INCONEL® alloy HX (UNS N06002/W.Nr. 2.4665) is a high-temperature, matrix-stiffened, nickel-chromium-iron-molybdenum alloy with outstanding oxidation resistance, and exceptional strength at up to 2200°F (1200°C).

It is used for components such as combustion chambers, afterburners and tail pipes in aircraft and land-based gas turbine engines; for fans, roller hearths and support members in industrial furnaces, and in nuclear engineering.

INCONEL alloy HX is readily fabricated and welded.

Table 1 - Limiting Chemical Composition, % by Weight

Carbon	0.05-0.15
Chromium	20.5-23.0
Cobalt	0.5-2.5
Iron	17.0-20.0
Manganese	1.0 max.
Molybenum	8.0-10.0
Nickel	Balance*
Silicon	1.0 max.
Tungsten	0.2-1.0
Phosphorus	0.04 max.
Sulfur	0.03 max

*Reference to the balance of the 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.

Physical Properties

Some physical properties for INCONEL alloy HX are given in Table 2. Thermal conductivity data (Table 3) and electrical resistivity (Table 5) were determined from 5 casts of cold-rolled sheet, 0.039-0.067 in (1-1.7 mm) thick, heated-treated at 2150°F (1175°C)/rapid air cooled.

Mean coefficient of linear thermal expansion data (Table 4) are for solution-treated material. A variation of ±5% can be expected for compositional changes within the release specification, processing history and form.

The dynamic moduli data (Table 6) were obtained from cold-rolled sheet, 0.039-0.067 in (1-1.7 mm) thick, heat-treated at 2150°F (1175°C)/rapid air cooled and vibrated in the flexural mode.

Table 2 - Physical Properties

Density, g/cm³	8.2
lb/in³	0.297
Melting Range, °C	1260-1355
°F	2300-2470
Specific Heat, J/kg °C	461 at 20°C
Btu/lb °F	0.110 at 70°F
Poisson's Ratio at room temperature..	0.320

Available Forms

INCONEL alloy HX is available as rod, bar, billet, extruded section, plate, sheet, strip, wire, pipe and tube.

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Table 3 - Thermal Conductivity

Temperature		Thermal Conductivity	
°C	°F	W/m °C	Btu/ft h °F
20	68	11.6	81
100	212	12.9	90
200	392	14.6	102
300	572	16.3	114
400	752	17.9	126
500	932	19.5	137
600	1112	21.1	148
700	1292	22.9	161
800	1472	24.6	173
900	1652	26.3	184
1000	1832	27.9	196

Table 4 - Mean Coefficient of Linear Thermal Expansion

°C	10^{-6}/°C	°F	10^{-6}/°F
20 -100	13.3	70 -200	7.40
-200	14.0	-600	7.96
-300	14.3	-1000	8.27
-400	14.5	-1200	8.53
-500	14.7	-1350	8.69
-600	15.1	-1500	8.88
-700	15.7	-1600	9.01
-800	16.0		
-900	16.3		
-1000	16.7		

Table 5 - Electrical Resistivity

Temperature		Electrical Resistivity	
°C	°F	μΩ cm	Ω circ mil/ft
20	68	116	698
100	212	118	710
200	392	120	722
300	572	122	734
400	752	124	746
500	932	126	758
600	1112	127	764
700	1292	127	764
800	1472	127	764
900	1652	127	764
1000	1832	128	770

Table 6 - Dynamic Moduli

Temperature		Dynamic Young's Modulus		Dynamic Torsional Modulus	
°C	°F	GPa	10^3 ksi	GPa	10^3ksi
20	68	205	29.7	80	11.6
100	212	202	29.3	78	11.3
200	392	195	28.3	75	10.9
300	572	190	27.6	72	10.4
400	752	183	26.5	70	10.2
500	932	177	25.7	66	9.6
600	1112	168	24.4	62	9.0
700	1292	161	23.3	60	8.7
800	1472	153	22.2	56	8.1
900	1652	145	21.0	53	7.7
1000	1832	135	19.6	49	7.1

Mechanical Properties

Room-temperature mechanical properties, typical of a single representative heat are quoted in Table 7. Data in Fig. 1 are for cold-rolled sheet, 0.039-0.067 in (1-1.7 mm) thick, heat-treated at 2150°F (1175°C)/rapid air cooled. Strain rates of 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures), and 0.1 min thereafter.

Data in Fig. 2 are for cold-rolled, welded sheet, 0.039-0.067 in (1-1.7 mm) thick, heat-treated at 2150°F (1175°C)/rapid air cooled. The sheet was welded by the gas-tungsten-arc (T.I.G.) process using INCONEL filler metal HX with argon as the shielding gas.

Creep-rupture properties of sheet (heat-treated at 2150°F (1175°C)/rapid air cooled) are shown in Fig. 3 by Larson-Miller presentation.

Table 7 - Mechanical Properties of Sheet at Room Temperature

Tensile Strength		0.2% Proof Stress		Elongation	Hardness
ksi	MPa	ksi	MPa	%	Rb
115	793	50	345	45.5	90

Figure 1. Tensile properties of INCONEL alloy HX sheet.

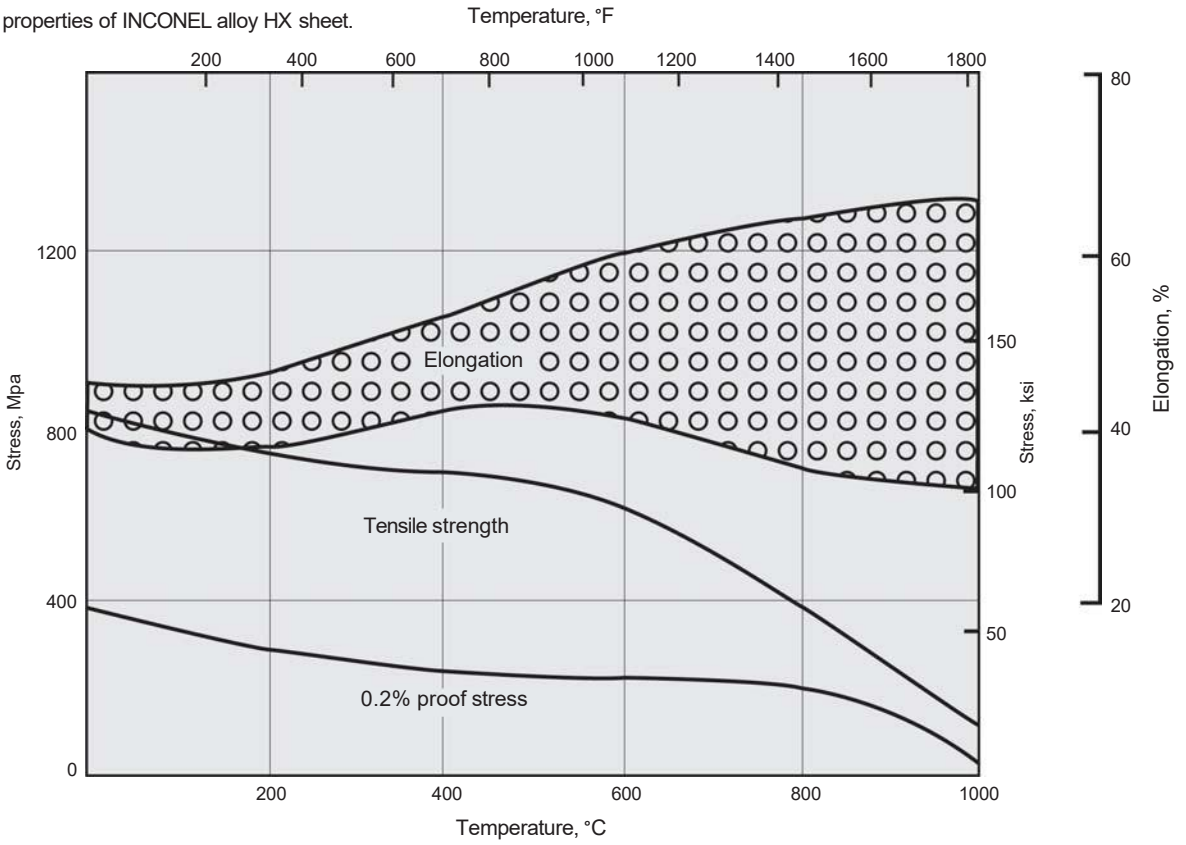


Figure 2. Tensile properties of INCONEL alloy HX welded sheet.

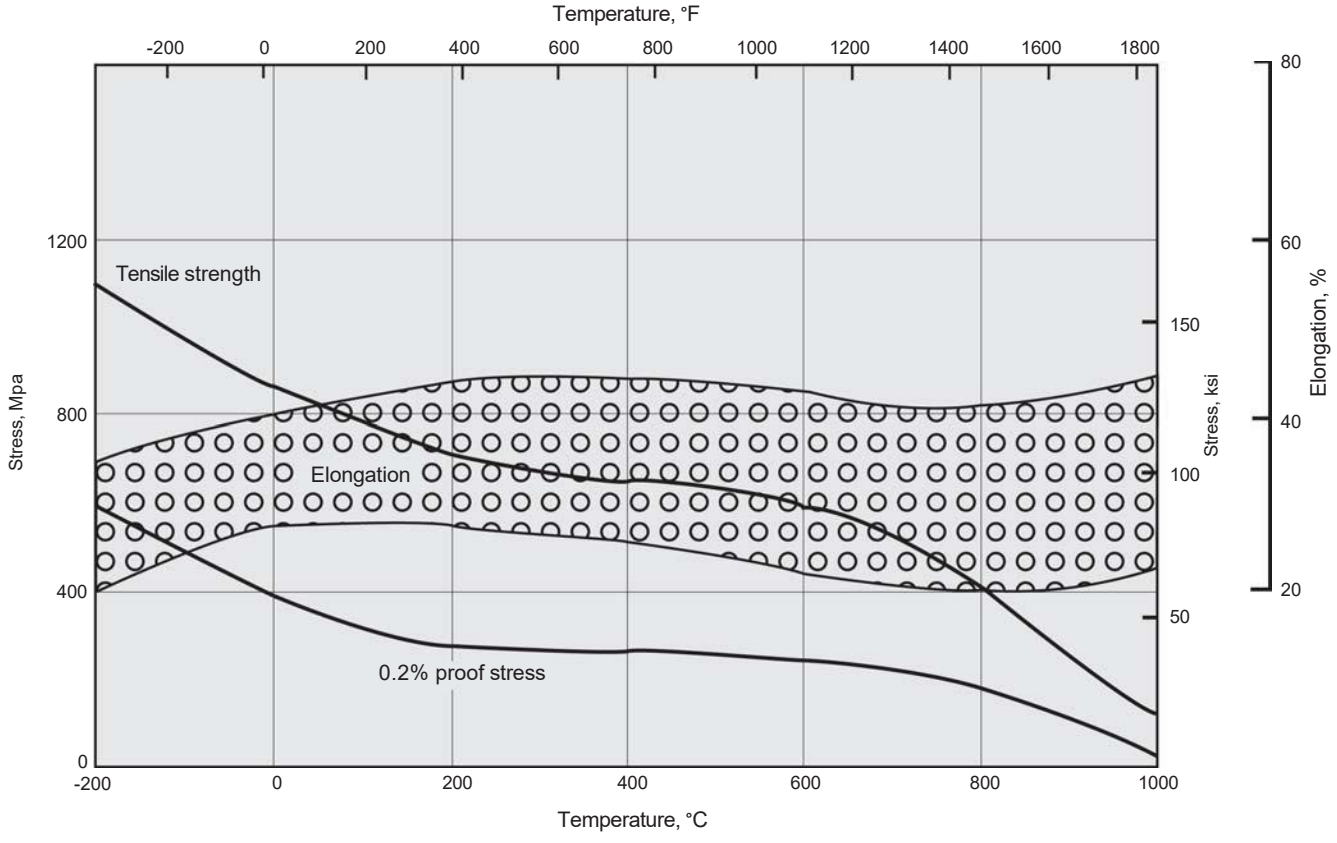
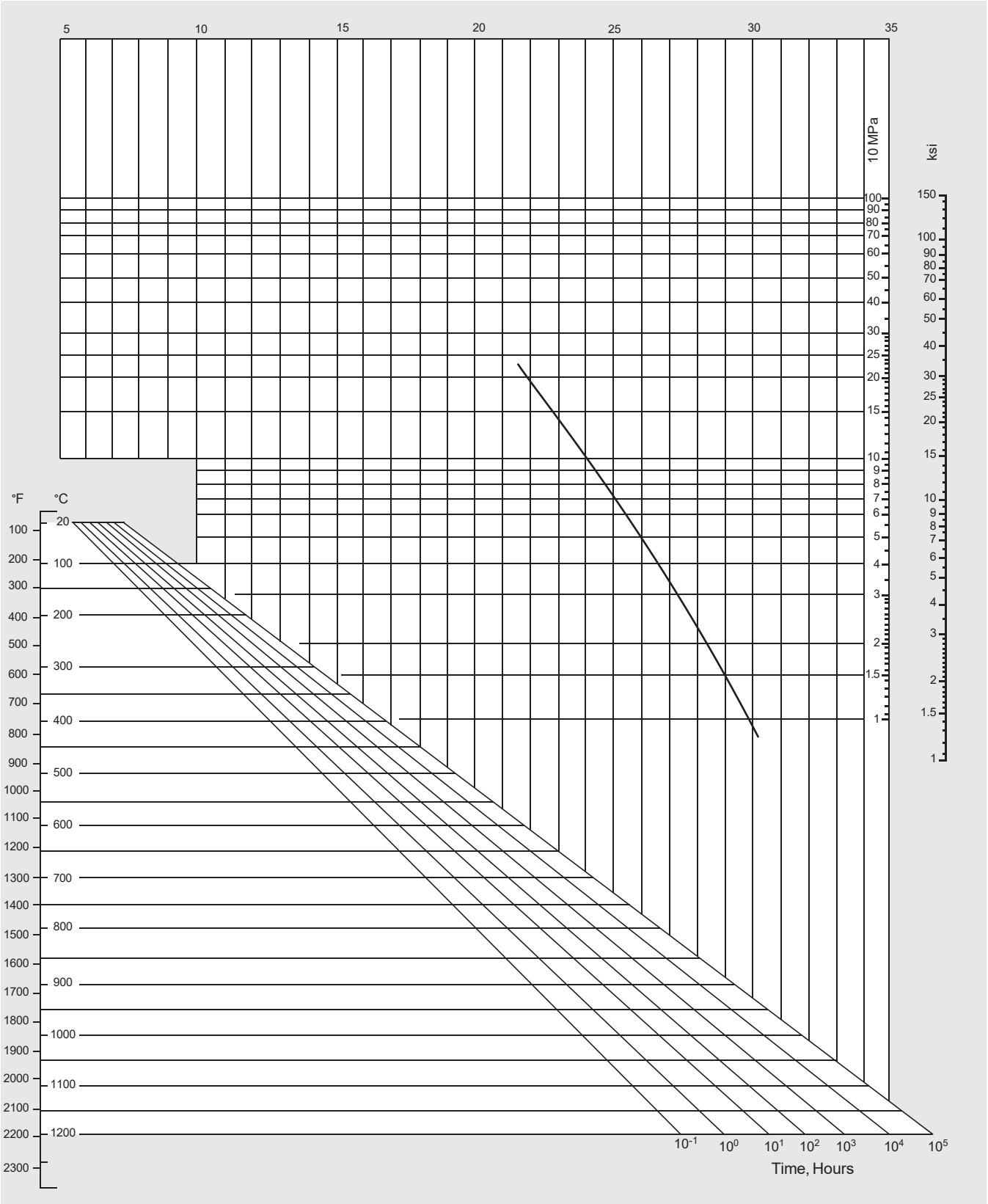


Figure 3. Creep-rupture properties of INCONEL alloy HX sheet.

Larson-Miller Parameter, T(20 +log t) x 10^{-3}, T in °K, t in hours



Corrosion Resistance

INCONEL alloy HX has outstanding oxidation resistance at temperatures up to 2200°F (1200°C). Test results at 1920 and 2010°F (1050 and 1100°C) for 100 hours' continuous exposure are shown in Fig. 4.

In a carburizing atmosphere of 2% methane plus 98% hydrogen flowing at 3 furnace volumes per hour for 100 hours at 1800°F (980°C), samples of a representative heat of INCONEL allow HX showed an average weight gain of 7.7 mg/cm².

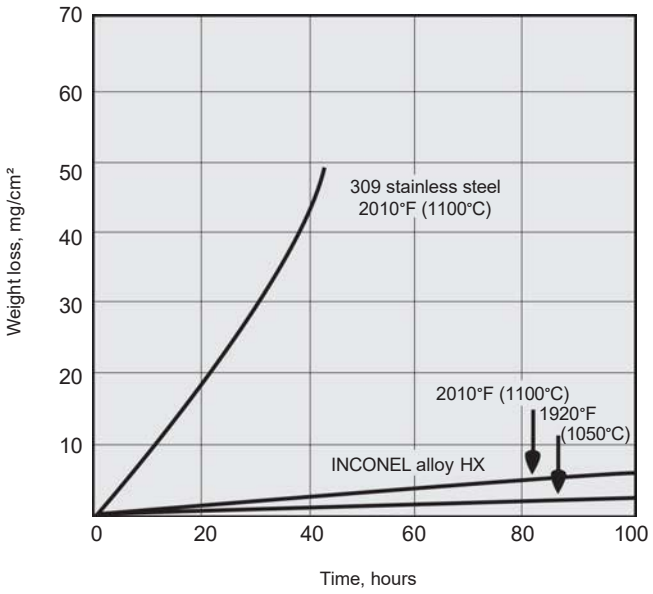


Figure 4. Comparative oxidation resistance of INCONEL alloy HX and AISI 309 stainless steel

Fabrication

Heat Treatment

The recommended heat treatment is 2150°F (1175°C), followed by rapid air cooling or water quenching. INCONEL alloy HX is normally supplied in this solution-heat-treated condition. For some applications it can be given other treatments. Consult Special Metals for further details.

Hot and Cold Forming

INCONEL alloy HX can be readily cold formed using slightly higher power than that used for austenitic stainless steels. It is best cold formed in the solution-heat-treated condition.

For hot forming, the alloy should be heated to a starting temperature of 2150°F (1175°C). It should not be hot worked below 1800°F (980°C).

Welding

The alloy can be welded by metal arc, gas-tungsten-arc (T.I.G.), gas-metal-arc (M.I.G.) and submerged arc processes. Welded surfaces must be thoroughly descaled and cleaned. Welding is best carried out flat since the fluidity of the alloy makes position welding difficult.

INCONEL welding electrode 117 and INCONEL filler metal 617 produce weldments that match or exceed base metal high-temperature strength and oxidation resistance. Matched composition welding consumables (INCONEL filler metal HX and INCONEL welding electrode HX) are available.

Pre-heating and post-weld heat treatments are not normally necessary. For the greatest corrosion resistance, however, solution-heat-treatment after welding may be necessary.

Machining

INCONEL alloy HX should be machined in the annealed condition using carbide or high-speed steel tools and a copious supply of sulfur-free cutting fluid. Tools and machines should be as rigid as possible to minimize deflection and vibration. Speeds and feeds will be similar to those for NIMONIC alloy 75.

Specifications

INCONEL alloy HX is designated as UNS N06002/ W.Nr 2.4665. Alloy HX is listed in NACE MR-01-75. The alloy is available as rod, bar, billet, extruded section, plate, sheet, strip, wire, pipe and tube. Specifications for INCONEL alloy HX include the following:

ASTM	
B 435	Plate, sheet and strip
B 366	Fittings
B 572	Rod
B 619	Welded pipe
B 622	Seamless pipe and tube
B 626	Welded tube
B 751	Tube Pipe
B 775	Pipe and Tube
B 829	

ASME	
SB 435	Plate, sheet and strip
SB 366	Fittings
SB 572	Rod
SB 619	Welded pipe
SB 622	Seamless pipe and tube
SB 626	Welded tube
SB 751	Tube
SB 775	Pipe
SB 829	Pipe and Tube

SAE	
AMS 5536	Sheet, strip and plate
AMS 5587	Seamless tube
AMS 5588	Welded tube
AMS 5754	Bar, forgings and rings
AMS 5798	Wire

BSI	
HR6	Billet, bar and forgings
HR204	Plate, sheet and strip

Deutschen Luftfahrt	
LW2.4665 Part 1	Sheet and strip
LW2.4665 Part 2	Bar and forgings

Ministère d'Etat de la Défense	
AIR 9165-43	Bar, forgings and sheet

AECMA	
PrEN2182	Bar
PrEN2182	Forgings
PrEn 2183	Forgings
PrEN2184	Section for welded rings
PrEN2185	Sheet, strip and plate

DIN	NiCr22Fe18Mo
17744	Composition
17750	Plate, Sheet and Strip
17751	Pipe and Tube
17752	Rod and Bar
17753	Wire
17754	Forgings

ISO	
6207	Tube
6208	Plate, Sheet and Strip
9723	Bar
9724	Wire
9725	Forgings