INCOLOY® alloy 925 (UNS N09925) is an age-hardenable nickel-iron-chromium alloy with additions of molybdenum, copper, titanium and aluminum. The alloy's chemical composition, listed in Table 1, is designed to provide a combination of high strength and excellent corrosion resistance. The nickel content is sufficient for protection against chloride-ion stress-corrosion cracking. The nickel, in conjunction with the molybdenum and copper, also gives outstanding resistance to reducing chemicals. The molybdenum aids resistance to pitting and crevice corrosion. The alloy's chromium content provides resistance to oxidizing environments. The titanium and aluminum additions cause a strengthening reaction during heat treatment.

INCOLOY alloy 925 is used in various applications requiring a combination of high strength and corrosion resistance. Because of the alloy's resistance to sulfide stress cracking and stress-corrosion cracking in "sour" (H_2S containing) crude oil and natural gas, it is used for down-hole and surface gas-well components including tubular products, valves, hangers, landing nipples, tool joints and packers. The alloy is also useful for fasteners, marine and pump shafting and high-strength piping systems.

Table 1 - Limiting Chemical Composition (UNS N09925) of INCOLOY alloy 925, %

Nickel	42.0-46.0
Chromium	19.5-22.5
Iron	22 min
Molybdenum	2.5-3.5
Copper	1.5-3.0
Titanium	1.9-2.4
Aluminum	0.1-0.5
Manganese	1.0 max.
Silicon	0.5 max.
Niobium	0.5 max.
Carbon	0.03 max.
Sulfur	0.03 max.

Physical Properties

Some physical constants of INCOLOY alloy 925 are given in Table 2. They are room-temperature values except for the melting range. Table 3 provides physical property data for INCOLOY alloy 925 at elevated temperatures. Coefficient of expansion and specific heat data over a range of temperatures are in Table 4. Elevated temperature thermophysical properties are given in Table 5.

Table 2 - Physical Properties of INCOLOY alloy 925

Density, lb/in^3	0.292
g/cm^3	8.08
Melting Range, F	2392-2490
C	1311-1366
Electrical Resistivity, ohm circ mil/ft	701
µΩ m	1.17
Permeability at 200 oersteds (15.9 kA/m)	1.001

Table 3 - Elevated Temperature Dynamic Young s Modulus and Shear Modulus Values for INCOLOY alloy 925 (hot rolled round, solution-annealed and aged)

Temperature		Young s Modulus		Shear Modulus		Poisson s Ratio
F	C	10^3 ksi	GPa	10^3 ksi	GPa	
70	21	28.9	199	11.2	77	0.293
100	38	28.8	199	11.1	76	0.299
200	93	28.3	195	10.8	75	0.308
300	149	27.8	192	10.6	73	0.316
400	204	27.3	188	10.4	72	0.315
500	260	26.8	185	10.2	70	0.317
600	316	26.3	182	10.0	69	0.319
700	371	25.9	178	9.8	68	0.319
800	427	25.4	175	9.6	66	0.323
900	482	24.9	172	9.4	65	0.323
1000	538	24.4	168	9.2	64	0.324
1100	593	23.8	164	9.0	62	0.326
1200	649	23.2	160	8.7	60	0.330
1300	704	22.5	155	8.4	58	0.334
1400	760	21.8	150	8.2	56	0.338
1500	816	21.0	145	7.9	54	0.335
1600	871	20.1	139	7.6	52	0.330
1700	927	19.2	132	7.2	50	0.326

Table 4 - Thermal Properties of INCOLOY alloy 925

Temperature	Coefficient of Expansion[a]	Specific Heat
F	10^{-6} in/in F	Btu/lb F
70	-	0.104
200	7.8	0.109
400	8.1	0.116
600	8.4	0.122
800	8.5	0.129
1000	8.7	0.136
1200	9.0	0.143
1400	9.5	0.150
1600	-	0.157
Temperature	**Coefficient of Expansion[a]**	**Specific Heat**
C	µm/m C	J/kg C
20	-	435
100	13.2	456
200	14.2	486
300	14.7	507
400	15.0	532
500	15.3	561
600	15.7	586
700	16.3	611
800	17.2	641
900	-	666

[a]Expansion testing in accordance with ASTM E228.
Reference temperature = 77 F (25 C).

Table 5 - Elevated Temperature Thermophysical Properties of INCOLOY alloy 925 (hot rolled round, solution-annealed and aged)

Temperature		Thermal Conductivity	
C	F	W/m C	BTU in/ft^2 h F
23	73	12.0	83.1
100	212	12.9	89.2
200	392	14.3	99.2
300	572	15.9	110.0
400	752	17.4	120.9
500	932	19.3	133.8
600	1112	22.2	153.7
700	1292	24.0	166.7
800	1472	28.2	195.8
900	1652	27.7	192.3
1000	1832	24.6	170.7
1100	2012	26.0	180.2
1150	2102	26.9	186.8

Mechanical Properties

Mechanical properties at room temperature of solution-annealed and solution-annealed plus aged products are given in Table 6. Mechanical properties limits for specification purposes are shown in Table 7 (Special Metals Corporation internal specification HA 46).

As shown in Figure 1, INCOLOY alloy 925 retains a substantial portion of its strength at temperatures up to about 1200°F (650°C).

Figure 2 shows rotating beam fatigue data for INCOLOY alloy 925 and MONEL alloy K-500.

Figure 3 shows mean axial stress vs. cycles of fatigue in the 1365°F (740°C) dual aged condition. The compression test result, at room temperature, for a solution-annealed and aged bar was 122.7 ksi (846 MPa) and the yield strength tension test result was 123.5 ksi (851 MPa)

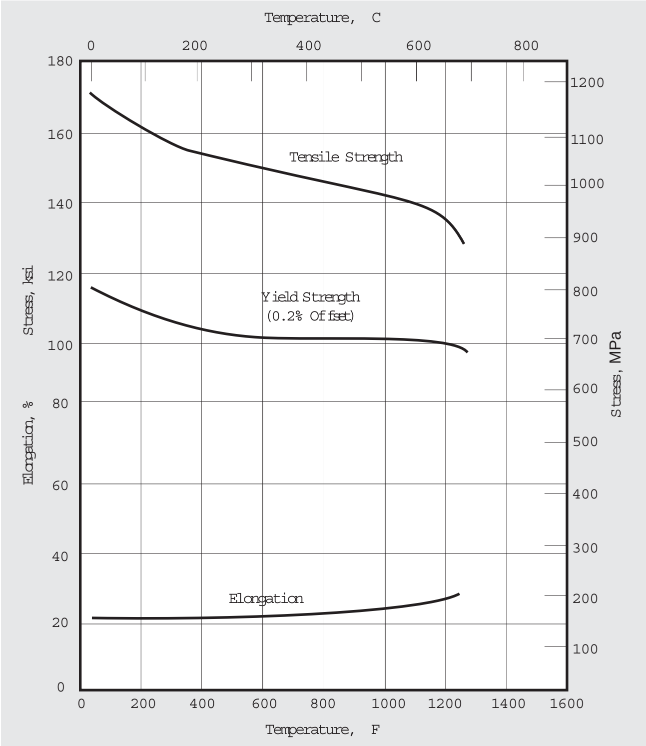

Figure 1. Tensile properties at high temperatures of solution-annealed and aged INCOLOY alloy 925.

Table 6 - Tensile Properties of INCOLOY alloy 925

Form/Condition	Tensile Strength		Yield Strength (0.2% Offset)		Elongation	Hardness*
	ksi	MPa	ksi	MPa	%	Rockwell
Round/Solution-Annealed	99.3	685	39.3	271	56	76 B
Round/Solution-Annealed and Aged	167.3	1154	120.6	832	27	32 C
Cold Drawn Tubing/Solution-Annealed and Aged	172.5	1189	120.4	830	27	35 C

*All values meet the requirements of NACE Standard MR0175.

Table 7 - Mechanical Property Limits for INCOLOY alloy 925, Solution-Annealed and Aged Material (SMC internal specification HA 46)

Condition	Diameter		Tensile Strength minimum		Yield Strength (0.2% offset) minimum		Elongation in 2 in (50.8 mm) or 4D min.	Reduction of Area minimum	Impact Strength[1] min. average		Hardness[2] Rockwell C	
	in	mm	ksi	MPa	ksi	MPa	%	%	ft lbf	kgf m	min.	max.
Cold Worked	5/8 to 3.0	15.9 to 76.2	140	965	105	724	18	25	35	4.85	26	38
Hot Worked	1 to 10	25.4 to 254	140	965	110	758	18	25	35	4.85	26	38

[1]Charpy V-Notch - Impact tests performed at -75 F (-60 C), in accordance with ASTM E23. Capability of meeting the strengths shown at room temperature is guaranteed.

[2]Hardness testing in accordance with ASTM E 18.

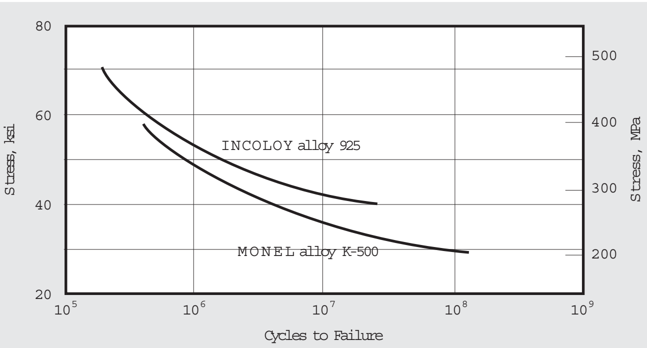

Figure 2. Rotating beam fatigue data for INCOLOY alloy 925 and MONEL alloy K-500.

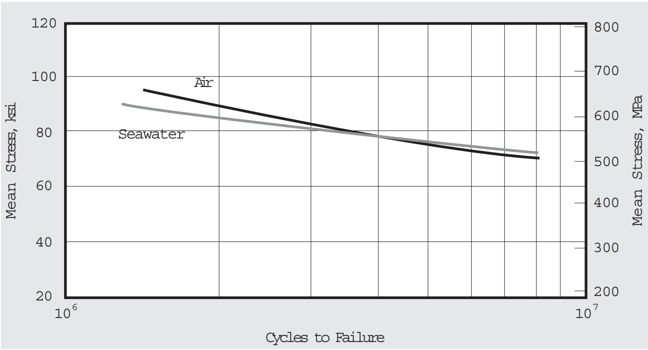

Figure 3. Mean axial stress vs. cycles of fatigue for INCOLOY alloy 925 in the 1365 F (740 C) dual aged condition. Tension-tension test.

Metallurgy

INCOLOY alloy 925 is an austenitic nickel-iron-chromium alloy made precipitation hardenable by additions of titanium and aluminum. The precipitation-hardening (age-hardening) heat treatment causes precipitation of gamma prime phase, Ni_3 (Al, Ti). The phase greatly increases both the hardness and strength of the alloy.

Exposure to elevated temperatures also causes formation of other phases, including eta and sigma. Figure 4 is a time-temperature-transformation diagram, and Figure 5 shows effects of the phases on impact strength of the solution-annealed plus aged alloy.

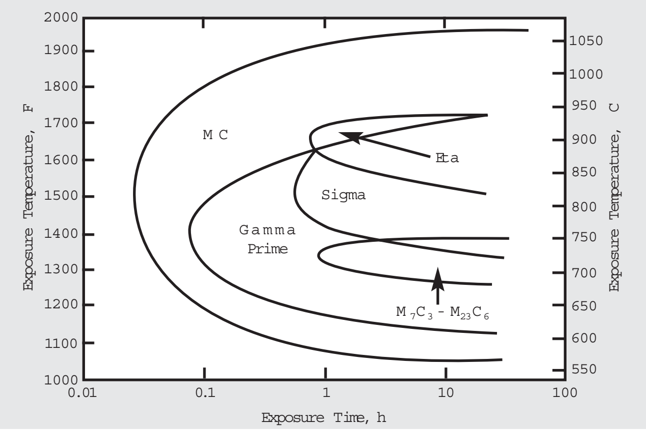

Figure 4. Time-temperature-transformation diagram for initially solution-annealed INCOLOY alloy 925 material.

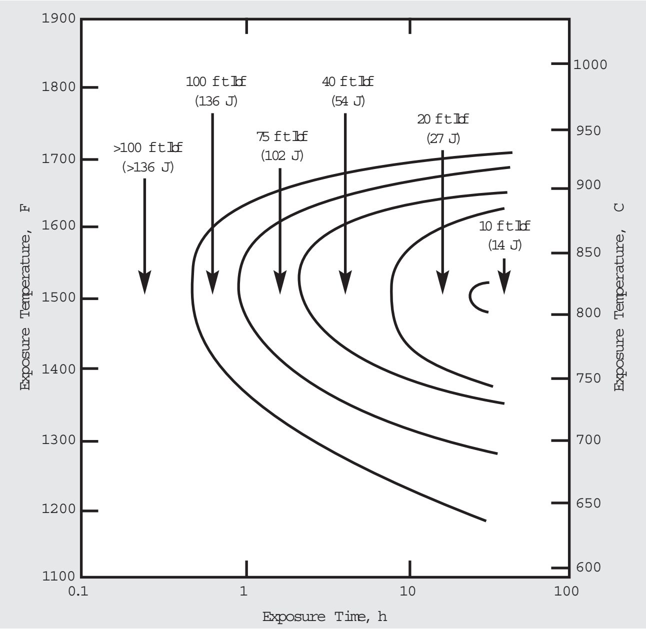

Figure 5. Effect of high-temperature exposure on impact strength of solution-annealed INCOLOY alloy 925 material. Base impact strength was 236 ft lbf (320 J).

Corrosion Resistance

INCOLOY alloy 925 has a high level of corrosion resistance. In both reducing and oxidizing environments, the alloy resists general corrosion, pitting, crevice corrosion, intergranular corrosion and stress-corrosion cracking. Some environments in which INCOLOY alloy 925 is particularly useful are "sour" (H_2S containing) crude oil and natural gas, sulfuric acid, phosphoric acid, and seawater.

The performance of INCOLOY alloy 925 under conditions representing sour gas wells is indicated in Figure 6 and Tables 8, 9 and 10. Figure 6 shows resistance to stress-corrosion cracking in a sour environment at high pressure and temperature. Table 8 shows that the alloy resists sulfide stress cracking, a form of hydrogen embrittlement. The tests involve exposure of stressed C-ring specimens (made from a portion of tubing cross section) to a solution containing hydrogen sulfide, sodium chloride and acetic acid.

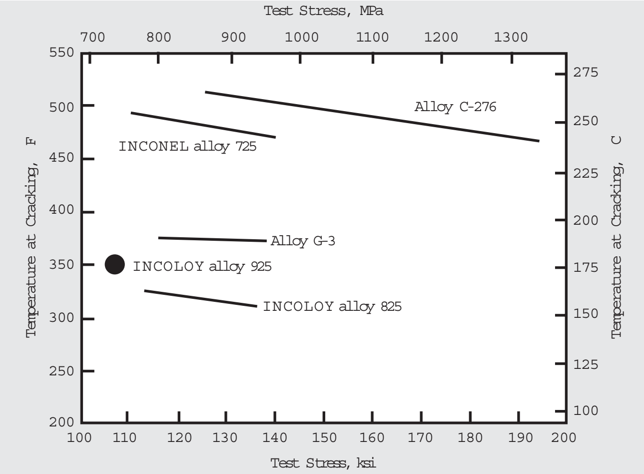

Figure 6. Results of autoclave C-ring tests in a solution of distilled water containing 25% sodium chloride, 0.5% acetic acid and 1 g/l sulfur with pressure of 120 psi (827 kPa) hydrogen sulfide. Test stresses were 100% of yield strength (0.2% offset).

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

Alloy	Material Condition	Simulated Well Age	Yield Strength (0.2% Offset)		Hardness	Duration	Sulfide Stress Cracking
			ksi	MPa	Rockwell C	Days	
INCONEL alloy 625	Cold Worked	None	125.0	862	30.5	42	No
	Cold Worked	None	160.0	1103	37.5	10	Yes
	Cold Worked	None	176.0	1214	41	6	Yes
INCONEL alloy 718	Age Hardened	None	120.0	827	30	42	No
	Age Hardened	None	130.0	896	37	42	No
	Age Hardened	None	134.0	924	38.5	42	No
	Age Hardened	None	139.0	958	38	42	No
	Age Hardened	None	156.0	1076	41	60	No
INCONEL alloy 725	Cold Worked	None	90.0	621	25	30	No
	Age Hardened	None	117.6	811	37	30	No
	Age Hardened	None	128.6	887	40	30	No
	Age Hardened	600 F (315 C)/1000 h	130.8	902	41.5	30	No
	Age Hardened	None	132.9	916	36	42	No
	Age Hardened	None	133.0	917	39	30	No
	CW & Aged	None	137.8	950	39	42	No
INCOLOY alloy 825	Cold Worked	None	138.0	952	30	42	No
	Cold Worked	None	147.0	1014	33	42	No
INCOLOY alloy 925	Age Hardened	None	114.0	786	38	42	No
	Cold Worked	None	139.0	958	35.5	42	No
	CW & Aged	None	176.0	1214	43.5	42	No
	CW & Aged	None	186.0	1282	46	42	No
	Age Hardened	500 F (260 C)/500 h	113.5	783	38	42	No
	Cold Worked	500 F (260 C)/500 h	139.5	962	35.5	42	No
	CW & Aged	500 F (260 C)/500 h	176.0	1214	43.5	42	No
	CW & Aged	500 F (260 C)/500 h	180.0	1214	44	42	No
	CW & Aged	500 F (260 C)/500 h	185.5	1279	46	42	No
Alloy G-3	Cold Worked	600 F (315 C)/1000 h	119.4	823	26	43	No
	Cold Worked	600 F (315 C)/1000 h	132.3	912	30	43	No
	Cold Worked	600 F (315 C)/1000 h	135.3	933	31	43	No
	Cold Worked	600 F (315 C)/1000 h	136.9	944	-	30	No, No[b]
	Cold Worked	600 F (315 C)/1000 h	137.7	949	-	30	No, No[b]
	Cold Worked	600 F (315 C)/1000 h	181.7	1253	-	30	No, Yes[b]
Alloy C-276	Cold Worked	600 F (315 C)/1000 h	126.6	873	32	43	No
	Cold Worked	600 F (315 C)/1000 h	155.1	1069	38	43	No
	Cold Worked	600 F (315 C)/1000 h	166.8	1150	35	43	No
	Cold Worked	600 F (315 C)/1000 h	188.7	1301	43	43	No

[a]Room-temperature tests at 100% of yield strength in 5% NaCl plus 0.5% acetic acid saturated with H_2S. All specimens were couple to carbon steel.
[b]Duplicate test specimens.

Table 9 reviews data on stress-corrosion cracking in sour environments, some of which contain elemental sulfur, at high temperatures and pressures. Table 10 shows general corrosion rates in sour environments. The results in Table 10 are for sour environments containing elemental sulfur, which increases the severity of the conditions.

Table 9 - Stress-Corrosion-Cracking Tests[a] in High-Temperature Sour Environments

Alloy	Material Condition	Yield Strength (0.2% offset)		Hardness	Test Media[b]	Duration	Stress Corrosion Cracking
		ksi	MPa	Rockwell C		Days	
INCONEL alloy 625	Cold Worked	128.0	883	37	A	15	No
	Cold Worked	177.1	1221	41	A	15	No
	Cold Worked	128.0	883	37	B	15	No
	Cold Worked	177.1	1221	41	B	15	No
	Cold Worked	125.0	862	30.5	C	42	No
	Cold Worked	160.0	1103	37.5	C	42	No
	Cold Worked	176.0	1214	41	C	42	No
INCONEL alloy 718	Age Hardened	120.0	827	30	C	42	No
	Age Hardened	134.0	924	38.5	C	42	No
	Cold Worked	197.0	1358	37.5	C	20	Yes
INCOLOY alloy 825	Cold Worked	131.0	903	30	A	15	Yes
	Cold Worked	138.0	952	30	C	42	No
	Cold Worked	147.0	1014	33	C	42	No
INCOLOY alloy 925	CW & Aged	166.0	1145	40.5	A	15	Yes
	Age Hardened	113.5	783	38	B	15	Yes
	CW & Aged	185.5	1279	46	B	15	Yes
	Age Hardened	114.0	786	38	C	42	No
	Cold Worked	139.0	958	35.5	C	42	No
	CW & Aged	176.0	1214	43.5	C	42	No
	CW & Aged	185.5	1279	46	C	42	No
Alloy G-3	Cold Worked	133.5	920	33	D	60	No
	Cold Worked	133.5	920	33	D	120	No
	Cold Worked	137.5	948	30	D	90	Yes
	Cold Worked	137.5	948	30	D	120	No
	Cold Worked	183.3	1264	38	D	120	No
	Cold Worked	133.5	920	33	E	60	No
	Cold Worked	133.5	920	33	E	120	No
	Cold Worked	137.5	948	30	E	120	No
	Cold Worked	183.3	1264	38	E	120	No
Alloy C-276	Cold Worked	194.7	1342	43.5	A	15	No
	Cold Worked	194.7	1342	43.5	B	15	No

[a]Autoclave tests on C-ring specimens stressed at 100% of yield strength.

[b]Test Media:

A = 15% NaCl plus 200 psi (1380 kPa) H_2S plus 100 psi (690 kPa) CO_2 plus 1 g/l of sulfur at 450 F (232 C).

B = 25% NaCl plus 200 psi (1380 kPa) H_2S plus 100 psi (690 kPa) CO_2 plus 1 g/l of sulfur at 400 F (204 C).

C = 15% NaCl saturated with H_2S plus 1000 psi (6.9 MPa) gas phase of 1% H_2S, 50% CO_2, 49% N_2 at 500 F (260 C).

D = 25% NaCl plus 100 psi (690 kPa) H_2S plus 200 psi (1380 kPa) CO_2 at 400 F (204 C).

E = Same as D but at 425 F (218 C).

Table 10 - Corrosion Tests[a] of INCOLOY alloy 925 in Free-Sulfur Environments

Alloy	Test Media[b]	Corrosion Rate	
		mpy	mm/a
Alloy C-276	A	0.2	0.005
	B	0.1	0.003
INCONEL alloy 625	A	0.7	0.018
	B	0.2	0.005
INCOLOY alloy 925	A	1.1	0.028
	B	1.2	0.030
INCOLOY alloy 825	A	1.1	0.028
	B	1.6	0.041
AISI Type 316	A	3.9	0.099
	B	4.5	0.114

[a]Autoclave tests of 15-day duration on unstressed coupons.

[b]Solution A: 15% NaCl plus 200 psi (1380 kPa) H_2S plus 100 psi (690 kPa) CO_2 plus 1 g/l of sulfur at 450 F (232 C).
Solution B: 25% NaCl plus 200 psi (1380 kPa) H_2S plus 100 psi (690 kPa)

The resistance of solution-annealed and aged INCOLOY alloy 925 to various acids is shown in Table 11. The tests were conducted according to Manual No. 3, "Guideline Information on Newer Wrought Iron- and Nickel-Base Corrosion-Resistant Alloys," of the Materials Technology Institute of the Chemical Process Industries, Inc.

Table 11 - Corrosion rates for INCOLOY alloy 925 solution-annealed and aged 0.125 in sheet, evaluated in acid environments for varied exposure time and temperatures as per MTI Manual No.3 procedures

Environment	Temperature		Corrosion Rate 0-192 h	
	C	F	mpy	mm/a
0.2% HCl	Boiling	Boiling	<0.1	<0.01
1% HCl	70	158	11	0.28
10% H_2SO_4	70	128	2	0.05
85% H_2PO_4	Boiling	Boiling	47	1.19
	90	194	<1	<0.03
80% CH_3CO_2H	Boiling	Boiling	<0.1	<0.01

Crevice Corrosion

Crevice corrosion tests in a solution of 3.5% sodium chloride at 77°F (25°C) for 1000 h resulted in no crevice attack and a corrosion rate of less than 1 mpy (0.03 mm/a). Fluorocarbon washers bolted to strip specimens had twenty crevices each, or forty crevices per specimen.

Working Instructions

Hot & Cold Forming

The hot working range for the alloy is 1600 to 2150°F (870 to 1175°C). At temperatures up to 2000°F (1095°C), INCOLOY alloy 925 has hot-working characteristics similar to those of INCOLOY alloy 825. For maximum corrosion resistance and highest strength after direct aging, final hot working should be done in the 1600 to 1800°F (870 to 980°C) range.

The cold-forming behavior of INCOLOY alloy 925 is similar to that of INCOLOY alloy 825 except that alloy 925 has a higher work-hardening rate.

Information on fabricating is available in the Special Metals publication "Fabricating" on the website, www.specialmetals.com.

Joining

INCOLOY alloy 725 welding products, designated INCO-WELD® filler metal 725NDUR®, are recommended for welding INCOLOY alloy 925. INCO-WELD filler metal 725NDUR provides higher strength and better corrosion resistance than the alloy 925 composition welding wire. Gas-tungsten-arc welding (GTAW) and gas-metal-arc welding (GMAW) are the preferred methods for welding with INCONEL alloy 725 welding products. 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.

Selected data for welding INCOLOY alloy 925 with INCO-WELD filler metal 725NDUR are contained in Table 12 and Figures 7 to 12.

Information on joining is available in the Special Metals publication "Joining" on the website, www.specialmetals.com.

Table 12 - Weld Impact Properties at Room Temperature for INCOLOY alloy 925, Welded with INCO-WELD Filler Metal 725NDUR

Heat Treat Condition		Welding Process	Charpy V-Notch Impact Strength Average		Charpy V-Notch Impact Strength Exposed at 1000 F (538 C) for 1000 h	
Pre-Weld	Post-Weld		ft/lbf	J	ft/lbf	J
Anneal	Age	GTAW	19	26	16.5	22
Anneal	Anneal+ Age	GTAW	42	57	37.5	51
Age	Age	GTAW	19	26	11.5	16
Anneal	Age	GMAW	20	27	15	20
Anneal	Anneal + Age	GMAW	35	47	28.5	39
Age	Age	GMAW	20	27	15	20

Anneal = 1900 F (1040 C)/1 h/AC
Age = 1365 F (740 C)/6-9 h/FC to 1150 F (621 C) –15 F (8 C) for a total aging time of 18 h.

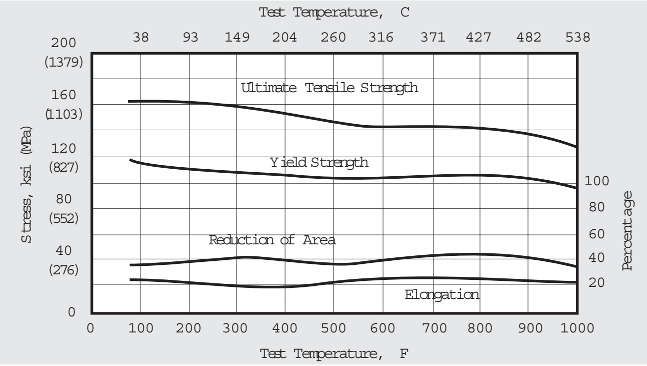

Figure 7. INCOLOY alloy 925 GTA weld data. Pre-weld treatment: anneal. Post-weld treatment: anneal plus age.
Note: Anneal = 1900 F (1040 C)/1 h/AC. Age = 1365 F (740 C)/6-9 h/FC to 1150 F (621 C) –15 F (8 C) for a total aging time of 18 h.

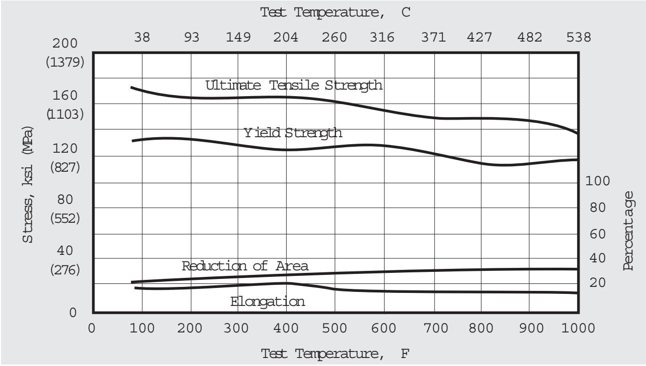

Figure 8. INCOLOY alloy 925 GTA weld data. Pre-weld treatment: anneal. Post-weld treatment: age.
Note: Anneal = 1900°F (1040°C)/1 h/AC. Age = 1365°F (740°C)/6-9 h/FC to 1150°F (621°C) ±15°F (8°C) for a total aging time of 18 h.

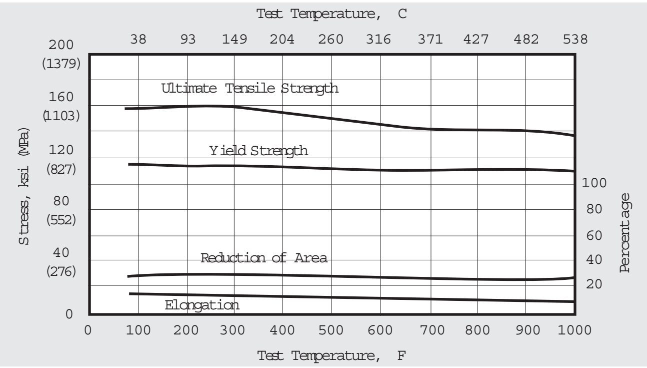

Figure 9. INCOLOY alloy 925 GTA weld data. Pre-weld treatment: age. Post-weld treatment: age.
Note: Anneal = 1900 F (1040 C)/1 h/AC. Age = 1365 F (740 C)/6-9 h/FC to 1150 F (621 C) –15 F (8 C) for a total aging time of 18 h.

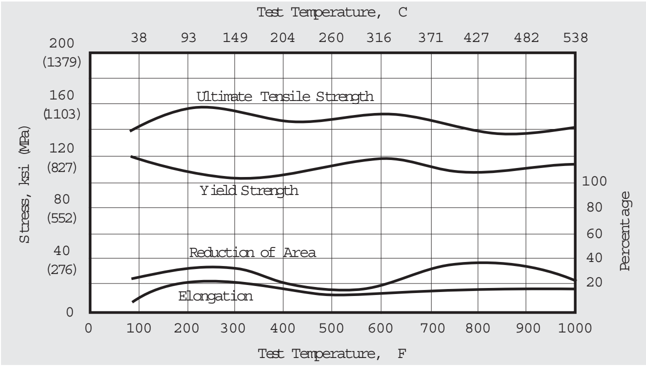

Figure 10. INCOLOY alloy 925 GMA weld data. Pre-weld treatment: anneal. Post-weld treatment: anneal plus age.
Note: Anneal = 1900 F (1040 C)/1 h/AC. Age = 1365 F (740 C)/6-9 h/FC to 1150 F (621 C) –15 F (8 C) for a total aging time of 18 h.

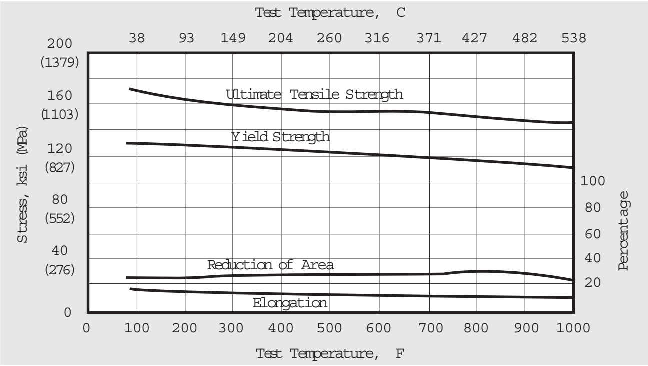

Figure 11. INCOLOY alloy 925 GMA weld data. Pre-weld treatment: anneal. Post-weld treatment: age.
Note: Anneal = 1900 F (1040 C)/1 h/AC. Age = 1365 F (740 C)/6-9 h/FC to 1150 F (621 C) –15 F (8 C) for a total aging time of 18 h.

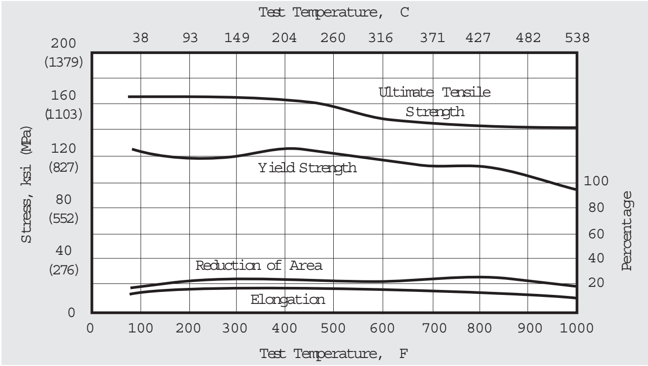

Figure 12. INCOLOY alloy 925 GMA weld data. Pre-weld treatment: age. Post-weld treatment: age.
Note: Anneal = 1900 F (1040 C)/1 h/AC. Age = 1365 F (740 C)/6-9 h/FC to 1150 F (621 C) –15 F (8 C) for a total aging time of 18 h.

Machining

INCOLOY alloy 925 is an age hardenable alloy with good machinability in the solution-annealed or aged conditions. Rigid tools with positive rake angles and techniques that minimize work hardening of the material are required. 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. Best results are obtained by rough machining before age hardening and finishing after heat treatment. Table 13 lists the machining data for INCOLOY alloy 925.

Information on machining is available in the Special Metals publication "Machining" on the website www.specialmetals.com.

Chip Control

When machining INCOLOY alloy 925, it is important to obtain good full turn chips. High speed steel tools require chip curlers or lipped tools. The lip should be wider and deeper for material in the solution-annealed condition. Typical dimensions, for chip breakers operating at 0.010 in/min (0.25 mm/min), are 0.020 in (0.5 mm) deep and 0.080 in (2 mm) wide.

Drilling

Steady feed rates minimize excessive work hardening during drilling. Heavy-duty, high speed drills with a heavy web are recommended. For twist drilling, recommended surface speeds are 20-30 ft/min (6-9 m/min) for the solution-annealed condition and 8-10 ft/min (2.4-3.0 m/min) for the aged condition. Feed rates range from 0.005 in/rev (0.13 mm/rev) to 0.015 in/rev (0.4 mm/rev) depending on the drill size. For gun drills [sizes from 1/16 in (1.6 mm) to 2 in (50 mm)], a feed rate of 0.0001-0.003 in/rev (0.0025-0.08 mm/rev) is recommended for both the solution-annealed and aged conditions. The surface speed should be kept at about 220 ft/min (67 m/min) for solution-annealed material and 60 ft/min (18 m/min) for material in the aged condition.

Table 13 - Machining data for INCOLOY alloy 925 Tool Material

		Annealed	Aged
App. hardness range (Rockwell)		80Rb	40Rc
Depth of cut	in	0.250	0.050
	m m	6.4	1.3
High speed steel			
Surface speed	ft/min	40-50	15-20
	m/min	12-15	4-6
Feed	in/rev	0.030	0.008
	mm/rev	0.8	0.2
Tool material		T-5	M-36
Carbide			
Surface speed - Brazed tool			
	ft/min	175-225	40-50
	m/min	53-69	12-15
Surface speed - Throw away			
	ft/min	200/250	50/100
	m/min	61-76	15-30
Feed	in/rev	0.020	0.008
	mm/rev	0.5	0.2
Tool material		C-6	C-2

Note: Water base-oil emulsion or chemical solution is used as cutting fluid.

Trepanning & Turning

A series of machining tests has been conducted on INCOLOY alloy 925 aged bar. The test consisted of O.D. turning on a Bullard CNC lathe and trepanning on a Boehringer trepan machine using American Heller trepan heads and inserts.

This test was to establish effective metal removal rates and to analyze movement of the material during machining caused by stress. Also, the test determines if the movement was being caused by stress induced by the machining process.

Trepanning:

Hole size	=	4.25 in (108 mm)
rev/min	=	56
in/rev	=	0.008 (0.2 mm/rev)
SFM	=	62

At 100 SFM there was good chip information, but rapid tool failure was noted at the higher SFM on the inside insert.

Turning:

Diameter	=	9.625 in (245 mm)
rev/min	=	46
in/rev	=	0.029 (0.74 mm/rev)
Surface feet/min	=	116 (35 m/min)
Depth of cut	=	0.1875 in (4.76 mm)
Tool	=	SECO SNMG-643 Grade TP20 MR5
Material Length	=	34.75 in (883 mm)

On material which had been trepanned, there was no ovality distortion while turning down to smaller diameters. On material which had been trepanned to produce a wall thickness of less than one inch (25 mm), distortion of up to 0.010 in (0.25 mm) was noted after turning. If the material was allowed to set for several weeks after trepanning, the run out was eliminated or substantially reduced. Reheating the material at 1150°F (621°C)/2 h after trepanning also substantially reduced run out during the turning operation. As a rule of thumb, the best stock removal rates were obtained by running slower SFM and heavier chip loads. It is also important to note that a good setup is critical in the turning operation to prevent additional ovality problems.

Threading

Lathe threading

Standard single-point lathe threading practices are adequate for threading INCOLOY alloy 925 in the solution-annealed or aged conditions. Threading speeds are 12-18 ft/min (3.7-5.5 m/min) for solution-annealed material and 3.0-3.5 ft/min (0.91-1.1 m/min) for aged material. 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 for INCOLOY alloy 925 can be produced by form grinding with aluminum oxide (150-320 grit) vitrified-bonded grinding wheels. The recommended coolant for thread grinding 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 direct aging of INCOLOY alloy 925. However, usually it is preferred to thread roll as-drawn or solution-annealed alloy 925 and then age harden. Material in the soft condition is more easily threaded and subsequent aging

Reaming

Operating speeds for reamers should be about 2/3 of the sped used for drilling. The reamer feed into the work should be 0.0015 to 0.004 in (0.4-0.1 mm) per flute per revolution. Feed rates that are 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 having steel shanks tipped with cemented carbide are recommended for age hardened alloy 925.

Warping

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

Heat Treatment

Solution annealing in preparation for age hardening should be done at 1800-1900°F (980-1040°C) for a minimum of 30 min and a maximum of 4 h. Cool at a rate equivalent to air cooling, or faster, for sizes of 1 in (25 mm) or under. Water quench all sizes over 1 in (25 mm).

The following age hardening treatment is normally used: 1350-1380°F (732-749°C)/6-9 h, FC to 1150°F (621°C), hold at 1150°F (621°C) ± 15°F (8°C) for a total aging time of 18 h. Cool at a rate equivalent to air cooling, or faster.

INCOLOY alloy 925 is designated as UNS N09925. Designations and specifications for the product include NACE MR-01-75, ASME Boiler and Pressure Vessel Code Case 2218 Section VIII Division 1, and Special Metals Corporation internal specification HA 46.

Alloy 925 is available as tube, round bar, flat bar and forging stock.

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