Nickel 99.2 – alloy 200
LC-Nickel 99.2 – alloy 201

Material Data Sheet No. 1001
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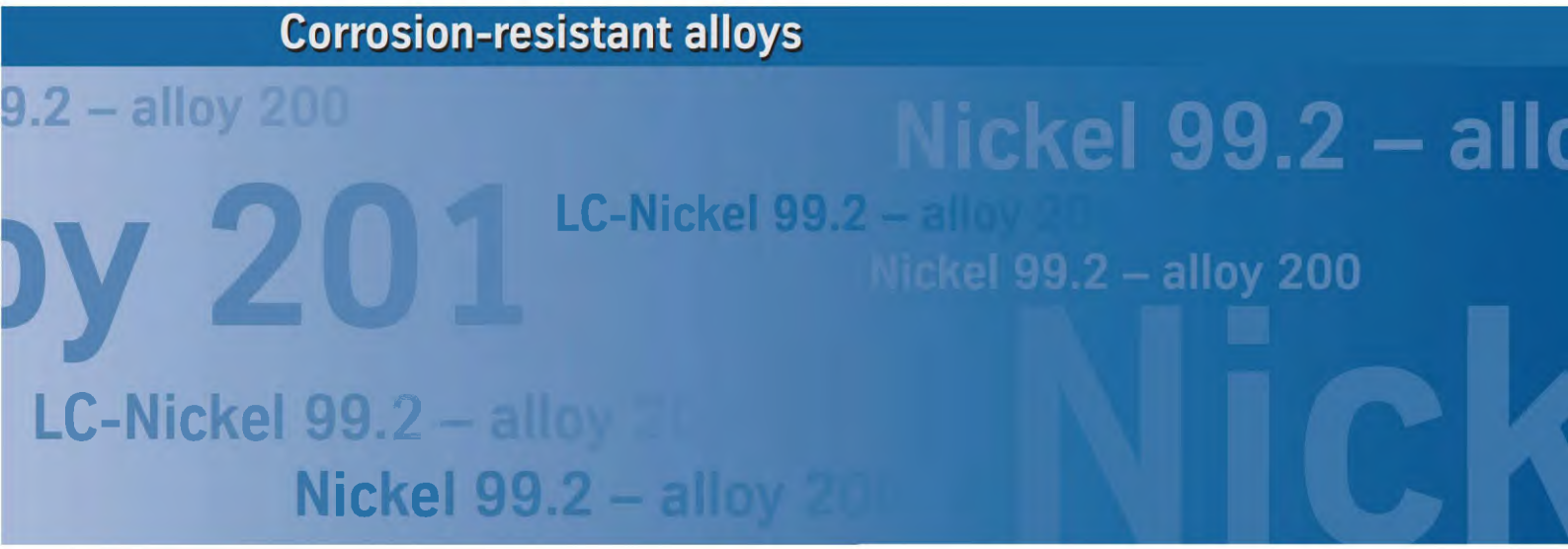

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A company of ThyssenKrupp Stainless

ThyssenKrupp VDM

ThyssenKrupp

Nickel 99.2 – alloy 200
LC-Nickel 99.2 – alloy 201

Nickel 99.2 is an unalloyed wrought nickel. It offers excellent corrosion resistance, good mechanical, magnetic and magnetostrictive properties and useful thermal and electrical conductivities.

LC-Nickel 99.2 with reduced carbon content (0.02 % max.) shows better corrosion resistance at elevated temperatures above 300 °C (570 °F) by avoiding graphite precipitation.

Nickel is characterized by:

- excellent corrosion resistance in many alkaline media
- good mechanical properties within a wide range of temperatures
- magnetization decreasing continuously between -273 and 360 °C (-458 and 680 °F) and showing paramagnetism above the Curie point

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. 2.4066** Ni 99.2 **W.-Nr. 2.4068** LC-Ni 99	17740 345[1]	17751 345[1]	17751	17750 345[1]	17752 345[1]	17750 345[1]	17753	17754 345[1]
F AFNOR									
UK	NA 11 NA 12		3074		3072	3076	3073	3075	
USA ASTM ASME AMS	UNS N02200 UNS N02201		B 161/163 SB 161/163	B 725/730	B 162 SB 162 5553[1]	B 160 SB 160	B 162 SB 162 5553[1]		
ISO	Ni 99.0 LC-Ni 99.0								

[1] LC-Nickel 99.2 only

Table 1 – Designations and standards.

Chemical composition

		Ni	Fe	C	Mn	Si	Cu	Mg*	Ti*	S
Nickel 99.2	min. max.	99.0	0.40	0.15	0.35	0.1	0.25			0.01
LC-Nickel 99.2	min. max.	99.0	0.40	0.02	0.35	0.2	0.25	0.15	0.1	0.01

*Values according to VdTÜV only

Table 2 – Chemical composition (wt.-%) of Nickel 99.2 and LC-Nickel 99.2 according to ASTM.

Physical properties

Density	8.9 g/cm³	0.32 lb/in.³
Melting range	1435 – 1445 °C	2615 – 2635 °F
Curie temperature	360 °C	680 °F

Temperature (T)		Specific heat		Thermal conductivity Nickel 99.2		Thermal conductivity LC-Nickel 99.2		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	W / m K	Btu in. / ft² h °F	µ Ω cm	Ω circ mil / ft	kN / mm²	10³ ksi	10^{-6} / K	10^{-6} / °F
-200	-328	150		78.5		93		2				10.1	
-184	-300		0.045		540		640		15				5.8
-129	-200		0.076		530		630		21				6.8
-100	-148	355		75		87		4.5				11.3	
-73	-100		0.091		505		590		33				6.3
0	32	426	0.102	71.5	500	81	560	8.5	51	207	30.0		
20	68	456	0.109	70.5	490	79	550	9	54	205	29.7		
93	200		0.113		465		510		75		29.1		7.4
100	212	475		66.5		73		13		200		13.3	
200	392	500		61.5		67		19		196		13.9	
204	400		0.132		425		460		114		28.4		7.7
300	572	570		57		60		26		190		14.3	
316	600		0.139		390		410		162		27.3		8.0
400	752	530		56		57		33		182		14.8	
427	800		0.124		390		390		207		26.1		8.3
500	932	525		57.5		58.5		37		175		15.2	
538	1000		0.128		405		410		229		24.7		8.5
600	1112	535		60		61		40		165		15.6	
649	1200		0.130		420		430		250		23.2		8.7
700	1292	550		62		63		43		153		15.8	
760	1400		0.133		435		445		265		21.0		8.9
800	1472	565		64		65.5		45		140		16.2	
871	1600		0.137		455		465		285		19.6		9.1
900	1652	580		66.5		68		48		134		16.5	
982	1800		0.144		470		480		305				9.3
1000	1832	590		69		70.5		51				16.7	

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

Nickel 99.2 – alloy 200
LC-Nickel 99.2 – alloy 201

Additional information on physical property data:

- Specific heat has a maximum at 358 °C (676 °F).
- Thermal conductivity shows lower values in material with impurities. This effect is very noticeable at lower temperatures. The conductivity value changes its direction of variation at temperatures above the Curie point.
- Thermal expansion likewise has an intermediate maximum at 360 °C (680 °F).
- Dynamic elastic modulus depends mainly on material condition, saturation magnetization and annealing temperature. It can have a minimum at temperatures around 200 °C (390 °F).

Mechanical properties

The following Mechanical properties are applicable to Nickel 99.2 and LC-Nickel 99.2 in the indicated forms and size ranges and in the annealed condition (unless otherwise specified). Material outside these size ranges with agreed properties is subject to special enquiry.

Sheet & plate	up to 50 mm	up to 2 in.
Strip	up to 3 mm	up to 0.12 in.
Rod & bar	up to 250 mm	up to 10 in.
Forgings	up to 150 mm	6 in.

Alloy	According to spec.	Condition	Tensile strength R_m N/mm²	ksi	Yield strength $R_{p\,0.2}$ N/mm²	ksi	Yield strength $R_{p\,1.0}$ N/mm²	ksi	Elongation A_5 %
Nickel 99.2 – alloy 200	DIN 17750	annealed	≥ 380	≥ 55	≥ 100	≥ 14.5	≥ 125	≥ 18.1	≥ 40
	ASTM B 160-163, 725, 730	annealed	≥ 380	≥ 55	≥ 105	≥ 15	–	–	≥ 40
		stress rel.	≥ 450	≥ 65	≥ 275	≥ 40	–	–	≥ 15
	Typical values	annealed	440	63.8	150	21.8	180	26.1	44
LC-Nickel 99.2 – alloy 201	DIN 17750, VdTÜV 345	annealed	≥ 340	≥ 49.3	≥ 80	≥ 11.6	≥ 105	≥ 15	≥ 40
	ASTM B 160-163, 725, 730	annealed	≥ 345	≥ 50	≥ 80	≥ 12	–	–	≥ 40
		stress rel.	≥ 415	≥ 60	≥ 205	≥ 30	–	–	≥ 15
	Typical values	annealed	415	60	125	18.1	150	21.8	47

Some standards show greater deviations for 0.2 % yield values.

Table 4 – Mechanical properties at room temperature.

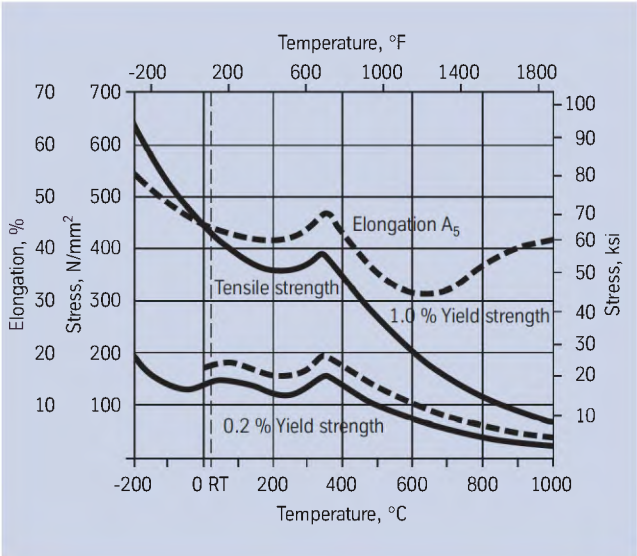

Fig. 1 – Typical short-time properties of annealed Nickel 99.2 at low and elevated temperatures.

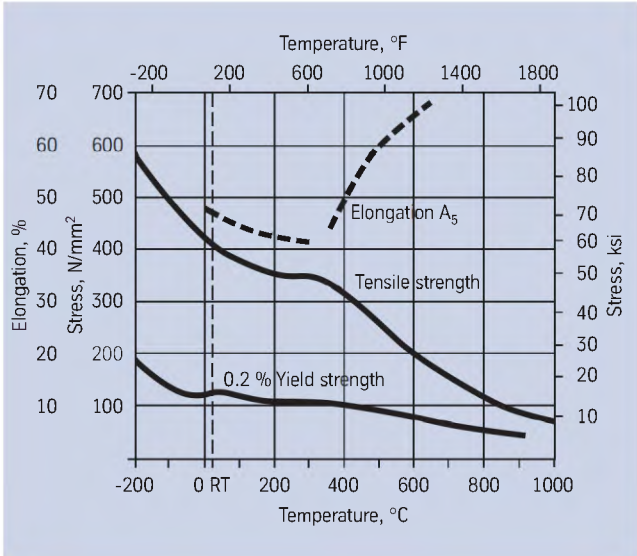

Fig. 2 – Typical short-time properties of annealed LC-Nickel 99.2 at low and elevated temperatures.

Temperature °C	Temperature °F	Tensile strength R_m N/mm²	Tensile strength R_m ksi	Yield strength $R_{p0.2}$ N/mm²	Yield strength $R_{p0.2}$ ksi	Yield strength $R_{p1.0}$ N/mm²	Yield strength $R_{p1.0}$ ksi	Elongation A_5 %
RT	RT	≥ 340	≥ 49.3	≥ 80	≥ 11.6	≥ 105	≥ 15.2	≥ 40
93	**200**		42.2		≥ 10.2		≥ 13.8	
100	212	290		≥ 70		≥ 95		
200	392	275		≥ 65		≥ 90		
204	**400**		39.9		≥ 9.4		≥ 13.1	
300	572	260		≥ 60		≥ 85		
316	**600**		37.1		≥ 8.6		≥ 12.2	
400	752	240		≥ 55		≥ 80		
427	**800**		33.6		≥ 7.9		≥ 10.5	
500	932	210		≥ 50		≥ 75		
538	**1000**		27.1		≥ 6.8		≥ 10.3	
600	1112	150		≥ 40		≥ 65		
Imperial values determined by graphs/diagrams								

Table 5 – Minimum short-time mechanical properties of LC-Nickel 99.2 at room and elevated temperatures according to VdTÜV data sheet 345.

Temperature °C	Temperature °F	Design stress Rp 1.0/10⁴h N/mm²	Design stress Rp 1.0/10⁴h ksi	Design stress Rp 1.0/10⁵h N/mm²	Design stress Rp 1.0/10⁵h ksi
360	680	–	–	80	11.6
380	716	85	12.3	70	10.2
400	752	75	10.9	60	8.7
420	788	67	9.7	52	7.5
440	824	59	8.6	44	6.4
460	860	51	7.4	36	5.2
480	896	43	6.2	29	4.2
500	932	35	5.1	23	3.3
520	968	28	4.1	17	2.5
540	1004	22	3.2	13	1.9
560	1040	17	2.5	9	1.3
580	1076	13	1.9	7	1.0
600	1112	10	1.5	6	0.9
Imperial values converted (N/mm² x 0.145 = ksi)					

Table 6 – Design stresses of LC-Nickel 99.2 at elevated temperatures according to VdTÜV data sheet 345. For calculation of pressure vessels these values must be reduced by safety factors according to AD-Merkblättern (data sheets) row B and S1.

Nickel 99.2 – alloy 200
LC-Nickel 99.2 – alloy 201

Product		Nickel 99.2 – alloy 200 condition					LC-Nickel 99.2 – alloy 201 condition			
		soft annealed		hot rolled		stress relieved	soft annealed		stress relieved	
Rod, bar, forgings		SB 160	–	–	SB 160	–	–	SB 160	–	–
Plate, sheet, strip		SB 162	–	SB 162	–	–	SB 162	–	–	–
Plate		SB 163	–	–	–	SB 163	SB 163	–	–	SB 163
Temperature										
°F	°C	ksi*					ksi*			
100	38	10.0	8.0	13.3	10.0	16.3	8.0	6.7	15.0	16.5
200	93						7.7	6.4		15.6
300	149						7.5	6.3		15.0
400	204							6.2	14.8	14.8
500	260			12.5	9.5	16.0			14.7	14.7
600	316			11.5	8.3	15.4			14.2	14.2
700	371	–	–	–	–	–	7.4	6.2	–	13.4
800	427	–	–	–	–	–	7.2	5.9	–	12.1
900	482	–	–	–	–	–	4.5	4.5	–	11.1
1000	538	–	–	–	–	–	3.0	3.0	–	–
1100	593	–	–	–	–	–	2.0	2.0	–	–
1200	649	–	–	–	–	–	1.2	1.2	–	–

*For conversion to N/mm² multiply by 6.9

Table 7 – Maximum allowable stress values in tension according to ASME.

Metallurgical structure
Nickel and LC-Nickel have face-centered-cubic structures between temperatures close to absolute zero and melting point.

Corrosion resistance
Nickel and LC-Nickel have excellent resistance to many corrosive media from acid to alkaline. They are most useful under reducing conditions but, where a passive oxide is formed, they may also be used in oxidizing conditions.

Their most significant property is extremely high resistance to caustic alkalies up to and including the molten state. The extra-low carbon content of LC-Nickel 99.2 gives virtual immunity to intergranular attack above about 315 °C (600 °F). The presence of chlorates must be kept to a minimum, as they accelerate the rate of attack.

The resistance of Nickel 99.2 and LC-Nickel 99.2 to mineral acids varies according to temperature and concentration and whether or not the solution is aerated. Corrosion resistance is better in deaerated acid.

In acid, alkaline and neutral salt solutions, Nickel 99.2 and LC-Nickel 99.2 show good resistance, but severe attack occurs in oxidizing salt solutions. Both alloys are resistant to all dry gases at room temperature. The low-carbon alloy can be used in dry chlorine and hydrogen chloride – at temperatures up to 550 °C (1020 °F).

Applications

Unalloyed wrought nickel combines excellent mechanical properties with good corrosion resistance. Above 300 °C (570 °F) working temperature, the low-carbon version is generally used. The limited carbon content lowers mechanical property values and work-hardening rate but promotes ductility.

Typical applications are:

- food production, such as handling of cooling brines, fatty acids and fruit juices – resistance to acid, alkaline and neutral salt solutions and to organic acids.
- vessels in which fluorine is generated and reacted with hydrocarbons – resistance to fluorine
- storing and transportation of phenol – immunity from any form of attack ensures absolute product purity
- manufacture and handling of sodium hydroxide, particularly at temperatures above 300 °C (570 °F). Industrial processes where sodium hydroxide is typically used, involve:
- production of viscose rayon and manufacture of soap – general corrosion resistance and virtual immunity to intergranular attack above 315 °C (600 °F)
- production of hydrochloric acid and chlorination of hydrocarbons such as benzene, methane and ethane – resistance at elevated temperatures to dry chlorine and hydrogen chloride
- manufacture of vinyl chloride monomer – resistance to hydrogen chloride at elevated temperatures

Fabrication and heat treatment

Nickel 99.2 and LC-Nickel 99.2 are easily hot or cold formed and machined by common industrial processes. Their weldability is excellent. Joining can be performed by all conventional welding processes.

Heating

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

Nickel and LC-Nickel may become embrittled if heated in the presence of contaminants such as sulphur, phosphorus, lead and other low-melting-point metals. Sources of contamination include marking and temperature-indicating paints and crayons, lubricating grease and fluids, and fuels. Fuels must be as low in sulphur as possible; e.g. natural and liquefied petroleum gases should contain less than 0.1 % by mass and town gas 0.25g/m^3 maximum of sulphur. Fuel oils containing no more than 0.5 % by mass of sulphur are satisfactory.

Electric furnaces are desirable due to close control of temperature and freedom from contamination. Gas-fired furnaces are acceptable if impurities are at low levels.

The furnace atmosphere should be neutral to slightly reducing and must not fluctuate between oxidizing and reducing. Direct flame impingement on the metal must be avoided.

Hot working

Nickel 99.2 and LC-Nickel 99.2 may be hot-worked in the temperature range 1200 to 800 °C (2200 to 1470 °F). Air cooling is satisfactory.

Soft annealing is recommended after hot working to ensure maximum corrosion resistance and controlled properties.

For hot working, the material may be charged into the furnace at maximum working temperature.

When the furnace has returned to temperature, the material should be soaked for 60 minutes per 100 mm (4 in.) of thickness. After soaking for the required time the metal should be withdrawn immediately and worked within the specified range. If the metal temperature falls below the minimum working temperature, it must be reheated.

Cold working

Cold working should be carried out on soft annealed material. The cold working characteristics of Nickel and LC-Nickel are similar to those of carbon steels and work-hardening will occur.

When heavy cold working is performed, interstage annealing is necessary. Recommended die materials are alloy tool steel, tungsten carbide or cast iron. Lubricants should be sulphur free and of the wetting type.

Heat treatment

Annealing of Nickel 99.2 and LC-Nickel 99.2 is carried out within the temperature range 700 – 850 °C (1290 – 1560 °F), soaking for approximately 3 minutes per mm (0.04 in.) of thickness. Temperature and time at temperature are important with regard to final grain size and must therefore be carefully considered when determining the annealing parameters.

Under certain circumstances the enhanced strength produced by cold work may be used to advantage. The material is heated to a temperature lower than necessary to cause recrystallization, but sufficiently high to induce relaxation of stresses.

Stress-relief annealing may be performed within the temperature range 550 to 650 °C (1020 to 1200 °F).

After soft annealing or stress relieving, air cooling is satisfactory. During any heating operation the precautions outlined earlier regarding cleanliness must be observed.

Descaling and pickling

Oxides of Nickel and LC-Nickel and discoloration adjacent to welds, are more adherent than on stainless steels. Grinding with very fine abrasive belts or discs is recommended.

Before pickling in a nitric/hydrofluoric acid mixture, oxides must be broken up by grit-blasting or by pretreatment in a fused salt bath.

Nickel 99.2 – alloy 200
LC-Nickel 99.2 – alloy 201

Machining
Nickel 99.2 and LC-Nickel 99.2 should be machined in the heat-treated condition. As the alloys exhibit a high work-hardening rate only low cuting 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
Nickel 99.2 and LC-Nickel 99.2 can be welded by all conventional processes, including gas tungsten-arc (GTAW/TIG), gas metal-arc (GMAW/MIG), pulsed arc and shielded metal-arc welding (SMAW/MMA).

Prior to welding, material should be in the soft annealed or stress-relieved condition, clean and free from scale, grease, marking paints etc.

Low heat input is necessary. Interpass temperature should not exceed 150 °C (300 °F).

Neither pre- nor post-weld heat treatment is required.

The following welding products are recommended:

Bare electrodes: Nickel S 9604 – FM 61
W.-Nr. 2.4155
SG-NiTi4
AWS A 5.14 ERNi-1

Covered electrodes: W.-Nr. 2.4156
EL-NiTi3
AWS A5.11 ENi-1

Only electrodes which do hot result in carbon and silicon pick-up, or which keep it to a minimum, should be used.

Availability
Nickel 99.2 and LC-Nickel 99.2 are 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[2]

Thickness mm	Width[3] mm	Coil i. d. mm			
0.04 – ≤ 0.10	4 – 200	300	400		
> 0.10 – ≤ 0.20	4 – 350	300	400	500	
> 0.20 – ≤ 0.25	4 – 750		400	500	600
> 0.25 – ≤ 0.60	6 – 750		400	500	600
> 0.60 – ≤ 1.0	8 – 750		400	500	600
> 1.0 – ≤ 2.0	15 – 750		400	500	600
> 2.0 – ≤ 3.0	25 – 750		400	500	600

inches	inches	inches			
0.0016 – ≤ 0.004	0.16 – 8	12	16		
> 0.004 – ≤ 0.008	0.16 – 14	12	16	20	
> 0.008 – ≤ 0.010	0.16 – 30		16	20	24
> 0.010 – ≤ 0.024	0.20 – 30		16	20	24
> 0.024 – ≤ 0.040	0.32 – 30		16	20	24
> 0.040 – ≤ 0.080	0.60 – 30		16	20	24
> 0.080 – ≤ 0.120	1.0 – 30		16	20	24

[1] Cut-to-length available in lengths from 250 to 4000 mm (10 to 158 in.)
[2] Maximum thickness 3 mm (0.125 in.)
[3] Wider widths 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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