NIMONIC® alloy 263

NIMONIC® alloy 263 (UNS N07263/W. Nr. 2.4650), an air melted nickel-base alloy, was developed by Rolls-Royce (1971) Ltd. to provide a sheet material which could be readily fabricated and would offer improved ductility in welded assemblies to replace NIMONIC alloy 80A.

It was designed as sheet material to meet specific design criteria in terms of proof stress and creep strength. It is now available in all standard forms.

The welding techniques for this alloy are similar to those in common use for other age-hardenable nickel-base alloys. During salvage welding operations, a pre-weld heat-treatment is not necessary on age-hardened assemblies but a subsequent age-hardening treatment is desirable after all salvage welding is completed. Material will age in service if temperatures are above 750°C.

Composition, %

The composition in BS HR 10 is as follows:

Carbon	0.04-0.08
Silicon	0.40 max.
Manganese	0.60 max.
Sulfur	0.007 max.
Silver	0.0005 max.
Aluminum	0.60 max.
Boron	0.005 max.
Bismuth	0.0001 max.
Cobalt	19.0-21.0
Chromium	19.0-21.0
Copper	0.20 max.
Iron	0.7 max.
Molybdenum	5.6-6.1
Lead	0.0020 max.
Titanium	1.9-2.4
Aluminum and titanium	2.4-2.8
Nickel	Balance*

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

Heat Treatment

NIMONIC alloy 263 is normally given a two-stage heat-treatment, that is, solution treatment and age hardening prior to service. This heat treatment is normally carried out in air. Material is usually supplied in the solution-treated condition and aged by the customer as part of the fabrication process. Material can however be supplied to any requested heat treatment condition. Details of recommended heat-treatments for various forms are given below, where the time at solution treatment temperature depends on section thickness.

Form	Solution Treatment	Aging Treatment
Extruded or forged bars and section for forging and /or machining	1½-2½ h/1150°C/WQ	8 h/800°C/AC
Hot-rolled sheet	½ h/1150°C/WQ or AC	8 h/800°C/AC
Cold-rolled sheet and cold-drawn section (including tube)	3-10 min/1150°C/ FBQ or WQ	8 h/800°C/AC

Cooling for hot-rolled sheet from solution treatment temperature may be by water quenching (WQ) or by air cooling (AC); the former is recommended. For cold-worked products, especially sheet, fluidized bed quenching (FBQ) produces less distortion than water quenching without any appreciable change of properties.

The solution treatment temperature of 1150°C yields a compromise between tensile and creep strengths, coupled with good ductility values in both cases.

Interstage annealing to remove residual cold-work is normally applied during manipulation operations. The treatment recommended for sheet is 15 min/1050-1100°C/WQ or AC.

Welding operations should be carried out with the material in the solution-treated condition. An 8 h/800°/AC aging treatment can be applied to the welded component. Details of welding practice are given subsequently under 'Fabrication'.

Physical Properties

Density, g/cm^3 .... 8.36
lb/in^3 .... 0.302
Melting Range
Liquidus temperature, °C 1355
Solidus temperature, °C 1300
Specific Heat, J/kg, °C 461

Density

The density values are the mean of 24 determinations on sheet and forged material. No significant difference in density between annealed and fully heat-treated sheet was detected. Compositional variation within the release specification was reflected in a density range of 8.33 to 8.39 g/cm^3.

Melting Range

The liquidus temperature was determined by inverse cooling and the solidus by metallographic examination. The accuracy of determination was ±5°C for the liquidus temperature, and +0, -10°C for the solidus temperature.

Specific Heat

Approximately 461 J/kg °C in the range 20-100°C.

Table 1 - Thermal Conductivity

°C	W/m•°C
20	11.72
100	12.98
200	14.65
300	16.33
400	18.00
500	19.68
600	21.35
700	23.03
800	24.70
900	26.80
1000	28.47

These values have been calculated from electrical resistance measurements on a single fully heat-treated sheet specimen using modified Wiedemann-Franz equations.

Table 2 - Mean Coefficient of Linear Thermal Expansion, 10^{-6}/°C

°C	Average data for extruded bar	Average data for billet slices forged	Data for sheet
20-100	10.3	10.2	11.0
20-200	11.9	12.1	12.1
20-300	12.5	12.8	12.6
20-400	13.1	13.3	13.0
20-500	13.6	13.9	13.4
20-600	14.2	14.5	13.9
20-700	15.2	15.7	14.6
20-800	16.2	16.7	15.3
20-900	17.9	18.3	16.5
20-1000	18.9	19.3	17.4

Table 3 - Electrical Properties

Electrical Resistivity at 20°C = 115 microhm •cm	
°C	Relative Resistance
20	1.000
100	1.013
200	1.030
300	1.046
400	1.062
500	1.078
600	1.094
700	1.098
800	1.087
900	1.078
1000	1.081

Table 4 - Magnetic Properties

Heat-treatment condition	Permeability μ at 0.02 T to 0.3 T
Annealed	1.000745
Fully heat-treated	1.000765

No change in permeability with field strength was detected; neither was the permeability significantly influenced by sample orientation with respect to rolling direction.

Dynamic Moduli

The dynamic Young's modulus data (Table 5) were obtained on cylindrical specimens from extruded and forged sections and on sheet specimens. Both forms of sample were tested in the fully heat-treated condition and vibrated in the flexural mode.

Table 5 - Dynamic Moduli, GPa

°C	Dynamic Young's modulus		Dynamic torsional modulus
	Extruded and forged section	Sheet	Sheet
20	224	221	86
100	219	219	84
200	213	212	81
300	206	205	79
400	199	198	76
500	192	162	73
600	185	185	70
700	175	177	66
800	163	168	62
900	154	154	57
1000	142	143	52

Tensile Properties

The data given in Table 6 and presented graphically in Figure 1 are for extruded section, subsequently forged, and given the recommended heat treatment. The data given in Table 7, and presented graphically in Figure 2 are for cold-rolled sheet 0.7 to 1.2 mm thick given the recommended heat treatment. Tensile properties at 780°C for plain and welded cold-rolled sheet 1.2 and 0.9 mm thick are compared in Table 8. The data represent the statistical analyses of routine release tests on 100 casts produced as 1.2 and 0.9 mm sheet. The welding of test specimens was carried out between the first and second stages of the heat treatment.

Table 6 - Tensile Properties of Bar

Heat treatment 2 h/1150°C/WQ + 8 h/800°C/AC				
°C	0.2% Proof Stress MPa	Tensile Strength MPa	Elongation on 5.65 √So, %	Reduction of Area %
20	585	1004	45	41
100	550	958	44	44
200	520	911	44	47
300	505	880	45	50
400	490	849	46	51
500	500	834	46	52
600	490	819	43	50
700	495	772	27	34
800	460	587	15	26
900	145	232	34	58
1000	70	108	69	72

Strain rate 0.005/min to proof stress (at room temperature) and 0.002/min to proof stress (at elevated temperatures) and 0.01/min thereafter.

Tensile Properties (continued)

Table 7 - Tensile Properties of Sheet

Heat treatment 3-10 min/1150°C/FBQ or WQ + 8 h/800°C/AC			
°C	0.2% Proof Stress MPa	Tensile Strength MPa	Elongation on 50 mm %
20	580	973	39
100	515	896	40
200	500	849	41
300	475	834	42
400	470	816	43
500	490	803	43
600	490	788	41
700	475	757	23
800	440	556	20
900	135	201	49
1000	70	108	65

Strain rate 0.005/min to proof stress (at room temperature) and 0.002/min to proof stress (at elevated temperatures) and 0.01/min thereafter.

Table 8 - Tensile Properties of Plain and Welded Sheet

Routine release data at 780°C for 1.2 and 0.9 mm cold-rolled sheet, Heat treatment 5 min/1150°C/AC + weld + 8 h/800°C/AC				
Parameter	Plain Sheet		Argon-arc autogenously butt welded sheet	
	Tensile Strength MPa	Elongation on 25 mm %	Tensile Strength MPa	Elongation on 25 mm %
Mean	632	24.0	629	11.7
Standard deviation	23	6.5	23	4.6
Minimum requirements of Rolls-Royce Specification MSRR. 7036	541	9	463	5

Strain rate 0.002/min to proof stress and 0.1/min thereafter.

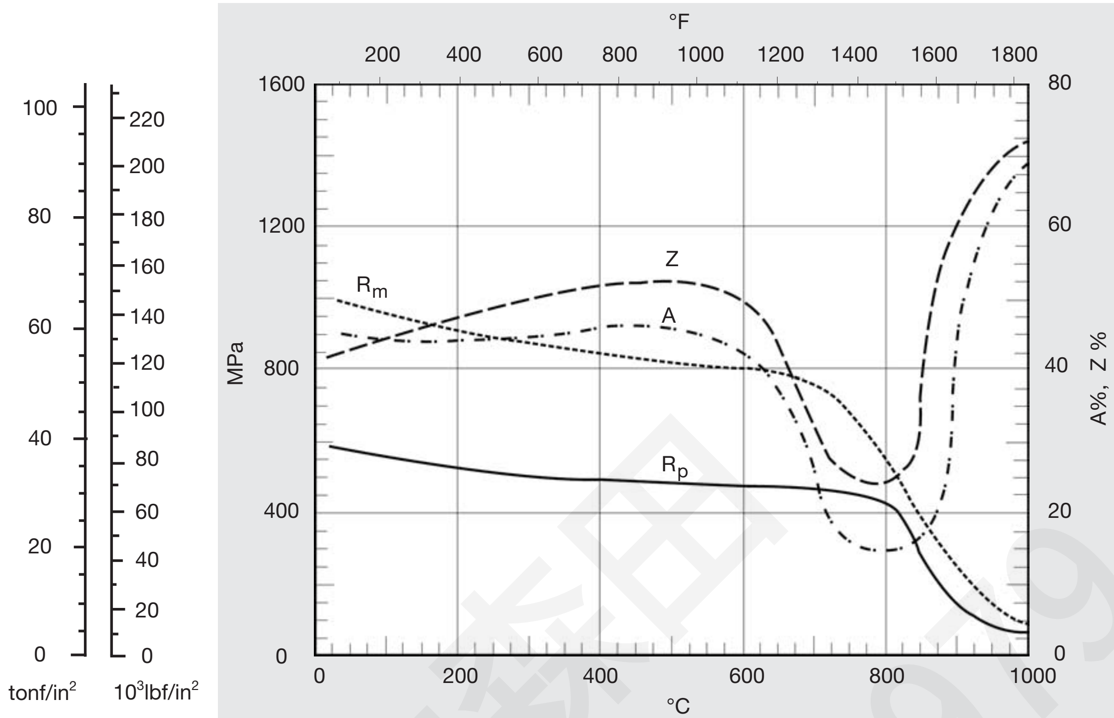


Figure 1. Tensile properties of bar. Heat treatment 2h/1150°C/WQ + 8h/800°C/AC

A= Elongation R_m= Tensile Strength R_p= 0.2% Proof Stress Z= Reduction of Area

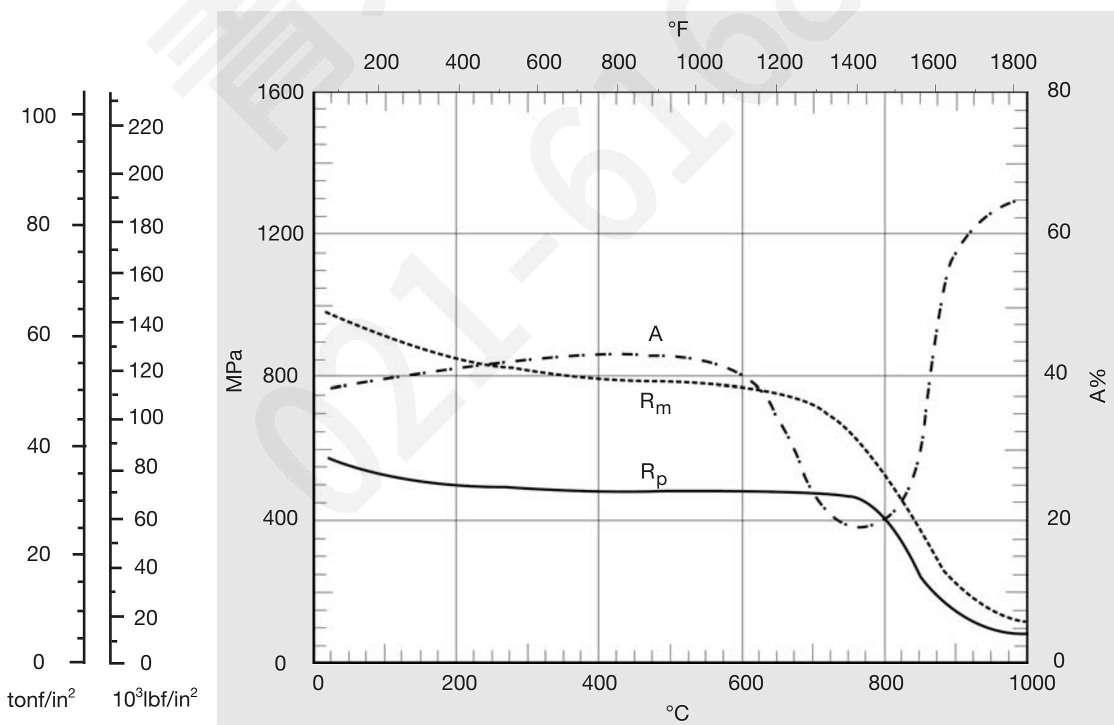


Figure 2. Tensile properties of sheet. Heat treatment 3-10 min/1150°C/FBQ or WQ + 8h/800°C/AC

A= Elongation R_m= Tensile Strength R_p= 0.2% Proof Stress Z= Reduction of Area

Creep Properties

Bar

Creep-rupture curves for bar given the recommended 2 h/1150°C/WQ + 8h/800°C/AC heat treatment are presented by Larson-Miller parameter in Figure 3. Derived creep-rupture properties of extruded section are shown in Table 9.

Total plastic strain data obtained on extruded section after the recommended heat treatment are given in Table 10. Stresses in the region of or above proof stress have been omitted since under these conditions the creep characteristics are markedly influenced by the method of applying the stress and the amount of strain on loading.

Sheet

Creep-rupture curves for fully heat-treated cold-rolled sheet are presented by Larson-Miller parameter in Figure 4. Derived creep-rupture properties of cold-rolled sheet are also shown in Table 11, where two sets of data were obtained from different casts. One cast was used for the 500 to 700°C data, and another for the 700 to 900°C data. For comparison, therefore, both sets of data are given at 700°C.

Preliminary total plastic strain data for 1.6 mm sheet, heat-treated 3 min/1190°C/FBQ + 8 h/800°C/AC, are given in Table 12. Again stresses in the region of or above proof stress have been omitted. Reducing the initial heat-treatment temperature from 1190°C to 1150°C would not cause a significant difference in total plastic strain.

Tests on autogenously welded sheet have shown that very similar creep-rupture strengths are obtained. Sheet welded by other than the autogenous process may show properties affected by the method of welding used.

Table 9 - Creep-Rupture Properties of Extruded Section

Heat treatment 2 h/1150°C/WQ + 8 h/800°C/AC					
°C	Stress, MPa, to give rupture in				
	30 h	100 h	300 h	1000 h	3000 h
550	(726)	695	680	633	(587)
600	641	618	595	556	(510)
650	479	541	510	471	(432)
700	510	448	386	317	(263)
750	378	317	263	224	(178)
800	263	216	178	142	(116)
850	165	133	103	77	(59)
900	86	74	54	42	(34)

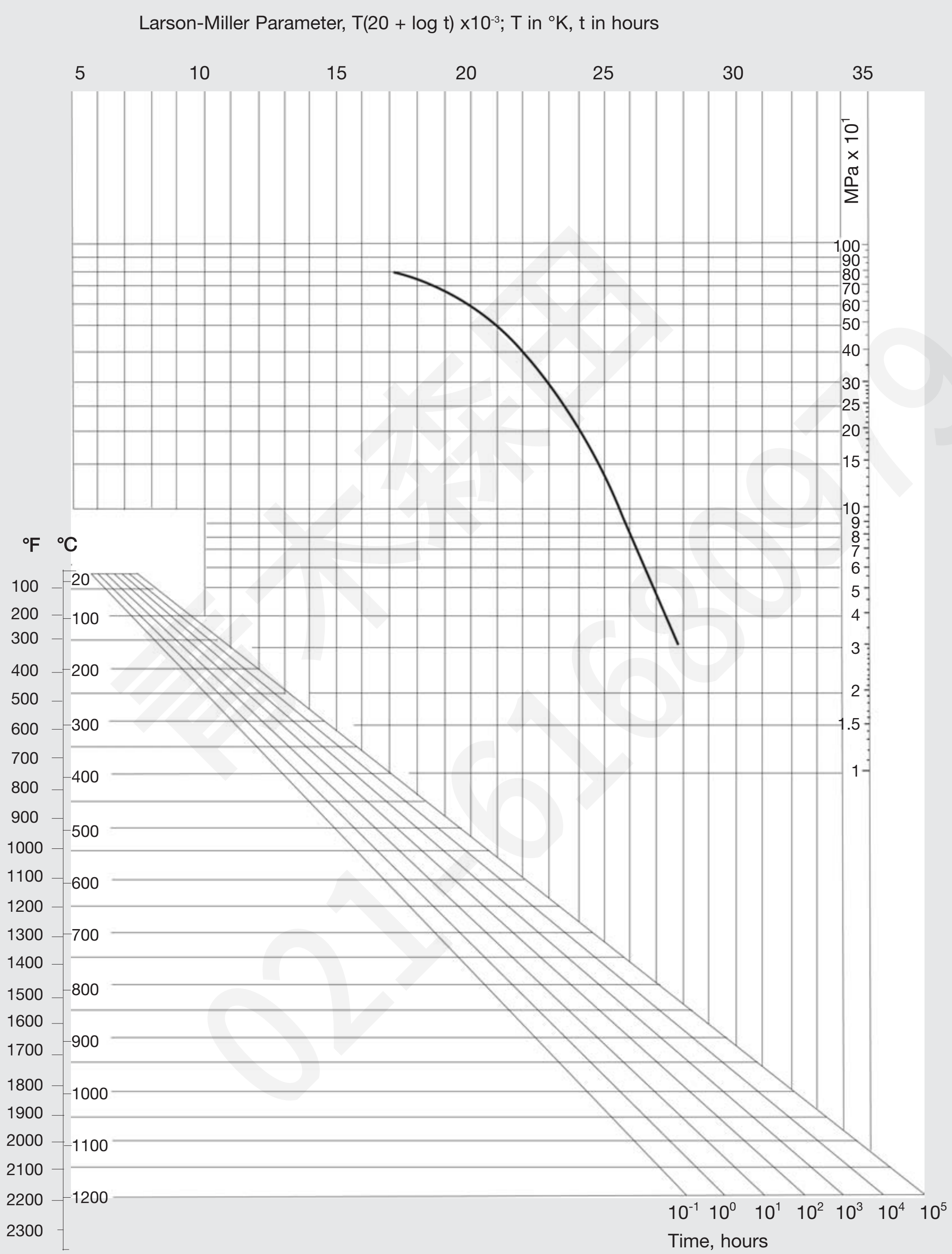
Values in parentheses are extrapolated from isothermal curves.

Table 10 - Total Plastic Strain Data for Extruded Section

Heat treatment 2 h/1150°C/WQ + 8 h/800°C/AC						
°C	Strain %	Stress, MPa, to give total plastic strain in				
		50 h	100 h	300 h	500 h	1000 h
700	0.1	(432)	386	324	301	270
	0.2	–	417	347	324	286
	0.5	–	432	371	340	309
	1.0	–	–	386	355	317
750	0.1	301	263	216	201	178
	0.2	317	278	232	208	185
	0.5	340	293	247	224	201
	1.0	355	309	263	239	208
800	0.1	178	162	136	125	110
	0.2	193	170	144	133	116
	0.5	208	185	153	139	124
	1.0	216	193	162	147	130
850	0.1	102	93	69	57	48
	0.2	111	99	77	68	52
	0.5	117	105	85	73	59
	1.0	127	113	93	77	63
900	0.1	51	45	37	(31)	(25)
	0.2	54	48	39	(34)	(26)
	0.5	59	51	42	37	(29)
	1.0	63	56	45	40	(32)

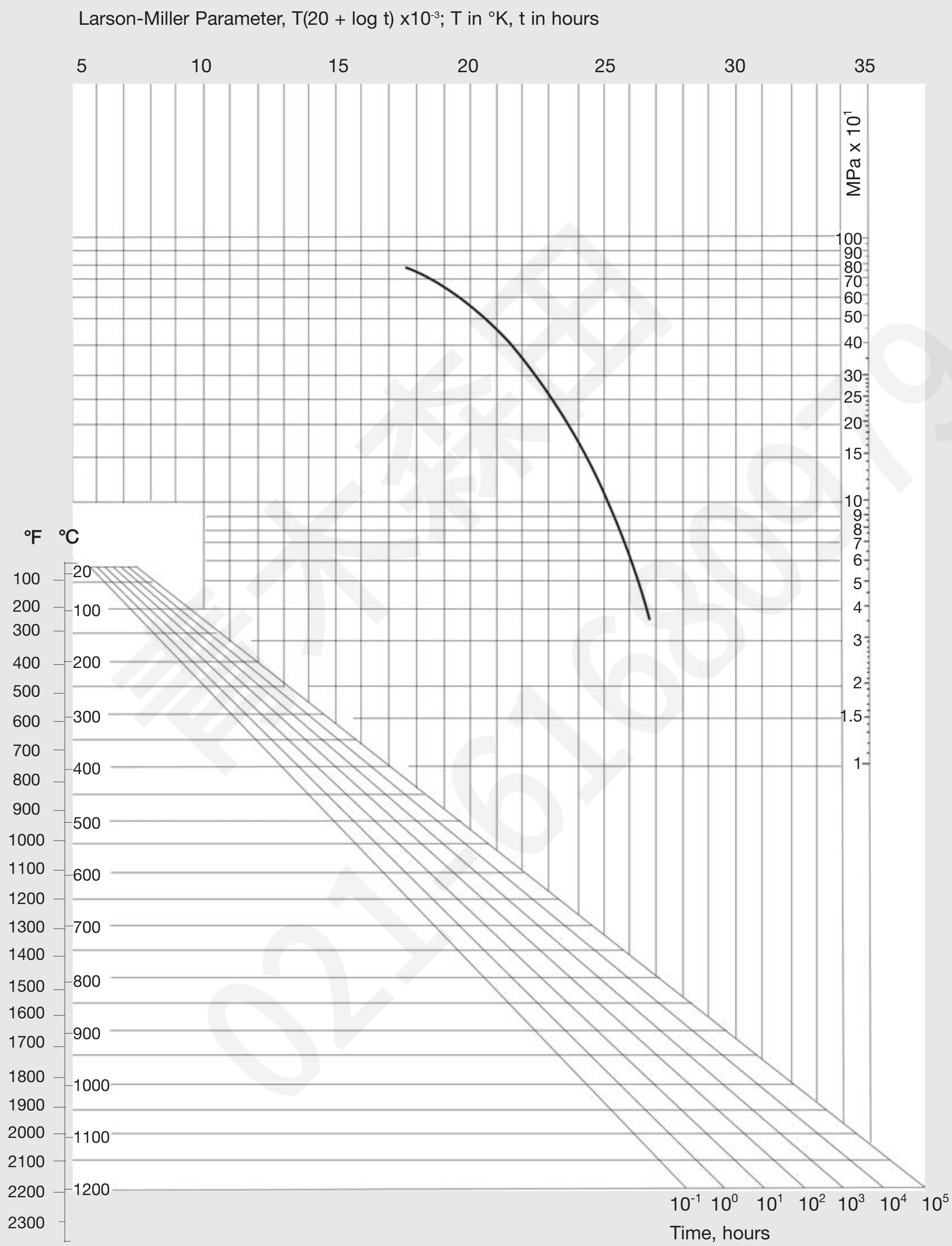
Values in parentheses are extrapolated from isothermal curves.

Figure 3 - Creep-Rupture Properties of bar. Heat treatment 2h/1150°C/WQ +8 h/800°C/AC



1 MPa = 1 N/mm² (1 MN/m²) = 0.1 hbar = 1.02 kgf/mm² = 0.0647 tonf/in²

Figure 4 - Creep-Rupture Properties of Sheet. Heat treatment 3-10 mins/1150°C/FBQ or WQ+8 h/800°C/AC



1 MPa = 1 N/mm^2 (1 MN/m^2) = 0.1 hbar = 1.02 kgf/mm^2 = 0.0647 tonf/in^2

Table 11 - Creep-Rupture Properties of Cold-Rolled Sheet

Heat treatment 3-10 min/1150°C/FBQ or WQ + 8 h/800°C/AC						
°C	Stress, MPa, to give rupture in					
	30 h	100 h	300 h	1000 h	3000 h	5000 h
550	803	757	710	672	(641)	—
600	656	625	595	564	(533)	—
650	595	556	510	448	(378)	—
700*	479	402	340	286	(247)	—
700*	—	363	317	263	216	201
750	—	270	224	185	147	131
800	—	181	147	116	83	73
850	—	103	79	60	46	42
900	—	57	46	36	<31	<31

*Two different casts, see text.
Values in parentheses are extrapolated from isothermal curves.

Table 12 - Total Plastic Strain Data for Cold-Rolled Sheet

Heat-treatment: 3 min/1190°C/FBQ + 8 h/800°C/AC							
°C	Strain %	Stress, MPa, to give total plastic strain in					
		50 h	100 h	300 h	1000 h	3000 h	5000 h
700	0.2	363	332	278	224	178	159
	0.5	409	371	317	255	208	185
750	0.2	239	208	178	142	113	97
	0.5	278	247	198	154	128	108
800	0.2	147	130	102	80	60	54
	0.5	165	145	119	91	68	60
850	0.2	80	69	54	40	—	—
	0.5	96	83	65	49	36	—
900	0.2	40	34	<31	<31	<31	<31
	0.5	46	40	<31	<31	<31	<31

Impact Data

The room temperature Charpy impact strength of extruded and forged section given the recommended heat treatment of 2 h/1150°C/WQ + 8 h/800°C/AC is in the region of 111 J.

Long term embrittlement has been investigated by room and elevated temperature Chargy impact testing of extruded and forged section given the recommended heat treatment. The data given in Tables 13 and 14 represent the findings of these investigations and in general show the results of duplicate tests.

Table 13 - Impact Values, J, at Room Temperature

Soaking time h	Soaking temperature, °C				
	600	700	750	800	900
30	111:103	73:75	68:80	98:98	190:176
100	88:92	54:58	65:56	87:79	160:165
300	87:100	34:30	41:43	58:52	108:119
1000	71: 71	27:33	24:22	62:57	56: 60
3000	98: 81	12:14	24:35	39:35	46: 53
10 000	27: 26	9:11	26:22	34:33	45: 45

Table 14 - Impact Values, J, at Elevated Temperatures

Soaking time h	Soaking and test temperature, °C			
	600	750	800	900
30	157:150	100:100	125:114	172:174
100	146:130	96:92	114:100	180:160
300	160:156	81:85	91:104	141:145
1000	108:114	71:69	87:79	123:119
3000	152:114	73:52	79:83	111:106
10 000	65:64	42:39	72:71	110:107

Fabrication

Hot Working

NIMONIC alloy 263 may be hot worked in the temperature range 950-1150°C.

Cold Working

Average mechanical properties pertinent to cold forming operations for annealed sheet 0.5 to 1.2 mm thick are given in the following table.

0.1% proof stress	343 MPa
0.2% proof stress	355 MPa
0.5% proof stress	369 MPa
Tensile strength	788 MPa
Elongation on 50 mm, %	59.7
Hardness	195 HV
Mean grain size	ASTM 6.5
Erichsen value	12.8 mm
Shear strength	588 MPa
Ratio of shear to tensile strength	0.75

The above data were obtained using an anneal of 3 minutes at 1190°C followed by fluidized bed quenching. A slight overall improvement in these properties is indicated by investigations using the 1150°C heat treatment.

Annealing

NIMONIC alloy 263 bar or heavy section is usually softened by a heat treatment of 2 h/1150°C/WQ, namely the first stage of the recommended two stage heat treatment for bar.

Annealing of NIMONIC alloy 263 sheet, required during manipulatory operations, should be by heating for 15 minutes in the temperature range 1050-1100°C followed by rapid cooling (water quenching for heavier sheet and air cooling for thin section sheet). Fluidized bed quenching may also be used.

Welding

Argon Shielded Process

NIMONIC alloy 263 is readily welded by automatic and manual T.I.G. processes and by M.I.G. processes. The choice of process depends on the joint configuration and on material thickness. For simple butt joints automatic T.I.G. welding can be used, with or without filler metal additions, depending on thickness. Material thinner than 1.6 mm can be welded without filler metal but above this thickness, filler metal must be added. The limiting thickness for automatic T.I.G. welding is around 3.25 mm.

For more complicated joints, or for thicker material, manual T.I.G. welding can be employed. This process can be used on all section thicknesses but the much faster M.I.G. processes are normally used for material above 4.8 mm thick particularly if a lot of welding is involved. As NIMONIC alloy 263 does not suffer from heat-affected-zone cracking, both “spray” and “dip” transfer conditions can be used when M.I.G. welding, although “dip” transfer is preferred.

The filler metal to be used for all argon-shielded welding processes is NIMONIC filler metal 263, of matching composition to the base alloy. It is available in 914 mm straight lengths at 3.3, 2.6, 2.0, 1.6, and 1.2 mm diameter for manual welding and on reels at 1.6, 1.1 and 0.9 mm diameter for automatic T.I.G. and M.I.G. welding.

The shielding gas should be either pure argon or argon plus 5% hydrogen, if the latter is preferred. On no account should argon-oxygen mixtures or carbon dioxide be used.

Resistance Welding

Resistance spot, stitch and seam welding techniques are in regular use on NIMONIC alloy 263 components.

Other Joining Processes

Many other joining process are available for NIMONIC alloy 263, but the choice of any one will depend on the application and the equipment available. For example, flash-butt welding is used for the manufacture of gas turbine rings, but finds little application elsewhere. In addition, high-temperature brazing, electron-beam welding and plasma-arc welding can all be used should the application warrant them. For the majority of applications argon-shielded and resistance welding techniques will suffice.