Type 332

(UNS N08800)

GENERAL PROPERTIES

Type 332 is a nickel and chromium austenitic stainless steel designed to resist oxidation and carburization at elevated temperatures. The nickel content, 32%, makes the alloy highly resistant both to chloride stress corrosion cracking and to embrittlement from precipitation of "sigma" phase. The general corrosion resistance is excellent. In the solution annealed condition, Type 332 has superior creep and stress rupture properties. Type 332 has been approved as a material of construction under ASME Boiler and Pressure Vessel Code, Section I — Power Boilers, Section III — Nuclear Vessels, Section VIII — Unfired Pressure Vessels.

TYPICAL ANALYSIS

Element	Percent
Carbon	0.03
Manganese	1.00
Phosphorous	0.020 max
Sulfur	0.010
Silicon	0.40
Chromium	20.5
Nickel	31.0
Titanium	0.30
Aluminum	0.30
Copper	0.20
Iron	Balance

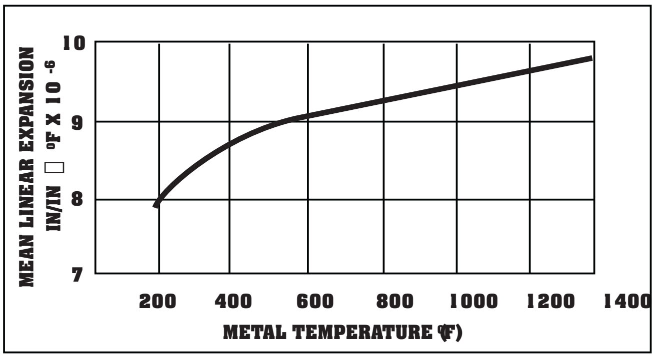
PHYSICAL PROPERTIES

Melting Range	2475-2525°F (1357-1385°C)
Density	0.29 lb/in^3 (8.027 g/cm^3)
Specific Heat (32°F-212°F)	0.12 (Btu/lb•°F)
Magnetic Permeability	1.0092 at 200 Oe
Curie Temperature	-175 °F (-115 °C)
Electrical Resistivity	99 microhm-cm

Thermal Conductivity

Temperature		Btu•in/hr•ft^2•°F	W/m•k
°F	°C		
68-212	20-100	80	11.6
68-800	20-427	127	18.4
68-1800	20-982	214	31.0

Coefficient of Thermal Expansion



Data are nominal and should not be construed as maximum or minimum values for specification or for final design. Data on any particular piece of material may vary from those shown herein.

MECHANICAL PROPERTIES

Tensile Properties (Typical)

The following tables illustrate the short-time high temperature tensile properties of Type 332 in two commonly used conditions.

1800°F Mill Anneal

Temp. °F	Tensile Strength psi	Yield Strength .2% Offset, psi	Elonga-tion %	Reduc-tion of Area, %
85	86 800	42 700	44.0	67.0
200	81 700	39 700	42.5	67.3
400	77 300	36 000	39.0	64.2
500	76 200	34 000	39.0	64.0
600	76 200	33 700	40.0	63.0
700	76 300	34 000	40.5	60.5
800	74 600	33 300	40.0	62.0
900	73 500	32 200	42.0	59.0
1000	72 000	31 700	38.5	60.5
1100	64 500	30 700	40.0	55.5
1200	54 000	29 000	55.5	56.0
1300	42 400	26 900	51.0	54.5
1400	32 100	22 600	85.0	74.0
1500	24 800	14 200	91.0	89.6

2100°F Solution Anneal

Temp. °F	Tensile Strength psi	Yield Strength .2% Offset, psi	Elonga-tion %	Reduc-tion of Area, %
85	76 100	28 200	52.0	69.5
200	71 000	24 100	53.0	75.6
400	65 400	21 000	49.5	64.5
600	66 300	17 000	53.0	69.5
800	65 800	18 100	53.0	62.5
900	66 000	14 900	56.0	65.5
1000	63 500	16 500	51.0	59.0
1100	60 300	14 200	50.5	53.5
1200	55 700	14 800	50.0	60.9
1300	42 700	14 200	43.0	42.8
1400	32 300	15 400	78.0	60.0
1500	25 200	15 600	96.0	71.0
1600	18 600	11 600	125.0	79.3
1700	13 400	9 000	128.0	90.6
1800	10 200	8 900	113.00	94.6

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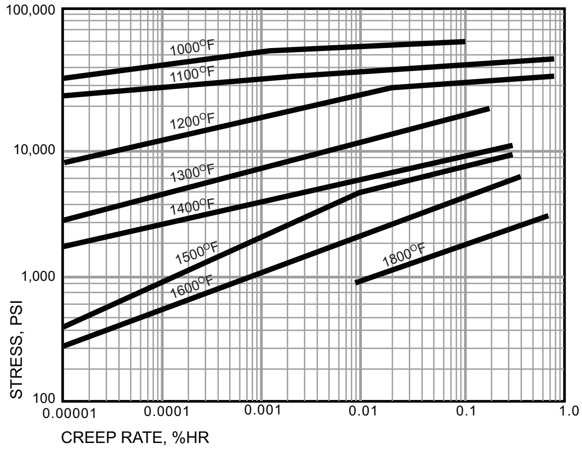
Mill annealed material will have a finer grain size and would be more suited to cold forming operations than the solution annealed material. The solution anneal provides a larger grain size to maximize the creep and stress rupture properties of Type 332 as shown in the following data:

Creep and Stress Rupture

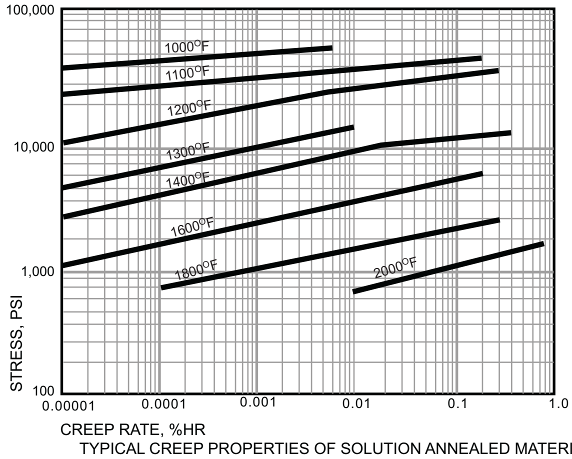
The creep and stress rupture data indicate that Type 332 is stronger than the common stainless steels such as Types 301, 304, 309, 310; yet Type 332 is weaker than superalloys such as A-286, Altemp® HX and Altemp® 600.

FIGURE 1



TYPICAL CREEP PROPERTIES OF MILL ANNEALED MATERIAL

FIGURE 2



TYPICAL CREEP PROPERTIES OF SOLUTION ANNEALED MATERIAL

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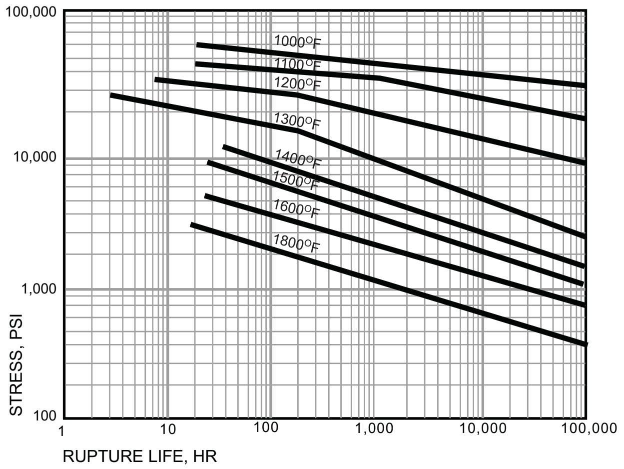
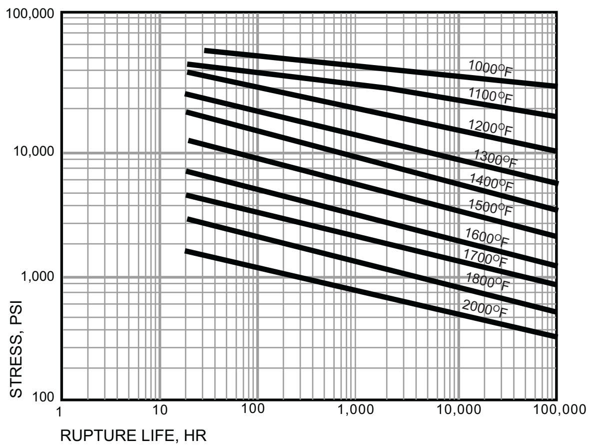
FIGURE 3



TYPICAL RUPTURE STRENGTH OF MILL ANNEALED MATERIAL

FIGURE 4



TYPICAL RUPTURE STRENGTH OF SOLUTION ANNEALED MATERIAL

Fatigue Strength

Rotating beam fatigue tests show the 10^7 cycle endurance limit of Type 332, in a given condition, is 40-50% of the ultimate tensile strength of the material in that condition. Good fatigue performance, however, is mainly dependent on design considerations such as the severity of notches, holes, sharp radii, or other stress raisers in the load bearing area.

Impact Resistance

Type 332, like other austenitic stainless steels, does not have a ductile-to-brittle transition temperature. The alloy maintains 80% of its room temperature impact strength at -423°F.

Corrosion and Oxidation Resistance

Type 332 is a highly corrosion resistant alloy, having a richer chromium and nickel content than the familiar austenitic Cr-Ni stainless steel Type 304 which finds extensive use in handling a vast number of corrosive substances. Under many environmental conditions of service, the performance of these two alloys is markedly similar. For example, comparable behavior can be expected in most rural and industrial atmospheres and in chemical mediums such as nitric acid and the various organic acids. Neither alloy is suggested for sulfuric acid service except at the lower concentrations and temperatures. Also, like the austenitic stainless steels, Type 332 is subject to sensitization (precipitation of chromium carbides at grain boundaries) if heated for excessive time in the 1000-1400°F temperature range. The sensitized metal may be subject to intergranular attack by certain corrosive agents including pickling acids or the Huey test (boiling 65% nitric acid).

Type 332 is highly resistant, although not totally immune, to stress corrosion cracking. Extensive field testing has shown remarkable performance in many types of equipment in the petroleum, chemical, food, and pulp and paper industries. Type 332 may offer a distinct advantage for use in moderately corrosive environments where service experience has indicated a tendency toward stress corrosion cracking of other austenitic stainless steels. On the other hand, because severe laboratory tests will produce stress corrosion failure, it is important to emphasize that susceptibility should be anticipated in the more critical applications.

Resistance to Oxidation and Carburization

Type 332 is particularly well suited for high temperature applications such as furnace parts and related heating equipment, for petrochemical reforming units and isocracker tubes, and for handling superheated steam in nuclear and conventional power plants. Due to its generous proportions of chromium and nickel, the alloy offers superior resistance to oxidation and scaling, and to carburization as well. It is an ideal material for the sheathing of electrical resistance heating elements for domestic appliances.

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The following oxidation data for Type 332 were obtained by exposing samples to the indicated temperature for 100 hours in still air and cooling. In general, total weight gains greater than 10 mg/cm^2 indicate that additional exposure at these temperatures will lead to rapid failures. The amount of oxide which spalled off is an indication of the alloys suitability for cyclic service between room temperature and the indicated temperature.

Since oxidation rates are greatly affected by heating and cooling rates as well as by the atmospheres involved, these data can only be used as approximate guidelines. Personnel at our Corporate Research Center will be glad to discuss specific applications and environments.

100 Hour Still Air Continuous Oxidation Tests

Nominal Composition					Sample Weight Gain (mg/cm^2)				
Alloy	**Cr**	**Ni**	**Ti**	**Al**	**1700°F**	**1800°F**	**1900°F**	**2000°F**	**2100°F**
332	21	32	0.4	0.3	.77	1.8	2.09	2.07	5.06
309	23	13	--	--	.80	1.2	2.1	2.5	4.0
310	25	20	--	--	.80	1.1	3.2	2.6	5.2

Annealing

Mill annealing at temperatures between 1800-1900°F is used to recrystallize the cold worked material and restore ductility for further forming operations. Typical mill annealed properties are shown in the following table:

Condition	Ultimate Tensile Strength psi	Yield Strength psi	Elongation in 2" Percent	ASTM Grain Size
Mill Annealed	86 000	43 500	43.5	7.5
Solution Annealed	76 500	29 000	53.5	2.5

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Solution annealing, carried out at temperatures between 2050°F and 2150°F, is used to develop a larger grain size for better creep and stress rupture performance. Typical solution annealed properties are shown at left. While the lower strengths and higher elongations may be desirable for cold forming, the large grain size of the solution annealed material would probably lead to orange peel.

Pickling and Descaling

After bright annealing in vacuum or dry hydrogen, the surface of Type 332 may be faintly discolored. This light discoloration can be removed in 5% H_2SO_4 at room temperature to maintain maximum corrosion resistance. When open annealing Type 332 in a direct fired or muffle furnace, a tightly adherent green-black oxide will form. This scale can be removed by treating the material in a fused salt bath followed by a pickle in 15% nitric acid + 3% hydrofluoric acid at 130°F. As the material is removed from the molten salt, it should be sprayed or immersed in water to remove as much salt as possible. Immersion times in the nitric-hydrofluoric acid should be kept to a minimum to avoid intergranular attack in the event the material has been sensitized.

FABRICATION

Hot and Cold Forming

Type 332 can be hot formed at temperatures between 1600°F and 2200°F with heavy reductions occurring above 1850°F. No reduction should be carried out below 1600°F because of possible cracking. The cooling rate from hot working temperatures is not critical with respect to thermal cracking. Type 332 is, however, subject to carbide precipitation in the 1000-1400°F temperature range. If the end use involves exposure to aggressive chemical environments, the parts should be rapidly cooled through this temperature range.

Cold Forming

Type 332 exhibits the excellent cold forming characteristics normally associated with a chromium-nickel stainless steel. The high nickel content of Type 332 prevents the austenitic to martensite transformation which can occur when Type 301 and Type 304 are cold worked. Hence, the alloy has a lower work hardening rate than Types 301 or 304 and can be used in multiple draw forming operations where relatively large amounts of deformation occur between anneals.

Machining

Type 332 in either the mill annealed, or solution annealed condition, is readily machinable by standard

what longer tool lives are obtained when machining material in the solution annealed condition. High metal removal rates coupled with good tool life and surface finish can be obtained when turning this alloy with CISC Grade C-2 cemented carbide tools.

Welding

Type 332 can be joined by the gas tungsten arc (GTAW), gas consumable electrode (MIG), or by stick electrode welding techniques commonly used on stainless steels. A number of welding rods and wires are commercially available for joining Type 332 while maintaining desirable high temperature properties. Since this alloy forms tightly adhering scales, which can be removed only by grinding, when heated in oxidizing atmospheres, inert gas shielding is desirable where such mechanical cleaning is not possible.