NIMONIC® alloy 91 is a wrought nickel-chromium-cobalt based alloy strengthened by additions of aluminum and titanium.

This alloy is a modification of NIMONIC alloy 90, but has an increased chromium content to improve corrosion resisistance in salt and sulfur contaminated environments. The alloy is suitable for long service up to about 900°C. It combines good strength and ductility with stability of microstructure and excellent resistance to hot corrosion.

NIMONIC alloy 91 is intended for high-temperature stressed parts such as blades in gas turbines burning impure fuels or operating in marine environments.

Table 1 - Chemical Composition, %

Carbon	0.10 max.
Silicon	1.0 max.
Copper	0.5 max.
Iron	1.0 max.
Manganese	1.0 max.
Chromium	27.0-30.0
Titanium	1.9-2.7
Aluminum	0.9-1.5
Cobalt	19.0-21.0
Niobium	0.4-1.1
Nickel	Balance*
Boron	0.002-0.01
Zirconium	0.1 max.

*Reference to the 'balance' of a composition does not guarantee this is exclusively of the element mentioned but that it predominates and others are present only in minimal quantities.

Physical Properties

Table 2 - Physical Properties

Density*, Mg/m^3	8.08
Melting Range,	
Liquidus temperature	1350°C
Solidus temperature (estimated)	1300°C

*The exact density of NIMONIC alloy 91 is dependent on compositional variation within the release specification.

Heat Treatment

NIMONIC alloy 91 should be heat-treated in at least two stages involving solution treatment at temperatures above 950°C followed by aging in the range 600-900°C.

The recommended heat-treatment is as follows: 4h/1150°C/ AC + 16h/850°C/AC.

Table 3 - Young's Modulus (static)

°C	GPa
20	222
100	204
200	218
300	195
400	207
500	163
600	167
700	149
800	159
900	132
1000	108

Table 4 - Specific Heat

°C	J/kg °C
20	447
100	468
200	495
300	521
400	548
500	574
600	601
700	627
800	654
900	680
1000	707

NIMONIC® alloy 91

Tensile Properties

Table 5- Tensile Properties of Extruded and Forged Bar

Heat Treatment 4h/1150°C/AC + 16h/850°C/AC

°C	0.1% Proof Stress MPa	0.2% Proof Stress MPa	Tensile Strength MPa	Elongation %	Reduction %
20	657	663	1180	31.2	29.3
200	599	610	1126	29.6	31.5
400	533	544	1001	28.0	26.6
600	530	547	993	21.6	23.5
700	561	581	947	28.0	27.9
800	535	556	644	25.6	24.9
900	293	315	365	22.4	24.2
1000	59	61	96	137.8	98.0

The data given in Table 5 and presented graphically in Fig. 1 are for extruded and forged bar after the recommended heat treatment. The test pieces were 30 mm gauge length by 5.6 mm diameter.

Strain rate 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures) and 0.1/min thereafter.

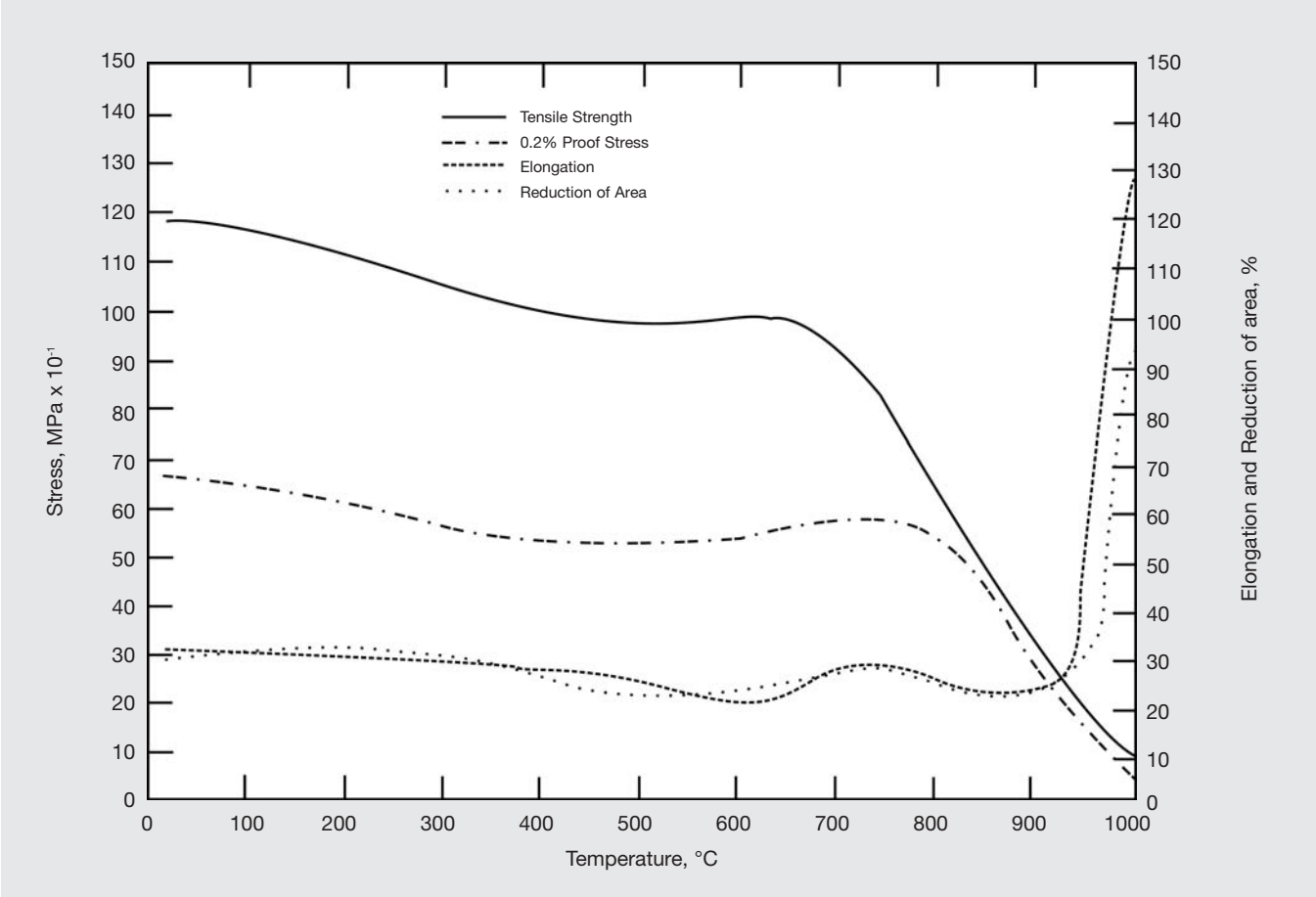


Figure 1. Tensile properties of extruded and forged bar. Heat treatment 4h/1150°C/AC + 16h/850°AC.

Thermal Fatigue Properties

The results of fatigue tests on NIMONIC alloy 91 and, for comparison, NIMONIC alloy 90 are shown in Table 6. Tests were carried out on tapered disc specimens 41.3 mm diameter by 0.25 mm edge radius in hot and cold fluidized beds.

Table 6 - Thermal Fatigue Properties

Peak temperature °C	Cycle to first microscopically distinguishable cracks	
	NIMONIC alloy 91	NIMONIC alloy 90
900	150-170	49 (4 tests)
1000	30-35	11 (4 tests)

Impact Data

The room temperature Charpy V-notch impact strength values of NIMONIC alloy 91 are as shown in Table 7. The test specimens were heat-treated 4h/1150°C/AC then exposed as indicated in the table. Test pieces were unstressed at 850°C, but under a stress of 231 MPa at 750°C.

Table 7 - Impact Values at Room Temperature

Soaking Time h	Soaking Temperature °C	Impact Value J
2020	750	16.3
1000	850	32.5 to 38

Creep-Rupture Properties

Figure 2 gives creep-rupture properties for NIMONIC alloy 91 extruded and forged bar after the recommended heat treatment. Results on extruded and cold-rolled bar are also given in Table 8. The properties for NIMONIC alloy 90 are also given in Figure 2 for comparison. Test pieces were 23 mm gauge length by 2.3 mm diameter. Larson-Miller curves should not be used for extrapolation much outside the test results shown.

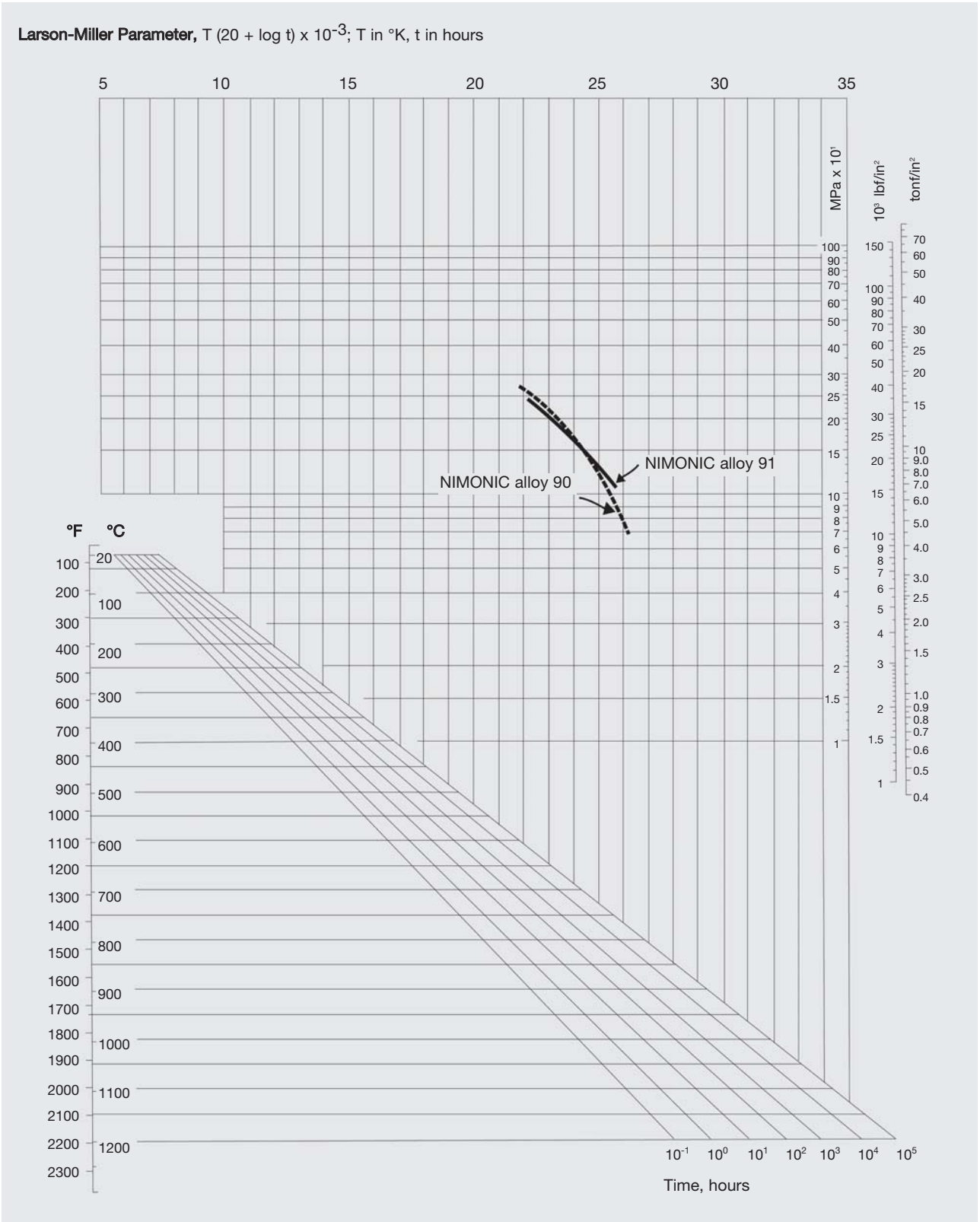
Table 8 - Creep-Rupture Properties of Bar

Heat Treatment 4h/1150°C/AC + 16h/850°C/AC

Test Condition		Extruded and Cold-Rolled		Extruded and Forged	
Stress MPa	°C	Life h	Elongation %	Life h	Elongation %
386	750	–	–	74	4.4
248	815	–	–	77	5.2
250	815	–	–	81	6.8
250	815	–	–	87	6.7
250	815	–	–	94	8.4
250	815	–	–	90	7.8
250	815	–	–	90	8.2
139	870	154	11.1	171	10.6
139	870	115	8.4	–	–
139	870	154	13.1	–	–
139	870	148	12.8	–	–

Creep-Rupture Properties (continued)

Figure 2. Creep-rupture properties for extruded and forged bar.
Heat treatment 4/1150°C/AC + 16h/850°C/AC



Corrosion Resistance

Static and cyclic oxidation tests were carried out on NIMONIC alloy 91 using cylindrical specimens 15 mm long by 12 mm diameter. Static oxidation test results on NIMONIC alloy 90 are given for comparison. The weight change was determined after descaling in molten NaOH + 1½% NaH.

Table 9 - Static Oxidation Properties

°C	Weight loss, mg/cm², at 100 hours	
	NIMONIC alloy 91	NIMONIC alloy 90
700	1.25	1.38	1.31
800	2.54	2.38	2.25
900	5.40	5.30	9.28
1000	10.90	10.00	10.4

Table 10 - Cyclic Oxidation Properties. Weight Change, mg/cm²

°C	Exposure time, hours								
	20	86	132	228	292	476	660	825	970
990	+0.84	+1.28	+1.89	+3.64	+3.08	-34.7	-67.9	-96.6	-134
1010	+0.94	+1.24	+1.97	+4.14	-11.62	-64.6	-109.6	-153	-205
1090	+0.26	+0.30	+2.61	-39.1	-77.7	-197	-292	-385	-470
1110	-0.32	+0.39	+2.81	-69.6	-121.0	-252	-376	-501	-563

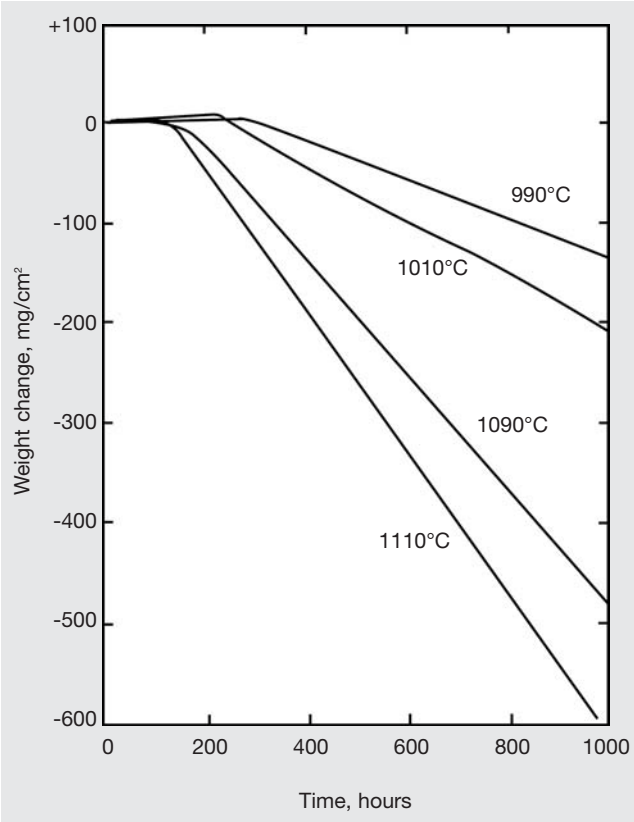


Figure 3. Cyclic oxidation properties of NIMONIC alloy 91.

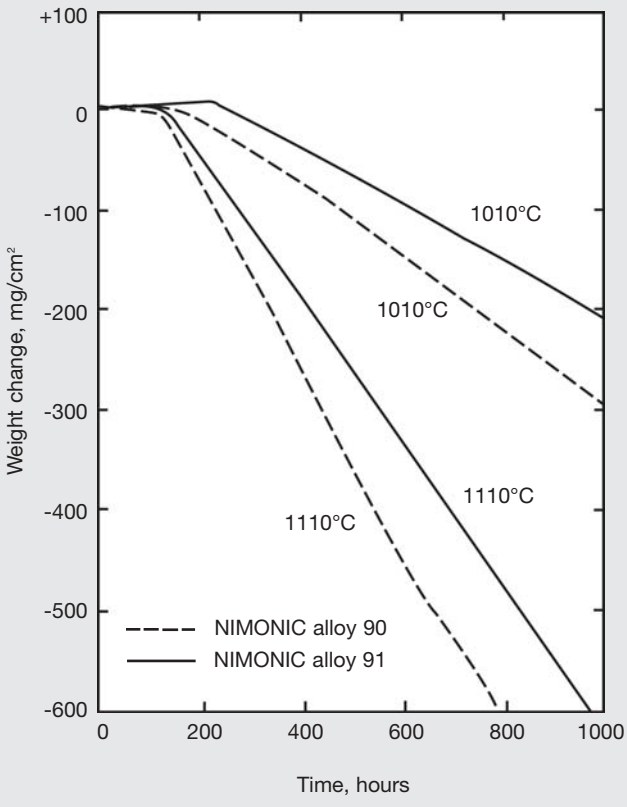


Figure 4. Cyclic oxidation properties of NIMONIC alloy 91 and NIMONIC alloy 90.

Corrosion Resistance (continued)

Table 11 - Fused Salt Half-Immersion Tests[a]

Alloy	Weight loss, mg/cm²					
	700°C		800°C		900°C	
	16h	300h	16h	300h	16h	300h
NIMONIC alloy 91	17.5, 7.08	26.4, 13.6	1.80,1.81	52.4, 28.0	3.57, 3.83	20.3, 19.2
NIMONIC alloy 90	15.2	34.6	–	399	1680	–

[a] In Na_2SO_4+25% NaCl heated in air. The weight loss was determined after descaling in molten NaOH+1½% NaH. The test specimens were 15 mm long by 12 mm diameter.

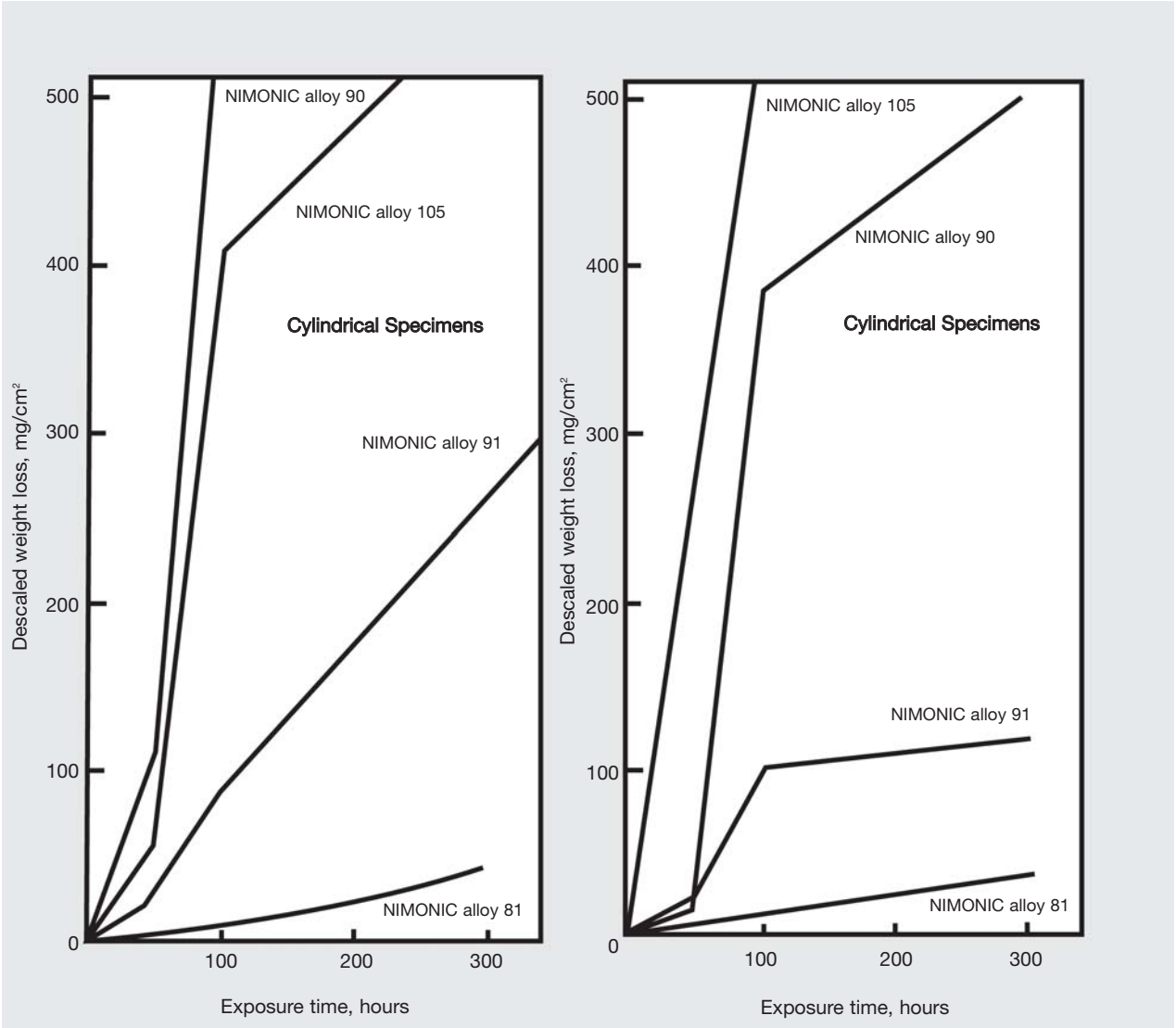


Figure 5. Corrosion resistance to 75% Na_2SO_4, 25% NaCl at 800°C. Salt shower test.

Figure 6. Corrosion resistance to 75% Na_2SO_4, 25% NaCl at 900°C. Salt shower test.

Fabrication

Hot Working

NIMONIC alloy 91 may be hot worked in the temperature range 950-1175°C.

Annealing

Interstage annealing should be carried out at 1150°C followed by free cooling in air or fluidized bed quenching.

Machining

NIMONIC alloy 91 should be in the fully heat-treated condition for all machining operations. The hardness range 290-370 HV necessitates the use of tungsten carbide tipped tools. High speed steel shock-proof tools should be used if the cut is of an intermittent nature.

Available Forms

NIMONIC alloy 91 is generally available in the following forms, subject to minimum order quantities:

bar for forging
rod and bar for machining
extruded section for direct machining

Other forms are subject to inquiry.

Specifications

Supplied to customer's specification, subject to agreement.

Publication Number SMC-074

SPECIAL METALS

www.specialmetals.com

U.S.A.
Special Metals Corporation

Billet, rod & bar, flat & tubular products
3200 Riverside Drive
Huntington, WV 25705-1771
Phone +1 (304) 526-5100
+1 (800) 334-4626
Fax +1 (304) 526-5643

Billet & bar products
4317 Middle Settlement Road
New Hartford, NY 13413-5392
Phone +1 (315) 798-2900
+1 (800) 334-8351
Fax +1 (315)798-2016

Atomized powder products
100 Industry Lane
Princeton, KY 42445
Phone +1 (270) 365-9551
Fax +1 (270) 365-5910

Shape Memory Alloys
4317 Middle Settlement Road
New Hartford, NY 13413-5392
Phone +1 (315) 798-2939
Fax +1 (315) 798-6860

United Kingdom

Special Metals Wiggin Ltd.
Holmer Road
Hereford HR4 9SL
Phone +44 (0) 1432 382200
Fax +44 (0) 1432 264030

Special Metals Wire Products
Holmer Road
Hereford HR4 9SL
Phone +44 (0) 1432 382556
Fax +44 (0) 1432 352984

China

Special Metals Pacific Pte. Ltd.
Room 1802, Plaza 66
1266 West Nanjing Road
Shanghai 200040
Phone +86 21 3229 0011
Fax +86 21 6288 1811

Special Metals Pacific Pte. Ltd.
Room 910, Ke Lun Mansion
12A Guanghua Road
Chaoyang District
Beijing 100020
Phone +86 10 6581 8396
Fax +86 10 6581 8381

France

Special Metals Services SA
17 Rue des Frères Lumière
69680 Chassieu (Lyon)
Phone +33 (0) 4 72 47 46 46
Fax +33 (0) 4 72 47 46 59

Germany

Special Metals Deutschland Ltd.
Postfach 20 04 09
40102 Düsseldorf
Phone +49 (0) 211 38 63 40
Fax +49 (0) 211 37 98 64

Hong Kong

Special Metals Pacific Pte. Ltd.
Unit A, 17th Floor, On Hing Bldg
1 On Hing Terrace
Central, Hong Kong
Phone +852 2439 9336
Fax +852 2530 4511

India

Special Metals Services Ltd.
No. 60, First Main Road, First Block
Vasantha Vallabha Nagar
Subramanyapura Post
Bangalore 560 061
Phone +91 (0) 80 2666 9159
Fax +91 (0) 80 2666 8918

Italy

Special Metals Services SpA
Via Assunta 59
20054 Nova Milanese (MI)
Phone +390 362 4941
Fax +390 362 494224

The Netherlands

Special Metals Service BV
Postbus 8681
3009 AR Rotterdam
Phone +31 (0) 10 451 44 55
Fax +31 (0) 10 450 05 39

Singapore

Special Metals Pacific Pte. Ltd.
24 Raffles Place
#27-04 Clifford Centre
Singapore 048621
Phone +65 6532 3823
Fax +65 6532 3621

Affiliated Companies

Special Metals Welding Products
1401 Burris Road
Newton, NC 28658, U.S.A.
Phone +1 (828) 465-0352
+1 (800) 624-3411
Fax +1 (828) 464-8993

Canada House
Bidavon Industrial Estate
Waterloo Road
Bidford-On-Avon
Warwickshire B50 4JN, U.K.
Phone +44 (0) 1789 491780
Fax +44 (0) 1789 491781

Controlled Products Group
590 Seaman Street, Stoney Creek
Ontario L8E 4H1, Canada
Phone +1 (905) 643-6555
Fax +1 (905) 643-6614

A-1 Wire Tech, Inc.
A Special Metals Company
4550 Kishwaukee Street
Rockford, IL 61109, U.S.A.
Phone +1 (815) 226-0477
+1 (800) 426-6380
Fax +1 (815) 226-0537

Rescal SA
A Special Metals Company
200 Rue de la Couronne des Prés
78681 Epône Cédex, France
Phone +33 (0) 1 30 90 04 00
Fax +33 (0) 1 30 90 02 11

DAIDO-*SPECIAL METALS* Ltd.
A Joint Venture Company
Daido Shinagawa Building
6-35, Kohnan 1-chome
Minato-ku, Tokyo 108-0057, Japan
Phone +81 (0) 3 5495 7237
Fax +81 (0) 3 5495 1853