SPECIAL METALS

INCOLOY® alloy 803 (UNS S35045), an iron-nickel-chromium alloy, is designed for use in petrochemical, chemical and thermal processing applications. The nickel and chromium contents of alloy 803 are higher than those of INCOLOY alloys 800H and 800HT®. The ratios of nickel, iron and chromium are balanced to provide optimum properties in the temperature range of 1550°F (840°C) to 2100°F (1150°C). Alloy 803 is a cost-effective material which provides an exceptional level of high-temperature corrosion resistance in oxidation, sulfidation and carburization environments. INCOLOY alloy 803 exhibits excellent stress-rupture strengths at elevated temperatures. These characteristics, along with a high resistance to carburization and cyclic oxidation, make INCOLOY alloy 803 the material of choice for many severe applications including ID-finned pyrolysis tubing in high-severity ethylene furnaces.

INCOLOY alloy 803 is produced in all major product forms in a wide variety of sizes, finishes and tempers. One unique product form is internally finned, either straight or spiralled fins, cold finished tubing. Strict process controls ensure complete material traceability and structure consistency throughout the manufacture of all INCOLOY alloy 803 products.

Table 1 - Limiting Chemical Composition, %

Nickel	32.0-37.0
Chromium	25.0-29.0
Iron	Balance*
Carbon	0.06-0.10
Aluminum	0.15-0.60
Titanium	0.15-0.60
Copper	0.75 max.
Sulfur	0.015 max.
Manganese	1.5 max.
Silicon	1.0 max.

*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 in minimal quantities.

Physical and Thermal Properties

Values for some physical properties are shown in Table 2. Thermal and electrical properties at temperatures up to 2000°F/1100°C are in Table 3. Modulus of elasticity at room and elevated temperatures is given in Table 4. Data for physical and thermal properties are for annealed material.

Table 2 - Physical Properties

Density, lb/in^3	0.284
g/cm^3	7.86
Young’s Modulus at 70°F (20°C), 10^3 ksi	28.3
GPa	195
Shear Modulus at 70°F (20°C), 10^3 ksi	10.7
GPa	73.8
Poisson’s Ratio at 70°F (20°C)	0.32
Permeability at 200 oersted (15.9 kA/m)	1.001
Melting Range, °F	2490-2555
°C	1365-1400
Specific Heat, Btu/lb•°F	0.114
J/kg•°C	479

Publication Number SMC-033

INCOLOY® alloy 803

Table 3 - Electrical and Thermal Properties

Temperature	Electrical Resistivity	Thermal Conductivity	Coefficient of Expansion[a]
°F	ohm•circ mil/ft	Btu•in/ft²•h°F	10^{-6} in/in/°F
70	618	78	-
200	639	87	7.76
400	662	97	8.18
600	684	115	8.58
800	703	129	8.87
1000	720	145	9.01
1200	736	160	9.24
1400	747	166	9.52
1600	755	171	9.72
1800	766	190	9.96
2000	-	201	10.23
°C	µΩ•m	W/m•°C	µm/m/°C
20	1.03	11.3	-
100	1.06	12.6	14.0
200	1.10	14.0	14.7
300	1.14	15.9	15.4
400	1.16	17.7	15.8
500	1.19	19.6	16.2
600	1.21	21.4	16.4
700	1.23	23.2	16.9
800	1.25	24.0	17.3
900	1.26	25.7	17.6
1000	1.27	27.4	18.0
1100	-	29.1	18.4

[a]Mean coefficient of linear expansion between 77°F (25°C) and temperature shown.

Table 4 - Modulus of Elasticity

Temperature	Tensile Modulus
°F	10^3 ksi
70	28.3
200	28.0
400	26.4
600	25.5
800	24.6
1000	23.7
1200	22.5
1400	21.3
1600	20.2
1800	19.2
°C	GPa
20	195.3
100	192.5
200	182.8
300	177.3
400	171.1
500	165.6
600	158.7
700	151.8
800	144.2
900	139.4
1000	131.8

Mechanical Properties

INCOLOY alloy 803 has good mechanical strength at room and elevated temperatures. Nominal room temperature mechanical properties for various products are listed in Table 5. High-temperature mechanical properties for solution annealed INCOLOY alloy 803 sheet, plate and tubing are shown in Figures 1, 2 and Table 6. INCOLOY alloy 803 has good thermal stability as evidenced by the tensile and impact properties after exposure to high temperatures shown in Tables 7 and 8. However, like many other iron-nickel-chromium alloys designed for service at high temperatures, INCOLOY alloy 803 can undergo solid state reactions when exposed to intermediate temperatures between 1100°F (590°C) and 1500°F (815°C) for long periods of time.[1,2,3] Such reactions can result in the precipitation of phases and compounds which can reduce the ductility and impact strength of alloy components (Table 9). Designers must consider these phenomena when alloy 803 is being used in applications in which it will be exposed to these temperatures for extended periods of time. It may be necessary to solution anneal material that has been so exposed to restore ductility prior to repair or deformation after service. Creep rate and rupture life for solution annealed INCOLOY alloy 803 are shown in Figures 3 and 4.

Table 5 - Nominal Room-Temperature Tensile Properties[a]

Form and Condition	Tensile Strength		Yield Strength (0.2% Offset)		Elongation
	ksi	MPa	ksi	MPa	%
Tubing, Cold-drawn & Solution Annealed	85-91	586-627	40-45	275-310	45-50
Plate, Hot-rolled & Solution Annealed	83-88	572-607	40-43	275-296	43-47
Sheet, Cold-rolled & Solution Annealed	80-90	552-621	40-48	275-331	40-45
Rod, Hot-finished & Solution Annealed	83-88	572-607	30-37	207-255	45-50

[a]Values shown are composites for various product forms and not suitable for specification purposes.

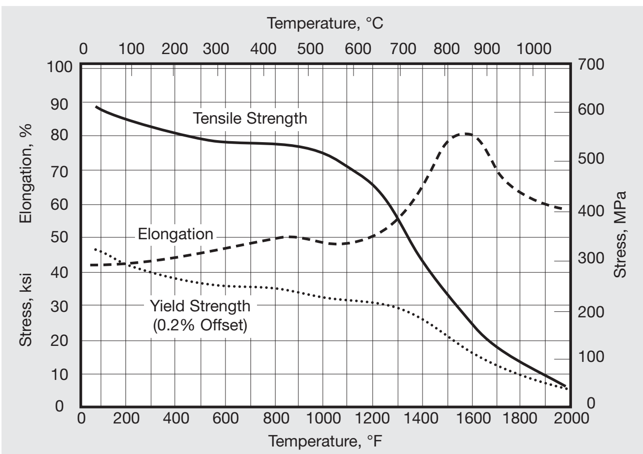

Figure 1. Tensile properties of solution annealed INCOLOY alloy 803 sheet.

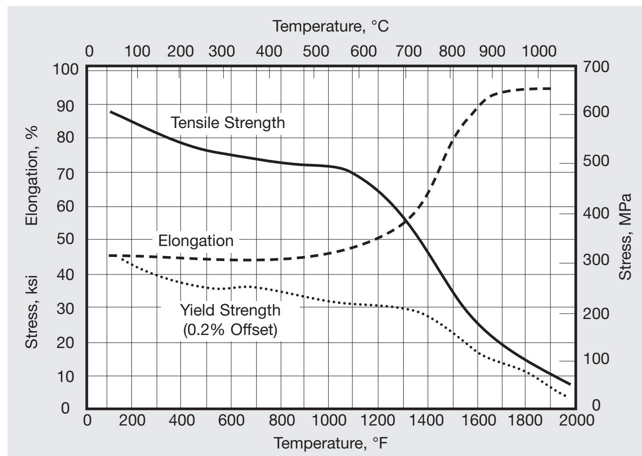

Figure 2. Tensile properties of solution annealed INCOLOY alloy 803 plate.

Table 6 - High-Temperature Tensile Properties of INCOLOY alloy 803 Solution Annealed Tubing

Temperature		Tensile Strength		Yield Strength (0.2% Offset)		Elongation	Reduction of Area
°F	°C	ksi	MPa	ksi	MPa	%	%
Room	Room	91	627	45	310	49	67
1200	649	65	448	28	193	49	55
1400	760	42	290	28	193	66	54
1600	871	27	186	18	124	88	66
1800	982	12	96	10	55	80	75
2000	1093	8	55	7	48	80	77

Table 7 - Thermal Stability of INCOLOY alloy 803. Room-Temperature Tensile and Impact Properties of INCOLOY alloy 803 following 500, 1000, and 2000 hours Isothermal Exposures

Condition	Yield Strength (0.2% Offset)		Tensile Strength		Elongation	Impact	
	ksi	MPa	ksi	MPa	%	ft•lbf	J/cm²
Solution Annealed	35.8	247	88.2	608	49.3	240	407
1200°F (650°C)/500 h	72.5	500	128.7	887	27.5	76, 78	129, 132
1200°F (650°C)/1000 h	72.2	498	126.8	874	25.6	73, 75	124, 127
1400°F (760°C)/500 h	45.9	316	105.3	726	33.9	91, 82	154, 139
1400°F (760°C)/1000 h	43.9	303	104.2	718	34.4	45, 51	76, 86
1400°F (760°C)/2000 h	41.9	289	101.9	703	32.9	47, 49	64, 66
1600°F (870°C)/500 h	38.6	266	93.5	645	38.1	80	136
1600°F (870°C)/1000 h	37.6	259	92.8	640	38.5	73, 65	124, 110

Table 8 - High-Temperature Tensile Test Results for INCOLOY alloy 803 after Solution Annealed and Solution Annealed plus Isothermally Exposed Conditions

Condition	Temperature		Yield Strength (0.2% Offset)		Tensile Strength		Elongation
	°F	°C	ksi	MPa	ksi	MPa	%
Solution Annealed (SA)	1200	650	43.3	299	79.2	546	38.7
SA + 1200°F (650°C)/500 h	1200	650	61.0	421	91.2	629	17.3
SA + 1200°F (650°C)/1000 h	1200	650	64.2	443	91.5	631	14.1
Solution Annealed (SA)	1400	760	29.2	201	45.1	311	48.6
SA + 1400°F (760°C)/500 h	1400	760	27.9	192	45.0	310	71.2
SA + 1400°F (760°C)./1000 h	1400	760	28.1	194	45.8	316	53.6
Solution Annealed (SA)	1600	870	16.7	115	24.6	170	85.7
SA + 1600°F (870°C)/500 h	1600	870	13.9	96	22.3	154	96.8
SA + 1600°F (870°C)/1000 h	1600	870	14.0	97	21.7	150	93.0

Table 9 - INCOLOY alloy 803 Room-Temperature Tensile Results

Exposure Temperature		Exposure Time	Yield Strength		Tensile Strength		Elongation	Reduction of Area	Hardness
°F	°C	hours	ksi	MPa	ksi	MPa	%	%	Rockwell 'B'
As Annealed	As Annealed		36.5	250	88.7	608	49.0	68.7	76
1350-1400	732-760	25000+	36.0	247	70.9	486	9.8	10.5	84
1400	760	8776.3	44.2	303	91.6	628	10.2	10.1	88
1500	816	8714.9	36.2	248	83.6	573	16.6	14.8	79
1600	871	8564.8	31.1	213	80.9	555	28.7	26.3	69
1700	927	7688.0	27.7	190	75.8	520	30.7	29.7	67
1800	982	5165.0	26.8	184	61.7	423	15.8	21.9	61
1900	1038	5832.1	26.7	183	62.3	427	29.6	25.7	61
2000	1093	5831.7	29.3	201	64.0	439	29.9	33.3	56

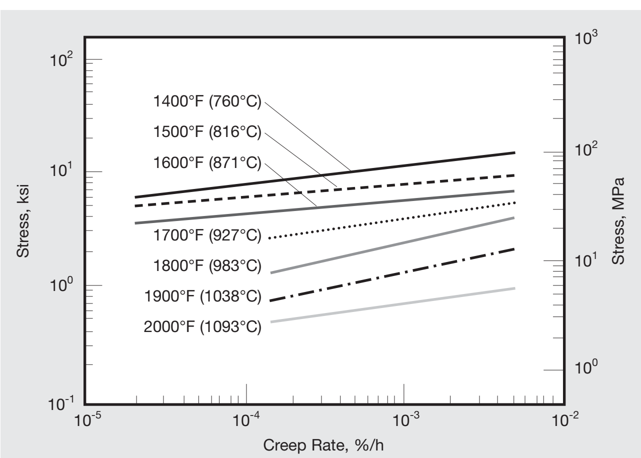

Figure 3. Creep strength of solution annealed INCOLOY alloy 803.

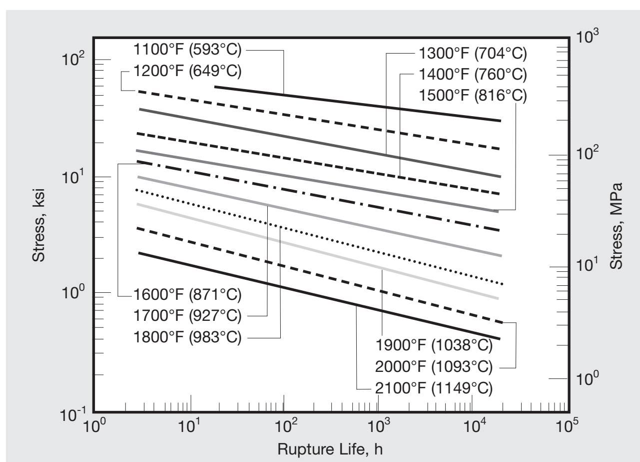

Figure 4. Rupture strength of solution annealed INCOLOY alloy 803

Corrosion Resistance

INCOLOY alloy 803 is characterized by an impressive resistance to various forms of high-temperature corrosion. This resistance to oxidation, carburization and sulfidation is shown in Figures 5 through 12. Carburization can cause a loss of an alloy's creep and stress-rupture strength and a reduction in resistance to thermal fatigue. Mixed oxidant carburizing environments (Figures 8 and 9) are the most typical atmospheres for applications involving heat-resistant alloys. INCOLOY alloy 803 forms a protective oxide in these environments. A more severe atmosphere is created by "oxygen-free" carburizing environments, as shown in Figures 10 and 11, which restrict the formation of protective oxides.

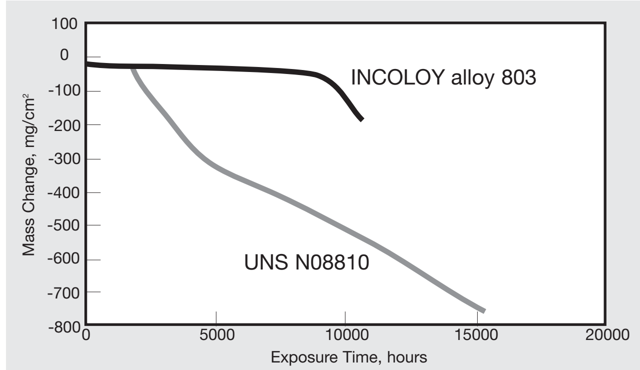

Figure 5. Static oxidation resistance of INCOLOY alloy 803 at 1000°C (1832°F) measured by the mass change occurring in air with 5% water vapor environment.

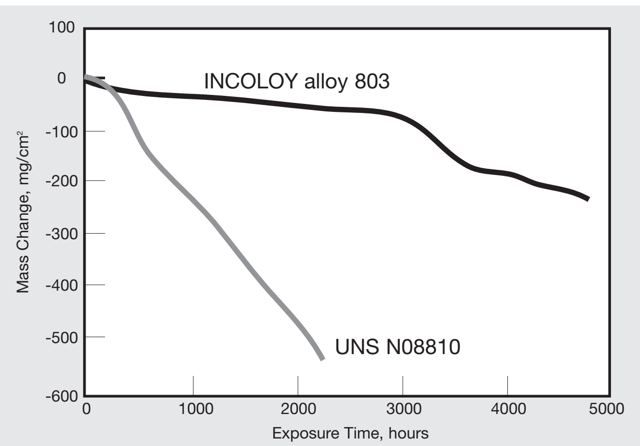

Figure 6. Static oxidation resistance of INCOLOY alloy 803 at 1100°C (2012°F) measured by the mass change occurring in air with 5% water vapor environment.

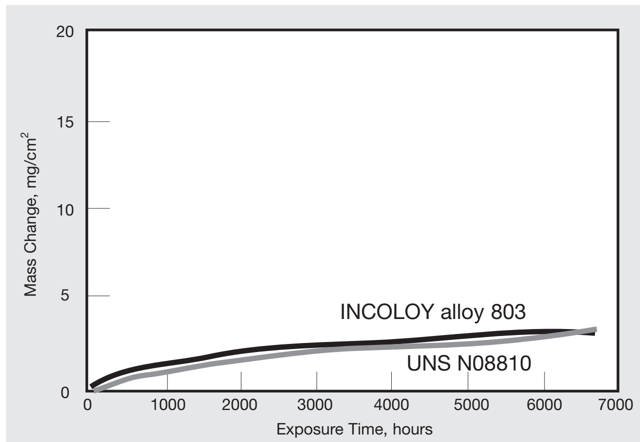

Figure 7. Sulfidation resistance of INCOLOY alloy 803 at 816°C (1472°F) measured by the mass change occurring in a H_2 - 45% CO_2 - 1% H_2S environment.

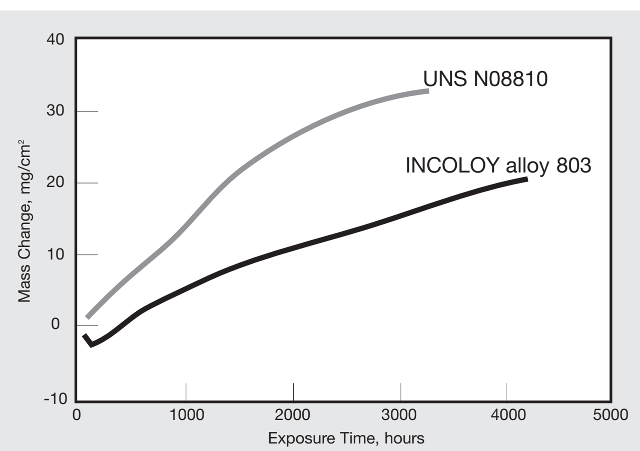

Figure 8. Carburization resistance of INCOLOY alloy 803 at 1000°C (1832°F) measured by the mass change occurring in a H_2 - 5.5% CH_4 - 4.5% CO_2 environment.

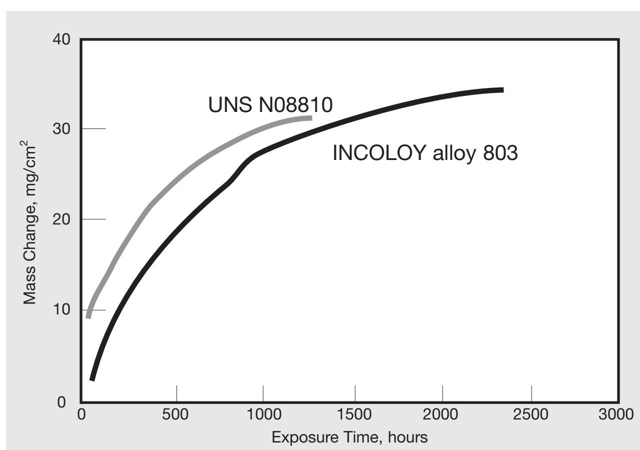

Figure 9. Carburization resistance of INCOLOY alloy 803 at 1100°C (2012°F) measured by the mass change occurring in a H_2 - 5.5% CH_4 - 4.5% CO_2 environment.

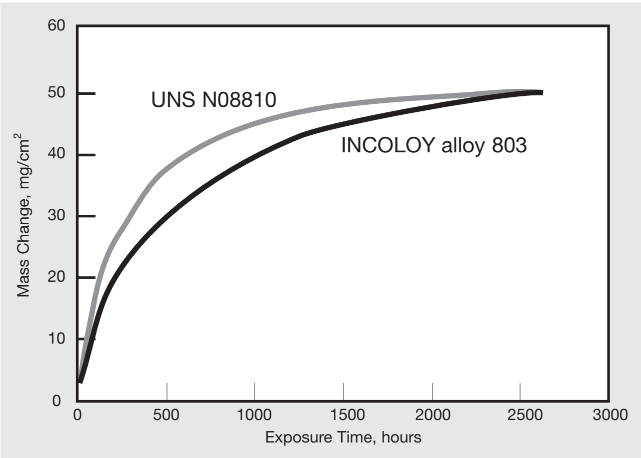

Figure 10. Carburization resistance of INCOLOY alloy 803 at 1000°C (1832°F) measured by the mass change occurring in a H_2 - 1% CH_4 environment.

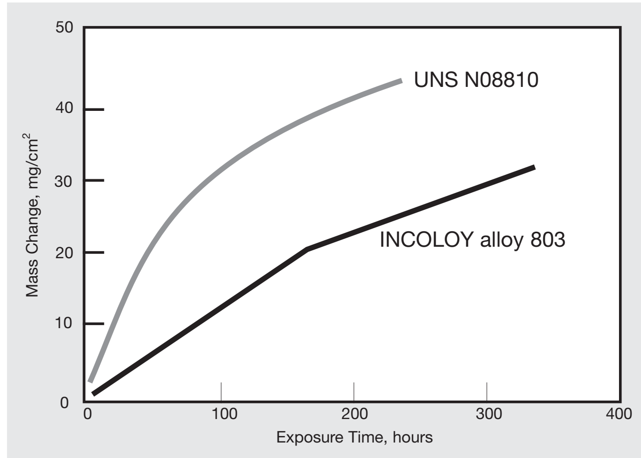

Figure 11. Carburization resistance of INCOLOY alloy 803 at 1100°C (2012°F) measured by the mass change occurring in a H_2 - 1% CH_4 environment.

INCOLOY alloy 803 provides resistance to carburizing environments over a range of oxygen potential conditions. An added benefit is the alloy's resistance to cyclic oxidation for thermal processing applications.

Like INCOLOY alloys 800, 800H and 800HT, INCOLOY alloy 803 shows good resistance to stress corrosion cracking. Also, like other "800 series" alloys, INCOLOY alloy 803 can be sensitized or made susceptible to intergranular attack in some aggressive aqueous media by exposure to the temperature range of 1000 to 1400°F (540 to 760°C). The Time-Temperature Sensitization (TTS) diagram in Figure 13 shows Huey test rates for INCOLOY alloy 803 solution annealed at 2150°F (1177°C).

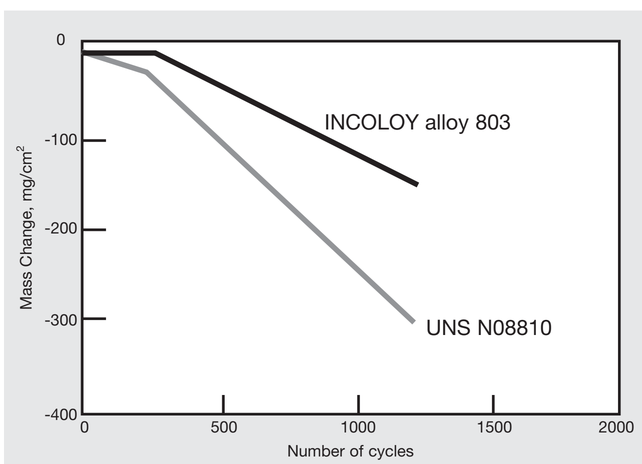

Figure 12. Cyclic oxidation resistance of INCOLOY alloy 803 at 2000°F (1093°C) measured by the mass change in cycles of 15 minutes heating and 5 minutes cooling in air.

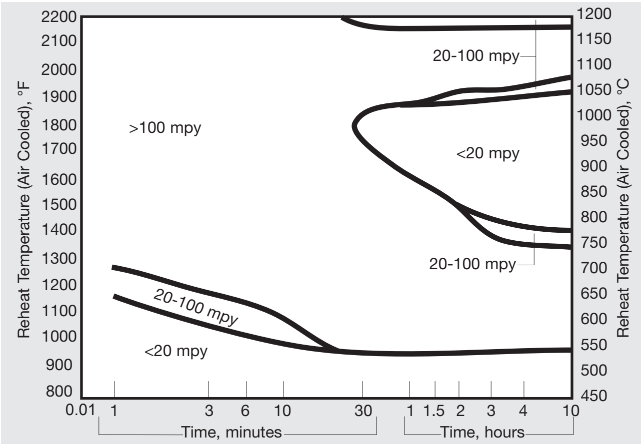

Figure 13. Time-temperature sensitization of INCOLOY alloy 803 finned tube. ASTM A262, Practice C (Huey) results. Specimens were solution annealed at 2150°F (1177°C)/15 min/WQ.

Fabrication

INCOLOY alloy 803 is readily formed by hot or cold working, and has good weldability and machinability. A typical work hardening curve for INCOLOY alloy 803 is shown in Figure 14. Hot forming of INCOLOY alloy 803 is performed in the temperature range of 1600°F-2200°F (870°C-1200°C). Heavy forging should be done at temperatures from 1850°F (1010°C) to 2200°F (1200°C). Forming at temperatures between 1200°F and 1600°F (650°C-870°C) can result in cracking of the workpiece.

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

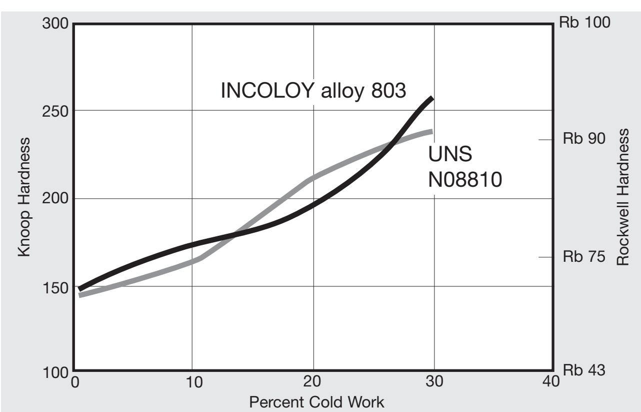

Figure 14. Hardness versus cold work for INCOLOY alloy 803 and UNS N08810 Plate.

Machining

Information on machining is available in the Special Metals publication “Machining” on the company website, www.specialmetals.com.

Joining

INCOLOY alloy 803 has the same good weldability as INCOLOY alloy 800H (UNS N08810). It should be joined using welding products that have comparably high creep-rupture strength and high-temperature corrosion resistance. For most environments, the recommended welding products are INCONEL Welding Electrode 117 and INCONEL Filler Metal 617. For sulfidation environments, the recommended welding products are INCONEL Welding Electrode 152 and INCONEL Filler Metal 52.

Information on joining is available in the publication “Joining” on the website www.specialmetals.com.

Available Products and Specifications

INCOLOY alloy 803 is designated as UNS S35045. Contact Special Metals for information on available product forms.

INCOLOY alloy 803 is approved under the Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers (ASME). Rules for construction of pressure vessels under ASME Section VIII, Division 1 for service at temperatures up to and including 1650°F (900°C) are defined in ASME Code Case 2304.

Plate, Sheet and Strip - ASTM A 240, ASTM A 480, ASME Code Case 2304

Seamless Pipe and Tubing - ASTM A 213, ASME SA 213

Welded Tubing - ASTM SA 249, ASME SA 249

Forgings - ASTM A 182, ASME SA 182

References

1. P. Ganesan, G.D. Smith & C.S. Tassen, “Corrosion Resistance of Alloy 803 in Environments Applicable to Fossil Energy Systems,” Paper no. 470, Corrosion ’95, The NACE International Annual Conference & Corrosion Show, Orlando, Florida, March 26-31, 1995.
2. P. Ganesan & C.S. Tassen, “Corrosion Resistance & Mechanical Properties of Alloy 803 for Heat Resisting Applications,” Paper no. 145, Corrosion ’97, NACE International, New Orleans, LA, March 9-14, 1997.
3. Howard W. Sizek, Brian A. Baker & Gaylord D. Smith, “Long Term, High Temperature Stability of Alloy 803 in the Chemical Process Industry,” Paper no. 68, Corrosion ’99, NACE International, San Antonio, TX, April 25-30, 1999.