INCONEL® alloy 725

INCONEL® alloy 725 (UNS N07725) is a nickel-chromium-molybdenum-niobium alloy that is highly resistant to corrosion and is age hardenable for extremely high strength. It has essentially the same corrosion resistance as INCONEL alloy 625, which is widely used in a broad range of severely corrosive environments. The strength of age-hardened INCONEL alloy 725 is of the order of twice that of annealed alloy 625. Because the strength of alloy 725 is developed by heat treatment, not by cold work, ductility and toughness remain high. Also, strength can be imparted to large or non-uniform sections that cannot be strengthened by cold work.

The chemical composition of INCONEL alloy 725 is given in Table 1. High levels of nickel and chromium provide corrosion resistance in reducing and oxidizing environments. The substantial molybdenum content enhances resistance to reducing media and provides a high degree of resistance to pitting and crevice corrosion. Additionally, the combination of elements makes the alloy resistant to hydrogen embrittlement and stress-corrosion cracking.

The properties of INCONEL alloy 725 are useful for a range of applications that require outstanding corrosion resistance along with high strength. The alloy is used for hangers, landing nipples, side pocket mandrels and polished bore receptacles in sour gas service, where it resists the effects of hydrogen sulfide, chlorides and carbon dioxide. The alloy is also attractive for high strength fasteners in marine applications, where it resists corrosion, pitting and crevice attack in sea water.

Table 3 - Thermal and Electrical Properties

Temperature	Coefficient of Expansion	Electrical Resistivity
°F	in/in-°F	ohm-cmil/ft
70	-	688.3
200	7.22	696.2
400	7.21	710.4
600	7.44	727.1
800	7.68	741.3
1000	7.79	758.6
1200	8.05	761.7
1400	-	776.1
1600	-	784.6
°C	µm/m-°C	µohm-m
20	-	1.144
100	13.0	1.158
200	13.1	1.179
300	13.4	1.206
400	13.7	1.226
500	14.1	1.251
600	14.4	1.265
700	-	1.273
800	-	1.302

[a]Mean coefficient of linear expansion between 70°F (21°C) and temperature shown.

Table 1 - Chemical Composition, %

Nickel	55.0-59.0
Chromium	19.0-22.5
Molybdenum	7.0-9.5
Niobium	2.75-4.0
Titanium	1.0-1.7
Aluminum	0.35 max.
Carbon	0.03 max.
Manganese	0.35 max.
Silicon	0.20 max.
Phosphorus	0.015 max.
Sulfur	0.010 max.
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

Some representative physical properties of INCONEL alloy 725 are given in Table 2. Values for thermal expansion and electrical resistivity over a range of temperatures are listed in Table 3. Resistivity at elevated temperature was calculated from observed percent change in the room-temperature value. Modulus of elasticity, determined dynamically, is given in Table 4. All values for physical properties are for material in the age-hardened condition.

Table 2 - Physical Properties

Density, lb/in^3	0.300
g/cm^3	8.31
Melting Range, °F	2320-2449
°C	1271-1343
Permeability at 200 oersted (15.9 kA/m)	<1.001
Young's Modulus (70°F), ksi x 10^3	29.6
GPa	204
Shear Modulus (70°F), ksi x 10^3	11.3
GPa	78
Poisson's Ratio (70°F)	0.31

Table 4 - Dynamic Modulus of Elasticity

Temperature	Young's Modulus	Shear Modulus	Poisson's Ratio
°F	ksi x 10^3	ksi x 10^3	
70	29.6	11.3	0.31
200	29.1	11.1	0.31
400	28.2	10.7	0.32
600	27.2	10.3	0.32
800	26.3	9.9	0.33
1000	25.4	9.6	0.32
1200	24.0	9.0	0.33
1400	22.5	8.4	0.34
1600	21.2	7.9	0.34

Temperature	Young's Modulus	Shear Modulus	Poisson's Ratio
°C	GPa	GPa	
20	204	78	0.31
100	200	76	0.32
200	194	74	0.31
300	188	71	0.32
400	182	69	0.32
500	177	67	0.32
600	169	63	0.35
700	160	61	0.32
800	150	56	0.33

Table 3a - Thermal Conductivity and Specific Heat Values for INCONEL alloy 725

Temperature, °C	Temperature, °F	Thermal Conductivity		Specific Heat	
		W/m K	BTU in/ft^2 h °F	J/kg °C	BTU/lb °F
23	73	10.631	73.76	430	0.103
93	200	11.724	81.34	446	0.107
100	212	11.827	82.06	447	0.107
149	300	12.666	87.88	457	0.110
200	392	13.544	93.97	468	0.112
204	400	13.615	94.46	469	0.113
260	500	14.491	100.54	481	0.115
300	572	15.122	104.92	489	0.117
316	600	15.390	106.78	492	0.118
371	700	16.346	113.41	503	0.121
400	752	16.843	116.86	508	0.122
427	800	17.284	119.92	511	0.123
482	900	17.920	124.33	517	0.124
500	932	18.152	125.94	519	0.125
538	1000	18.864	130.88	531	0.127
593	1100	19.912	138.15	550	0.132
600	1112	20.037	139.02	552	0.133
649	1200	21.205	147.12	577	0.139
700	1292	22.424	155.58	604	0.145
704	1300	22.453	155.78	604	0.145
760	1400	22.807	158.24	607	0.146
800	1472	23.062	160.01	609	0.146
816	1500	23.179	160.82	610	0.146
871	1600	23.596	163.71	615	0.148
900	1652	23.812	165.21	618	0.148
927	1700	24.226	168.08	624	0.150
982	1800	25.086	174.05	635	0.152
1000	1832	25.361	175.96	639	0.153
1038	1900	25.994	180.35	645	0.155
1093	2000	26.925	186.81	653	0.157
1100	2012	27.038	187.59	654	0.157
1149	2100	28.292	196.29	663	0.159
1200	2192	29.604	205.39	673	0.163

Mechanical Properties

In the age-hardened condition, INCONEL alloy 725 displays high strength along with excellent ductility and toughness. Mechanical properties over a range of temperatures are shown in Figures 1 and 2. Table 5 gives typical tensile properties, hardness, and impact strength for various product forms. The data in Table 6 indicate the good flattening properties of age-hardened tubing. Table 7 lists the average high-temperature tensile properties for annealed + aged bar, 0.625 to 6.5 inches (16 to 165 mm) diameter.

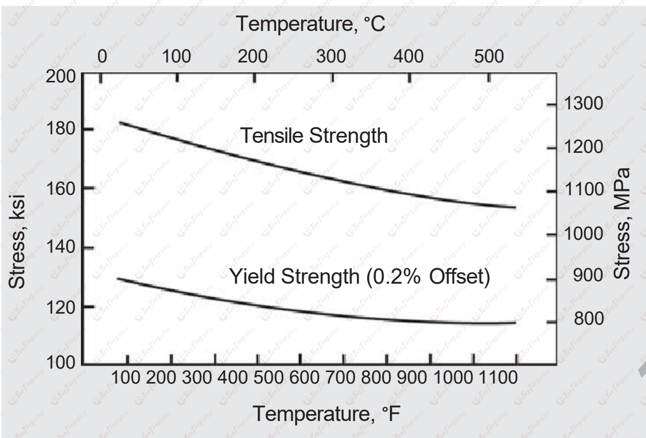

Figure 1. Tensile and yield strength of INCONEL alloy 725.

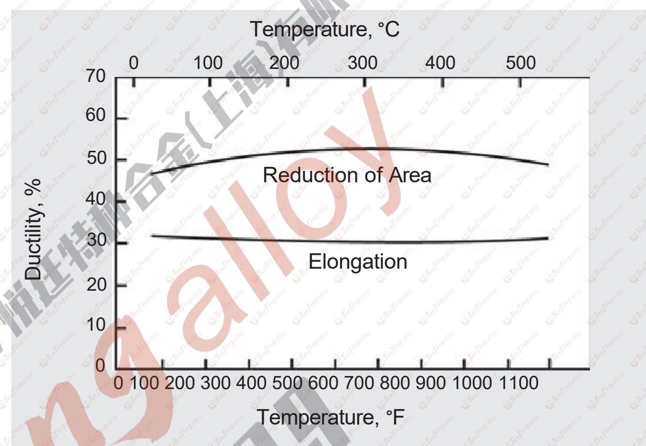

Figure 2. Elongation and reduction of area of INCONEL alloy 725.

Table 5 - Typical Room Temperature Mechanical Properties

Form	Condition	Yield Strength (0.2% Offset)		Tensile Strength		Elongation	Hardness	Charpy Impact	
		ksi	MPa	ksi	MPa	%	R_C	ft-lbf	J
Round[a]	Annealed	62.0	427	124.0	855	57	5	- 68	- 92
	Age Hardened	133.0	917	180.0	1241	30	36		
Round[b]	Age Hardened	131.0	903	180.0	1241	31	36	97	132
Tube	Annealed	48.4	334	113.6	783	60	5	-	-
	Age Hardened	133.6	921	183.9	1268	27	39	-	-

[a]Transverse specimens from hot-finished rounds of 4.0 to 7.5 in (102 to 190 mm) diameter.
[b]Longitudinal specimens from hot-finished rounds of 0.5 to 7.5 in (13 to 190 mm) diameter.

Note: The above mechanical properties are "mean" values, and do not represent variances resulting from differences in thermo-mechanical processing.

Table 6 - Flattening Tests on Age-Hardened Tubing

Yield Strength (0.2% Offset)		Hardness	Flattening*
ksi	MPa	R_C	%
117	807	36	>52.8
133	917	39	38.8

*Reduction in diameter at 5% drop in load of ring specimen from tubing 2.375 in (60 mm) outside diameter and 0.217 in (5.5 mm) wall.

Table 7 - Average High-Temperature Properties for 0.625 to 6.5 in (16 to 165 mm) Diameter Rod, Annealed + Aged*

Temperature		Yield Strength (0.2% Offset)		Tensile Strength		Elongation	Reduction of Area
°F	°C	ksi	MPa	ksi	MPa	%	%
75	23	129.4	892	181.9	1254	32.0	48.4
100	38	131.7	908	182.2	1256	32.6	49.2
200	93	125.9	868	178.4	1230	29.6	47.0
300	149	119.8	826	172.4	1189	30.9	50.2
400	204	119.5	824	169.7	1170	30.7	52.4
500	260	117.6	811	165.5	1141	31.0	52.7
600	315	113.4	782	159.5	1099	32.4	54.2
650	343	117.4	809	159.8	1102	31.1	53.5
700	371	115.7	798	158.9	1096	30.8	53.4
750	399	115.9	799	157.8	1088	30.8	53.9
800	426	118.6	818	160.4	1106	29.6	49.6
850	454	114.6	790	155.3	1071	31.5	51.6
900	482	117.1	807	155.9	1075	30.7	49.7
950	510	111.6	769	154.4	1065	31.7	50.1
1000	538	112.9	778	153.4	1058	31.0	47.7

* Solution treated at 1900°F (1038°C) then aged at 1350°F (732°C)/8 h/FC at 100°F (56°C)/h to 1150°F (621°C)/8 h/AC.

Corrosion Resistance

High nickel, chromium and molybdenum contents enable INCONEL alloy 725 to resist a broad range of corrosive environments. The alloy is especially resistant to media containing carbon dioxide, chlorides and hydrogen sulfide, such as those encountered in deep sour gas wells. In such environments, INCONEL alloy 725 resists corrosion, pitting, hydrogen embrittlement and stress-corrosion cracking. Table 8 shows the performance of the alloy in a standard test (NACE TM0177) used to determine resistance to sulfide stress cracking (hydrogen embrittlement) in a sour well environment. Table 10 shows the alloy has good resistance to stress-corrosion cracking at temperatures up to about 450°F (230°C) in a severe sour environment containing elemental sulfur.

INCONEL alloy 725 is approved under NACE MR0175 for use in sour gas wells.

INCONEL alloy 725 displays excellent resistance to general and localized corrosion in brines and sea water. Table 11 shows the results of crevice corrosion tests in sea water. These data show alloy 725 to be superior to alloy 625 in resistance to crevice corrosion initiation.

Figure 3 shows the results of C-ring laboratory tests, in a severely aggressive 25% NaCl, 0.5% acetic acid, 1g/l sulfur environment, with 120 psi (825 kPa) hydrogen sulfide. Figure 4 plots mean axial stress vs. cycles of fatigue for INCONEL alloy 725 in the dual aged condition [1350°F (732°C)/8h, FC@100°/h., 1150°F (621°C)/8h/AC].

Table 8 - C-Ring Tests in NACE Solution (TM0177)[a]

Alloy	Material Condition	Yield Strength (0.2% Offset)		Hardness	Duration	Sulfide Stress Cracking
		ksi	MPa	Rc	Days	
INCONEL alloy 725	Cold Worked	90.0	621	25	30	No
	Age Hardened	117.6	811	37	30	No
	Age Hardened	128.6	887	40	30	No
	Age Hardened[b]	130.8	902	41.5	30	No
	Age Hardened	132.9	916	36	42	No
	Age Hardened	133.0	917	39	30	No
	CW & Aged	137.8	950	39	42	No
INCONEL alloy 625	Cold Worked	125.0	862	30.5	42	No
	Cold Worked	160.0	1103	37.5	10	Yes
	Cold Worked	176.0	1214	41	6	Yes
INCONEL alloy 718	Age Hardened	120.0	827	30	42	No
	Age Hardened	130.0	896	37	42	No
	Age Hardened	134.0	924	38.5	42	No
	Age Hardened	139.0	958	38	42	No
	Age Hardened	156.0	1076	41	60	No
	Cold Worked	197.0	1358	37.5	2	Yes
	Cold Worked	197.0[c]	1358[c]	37.5	25	Yes

[a]Room-temperature tests at 100% of yield strength in 5% NaCl plus 0.5% acetic acid saturated with H_2S. All specimens were coupled to carbon steel.
[b]Also exposed to a simulated well age of 600°F (315°C)/1000 h.
[c]Test stress was 84% of yield strength: 165 ksi (1138 MPa).

Table 9 - C-Ring Test Data
Environment: 25% NaCl + 300 psig H_2S + 700 psig CO_2 + 1g/L S° at 350°F for 90 Days; Triplicate Specimens Stress to 100% of the 0.2% Yield Strength.

Alloy 725	No Cracking

Table 10 - Stress-Corrosion Cracking Tests in a Simulated Sour Well Environment [a]

Alloy	Material Condition	Yield Strength (0.2% Offset)		Stress-Corrosion Cracking at:						
		ksi	MPa	350°F (177°C)	375°F (191°C)	400°F (204°C)	425°F (218°C)	450°F (232°C)	475°F (246°C)	500°F (260°C)
INCONEL alloy 725	Age Hardened	117.6	811	No	No	No	No	No	Yes[b]	No
	Age Hardened	128.6	887	No	No	No	No	Yes	-	-
	Age Hardened	132.9	916	No	No	No	No	No	No	No
	Age Hardened	133.0	917	No	No	No	No	No	Yes[b]	No
INCONEL alloy 625	Cold Worked	144.0	993	No	Yes	-	-	-	-	-
	Cold Worked	160.0	1103	No	Yes	-	-	-	-	-
INCONEL alloy 718	Age Hardened	130.3	898	Yes[c]	-	-	-	-	-	-

[a]C-ring autoclave tests of 14-day duration at 100% of yield strength in 25% NaCl plus 0.5% acetic acid plus 1g/l sulfur plus 120 psi (827 kPa) H_2S.

[b]One of two specimens cracked.

[c]At 275°F (135°C).

Table 11 - Crevice Corrosion Tests in Sea Water[a]

Alloy	Condition	Corrosion Initiation	Sites Attacked	Depth Attacked	
		Days	%	in	mm
INCONEL alloy 725	Age Hardened	-	0	0	0
INCONEL alloy 625	Annealed	2-5	25-75	0.010	0.26[b]

[a]30-day tests in flowing sea water at 86°F (30°C) with crevices formed by acrylic plastic washers bolted to sheet specimens.

[b]Average of maximum depth per crevice. Range of maximum attack was 0.0008 to 0.026 in (0.02 to 0.66 mm).

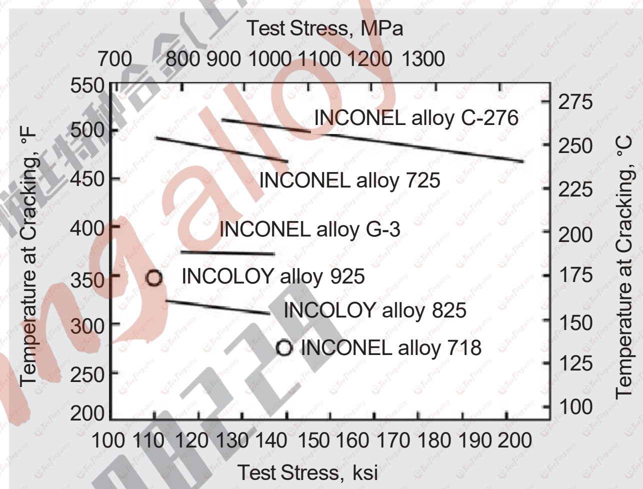

Figure 3 - Results of autoclave C-ring tests in a solution of distilled water containing 25% sodium chloride, 0.5% acetic acid, and 1 g/l sulfur with pressure of 120 psi (825 kPa) hydrogen sulfide. Test stresses were 100% of yield strength (0.2% offset).

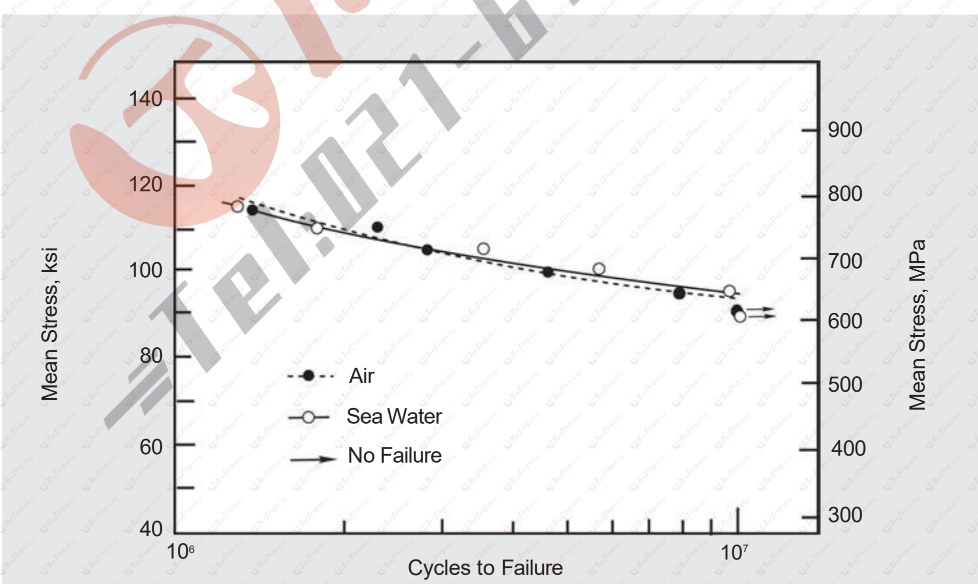

Figure 4 - Mean axial stress vs. cycles of fatigue for INCONEL alloy 725 in the dual aged condition [1350°F (732°C)/8h, FC@100°/h., 1150°F (621°C)/8h/AC] tension-tension test. Tested at the LaQue Center for Corrosion Technology. (R-value = Min. stress/Max. Stress=0.6)

Corrosion results for alloy 725 in mineral acids, compared to alloys 625 (N06625) and C-276 (N10276) are shown in Table 12. In all of the mineral acid environments of this study, both annealed and annealed plus aged alloy 725 exhibited corrosion resistance comparable to mill annealed alloys 625 and C-276.

Table 12 - Average Corrosion Rates for Alloy 725 (N07725) in Mineral Acids* Compared to Literature Data for Alloy 625 (N06625) and Alloy C-276 (N10276)

Alloy 725 Condition	3% HCl 150°F (66°C)		5% HCl 150°F (66°C)		10% HCl 150°F (66°FC)		Boiling 10% H_2SO_4		Boiling 10% HNO_3		Boiling 30% H_3PO_4		Boiling 80% H_3PO_4	
	mpy	mm/a	mpy	mm/a	mpy	mm/a	mpy	mm/a	mpy	mm/a	mpy	mm/a	mpy	mm/a
1	<1	<0.03	<1	<0.03	105	2.67	25	0.64	<1	<0.03	3	0.08	73	1.85
2	<1	<0.03	<1	<0.03	268	6.81	25	0.64	<1	<0.03	5	0.13	62	1.57
3	<1	<0.03	<1	<0.03	250	6.35	25	0.64	<1	<0.03	3	0.08	45	1.14
4	<1	<0.03	<1	<0.03	218	5.54	28	0.71	<1	<0.03	2	0.05	35	0.89
Literature														
Alloy 625	<1	<0.03	69	1.75	93	2.36	18	0.45	<1	<0.03	<10	<0.25	25	0.63
Alloy C-276	<5	<0.13	5-20	0.13-0.51	20	0.51	20	0.51	16	0.41	<5	<0.13	5-25	0.13-0.64

Condition:
1. 1900°F (1038°C) anneal
2. 1900°F (1038°C) anneal + 1400°F (760°C)/6h/AC
3. 1900°F (1038°C) anneal + 1375°F (746°C)/8h, FC at 100°F (56°C)/h to 1150°F (620°C)/8h/AC
4. 1900°F (1038°C) anneal + 1350°F (732°C)/8h, FC at 100°F (56°C)/h to 1150°F (620°C)/8h/AC

*Two week duration

Table 13 - Corrosion Rates for Alloy 725 (UNS N07725), 0.125-in. Sheet, Evaluated in Acid Environments for Varied Exposure Times and Temperatures as per MTI Manual No. 3 Procedures

Environment	Temperature °C (°F)	Corrosion Rate 0-96 Hours		96-192 Hours		0-192 Hours	
		mpy	mm/a	mpy	mm/a	mpy	mm/a
0.2% HCl	Boiling	<0.1	<0.01	<0.1	<0.01	<0.1	<0.01
1% HCl	Boiling	4.6	0.12	1.9	0.05	10.2	0.26
	90 (194)	25.0	0.64	2.0	0.05	2.0	0.05
5% HCl	70 (158)	193.8	4.92	203.3	5.16	169.7	4.31
	50 (122)	52.8	1.34	52.5	1.33	44.7	1.14
	30 (86)	9.4	0.24	6.6	0.17	7.8	0.18
10% H_2SO_4	Boiling	9.9	0.25	21.5	0.55	4.6	0.12
60% H_2SO_4	70 (158)	25.5	0.65	25.6	0.65	16.0	0.41
	50 (122)	23.1	0.59	0.71	0.02	29.0	0.74
	30 (86)	1.5	0.04	1.3	0.03	7.1	0.18
95% H_2SO_4	70 (158)	66.3	1.68	67.5	1.71	42.0	1.07
	50 (122)	72.6	1.84	50.1	1.27	23.0	0.58
	30 (86)	11.0	0.28	13.3	0.34	13.0	0.33
85% H_2PO_4	Boiling	30.7	0.78	31.2	0.79	58.0	1.47
	90 (194)	0.54	0.01	0.50	0.01	0.32	0.01
80% CH_3CO_2H	Boiling	<0.1	<0.01	<0.1	<0.01	<0.1	<0.01

Heat Treatment

INCONEL alloy 725 is strengthened by precipitation of gamma double-prime (γ ”) phase during an aging heat treatment. Before it is aged, the material should be given a solution anneal at 1900°F (1040°C). Air cooling after solution annealing is the preferred cooling method.

For sour gas applications, the recommended aging treatment is 1350°F (730°C)/8h/furnace cool at 100°F (56°C)/h to 1150°F (620°C)/8h/air cool.

Welding

INCONEL alloy 725 welding products, designated INCO-WELD® Filler Metal 725NDUR®, provide a higher strength alternative to alloy 625 welding wire. Gas-tungsten-arc welding (GTAW) and gas-metal-arc welding (GMAW) are the preferred methods for welding INCONEL alloy 725. When GMAW is used, current levels should not exceed 180 amps for standard GMAW power sources in the “spray arc” metal transfer mode. Submerged-arc welding (SAW) and shielded-metal-arc welding (SMAW) are not recommended.

Table 14 shows average slow strain rate (SSR) ratio test data for 1-pass weld overlays in a 5% NaCl + 75 psig (517 kPa) H_2S + 400 psig (2758 kPa) CO_2 environment at 300°F (149°C). The most common pass/fail criterion for SSR testing is a ratio of time to failure (TTF), % reduction of area (% RA) and/or % elongation measured in a simulated oil patch environment relative to the same parameter in an inert environment (air). Ratios above 0.90 are considered acceptable “pass” levels.

The absence of secondary cracking indicates good stress-corrosion cracking resistance. INCONEL alloy 725, like alloy 625, show excellent resistance to stress-corrosion cracking.

Tables 15 and 16 respectively show room-temperature tensile and Charpy V-notch (CVN) impact test results for all-weld-metal samples of INCO-WELD Filler Metal 725NDUR in the as-welded, direct aged, and annealed-plus-aged conditions. As-welded material exhibited excellent impact properties and lower yield strengths than the annealed-plus-aged material. The direct aged material exhibited low impact strength. Optimum results were obtained by annealing INCONEL alloy 725 prior to welding, then applying a solution anneal and age after welding.

Table 14 - Slow Strain Rate Ratio Data

Filler Metal	Time to Failure Ratio	% Reduction of Area Ratio	% Elongation Ratio	Secondary Cracking
INCO-WELD 725NDUR*	0.98 1.07	1.11 0.97	1.00 1.11	No No
INCONEL alloy 625**	0.95 0.90	1.20 0.92	0.95 0.90	No No

*Overlay on AISI 4140 steel, condition 1225°F (663°C) 2 h/AC.

**Overlay on AISI 4130 steel, condition 1175°F (635°C) 2 h/AC.

Table 15 - Typical INCO-WELD Filler Metal 725NDUR All-Weld-Metal GMA Room-Temperature Tensile Properties

Test Orientation	Base Metal Pre-Weld Treatment	Post-Weld Treatment	Yield Strength		Tensile Strength		Elongation	Reduction of Area	Side Bend Indications
			ksi	MPa	ksi	MPa	%	%	
Transverse	Annealed	As-Welded	73.6	507	124.9	861	39.0	34.4	P 2T
Longitudinal	-	As-Welded	76.0	524	119.8	826	33.0	30.6	P 2T
Longitudinal	-	Aged	130.1	897	172.1	1187	20.0	22.5	F 2T
Transverse	Annealed	Aged	141.0	972	179.8	1240	13.0	19.5	P 4T
Longitudinal	-	Annealed, Aged	129.9	896	173.9	1199	19.0	28.6	P 4T
Transverse	Annealed, Aged	Annealed, Aged	131.8	909	171.4	1181	25.0	29.8	P 4T
Longitudinal	-	Annealed(2), Aged	126.5	872	174.8	1205	21.0	28.4	P 4T
Transverse	Annealed	Annealed(2), Aged	126.5	873	172.8	1191	28.0	42.7	P 4T

Anneal = 1900°F (1038°C)/1h/AC. Anneal (2) = 1950°F (1066°C)/1 h/AC.
Age = 1350°F (732°C)/8 h/FC at100°F (56°C)/h to 1150°F (620°C)/8 h/AC.

P = Pass
F = Fail

Table 16 - Typical INCO-WELD Filler Metal 725NDUR All-Weld-Metal GMA Impact Properties

Post-Weld Heat Treatment	CVN Impact at 75°F (24°C)		CVN Impact at -75°F (-59°C)	
	ft-lbf	J	ft-lbf	J
As-welded	66	89	-	-
1350°F (732°C)/8h/FC at 100°F (56°C)/h to 1150°F (620°C)/8h/AC	16	22	18	24
1900°F (1038°C) anneal, plus 1350°F (732°C/8h/FC at 100°F (56°C)/h to 1150°F (620°C)/8h/AC	42	57	39	53
1950°F (1066°C) anneal, plus 1350°F (732°C)/8h/FC at 100°F (56°C)/h to 1150°F (620°C)/8h/AC	56	76	79	107

Hot Forming

Because of its strength, INCONEL alloy 725 is more resistant that most materials to deformation during hot forming. It is readily hot-worked if sufficiently powerful equipment is used.

Hot forming is performed in the 1650°-2050°F (899°-1121°C) temperature range. In the last operation, the metal should be worked uniformly with a gradually decreasing temperature, finishing with some light reduction in the 1650°-1750°F (899°-954°C) range. This procedure is necessary to ensure notch ductility in stress-rupture applications when material has been annealed and aged. In heating for hot working, the material should be brought up to temperature, allowed to soak a short time to ensure uniformity, and withdrawn.

To avoid duplex grain structure, INCONEL alloy 725 should be given uniform reductions. Final reductions of 20% minimum should be used for open-die work, and 10% minimum for closed-die work. Parts should be air-cooled from the hot-working temperature rather than water-quenched.

Care should be taken to avoid overheating the metal by heat buildup due to working. Also, the piece should be reheated when any portion has cooled below 1650°F (899°C). Preheating tools and dies to 500°F (260°C) is recommended. Any ruptures appearing on the surface of the workpiece must be removed at once.

Machining

INCONEL alloy 725 is an age hardenable alloy. Machining may be accomplished in the annealed or aged conditions. Excellent results have been obtained with SPC-633T tooling of KC-950 coated grade. For example, in a single-point turning of round stock, the cutting tool remained in good condition after turning 18 inches (457 mm) of bar length. The cutting speed was 55 surface feet (16.8 m)/min with 0.014 inches (0.36 mm) feed and 0.190 inches (4.8 mm) depth of cut. Other carbide tools and steel tools are listed in Table 17 with their recommended speeds, depths of cut, and feed rates.

Cemented carbide tools produce the highest cutting rates and are recommended for most turning operations involving uninterrupted cuts. High speed steel tools may be used for interrupted cuts, finishing to close tolerances, finishing with the smoothest surfaces, and cutting with the least amount of work hardening.

Chip Control

When machining INCONEL alloy 725, it is important to obtain good full turn chips. High speed steel tools may require chip curlers or lipped tools. The lip should be wider and deeper for the material in the annealed condition. Typical dimensions, for chip breakers, operating at 0.01 in/min (0.25 mm/min), are 0.020 inches (0.51 mm) deep and 0.080 inches (2.03 mm) wide.

Drilling

Steady feed rates minimize excessive work hardening during drilling. Heavy duty, high speed drills with heavy webs are recommended. For twist drilling, recommended surface speeds are 10-12 ft/min (305-366 cm/min) for the annealed condition, and 8-10 ft/min (244-305 cm/min) for the aged condition. Feed rates range from 0.005 to 0.015 in/rev.(0.13 to 0.38 mm/rev.) depending on the drill size.

For gun drills, sizes from 1/16 to 2 inches (1.6 to 51 mm), a feed rate of 0.0001-0.003 in/rev. (0.003-0.08 mm/rev.) is recommended for both the annealed and aged conditions. The surface speed should be kept at about 100 ft/min (30.5 m/min) for annealed material and 60 ft/min (18.3 m/min) for material in the aged condition.

Threading

Lathe Threading

Standard single-point lathe threading practices are adequate for threading INCONEL alloy 725 in the annealed or aged conditions. Recommended threading speeds are 3.0-3.5 ft/min (91-107 cm/min). The depth of cut will vary, becoming less as the work progresses.

Die Head Threading

Threading dies should be made of molybdenum high-speed steel (Grade M-2 or M-10). A chaser throat angle of 15 to 20° is recommended for producing V threads where no shoulder is involved. When close-to-shoulder threading must be done, a 15° rake angle is recommended. The speeds given for lathe threading also apply to die threading.

Thread Grinding

External threads can be produced in INCONEL alloy 725 by form grinding with aluminum oxide (150-320 grit) vitrified-bonded grinding wheels. The recommended coolant is a high-grade grinding oil of about 300 seconds viscosity at 70°F (21°C). Extreme care must be taken to prevent overheating during grinding.

Thread Rolling

Maximum tensile properties may be obtained by thread rolling after aging. However, usually it is preferred to thread roll as-drawn or annealed material, and then age harden. Material in the un-aged condition is more easily threaded, and subsequent aging tends to stress relieve the cold-worked threads.

Reaming

Operating speeds for reamers should be about two-thirds of the speeds used for drilling. The reamer feed into the work should be 0.0015-0.004 in (0.04-0.1 mm) per flute per revolution. Feed rates too low will result in glazing and excessive wear. Conventional fluted reamers, flat solid reamers and insert tools for built-up reamers are made of high-speed steel. Composite tools with steel shanks tipped with cemented carbide are recommended.

Warping

Stresses produced during the machining process may result in distortion or warping. This can be minimized by reducing the machining speed and/or the depth of cut.

Table 17-Machining Parameters for INCONEL alloy 725*

Depth of Cut	High Speed Steel			Carbide			
	Tool Material	Surface Speed	Feed	Tool Material	Surface Speed		Feed
					Brazed Tool	Throw-Away	
in (mm)		ft/min (m/min)	in/rev (mm/rev)		ft/min (m/min)	ft/min (m/min)	in/rev (mm/rev)
0.25 (6.4)	T-5	12-18 (3.7-5.5)	0.010 (0.25)	C-2	30-40 (9.1-12.2)	40-60 (12.2-18.3)	0.010 (0.25)
0.05 (1.3)	M-36	15-20 (4.6-6.1)	0.008 (0.20)	C-2	40-50 (12.2-15.2)	50-100 (15.2-30.5)	0.008 (0.20)

*Annealed or aged material. Hardness range, approximately 85 Rb to 40 Rc. Water base, oil emulsion or chemical solution as cutting fluid.

Available Products and Specifications

INCONEL alloy 725 is designated as UNS N07725. The product is available as round bar and wire.

Bar and wire - ASTM B 805, ASME Code Case 2217

Bar and forging stock - SMC specification HA91, ASME Code Case 2217

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