Technical Datasheet CARPENTER

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Carpenter 13-8 Stainless

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Identification

UNS Number

- S13800

Type Analysis

Carbon (Maximum)	0.05 %	**Manganese (Maximum)**	0.10 %
Phosphorus (Maximum)	0.010 %	**Sulfur (Maximum)**	0.008 %
Silicon (Maximum)	0.10 %	**Chromium**	12.25 to 13.25 %
Nickel	7.50 to 8.50 %	**Molybdenum**	2.00 to 2.50 %
Aluminum	0.90 to 1.35 %	**Nitrogen (Maximum)**	0.01 %
Iron	Balance		

General Information

Description

Carpenter 13-8 stainless is a martensitic precipitation/age-hardening stainless steel capable of high strength and hardness along with good levels of resistance to both general corrosion and stress-corrosion cracking. In addition, the alloy exhibits good ductility and toughness in large sections in both the longitudinal and transverse directions. The excellent properties of 13-8 stainless are obtained through close control of chemical composition and microstructure plus specialized melting which reduces impurities and minimizes segregation. Compared to other ferrous-base materials, this alloy offers a high level of useful mechanical properties under severe environmental conditions.

Carpenter 13-8 stainless has good fabrication characteristics and can be age-hardened by a single low temperature treatment. Cold work prior to aging increases the aging, especially for lower aging temperatures.

Carpenter 13-8 stainless has been used for valve parts, fittings, cold-headed and machined fasteners, shafts, landing gear parts, pins, lockwashers, aircraft components, nuclear reactor components and petrochemical applications requiring resistance to stress-corrosion cracking. Generally, this alloy should be considered where high strength, toughness, corrosion resistance, and resistance to stress-corrosion cracking are required in a steel showing minimal directionality in properties.

Elevated Temperature Use

Carpenter 13-8 stainless has displayed excellent resistance to oxidation up to approximately 1100°F (539°C). Long-term exposure to elevated temperatures can result in reduced toughness in precipitation hardenable stainless steels. The reduction in toughness can be minimized in some cases by using higher aging temperatures. Short exposures to elevated temperatures can be considered, provided the maximum temperature is at least 50°F (28°C) less than the aging temperature.

Corrosion Resistance

In Condition H 950, 13-8 stainless has rusting resistance similar to that of Type 304 Stainless in 5 weight percent salt fog. In strongly oxidizing and reducing acids and in atmospheric exposures, the general-corrosion resistance of 13-8 stainless approaches that of Type 304. As with other precipitation hardening stainless steels, the alloy's level of general-corrosion resistance is greatest in the fully hardened condition and decreases slightly as the aging temperature is increased.

Numerous tests representing a marine environment have shown the alloy, in both the wrought and welded conditions, to have a high level of resistance to stress-corrosion cracking. For best resistance to stress-corrosion cracking, a minimum aging temperature of 1000°F (538°C) is suggested.

For optimum corrosion resistance, surfaces must be free of scale, lubricants, foreign particles, and coatings applied for drawing and heading. After fabrication of parts, cleaning and/or passivation should be considered.

Important Note: *The following 4-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact.*

Nitric Acid	Moderate	Sulfuric Acid	Restricted
Phosphoric Acid	Restricted	Acetic Acid	Moderate
Sodium Hydroxide	Moderate	Salt Spray (NaCl)	Good
Sea Water	Restricted	Humidity	Excellent

- Typical Stress-Corrosion-Cracking Resistance in an Atmospheric Marine Environment

Properties

Physical Properties		
Specific Gravity		
Condition H 1000	7.76	
Density		
Condition H 1000	0.2800	lb/in³
Mean Coefficient of Thermal Expansion		
70°F, 200°F, Condition H 950	5.90	$x 10^{-6}$ in/in/°F
70°F, 400°F, Condition H 950	6.00	$x 10^{-6}$ in/in/°F
70°F, 600°F, Condition H 950	6.20	$x 10^{-6}$ in/in/°F
70°F, 800°F, Condition H 950	6.30	$x 10^{-6}$ in/in/°F
70°F, 900°F, Condition H 950	6.60	$x 10^{-6}$ in/in/°F
70°F, 200°F, Condition H 1000	5.70	$x 10^{-6}$ in/in/°F
70°F, 400°F, Condition H 1000	6.00	$x 10^{-6}$ in/in/°F
70°F, 600°F, Condition H 1000	6.20	$x 10^{-6}$ in/in/°F
70°F, 800°F, Condition H 1000	6.30	$x 10^{-6}$ in/in/°F
70°F, 900°F, Condition H 1000	6.60	$x 10^{-6}$ in/in/°F
70°F, 200°F, Condition H 1050	5.70	$x 10^{-6}$ in/in/°F
70°F, 400°F, Condition H 1050	5.90	$x 10^{-6}$ in/in/°F
70°F, 600°F, Condition H 1050	6.20	$x 10^{-6}$ in/in/°F
70°F, 800°F, Condition H 1050	6.40	$x 10^{-6}$ in/in/°F
70°F, 900°F, Condition H 1050	6.60	$x 10^{-6}$ in/in/°F
70°F, 200°F, Condition H 1100	6.00	$x 10^{-6}$ in/in/°F
70°F, 400°F, Condition H 1100	6.20	$x 10^{-6}$ in/in/°F
70°F, 600°F, Condition H 1100	6.40	$x 10^{-6}$ in/in/°F
70°F, 800°F, Condition H 1100	6.60	$x 10^{-6}$ in/in/°F
70°F, 900°F, Condition H 1100	6.80	$x 10^{-6}$ in/in/°F
• Mean Coefficient of Thermal Expansion		
Thermal Conductivity		
212°F, Condition A	97.20	BTU-in/hr/ft²/°F
• Thermal Conductivity		
Modulus of Elasticity (E)		
73°F, Condition H 1000, Longitudinal	28.3	$x 10^{3}$ ksi
Modulus of Rigidity (G)		
73.0°F, Condition H 950	11.1	$x 10^{3}$ ksi
73.0°F, Condition H 1000	10.9	$x 10^{3}$ ksi
Electrical Resistivity		
212°F, Condition A	613.0	ohm-cir-mil/ft
• Electrical Resistivity		
Magnetic Properties		
Magnetic Permeability		
Condition H 950, 10.5 Oe	52.000	Mu
Condition H 950, 54.7 Oe	127.00	Mu
Condition H 950, 111 Oe	85.000	Mu
Condition H 950, 165 Oe	65.000	Mu
Condition H 950, 217 Oe	53.000	Mu
Condition H 950, 264 Oe	46.000	Mu
• Magnetic Permeability		
Typical Mechanical Properties		
• Typical Cryogenic and Elevated Temperature Tensile Properties		
• Typical Cryogenic Charpy V-Notch Impact Strength		

- Typical Longitudinal Room Temperature Mechanical Properties
- Typical Notch Tensile Strength as a Function of Notch Concentration and Test Temperature
- Typical Room Temperature Compressive Properties
- Typical Room Temperature Torsional Properties
- Typical Rotating Beam Fatigue Strength
- Typical Transverse Room Temperature Mechanical Properties

Heat Treatment

Carpenter 13-8 stainless is hardened by heating solution-treated material, Condition A, to a temperature of 950°F (510°C) to 1150°F (621°C) for four hours, then air cooling. The various heat treatments are as follows (note all times are "at temperature"):

Solution Treatment

Condition A (Solution Treated or Annealed):
Heat at 1700°F (927°C) ±15°F (±8°C) (time dependent on section size), cool to below 60°F (16°C) so that the material is completely transformed to martensite. Normally, a one-hour hold at temperature is suggested. Sections under 36 sq. inches (232.3 sq. cm) can be quenched in a suitable liquid quenchant; larger sections should be air cooled.

Deformation (Size Change) in Hardening

Upon aging, a predictable size change will occur for 13-8 stainless. Increasing amounts of contraction occur as aging temperature is increased.

- Size Change Upon Aging

Age

Condition RH 950 (Precipitation or Age Hardened):
Cold treat solution-treated material to -100°F (-73°C) for 2 hours minimum. Air warm to room temperature. This must be done within 24 hours after solution treatment. Heat cold-treated material to 950°F (510°C) ±10°F (±6°C) for 4 hours. Air cool.

Condition H 950, H 1000, H 1050, H 1100, H 1150 (Precipitation or Age Hardened):
Heat solution-treated material at specified temperature ±10°F (±6°C) for 4 hours. Air cool.

Condition H 1150M (Precipitation or Age Hardened):
Heat solution-treated material at 1400°F (760°C) ±10°F (±6°C) for 2 hours. Air cool; then treat at 1150°F (621°C) ±10°F (±6°C) for 4 hours. Air cool.

Heat Treating After Overaging:
Carpenter 13-8 stainless in the H 1150 and H 1150M overaged conditions will not respond to further aging treatments. Therefore, if the alloy is obtained in either condition (for forging, optimum cold heading and machining) it must be solution treated at 1700°F (927°C) after these operations and before subsequent aging.

It should be kept in mind that the hardness for the H 1150 condition falls within the hardness range for the solution-treated condition; therefore, hardness cannot be used to distinguish between the H 1150 and solution-treated conditions.

Workability

Hot Working

Carpenter 13-8 stainless can be readily forged, hot headed and upset. Material which is hot-worked must be solution treated prior to hardening if the material is to respond properly to hardening.

Forging

Heat uniformly to 2150/2200°F (1177/1204 °C) and hold one hour at temperature before forging. Do not forge below 1750°F (954°C). To obtain optimum grain size and mechanical properties, forgings should be cooled in air to 60°F (16°C) before further processing. Forgings must be solution treated prior to hardening.

Cold Working

Carpenter 13-8 stainless can be fabricated by cold working to an extent which is limited by the high initial yield strength.

Machinability

Carpenter 13-8 stainless can be machined in both the solution-treated and various age-hardened conditions. In Condition A the alloy gives good tool life and surface finish when machined at speeds 20 to 30% lower then those used for Carpenter Custom 630 (17Cr-4Ni) or 20 to 30% lower than used for Stainless Types 302 and 304. The machinability as age-hardened will improve as the hardening temperature is increased.

Condition H 1150M provides optimum machinability. Having procured Condition H 1150M for best machinability, higher mechanical properties can be developed only by solution treating and heat treating at standard hardening temperatures.

Following are typical feeds and speeds for Carpenter 13-8 stainless.

- Machinability Tables 1
- Machinability Tables 2

Additional Machinability Notes

When using carbide tools, surface speed feet/minute (sfpm) can be increased between 2 and 3 times over the high-speed suggestions. Feeds can be increased between 50 and 100%.

Figures used for all metal removal operations covered are average. On certain work, the nature of the part may require adjustment of speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds or feeds should be increased or decreased in small steps.

Shearing

Bars and forging billets should be cold cut by sawing. Abrasive wheel cutting can cause small surface cracks, particularly when cutting annealed stock, and should be avoided.

Weldability

Carpenter 13-8 stainless can be welded using the inert-gas shielded or resistance welding processes. When a filler metal is required, 13-8 welding consumables should provide welds with properties similar to those of the base metal. When designing the weld joint, care should be exercised to avoid stress concentrators, such as sharp corners, threads, and partial- penetration welds. When high weld strength is not needed, a standard austenitic stainless filler, such as E/ER308L, should be considered.

Normally, welding in the solution-annealed condition has been satisfactory; however, where high welding stresses are anticipated, it may be advantageous to weld in the overaged (H 1150) condition. Usually, preheating is not required to prevent cracking. If welded in the solution-treated condition, the alloy can be directly aged to the desired strength level after welding. However, the optimum combination of strength, ductility and corrosion resistance is obtained by solution treating the welded part before aging. If welded in the overaged condition, the part must be solution treated before aging.

Other Information

Descaling (Cleaning)

Descaling following forging and annealing can be accomplished by acid cleaning or grit blasting. The acid treatment consists of 2 minutes in 50% by volume muriatic acid at 180°F (82°C), followed by 4 minutes in a mixture of 15% by volume nitric acid, plus 3% by volume hydrofluoric acid at room temperature. Water rinse and desmut in 20% by volume nitric acid at room temperature. Repeat cleaning procedure as necessary but decrease the times by 50% (i.e., 1 and 2 minutes, respectively).

The heat tint from aging can be removed by polishing, vapor blasting or pickling 4 to 6 minutes in a mixture of 15% by volume nitric acid, plus 3% by volume hydrofluoric acid, followed by a water rinse. Repeat the acid cleaning procedure if necessary, but decrease the time by 2 to 3 minutes. Desmut in 20% by volume nitric acid at room temperature.

After acid cleaning, bake 1 to 3 hours at 300/350 °F (149/177 °C) to remove hydrogen.

Applicable Specifications

- AMS 5629
- ASTM A564 (Grade XM-13)
- ASTM A693 (Grade XM-13)
- ASTM A705 (Grade XM-13)

Forms Manufactured

- Bar-Flats
- Bar-Rounds
- Billet
- Hollow Bar
- Strip
- Wire
- Wire-Rod

Technical Articles

- A Guide to Etching Specialty Alloys for Microstructural Evaluation
- Advanced Stainless Offers High Strength, Toughness and Corrosion Resistance Wherever Needed
- Alloy Selection for Cold Forming (Part I)
- Alloy Selection for Cold Forming (Part II)
- How to Passivate Stainless Steel Parts
- New Ph Stainless Combines High Strength, Fracture Toughness and Corrosion Resistance

- New Requirements for Ferrous-Base Aerospace Alloys
- New Stainless Steel for Instruments Combines High Strength and Toughness
- Passivating and Electropolishing Stainless Steel Parts
- Selecting New Stainless Steels for Unique Applications
- Selection of High Strength Stainless Steels for Aerospace, Military and Other Critical Applications
- Steels for Strength and Machinability

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