INCOLOY® alloy 903 (UNS N19903) is an age-hardenable nickel-iron-cobalt alloy whose outstanding characteristics are a constant low coefficient of thermal expansion, a constant modulus of elasticity, and high strength. The nominal composition is shown in Table 1.

The alloy's characteristics make it an excellent candidate for applications such as rocket-engine thrust chambers, steam-turbine bolts, springs, gage blocks, and ordnance hardware.

Table 1 - Limiting Composition, wt %

Nickel	36.0-40.0
Cobalt	13.0-17.0
Aluminum	0.30-1.15
Titanium	1.00-1.85
Niobium	2.40-3.50
Iron	Balance*

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

Table 2 - Physical Constants of Age-Hardened INCOLOY alloy 903

Density, lb/in^3	0.298
g/cm^3	8.25
Curie Temperature	
°F	780-880
°C	416-471
Melting Range	
°F	2405-2539
°C	1318-1393

Thermoelastic Properties

The composition of INCOLOY alloy 903 is designed to provide a constant low coefficient of thermal expansion. Figure 1 shows expansion curves for four different samples. As shown by the curves, the alloy typically exhibits a coefficient of expansion of about 4.0 x 10^{-6} in/in/°F (7.2 µm/m/°C) from room temperature to around 800°F (425°C).

The expansion characteristics of alloy 903 are highly reproducible both in static and cyclic exposure to temperature. It exhibited no change in coefficient of expansion after exposure for 500 hours at 1100°F (595°C). Fifty cycles of heating to 1200°F (650°C), holding at temperature for 15 min, and air cooling resulted in a reproducibility of expansion within 1%.

INCOLOY alloy 903 maintains its rigidity over a wide temperature range. As shown in Table 4, the modulus of elasticity remains virtually constant from -320°F (-196°C) to +1200°F (+650°C).

Because of alloy 903's low coefficient of thermal expansion and constant modulus of elasticity, it is highly resistant to thermal fatigue and thermal shock.

Physical Constants and Thermal Properties

Some physical constants for INCOLOY alloy 903 are listed in Table 2. Thermal properties for the alloy are shown in Table 3. Physical properties are reported for age-hardened material.

Table 3 - Thermal Properties of Age-Hardened INCOLOY alloy 903

Temperature	Specific Heat[a]	Electrical Resistivity	Thermal Conductivity[b]
°F	Btu/lb•°F	ohm•circ mil/ft	Btu•in/ ft²•h•°F
100	0.105	379	117
200	0.108	433	119
400	0.115	532	124
600	0.122	626	128
800	0.129	692	134
1000	0.136	728	145
1200	0.143	734	158
°C	J/kg•°C	µΩ•m	W/m•°C
50	442	0.650	16.9
100	454	0.735	17.2
200	482	0.880	17.9
300	507	1.020	18.3
400	532	1.135	19.0
500	559	1.195	20.3
600	584	1.220	21.9

[a] Calculated from chemical composition.

[b] Calculated from electrical resistivity.

INCOLOY® alloy 903

Table 4 - Modulus of Elasticity[a] of Age-Hardened INCOLOY alloy 903

Temperature	Tensile Modulus	Torsional Modulus	Poisson's Ratio[b]		Temperature	Tensile Modulus	Torsional Modulus	Poisson's Ratio[b]
°F	10^3 ksi	10^3 ksi			°C	GPa	GPa	
-320	21.59	—	—		-196	148.9	—	—
-200	21.42	—	—		-100	147.4	—	—
-100	21.34	—	—		-50	146.9	—	—
0	21.29	—	—		0	146.8	—	—
100	21.30	8.63	0.234		50	146.9	59.3	0.239
200	21.35	8.56	0.247		100	147.2	59.0	0.247
300	21.42	8.62	0.242		150	147.8	59.5	0.242
400	21.52	8.75	0.230		200	148.4	60.3	0.231
500	21.67	8.84	0.226		250	149.3	60.9	0.226
600	21.84	8.88	0.230		300	150.2	61.2	0.227
700	22.00	8.89	0.237		350	151.3	61.2	0.236
800	22.18	8.84	0.255		400	152.4	61.4	0.241
900	22.34	8.65	0.291		450	153.5	60.3	0.273
1000	22.10	8.41	0.314		500	153.9	59.2	0.300
1100	21.75	8.10	0.343		550	151.8	57.6	0.318
1200	21.43	7.64	0.402		600	149.8	55.4	0.352

[a] Determined by dynamic method.
[b] Calculated from moduli of elasticity.

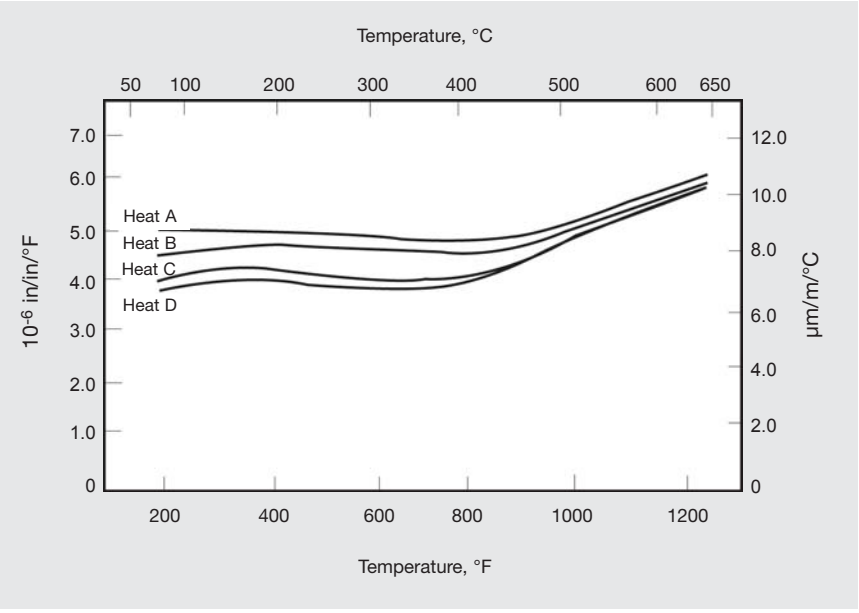

Figure 1. Typical coefficients of thermal expansion (from room temperature to temperature shown) of INCOLOY alloy 903.

Mechanical Properties

INCOLOY alloy 903 has high mechanical properties at room temperature and retains much of its strength up to around 1200°F (650°C). Typical room-temperature and 1200°F (650°C) tensile properties for the alloy are shown in Table 5. Typical room-temperature mechanical properties for the alloy after 1000 hours' exposure to elevated temperatures are listed in Table 6. As indicated by the impact strength, no deleterious phases were present in the alloy. A comparison of notch- and smooth-bar tensile strength is shown in Figure 2. All properties are reported for age-hardened material.

Stress-rupture properties of the alloy are governed by thermo-mechanical processing. Typical stress to produce rupture in 100 h of age-hardened material at 1200°F (650°C) is 85 ksi (586 MPa).

Room-temperature plane strain fracture toughness (K_{IC}) of age-hardened alloy 903 is 100.6 ksi • $\sqrt{\text{in}}$ (111.36 MPa • $\sqrt{\text{m}}$) (average of three tests).

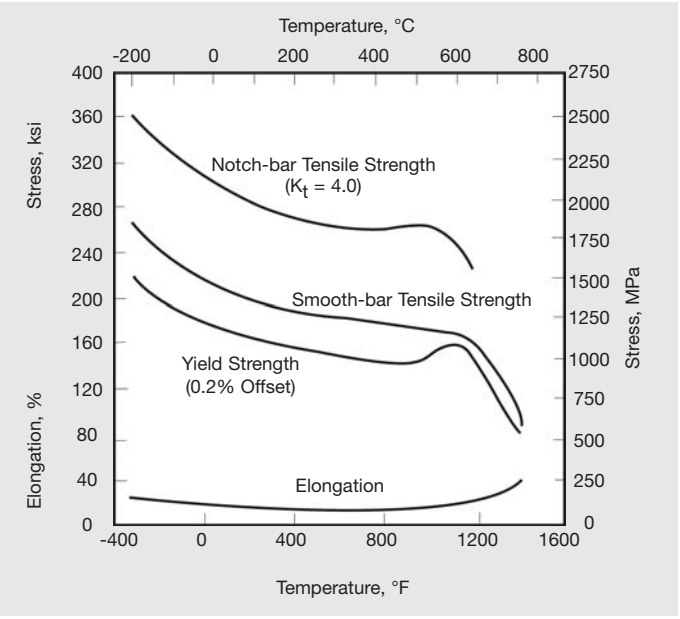

Figure 2. Tensile properties of smooth and notched specimens of solution-treated and age-hardened INCOLOY alloy 903.

Table 6 - Room Temperature Tensile Properties After 1000 Hours of Exposure to Elevated Temperatures[a]

Exposure Temperature		Yield Strength (0.2% Offset)		Tensile Strength		Elongation %	Reduction of Area %	Impact Strength	
°F	°C	ksi	MPa	ksi	MPa			ft•lbf	J
70	21	165.5	1141	198.5	1369	17	43	24	32.5
1100	595	169.5	1169	200.5	1382	16	44	25	33.9
1200	650	149.0	1027	185.0	1276	19	47	26	35.3
1300	705	107.0	738	149.0	1027	20	41	—	—

[a] Material heat treated 1550°F (845°C)/1 h, W.Q. + 1325°F (720°C)/8 h, F.C. at 100°F (56°C)/h to 1150°F (620°C)/8 h, A.C.

Table 5 - Typical Tensile Properties[a]

Temperature		Yield Strength (0.2% Offset)		Tensile Strength		Elong-ation, %	Reduction of Area, %
°F	°C	ksi	MPa	ksi	MPa		
70	21	160	1103	190	1310	14	40
1200	650	130	896	145	1000	18	55

[a] Material heat treated 1550°F (845°C)/1 h, W.Q. + 1325°F (720°C)/8 h, F.C. at 100°F (56°C)/h to 1150°F (620°C)/8 h, A.C.

Table 7 - 500-h Static Oxidation Resistance of INCOLOY alloy 903

Test Temperature		Weight Gain[a]	Depth of Attack	
°F	°C	mg/cm²	in	cm
1000	540	0.7	0.0015	0.0038
1100	595	2.2	0.0025	0.0064
1200	650	2.7	0.0040	0.0102

[a] No scaling evident

Oxidation Resistance

The static oxidation resistance of INCOLOY alloy 903 is shown in Table 7. Testing was conducted for 500 h at 1000°F (540°C), 1100°F (595°C), and 1200°F (650°C).

Cyclic oxidation resistance of alloy 903 is shown in Table 8. The specimens were alternately exposed to the test temperature for 15 min and cooled in air for 5 min.

Because alloy 903 contains no chromium, oxidation resistance may become a consideration for some high-temperature applications. In such cases, protective coatings may be desirable.

Table 8 - Cyclic Oxidation Resistance of INCOLOY alloy 903

Cyclic[a] Exposure Time, h	Weight Gain, mg/cm²		
	1000°F (540°C)	1100°F (595°C)	1200°F (650°C)
100	0.32	0.6	1.1
200	0.38	0.7	1.9
300	0.40	0.9	2.4
400	0.43	1.0	3.0
500	0.48	1.1	3.6

[a] 15 min heating and 5 min cooling in air.

www.specialmetals.com

Fabrication

HOT FORMING

INCOLOY alloy 903 should be hot worked in the 1500-2050°F (815-1120°C) temperature range. For applications in which high stress-rupture properties are required, the alloy should be given a minimum of 40% reduction at temperatures of 1500 to 1600°F (816-871°C). When tensile properties govern, alloy 903 should be worked in the same manner as INCONEL alloy X-750. Details are given in Special Metals' publication "Fabricating", on the website www.specialmetals.com. Since INCOLOY alloy 903 is softer than alloy X-750 between 1600 and 2000°F (870 and 1095°C), forming forces are lower.

MACHINING

In either the solution-treated or age-hardened condition, INCOLOY alloy 903 should be machined with the tooling and procedures recommended for Group D-2 alloys in Special Metals' publication "Machining", on the website www.specialmetals.com.

JOINING

INCOLOY alloy 903 is readily joined by the gas-tungsten-arc process. Consult Special Metals publication "Joining" on the website www.specialmetals.com for more joining information

HEAT TREATMENT

Solution treatment before age-hardening should be performed in the 1500-1800°F (815-980°C) range, depending on the product and prior condition. For optimum mechanical properties, an age-hardening treatment of 1325°F (720°C)/8h, F.C. at 100°F (56°C)/h to 1150°F (620°C)/8 h, A.C. is recommended.

Available Products and Specifications

INCOLOY alloy 903 is designated UNS N19903. The alloy is available as sheet, plate, rod, bar, and forging stock.

U.S.A.
Special Metals Corporation
3200 Riverside Drive
Huntington, WV 25705-1771
Phone +1 (304) 526-5100
+1 (800) 334-4626
Fax +1 (304) 526-5643

4317 Middle Settlement Road
New Hartford, NY 13413-5392
Phone +1 (315) 798-2900
+1 (800) 334-8351
Fax +1 (315)798-2016

United Kingdom
Special Metals Wiggin Ltd.
Holmer Road
Hereford HR4 9SL England
Phone +44 (0) 1432 382200
Fax +44 (0) 1432 264030

Publication Number SMC -100