min.	Flux/ shielding gas rate l/min.	Plasma-gas rate l/min.	Plasma-nozzle diameter mm
3.0	Manual GTAW	2.0		90	10	110 – 120	11	10 – 15	Ar W3[1] 8 – 10		
6.0	Manual GTAW	2.0 – 2.4		100 – 110	10	120 – 130	12	10 – 15	Ar W3[1] 8 – 10		
8.0	Manual GTAW	2.4		110 – 120	11	130 – 140	12	10 – 15	Ar W3[1] 8 – 10		
10.0	Manual GTAW	2.4		110 – 120	11	130 – 140	12	10 – 15	Ar W3[1] 8 – 10		
3.0	Autom. GTAW	1.2	0.5	manual		150	10	25	Ar W3[1] 15 – 20		
5.0	Autom. GTAW	1.2	0.5	manual		150	10	25	Ar W3[1] 15 – 20		
2.0	Hot wire GTAW	1.0	0.3			180	10	80	Ar W3[1] 15 – 20		
10.0	Hot wire GTAW	1.2	0.45	manual		250	12	40	Ar W3[1] 15 – 20		
4.0	Plasma arc	1.2	0.5	165	25			25	Ar W3[1] 30	Ar W3[1] 3.0	3.2
6.0	Plasma arc	1.2	0.5	190 – 200	25			25	Ar W3[1] 30	Ar W3[1] 3.5	3.2
6.0	SMAW	2.5		40 – 70	approx. 21	40 – 70	approx. 21				
8.0	SMAW	2.5–3.25		40 – 70	approx. 21	70 – 100	aprrox. 22				
16.0	SMAW	4.0				90 – 130	approx. 22				

[1] Argon or argon + max. 3 % hydrogen
In all gas-shielded welding operations, ensure adequate back shielding.
These figures are only a guide and are intended to facilitate setting of the welding machines.

Table 9 – Welding parameters (guide values).

Welding process	Heat input per unit length kJ/cm	Welding process	Heat input per unit length kJ/cm
GTAW, manual, fully mechanised	max. 8	Plasma arc	max. 10
Hot wire GTAW	max. 6	SMAW, manual metal arc (MMA)	max. 7

Table 10 – Heat input per unit length (guide values).

Nicrofer® 6030 – alloy 690

Availability

Nicrofer 6030 is available in the following standard product forms:

Sheet & plate

(for cut-to-length availability, refer to strip)

Conditions:
hot or cold rolled (hr, cr),
thermally treated and pickled

Thickness mm	hr / cr	Width[1] mm	Length[1] mm
1.10 – < 1.50	cr	2000	8000
1.50 – < 3.00	cr	2500	8000
3.00 – < 7.50	cr / hr	2500	8000
7.50 – ≤ 25.00	hr	2500	8000[2]
> 25.00[1]	hr	2500[2]	8000[2]

inches		inches	inches
0.043 – < 0.060	cr	80	320
0.060 – < 0.120	cr	100	320
0.120 – < 0.300	cr / hr	100	320
0.300 – ≤ 1.000	hr	100	320[2]
> 1.000[1]	hr	100[2]	320[2]

[1] other sizes subject to special enquiry
[2] depending on piece weight

Discs and rings

Conditions:
hot rolled or forged,
thermally treated,
pickled or machined

Product	Weight kg	Thickness mm	o. d.[1] mm	i. d.[1] mm
Disc	≤ 10000	≤ 300	≤ 3000	
Ring	≤ 3000	≤ 200	≤ 2500	on request

	lbs	inches	inches	inches
Disc	≤ 22000	≤ 12	≤ 120	
Ring	≤ 6600	≤ 8	≤ 100	on request

[1] other sizes subject to special enquiry

Rod & bar

Conditions:
forged, rolled, drawn,
thermally treated,
pickled, machined, peeled or ground

Product	Forged[1] mm	Rolled[1] mm	Drawn[1] mm
Rod (o. d.)	≤ 600	8 – 100	12 – 65
Bar, square (a)	40 – 600	15 – 280	not standard
Bar, flat (a x b)	(40 – 80) x (200 – 600)	(5 – 20) x (120 – 600)	(10 – 20) x (30 – 80)
Bar, hexagonal (s)	40 – 80	13 – 41	≤ 50

	inches	inches	inches
Rod (o. d.)	≤ 24	5/16 – 4	1/2 – 2 1/2
Bar, square (a)	1 5/8 – 24	10/16 – 11	not standard
Bar, flat (a x b)	(1 5/8 – 3 1/8) x (8 – 24)	(3/16 – 3/4) x (4 3/4 – 24)	(3/8 – 3/4) x (1 1/4 – 3 1/8)
Bar, hexagonal (s)	1 5/8 – 3 1/8	1/2 – 1 5/8	≤ 2

[1] other sizes and conditions subject to special enquiry

Forgings

Shapes other than discs, rings, rod and bar are subject to special enquiry. Flanges and hollow shafts may be available up to a piece weight of 10 t.

Strip[1)]
Conditions:
cold rolled,
thermally treated and pickled or bright annealed
[1)] Strip and cut-to-length availability subject to special enquiry.

Wire
Conditions:
bright drawn, 1/4 hard to hard,
bright annealed

Dimensions:
0.01 – 12.0 mm (0.0004 – 0.47 in.) diameter,
in coils, pay-off packs, on spools and spiders

Welding filler metals
Suitable welding rods, wire, strip electrodes and electrode core wire are available in all standard sizes.

Seamless tube and pipe
Using ThyssenKrupp VDM cast materials seamless tubes and pipes are produced and available from DMV STAINLESS SAS, Tour Neptune, F-92086 Paris, La Défense Cedex (Fax: +33-1-4796 8141; Tel.: +33-1-4796 8140; E-mail: dmv-hq@dmv-stainless.com).

Welded tube and pipe
Welded tubes and pipes are obtainable from qualified manufacturers using ThyssenKrupp VDM semi-fabricated products.

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