INCONEL® alloy 78

The newest of the high-performance superalloys invented by Special Metals Corporation, INCONEL® alloy 783 (UNS R30783/U.S. Patent 5,478,417), is an oxidation-resistant, low expansion, nickel-cobalt-iron alloy with aluminum, chromium, and niobium additions. The new alloy is of considerable interest to aircraft gas turbine engine designers and materials engineers for containment and clearance control components such as rings, casings, shrouds and seals for compressors, turbines and exhaust systems. The three-phase age hardenable alloy offers a range of improvements for these applications over alternative alloys in current use:

A coefficient of thermal expansion approximately 20% lower than that of INCONEL alloy 718.

Excellent resistance to oxidation, demonstrated in cyclic tests, at temperatures up to and beyond 1300°F (704°C).

Resistance to SAGBO (stress accelerated grain boundary oxidation) comparable to that of INCONEL alloy 718, and significantly better than that of INCOLOY alloy 909.

A density of 0.282 lb/in^3 (7.81 g/cm^3), 5% less than INCONEL alloy 718 or INCOLOY® alloy 909, contributing to an important potential improvement in strength-to-weight ratios.

Manufacturing/processing characteristics comparable to those of INCONEL alloy 718, and less limiting than those of INCOLOY alloy 909.

Special Metals' INCONEL alloy 783 is available as forging billet (AMS 5940), rod and bar for machining, extruded section, and wire rod. Sheet product is currently under development.

Table 1 - Limiting Chemical Composition*, %

Chromium	2.5-3.5
Nickel	26.0-30.0
Iron	24.0-27.0
Niobium	2.5-3.5
Aluminum	5.0-6.0
Cobalt	Remainder
Boron	0.003-0.012
Carbon	0.03 max.
Manganese	0.50 max.
Silicon	0.50 max.
Phosphorus	0.015 max.
Sulfur	0.005 max
Titanium	0.1-0.4
Copper	0.50 max

*In compliance with UNS R30783

Physical Properties

Table 2 - Physical Constants

Density, g/cm^3	7.81
lb/in^3	0.282
Melting Range, °F	2437-2565
°C	1336-1407
Specific Heat, Btu/lb•°F (77°F)	0.109
J/kg•°C (25°C)	455

Table 3 - Coefficient of Thermal Expansion*

°F	°C	in/in/°F x 10^{-6}	µm/µm/°C
200	93	5.60	10.08
300	149	5.66	10.19
400	204	5.70	10.26
500	260	5.74	10.33
600	316	5.77	10.39
700	371	5.84	10.51
800	427	6.08	10.94
900	482	6.33	11.39
1000	538	6.57	11.83
1100	593	6.85	12.33
1200	649	7.15	12.87

*Mean coefficient of linear expansion between 70°F and the temperature shown. Inflection point = 780°F.

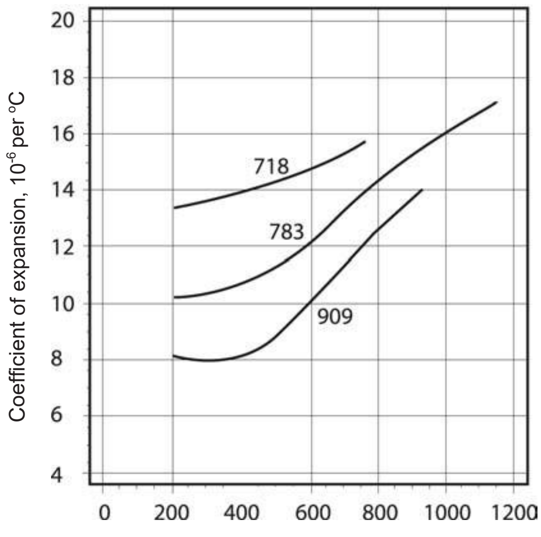

Figure 1- Mean coefficient of linear expansion between 25°C and the temperature shown. (Alloys annealed and aged.)

Table 4- Dynamic Modulus of Elasticity, Shear Modulus, and Poisson's Ratio

Temperature		Young's Modulus		Shear Modulus		Poisson's Ratio
°F	°C	10^3 ksi	GPa	10^3ksi	GPa	
72	21	25.72	177.3	9.83	67.8	0.31
200	93	25.46	175.5	9.71	67.0	0.31
300	149	25.31	174.5	9.65	66.5	0.31
400	204	25.12	173.2	9.58	66.1	0.31
500	260	25.01	172.4	9.49	65.4	0.32
600	316	24.85	171.3	9.42	65.0	0.32
700	371	24.78	170.9	9.44	65.1	0.31
800	427	24.57	172.2	9.42	65.0	0.30
900	482	24.20	166.9	9.25	63.8	0.31
1000	538	23.76	163.8	9.11	62.8	0.30
1100	593	23.30	160.7	8.93	61.6	0.31
1200	649	22.71	156.6	8.73	60.2	0.30
1300	704	22.12	152.5	8.50	58.6	0.30
1400	760	21.45	147.9	8.28	57.1	0.29
1500	816	20.62	142.2	8.11	55.9	0.27
1600	871	19.61	135.2	7.66	52.8	0.28
1700	927	18.67	128.7	7.22	49.8	0.29

Table 5- Thermal Conductivity (for annealed material)

°F	°C	Btu-in/ft²-h-°F	W/m-°C
70	21	71	10.1
200	93	80	11.4
400	204	91	13.0
600	316	104	14.8
800	427	108	15.4
1000	538	134	19.1
1200	649	154	22.0
1400	760	170	24.2

Mechanical Properties

In the age-hardened condition, INCONEL alloy 783 has high mechanical properties at room temperature and retains much of its strength at temperatures to about 1300°F (704°C). All mechanical properties given here are for the standard heat treatment:

Solution anneal at 2050°F (1121°C)/1 hr, air cool, plus "beta age" at 1550°F (845°C)/4 hr, air cool to room temperature, plus age harden at 1325°F (718°C)/8 hr, furnace cool at 100°F (55°C)/ hr to 1150°F (621°C)/8 hr, and air cool.

Tensile Properties

Table 6- Tensile Properties

Test Temperature		Yield Strength		Tensile Strength		Elongation	Reduction of Area
°F	°C	ksi	MPa	ksi	MPa	%	%
70	21	113.0	779	171.0	1194	24	44
800	427	104.0	717	156.0	1076	25	42
1000	538	99.5	686	150.0	1034	25	46
1200	649	99.0	683	142.0	979	28	39
1300	704	88.0	607	117.0	807	39	64

Stress Rupture

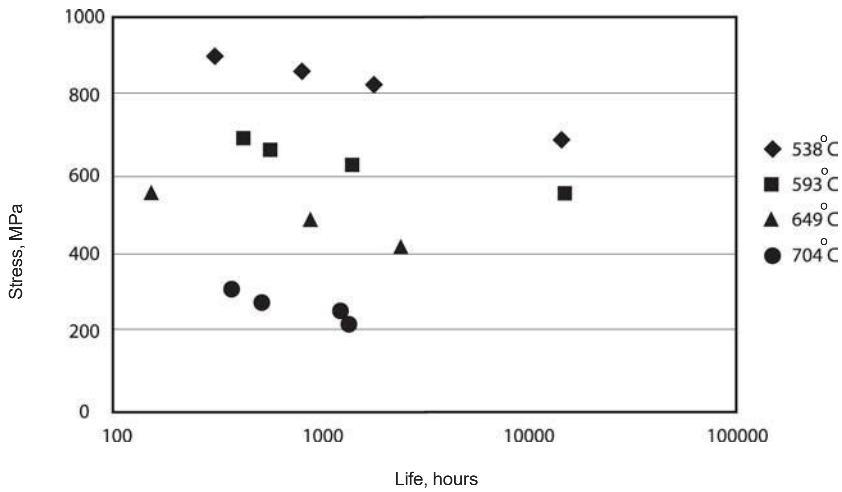

Figure 2 - Stress rupture properties of INCONEL alloy 783

Static Crack Growth Behavior In Air, 538°C

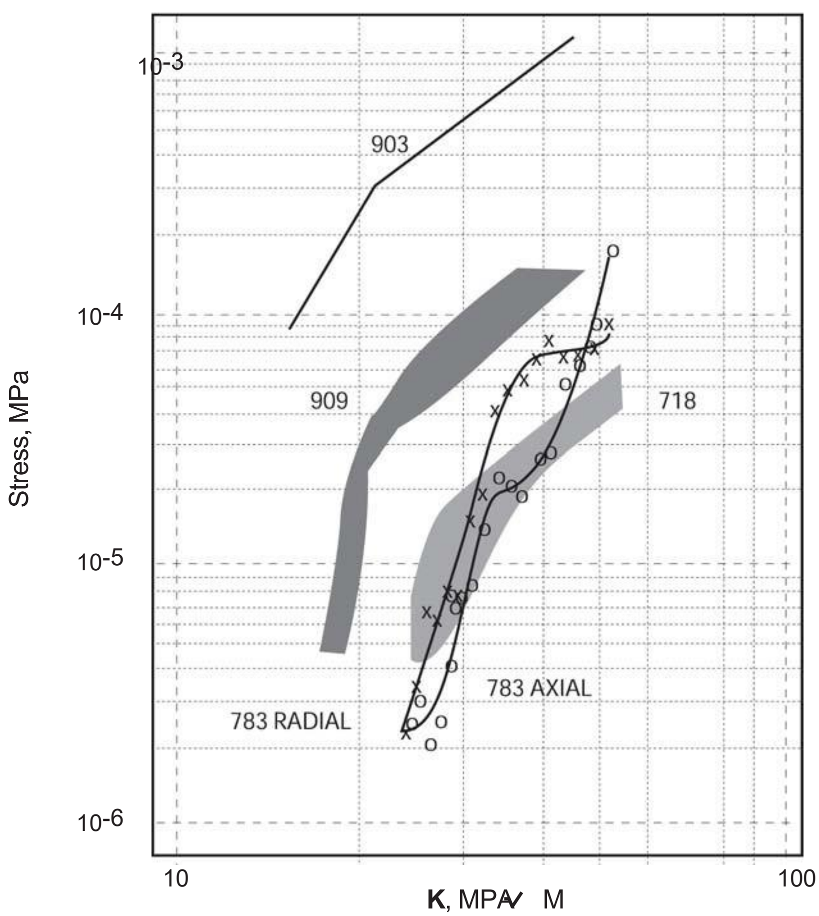

Figure 3 - 1000°F (538°C) crack growth curves comparing behavior of INCONEL alloys 783, 718, and INCOLOY alloy 909 in air [2].

Extended Exposure at Elevated Temperatures

High temperature tensile properties of INCONEL alloys 783, 718, and INCOLOY alloy 909 tested at 1200°F (649°C) following isothermal exposure at 1100°F (593°C) are shown in Figure 4. Under these test conditions the yield strength of alloys 783 and 718 remain constant or increase while alloy 909 continues to decline. The elongation value for alloy 783 declines to about 10% after 8000 hours of exposure but then increases thereafter.

High temperature tensile properties of INCONEL alloys 783, 718 and INCOLOY alloy 909 tested at 1300°F (704°C) following isothermal exposure at 1300°F (704°C) are shown in Figure 5. Alloy 783 offers superior performance when compared to alloy 909 in these test conditions.

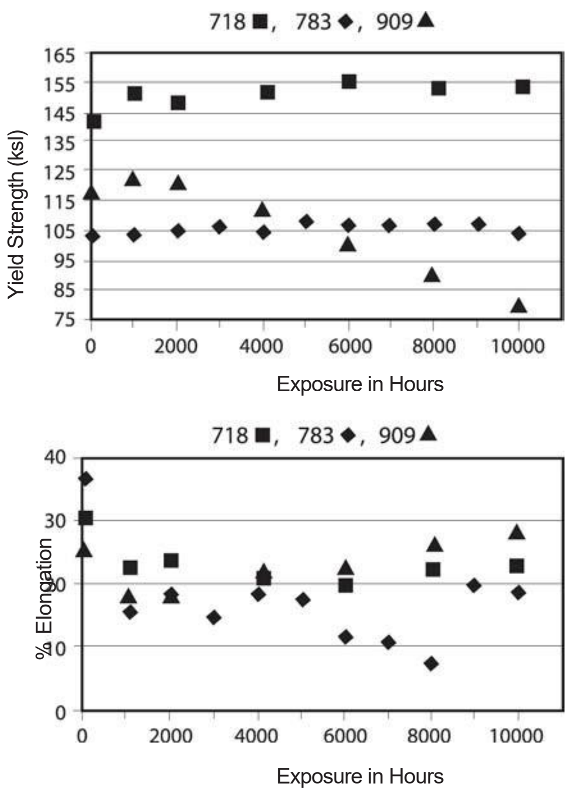

Figure 4 - High temperature tensile properties of INCONEL alloys 783, 718 and INCOLOY alloy 909 tested at 1200°F (649°C) following isothermal exposure at 1100°F (593°C).

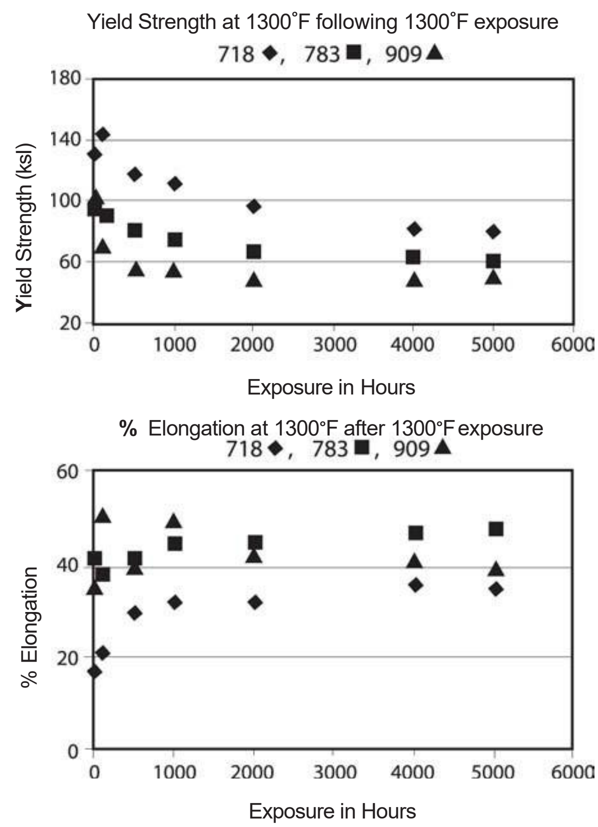

Figure 5- High temperature tensile properties of INCONEL alloys 783, 718 and INCOLOY alloy 909 tested at 1300°F (704°C) following isothermal exposure at 1300°F (704°C).

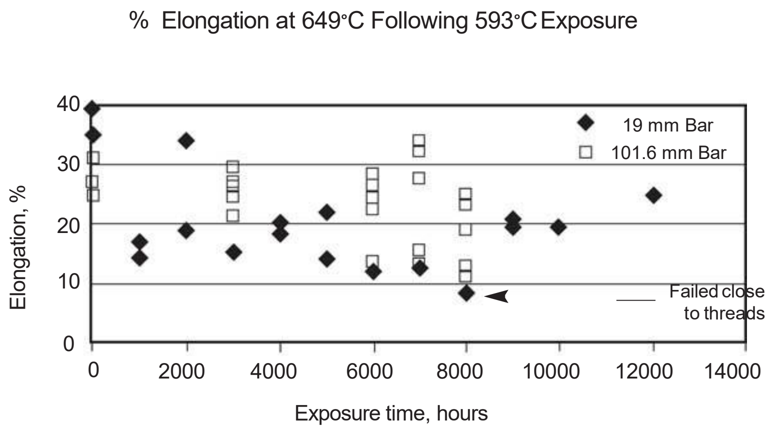

Figure 6- The 1200°F (649°C) elongation of materials following isothermal exposure at 1100°F (593°C). Open squares indicate data obtained from the repeat testing [3].

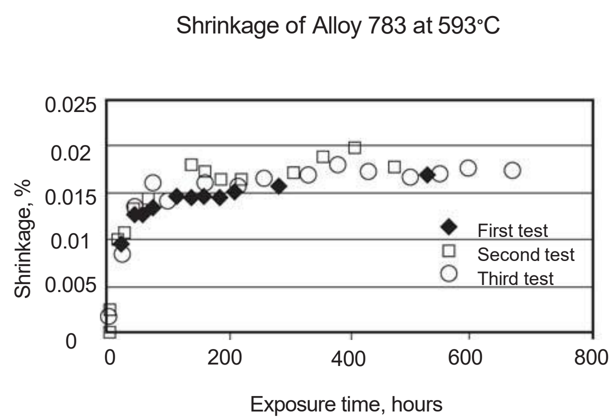

Figure 7- Shrinkage of alloy 783 on isothermal exposure at 593°C. This change in dimensions was in-situ monitored at 593°C with a dilatometer [3].

Elevated Temperature Fatigue

Tension-tension fatigue data for INCONEL alloy 783 aged for 1000 hours at 1100°F (593°C) and then tested at 800°F (427°C) and 1200°F (649°C) are shown in Figure 8.

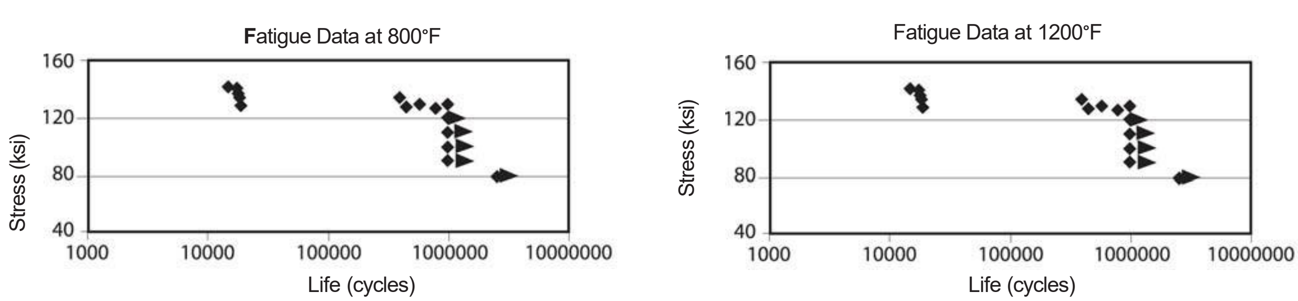

Figure 8- Tension-tension fatigue data for INCONEL alloy 783 exposed for 1000 hours at 1100°F (593°C) and then tested at 800°F (427°C) and 1200°F (649°C). R=0.1, Frequency=10 hertz

Oxidation and Salt Spray Resistance

To achieve low CTE, alloys based on Ni-Fe-Co compositions require the chromium content be maintained at low levels. Added Cr lowers the Curie temperature and thereby increases thermal expansion rate over a wider temperature range. The necessary lack of Cr reduces resistance to both general oxidation and stress accelerated grain boundary oxygen enhanced cracking (SAGBO). Increased amounts of Al in alloys strengthened by γ′alone promotes SAGBO. Alloy 783 is the culmination in the development of an alloy system with very high aluminum content that, in addition to forming γ′, causes β aluminide phase precipitation in the austenitic matrix. It was discovered that this type of structure could be processed to resist both SAGBO and general oxidation, while providing low thermal expansion and useful mechanical properties up to 700°C.

Figure 9 provides a comparison of the cyclic oxidation resistance of INCONEL alloys 783, 718, and INCOLOY alloy 909 at 704°C (1300°F). The oxidation rate of alloy 783 is slightly greater than alloy 718 at 704°C, but is still excellent compared to alloy 909.

In Figures 10 and 11, test samples were prepared from wrought alloys 783, 909, 718 and a martensitic M152 alloy for salt spray testing. A series of specimens were fully heat- treated per specification and tested in the as-machined, bare metal condition. Two cylindrical alloy 783 samples (783C & 783D) were fully machined then annealed and aged resulting in a thin oxide scale. A third series was processed to evaluate a chromide-coated condition. One set of samples was tested as per ASTM B117-97 and the other set was tested as per ASTM B117-97 with intermittent exposure of twice a week at 649°C for 24 hours [1}.

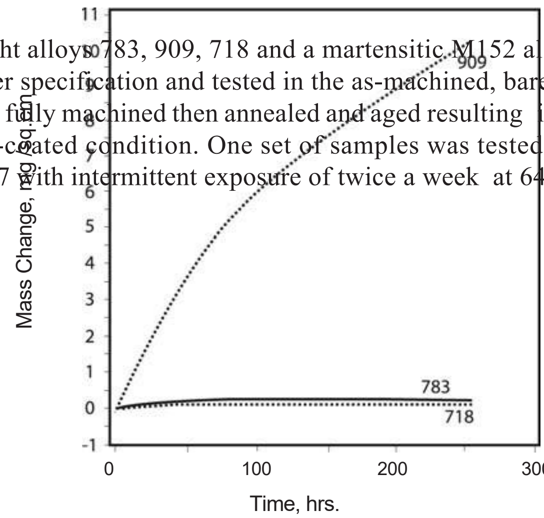

Figure 9 - Weight loss for INCONEL alloys 783, 718, and INCOLOY alloy 909 after 1300°F (704°C) cyclic oxidation tests (60 min. in/ 20 min. out).

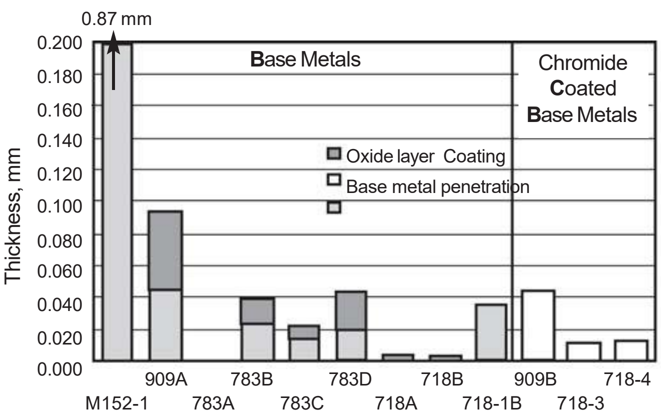

Figure 10- Measurements of metal affected by 1,009 hours of salt spray at 35°C in 5% NaCl. Testing was done as per ASTM B117-97. Trends indicate the resistance alloy 783 is far superior to other low CTE alloys and on par with alloy 718. Letters and numbers after the alloy show multiple samples.

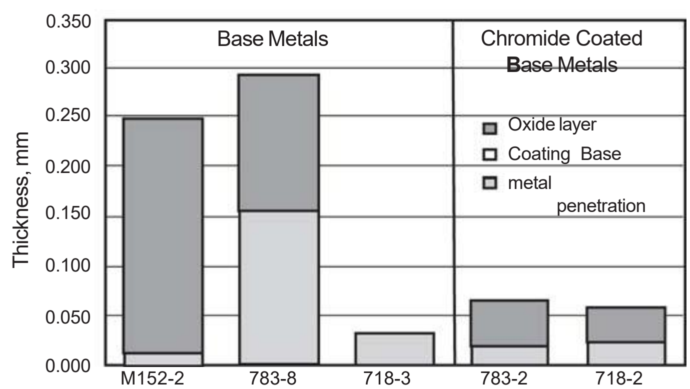

Figure 11- Extent of corrosive attack after 1,009 hours of salt spray exposure and 649°C thermal exposure. Samples were tested as per ASTM B117-97 and also after intermittent exposure to 649°C for 24 hours twice a week.

Fabrication

INCONEL alloy 783 has good fabricability and can be formed, machined, and welded by conventional procedures for nickel alloys. In most operations, its behavior is similar to that of INCONEL alloy 718.

Hot Forming

The temperature range for hot forming of INCONEL alloy 783 is 1700°F to 2050°F (927°C to 1121°C). Alloy 783 works similarly to INCONEL alloy 718, but is a bit "softer" at high temperatures, and begins to stiffen quickly as temperature drops below 1700°F (927°C).

1. Initial Forging- ingots are heated to 2050°F (1121°C) and finished to 8-in diameter billet with 1900°- 1950°F (1038°-1066°C).
2. Intermediate Forging- heat billets to 1900°F (1038°C); final reheat from 1800°-1850°F (982°- 1010°C).

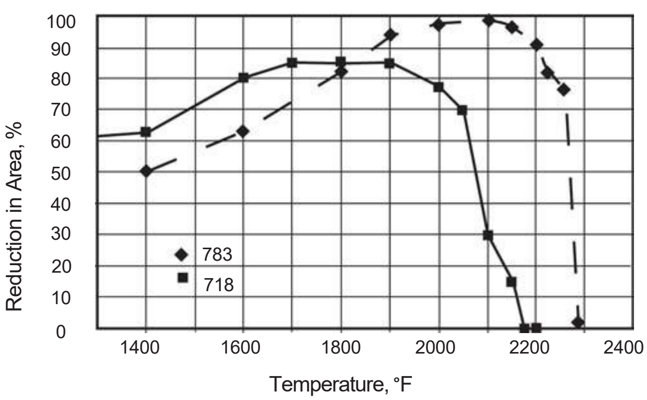

Figure 12- Gleeble hot ductility of alloys 783 and 718.

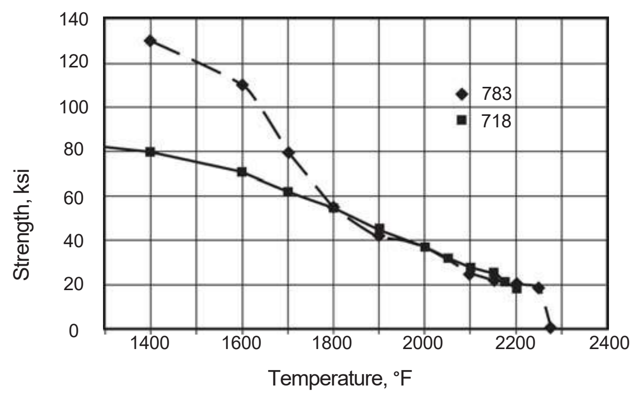

Figure 13- Gleeble fracture strength of alloys 783 and 718.

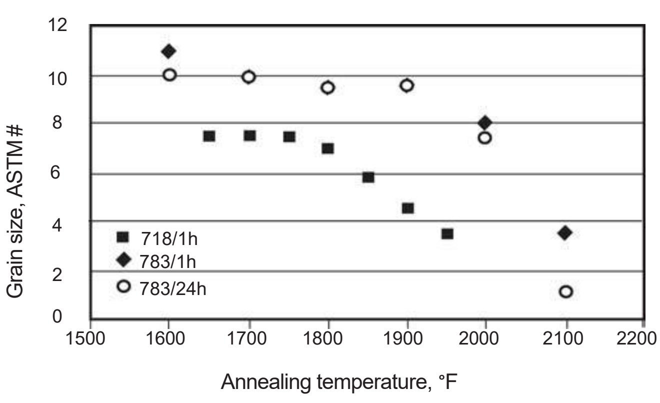

Figure 14- Annealing temperature versus grain size of hot worked alloys 783 and 718.

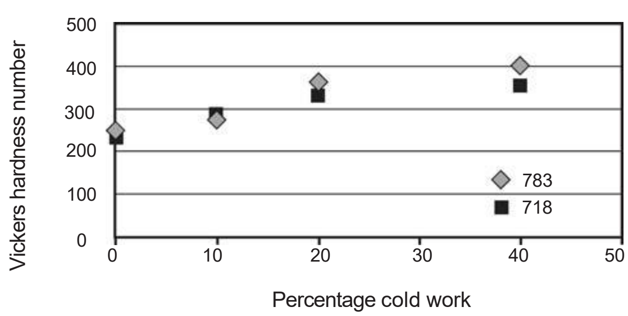

Figure 15- Work hardening characteristics of alloys 783 and 718.

Machining

INCONEL alloy 783 is machined by conventional practices for high-strength nickel alloys. Rough machining should be done with the material in the annealed condition.

Heat Treatment

INCONEL alloy 783 is heat treated as follows:

Solution anneal at 2050°F (1121°C)/1 hr, air cool, plus "beta age" at 1550°F (845°C)/4 hr, air cool to room temperature, plus age harden at 1325°F (720°C)/8 hr, furnace cool at 100°F (55°C)/hr to 1150°F (620°C)/8 hr, and air cool.

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