

VDM® Cronifer 40 B

Cronifer® 40 B

Cronifer® 40 B is a cost effective alloy for heating elements with superior properties.

Cronifer® 40 B is characterized by:

- sagging behavior similar to Cronifer® II
- excellent corrosion resistance at high temperatures

- excellent life time
- ease of working and processing
- a reduced nickel content compared to Cronifer II

Designations and standards

Country	Material designation	Specification		
		Chemical composition	Sheet & Plate	Strip
National standards				
D DIN EN	1.4888 X10NiCrSiLa 38-22			

Table 1 - Designations and standards.

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Al	La	S	P	Cu
min.	36	20	bal.			1.3		0.03			
max.	39	23		0.12	1.0	2.2	0.5	0.20	0.03	0.03	0.5

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

Physical properties

Density	7.95 g/cm ³	0.287 lb/in. ³
Melting range	1350 °C (Solidus) - 1395 °C (Liquidus)	2462 °F (Solidus) - 2543 °F (Liquidus)

Temperature (T)		Electrical resistivity (ρ)		Temperature factor $c_t = \rho(T)/\rho(20\text{ °C})$	Thermal conductivity		Specific heat		Coefficient of thermal expansion between 20 °C/68°F and T	
°C	°F	μΩ·cm	Ω·circ mil ft		$\frac{W}{m \cdot K}$	$\frac{Btu \cdot in.}{ft^2 \cdot h \cdot °F}$	$\frac{J}{kg \cdot K}$	$\frac{Btu}{lb \cdot °F}$	$\frac{10^{-6}}{K}$	$\frac{10^{-6}}{°F}$
20	68	106	638	1.00	12	83	490	0.117		
100	212	109	654	1.03	13	90	500	0.120		
200	392	112	674	1.06	14	97	510	0.122	16.4	9.1
300	572	116	695	1.09						
400	752	118	712	1.12	18	125	540	0.129	16.7	9.3
500	932	121	725	1.14						
600	1112	122	735	1.15	21	146	595	0.142	17.0	9.4
700	1292	124	744	1.16						
800	1472	125	753	1.18	23	160	600	0.143	17.3	9.2
900	1652	127	763	1.20						
1000	1832	128	773	1.21	26	180	640	0.153	17.8	9.9

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

Mechanical properties

Product	0.2 % Yield strength $R_{p0.2}$		Tensile strength R_m		Elongation A %	Hardness HV (For information only)
	MPa	ksi	MPa	ksi		
Wire	≥ 270	≥ 39.2	≥ 600	≥ 87.0	$A_{100} \geq 28$ *)	–
Strip	≥ 270	≥ 39.2	≥ 600	≥ 87.0	$A_{50} \geq 35$ $A_5 \geq 40$	140 - 200

*) Diameter ≥ 0.4 mm

Table 4 - Minimum mechanical properties in the solution-annealed condition for different product forms at room temperature.

Product	0.2 % Yield strength $R_{p0.2}$		Tensile strength R_m		Elongation A
	MPa	ksi	MPa	ksi	%
Wire	350	50.8	700	102	32 (A_{100})
Strip	330	47.9	650	94.3	45 (A_5)

Table 5 - Typical mechanical properties at room temperature.

Temperature T		0.2 % Yield strength $R_{p0.2}$		Tensile strength R_m		Elongation A_{50}
°C	°F	MPa	ksi	MPa	ksi	%
20	68	330	48	689	100	37
100	212	272	39	611	89	42
300	572	228	33	595	86	44
500	932	203	29	582	84	40
600	1112	192	28	510	74	48
700	1292	170	25	319	46	61
800	1472	132	19	156	23	29
900	1652	74	11	88	13	22
1000	1832	34	4.9	39	5.6	23

Table 6 - Typical mechanical properties for strip (2 mm thick, grain diameter 37 μ m) at elevated temperatures.

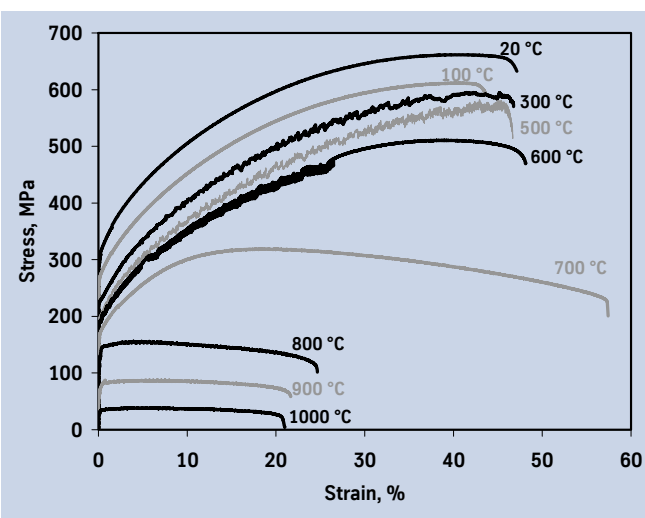


Fig. 1 - Stress-Strain curves for Cronifer® 40 B at various temperatures.

Sagging test

Cronifer® 40 B has superior mechanical properties at high temperatures in comparison to other heating element alloys. During operation at high temperatures, the wire coils must not sag to the extent that they could touch the unit's housing and produce a short circuit. To measure the extent to which the heating coils sag, wire of 1.29 mm diameter is wound into heating coils with an inside diameter of 14 mm and 31 windings. The coils are then inserted into fasteners, separated by 100 mm and electrically heated to a starting temperature of 1000 °C. Every 30 seconds the current is interrupted for 30 seconds. Every test is done with at least 4 coils from the same production lot. After four

hours of operation, the amount to which the coils have sagged in the middle is measured and averaged over the coils of the same test. Figure 2 shows the results for Cronifer® II, Cronifer® III and Cronifer® 40 B. All wires had the same grain size of 22 µm, because grain size also influences the sagging of the heating element coil. Cronifer® II sagged by about 5.5 mm, Cronifer® III by about 7 mm and an alloy with 40 % nickel melted according to the same principles as Cronifer® II also by about 7 mm. Cronifer® 40 B sagged by only 4 mm and therefore showed superior properties.

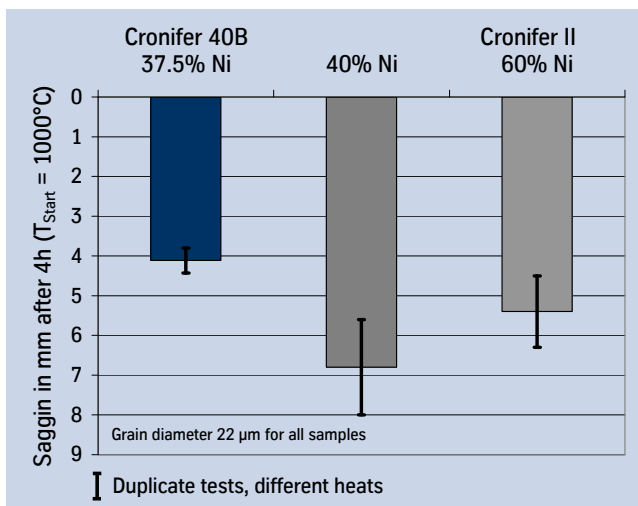


Fig. 2 – Sagging of electrically heated coils of different materials for heating elements. Measured at a starting temperature of 1000 °C on wires with a diameter of 1.29 mm.

Metallurgical structure

Cronifer® 40 B has a face-centered-cubic structure.

Corrosion resistance

Cronifer® 40 B shows excellent oxidation resistance. This is the result of its high chromium and silicon content. The scale is very resistant to spalling because of the addition of about 0.1 % lanthanum.

The life time of alloys for heating elements is tested on wire of 0.40 mm diameter. The wire is heated electrically to a temperature of 1150 °C., with the current being interrupted for 15 seconds every two minutes. Each test is done with 5 samples from the same production lot, which are averaged.

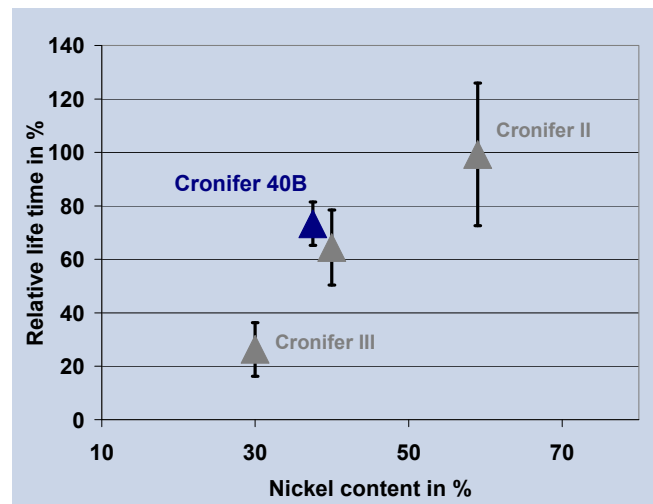


Fig. 3 - Relative life time of various alloys for heating elements.

Figure 3 shows the relative life time of various heating element alloys, as a function of nickel content. Life time rises with increasing nickel content. Cronifer® 40 B has a life time that is significantly above that of the standard alloys. Its life time is 80 % that of Cronifer® II and more than three times that of Cronifer® III.

Applications

- Electric furnaces
- Open heating elements for appliances
- Resistors
- Exhaust systems

Fabrication and heat treatment

Cronifer® 40 B can be hot and cold worked and machined.

Heating

Production pieces must be clean and free from all kinds of contaminants before and during any heating operation.

Cronifer® 40 B may become embrittled, if heated in the presence of contaminants such as sulfur, 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 sulfur as possible. Natural gas should contain less than 0.1 wt.-% sulfur. Liquid fuels with a sulfur content not exceeding 0.5 wt.-% are suitable.

Due to their close control of temperature and lack of contamination, thermal treatments in electric furnaces under vacuum or in 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 kept at low levels so that a neutral or slightly oxidizing furnace atmosphere is attained.

A furnace atmosphere fluctuating between oxidizing and reducing conditions must be avoided as well as direct flame impingement on the metal.

Cold working

For cold working the solution-annealed condition is recommended.

Heat treatment

Solution annealing can be performed at temperatures typically above 1150 °C., followed by quenching in water or fast cooling with air or a protective atmosphere.

After cold forming a recrystallization heat treatment typically above 1150 °C., is required.

Descaling and pickling

Oxides of Cronifer® 40 B and discoloration adjacent to welds are more adherent than on standard 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, the surface oxide layer must be broken up by abrasive blasting, by carefully performed grinding or by pretreatment in a molten salt bath. Particular attention should be paid to the pickling time and temperature.

Design heating elements

B&S Gauge	Diameter		Nominal Resistance		Weight Factor	
	mm	In.	Ω/m	Ω/ft	m/kg	ft/lb
14	1.628	0.0641	0.509	0.155	60.4	89.9
14.5	1.536	0.0605	0.572	0.174	67.9	101.0
15	1.450	0.0571	0.642	0.196	76.2	113.4
15.5	1.368	0.0539	0.721	0.220	85.6	127.4
16	1.291	0.0508	0.810	0.247	96.1	143.0
16.5	1.218	0.0480	0.910	0.277	108.0	160.7
17	1.150	0.0453	1.021	0.311	121.1	180.2
17.5	1.085	0.0427	1.146	0.349	136.0	202.5
18	1.024	0.0403	1.287	0.392	152.7	227.3
18.5	0.966	0.0380	1.446	0.441	171.6	255.4
19	0.912	0.0359	1.623	0.495	192.6	286.6
19.5	0.860	0.0339	1.825	0.556	216.5	322.3
20	0.812	0.0320	2.047	0.624	242.9	361.5
21	0.723	0.0285	2.582	0.787	306.4	455.9
22	0.644	0.0254	3.254	0.992	386.2	574.7
23	0.573	0.0226	4.111	1.253	487.8	725.9
24	0.511	0.0201	5.169	1.575	613.3	912.8
25	0.455	0.0179	6.519	1.987	773.6	1151.3

Table 7 – Information commonly used in the design of heating coils.

Availability

Cronifer® 40 B is available as strip and wire.

Strip¹⁾**Conditions**

cold rolled, solution annealed and pickled or bright annealed²⁾

Thickness mm	Width ³⁾ mm	Coil I.D. mm
0.02 - ≤ 0.10	4 - 200 ⁴⁾	300 400
> 0.10 - ≤ 0.20	4 - 350 ⁴⁾	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 ²⁾ - ≤ 3.5 ²⁾	25 - 750	400 500 600

¹⁾ Cut-to-length available in lengths from 250 to 4000 mm

²⁾ Maximum thickness: bright annealed - 3 mm
cold rolled only - 3.5 mm

³⁾ Wider widths subject to special enquiry

⁴⁾ Wider widths up to 730 mm subject to special enquiry

Thickness inches	Width ³⁾ inches	Coil I.D. inches
0.0008 - ≤ 0.004	0.16 - 8 ⁴⁾	12 16
> 0.004 - ≤ 0.008	0.16 - 14 ⁴⁾	12 16 20
> 0.008 - ≤ 0.010	0.16 - 30	16 20 24
> 0.010 - ≤ 0.024	0.24 - 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 ²⁾ - ≤ 0.140 ²⁾	1.00 - 30	16 20 24

¹⁾ Cut-to-length available in lengths from 10 to 158 in.

²⁾ Maximum thickness: bright annealed - 0.120 in.
cold rolled only - 0.140 in.

³⁾ Wider widths subject to special enquiry

⁴⁾ Wider widths up to 29 in. subject to special enquiry

Wire**Conditions**

Cold drawn, bright annealed or annealed and oxidized

Dimensions

Round wire: 0.01 to 12.0 mm (0.0004 to 0.48 in.) diameter

Flat wire: 0.08 – 1.5mm x 0.4 – 5.5 mm (0.003 - 0.06 x
0.016 - 0.22 in.)

in coils, carriers, standard drums, spools and special
spools.

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