INCONEL® alloy 718SPF™ is a specifically "tailored" version of INCONEL alloy 718, designed for the superplastic forming process. The alloy is optimized for the process by rigorous control of composition, melt practice and rolling conditions.

INCONEL alloy 718SPF was developed to meet the need for a nickel-base alloy suitable for manufacture into complex shaped components subject to a combination of high temperature, high temperature corrosion and high stress. INCONEL alloy 718SPF meets all the mechanical property requirements of AMS 5596G, as annealed plus aged, as well as all requirements of AMS 5950, which is specific to INCONEL alloy 718SPF.

Superplastic forming, now highly sophisticated and used extensively for producing commercial and military aircraft components, is an ideal process for manufacturing complex shaped parts. Use of superplastic forming can enhance component performance and reliability while lowering overall manufacturing cost by reducing the need for extensive welding or other joining methods, lowering the inventory of parts and simplifying the manufacturing process.

Composition and Physical Properties

INCONEL alloy 718SPF has the same composition and physical properties as INCONEL alloy 718. Limiting chemical composition is shown in Table 1; physical constants in Table 2; and elastic properties as a function of temperature in Tables 3 and 4 on page 3. Thermal and electrical properties are listed in Tables 5 to 7. The data in Tables 2 to 7 are typical and can vary slightly, depending on the composition and condition of the test specimen.

Table 1 - Limiting Chemical Composition, %*

Ni (+Co)	50.00-55.00
Cr	17.00-21.00
Nb (+Ta)	4.75-5.25
Mo	2.80-3.30
Ti	0.65-1.15
Al	0.20-0.80
Co	1.00 max.
C	0.05 max.
Mn	0.35 max.
Si	0.35 max.
P	0.015 max.
S	0.002 max.
B	0.006 max.
Cu	0.30 max.
N	0.01 max.
Fe	Balance†

* Conforms to AMS specifications

†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.

Table 2 - Physical Constants

Density, annealed, lb/in³	0.296
g/cm³	8.19
annealed & aged, lb/in³	0.297
g/cm³	8.22
Melting Range, °F	2300-2437
°C	1260-1335
Specific Heat, at 70°F, Btu/lb °F	0.104
at 21°C, J/kg °C	435
Curie Temperature, annealed, °F	<-320
°C	<-197
annealed & aged, °F	-170
°C	-113
Permeability at 200 H and 70°F (21°C)	
annealed	1.0013
annealed & aged	1.0011

Table 3 - Modulus of Elasticity at Low Temperatures*

Temperature		Young's Modulus		Torsional Modulus		Poisson's
°F	°C	ksi x 10^3	GPa	ksi x 10^3	GPa	Ratio
-308	-190	31.3	216	12.5	86	0.254
-86	-66	30.6	211	11.8	81	0.299
70	21	29.8	205	11.6	80	0.284
147	64	29.7	205	11.4	79	0.307
227	109	29.3	202	11.2	77	0.303
320	160	28.9	199	11.1	77	0.308

*Cold-rolled sheet, heat-treated in accordance with AMS 5596B.

Physical Properties (continued)

Table 4 - Modulus of Elasticity*

Temperature		Young's Modulus		Torsional Modulus		Poisson's Ratio
°F	°C	ksi x 10^3	GPa	ksi x 10^3	GPa	
70	21	29.0	200	11.2	77	0.294
100	38	28.8	199	11.2	77	0.291
200	93	28.4	196	11.0	76	0.288
300	149	28.0	193	10.9	75	0.280
400	204	27.6	190	10.8	74	0.280
500	260	27.1	187	10.6	73	0.275
600	316	26.7	184	10.5	72	0.272
700	371	26.2	181	10.3	71	0.273
800	427	25.8	178	10.1	70	0.271
900	482	25.3	174	9.9	68	0.272
1000	538	24.8	171	9.7	67	0.271
1100	593	24.2	167	9.5	66	0.276
1200	649	23.7	163	9.2	63	0.283
1300	704	23.0	159	8.9	61	0.292
1400	760	22.3	154	8.5	59	0.306
1500	816	21.3	147	8.1	56	0.321
1600	871	20.2	139	7.6	52	0.331
1700	927	18.8	130	7.1	49	0.334
1800	982	17.4	120	6.5	45	0.341
1900	1038	15.9	110	5.8	40	0.366
2000	1093	14.3	99	5.1	35	0.402

*Hot-rolled flat, heat-treated 1800°F (982°C)/1h/AC + 1325°F (719°C)/8h/FC at 20°F (11°C) per hour to 1150°F (621°C), and held for total aging time of 18 hours. Dynamic testing involved frequencies of 813 to 571 cps in bending, and 3110 to 2097 cps in torsion.

[†]Calculated from $\frac{E-2G}{2G}$, where E is Young's modulus and G is torsional modulus.

Table 5 - Thermal Conductivity

Temperature		Annealed[a]		Annealed + Aged[b]	
°F	°C	Btu in/ft² h °F	W/m K	Btu in/ft² h °F	W/m K
70	21	77	11.1	79	11.4
200	93	86	12.4	87	12.5
400	204	98	14.1	100	14.4
600	316	111	16.0	112	16.1
800	427	123	17.7	124	17.9
1000	538	135	19.4	136	19.6
1200	649	147	21.2	148	21.3
1400	760	160	23.0	161	23.2
1600	871	173	24.9	173	24.9
1800	982	185	26.6	186	26.8
2000	1093	196	28.2	199	28.7

[a]1800°F (982°C) for 1 h.

[b]1800°F (982°C) for 1 h, plus 1325°F (719°C) for 8 h, furnace cooled at 20°F (11°C) per hour to 1150°F (621°C) and held for total aging time of 18 hours.

Conductivity calculated from resistivity values.

Table 6 - Electrical Resistivity

Temperature		Annealed[a]		Annealed + Aged[b]	
°F	°C	ohm/circ mil ft	microhm cm	ohm/circ mil ft	microhm cm
70	21	753	125	725	120
200	93	762	126	733	122
400	204	772	128	755	125
600	316	775	129	768	127
800	427	784	130	775	129
1000	538	798	132	788	131
1200	649	805	134	794	132
1400	760	802	133	797	132
1600	871	799	133	796	132
1800	982	801	133	800	133
2000	1093	811	135	796	132

[a]1800°F (982°C) for 1 h.

[b]1800°F (982°C) for 1 h, plus 1325°F (719°C) for 8 h, furnace cooled at 20°F (11°C) per hour to 1150°F (621°C) and held for total aging time of 18 hours.

Table 7 - Thermal Expansion

Temperature		Mean Coefficient of Linear Thermal Expansion[ab]	
°F	°C	in/in/°F x 10^{-6}	m/m/°C x 10^{-6}
-320	-196	5.9[c]	10.62[c]
200	93	6.75	12.15
400	204	7.38	13.28
600	316	7.65	13.77
800	427	7.85	14.13
1000	538	8.00	14.40
1200	649	8.27	14.89

[a]From 70°F (21°C) to temperature shown.

[b]Annealed 1750°F (954°C) for 1 h, aged 1325°F (719°C) for 8 h, furnace cooled to 1150°F (621°C), held for 8 h, air cooled.

[c]Samples tested in both the annealed and annealed plus aged condition. Aging treatment included holding for 10 h at 1150°F (621°C).

Mechanical Properties

INCONEL alloy 718SPF is produced with an annealed temper. Typical annealed and annealed plus aged properties are presented in Table 8. The effect of varying gauge on stress rupture life is presented in Table 9 for two aging conditions. The alloy is produced to a grain size of ASTM No. 10 (0.01 mm/0.0004 in) or finer. As produced, INCONEL alloy 718SPF sheet meets the strength and ductility requirements of AMS 5596G, as annealed plus aged.

Table 10 presents data on the tension-tension fatigue-resistance of INCONEL alloy 718SPF (ASTM grain size #13), and compares the results with those for conventionally produced alloy 718 (ASTM grain size #4.5) in similar test conditions. The axial fatigue testing was carried out at a frequency of 59 Hz.

Mechanical Properties (continued)

Table 8 - Typical Mechanical Properties

	INCONEL alloy 718SPF Annealed[a]	AMS 5596G Solution Annealed[b]	AMS 5950 Solution Annealed[b]
Room Temperature Tensile Properties			
0.2% Y.S., ksi (MPa)	120 (829)	80 (552) max.	155 (1069) max.
U.T.S., ksi (MPa)	162 (1117)	140 (965) max.	185 (1276) max.
Elongation, %	31	30 min.	20 min.
Hardness, Rc	24	25.5 max.	34 max.
Grain Size, ASTM No.	12	—	10 or finer
		Aged[c]	
0.2% Y.S., ksi (MPa)	202 (1393)	150 (1034) min.	148 (1020) min.
U.T.S., ksi (MPa)	225 (1551)	180 (1241) min.	180 (1241) min.
Elongation, %	16	12 min.	12 min.
Hardness, Rc	45	36 min.	36 min.
1200°F (649°C) Tensile Properties		**Aged[c]**	
0.2% Y.S., ksi (MPa)	160 (1103)	120 (827) min.	120 (827) min.
U.T.S., ksi (MPa)	177 (1220)	145 (1000) min.	145 (1000) min.
Elongation, %	22	5 min.	5 min.
1200°F (649°C)/100 ksi (690 MPa) Stress Rupture Properties		**Aged[c]**	
Life, h	95.0	23.0 min.	23.0 min.
Elongation, %	11.2	4 min.	4 min.

[a]Continuous process anneal, 1700°F (927°C) at 15 ft (4.57 m) per minute.

[b]1725°F (940°C) to 1825°F (995°C)

[c]1750°F (954°C)/1 h/AC + 1325°F (719°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C) + 1150°F (621°C)/8 h/AC.

Table 9 - Stress Rupture Properties at 1200°F (649°C)/100 ksi (690 MPa) Versus Gauge

Gauge, Inches (mm)	Stress Rupture Life, Hours	% Elongation
	Aged[a]	
0.050 (1.270)	78.7	15.6
0.040 (1.016)	67.4	19.9
0.030 (0.762)	61.4	14.0
0.010 (0.254)	60.7	15.3
	Aged[b]	
0.050 (1.270)	108.8	36.9
0.030 (0.762)	96.7	15.2

[a]1750°F (954°C)/1 h/AC + 1325°F (719°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C)/8 h/AC.

[b]Direct age at 1325°F (719°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C)/8 h/AC.

Table 10 - Axial Fatigue Results for INCONEL alloy 718SPF (ASTM Grain Size 13) vs. Conventional Alloy 718 (ASTM Grain Size 4.5)

Alloy	Heat Treatment	Test Temperature		Max./Min. Stress		Cycles
		°F	°C	ksi	MPa	
INCONEL alloy 718	B+C	600	316	95/19	655/131	395,898 F.G.
	B+C	600	316	100/20	689/138	242,598 F.G.
	B+C	600	316	110/22	758/152	129,464 F.G.
INCONEL alloy 718SPF	A+C	600	316	110/22	758/152	10,033,154 R.O.
	A+C	600	316	140/28	965/193	>2,625,914 TAB
	A+C	600	316	180/36	1241/248	21,600 F.G.
INCONEL alloy 718	B+C	1000	538	90/18	621/124	>862,762 P.H.
	B+C	1000	538	95/19	655/131	>273,663 P.H.
	B+C	1000	538	100/20	689/138	>151,516 F.G.
INCONEL alloy 718SPF	A+C	1000	538	100/20	689/138	11,128,768 R.O.
	A+C	1000	538	120/24	827/165	13,999,099 R.O.

A = 1750°F (954°C)/2 h/muffle cool in Ar.
B = 1950°F (1066°C)/30 min/muffle cool in Ar.
C = 1325°F (718°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C)/8 h/AC.

F.G. = Failed in gauge section
R.O. = Runout
P.H. = Pin hole failure
TAB = Failed outside gauge area

Using a longer term age of 16 hours at 1150°F (621°C), data on the fatigue resistance properties for INCONEL alloy 718SPF (ASTM grain size #13) and alloy 718 (ASTM grain size #4.5) are presented in Table 11.

Using these same alloys, notched fatigue (K_T = 3.01) data were obtained for the two test temperatures. The results are shown in Table 12.

Table 11 - Axial Fatigue Results for INCONEL alloy 718SPF (ASTM Grain Size 13) vs. Conventional Alloy 718 (ASTM Grain Size 4.5). Frequency = 59 Hz

Alloy	Heat Treatment	Test Temperature		Max./Min. Stress		Cycles
		°F	°C	ksi	MPa	
INCONEL alloy 718	A	600	316	95/19	655/131	515,896 F.G.
	A	600	316	100/20	689/138	300,320 F.G.
	A	600	316	110/22	758/132	211,098 F.G.
INCONEL alloy 718SPF	B	600	316	110/22	758/152	11,022,717 R.O.
	B	600	316	140/28	965/193	10,100,487 R.O.
	B	600	316	180/36	1241/248	20,300 F.G.
INCONEL alloy 718	A	1000	538	90/18	621/124	1,704,754 F.G.
	A	1000	538	95/19	655/131	>556,045 P.H.
	A	1000	538	100/20	689/138	471,194 F.G.
INCONEL alloy 718SPF	B	1000	538	100/20	689/138	10,260,863 R.O.
	B	1000	538	120/24	827/165	10,068,348 R.O.
	B	1000	538	140/28	965/193	10,453,000 R.O.

A = 1950°F (1066°C)/30 min/muffle cool in Ar + 1275°F (691°C)/8 h/AC + 1150°F (621°C)/16 h/AC.
B = 1750°F (954°C)/2 h/muffle cool in Ar + 1275°F (691°C)/8 h/AC + 1150°F (621°C)/16 h/AC.

F.G. = Failed in gauge section
R.O. = Runout
P.H. = Pin hole failure

Mechanical Properties (continued)

Table 12 - Axial Fatigue Results for INCONEL alloy 718SPF (ASTM Grain Size 13) vs. Conventional Alloy 718 (ASTM Grain Size 4.5) with Notched Specimen of K_t = 3.01

Alloy	Heat Treatment	Test Temperature		Max./Min. Stress		Cycles
		°F	°C	ksi	MPa	
INCONEL alloy 718	A	600	316	85/8.5	586/59	16,300 F.N.
	A	1000	538	90/9.0	620/62	11,300 F.N.
	C	600	316	95/9.5	655/65	12,400 F.N.
	C	600	316	85/8.5	586/59	18,800 F.N.
	C	1000	538	90/9.0	620/62	8,300 F.N.
INCONEL alloy 718SPF	B	600	316	100/10.0	689/69	14,000 F.N.
	B	1000	538	95/9.5	655/65	15,100 F.N.
	C	600	316	100/10.0	689/69	23,500 F.N.
	C	600	316	95/9.5	655/65	15,600 F.N.
	C	1000	538	95/9.5	655/65	14,000 F.N.

A = 1950°F (1066°C)/30 min/muffle cool in Ar + 1275°F (691°C)/8 h/AC + 1150°F (621°C)/16 h/AC.
B = 1750°F (954°C)/2 h/muffle cool in Ar + 1275°F (691°C)/8 h/AC + 1150°F (621°C)/16 h/AC.
C = 1750°F (954°C)/2 h/muffle cool in Ar + 1325°F (718°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C)/8 h/AC.

F.N. = Failed at Notch

Superplastic Forming Characteristics

INCONEL alloy 718SPF possesses two essential characteristics that make the alloy amenable to superplastic forming:

- Grain size stability over the time and temperature regime employed for superplastic forming (See Figure 1).
- A combination of low flow stress and significant ductility using typical superplastic forming process conditions (See Figure 2).

The effect of lower temperatures on flow stress and total engineering strain at constant strain rate is depicted in Figure 3.

For the typical initial strain rates currently employed for superplastic forming, the expected range of engineering strain for INCONEL alloy 718SPF is given in Figure 4. The effect of lower temperatures on the engineering strain as a function of the initial strain rate is shown in Figure 5. For the same initial strain rates, the expected true stresses for INCONEL alloy 718SPF are given in Figure 6 and for lower temperatures in Figure 7.

Superplastic forming process engineers frequently evaluate the superplastic forming applicability of a given set of process conditions on the basis of its "m" value, where "m" is defined as:

$$m = \left(\frac{\partial \mathrm{Ln}\sigma}{\partial \mathrm{Ln}\varepsilon}\right) \varepsilon, T$$

"m" values are a measure of dimensional stability as defined by resistance to necking during superplastic forming. The value of m for three temperatures between 1700°F (927°C) and 1900°F (1038°C) is given in Figure 8. Using the data presented in Figure 7, the activation energy for the superplastic forming process can be determined by plotting σ^n/T versus 1/T as shown in Figure 9. Where the stress exponent (n) is different for different strain rate ranges or varies with grain size, the activation energy will vary according.

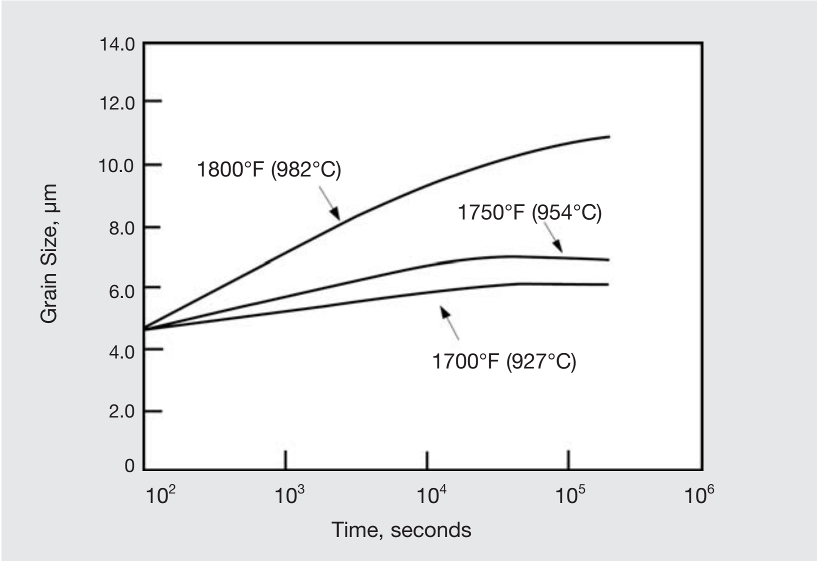


Figure 1 - Grain growth vs. time at 1700°F (927°C), 1750°F (954°C) and 1800°F (982°C).

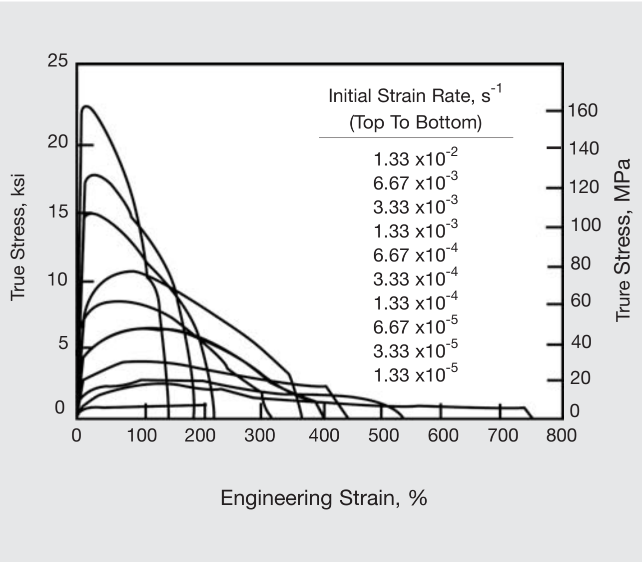


Figure 2 - True stress vs. engineering strain for 10 strain rates at 1750°F (954°C).

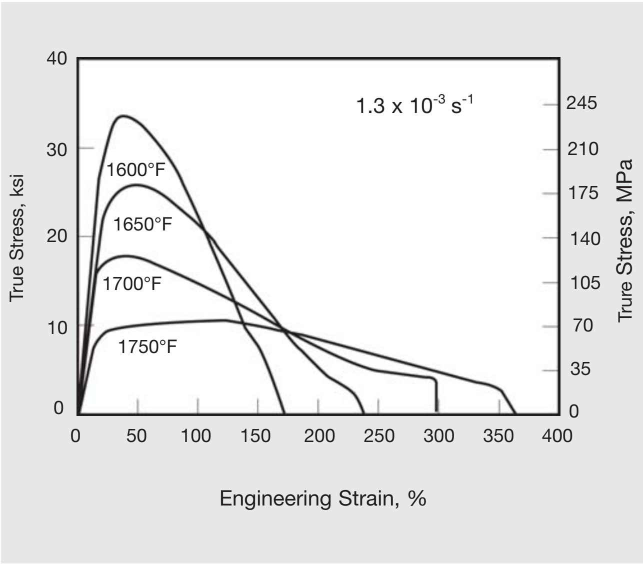


Figure 3 - The effect of lower temperatures on flow stress and total engineering strain at constant strain rate.

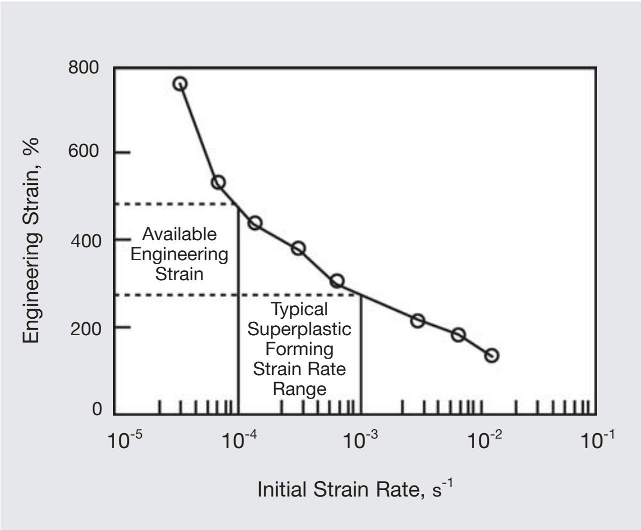


Figure 4 - Engineering strain vs. strain rate at 1750°F (954°C). For typical superplastic forming strain rates, the available engineering strain is highlighted.

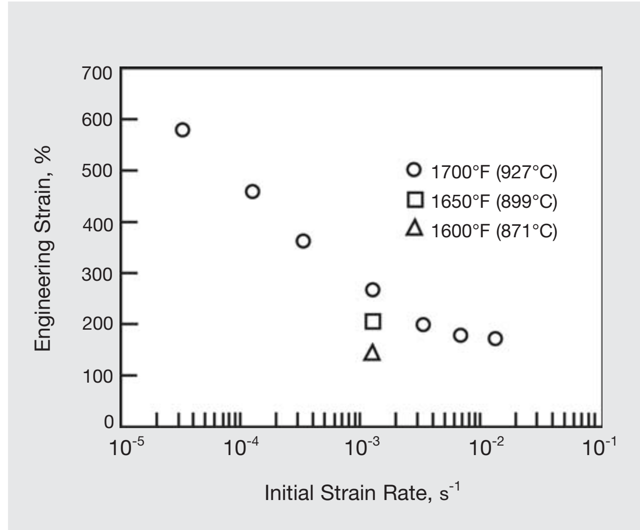


Figure 5 - The effect of lower temperatures on the engineering strain as a function of the initial strain rate.

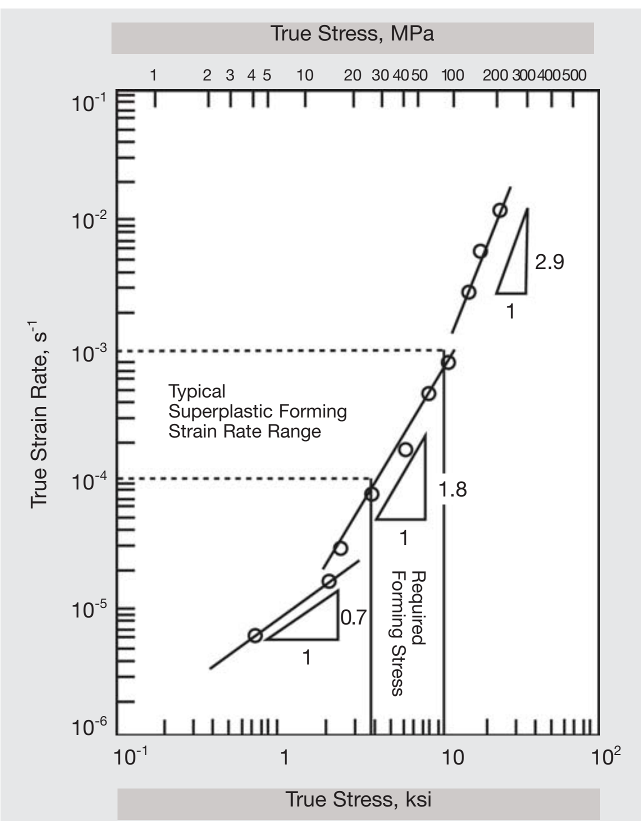


Figure 6 - True strain vs. true stess (both at maximum stress). This plot defines the maximum stresses that must be generated during superplastic forming to deform INCONEL alloy718SPF at the conventional strain rates of 10^{-3} to $10^{-4}s^{-1}$. The necessary stress range is from nearly 4 to 12 ksi (27.6 to 82.7 MPa).

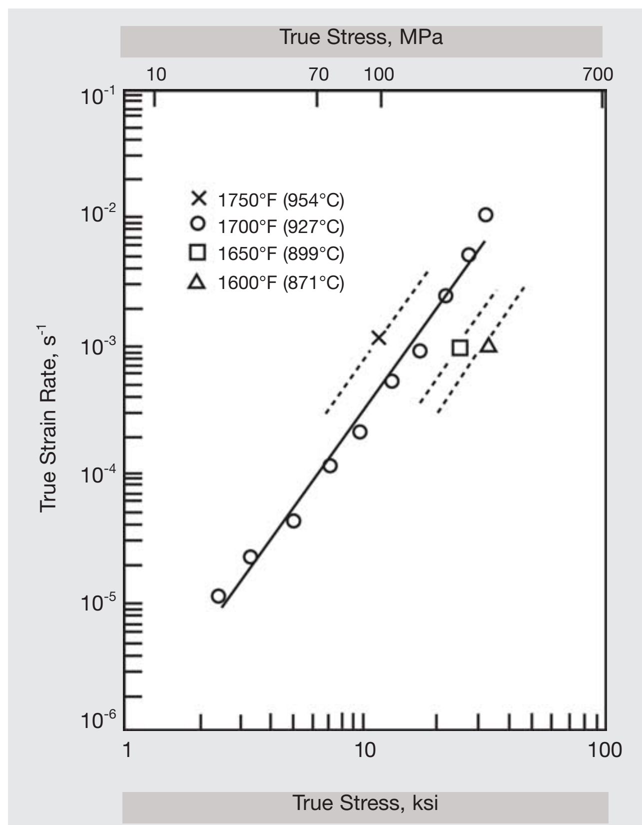


Figure 7 - True strain vs. true stress (for lower temperatures).

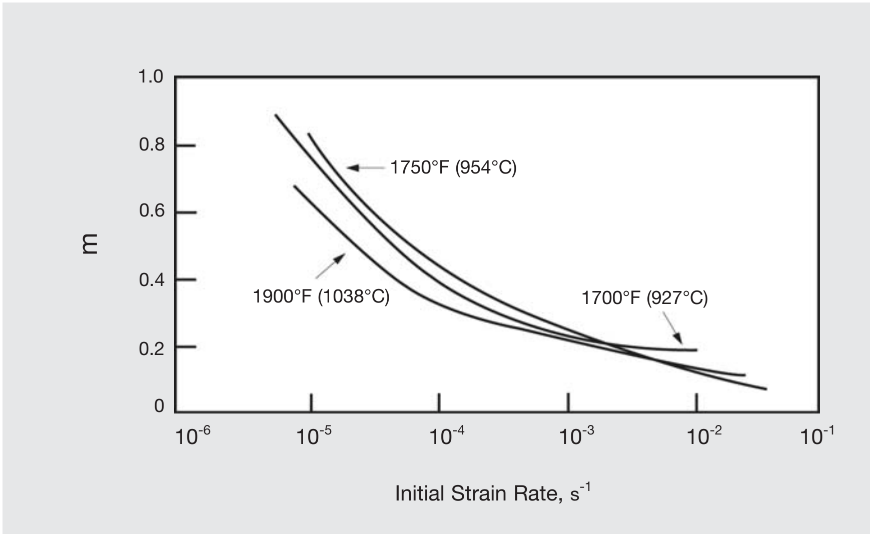


Figure 8 - “m” values; a measure of strain rate sensitivity vs. strain rate for temperatures between 1700°F (927°C) and 1900°F (1038°C).

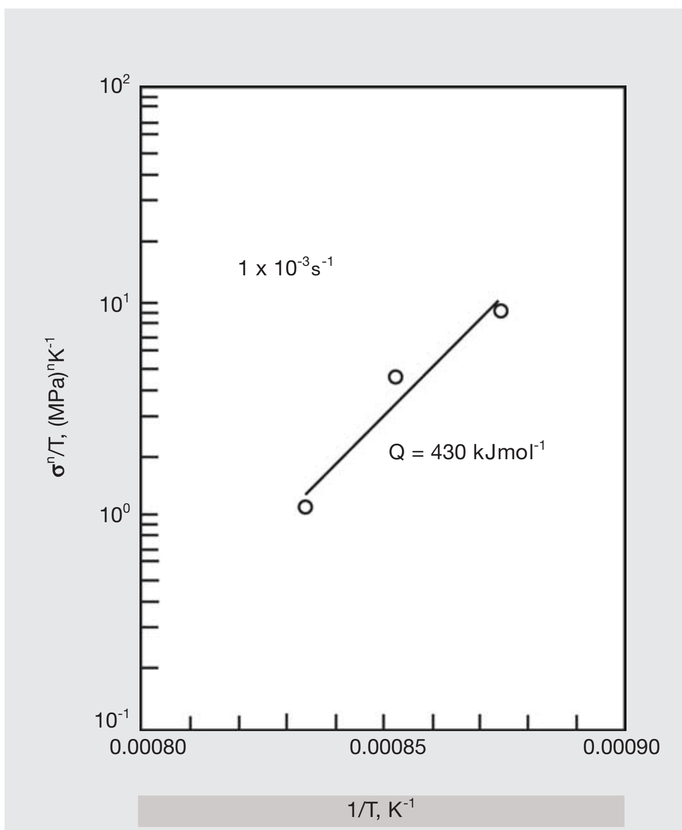


Figure 9 - Using the data presented in Figure 7, the activation energy for the superplastic forming process can be determined by plotting σ^n/T versus 1/T as shown above. Where the stress exponent (n) is different for different strain rate ranges or varies with grain size, the activation energy will vary accordingly.

Superplastically Formed Properties and Characteristics

The superplastic forming process for INCONEL alloy 718SPF involves the shaping of sheet between ceramic or metallic platens at temperatures near 1750°F (954°C). The sheet is subjected to an inert gas pressure of about 300 psi (2.1 MPa) for periods up to four hours.

Table 13 compares the annealed properties of INCONEL alloy 718SPF with that of superplastic alloy formed material with reductions in gauge of 13%, 19% and 33%. Note that, under these conditions, the alloy exceeds the maximum annealed strength requirements of AMS 5596G but not the minimum requirements for ductility and hardness. This is largely due to the ultra-fine grain size of the material which remains essentially constant during superplastic forming. While grain size remains constant, increasing deformation as a result of the superplastic forming process reduces hardness, tensile strength and elongation.

Table 14 shows the effect of annealing time (0.33 and 1.0 h) at 1750°F (954°C) on restoring aged room temperature tensile ductility (the minimum elongation of AMS 5596G is 12%). Tensile properties and hardness are satisfactory, as are all tensile properties at 1200°F (649°C) for the times evaluated. Because of the fine grain size of the post-superplastically formed material, it is not possible to achieve the stress rupture life of AMS 5596G without incorporating a grain growth annealing step prior to the aging heat treatment, as indicated in Table 15. HIPing (hot isostatic processing) of superplastically formed components may be especially advantageous for enhancing stress rupture and fatigue properties.

Table 13 - Effect of Superplastic Forming* on Typical Room Temperature Tensile Properties of INCONEL alloy 718SPF [0.048 in (1.22 mm) Gauge Sheet]

		Room Temperature Tensile Properties as Function of Percent Reduction in Gauge		
	Annealed†	13%	19%	33%
0.2% Y.S., ksi (MPa)	118 (815)	109 (750)	112 (773)	102 (700)
U.T.S., ksi (MPa)	162 (1114)	161 (1108)	160 (1102)	146 (1003)
Elongation, %	33.0	22.0	22.0	14.0
Hardness, Rc	23	29	27	Rb 99
Grain Size, ASTM No.	12	12	12	12

* Superplastic forming conditions: 1750°F (954°C)/0.3 ksi (2.06 MPa)

†Continuous process anneal: 1700°F (927°C) 15 ft (4.57 m)/min.

Table 14 - Effect of Time at an Annealing Temperature of 1750°F (954°C) Prior to Aging* after Superplastic Forming to 33% Reduction in Gauge

	Room Temperature Tensile Properties			
	0.0 h	0.33 h	1.0 h	AMS 5596G†
0.2% Y.S., ksi (MPa)	143 (989)	165 (1140)	173 (1193)	150 (1034)
U.T.S., ksi (MPa)	170 (1171)	192 (1325)	199 (1372)	180 (1241)
Elongation, %	6.0	9.0	16.0	12.0
Hardness, Rc	41	44	44	36
	1200°F (649°C) Tensile Properties			
	0.0 h	0.33 h	1.0 h	AMS 5596G†
0.2% Y.S., ksi (MPa)	124 (855)	153 (1055)	145 (1001)	120 (827)
U.T.S., ksi (MPa)	146 (1007)	162 (1120)	168 (1155)	145 (1000)
Elongation, %	26.0	16.0	20.0	5.0

*Aging conditions: 1325°F (719°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C) + 1150°F (621°C)/8 h/AC.

†Minimum properties.

Table 15 - Effect of Solution Annealing on Stress Rupture Life of Superplastically Formed INCONEL Alloy 718SPF

Condition	Stress Rupture Conditions 1200°F (649°C)/100 ksi (690 MPa)	
	Life	Elongation
	h	%
Superplastic Forming[a] (46% reduction) + Age[b]	11.7	9.0
	11.9	6.6
Superplastic Forming[a] (17% reduction) + Age[c]	47.1	2.1

[a] 1750°F (954°C)/0.3 ksi (2.06 MPa).

[b] 1750°F (954°C)/1 h/AC plus 1325°F (719°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C)/8 h/AC.

[c] 1900°F (1038°C)/1 h/AC plus 1325°F (719°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C)/8 h/AC.

Like most nickel alloys, INCONEL alloy 718SPF is subject to cavitation. As shown in Figure 10, the area of cavitation, while minimal at elongations of less than 150%, increases significantly with increasing elongations beyond 200%. Decreasing strain rates at any given elongation also increase the area of cavitation. The area of cavitation for two initial strain rates and total strains of less than 200% are presented in Table 16 along with the average cavity size for each total strain.

Use of background pressure during the superplastic forming operation is an effective method for reducing cavitation. Cavitation data as a function of maximum true strain and background pressure are presented in Figures 11 and 12 for initial strain rates of 1 x $10^{-4}s^{-1}$ and 3 x $10^{-5}s^{-1}$, respectively.

Hot isostatic pressure exposure at 1750°F (954°C) and 15 ksi (103 MPa) has been found to eliminate cavitation in superplastically processed sheet that has been reduced 33% in thickness.

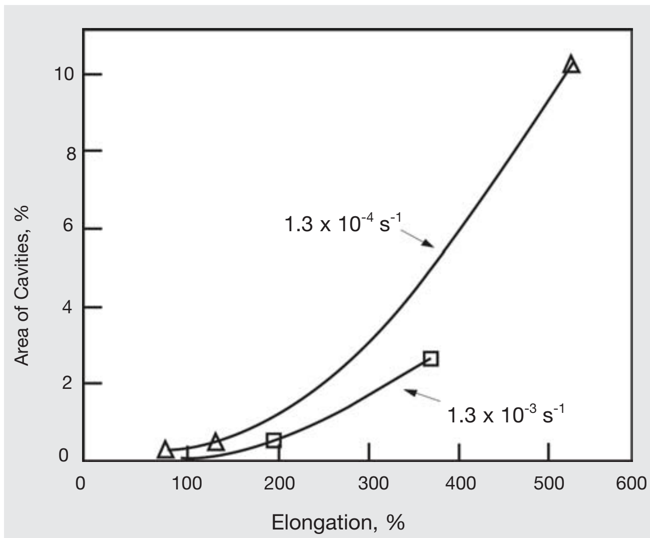


Figure 10 - Percent area of cavitation vs. total elongation for two typical strain rates at 1750°F (954°C).

Table 16 - The Effect of Strain Rate and Total Strain at 1750°F (954°C) on the Size and Area of Cavitation of INCONEL Alloy 718SPF

Initial Strain Rate, s^{-1}	1.3 x 10^{-3}	1.3 x 10^{-4}	1.3 x 10^{-3}	1.3 x 10^{-4}
Total Strain, %	86.0	73.0	194.0	132.0
Cavitation Area, %	0.04	0.18	0.45	0.34
Avg. Cavity Size, µm²	2.40	8.90	10.50	11.20

Superplastically Formed Properties and Characteristics (continued)

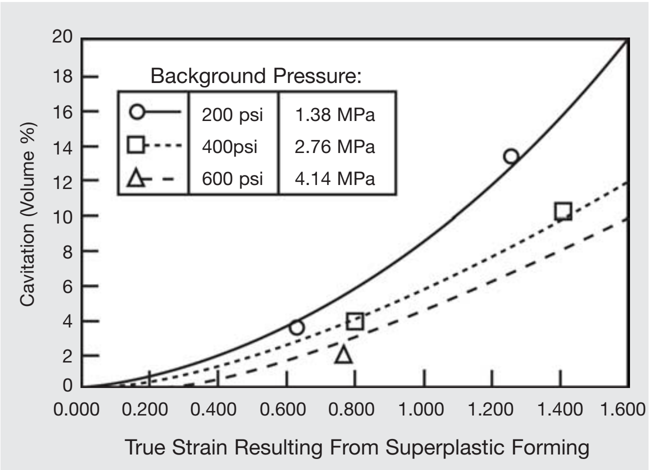


Figure 11 - Cavitation volume percent in INCONEL alloy 718SPF sheet as a function of true strain and background pressure for an initial strain rate of 1 x $10^{-4}s^{-1}$.

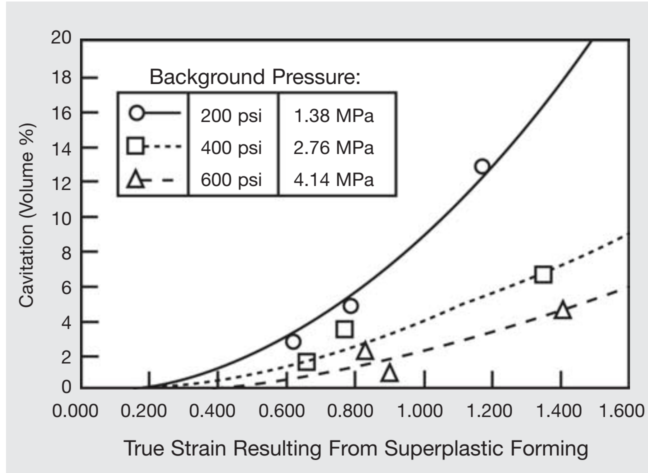


Figure 12 - Cavitation volume percent in INCONEL alloy 718SPF sheet as a function of true strain and background pressure for an initial strain rate of 3 x $10^{-5}s^{-1}$.

To assist designers and manufacturing engineers to effectively fabricate superplastically formed parts using INCONEL alloy 718SPF, a schematic of the press seal is depicted in Figure 13 for the background pressure study reported in the bulletin.

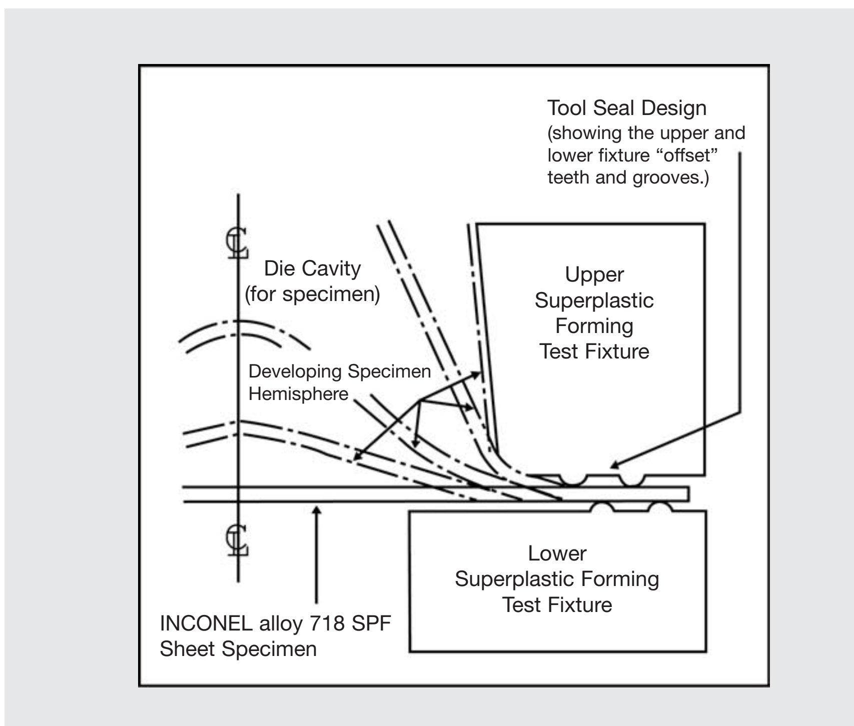
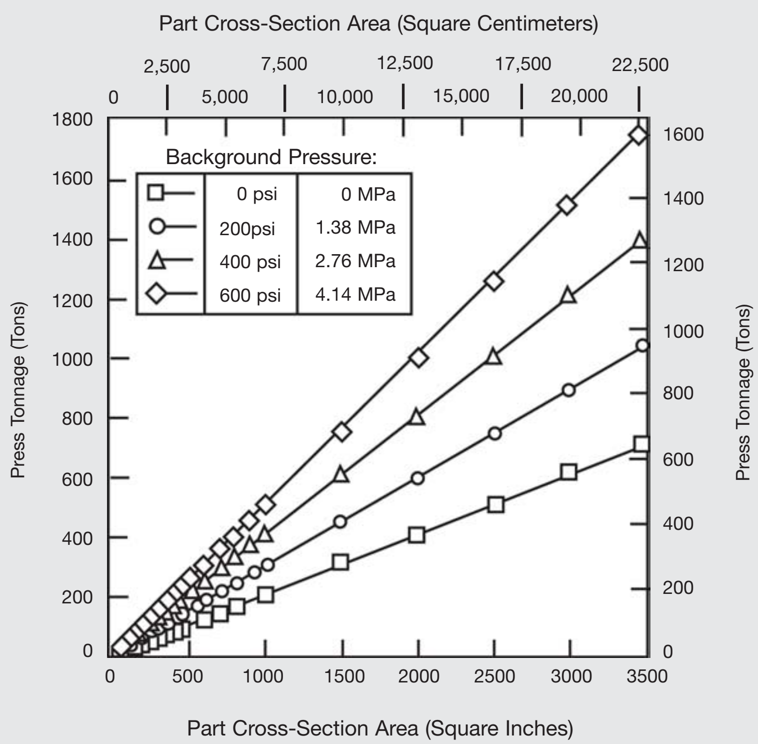


Figure 13 - Sealing design for the biaxial superplastic forming testing.



Based on measure flow stress data, press tonnage requirements as a function of part cross section and desired background pressure are presented in Figure 14.

Table 17 represents the stress rupture properties for two strain levels and two HIP conditions.

Axial fatigue properties are presented in Table 18.

Figure 14 - Press tonnage requirements for 0.03 in (0.76 mm) INCONEL alloy 718SPF sheet.

Table 17 - Effect of HIP on Stress Rupture Properties

Condition	Stress Rupture Conditions 1200°F (649°C)/100 ksi (690 MPa)	
	Life,hrs	Elongation,%
Superplastic Forming + HIP + Age[a]	43.1	23.0
Superplastic Forming + HIP + Age[b]	41.8	7.0

[a] Sample was superplastically reduced 46 % in gauge, then HIPed at 1750°F (954°C)/30 min/58 ksi (400 MPa), then aged at 1325°F (719°C)/8 hr/FC at 100°F (56°C)/hr to 1150°F (621°C)/10 hr/AC.

[b] Sample was superplastically reduced 60 % in gauge, then HIPed at 1750°F (954°C)/60 min/15 ksi (103 MPa), then aged at 1325°F (719°C)/8 hr/FC at 100°F (56°C)/hr to 1150°F (621°C)/10 hr/AC.

Table 18 - Effect of HIP on Axial Fatigue Properties[a]. Frequency = 59 Hz

Test Temperature		Max./Min. Stress		Cycles
°F	°C	ksi	MPa	
600	316	140/28	965/193	29,847 F.G.
600	316	120/24	828/166	31,362 F.G.
1000	538	140/28	965/193	11,533 F.G.
1000	538	120/24	828/166	152,843 P.H.
1200	649	100/10	690/138	10,000,000 R.O.

[a]Sample was superplastically reduced 60% in gauge, then HIPed at 1750°F (954°C)/60 min/58 ksi (103 MPa), then aged at 1325°F (719°C)/8 hr/FC at 100°F (56°C)/hr to 1150°F (621°C)/10 hr/AC.

F.G. = Failed in gauge section
P.H. = Pin hole failure
R.O. = Runout

Like INCONEL alloy 718, INCONEL alloy 718SPF can be diffusion bonded. Table 19 presents typical lap shear strength data for varying HIP conditions of pressure and temperature.

Table 19 - Effect of Diffusion Bonding Conditions* on Shear Strength of INCONEL Alloy 718SPF

	a	b	c	d
Shear Strength, ksi (MPa)	64.7 (446)	66.0 (455)	62.6 (432)	61.7 (425)
Ultimate Tensile Strength, ksi (MPa)	125.0 (862)	148.6 (1025)	143 (986)	165.2 (1139)
Fracture Location	base material	base material	base material	base material
HIP Pressure, ksi (MPa)	60 (414)	60 (414)	25 (172)	15 (103)
HIP °F (°C)	2100 (1150)	1950 (1065)	1825 (995)	1750 (954)
HIP Time, hrs.	1.0	1.0	4.0	4.0

* All lap surfaces were polished to 6 micron finish and then the test samples were sealed between mild steel sheets.

Corrosion Resistance

INCONEL alloy 718SPF, like alloy 718, has excellent resistance to corrosion in many media. This characteristic, similar to that of other nickel-chromium alloys, is a function of its composition.

Nickel contributes to a resistance to corrosion by many inorganic and organic compounds, other than those that are strongly oxidizing, throughout wide ranges of acidity and alkalinity. It is also useful in providing resistance to chloride-ion stress-corrosion cracking.

Chromium imparts an ability to withstand attack by oxidizing media and sulfur compounds.

Molybdenum is know to contribute to resistance to pitting in many media.

Above all, INCONEL alloy 718SPF is important for its strength and corrosion resistance at high operating temperatures.

Available Products and Specifications

INCONEL alloy 718SPF is available as annealed sheet, in thicknesses from 0.02 to 0.08 inches (0.5 to 2.0 mm). Widths up to 36 inches (914 mm) are available as flat cut lengths, or as coils weighing up to 10,000 lb (4500 kg).

Designations and specifications for INCONEL alloy 718SPF include the following:

UNS N07719
SAE AMS 5914
SAE AMS 5950

Metallography

INCONEL alloy 718SPF is an age-hardenable austenitic material. Its strength is largely dependent on the precipitation of a gamma prime phase following heat treatment.

A major part of the development of INCONEL alloy 718, of which alloy 718SPF is a derivative, was concerned with the establishment of the proper heat treatments for optimum properties. These heat treatments, and the applications for which they were developed, are described in the datasheet for INCONEL alloy 718 on the website www.specialmetals.com.

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