

NIMONIC® alloy PE16 is a wrought nickel-chromium-iron-base alloy strengthened by additions of molybdenum, titanium and aluminum. It was developed for service mainly in the temperature range 500-750°C, and combines the high strength of the age hardening nickel-base alloys with excellent fabricational characteristics.

The alloy is used in gas turbine flame tubes, nuclear reactor parts, missile hot components, superheater tubing, and aircraft ducting systems.

Composition, %

Carbon	0.04-0.08
Silicon	0.5 max.
Manganese	0.2 max.
Sulfur	0.015 max.
Silver	0.0005 max.
Aluminum	1.1-1.3
Boron	0.005 max.
Bismuth.....	0.0001 max.
Cobalt	2.0 max.
Chromium.....	15.5-17.5
Copper.....	0.5 max.
Molybdenum	2.8-3.8
Nickel + Cobalt	42.0-45.0
Lead.....	0.0015 max.
Titanium.....	1.1-1.3
Zirconium	0.02-0.04
Iron	Balance*

*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 1- Physical Properties

Density, Mg/m ³	8.00
lb/in ³	0.289
Melting Range	
Liquidus Temperature, °C.....	1355
Solidus Temperature, °C	1310
Specific Heat, (20-400°C), J/kg°C.....	544

The exact density of NIMONIC alloy PE16 is dependent on compositional variation within the release specification, on form and on heat treatment.

Heat Treatment

The heat treatment recommended for NIMONIC alloy PE16 is dependent on the intended service condition. Two are recommended, namely:

- (a) 4 h/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC
- (b) 2 h/1040°C/AC + 2 h/800°C/AC + 16 h/700°C/AC

Data shows that heat treatment (b) gives slightly higher creep-rupture properties at longer times. Heat treatment (a) gives material of greater metallurgical stability, and is recommended for general applications. If high proof stress up to 600°C is the sole criterion then heat treatment (b) should be applied.

For both the above heat treatments, the first stage at 1040°C should be for 5-15 minutes for thin section material such as sheet.

WELDING

Welding should be carried out in the solution-treated condition. Post-weld heat treatments of either

- 1 h/900°C/AC + 8 h/750°C/AC or
- 2 h/800°C/AC + 16 h/700°C/AC

should then be applied, depending on the intended service condition. This practice will generally yield good properties in both the weld metal and weld area.

Details of welding practice are given subsequently under Fabrication.

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Physical Properties (continued)

Table 2 - Thermal Conductivity and Electrical Resistivity

°C	Thermal Conductivity W/m °C	Electrical Resistivity at 20°C = 1.1 MΩm
		Relative Resistance
20	11.72	1.000
100	13.82	1.022
200	15.07	1.047
300	16.75	1.073
400	18.42	1.094
500	19.68	1.109
600	21.35	1.121
700	23.03	1.132
800	25.12	1.129
900	26.80	1.129
1000	28.47	1.139

Table 3 - Mean Coefficient of Linear Thermal Expansion

°C	µm/m - °C
20-100	13.8
20-200	14.6
20-300	14.9
20-400	15.1
20-500	15.5
20-600	16.0
20-700	16.4
20-800	17.2
20-900	18.0
20-1000	18.5

Dynamic Moduli

Table 4 - Dynamic Moduli

°C	Dynamic Young's Modulus GPa	Dynamic Torsional Modulus GPa
20	198	74
100	193	73
200	187	71
300	180	69
400	175	66
500	168	62
600	161	59
700	153	55
800	144	53
900	134	48
1000	122	42

Tensile Properties

The data given in Tables 5 and 6, and presented graphically in Figures 1 and 2, are for extruded and subsequently cold stretched bar after application of the two recommended heat treatments.

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.

Table 5 - Tensile Properties of Bar

Heat treatment 4 h/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC

°C	0.2% Proof Stress MPa	Tensile Strength MPa	Elongation on 5.56 √So, %	Reduction of Area %
20	450	830	29	55
100	425	810	29	54
200	395	780	30	54
300	380	770	31	54
400	365	750	31	55
500	380	730	31	55
600	410	680	30	51
700	410	590	28	35
800	290	350	37	52
900	100	140	74	96
1000	50	80	>100	98

Table 6 - Tensile Properties of Bar

Heat treatment 2 h/1040°C/AC + 2 h/800°C/AC + 16 h/700°C/AC

°C	0.2% Proof Stress MPa	Tensile Strength MPa	Elongation on 5.56 √So, %	Reduction of Area %
20	525	880	37	54
100	500	850	35	55
200	480	810	33	55
300	470	800	29	55
400	465	780	27	54
500	470	750	26	53
600	475	730	27	51
700	445	620	33	51
800	290	380	53	63
900	100	140	>100	94
1000	50	90	>100	99

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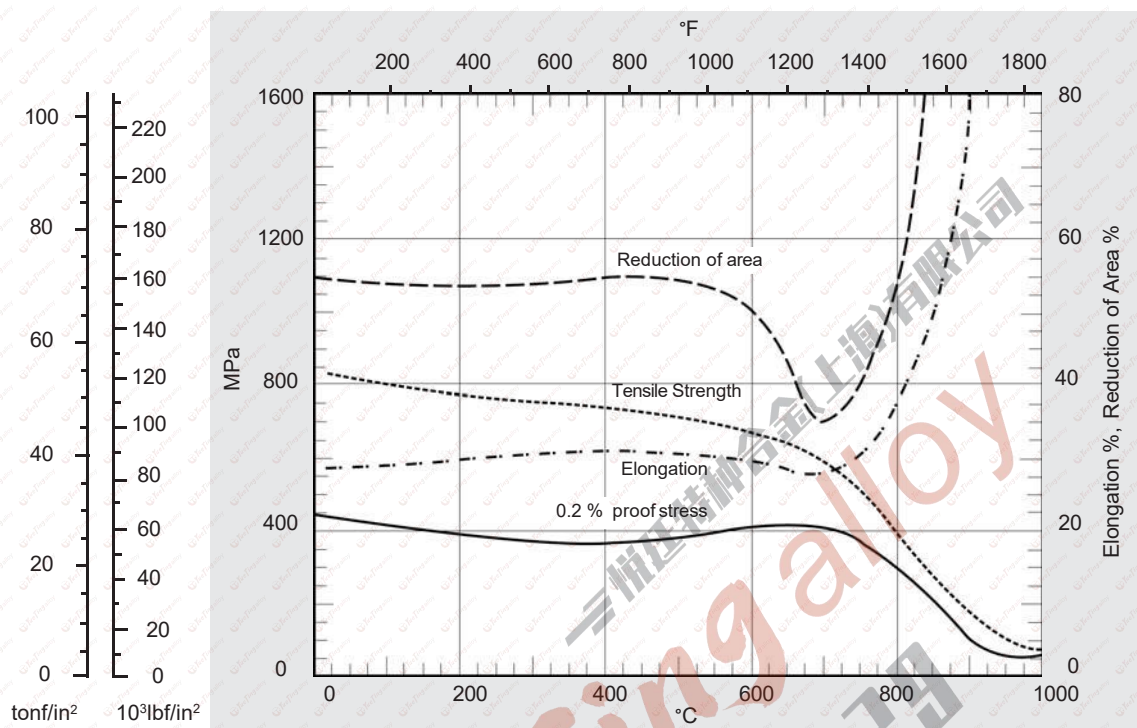


Figure 1. Tensile properties of bar
Heat treatment 4 h/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC

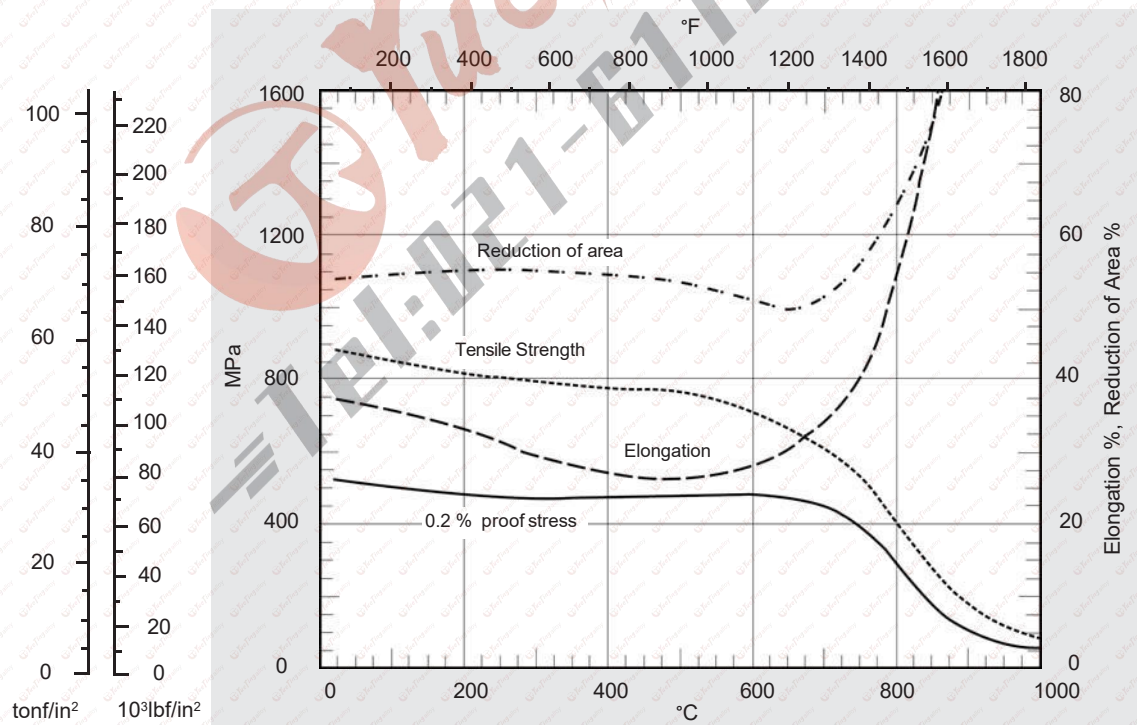


Figure 2. Tensile properties of bar
Heat treatment 2 h/1040°C/AC + 2 h/800°C/AC + 16 h/700°C/AC

Tensile Properties (continued)

Table 7 - Tensile Properties of Sheet

Heat treatment 15 min/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC

°C	0.2% Proof Stress MPa	Tensile Strength MPa	Elongation on 50 mm, %
20	539	950	26.9
100	507	902	26.5
200	483	881	23.2
300	481	857	24.8
400	479	833	26.8
500	476	809	24.3
600	483	806	24.5
700	489	672	36.8
800	306	380	46.1
900	86	136	111.1
1000	45	73	101.6

Table 8 - Tensile Properties of Sheet

Heat treatment 15 min/1040°C/AC + 2 h/800°C/AC + 16 h/700°C/AC

°C	0.2% Proof Stress MPa	Tensile Strength MPa	Elongation on 50 mm, %
20	607	993	25.2
400	585	892	21.4
500	565	871	20.4
600	565	848	18.4
700	522	666	33.8
800	309	392	54.1

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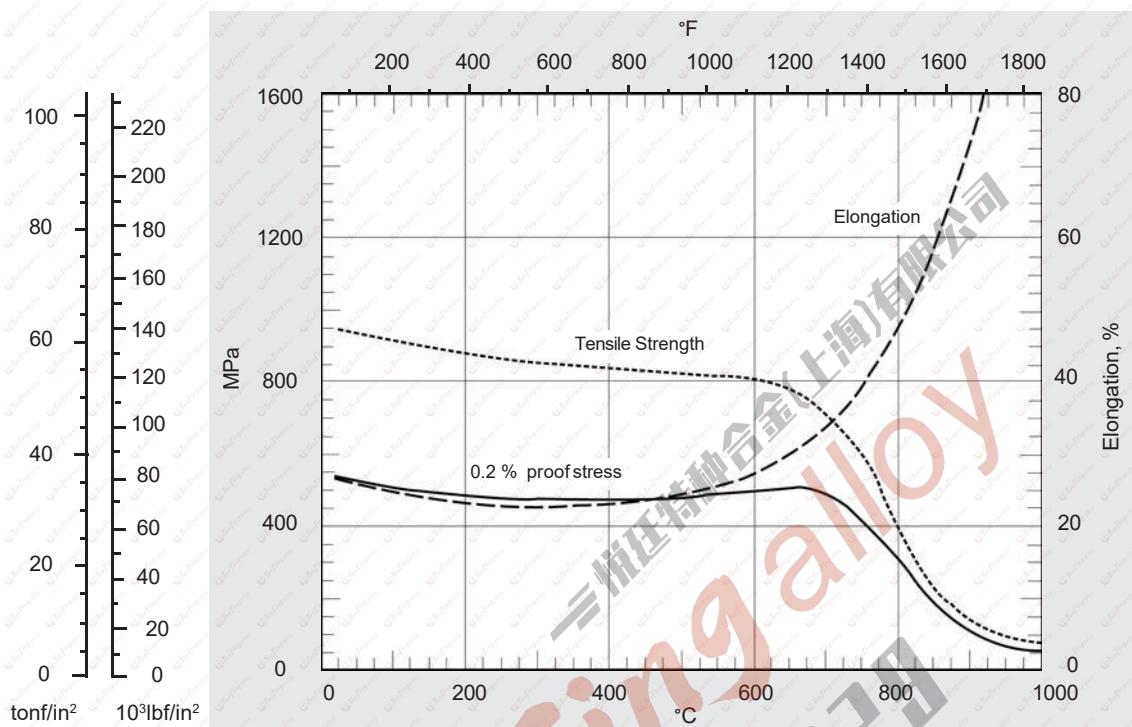


Figure 3. Tensile properties of sheet
Heat treatment 15 min/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC

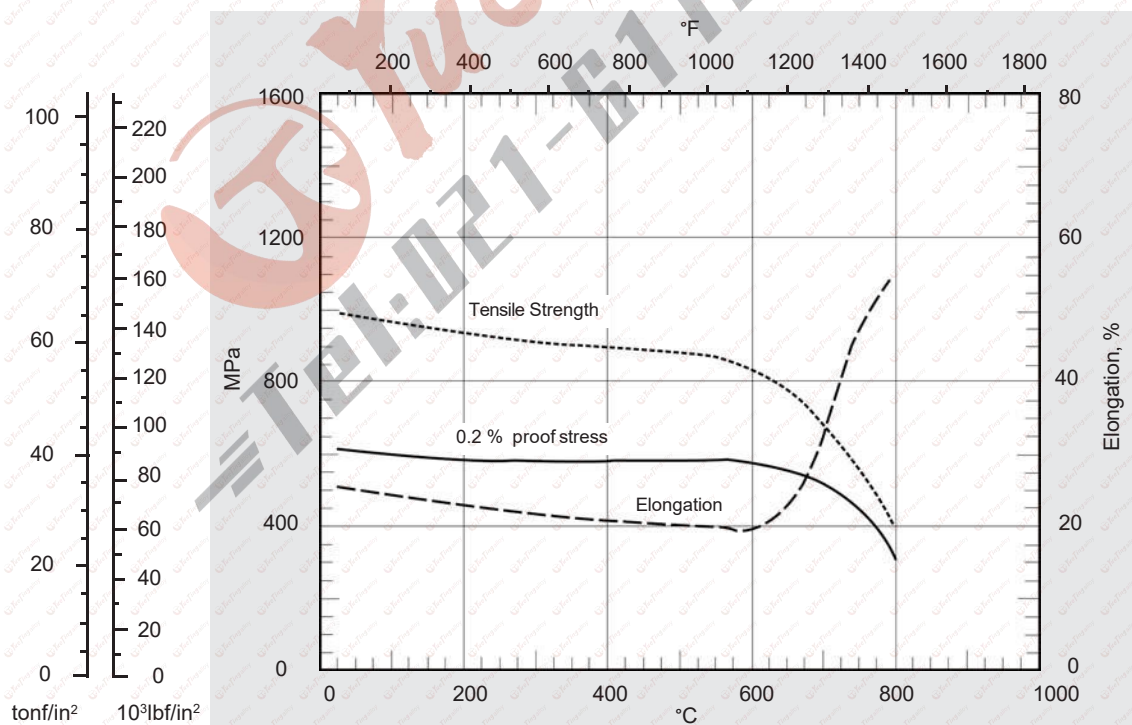


Figure 4. Tensile properties of sheet
Heat treatment 15 min/1040°C/AC + 2 h/800°C/AC + 16 h/700°C/AC

Table 9 - Tensile Properties of Welded Sheet

Hounsfield Tensometer tests for plain and welded cold-rolled sheet 1.6 mm thick

Type of sample	Test Temperature °C	Post-weld heat treatment or aging treatment					
		1 h/900°C/AC + 8 h/750°C/AC			2 h/800°C/AC + 16 h/700°C/AC		
		Tensile Strength MPa	Elongation on 25 mm %	Location of Fracture	Tensile Strength MPa	Elongation on 25 mm %	Location of Fracture
Plain	550	800	25	—	860	24	—
		800	28	—	830	20	—
	650	710	33	—	760	32	—
		700	34	—	760	30	—
Autogenous weld	550	700	13	W	790	9	W
		700	13	W	790	13	W
	650	670	11	W	710	10	W
		640	9	W	730	16	W
NIMONIC alloy PE16 filler metal weld, not dressed	550	750	16	W	830	17	PM
		790	20	PM	850	21	PM
	650	700	27	PM	760	29	PM
		730	27	PM	760	24	PM
NIMONIC alloy PE16 filler metal weld, surface ground	550	600	9	W	760	10	W
		620	9	W	750	8	W
	650	620	8	W	730	11	W
		590	8	W	680	7	W

W= weld metal
PM= parent metalCross head speed= 1.6 mm/min
Equivalent strain rate= 0.005/min

Creep Properties

The creep properties are given for bar, sheet and tube after the two recommended heat treatments. Test data at 600°C have deliberately been excluded because the creep-stresses involved are generally in the region of proof stress. Under these conditions the creep characteristics are markedly influenced by the method of applying the stress and the amount of strain on loading. In addition the significant increase in test data scatter at around proof stress calls for greater caution in the interpretation of the results so far obtained.

Sheet

Creep-rupture properties for cold-rolled sheet are shown as a double curve by Larson-Miller presentation in Figure 7, and by log stress-log time curves in Figure 8. Again the Larson-Miller curves should not be used for extrapolations much outside the test conditions indicated by the corresponding derived creep-rupture properties given in Tables 14 and 15.

Total plastic strain data for both heat treatments, carried out on sheet 1.2 mm thick made from the same cast, are given in Tables 16 and 17.

Bar

Creep-rupture properties for NIMONIC alloy PE16 bar, by Larson-Miller presentation, are shown in Figure 5, and by log stress-log time curve in Figure 6. The difference in the effect of the two recommended heat treatments on the creep-rupture properties of bar cannot clearly be delineated by two curves on the Larson-Miller diagram. A single mean curve is therefore given.

Derived creep-rupture properties and total plastic strain data are shown for both heat treatments in Tables 10 to 13 inclusive.

The Larson-Miller diagram should not be used for extra-polations much outside the range of temperature and time indicated by the derived creep-rupture properties shown in Tables 10 and 11.

Total plastic strain data are shown for both heat treatments in Tables 12 and 13.

Tube

Creep-rupture data for cold-drawn tube are shown by log stress-log time curves in Figure 9. Derived creep-rupture properties are given in Tables 18 and 19.

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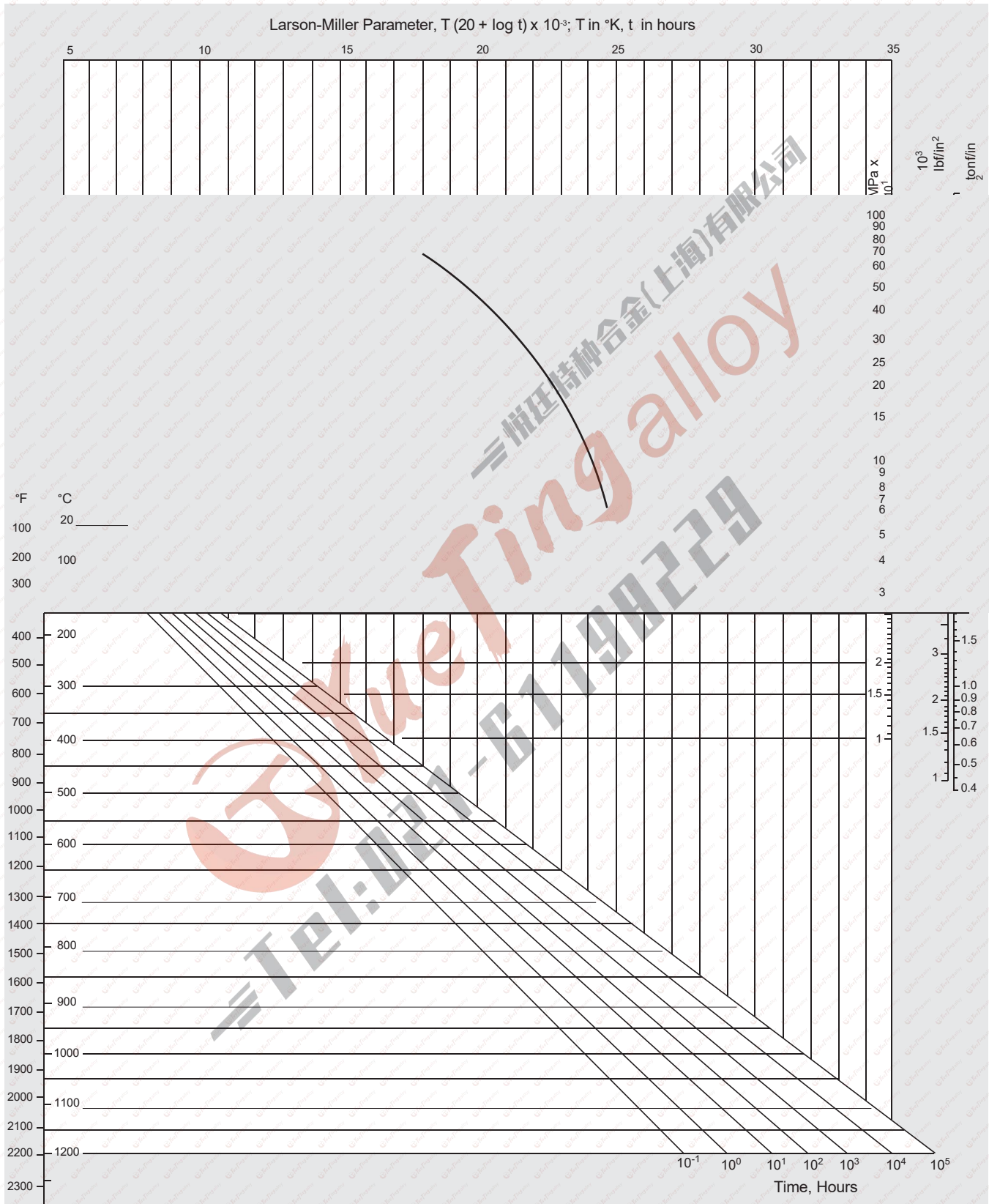


Figure 5. Creep-rupture properties of bar. Heat treatment: 4 h/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC.

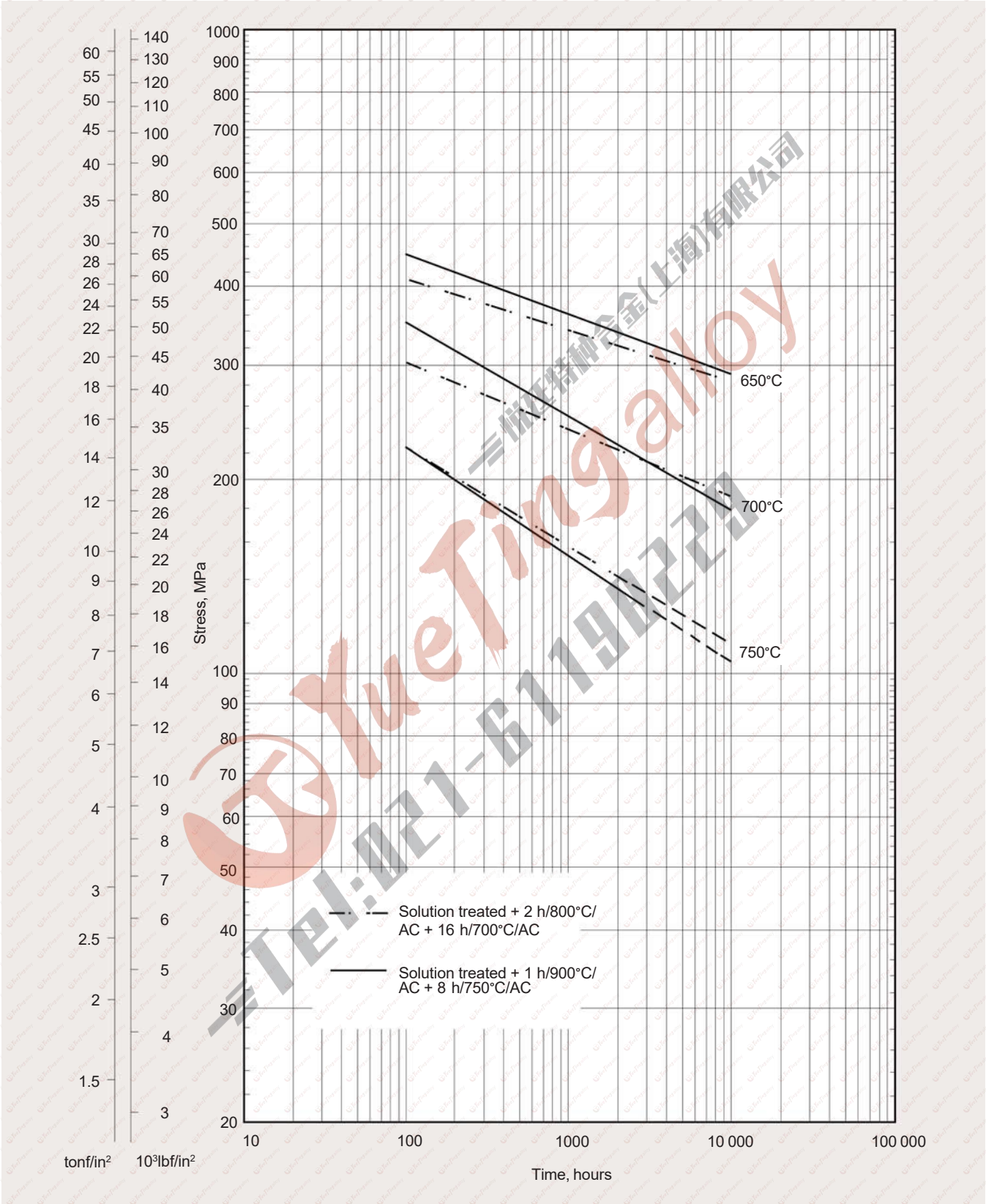


Figure 6. Creep-rupture properties for bar.

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Table 10 - Creep-Rupture Properties of Bar

Solution treated and then aged 1 h /900°C/AC + 8 h/750°C/AC

°C	Stress, MPa, to produce rupture in				Elongation at fracture on 5.65 $\sqrt{S_0}$, %
	300 h	1000 h	3000 h	10 000 h	
650	—	363	332	285	13-20
700	301	255	217	178	21-28
750	185	155	128	100	13-27

Table 11 - Creep-Rupture Properties of Bar

Solution treated and then aged 2 h /800°C/AC + 16 h/700°C/AC

°C	Stress, MPa, to produce rupture in					Elongation at fracture on 5.65 $\sqrt{S_0}$, %
	100 h	300 h	1000 h	3000 h	10 000 h	
650	—	371	340	317	279	15-19
700	301	271	243	217	178	26-29
750	—	185	162	132	(108)	—

() Extrapolated data

Table 12 - Total Plastic Strain Data for Bar

Solution treated and then aged 1 h/900°C/AC + 8 h/750°C/AC						
Test Temperature °C	Strain, %	Stress, MPa, to give total plastic strain in				
		100 h	300 h	1000 h	3000 h	10 000 h
650	0.1	332	293	255	217	(170)
	0.2	355	317	279	239	201
	0.5	386	347	309	271	231
	1.0	394	355	317	285	247
700	0.1	209	185	155	132	—
	0.2	239	209	178	148	115
	0.5	263	231	201	170	137
	1.0	279	247	209	185	155
750	0.1	132	116	89	70	53
	0.2	151	131	108	86	64
	0.5	162	145	124	105	85
	1.0	170	153	131	113	92

() Extrapolated data

Table 13 - Total Plastic Strain Data for Bar

Solution treated and then aged 2 h/800°C/AC + 16 h/700°C/AC						
Test Temperature °C	Strain, %	Stress, MPa, to give total plastic strain in				
		100 h	300 h	1000 h	3000 h	10 000 h
650	0.1	317	285	247	216	185
	0.2	332	305	279	239	209
	0.5	347	332	293	263	224
	1.0	355	332	309	271	231
700	0.1	209	178	150	124	(93)
	0.2	231	201	170	145	115
	0.5	255	224	193	170	137
	1.0	263	239	209	178	151
750	0.1	124	99	77	60	46
	0.2	151	128	104	78	57
	0.5	162	145	124	105	(85)
	1.0	180	155	131	113	93

() Extrapolated data

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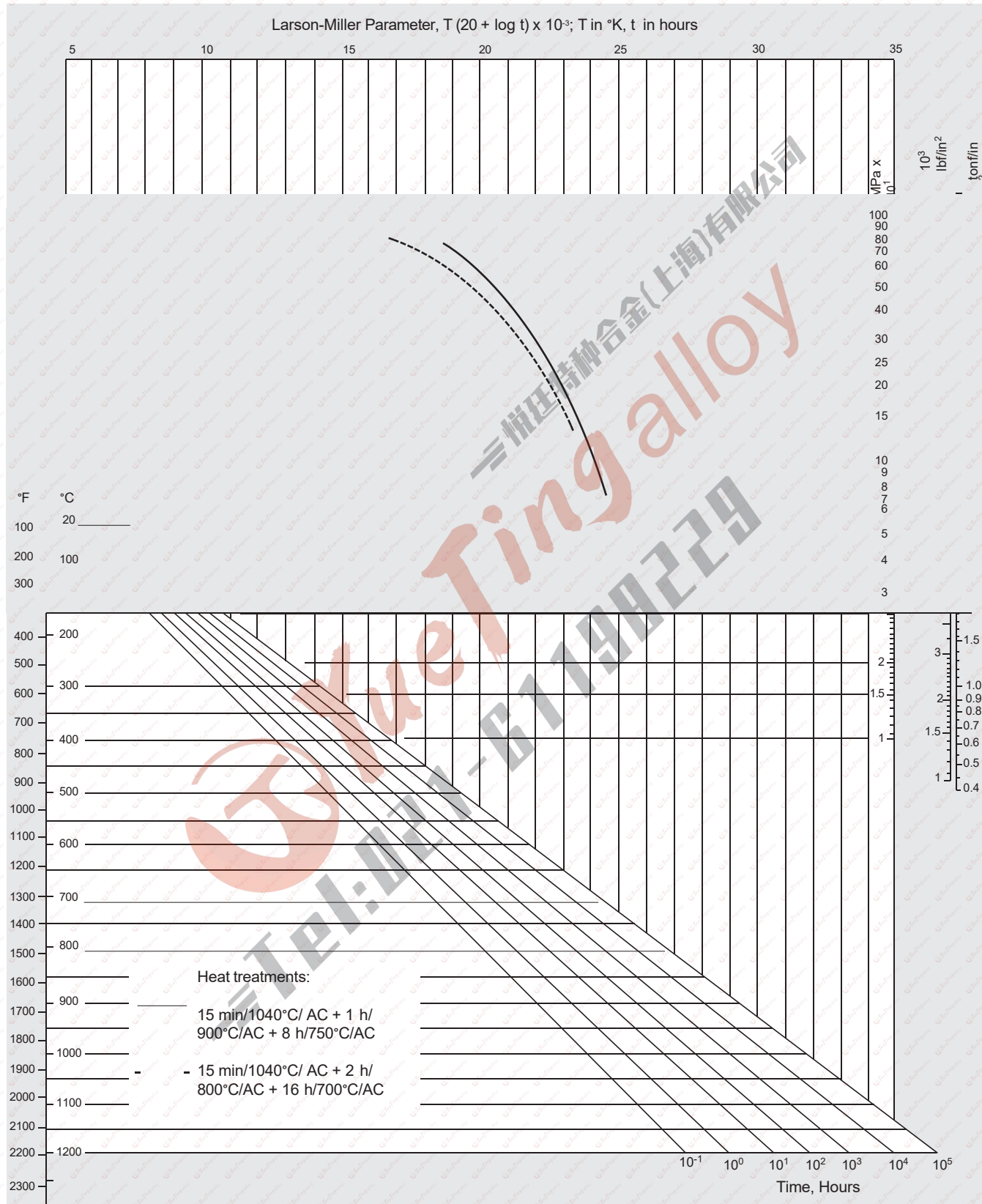


Figure 7. Creep-rupture properties of sheet.

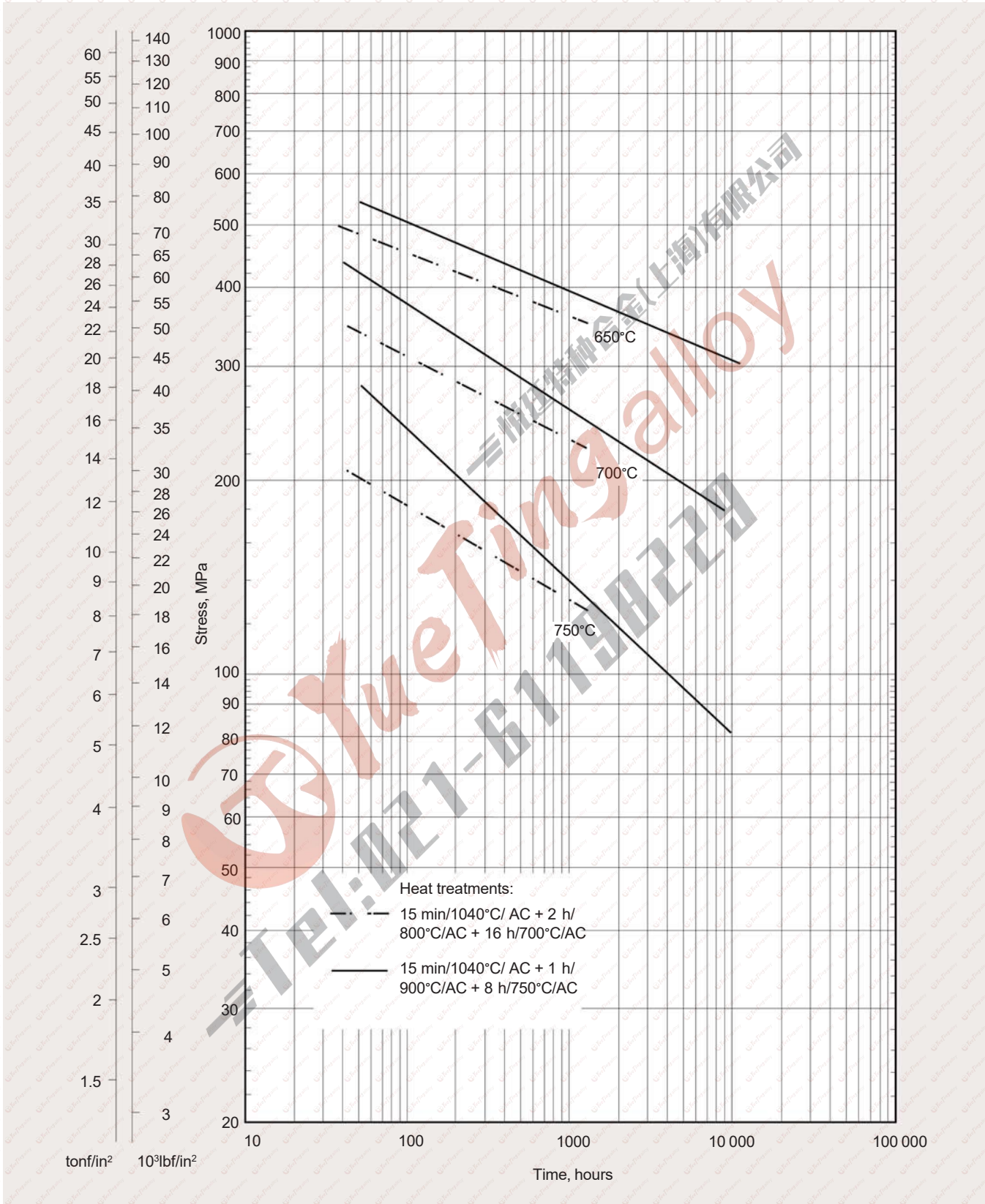


Figure 8. Creep-rupture properties of sheet.

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Table 14 - Creep-Rupture Properties of Sheet

Heat treatment 15 min/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC							
°C	Stress, MPa, to give rupture in						Elongation at fracture on 50 mm, %
	50 h	100 h	300 h	1000 h	3000 h	5000 h	
650	530	510	460	400	340	320	12-14
700	400	370	325	260	217	185	11-20
750	280	250	185	142	110	94	14-20

Table 15 - Creep-Rupture Properties of Sheet

Heat treatment 15 min/1040°C/AC + 2 h/800°C/AC + 16 h/700°C/AC					
°C	Stress, MPa, to give rupture in				Elongation at fracture on 50 mm, %
	50 h	100 h	300 h	1000 h	
650	480	450	400	360	9-21
700	340	310	270	230	16-23
750	200	185	155	131	28-41

Table 16 - Total Plastic Strain Data for Sheet

Heat treatment 15 min/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC

°C	Strain, %	Stress, MPa, to give total plastic strain in					
		50 h	100 h	300 h	1000 h	3000 h	5000 h
650	0.1	370	340	260	180	—	—
	0.2	430	390	320	280	200	170
	0.5	460	430	370	320	260	250
	1.0	490	460	400	340	290	280
700	0.1	200	170	127	78	—	—
	0.2	235	220	170	124	78	—
	0.5	290	260	220	170	129	110
	1.0	310	290	250	200	151	131
750	0.1	93	70	31	<30	<30	<30
	0.2	131	97	62	37	<30	<30
	0.5	170	147	96	64	48	43
	1.0	185	170	131	81	62	54

Table 17 - Total Plastic Strain Data for Sheet

Heat treatment 15 min/1040°C/AC + 2 h/800°C/AC + 16 h/700°C/AC

°C	Strain, %	Stress, MPa, to give total plastic strain in			
		50 h	100 h	300 h	1000 h
650	0.1	330	310	280	240
	0.2	355	340	300	260
	0.5	390	360	330	285
	1.0	420	390	355	310
700	0.1	180	155	116	93
	0.2	210	185	147	116
	0.5	270	230	180	139
	1.0	310	270	210	162
750	0.1	54	38	24	16
	0.2	83	62	38	24
	0.5	124	100	70	46
	1.0	162	131	93	70

NIMONIC® alloy PE16

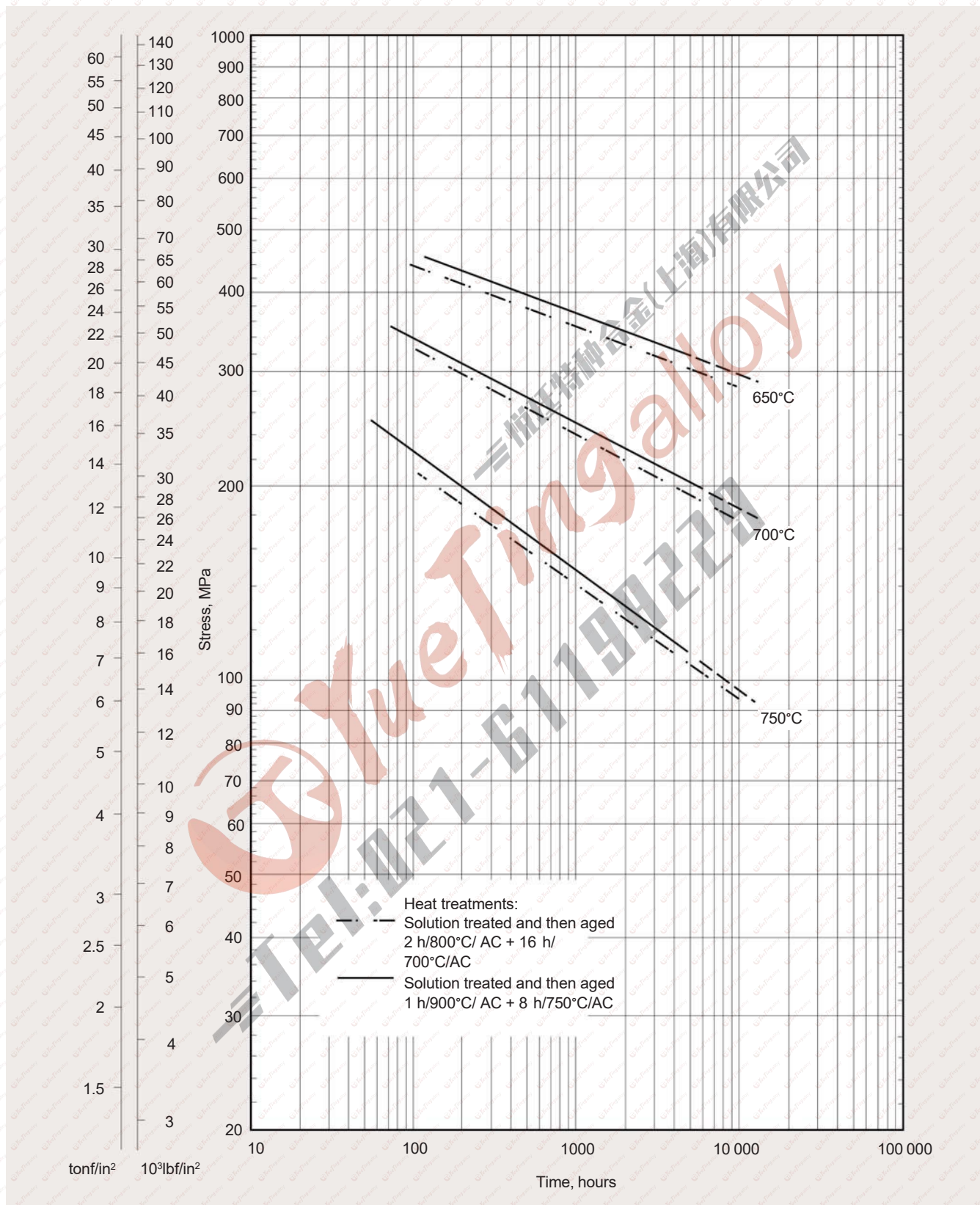


Figure 9. Creep-rupture properties of tube.

Table 18 - Creep-Rupture Properties of Tube

Solution treated and then aged 1 h /900°C/AC + 8 h/750°C/AC								
°C	Stress, MPa, to produce rupture in							Elongation at fracture on 5.65 Sb, %
	50 h	100 h	300 h	1000 h	3000 h	5000 h	10 000 h	
650	—	450	420	390	340	325	(290)	31-39
700	360	340	290	255	220	200	(180)	25-38
750	250	220	185	155	116	108	(93)	23-25

() Extrapolated data

Table 19 - Creep-Rupture Properties of Tube

Solution treated and then aged 2 h /800°C/AC + 16 h/700°C/AC						
°C	Stress, MPa, to produce rupture in					Elongation at fracture on 5.65 √So, %
	100 h	300 h	1000 h	3000 h	10 000 h	
650	440	390	355	320	285	17-25
700	325	280	240	210	170	23-38
750	210	170	139	108	93	33-48

() Extrapolated data

Impact Data

The room-temperature Charpy impact strength for NIMONIC alloy PE16 extruded and subsequently cold-stretched is in the region of 108 J after either of the recommended heat treatments.

Long term embrittlement of this alloy has been investigated by Charpy impact testing at room and elevated temperatures of material heat treated for 8 h/1040°C/AC + 1 h/900°C/AC + 8 h/750°C/AC, namely before finalization of the two currently recommended heat treatments. The data given in Tables 20 and 21 represent the finding of these investigations, and in general show the results of duplicate tests.

NIMONIC® alloy PE16

Table 20 - Impact Values, J, at Room Temperature

Soaking time h	Soaking Temperature, °C				
	500	600	650	700	800
30	133 : 109	103 : 98	95 : 98	98 : 100	128 : 125
100	110 : 104	95 : 90	88 : 95	88 : 84	123 : 117
300	110 : 111	91 : 94	81 : 85	79 : 71	106 : 110
1000	96 : 95	84	65 : 64	54 : 52	80 : 60
3000	—	75 : 79	46 : 48	35 : 29	57 : 54
10 000	117 : 102	57 : 62	34 : 52	26 : 29	58 : 61

Table 21 - Impact Values, J, at Elevated Temperature

Soaking time h	Soaking and Test Temperature, °C				
	500	600	650	700	800
30	95 : 100	100 : 92	76	81 : 81	109 : 114
100	109 : 103	80 : 87	76 : 76	76 : 79	113 : 110
300	95 : 96	80 : 77	71 : 72	73 : 71	111 : 103
1000	95 : 92	72 : 71	60 : 60	62 : 66	84 : 91
3000	—	62 : 73	57 : 49	50 : 52	65 : 75
10 000	106 : 109	65 : 62	58 : 56	46 : 38	84 : 79

Nuclear Properties

NIMONIC alloy PE16 has been extensively used in nuclear reactors, particularly the advanced gas-cooled reactor and sodium-cooled fast breeder reactor systems.

A major application in the advanced gas-cooled reactor is the tie bars from which the fuel assemblies are suspended. The average thermal neutron absorption cross-section has therefore been calculated from the composition as 3.5 barns. Based on research and development, chiefly by the UKAEA, NIMONIC alloy PE16 is highly regarded as a fuel sub-assembly and core structural material for the sodium-cooled fast breeder reactor, particularly for sub-assembly hexagon wrappers, fuel pins and spacers. The main reasons for the success of NIMONIC alloy PE16 are its resistance to corrosion by liquid sodium (see Figure 12), and its outstanding resistance to swelling by void formation in fast neutron environments as shown in Figures 10 and 11.

Figures 10, 11 and 12 are produced respectively from References 1, 2 and 3 from which acknowledgement is made to the United Kingdom Atomic Energy Authority and the British Nuclear Energy Society.

References:

1. 'The Significance of Fast Neutron Induced Voids in the Design of Fast Reactors', J.F.W. Bishop, UKAEA, Risley. Paper to the British Nuclear Energy Society Conference 'Voids Formed by Irradiation of Reactor Materials', Reading, 1971.
2. 'Performance Development of the PFR Fuel and the Use of PFR as a Fuel Development Facility', J.F.W. Bishop, UKAEA, Risley. Paper to the British Nuclear Energy Society Conference, 'Fast Reactor Power Stations', London, 1974.
3. 'Corrosion and Mass Transport of Steel and Nickel Alloys in Sodium Systems', A.W. Thorley and C. Tyzack, UKAEA, Risley. Paper 41 to the British Nuclear Energy Society Conference 'Liquid Alkali Metals', Nottingham, 1973.

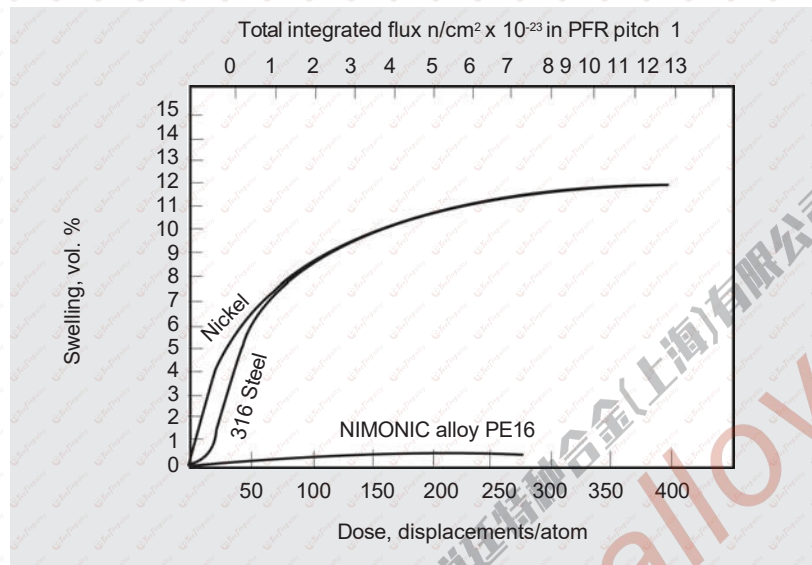


Figure 10. Dose dependence of swelling by void formation produced at 525°C by irradiation by carbon ions in the UKAEA variable energy cyclotron to simulate fast-neutron-induced void formation experienced in PFR. The swelling of NIMONIC alloy PE16 is low.

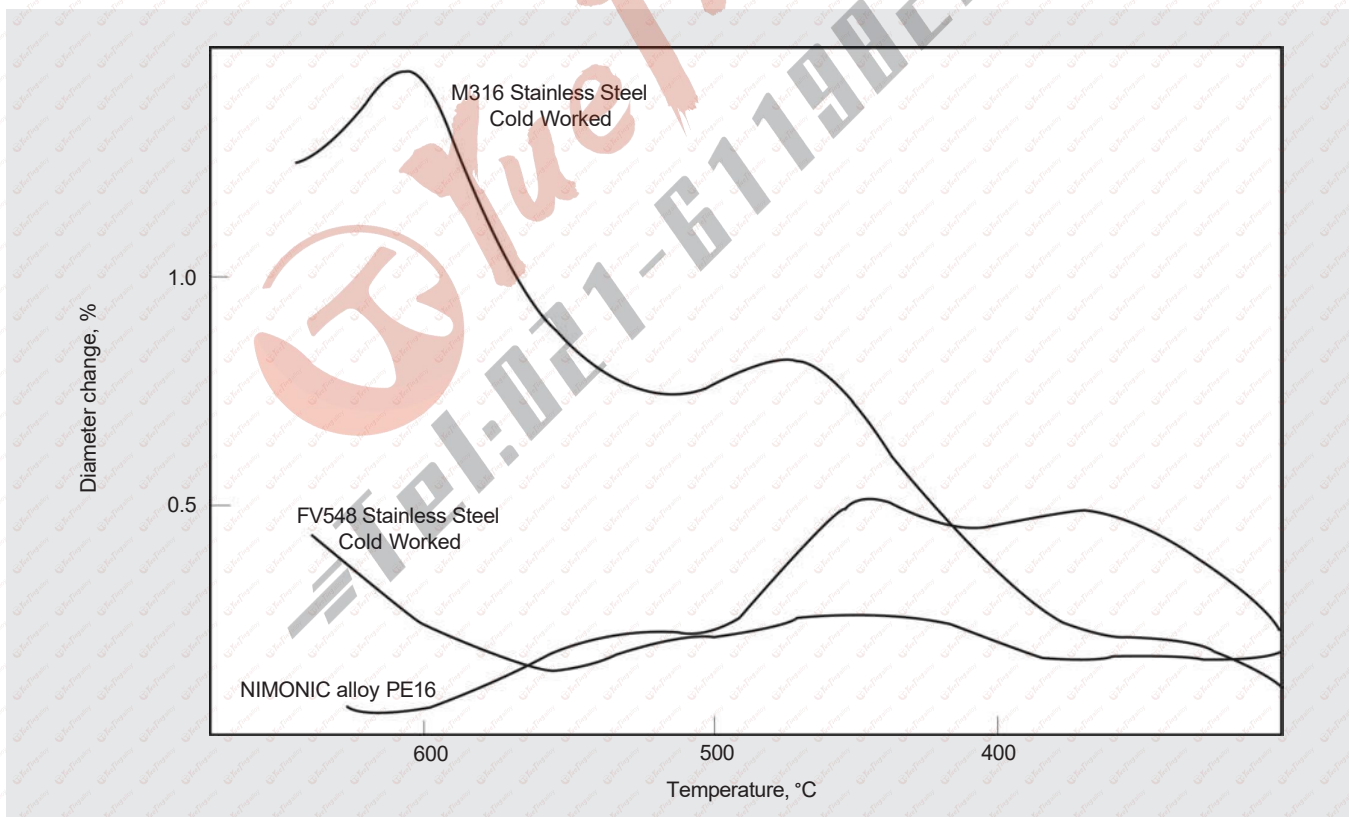


Figure 11. Dimensional changes, due chiefly to void swelling in fuel pins from a sub-assembly exposed to 11.2% peak burn-up in the UKAEA Dounreay Fast Reactor (DFR) confirming the low void swelling in heat treated NIMONIC alloy PE16 by carbon ion irradiation shown in Figure 10.

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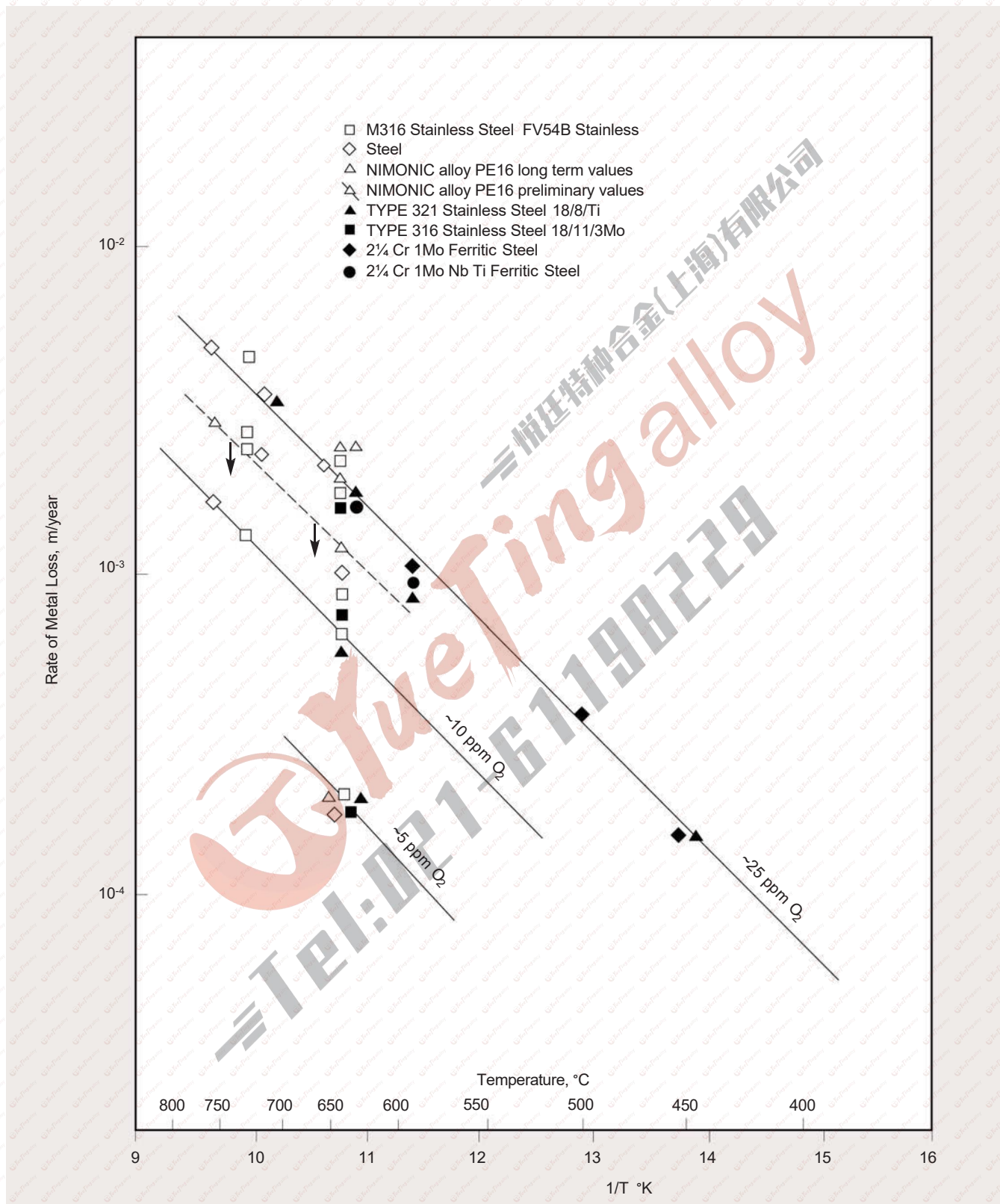


Figure 12. Exposure of NIMONIC alloy PE16 and other materials to flowing liquid sodium.

Corrosion Resistance

Laboratory corrosion testing of NIMONIC alloy PE16 has been defined in molten salt tests, using the following mixtures:

Salt mixture A 0.5% NaCl + 99.5% Na₂SO₄ B 25.0% NaCl + 75.0% Na₂SO₄ C 20.0% V₂O₅ + 80.0% Na₂SO₄ D 80.0% V₂O₅ + 20.0% Na₂SO₄ E 20.0% V₂O₅ + 60.0% Na₂SO₄ + 20.0% NaCl

Results of these tests are tabulated and compared with an austenitic stainless steel of typical composition 15.0% Cr, 10.0% Ni, 6.0% Mn, 1.0% Nb, 1.0% Mo, 0.5% Si.

Table 22 - Corrosion Resistance to Salt Mixtures

Material	°C	Weight loss, mg/cm ² , after 300 h exposure				
		Salt Mixture				
		A	B	C	D	E
NIMONIC alloy PE16	700	22.6	192	104.4	515	100.5
	800	26	777	1630	1449	64
	900	6.0	183	1310	>2000	44.7
Austenitic stainless steel	700	13.5	53.6	167	624	203
	800	35.7	382	74.1	1730	186.7
	900	23.9	835	21.9	>2000	200

Except for salt mixture C, these results show comparable corrosion resistance with the austenitic stainless steel.

Fabrication

Hot Working

NIMONIC alloy PE16 may be hot worked in the temperature range 950-1180°C. Further advice on specific hot working conditions may be obtained from the Marketing Department.

Cold Working

Average mechanical properties pertinent to cold forming operations for sheet annealed 15 min/1040°C/AC and of 0.7-0.9 mm thickness are given below.

Table 23 - Average Mechanical Properties

0.1 % proof stress	242 MPa
0.2 % proof stress	255 MPa
0.5 % proof stress	272 MPa
Tensile strength	678 MPa
Percentage elongation on 50 mm	42.0
Hardness	163 HV
Mean grain size	ASTM 8.5
Erichsen value	12.0 mm
Typical plastic anisotropy, R value †	0.85
Shear strength	518 MPa
Ratio of shear to tensile strength	0.76

† Mean value of plastic anisotropy ratio R for tests at 0°, 45° and 90° to the final rolling direction using the formula $R = \frac{1}{3}(R_0 + 2R_{45} + R_{90})$.

Annealing

Interstage annealing of NIMONIC alloy PE16 should be carried out at 1040°C, followed by air cooling. The recommended time at temperature depends on the form and section thickness as indicated:

Table 23

Bar	1/2 - 1 h/1040°C/AC
Sheet	5 - 15 min/1040°C/AC
Cold-drawn tube	1/4 - 4 h/1040°C/AC

Additional information on the effects of annealing conditions for 0.9 mm NIMONIC alloy PE16 sheet is shown in Figures 13 and 14. The very rapid softening of thin sheet is clearly indicated in Figure 13, and the effect of high temperature annealing on grain growth is demonstrated by Figure 14.

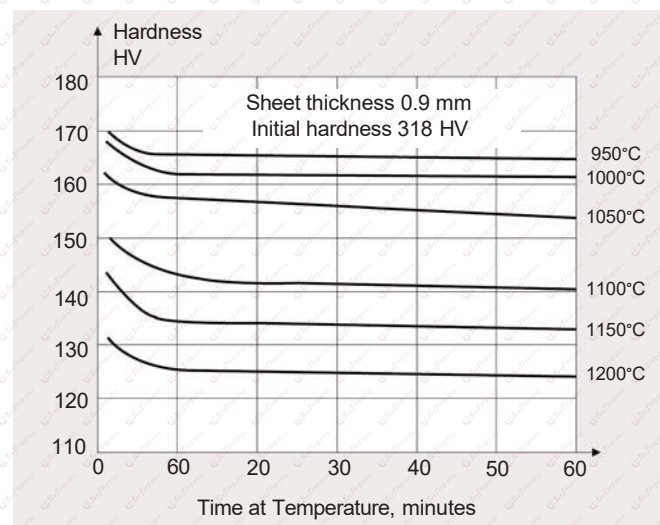


Figure 13. Softening curve for NIMONIC alloy PE16 sheet air cooled from temperature.

NIMONIC® alloy PE16

Welding

NIMONIC alloy PE16 can be welded both to itself and to a variety of other materials using many of the normal welding processes. In practice, however, manual argon-arc welding (T.I.G.) or M. I. G. welding with dip-transfer conditions are the most commonly employed.

Metallic-Arc Welding

Metallic-arc welding using flux-coated electrodes can be used, but electrodes that will develop matching mechanical properties to the parent material have not been developed. However, for possible dissimilar metal joints involving steels or non-precipitation hardening nickel-base alloys, metallic-arc welding can be usefully employed. Special Metals Welding Products Company (website: www.specialmetalswelding.com) should be consulted for specific advice.

Argon Shielded Process

Material up to 1.5 mm thick can be fusion welded without the addition of filler wire, although the properties of such joints are slightly below those of the parent material. Above this thickness NIMONIC filler metal PE16 should be added to the joint, which will then develop properties matching those of the parent material. Where the material is sufficiently thick to allow M.I.G. welding to be employed, dip-transfer conditions should be used with either 0.8 or 1.1 mm diameter wire. Welding with spray transfer conditions results in cracking in both the weld metal and the heat-affected zone.

These processes can also be used for joining the alloy to a variety of other materials, and the criterion is in the selection of a suitable filler material. The Special Metals Welding Products Company (www.specialmetalswelding.com) should be consulted for specific advice.

Other Joining Processes

NIMONIC alloy PE16 can also be joined by such processes as flash butt welding; resistance, spot, stitch and seam welding; electron-beam welding, and high temperature brazing. The choice of any one particular process will, of course, depend on the application and form of the material.

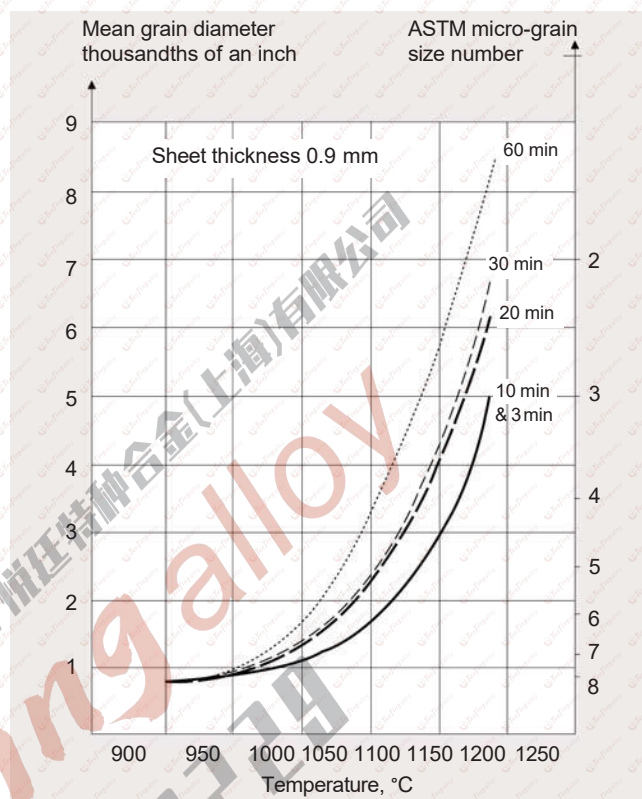


Figure 14. Grain size - annealing condition curves for NIMONIC alloy PE16 sheet.

Heat Treatment

Whichever welding process is being employed, the material to be welded should be in the annealed or solution treated condition. If forming operations prior to welding induce a large amount of cold work into the material, then annealing is recommended prior to welding. After welding the two-stage heat treatment of either:

1 h/900°C/AC + 8 h/750°C/AC or
2 h/800°C/AC + 16 h/700°C/AC

is necessary to develop the good properties in the weld and heat-affected zone. The choice of heat treatment is dependent on the intended service condition as discussed under the 'Heat Treatment' section on page 1.

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