

## Nickel-Chrome Inconel Alloy 600 (UNS N06600)



Nickel-Chrome Alloy Inconel 600 is employed in applications that need great high temperature corrosion resistance up to 2000oF. It offers good mechanical properties. It has high strength and suitable welding properties. It is a common material for use in aerospace and land based gas turbine engines, heat processing industries and chemical processing plants.

The versatile nature of Inconel 600 alloy has made it purposeful in the diverse operations that are conducted at the different temperature ranges from cryogenic temperature to 2000oF. It is implemented in the chemical applications that need high strength and resistance to corrosion features.

### Chemical Composition

Carbon (C)	0.05 %
Manganese (Mn)	0.25 %
Sulfur (S)	0.002 %
Silicon (Si)	0.20 %
Chromium (Cr)	15.5 %
Nickel + Cobalt (Ni + Co) Rem %	
Iron (Fe)	8 %
Copper (Cu)	0.10 %

### Physical Properties

Density	0.304 lb./cubic in. or 8.43 g/cubic cm at RT
<b>Electrical resistivity</b>	
At 70 of or 21 oC	40.6 $\mu\Omega$ -inch or 1.03 $\mu\Omega$ -m
At 200 of or 93 oC	40.9 $\mu\Omega$ -inch or 1.04 $\mu\Omega$ -m
At 400 of or 204 oC	41.5 $\mu\Omega$ -inch or 1.05 $\mu\Omega$ -m
At 600 of or 316 oC	42.2 $\mu\Omega$ -inch or 1.07 $\mu\Omega$ -m
At 800 of or 427 oC	43 $\mu\Omega$ -inch or 427 $\mu\Omega$ -m

Modulus of elasticity	30 x 10 (6) psi or 207 GPa at room temp.
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## Corrosion Resistance

The chemical constituents of Inconel 600 make it to resist the diverse corrosive conditions. In the presence of chromium it offers resistance to oxidation and due to high concentration of nickel it resists the reducing and alkaline conditions. The suitable nickel content offers tremendous resistance to varied organic and inorganic compounds and shows inert nature towards chloride ion stress corrosion cracking. The presence of chromium provides resistance to sulfur compounds and oxidizing conditions at the high temperatures. Alloy 600 offers excellent resistance to corrosion in the highly pure water and chloride ion stress corrosion cracking in the water equipments.



### Chlorine

The potential of alloy 600 to crack transgranularly in the chloride solutions decreases with an increase in concentration of nickel. Inconel 600 consists of 72% nickel that is highly adequate to resist the stress corrosion cracking in the chloride solutions.

### Sulfur

Inconel 600 provides excellent resistance to sulfur compounds at the intermediate temperatures though it is susceptible to sulfidation when subjected at the elevated temperature in the presence of sulfur. The molybdenum disulfide is a lubricant that is lemented to secure the group of components. It should not be utilized if the alloy is set into temperatures over 800oF.

### Nitrogen

Alloy 600 fits best for using in the nitriding containers as it offers large resistance to nitrogen at the elevated temperatures.

### Corrosion rate in sulfuric acid solutions

Acid wt %	temp		Time hours	Velocity		Corrosion rate			
	oF	oC		Ft/min	m/min	Non-aerated		aerated	
						Mpy	Mm/a	Mpy	Mm/a
0.2 %	212 oF	100 oC	-	-	-	3.7 Mpy	0.09 Mm/a	-	-
1 %	86 oF	30 oC	120	15.5	4.72	-	-	49 Mpy	1.24 Mm/a
1 %	172 oF	78 oC	22	15.5	4.72	-	-	110 Mpy	2.79 Mm/a
5 %	65 oF	18 oC	100	None	None	2.4 Mpy	0.06 Mm/a	-	-
5 %	86 oF	30 oC	20	15.5	4.72	9 Mpy	0.23 Mm/a	-	-
5 %	86 oF	30 oC	23	16	4.88	-	-	78 Mpy	1.98 Mm/a
5 %	140 oF	60 oC	100	None	None	10 Mpy	0.25 Mm/a	-	-
5 %	176 oF	80 oC	20	16	4.88	30 Mpy	0.76 Mm/a	150 Mpy	3.81 Mm/a
10 %	-	-	24	None	None	4.2 Mpy	0.11 Mm/a	-	-
70 %	86 oF	30 oC	20	15.5	4.72	46 Mpy	1.17 Mm/a	-	-
93 %	86 oF	30 oC	20	15.5	4.72	270 Mpy	6.86 Mm/a	10 Mpy	0.25 Mm/a

### Thermal Properties

Temperatures		Value	
oF	oC	Btu-ft / h-ft <sup>2</sup> - Degrees F	W/m - Degrees K
70 oF	21 oC	8.6	14.8
200 oF	93 oC	8.9	15.4
400 oF	204 oC	9.9	17.1
600 oF	316 oC	10.8	18.7
800 oF	427 oC	11.9	20.6
1000 oF	538 oC	13	22.5

### Linear Coefficient of Thermal Expansion

Temperature		Linear Coefficient of Thermal Expansion	
		10 <sup>-6</sup> / Degrees F	10 <sup>-6</sup> / Degrees F
70 oF to 200 oF	21 oC to 93 oC	6.9	12.4
70 oF to 400 oF	21 oC to 204 oC	7.3	13.1
70 oF to 600 oF	21 oC to 316 oC	7.6	13.7
70 oF to 800 oF	21 oC to 427 oC	7.9	14.2
70 oF to 1000 oF	21 oC to 538 oC	8.1	14.6
70 oF to 1200 oF	21 oC to 649 oC	8.4	15.1
70 oF to 1400 oF	21 oC to 760 oC	8.7	15.7

## Mechanical Properties

Inconel 600 is not easily precipitation hardenable however it can be hardened and reinforced by cold processing. It offers broad strength and hardness on the base of its production conditions. Inconel 600 alloy attains moderate yield strength about 25,000 to 50,000 ksi and it is combined with the elongation 55 to 35% offering fabrication with nominal issues. In the intense cold processing, it provides high tensile strength of 220,000 psi. Inconel 600 offers excellent impact strength even at the standard room temperature and retains its strength at the low temperatures. It doesn't show tough to brittle conversion with the decreasing temperature.

### Annealed Alloy 600 Mechanical Properties

Forms & conditions	Tensile strength		0.2 % Yield strength		Elongation % in 2 inch	Reduction of area %	Rockwell, hardness
Roll & Bar							
Cold drawn							
Annealed	80 ksi to 100 ksi	552 MPa to 689 MPa	25 ksi to 50 ksi	172 MPa to 345 MPa	55 ksi to 35 ksi	70 MPa to 60 MPa	65 to 85
As-drawn	105 ksi to 150 ksi	724 MPa to 1034 MPa	80 ksi to 125 ksi	552 MPa to 862 MPa	30 ksi to 10 ksi	60 MPa to 30 MPa	90B, 30C
Hot Rolled							
Annealed	80 ksi to 100 ksi	552 MPa to 689 MPa	30 ksi to 50 ksi	207 MPa to 345 MPa	55 ksi to 35 ksi	70 MPa to 60 MPa	65 to 85B
As-rolled	85 ksi to 120 ksi	586 MPa to 827 MPa	35 ksi to 90 ksi	241 MPa to 621 MPa	50 ksi to 30 ksi	65 MPa to 50 MPa	75 to 95 B
Hot finished	80 ksi to 120 ksi	586 MPa to 827 MPa	35 ksi to 90 ksi	241 MPa to 621 MPa	50 ksi to 30 ksi	65 MPa to 50 MPa	75 to 95B
Strip							
Annealed	80 ksi to 100 ksi	552 MPa to 689 MPa	30 ksi to 45 ksi	207 MPa to 310 MPa	55 ksi to 35 ksi		84B

### High temperature Tensile Properties

Temperature		Tensile strength		Yield Strength		Elongation in 2 inch
oF	oC	Ksi	MPa	Ksi	Mpa	%
600 oF	316 oC	90.5 Ksi	624 MPa	31 Ksi	214 MPa	46 %
800 oF	427 oC	88.5 Ksi	610 MPa	29.5 Ksi	203 MPa	49 %
1000 oF	538 oC	84 Ksi	579 MPa	28.5 Ksi	196 MPa	47 %
1200 oF	649 oC	65 Ksi	448 MPa	26.5 Ksi	183 MPa	39 %
1400 oF	760 oC	27.5 Ksi	190 MPa	17 Ksi	117 MPa	46 %
1600 oF	871 oC	15 Ksi	103 MPa	9 Ksi	52 MPa	80 %
1800 oF	982 oC	7.5 Ksi	52 MPa	4 Ksi	28 MPa	118 %

### Inconel 600 Stress Cracking Properties

Temperature		Stress required to cause cracking					
oF	oC	10 hours		100 hours		1000 hours	
		Ksi	MPa	Ksi	MPa	Ksi	MPa
Cold Drawn, Annealed for three Hours up to 1750°F or 954°C then Air quenched							
1000 oF	538 oC	74 Ksi	510 MPa	50 Ksi	345 MPa	34 Ksi	234 MPa
1200 oF	649 oC	34 Ksi	234 MPa	23 Ksi	159 MPa	14.5 Ksi	100 MPa
1400 oF	760 oC	13 Ksi	90 MPa	8.4 Ksi	58 MPa	5.6 Ksi	39 MPa
1600 oF	871 oC	7.5 Ksi	52 MPa	4.8 Ksi	33 MPa	3 Ksi	21 MPa
1800 oF	982 oC	4.4 Ksi	30 MPa	2.8 Ksi	19 MPa	1.8 Ksi	12 MPa
2000 oF	1093 oC	2.1 Ksi	14 MPa	2.4 Ksi	17 MPa	-	-
Hot rolled, annealed for two hours up to 1650oF or 899oC							
1350 oF	732 oC	20 Ksi	138 MPa	13.5 Ksi	93 MPa	9.2 Ksi	63 MPa
1600 oF	871 oC	8.1 Ksi	56 MPa	5.3 Ksi	37 MPa	-	-
1800 oF	982 oC	4.4 Ksi	30 MPa	2.8 Ksi	19 MPa	1.8 Ksi	12 MPa
2000 oF	1093 oC	2.1 Ksi	14 MPa	1.4 Ksi	10 MPa	-	-
Solution annealed for 20 hours up to 2050oF or 1121oC then air quenched							
1350 oF	732 oC	19 Ksi	131 MPa	14 Ksi	97 MPa	9.8 Ksi	68 MPa
1500 oF	816 oC	11.5 Ksi	79 MPa	8 Ksi	55 MPa	5.6 Ksi	39 MPa
1600 oF	871 oC	8 Ksi	55 MPa	5.3 Ksi	37 MPa	-	-
1800 oF	982 oC	4.4 Ksi	30 MPa	2.8 Ksi	19 MPa	1.8 Ksi	12 MPa
2000 oF	1093 oC	2.1 Ksi	14 MPa	1.4 Ksi	10 MPa	-	-

### Inconel 600 Standard High temperature tensile characteristics

Temperatures		Tensile strength		0.2 % yield strength		% elongation in 2 inch
oF	oC	Ksi	MPa	Ksi	MPa	
600 oF	316 oC	90.5 Ksi	624 MPa	31 Ksi	214 MPa	46 %
800 oF	427 oC	88.5 Ksi	610 MPa	29.5 Ksi	203 MPa	49 %
1000 oF	538 oC	84 Ksi	579 MPa	28.5 Ksi	196 MPa	47 %
1200 oF	649 oC	65 Ksi	448 MPa	26.5 Ksi	183 MPa	39 %
1400 oF	760 oC	27.5 Ksi	190 MPa	17 Ksi	117 MPa	46 %
1600 oF	871 oC	15 Ksi	103 MPa	9 Ksi	62 MPa	80 %
1800 oF	982 oC	7.5 Ksi	52 MPa	4 Ksi	28 MPa	118 %

### Creep and Stress rupture properties

Temperature		Alloy	Stress to produce rupture					
oF	oC		10 hours		100 hours		1000 hours	
			Psi	MPa	Psi	MPa	Psi	MPa
1000 of	540 oC	SS 304	-	-	43,000 Psi	297 MPa	34,000 Psi	234 MPa
1000 of	540 oC	In 600	74,000 Psi	510 MPa	50,000 Psi	345 MPa	34,000 Psi	234 MPa
1000 of	540 oC	In A286	100,000 Psi	690 MPa	95,000 Psi	655 MPa	88,000 Psi	607 MPa
1200 of	650 oC	SS 304	-	-	23000 Psi	159 MPa	16,000 Psi	110 MPa
1200 of	650 oC	In 600	34,000 Psi	234 MPa	23000 Psi	159 MPa	14,500 Psi	100 MPa
1200 of	650 oC	In A286	40,000 Psi	276 MPa	32000 Psi	221 MPa	21,000 Psi	145 MPa
1350 of	730 oC	In 600	20,000 Psi	138 MPa	13500 Psi	93 MPa	9,200 Psi	63 MPa

1350 of	730 oC	In A286	49,000 Psi	338 MPa	35000 Psi	261 MPa	21,000 Psi	145 MPa
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Above data shows that Inconel 600 has moderate load carrying ability in the given temperature limits.

## Fabrication

Before heating, **Inconel 600 alloy** is cleaned properly and heating is recommended in absence of sulfur. The furnace environment for alloy formation or open annealing should be slowly reduced to avoid the extensive oxidation of material. The rate of alloy's quenching has the minor effect on its mechanical properties. When it is set into carbide precipitation at temperature limits of 1000oF to 1400oF, it should be cooled quickly if it is required to be pickled or employed in the environments that need not to be sensitized. Inconel 600 can be glowing heated in the dry hydrogen or vacuum and often pickled to receive the shiny alloy surface. The hot processing temperature limits of **Inconel 600** are 1600oF to 2250oF or 870oC to 1230oC. The heavy hot processing of alloy is recommended to perform at temperature ranges of 1900oF to 2250oF or 1040oC to 1230oC.

### Machining

Inconel 600 machining property is more than the stainless steel 304, however lesser than stainless steel 303. This Inconel alloy is best serviced on the heavy duty device that is used for cutting equipments that are big and heavy to maintain the loads and immediately remove the heat produced. The equipments used should be sharp and possesses complete dimensions.

### Welding

Inconel 600 is easily weldable. It shows superior welding character as compare to the high steel alloys. The precautions should be followed while welding because of tendency of hot fracturing of welds and fractures of cater pipe.

Alloy 600 is readily joined by following the traditional welding methods. The welding materials used for connecting Inconel 600 alloy are INCONEL Welding Electrode 182 that is efficient in providing the shielded metal arc welding. The INCONEL Filler Metal 82 is used for gas tungsten arc and gaseous metal arc welding. The INCONEL Filler Metal 82 and INCOFLUX 4 Submerged Arc Flux are used for the submerged arc method.

## Applications

### Thermocouple Insulation:-



The thermocouples are double insulated with the abrasion resistant Inconel 600 alloy that offers elevated temperature fiber insulation. It offers secured performance up

to 1090°C or 2000°F that makes a thermocouple the best material for using in the diverse applications that are conducted at the elevated temperatures. The thermocouples insulated by Inconel 600 are unsurpassed for profiling ovens and incinerators.

### Jet Engines:-

The high temperature and corrosion resistant Inconel 600 can be machined at temperature ranges more than 1000°F. It is incomparable in terms of its creeping resistance, oxidation resistance and corrosion resistance at the elevated temperatures.

Due to these properties, alloy 600 is commonly used in the production of jet engine parts. In the present time, fuel efficiency and competent drive are the essential factors that are considered while aircraft engine design. The engineers for long, trust on the superalloy Inconel for its excellent high temperature and stress corrosion features.

### Aerospace Industry



The main engine of space shuttle consists of 65% Inconel alloy in its structure. Inconel 600 alloy has broad use in the rocket engines due to its significant properties of excellent corrosion resistance, high temperature performance and sustenance of its properties over the wide range of temperatures.

### Incinerators



Due to the production of chromic, nitrous acid, iron and copper compounds, nitrites, chromates and urea in an Incinerator, its internal surfaces are intensely oxidized. To avoid this corrosion, Inconel 600 alloy is used that offers adequate resistance to oxidation and erosion. The content of iron creates an external oxidizing layer on the incinerator's surface. It doesn't allow oxidation more than

6% and provides extensive resistance to corrosion.

The flexibility of Inconel alloy 600 has made it usable in the different operations at the cryogenic temperatures of 2000°F or 1095°C. The alloy is utilized in the chemical operations for its high potential and resistance to corrosion. Inconel 600's operations include the heaters, bubble towers and condensers for treatment of fatty acids, tube sheets and abietic acid treatment systems. The robustness of Inconel 600 is also used in the retorts, muffles, roller hearths and furnaces and heat processing baskets.

## **Available Forms**

Wire, Mesh, Rod, Bar, Tube, Pipe, Strip, Foil, Plate Sheet, Flanges