Incoloy 800 Alloy

The **Incoloy 800 alloy** is produced by the special constitution of chemical elements that provides superior chemical properties such as excellent temperature strength and resistance to oxidation and various other chemical environments like carburization. The alloy offers high resistance to corrosion with an increase in temperature.

The new elements of **Incoloy** series are the refined elements that have established the industrial standards in the high temperature operations that require the appropriate creeping and rupturing characteristics. The Incoloy 800 is a nickel, iron and chromium alloy with the supreme resistance to corrosion. The resistance to heat and corrosion even with the limited nickel concentration makes this alloy a strategic product.

The **Incoloy 800 alloy** has been used in the extensive series of operations due to its vital resistance to oxidation, carburization and other corrosions that are introduced in the elevated temperature conditions. The operations series consists of furnace operations and manufacturing equipments, petrochemical furnace cracker vessels, pigtails and headers, and shielding for electrical heating elements.

ASTM Specification for Incoloy 800 Series

Alloy	Pipe Smls	Pipe Welded	Tube Smls	Tube Welded	Sheet/Plate	Bar	Forging	Fitting
Incoloy 800	B407	B154	B163	B515	B409	B408	B564	B366
Incoloy 800H	B407	B154	B163	B515	B409	B408	B564	B366
Incoloy 800HT	B407	B154	B163	B515	B409	B408	B564	B366

Background of Incoloy 800

The **Incoloy 800 alloy** was granted by the ASME Boiler and Pressure Vessel group in 1963 and its stress layout code case 1325 was published. Then the aluminum and titanium were introduced as the significant constituents and the annealed metal was isolated from the solution annealed metal. The Grade 1 is annealed at temperature of 1800oF or 980oC whereas the grade 2 annealing is performed at 2100oF or 1150oC. The code case had included first to eight sections and the design stresses for first grade to 1100oF or (593oC) and for second grade to 1500oF (816oC).

In the next time, the group made several amendments and in 1965, extruded vessel was considered as second grade alloy without the heat processing. In the subsequent year, the ASTM specifications had been granted for considering as Incoloy 800 and used to replace the inconel 600 alloy. Later in 1967, an exclusive pressure tube plan for first grade alloy was included and the next year the same plan was followed for second grade. Further in 1969, the design stresses were improved to bring moderations in the method to conclude the stress. The least tensile force curve was increased by ten percent and the cracking level was increased by 62.5 to 67% of the extrapolated 100,000 hours break strength.

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After 6 months, the case was altered from considering the first to eight sections and section first was considered only because the layout stress for eighth section was added in the UNF-23 list. The double sets of design stresses were included for each level that provides the values when the 2/3rd yield value of level was utilized and the second set used when 90% of yield value was utilized.

The manufacturers of incoloy 800 came in the alloy market had used different content of elements providing different values of creep and rupture. Some have introduced alloy with comparatively lower strength. The standard property values are determined at the temperatures of 1500oF (593-816oC), and 1650oF (871 and 899oC). The concentration of aluminum and titanium ensure the higher creep and stress rupture characteristics as compare to incoloy 800H and the new alloy with enhanced concentration of aluminum and titanium is called as **incoloy 800HT**. It is heat processed at 2100oF or 1149oC. The concentration of carbon is 0.06 to 0.10% in incoloy 800HT whereas it is 0.05 to 0.10% in incoloy 800H. The content of aluminum and titanium is 0.85 to 1.20% however in incoloy 800H, it is 0.30 to 1.20%.

The highest permitted stress of incoloy 800HT is included in ASME code case 1987. It meets the entire criteria for UNS N08811 and N08810 that are made for incoloy 800H and it can be authenticated to both or single UNS codes. It is essential to note that **incoloy 800HT alloy** offers more permit-able design stress as compare to UNS N08810. That's why the other materials that are manufactured to UNS N08810 refer to incoloy 800H cannot be authenticated for UNS N08811 code without meeting the criteria for this grade. The incoloy 800HT is a product of extended analysis and maintenance of the ultimate features of incoloy series alloys.

Chemical Composition of Incoloy 800

The carbon content present in the **incoloy 800 alloy** is proportion to creep and cracking properties of alloy such that more carbon content, more are the creep and cracking properties. Therefore carbon is added significantly in the alloy on the base of special application requirements. The carbon is added by 0.05% to 0.10% in the ASTM and ASME limits.

Chemical composition of incoloy series alloys

Element	Incoloy 800	Incoloy 800H	Incoloy 800HT
Ni	30.0-35.0	30.0-35.0	30.0-35.0
Cr	19.0-23.0	19.0-23.0	19.0-23.0
Fe	39.5 min.	39.5 min	39.5 min
C	0.10 max	0.05-0.10	0.06-0.10
Al	0.15-0.60	0.15-0.60	0.25-0.60
Ti	0.15-0.60	0.15-0.60	0.25-0.60
Al+Ti	0.30-1.20	0.30-1.20	0.85-1.20
ASTM grain size	Not mentioned	5 or coarser	5 or coarser

The special element requirements of incoloy 800H are mentioned in the below table:

C	0.08 max.
Al + Ti	0.4-0.7
ASTM grain size	Unique

The Incoloy 800H and 800HT offer extremely high creep and cracking strength properties as compare to incoloy 800. These alloys possess almost similar chemical composition such that the content % of the basic elements like nickel, chromium and iron is same. But, the composition varies in terms of concentration of carbon, titanium and aluminum. The concentration of carbon in incoloy 800 is 0.10%.

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The chemical composition of incoloy 800HT is more limited as compare to 800H. The concentration of carbon in incoloy 800HT is 0.06 – 0.10% and aluminum + titanium concentration is 0.85 – 1.20%. The concentration of elements in the incoloy 800HT always lie within the limits of alloy 800H. However the concentration limits of **incoloy 800H alloy** may or may not reside within the limits of 800HT alloy.

Besides of the limited concentration of carbon, both 800H and 800Ht alloys are annealed at the high temperatures to obtain the suitable grain size of level ASTM five. The annealing and limited chemical content% offer the incoloy alloys superior creep and rupture forces. On the base of certain operations the grain size requirements of **Incoloy 800H/800HT alloy** vary significantly such as in certain application the concentration of aluminum and titanium in incoloy 800H is restricted to 0.4 – 0.7% for medium processing temperatures of 1000oF to 1400oF or 540oC to 760oC.

The mechanical features of incoloy 800/800HT are paired with their resistance to corrosion properties at the elevated temperatures that makes the incoloy alloys very purposeful for using in the different high temperature and long term oriented operations. These alloys are also significantly used in the variety of corrosive media. The chemical composition limits of incoloy 800H and 800HT reside within the limits of INCOLOY alloy 800.

The special grain size criteria of incoloy alloys provided following:

	INCOLOY alloy 800H & 800HT
Plate	ASTM 1-5
Tube/Pipe	ASTM 1-5
Sheet	ASTM 2-5

Physical properties of Incoloy 800H/800HT alloy

Density g/cm3	7.94
Melting Range	2475-2525oF or 1357-1385oC
Specific Heat	460 J/kg•°C
Permeability at 70°F (21°C), Annealed	1.014
Curie Temperature	-175oF or -115oC

The modulli of elasticity of **Incoloy 800H/800HT alloy** are given below:

Temperature oF	Tensile Modulus, 10(3)ksi	Shear Modulus,10(3)ksi	Poisson's Ratio
-310	30.55	11.45	0.334
75	28.50	10.64	0.339
200	27.82	10.37	0.341
400	26.81	9.91	0.353
600	25.71	9.47	0.357

The electric and thermal properties of **Incoloy 800H/800 alloy** are given below:

Temperature oF	Electrical Resistivity ohm•circ mil/ft	Thermal Conductivity Btu•in/ft(2) in/in/°F	Coef. Of Expansion 10(-6) in/in/°F
70	595	80	-
100	600	83	-
200	620	89	7.9
400	657	103	8.8
600	682	115	9.0

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Corrosion Resistance Properties of Incoloy 800

The Incoloy 800 alloy offers excellent resistance to the chloride ion stress corrosion cracking and embrittlement in precipitation sigma phase. The alloy offers superior resistance to corrosion in the different media. In the solution annealed form, it offers high creep stress rupturing features. It can be sensitized to intergranular corrosion in the rigorous conditions.

In an analysis, alloy 800 is subjected to boiling nitric acid of 65% concentration for 5 hours that determines alloy's inclination to sensitization. When Incoloy 800 is set to heat from welding or other processes, precautions should be made to prevent sensitization when it needs to be pickled or kept in the various severe conditions. The sensitization of alloy is not an issue in the various elevated temperature operations.

Mechanical Properties of Incoloy 800

The Incoloy alloy 800 comprises of large mechanical strength over high temperatures. It is suitable for using up to 1500oF. The vital difference between incoloy alloy series depends on the difference of their mechanical properties. The difference in the mechanical properties is due to difference in their chemical composition and the different temperature annealing. Generally the **Incoloy 800 alloy** possesses higher mechanical properties at the room temperatures and minimum to high temperature exposures. On the other side the incoloy 800H and 800HT alloy offer high creep and stress rupture strength at the higher temperature exposures.

Tensile Properties of Incoloy 800 alloy

The Incoloy 800 alloy offers high tensile features at the room and high temperatures. The tensile characteristics at room temperature and 1200oF to 1800oF of extruded pipe and tubing are described as following:

Temperature		Tensile Strength		Yield Strength		Elongation	Reduced Area
oF	oC	Ksi	Mpa	Ksi	Mpa	%	%
85	30	76.0	524	26.6	183	60	-
1200	650	52.5	362	18	124	47	59
1400	760	30.3	209	15.7	108	85	73
1500	815	23.6	163	17.3	119	98	79.5
1600	870	16.0	110	13.5	93	109.5	92.5
1700	925	11.8	81	9.2	63	111.5	93

The cold processing improves the tensile characteristics of Incoloy alloy. The characteristics of cold drawn rod are shown in the following table:

Temperature		Tensile Strength		Yield Strength		Elongation	Reduced Area
oF	oC	Ksi	Mpa	Ksi	Mpa	%	%
85	30	111.8	771	100	690	17	64
200	95	107.5	741	95	655	16	63.3
400	205	102.5	707	94.2	650	13	58.8
600	315	99.5	686	93	641	12	56.6
700	370	96.3	664	91.5	631	15	53.2
900	480	96.3	664	90	621	15	52.5

The elevated temperature toughness and tensile features of annealed and hot treated alloy are described as following:

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Condition	Temperature		Hardness	Tensile Strength		Yield Strength	
	oF	oC	BHN	Ksi	MPa	Ksi	MPa
Annealed	80	25	138	85.5	590	36.2	250
	800	425	120	74.1	511	24.9	172
	1000	540	119	73.7	508	25.8	178
	1200	650	110	58.7	405	25.5	176
Hot Treated	80	25	198	96.4	665	64.6	445
	800	425	170	84.5	583	52.0	359
	1000	540	161	84.0	579	52.4	361
	1200	650	145	65.3	450	48.3	333

Impact Strength

The Incoloy 800 alloy attains high impact strength at the room to cryogenic temperatures. The following table describes the impact strength of annealed alloy subsequent to its exposure in to 1400oF temperatures for 1500 hours.

Exposure Time	Charpy V-Notch Impact Strength	
hours	ft•lbf	J
0	106, 107, 108	144, 145, 146
500	96, 99, 100	130, 134, 136
1000	99, 99, 101	134, 134, 137
1500	96, 99, 100	130, 134, 136

Compressive Characteristics

The compressive yield strength of Incoloy 800 alloy is similar to the tensile yield strength. The following table shows the compressive and tensile features of Incoloy 800 alloy:

Condition	Compression				Tension					
	Yield Strength		Yield Strength		Yield Strength		Yield Strength		Tensile strength	
	Ksi	Mpa	Ksi	Mpa	Ksi	Mpa	Ksi	Mpa	Ksi	Mpa
Hot-Rolled Annealed	39	269	41.6	287	38.8	268	41.1	283	89.3	616
As-Extruded	21	145	25.4	175	21.0	145	27.5	190	69.5	479

Fatigue Strength of Incoloy 800

The **Incoloy 800H/800HT alloy** are made to explore their high temperature tendencies. The concentration of carbon in incoloy alloys provides the elevated temperature strength and resistance to creep and cracking. The alloys are annealed to the last stage of formation to get the carbon in the condition of high temperature features.

The fatigue strength of annealed and cold treated Incoloy 800 alloy at 1600oF is shown in the following table:

Material Condition	Tensile Strength,ksi	10-4 Cycles, ksi	10-5 Cycles, ksi	10-6 Cycles, ksi	10-7 cycles, ksi	10-8 cycles, ksi
Hot-Rolled	92	57	54	53	52	51
Hot-Rolled Annealed	82	47	43	38	35	31
Cold-Drawn	114	-	65	49	37	33
Cold-Drawn Annealed	82	48	43	39	36	52

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Creep Rupturing Properties

The creep and rupture strength of incoloy 800 are their superior features. The limited composition and solution annealing processing are made to produce the appropriate creep rupture characteristics. The alloy 800 is not preferred in the operations that need adequate creep rupturing features. In such cases Incoloy 800H and 800HT is used.

ASME Boiler and Pressure Vessel Code

The incoloy 800H is accepted under the boiler and pressure tube code of the American Society of Mechanical Engineers (ASME). The norms of building the power boilers are mentioned in the first section and for constructing the pressure vessels, instructions are mentioned in the eighth section. The first section building is allowed for processing up to 1500oF or 816oC. The eighth section building is also explained by the code case 1983 and is permitted for processing up to 1800oF or 982oC.

Microstructure of Incoloy 800 alloy

The design stress information for alloy 800H in eighth section, basically 304 stainless steel incoloy 800H and 800HT are of austenitic solid solution forms. The titanium nitride, titanium carbide and chromium carbide are basically available in the microstructure form of alloys. The nitrides are constant at all temperatures lower than the melting point and unaltered by the heat processing.

The chromium carbides are precipitated into alloys at the temperature ranges of 1000oF and 2000oF or 540oC to 1095oC. Thereby the alloy 800H and 800HT are equivalent to other austenitic alloys and these might be prone to the intergranular corrosion in the rigorous conditions by exposure in temperature limits from 1000oF to 1400oF or 540oC to 760oC.The annealed alloy also provides improved grain size that more enhances the potential and resistance to creep and rupture at the elevated temperature conditions.

Working Guidelines

Different machined forms of incoloy 800 are forged into the end products and equipments by following the ordinary methods. The alloy 800 is readily forged by hot or cold processing and it has superior welding and machining character.

Heating and Pickling of Incoloy 800 alloy

The heating specimen should be clean that whole oil, grease, dust and other unwanted materials should be removed before beginning the heating process. The heating is preferred in the nominal sulfur conditions. The open heating in the nominal sulfur content and furnace conditions should be done in the reducing medium to avoid the extensive oxidation. Due to eagerness of chromium to get oxidized in a refractory oxide or water, it is tough to bright anneal the incoloy 800 in the common commercial annealing furnace. In the limited conditions, the incoloy alloy can be bright annealed in arid, pure hydrogen atmosphere.

The incoloy 800 is annealed in the muffle furnaces by utilizing reducing media. The contended atmosphere is produced by products of combustion from minor sulfur natural gas burnt with minimum air. It creates thin, long standing and green black oxide layer on alloy. The oxidizing media create heavy oxide scale that is tough to clean. Such type of cleaning needs grinding to some extent. The certain annealing processes are based on the quantity of cold processing of specimen.

The mechanical features of severely cold processed alloy are nominally influenced at temperatures lower than 1000oF. The stress release starts from 1000oF and fulfills after 1.5 hours at 1600oF. The softening of alloy is done by annealing up to 1400oF and is completed after 10 – 15 minutes heating up to 1800oF.

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The suitable grain growth starts at 1800oF. The suitable annealing can be done by heating Incoloy 800 up to 1900oF for 2-5 minutes. The annealing temperature influences the grain size and room temperature mechanical characteristics of alloy 800. The alloy material is held at temperature for 15 minutes and air quenching is done prior to analysis. The oxide layer and scale produced are cleaned through pickling process. As the incoloy 800 resists the chemical corrosion therefore specific pickling methods are followed.

Hot and cold Fabrication of Incoloy 800

The hot fabrication of Incoloy 800 is performed at temperatures from 1600oF to 2200oF. The heavy forging is performed at 1850oF to 2200oF. The forging done at 1200oF to 1600oF may cause cracking in the material. The quenching rate followed after hot forging is not significant in correspondence to thermal cracking.

The Incoloy 800 alloy is subjected to carbide precipitation at 1000oF to 1400oF and it should be quenched quickly while preventing sensitization. The cold processing is performed by following processes that are followed for processing of Inconel 600 and stainless steel alloys. The work toughening rate of Incoloy 800 is more than the mild steel rate however it is lesser than steel 304. The work toughening rate of alloy 800 is almost similar with the Inconel 600.

Machining of Incoloy 800

The Incoloy 800 is readily machined by following the standard processes. The turning can be done by large metal eradication rates, high apparatus service life and excellent surface finish and by utilizing coated carbide equipments. The coated carbide equipments provide enhanced service life at seizing rate of 110-190 sfpm and 0.20 to 0.89 mm per rev. The large speed steel equipments provide extended life at the cutting speed of 35-95 sfpm and input rate of 0.008 to 0.035 ipr.

Welding Features of Incoloy 800 alloy The Incoloy 800 offers excellent welding character. It can be welded by whole welding methods.

The alloy that needs to be welded should be cleaned and accurate joined layouts should be utilized. The Inco Weld A electrode is a preferred welding product that is used in the shielded metal arc welding. The Inconel filer metal 82 is used in gas tungsten arc welding method. The incoflux 4 submerged arc flux is utilized in the submerged arc method. These materials are utilized for unlike welding needs for Incoloy 800.

The stress rupturing features of weldmetals are described in the following table:

Welding Product	Temperature		Stressa for Rupture in		
	oF	oC	100 hours, ksi	1000 hours, ksi	10,000 hours, ksi
INCO-WELD A Electrode	1000	540	60.0	51.0	39
	1200	650	35.0	24.5	16.0
	1400	760	16.5	11.0	7.1
	1600	870	7.0	3.65	1.9
	1800	980	2.3	0.9	-
INCONEL Filler Metal 82	1000	540	58.0	52.0	47.0
	1200	650	36	27.5	20.5
	1400	760	16	11.5	8.3
	1600	870	6.8	3.5	1.75
	1800	980	2.7	1.25	0.57

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Applications of Incoloy 800 alloy

In the hydrocarbon treatment operations the Incoloy alloys are significantly used in the steam and hydrocarbon filtration for catalyst tubing, convection vessels, pigtails, opening manifolds and cooling-system piping; in ethylene preparation for both convection and cracking vessels, and pigtails; in oxy-alcohol preparation for tubing in hydrogenation heaters; in hydrodealkylation systems for heater vessels; and in the preparation of vinyl chloride monomer for cracking tubes, return curves and inlet and outlet flanges.

The **Incoloy 800 alloy** is also widely used in the industrial heating systems. In the different kinds of heating furnaces, these alloys are utilized in the radiant tubes, muffles, retorts, and assorted furnace fixtures. Moreover power production plants use these alloys in the steam superheating tubing and elevated temperature heat exchangers in gas-quenched nuclear reactors.

Product Forms

The **Incoloy 800 alloy** is offered in the various forms. The specification of the different forms is provided as following:

Wire	0.05mm to 15.0mm
Wire Mesh Screen	Mesh size:0.2 mesh/inch, thickness: 0.1 mm to 5.0mm, aperture rate: 10%-90%
Sheet and Plate	Thickness: above 1mm, width: 100mm-1700mm, length: 800mm-3000mm
Tape/Ribbon	Thickness: 0.05mm above, Width: 2mm above
Pipe and Tubing	Thickness-1-20mm, Out diameter:16-219mm
Strip	Thickness – 0.05mm above, Width- 2mm above
Rod and Bar	Diameter: 3mm above, length: 20mm above

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