ALLOY 800H / 800HT

The story of the alloy series, from 800, through 800H, 800HT

The Alloy 800 series is the result of years of monitoring and maintaining the ultimate chemical properties for high-temperature strength and resistance to oxidation, carburization and other types of high-temperature corrosion.

Each one a refinement of the one before, these alloys have set the industry standard in high-temperature applications requiring optimum creep and rupture properties.

Nickel-iron-chromium Alloy 800 was introduced to the market in the 1950s to fill the need for a heat- and corrosion-resistant alloy with a relatively low nickel content since nickel was, at the time, designated a "strategic" metal. Over the past forty years it has been widely used for its strength at high temperatures and its ability to resist oxidation, carburization, and other types of high-temperature corrosion. Applications include furnace components and equipment, petrochemical furnace cracker tubes, pigtails and headers, and sheathing for electrical heating elements.

In 1963, the alloy was approved by the ASME Boiler and Pressure Vessel Committee, and the design stresses were published in Code Case 1325. For the first time, aluminum and titanium were listed as purposeful additions (at 0.15 to 0.60% each), and annealed material was differentiated from solution-annealed material. The new terms "Grade 1 annealed at approximately 1800°F (980°C)" and "Grade 2, annealed at approximately 2100°F (1150°C)" came into use. The Code Case covered Sections I and VIII, and listed design stresses for Grade 1 to 1100°F (593°C) and for Grade 2 to 1500°F (816°C).

Over the next few years, the Committee made several revisions. In 1965, extruded tube was accepted as Grade 2 material without heat treatment. By the following year, ASTM specifications had been approved for Alloy 800, and these were listed to replace those covering Alloy 600. In 1967, an external pressure vessel chart for Grade 1 was added, and the following year the same addition was made for Grade 2.

In 1969, design stresses were increased as a result of changes in the criteria to determine those stresses. The minimum tensile strength curve was increased 10% and the rupture criterion was increased from 62.5 to 67% of the extrapolated 100,000 hour rupture strength.

Six months later, the Case was changed from covering Sections I and VIII to Section I only since the design stresses for Section VIII had been included in Table UNF-23. There were also two sets of design stresses listed for each grade, one giving the values when the two-thirds yield strength criterion was used, the other when 90% of yield strength was used.

Alloy 800H (UNS N08810)

It had been known for some time that higher carbon Alloy 800 had higher creep and rupture properties than low-carbon material. For that reason it was melted to a carbon range of 0.05 to 0.10% except for special orders which specified a lower carbon content. The carbon range of 0.05 to 0.10% is within the ASTM and ASME specification limits for Alloy 800 and is in the upper portion of that range.

For this material data was generated and presented to the ASME Code. The Code approved higher design stresses for Section I and Divisions 1 and 2 of Section VIII, which appeared in Code Case 13257. Note that Alloy 800H required not only a carbon range of 0.05 to 0.10% but also an average grain size of ASTM 5, or coarser.

With the issuance of Code Case 1325-7 and the common use of the term "800H", there was no longer a need to refer to "Grade 2" because it was replaced by Alloy 800H, and the material that had been called Grade 1 became, simply, Alloy 800.

Alloy 800HT (UNS N08811)

The Metals Property Council for ASME gathered data from other manufacturers and made for Alloy 800H a new analysis using parametric procedures, involving 87 heats and 1,052 data points. This additional data included results with considerably lower strength, and the new analysis, which reflected the results of all the available data, resulted in a recommendation that the design stresses be revised. These revised values were lower for temperatures of 1100 through 1500°F (593-816°C), and about the same for 1600 and 1650°F (871 and 99°C). The aluminum and titanium contents in the upper portion of the specified material range resulted in higher creep and stress rupture properties than competitive Alloy 800H.

To maintain higher allowable design stresses a variation of Alloy 800H, Alloy 800HT (UNS N08811), was introduced. Alloy 800HT has a restricted chemistry, within the limits of Alloy 800H, and requires a heat treatment of 2100°F (1149°C) minimum. The carbon is 0.06 to 0.10% (800H is 0.05 to 0.10%), the Al+Ti is 0.85 to 1.20% (800H 0.30 to 1.20% Al+Ti).

The maximum allowable stresses for Alloy 800HT (UNS N08811) are contained in ASME Code Case 1987 – latest revision. The alloy meets all the requirements for UNS N08811 and N08810 (Alloy 800H) and can be certified to either or both UNS numbers. It is important to note that Alloy 800HT (UNS N08811) has higher maximum allowable design stresses than UNS N08810. Therefore, other materials produced to UNS N08810 (Alloy 800H) cannot be certified as UNS N08811 unless they meet the additional requirements for this designation. Alloy 800HT is the result of years of monitoring and maintaining the ultimate properties in this series.

Alloys 800H and 800HT

Alloys 800H and 800HT have significantly higher creep and rupture strength than Alloy 800. The three alloys have nearly identical chemical composition limits. As Table 1 shows, the base elements in all three alloys are the same. However, chemical composition limits vary with carbon, aluminum and titanium. The carbon content of Alloy 800 (UNS N08800) is 0.10% max with no limit on the lower end. The carbon content for Alloy 800H (UNS N08810) is 0.05 to 0.10%, which is the upper end of the 0.10% maximum specified for Alloy 800.

The chemical limits for Alloy 800HT (UNS N08811) are even more restrictive yet still within the limits specified for Alloy 800H. The carbon content for Alloy 800HT is further restricted to 0.06 – 0.10%. Additionally, the Al plus Ti content of Alloy 800HT is restricted to 0.85 – 1.20%. *Note that the chemical composition for Alloy 800HT will always be within the limits of Alloy 800H. Note also that the limits for Alloy 800H may or may not be within the limits of Alloy 800HT.*

In addition to the controlled carbon content, Alloys 800H and 800HT receive a high-temperature annealing treatment that produces an average grain size of ASTM 5 or coarser. The annealing treatment and restricted chemical composition are responsible for these alloys having greater creep and rupture strength. For specific applications, chemical and /or grain size limits may differ from the general requirements given in Table 1.

The mechanical properties of Alloys 800H and 800HT, combined with their resistance to high-temperature corrosion, make these alloys exceptionally useful for many applications involving long-term exposure to elevated temperatures and corrosive atmospheres. In the hydrocarbon processing industry, these alloys are used in steam/hydrocarbon reforming for catalyst tubing, convection tubing, pigtails, outlet manifolds, and quenching-system piping; in ethylene production for both convection and cracking tubes, and pigtails; in oxy-alcohol production for tubing in hydrogenation heaters; in hydrodealkylation units for heater tubing; and in the production of vinyl chloride monomer for cracking tubes, return bends and inlet and outlet flanges.

Industrial heating is another area of wide usage for both Alloys 800H and 800HT. In various types of heat-treating furnaces, these alloys are used for radiant tubes, muffles, retorts, and assorted furnace fixtures. Alloys 800H and 800HT are also used in power generation for steam superheating tubing and high-temperature heat exchangers in gas-cooled nuclear reactors.

Physical Constants and Thermal Properties

Since the compositional range for Alloys 800H and 800HT falls within that for Alloy 800, the alloys show no significant differences in physical and thermal properties. Values for various properties are given in Tables 2, 3 and 4.

Mechanical Properties

The major differences between alloys 800, 800H and 800HT are mechanical properties. The differences stem from the restricted compositions of alloys 800H and 800HT and the high-temperature anneals used for these alloys. In general, Alloy 800 has higher mechanical properties at room temperature and during short-time exposure to elevated temperatures, whereas Alloys 800H and 800HT have superior creep and rupture strength during extended high-temperature exposure.

Tensile Properties

Typical tensile properties of Alloys 800H and 800HT at temperatures to 2000°F (1095°C) are shown in Figure 1. The data are for annealed extruded tubing of 5-in (127-mm) outside diameter and 0.5-in (12.7-mm) wall. Tensile properties and hardness of Alloys 800H and 800HT at room and elevated temperatures are shown in Table 5. The tests were performed on annealed plate, 0.813 in (20.7 mm) thick.

Fatigue Strength

Low-cycle fatigue strength of Alloys 800, 800H and 800HT at room temperature and 1400°F (760°C) is shown in Figure 2. Low-cycle fatigue data for Alloys 800, 800H and 800HT are compared at 1000°F (538°C) and 1200°F (649°C) in Figures 3 and 4.

Creep and Rupture Properties

The outstanding characteristics of both Alloys 800H and 800HT are their high creep and rupture strengths. The controlled chemistries and solution annealing treatment are designed to produce optimum creep-rupture properties. Figure 5 shows creep strength of Alloys 800H and 800HT at various temperatures.
Rupture strength of these alloys is shown by the data plotted in Figure 6.
The excellent creep-rupture strength of Alloy 800HT (UNS N08811) is illustrated by the Larson-Miller parameter plot in Figure 7.

ASME Boiler and Pressure Vessel Code

Alloy 800H (UNS N08810) is approved under the Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers (ASME). Rules for construction of power boilers are defined under Section I, and those for pressure vessels under Section VIII, Divisions 1 and 2. Design stress values for Alloy 800H for Section I and Section VIII, Division 1 construction are listed in Table 1B of Section II (Materials), Part D (Properties). Section I construction is also addressed by Code Case 1325. Construction is permitted for service up to 1500°F (816°C). Section VIII, Division 1 construction is also addressed by Code Case 1983 and is allowed for service up to 1800°F (982°C).
Design stress values for Alloy 800H for Section VIII, Division 2 construction are listed in Table 2B of Section II (Materials), Part D (Properties). Section VIII, Division 2 construction is allowed for service up to 800°F (427°C).
The use of Alloy 800H for nuclear construction is addressed under Section III of the ASME Code and by Code Cases N-201, N-253, and N-254. Design stress values for Section III, Class 1 construction are the same as those in Table 2B of Section II (Materials), Part D (Properties). Design stress values for Section III, Class 2 construction are the same as those in Table 1B of Section II (Materials), Part D (Properties).

Because of the extensive quality assurance and testing required for material for nuclear construction, the designer or fabricator is cautioned to be fully aware of the requirements of Section III before beginning such construction.
Design stress values for Alloy 800HT for Sections I and VIII, Division 1 construction are listed in Table 1B of Section II (Materials), Part D (Properties). The allowable stresses for Alloy 800HT for service at 1100°-1650°F are higher than those for Alloy 800H. All material supplied as Alloy 800HT (UNS N08811) will meet the requirements defined by ASME for Alloy 800H (UNS N08810). Thus, the information stated in the paragraphs above is also applicable to Alloy 800HT. Maximum allowable stress values for Alloy 800HT for service temperatures up to 1800°F (982°C) are defined by incorporating the values from Table 1B of Section II (Materials), Part D (Properties) and Code Case 1983.

Microstructure and Metallurgy
Alloys 800H and 800HT are austenitic, solidsolution alloys. Titanium nitrides, titanium carbides, and chromium carbides normally appear in the alloys' microstructure. The nitrides are stable at all temperatures below the melting point and are therefore unaffected by heat treatment. Chromium carbides precipitate in the alloys at temperatures between 1000 and 2000°F (540 and 1095°C). Consequently, Alloys 800H and 800HT are similar to other austenitic alloys in that they can be rendered susceptible to intergranular corrosion (sensitized) in certain aggressive environments by exposure to temperatures of 1000 to 1400°F (540-760°C).
Alloy 800H and 800HT products are produced so as to optimize their high temperature properties. The carbon content in Alloys 800H and 800HT results in high temperature strength and resistance to creep and rupture. Alloy 800H and 800HT products are solution annealed as a final stage of production so that the carbon is in the condition to make its optimum contribution to high temperature properties. The solution anneal also results in a large grain size which further contributes to strength and resistance to creep and rupture at high temperatures.

Corrosion Resistance
Alloys 800, 800H and 800HT have the same nickel, chromium, and iron contents and generally display similar corrosion resistance. Since Alloys 800H and 800HT are used for their high-temperature strength, corrosive environments to which these alloys are exposed normally involve high-temperature reactions such as oxidation and carburization.

Oxidation
Because of their high chromium and nickel contents, Alloys 800H and 800HT have excellent resistance to oxidation. The chromium promotes the formation of a protective surface oxide, and the nickel enhances the protection, especially during cyclic exposure to high temperatures. Figures 8 and 9 show the scaling resistance of Alloys 800H and 800HT in severe cyclic oxidation tests at 1800°F (980°C) and 2000°F (1095°C). The tests were conducted in air and consisted of alternating exposure to temperatures for 15 minutes and cooling in still air for 5 minutes. The specimens were subjected to 1000 h of cyclic exposure with periodic removal for weight-change measurements. Table 8 gives the results of oxidation tests conducted in the fire box of a refinery furnace. The furnace operated at 1600°F to 2100°F (870-1150°C) and was fired by fuel having no sulfur. The samples were exposed in the furnace for 3 months.
In atmospheres that are oxidizing to chromium but reducing to nickel, nickel-chromium alloys may be subject to internal oxidation. The condition, which causes severe embrittlement, is characterized by extensive oxidation of chromium, leaving the remaining metal strongly magnetic. Susceptibility to internal oxidation is decreased by the addition of iron to nickel-chromium alloys. Alloys 800H and 800HT, with 46% iron, are resistant to internal oxidation.

Carburization
The high nickel content of Alloys 800H and 800HT provides good resistance to carburizing environments. Table 9 shows the resistance to carburizing atmospheres at 1700°F (925°C) and 1800°F (980°C) for these alloys.
Table 10 indicates the superiority of Alloys 800H and 800HT over materials of lower nickel content in a 25-h gascarburization test performed at 2000°F (1095°C). The test atmosphere consisted of 2% methane hydrogen.
Table 11, results of 100-h carburization tests at 2000°F (1095°C), compares Alloys 800H and 800HT with some other alloys having high resistance to carburization. The atmosphere was composed of 2% methane and 5% argon in hydrogen.

Sulfidation
Because of their high chromium content, Alloys 800H and 800HT have good resistance to many sulfur-containing atmospheres at high temperatures. Table 12 gives the results of sulfidation tests performed at 1110°F (600°C) and 1290°F (700°C) in an atmosphere of 1.5% hydrogen sulfide in hydrogen. The weight-loss measurements are for descaled specimens after 100 h of exposure.

Nitriding
Studies involving various nitriding environments have shown that the resistance of nickel-iron-chromium alloys to nitriding increases with increasing nickel content. Although Alloy 600 (76% nickel) is usually preferred for nitriding service, Alloys 800H and 800HT (32% nickel) have good resistance to many nitriding atmospheres. Table 13 compares Alloys 800H and 800HT with several other materials in tests performed in an ammonia converter. The samples were exposed for 3 years to the atmosphere of 65% hydrogen and 35% nitrogen at 11 ksi (75.8 MPa) and 1000°F (540°C).

Working Instructions
The heating, pickling, and machining procedures described for Alloy 800 also apply to Alloys 800H and 800HT.

Heating and Pickling
All material to be heated must be clean. Oil, paint, grease, shop soil and other foreign substances must be removed prior to the heating operation.
Heating must be performed in a low-sulfur atmosphere. Open heating must be done with low-sulfur fuel, and the furnace atmosphere must be maintained in a reducing condition to prevent excessive oxidation.
Because of the readiness with which chromium is oxidized into a refractory oxide by air, carbon dioxide or water vapor, 800-series alloys cannot be bright annealed in the usual industrial annealing furnace. Under closely controlled conditions, the alloy can be bright annealed in dry, pure hydrogen (dew point of -73°F (-58°C) or lower, less than 0.004% by volume water, and less than 0.007% by volume air).
Alloys 800H and 800HT are normally annealed in box or muffle furnaces using prepared reducing atmospheres. A satisfactory atmosphere is formed by the products of combustion from low-sulfur natural gas burned with a deficiency of air. It produces a thin, adherent, green/black film of oxide on the material. Oxidizing atmospheres produce a heavy black scale that is difficult to remove. Removal of such scale often requires considerable grinding. The alloys usually must be pickled after being heated if a bright surface is required. Because of the alloy’s inherent resistance to chemical attack, specialized pickling procedures are needed.

Hot Working Characteristics
Proper temperature control during deformation is the most important factor in achieving hot malleability. Preheating all tools and dies to 500°F (260°C) is recommended to avoid chilling the metal during working. Heavy forging should not be done so rapidly that the metal becomes overheated. In hot bending operations, the metal should be worked as soon as possible after removal from the furnace to minimize surface cooling before bending is completed.
The hot forming range for Alloys 800H and 800HT is 1600–2200°F (870–1200°C). Heavy forging should be done at temperatures down to 1850°F (1010°C) and light working can be accomplished down to 1600°F (870°C). No working should be done between 1200 to 1600°F (650–870°C).
The rate of cooling following hot forming is not usually critical for these alloys with respect to thermal cracking. However, they are subject to some carbide precipitation in the 1000 to 1400°F (540–760°C) temperature range and should be rapidly cooled through that range when sensitization is a concern.
Cooling after hot working should be air cool or faster. Heavy sections may become sensitized during cooling from the hot-working temperature, and therefore be subject to intergranular corrosion in certain media.

Cold Working Characteristics
These alloys, like many of the stainless steels, are austenitic and have a face-centered cubic crystallographic structure. Austenitic alloys, in comparison to ferritic materials, typically require more power to deform, but because of the many crystallographic planes available they are very ductile. In the annealed condition the tensile strength to yield strength ratio is high, typically greater than 2. Thus, large amounts of cold work can be performed before annealing is necessary. The work-hardening rates for these alloys are somewhat lower than for the common grades of austenitic stainless steels. Figure 10 shows the effect of cold rolling on tensile properties for Alloys 800H and 800HT.

Annealing - Basic Practice
Specific annealing procedures for Alloys 800H and 800HT depend on the amount of cold work, intended grain size and cross section of the material. The mechanical properties of heavily cold worked material are only slightly affected by temperatures below 1000°F (540°C). Stress relief begins at about 1000°F (540°C) and is virtually complete after 1600°F (870°C) for a time commensurate with thickness. As an example, a general guideline for stress relief for plate products would be 1 hour per inch (25mm) of thickness or 1½ hours at 1600°F (870°C), whichever is the greater. A stress relief will generally require more time than a recrystallization anneal. Figure 11 shows the effect of cold work in reducing the recrystallization temperature for Alloys 800H and 800HT strip. Time at temperature was 30 minutes. The lower curve indicates the temperature when recrystallization began, and the upper curve when complete.
Intermediate temperatures will usually result in a fine recrystallized structure interspersed With a cold-worked, elongated grain structure. Temperatures above the upper curve will cause grain growth. These alloys are designed for high-temperature service. Optimum resistance to time-dependent deformation (creep) at elevated temperatures is obtained by heating to a temperature to cause grain growth. The temperature normally used is 2100 to 2200°F (1150–1200°C). Depending on the size and furnace characteristics, the time at temperature is adjusted to achieve a grain size of ASTM No. 5 or coarser. The temperature and time should also be adjusted to limit excessive grain growth since little additional creep strength is obtained as additional grain growth occurs. One disadvantage of excessive grain growth is the lowering of toughness after exposure to elevated temperature. Material that will be cold formed more than about 20% should be ordered in the fine grain condition. Material that will be heated for hot working should be in the as-hot finished condition or as-annealed.

For optimum creep rupture strength after fabrication, the material should be annealed as indicated above to obtain a minimum average grain size of ASTM No. 5. One advantage in deforming fine grain material is the reduced surface roughness commonly called "orange peel". Another is the reduced thermal cracking tendency of the fine grain versus the coarse grain material. Highly cold-worked components having shapes that do not allow springback are especially susceptible to cracking when heated. The driving force for these tight cracks is a high residual tensile stress. The fine grain material will relax residual stresses more rapidly when heated to the annealing temperature, thus reducing the tendency for cracking. At times it is not possible to heat treat after fabrication because of component size or economics. The following are guidelines for applications where coarse grain material is placed in elevated temperature service. One is to limit cold work to less than 20% strain and another is to limit the service temperature and duration so as not to cause recrystallization. Figure 12 shows the beginning of recrystallization after cold straining 10 and 20% versus annealing time or service duration. This figure presents only an approximation of the temperature and duration limits since the compositional variations from heat to heat and the thermomechanical history involved will influence recrystallization behavior. In summary, post fabrication heat treatments depend on the amount of resulting strain from the fabrication (forming and/or welding) and the service conditions. From this, and the data contained in Figures 10, 11, 12, and 13 one can determine whether to use the 1600°F (870°C) stress relieving temperature or the 2100°F (1150°C) minimum solution annealing temperature when conducting post fabrication heat treatments.

Machining
The alloys are readily machined by standard methods. Turning operations can be performed with high metalremoval rates, good tool life, and good surface finish using coated carbide tools. Good results have also been obtained with high-speed-steel tools, which are better for interrupted cutting. Coated carbide tools have shown good life at cutting speeds of 110-190 sfpm (33.5-57.9 m/min) and a feed of 0.008-0.035 ipr (0.20-0.89 mm/rev.). High speed steel tools have been shown to have good life at cutting speeds of 3595 sfpm (10.7-29.0 m/min) and a feed of 0.008-0.035 ipr (0.20-0.89 mm/rev.).

Joining
Alloys 800H and 800HT have the same good weld ability as Alloy 800. Both are normally used for applications requiring high creep-rupture strength and should be joined with welding products that have suitable strength characteristics for the intended service temperatures.

Table 1 - Limiting Chemical Compositions, %, for alloys 800, 800H, and 800HT

General Requirements			
UNS designation	N08800	N08810	N08811
	800	800H	800HT
Nickel	30.0-35.0	30.0-35.0	30.0-35.0
Chromium	19.0-23.0	19.0-23.0	19.0-23.0
Iron	39.5 min.	39.5 min.	39.5 min.
Carbon	0.10 max.	0.05-0.10	0.06-0.10
Aluminum	0.15-0.60	0.15-0.60	0.25-0.60
Titanium	0.15-0.60	0.15-0.60	0.25-0.60
Aluminum + Titanium	0.30-1.20	0.30-1.20	0.85-1.20
ASTM grain size	Not specified	5 or coarser	5 or coarser

Note: These alloys can be specified to more restrictive compositions on a specific order basis.

alloy 800H, Special Requirements*	
Carbon	0.08 max.
Aluminum + Titanium	0.4-0.7
ASTM grain size	Special

*As agreed for specific orders.

Special Grain Size Requirements* alloys 800H and 800HT	
Plate	ASTM 1-5
Tube/Pipe	ASTM 1-5
Sheet	ASTM 2-5

*As agreed for specific orders.

Table 3 - Modulus of Elasticity[a]

Temperature	Tensile Modulus	Shear Modulus	Poisson's Ratio[b]
°F	10^3 ksi	10^3 ksi	
-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
800	24.64	9.04	0.363
1000	23.52	8.60	0.367
1200	22.37	8.12	0.377
1400	21.06	7.58	0.389
1600	19.20	6.82	0.408
°C	GPa	GPa	Poisson's Ratio[b]
-190	210.6	78.9	0.334
20	196.5	73.4	0.339
100	191.3	71.2	0.343
200	184.8	68.5	0.349
300	178.3	66.1	0.357
400	171.6	63.0	0.362
500	165.0	60.3	0.367
600	157.7	57.4	0.373
700	150.1	54.3	0.381
800	141.3	50.7	0.394

[a]Determined by dynamic method.
[b]Calculated from moduli of elasticity.

Table 2 - Physical Constants

Density, lb/in³	0.287
g/cm³	7.94
Melting Range, °F	2475-2525
°C	1357-1385
Specific Heat, (32-212°F), Btu/lb•°F	0.11
(0-100°C), J/kg•°C	460
Permeability at 70°F (21°C) and 200 oersted (15.9 kA/m)	
Annealed	1.014
Hot-Rolled	1.009
Curie Temperature, °F	-175
°C	-115

Table 4 - 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	595	80	-
100	600	83	-
200	620	89	7.9
400	657	103	8.8
600	682	115	9.0
800	704	127	9.2
1000	722	139	9.4
1200	746	152	9.6
1400	758	166	9.9
1600	770	181	10.2
1800	776	214	-
2000	788	-	-
°C	μΩ•m	W/m°C	μm/m/°C
20	0.989	11.5	-
100	1.035	13.0	14.4
200	1.089	14.7	15.9
300	1.127	16.3	16.2
400	1.157	17.9	16.5
500	1.191	19.5	16.8
600	1.223	21.1	17.1
700	1.251	22.8	17.5
800	1.266	24.7	18.0
900	1.283	27.1	-
1000	1.291	31.9	-

[a]Between 70°F (21°C) and temperature shown.

Table 5 - Tensile properties and hardness of alloys 800H/800HT at high temperatures

Temperature		Hardness BHN	Tensile Strength		Yield Strength (0.2% Offset)	
°F	°C		ksi	MPa	ksi	MPa
80	27	126	77.8	536	21.7	150
800	425	–	67.5	465	18.8	130
1000	540	90	62.7	432	13.0	90
1200	650	84	54.8	378	13.5	93
1300	705	82	47.7	329	15.8	109
1400	760	74	34.2	236	13.1	90

Table 6 - Room-temperature properties of cold-rolled (20%) alloys 800H and 800HT after high-temperature exposure

Exposure Temperature		Exposure Time	Impact Strength[a]		Yield Strength (0.2% Offset)		Tensile Strength		Elongation	Reduction of Area
°F	°C	h	ft•lbf	J	ksi	MPa	ksi	MPa	%	%
No exposure		–	112	152	113.0	779	114.0	786	15.5	58.0
1000	540	1,000	63	85	114.5	789	127.5	879	18.5	50.5
		4,000	78	106	112.5	776	125.5	865	20.0	52.5
		8,000	61	83	113.5	783	128.5	886	20.0	47.0
		12,000	61	83	113.5	783	128.5	886	20.0	52.0
1200	650	1,000	87	118	90.5	624	109.0	752	23.0	46.5
		4,000	65	88	79.4	547	107.0	738	21.5	43.0
		8,000	62	84	81.4	561	106.5	734	25.5	52.5
		12,000	63	85	78.9	544	105.0	724	24.0	50.0

[a]Charpy V-Notch tests.

Table 7 - Representative Rupture-Strength Values for alloys 800H/800HT

Temperature		10,000 h		30,000 h		50,000 h		100,000 h	
°F	°C	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
1200	650	17.5	121	15.0	103	14.0	97	13.0	90
1300	705	11.0	76	9.5	66	8.8	61	8.0	55
1400	760	7.3	50	6.3	43	5.8	40	5.3	37
1500	815	5.2	36	4.4	30	4.1	28	3.7	26
1600	870	3.5	24	3.0	21	2.8	19	2.5	17
1700	925	1.9	13	1.6	11	1.4	10	1.2	8.3
1800	980	1.2	8.3	1.0	6.9	0.9	6.2	0.8	5.5

Table 8 - Corrosion rates in refinery furnace atmosphere

Alloy	Corrosion Rate	
	mpy	mm/y
alloys 800H/800HT	6.0	0.15
Type 310 Stainless Steel	8.9	0.23
Type 309 Stainless Steel	84.5	2.15
Type 304 Stainless Steel	Complete oxidation	

Table 9 - Results of 100-h gas-carburization tests in hydrogen plus 2% methane

Alloy	Weight Gain, mg/cm²	
	1700°F (925°C)	1800°F (980°C)
alloy 600	2.66	–
alloy 601	2.72	4.32
alloys 800H/800HT	4.94	11.6
Type 330 Stainless Steel	6.42	12.4

Table 10 - Results of gas-carburization tests at 2000°F (1095°C) 25-h tests in hydrogen plus 2% methane

Alloy	Weight Gain, mg/cm²
alloy 600	2.78
alloys 800H/800HT	5.33
Type 310 Stainless Steel	18.35
Type 309 Stainless Steel	18.91

Table 11 - Results of gas-carburization tests at 2000°F (1095°C) 100-h tests in hydrogen plus 2% methane and 5% argon

Alloy	Weight Gain, mg/cm²
alloy 600	12.30
alloy 601	16.18
alloys 800H/800HT	21.58
Type 330 Stainless Steel	24.00

Table 12 - Results of 100-h gas-sulfidation tests in hydrogen plus 1.5% hydrogen sulfide

Alloy	Weight Loss[a], mg/cm²	
	1110°F (600°C)	1290°F (700°C)
alloy 601	15.6	79.3
alloys 800H/800HT	29.5	147.0
Type 310 Stainless Steel	32.6	138.4
Type 304 Stainless Steel	37.8	191.6

[a]Descaled specimens.

Table 13 - Results of nitriding tests in ammonia converter[a]

Material	Depth of Nitriding			
	1 year		3 years	
	in.	mm	in.	mm
alloys 800H/800HT	0.0054	0.137	0.0053	0.135
Type 310 Stainless Steel	0.0088	0.224	0.0092	0.234
Type 309 Stainless Steel	0.0095	0.241	0.0096	0.244
Type 446 Stainless Steel	0.0417	1.059	0.0453	1.151
Type 304 Stainless Steel	0.0427	1.085	0.0440	1.118

[a]Atmosphere of 65% hydrogen and 35% nitrogen at 11 ksi (75.8 MPa) and 1000°F (540°C)

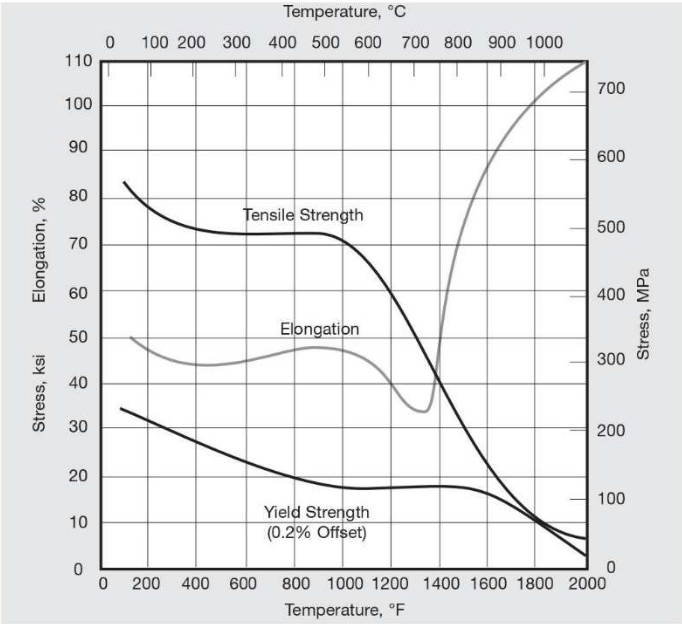

Figure 1. High-temperature strength tensile properties of alloys 800H and 800HT.

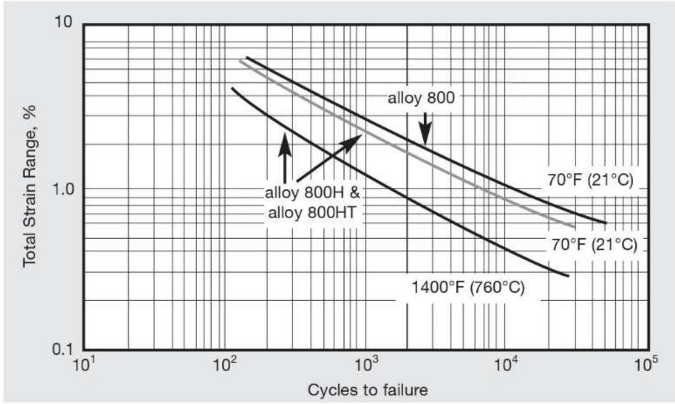

Figure 2. Low-cycle fatigue strength of alloys 800, 800H and 800HT. Bending strain was used for alloy 800; axial strain was used for alloys 800H and 800HT.

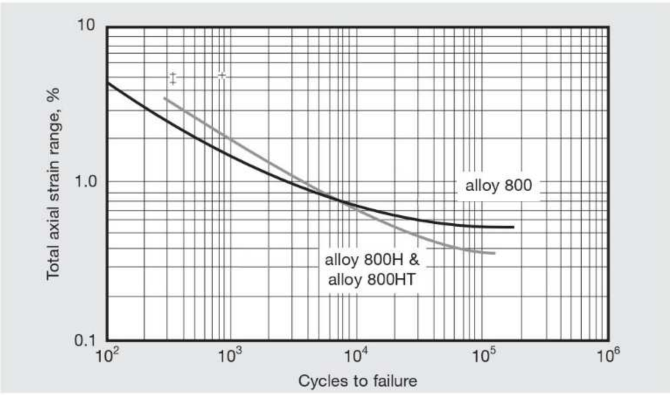

Figure 3. Low-cycle fatigue strength of alloys 800, 800H and 800HT at 1000°F (540°C).

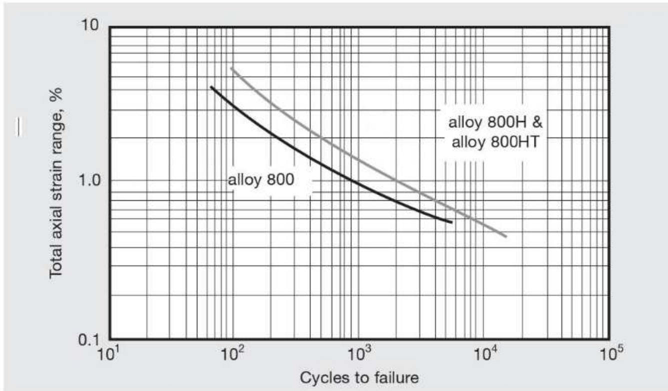

Figure 4. Low-cycle fatigue strength of alloys 800, 800H and 800HT at 1200°F (650°C).

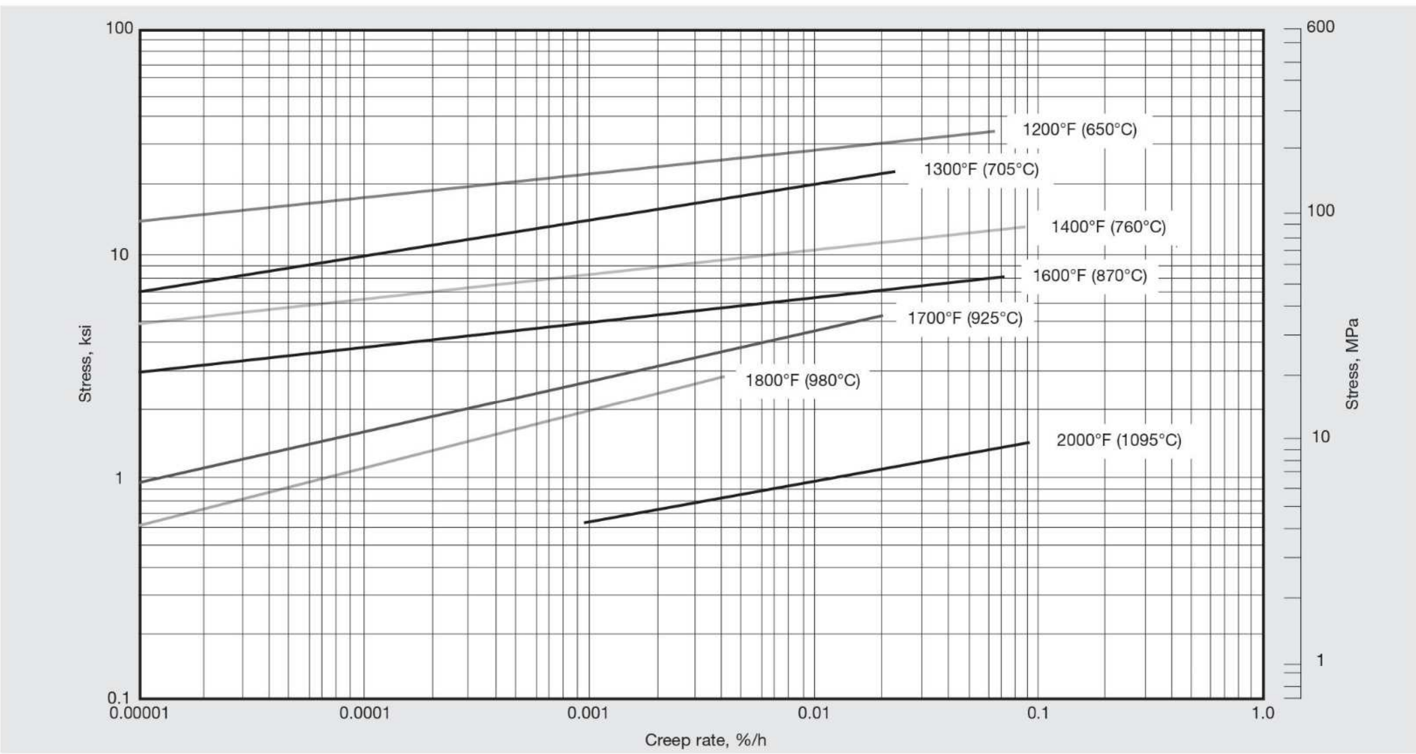

Figure 5. Typical creep strength of alloys 800H and 800HT.

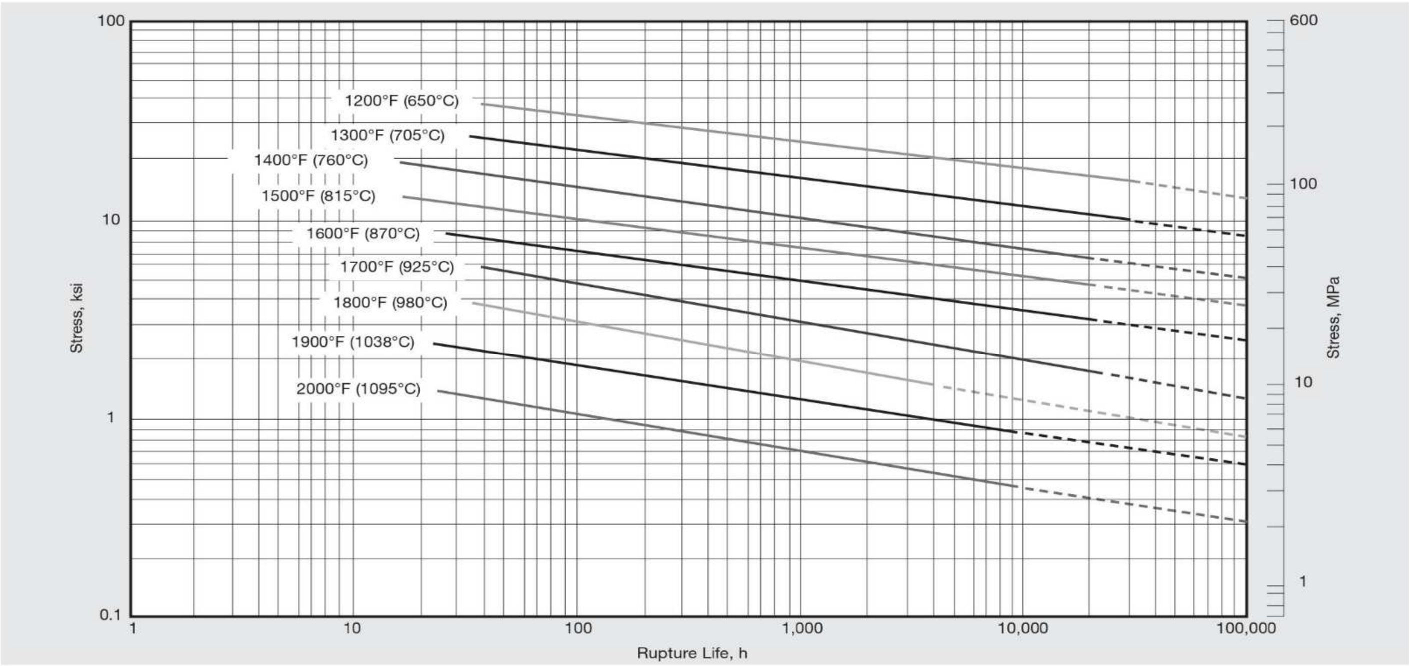

Figure 6. Typical rupture strength of alloys 800H and 800HT

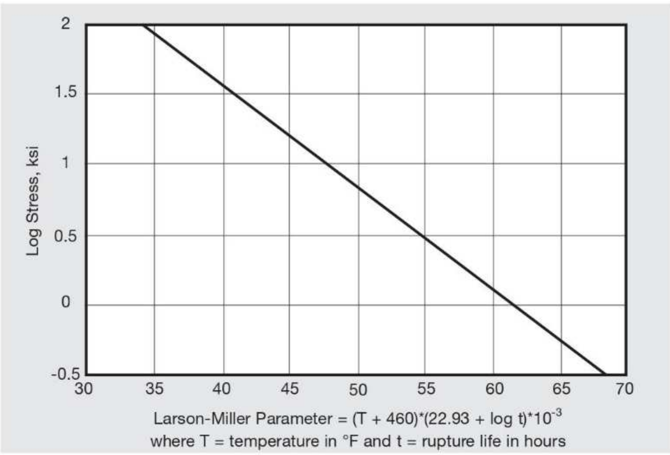

Figure 7. Creep-rupture strength of alloy 800HT (UNS N08811)

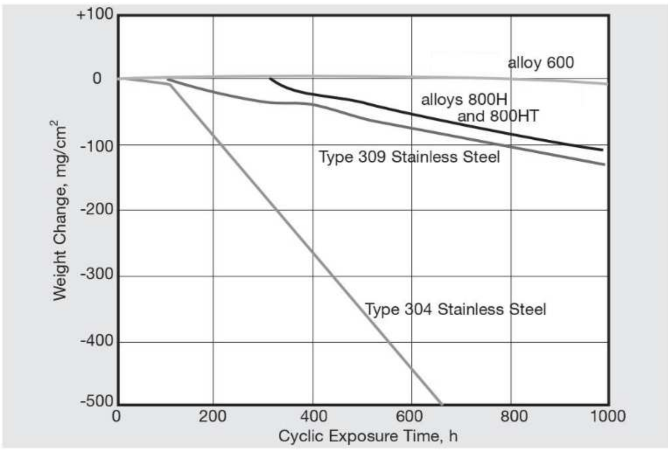

Figure 8. Results of cyclic oxidation tests at 1800°F (980°C). Cycles consisted of 15 min heating and 5 min cooling in air.

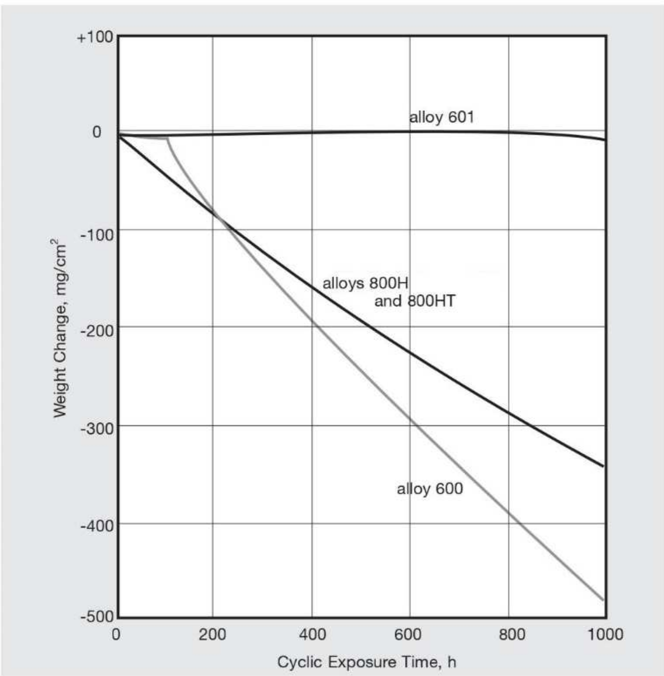

Figure 9. Results of cyclic oxidation tests at 2000°F (1095°C). Cycles consisted of 15 min heating and 5 min cooling in air.

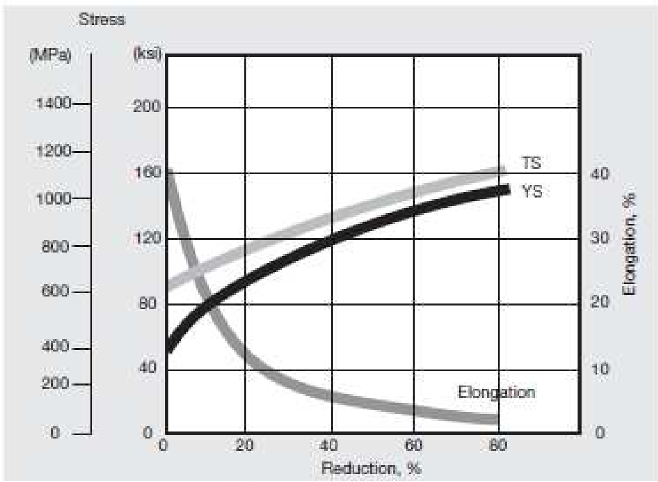

Figure 10. Effect of cold rolling on tensile properties of alloys 800H and 800HT (UNS N08810 and N08811)

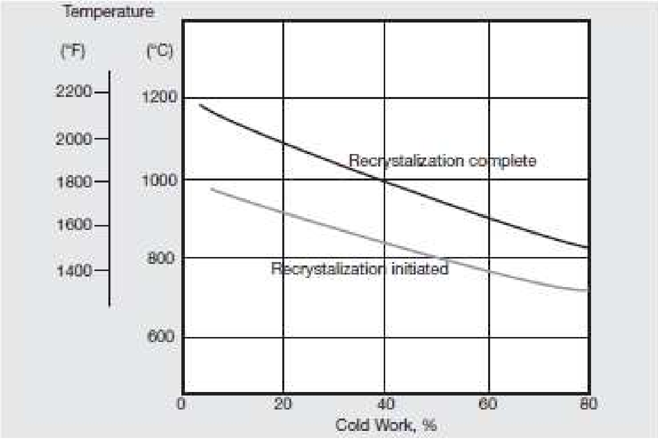

Figure 11. Effect of cold work on recrystallization of alloys 800H and 800HT (UNS N08810 and N08811)

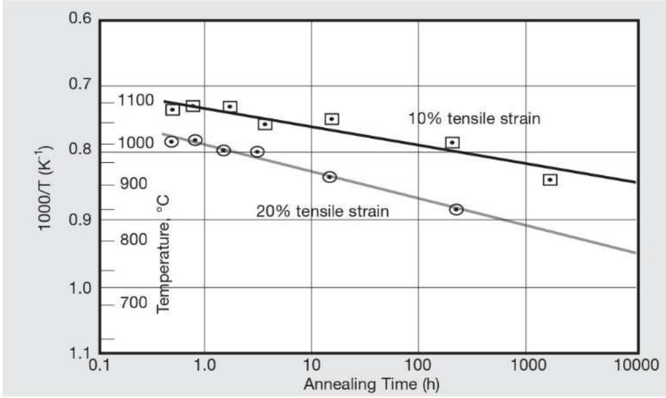

Figure 12. Time at temperature for the onset of recrystallization in alloys 800H and 800HT (UNS N08810 and N08811)

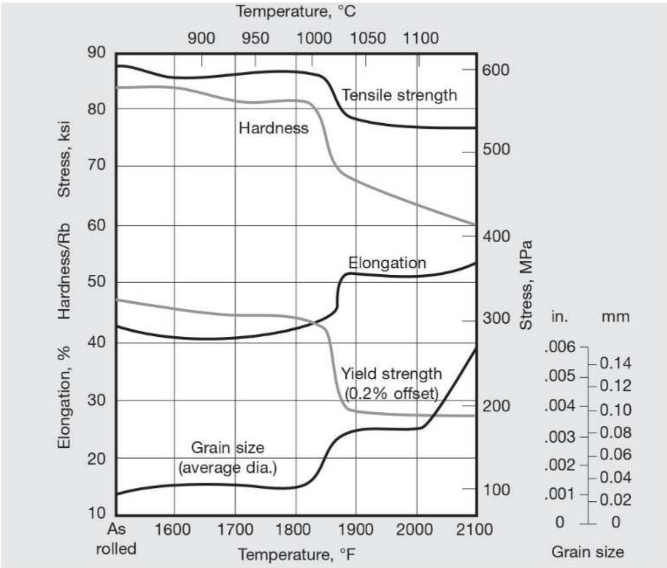

Figure 13. Effect of annealing temperatures on properties of alloys 800 (UNS N08800), 800H (UNS N08810), and 800HT (UNS N08811).