VDM Metals

VDM® Alloy C-263
Nicrofer 5120 CoTi

Material Data Sheet No. 4020
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Nicrofer® 5120 CoTi – alloy C-263

The high-temperature alloy Nicrofer 5120 CoTi is a precipitation-hardening creep-resisting nickel-chromium-cobalt-molybdenum alloy developed by Rolls-Royce.

It is normally supplied in the high-temperature annealed condition and is recommended for service up to 850 °C (1560 °F).

Nicrofer 5120 CoTi is characterized by:

- excellent resistance to oxidation and scaling up to 1000 °C (1800 °F)
- good mechanical properties and excellent creep values at elevated temperatures
- good weldability without susceptibility to post-weld heat treatment cracking
- improved wear characteristics

Designations and standards

Country National standards	Material designation	Specification							
		Chemical composition	Tube and pipe seamless	welded	Sheet and plate	Rod and bar	Strip	Wire	Forgings
D WL	W.-Nr. 2.4650 NiCo20Cr20MoTi	Teil 1 + 2			Teil 1	Teil 2	Teil 1		Teil 2
F AFNOR	NCK20 D				AIR 9165	AIR 9165			AIR 9165
UK BS			HR 404		HR 206	HR 10			
USA ASTM ASME AMS	UNS N07263	5872			5872		5872		
ISO	NiCo20Cr20Mo5Ti2Al								

Table 1 – Designations and standards.

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Cu	Mo	Co
min.	bal.	19.0		0.04				5.6	19.0
max.		21.0	0.7	0.08	0.6	0.4	0.2	6.1	21.0

	Al	Ti	Al + Ti	P	S	B	Pb*	Ag*	Zr*
min.	0.30	1.90	2.40						
max.	0.60	2.40	2.80	0.015	0.007	0.005	0.002	0.0005	0.02

*determination only if requested

Table 2 – Chemical composition (wt.-%).

Physical properties

Density	8.4 g/cm³	0.30 lb/in.³
Melting temperature	1300 – 1360 °C	2370 – 2480 °F
Permeability at 20 °C/68 °F (RT)	< 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	10³ ksi	10⁻⁶/K	10⁻⁶/°F
0	32	422	0.100	11.6	81	115	688	223	32.3		
20	68	426	0.102	11.7	81	115	692	222	32.3		
93	200		0.106		89		700		31.6		6.0
100	212	447		13.0		117		218		10.7	
200	392	472		14.7		118		212		12.0	
204	400		0.113		102		713		30.6		6.7
300	572	497		16.3		120		206		12.5	
316	600		0.119		115		725		29.6		7.0
400	752	523		18.0		122		198		13.0	
427	800		0.126		128		737		28.4		7.3
500	932	548		19.7		124		192		13.5	
538	1000		0.133		141		751		27.2		7.6
600	1112	573		21.4		126		184		14.1	
649	1200		0.139		154		761		25.9		8.0
700	1292	598		23.0		126		176		14.9	
760	1400		0.146		167		755		24.3		8.5
800	1472	624		24.7		125		165		15.9	
871	1600		0.153		181		747		22.6		9.2
900	1652	649		26.8		124		153		17.2	
982	1800		0.159		196		746		20.8		9.9
1000	1832	674		28.5		124		143		18.2	

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

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Mechanical properties

The following properties are applicable to Nicrofer 5120 CoTi in the indicated size ranges (see availability).
Specified properties of material outside these size ranges are subject to special enquiry.

A. Hot or cold-rolled sheet, solution treated and descaled

Hardness			max. 250 HB
Bending (parallel to the rolling direction)			180°
	≤ 1.27 mm	≤ 0.050 in.	factor 1
	> 1.27 to 4.75 mm	> 0.050 to 0.187 in.	factor 2
Grain size			
hot-rolled sheet		≤ 127 µm	ASTM No. 3
cold-rolled sheet		≤ 90 µm	ASTM No. 4

B. Hot or cold-formed, solution treated, precipitation-hardened and descaled

After precipitation hardening the product will meet the following properties at 780 ± 2 °C (1435 ± 3 °F) after 20 min. at temperature:

Tensile strength	R_m	≥ 540 N/mm²	≥ 78.5 ksi
Yield strength	$R_{p0.2}$	≥ 400 N/mm²	≥ 58.5 ksi
Elongation	A_5	≥ 15 %	
Creep strength	under continuous stress of 120 N/mm²/17 ksi for 50 hours total plastic strain ≤ 0.1 %		

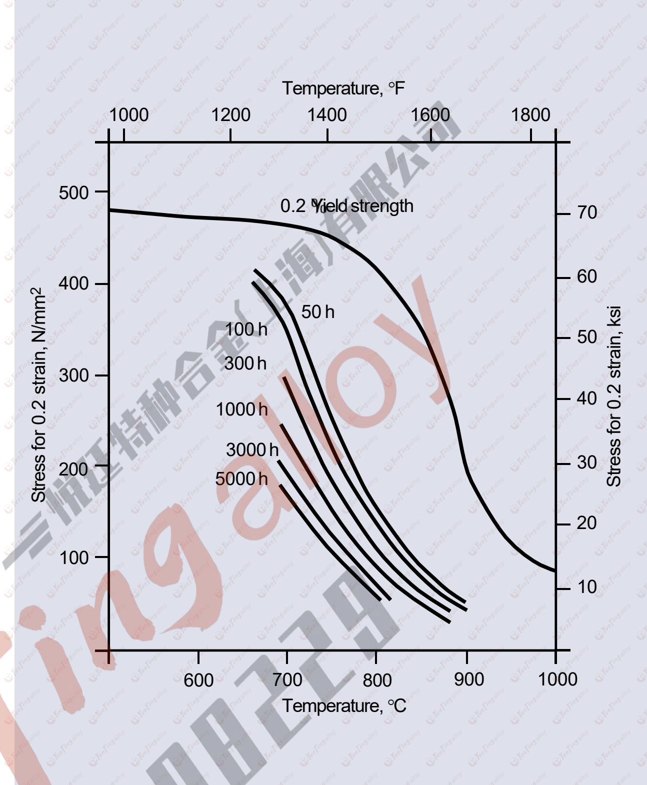

Fig. 2 – 0.2 % total plastic strain data for solution-treated and age hardened cold-rolled sheet.

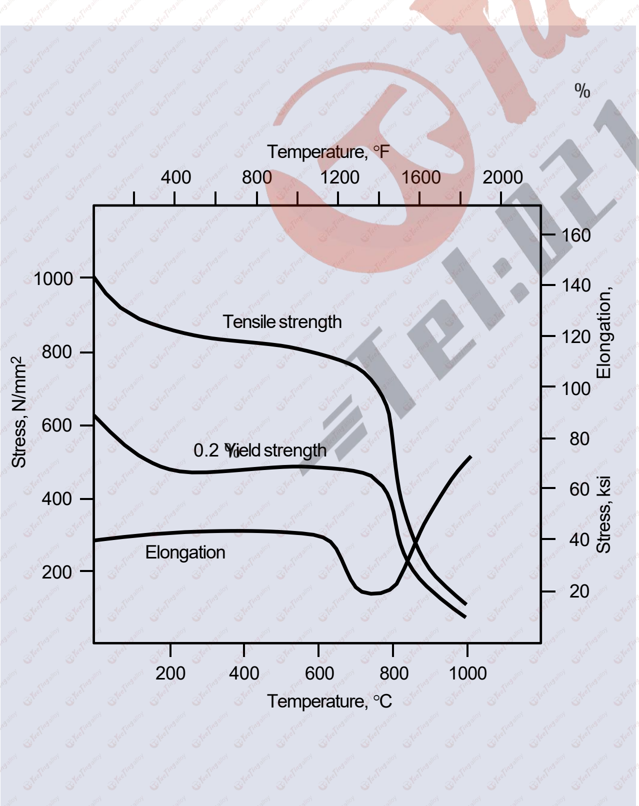

Fig. 1 – Typical short-time properties of solution-treated and precipitation-hardened Nicrofer 5120 CoTi sheet and plate at room and elevated temperatures.

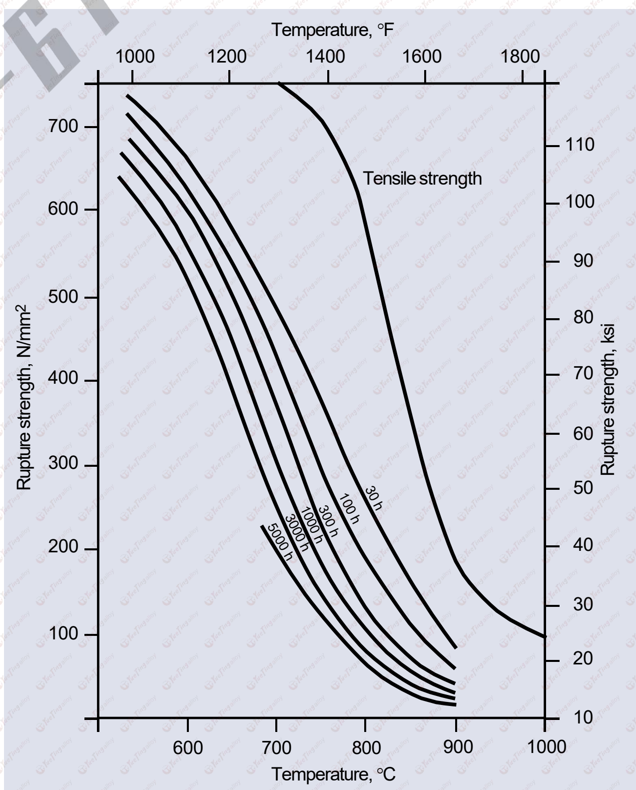

Fig. 3 – Creep rupture values of solution-treated and age hardened cold-rolled sheet.

Metallurgical structure

The high-temperature strength of Nicrofer 5120 CoTi is obtained by two strengthening mechanismus. The cobalt and molybdenum additions give solid-solution strengthening. The aluminium and titanium additions form precipitates of the γ'-phases Ni_3(Al, Ti) on age-hardening.

The cobalt addition also increases the solubility of γ' above 1100 °C (2010 °F), thus facilitating hot working despite the high aluminium and titanium contents.
Boron and zirconium also improve creep rupture properties.

In the fully heat-treated condition, the microstructure of Nicrofer 5120 CoTi shows fine discontinuous precipitates of carbides ($M_{23}C_6$) at the grain boundaries.

Continuous $M_{23}C_6$ films must be avoided, as this can lead to poor ductility and hot trearing during welding. Correct solution treatment will avoid this effect.

Corrosion resistance

Nicrofer 5120 CoTi shows excellent oxidation resistance up to 1000 °C (1830 °F).

Applications

Due to its high-temperature corrosion resistance and excellent high-temperature strength up to 815 °C (1500 °F), combined with ease of fabrication and weldability, Nicrofer 5120 CoTi findswide application in high-temperature service, especially in aircraft and istustrial gas turbines. Examples are combustion chambers, exhaust cones and rings.

Fabrication and heat treatment

Nicrofer 5120 CoTi is readily fabricated by usual industrial procedures.

Heating

It is very important that the workpiece be clean and free from any contaminant before and during heating.

Nicrofer 5120 CoTi 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 low in sulphur; e.g. natural and liquefied petroleum gases should contain less than 0.1 % by mass and town gas 0.25 g/m³ maximum of sulphur. Fuel oils containing no more than 0.5 % by mass 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 oxidizing and must not fluctuate between oxidising and reducing. Flame impingement on the metal must be avoided.

Hot working

Nicrofer 5120 CoTi may be hot-worked in the range 1170 to 950 °C (2140 to 1740 °F). Cooling should be by water quenching or as fast as possible.

During the final hot working operation, the temperature must not exceed 1120 °C (2050 °F).

Solution treatment is recommended after hot working to ensure optimum properties.

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

Cold working

Cold working should be carried out on solution-treated material. Nicrofer 5120 CoTi has a much higher work-hardening rate than austenitic stainless steel and the forming equipment must be adapted accordingly.

When cold working is performed, interstage annealing may become necessary.

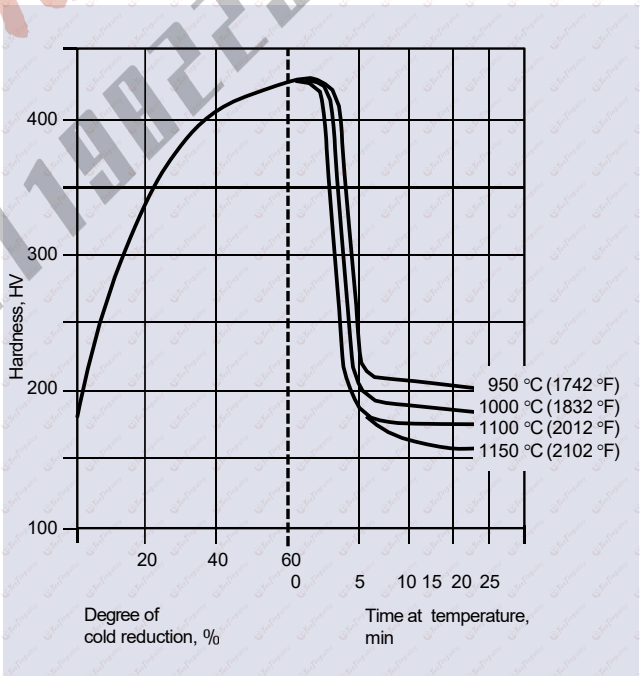

Fig. 4 – Influence of cold working and subsequent annealing on the hardness of cold-rolled sheet (1.0 to 1.5 mm/0.04 to 0.06 in.).

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Heat treatment Solution treatment should be carried out at 1150 ± 10 °C (2100 ± 15 °F),

sheet and plate 5 to 15 min. WQ or AC,
rod and bar 0.5 to 2.5 h WQ
to hardness of max. 230 HB.

Intermediate softening
between cold-forming processes
at 1080 ± 10 °C (1980 ± 15 °F),
4 to 6 min., AC.

Diffusion annealing
of welding seams
at 1150 °C (2100 °F)
1 h AC.

Precipitation heat treatment
should be carried out
at 800 ± 15 °C (1475 ± 25 °F),
ageing time at temperature 8 hours ± 0.5 h, AC to hardness of min. 275 HV.

During any heating operation the precautions outlined earlier regarding cleanliness must be observed.

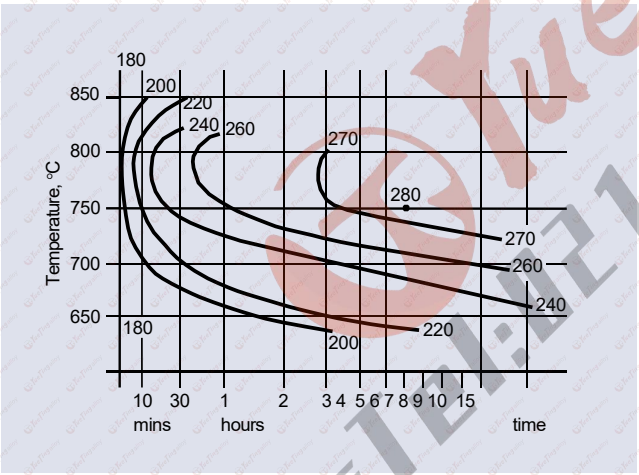

Fig. 5 – Effect of ageing time and temperature on hardness (HV) of solution-treated sheet material with initial hardness HV 30 – 180.

Descaling
Oxides of Nicrofer 5120 CoTi 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.

Machining
Nicrofer 5120 CoTi should be machined in the annealed condition. The alloy's high work-hardening rate should be considered; i.e. only low surface cutting speeds are possible compared with low-alloyed standard austenitic stainless steel. Tools should be engaged at all times. Heavy feeds are important in getting below the work-hardened 'skin'.

Joining
The precipitation-hardening alloy Nicrofer 5120 CoTi is suitable for the fabrication of complex welded structures, and can be repair-welded. Weld ductility, ease of fabrication and high strength are the main advantages of this quaternary alloying system.

Nicrofer 5120 CoTi can be welded by conventional processes as gas tungsten-arc (TIG/GTAW), plasma, laser, and electron-beam welding; heavier wall thicknesses can be welded with MIG pulsed-arc welding.

Matching material or the following welding products are recommended:

TIG/MIG-PA	Nicrofer S 5120	W.-Nr. 2.4650 NiCo20Cr20MoTi BS 2901 NA38

Prior to welding, material should be in the annealed condition, clean and free from scale, grease, marking paints, etc. A zone approximately 25 mm (1 in.) wide on each side ot the joint should be ground to bright metal.

Low heat input is necessary. Interpass temperature should not exceed 100 °C (210 °F).

Nicrofer 5120 CoTi is not susceptible to post-weld heat treatment cracking, due to the very low ageing rate which permits stress relief to take place prior to precipitation of γ'-phase. It is also free from heat-affected-zone cracking.

Availability

Nicrofer 5120 CoTi is available in the following standard mill products forms.

Sheet and plate

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

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

Thickness mm	hr/cr	Width* mm	Length* mm
1.10 – < 1.50	cr	2000	6000
≥ 1.50 – < 6.0	cr	2000	6000
≥ 6.0 – < 10.0	cr	2000	4000**
≥ 6.0 – < 10.0	hr	2000	4000**
≥ 10.0 – < 20.0	hr	2000	2500**
≥ 20*	hr		
inches		inches	inches
0.043 – < 0.060	cr	80	240
≥ 0.060 – < 1/4	cr	80	240
≥ 1/4 – < 3/8	cr	80	160**
≥ 1/4 – < 3/8	hr	80	160**
≥ 3/8 – < 3/4	hr	80	120**
≥ 3/4*	hr		

*other sizes subject to special enquiry
**depending on piece weight

Disc and ring

Conditions:
hot rolled or forged, solution-treated, pickled or machined

Product	Weight kg	Thickness mm	o.d.* mm	i.d. mm
Disc	≤ 4000	≤ 200	≤ 2000	–
Ring	≤ 3000	≤ 200	≤ 2500	on request
	lb	inches	inches	inches
Disc	≤ 8800	≤ 8	≤ 80	–
Ring	≤ 6600	≤ 8	≤ 100	on request

*other sizes subject to special enquiry

Rod and bar

Conditions:
forged, rolled, drawn,
solution-treated or precipitation hardened,
pickled, machined, peeled or ground

Product	forged* mm	rolled* mm	drawn* mm
round d	≤ 200	15 – 75	12 – 65
square a	40 – 300	15 – 100	12 – 65
flat a x b	40 – 80 x 200 – 600	5 – 20 x 120 – 600	10 – 20 x 30 – 80
hexagon s	40 – 80	13 – 50	12 – 60
	inches	inches	inches
round d	≤ 8	5/8 – 3	1/2 – 2 1/2
square a	1 5/8 – 12	5/8 – 4	1/2 – 2 1/2
flat a x b	1 5/8 – 3 1/8 x 8 – 24	3/16 – 3/4 x 5 – 24	3/8 – 3/4 x 1 1/4 – 3 1/8
hexagon s	1 5/8 – 3 1/8	1/2 – 2	1/2 – 2 3/8

*other sizes subject to special enquiry

Forgings

Shapes other than discs, rings, rod and bar are subject to special enquiry.

Strip*

Conditions:
cold rolled, annealed and pickled
or bright annealed**

Thickness mm	Width mm	Coil i.d. mm				
0.04 – ≤ 0.10	30 – 120	100	300			
> 0.10 – ≤ 0.20	4 – 200		300	400		
> 0.20 – ≤ 0.25	4 – 400		300	400		
> 0.25 – ≤ 0.60	5 – 635		300	400		
> 0.60 – ≤ 1.0	8 – 635			400	500	
> 1.0 – ≤ 2.0	15 – 635			400	500	600
> 2.0 – 3.0	25 – 635			400	500	600
inches	inches	inches				
0.0016 – ≤ 0.004	1.20 – 5 4		12			
> 0.004 – ≤ 0.008	0.16 – 8		12	16		
> 0.008 – ≤ 0.010	0.16 – 16		12	16		
> 0.010 – ≤ 0.024	0.20 – 25		12	16		
> 0.024 – ≤ 0.04	0.32 – 25			16	20	
> 0.04 – ≤ 0.08	0.60 – 25			16	20	24
> 0.08 – - 0.12	1.0 – 25			16	20	24

*cut-to-length available in lengths from 500 to 3000 mm (20 to 120 in.)
**maximum thickness 3.0 mm (1/8 in.)

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

Dimensions:
0.01 – 12.7 mm (0.0004 – 1/2 in.) diameter
in coils, pay-off packs, on spools and spiders.

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

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