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INCONEL® alloy 603XL

INCONEL® alloy 603XL (patent applied for) is a Ni-Cr alloy with the addition of silicon, molybdenum and rare earth elements. The outstanding characteristics of INCONEL alloy 603XL are its resistance to high temperature oxidation and nitridation. The alloy has high mechanical strength and is readily formed, machined and welded.

The unique combination of high temperature properties make the alloy suitable for many thermal processing applications such as furnace muffles, fixtures, radiant tubes, strand annealing tubes, furnace mesh belts and refractory anchors.

The excellent resistance to oxide spalling make INCONEL alloy 603XL an excellent choice for applications where oxide contamination can not be tolerated such as the electronics, glass and ceramics / tableware industries. Its excellent resistance to nitridation can provide a longer service life in high temperature nitrogen based atmospheres, such as in furnace mesh belts utilized in the powder metal sintering industry and other thermal processing applications.

Table 1 - Chemical Composition, wt %

Nickel	Balance*
Chromium	15-23
Molybdenum	4.0 max.
Titanium	0.5 max.
Aluminum	0.5 max.
Carbon	0.3 max.
Manganese	0.3 max.
Silicon	2.0 max.
Rare earths	0.1 max.

*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.

Product Forms

Contact Special Metals.

Physical Properties

Density, lb/in³	0.308
g/cm³	8.54
Melting Range, °F	2516-2552
°C	1380-1400
Electrical Resistivity, ohm circ mil/ft	698
ohm cm	116

Thermal Properties

Temper-ature	Specific Heat	Thermal Conductivity	Coefficient of Expansion
°F	Btu/lb-°F	BTU-in/ ft²-hr-°F	in./in./°F X10⁶
200	0.113	74.453	7.13
400	0.116	83.949	7.46
600	0.119	95.836	7.70
800	0.126	108.284	7.91
1000	0.135	123.010	8.17
1200	0.143	139.308	8.49
1400	0.148	155.214	8.86
1600	0.151	168.683	9.24
1800	0.154	178.752	9.59
2000	0.160	186.716	9.98
2100	0.163	197.294	–
2200	0.167	219.804	–
°C	J/kg-°C	W/m-°C	µm/m/°C
23	439	11	–
100	467	12	12.87
200	491	14	13.42
300	506	15	13.79
400	515	17	14.14
500	524	18	14.56
600	608	23	14.98
700	610	24	15.59
800	623	25	16.15
900	625	26	16.80
1000	655	28	17.37
1100	673	30	18.01
1200	699	33	–

Publication Number SMC-060

Mechanical Properties

Temperature, °F	Young's Modulus, 10^6 psi	Shear Modulus, 10^6 psi	Poisson's Ratio	Temperature, °C	Young's Modulus, GPa	Shear Modulus, GPa	Poisson's Ratio
72	31.8	11.9	0.33	22	218.6	81.9	0.33
200	31.3	11.7	0.33	100	215.3	80.7	0.33
400	30.5	11.4	0.34	200	210.2	78.7	0.34
600	29.5	11.0	0.34	300	204.4	76.3	0.34
800	28.5	10.5	0.36	400	198.2	73.7	0.34
1000	27.5	10.2	0.35	500	191.5	71.0	0.35
1200	26.1	9.6	0.36	600	184.4	68.1	0.35
1400	24.7	9.1	0.36	700	176.3	64.9	0.36
1600	23.2	8.5	0.36	800	166.8	61.4	0.36
1800	20.7	8.1	0.36	900	155.1	57.2	0.36
1900	18.9	–	–	1000	137.9	–	–
2000	17.1	–	–	1100	115.2	–	–

Tensile Properties

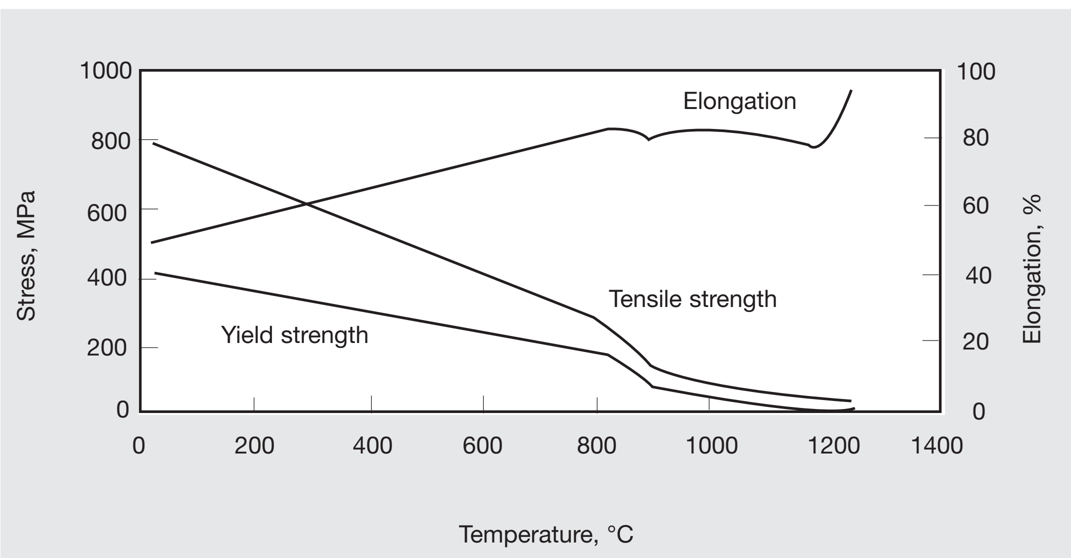


Figure 1. Tensile Properties.

High Temperature Corrosion

Oxidation Resistance

INCONEL alloy 603XL has excellent oxidation resistance to 1250°C (2282°F) with the alloying additions promoting excellent oxide scale adherence and reducing the rate of mass change in both static and cyclic conditions.

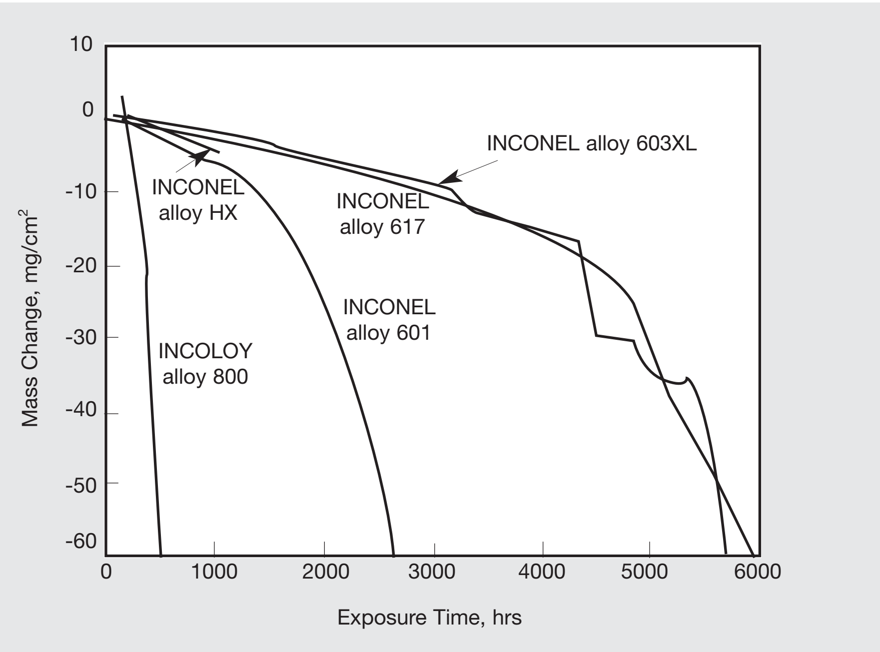


Figure 2. Mass Change After Exposure to Air + 5% Water Vapor at 1100°C.

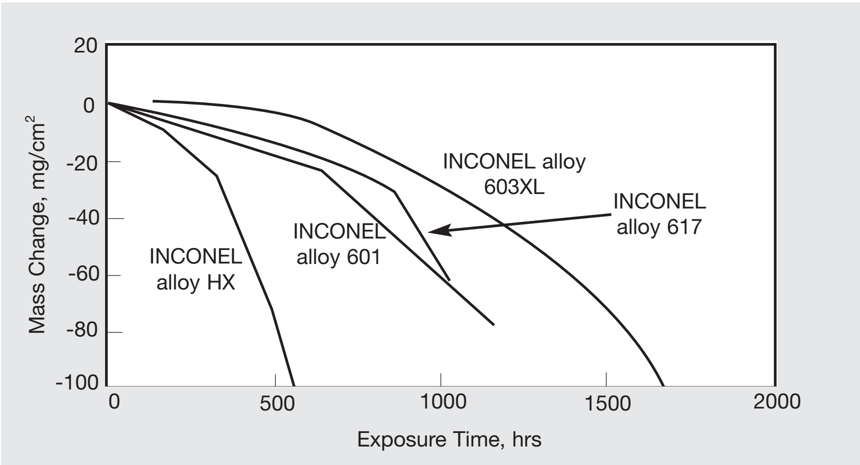


Figure 3. Mass Change After Exposure to Air + 5% Water Vapor at 1200°C.

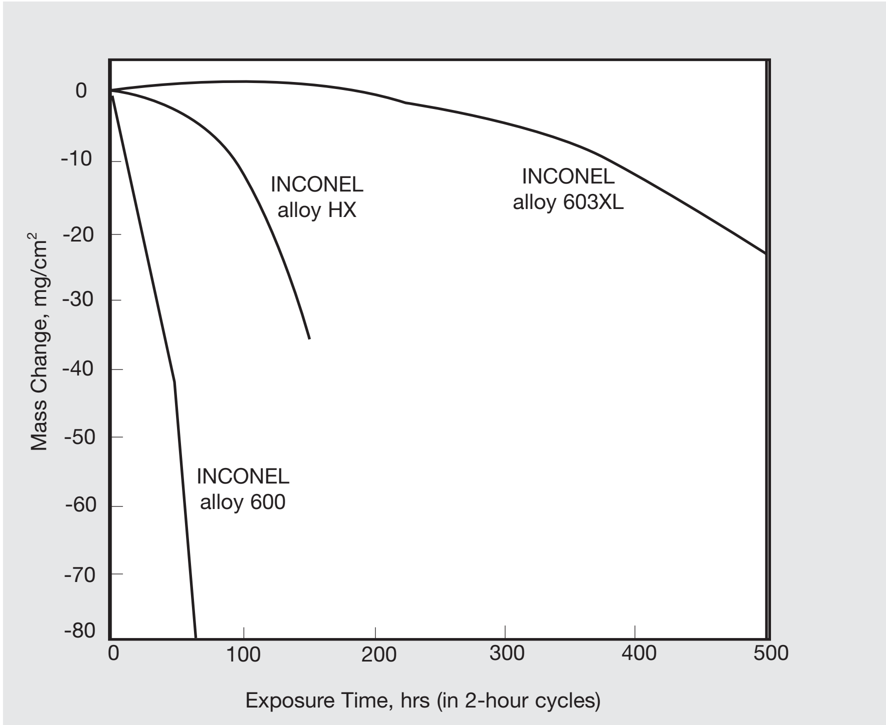


Figure 4. Mass Change After Cyclic Exposure in Oxygen at 1200°C.
(One cycle = 2 hrs at temperature + 10 mins cooling to ambient temperature.)

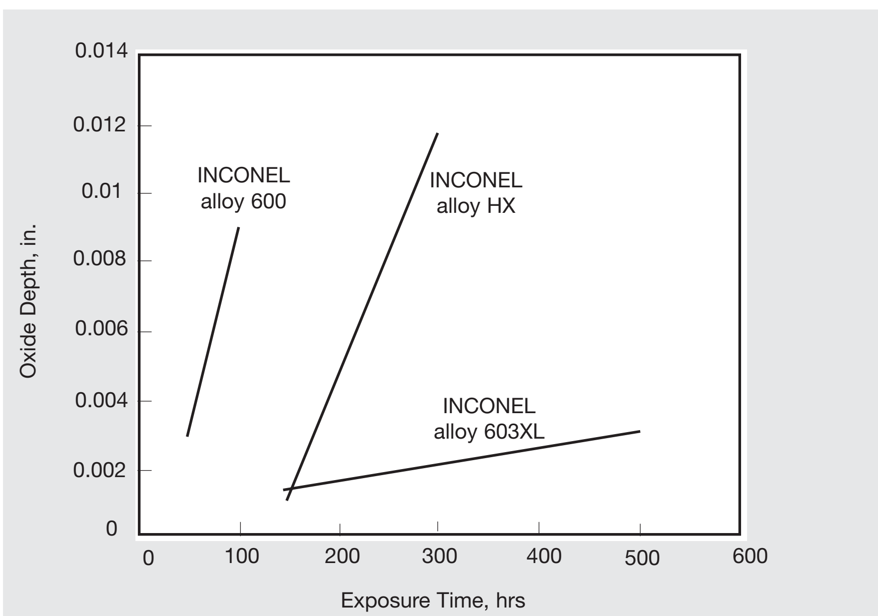


Figure 5. Depth of Oxidation After Cyclic Exposure in Oxygen at 1200°C.
(One cycle = 2 hrs at temperature + 10 mins cooling to ambient temperature.)

Nitridation Resistance

INCONEL alloy 603XL has excellent resistance to nitridation up to 1180°C (2150°F). Lacking the alloying elements such as Nb or Al that form internal nitrides INCONEL alloy 603XL exhibits freedom from microstructural degradation in nitrogen based atmospheres.

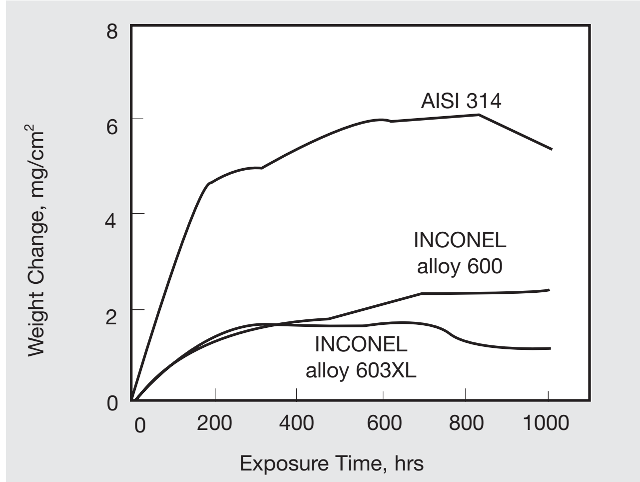


Figure 6. Nitridation Resistance at 1121°C.

Carburization Resistance

INCONEL alloy 603XL possesses admirable resistance to both oxidizing-carburizing and reducing-carburizing conditions, by virtue of its high nickel content and its scale-forming additions.

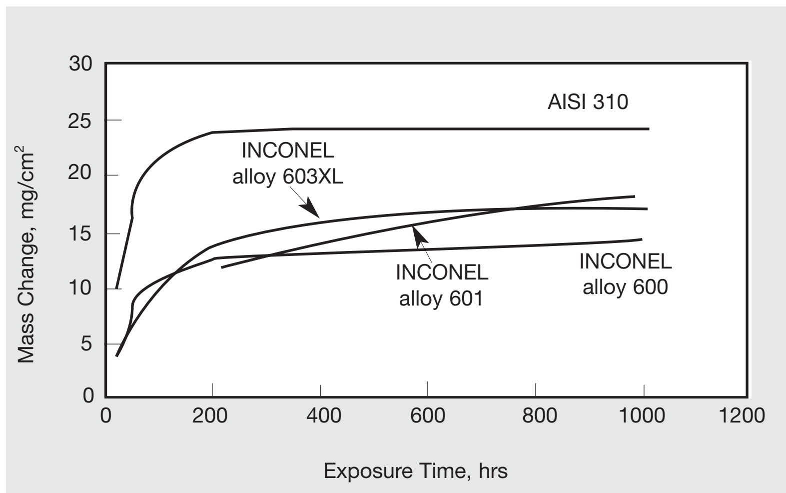


Figure 7. Mass Change After Exposure in H_2-1%CH_4 at 1000°C.

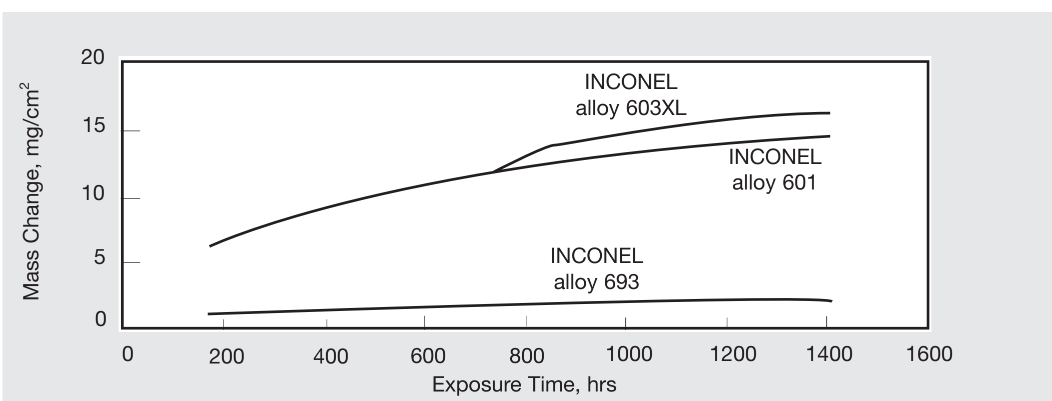
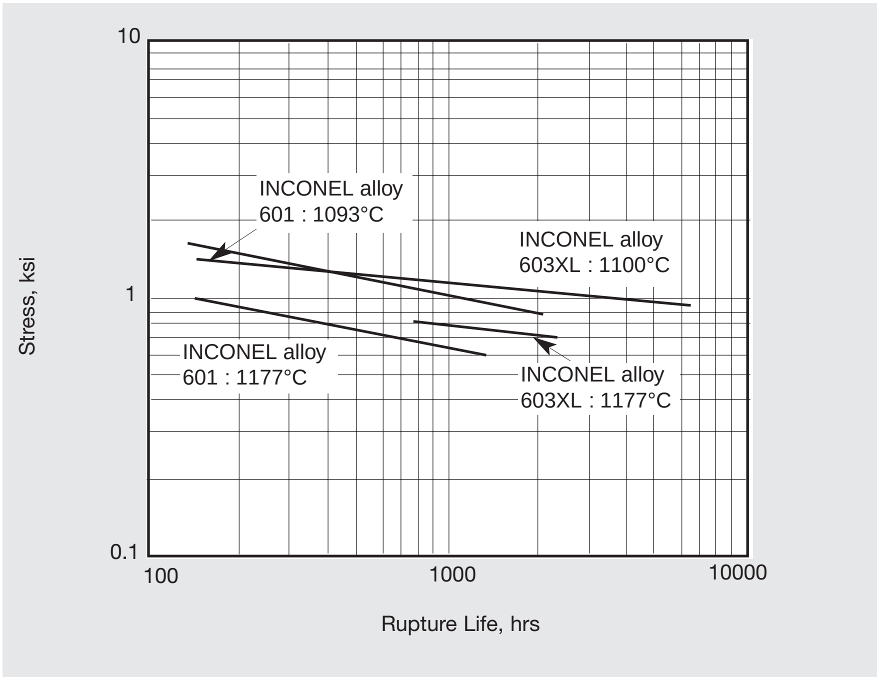
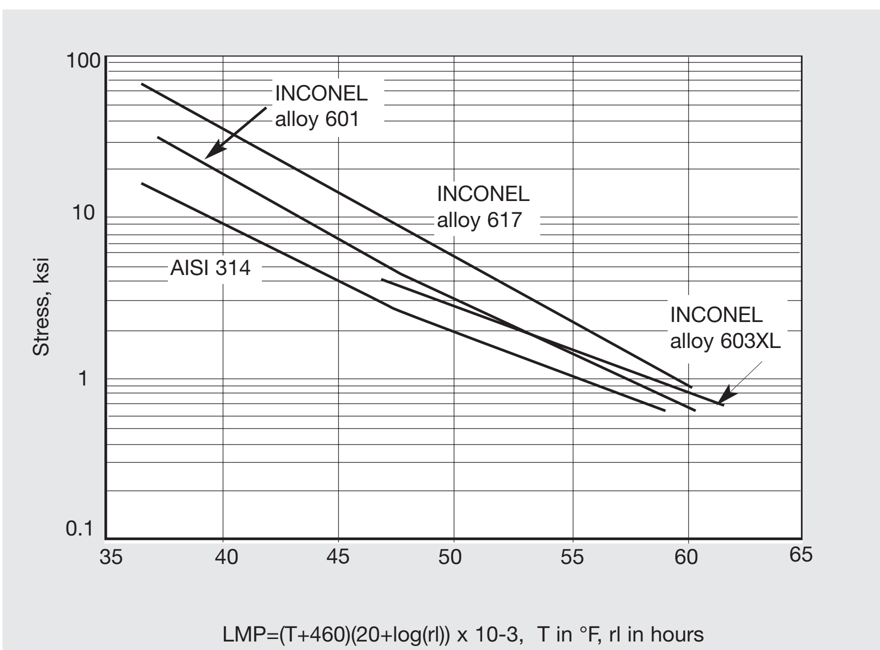


Figure 8. Mass Change After Exposure in H_2-5.5%CH_4-4.5%CO_2 at 1000°C.

Stress Rupture



Creep Rupture Life



Heat Treatment

INCONEL alloy 603XL is typically annealed between 1100 °C to 1175 °C followed by air cooling or equivalent.

Joining

INCONEL alloys are generally joined with the gas tungsten arc welding (GTAW) process; however, other methods are applicable, such as electron beam. Metallurgical factors and characteristics must be considered when selecting any joining process. When using the GTAW process with filler metal additions, the recommended shielding gases are argon or helium or a mixture of the two. Small quantities (<5 %) of hydrogen can be added (to argon) to increase welding penetration and speed for single pass welding. Material should be fabricated with low to moderate heat input levels. Interlayer/pass oxidation must be removed to reduce the potential of weld defects. Direct current, straight polarity is the common choice when GTA welding, however alternating current can be used to help reduce excessive oxidation. Successful weldments have been fabricated with INCONEL alloy 603XL using INCONEL Filler Metal 617.

Thin material is generally joined without filler metal (autogenous) using the Gas Tungsten Arc Welding (GTAW) or Plasma Arc Welding (PAW) processes. Additions of nitrogen (2-5%) to the argon shielding gas have produced acceptable welds in INCONEL alloy 603XL when using the GTAW process. High speed welding using the GTAW process, requires magnetic arc deflection to maintain the arc in proper relation to the torch. While thin gauges can be welded at high speeds, the weld grain structure will be coarse and not exhibit the highest ductility. For optimum ductility, travel speed must be slow enough to produce an elliptical weld puddle rather than the tear-drop shape which results from high speed welding (see figure, below). The solidification direction in elliptical puddles is constantly changing relative to grains, producing a competitive solidification and a resultant finer structure. This in turn will produce the highest as-welded ductility.

Additional guidelines for joining can be found in the Special Metals publication "Joining" on the website, www.specialmetals.com.

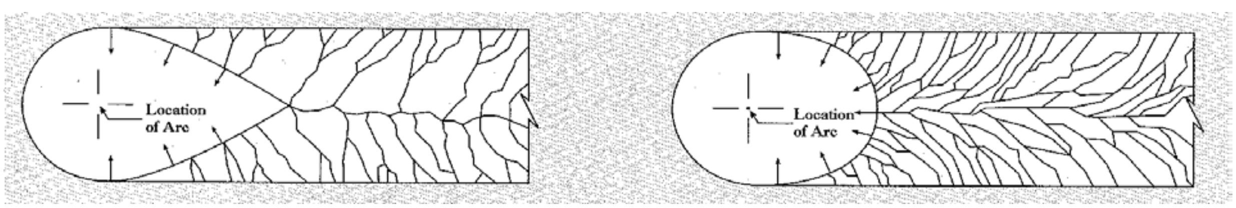


Figure 11 - Grain Structure as a function of welding speed. High welding speed is illustrated on the left.

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