Technical Datasheet

CARPENTER

CarTech® 13-8 Stainless

Identification

UNS Number

- S13800

Type Analysis

Single figures are nominal except where noted.

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

CarTech 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 CarTech 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.

CarTech 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.

CarTech 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
0.062" (1.57 mm) thick strip

Aged Condition	Applied Stress[a]		Days to Failure[b] 80-ft lot (Kure Beach)
	ksi	MPa	
H 950[c]	204	1406	1 sample failed after 353 days; 1—1077 days; 1 NF[b]
	184	1269	1 sample failed after 51 days; 2 NF
	153	1055	1 sample failed after 1077 days; 2 NF
H 1000[c]	199	1372	3 NF
	179	1234	3 NF
	149	1027	3 NF
H 1050[c]	172	1186	3 NF
	155	1069	3 NF
	149	1027	3 NF
Solution treated, welded, aged at 1000°F (538°C) for 4 hours	195	1344	3 samples failed after 43 days
	176	1213	3 samples failed after 43 days
	146	1007	1 sample failed after 43 days; 1—100 days
Solution treated, welded solution treated and aged at 1000°F (538°C) for 4 hours	195	1344	3 NF
	176	1213	3 NF
	146	1077	3 NF

(a) Applied stresses were 100, 90 and 75 percent of the 0.2 percent yield strength, using smooth bent beam specimens tested in the longitudinal direction.
(b) NF indicates No Failure in 1405 days' exposure.
(c) Heat treatment includes solution treatment at 1700°F (927°C), 15 minutes.

Properties

Physical Properties

Specific Gravity (Condition H 1000)	7.76	
Density (Condition H 1000)	7750	kg/m³

Mean CTE		
21 to 93°C, Condition H 950	10.6	x 10^{-6} cm/cm/°C
21 to 204°C, Condition H 950	10.8	x 10^{-6} cm/cm/°C
21 to 316°C, Condition H 950	11.2	x 10^{-6} cm/cm/°C
21 to 427°C, Condition H 950	11.3	x 10^{-6} cm/cm/°C
21 to 482°C, Condition H 950	11.9	x 10^{-6} cm/cm/°C
21 to 93°C, Condition H 1000	10.3	x 10^{-6} cm/cm/°C
21 to 204°C, Condition H 1000	10.8	x 10^{-6} cm/cm/°C
21 to 316°C, Condition H 1000	11.2	x 10^{-6} cm/cm/°C
21 to 427°C, Condition H 1000	11.3	x 10^{-6} cm/cm/°C
21 to 482°C, Condition H 1000	11.9	x 10^{-6} cm/cm/°C
21 to 93°C, Condition H 1050	10.3	x 10^{-6} cm/cm/°C
21 to 204°C, Condition H 1050	10.6	x 10^{-6} cm/cm/°C
21 to 316°C, Condition H 1050	11.2	x 10^{-6} cm/cm/°C
21 to 427°C, Condition H 1050	11.5	x 10^{-6} cm/cm/°C
21 to 482°C, Condition H 1050	11.9	x 10^{-6} cm/cm/°C
21 to 93°C, Condition H 1100	10.8	x 10^{-6} cm/cm/°C
21 to 204°C, Condition H 1100	11.2	x 10^{-6} cm/cm/°C
21 to 316°C, Condition H 1100	11.5	x 10^{-6} cm/cm/°C
21 to 427°C, Condition H 1100	11.9	x 10^{-6} cm/cm/°C
21 to 482°C, Condition H 1100	12.2	x 10^{-6} cm/cm/°C

Mean Coefficient of Thermal Expansion

H 950	10^{-6}/°F	10^{-6}/K	H 1050	10^{-6}/°F	10^{-6}/K
70 to 200°F (21 to 93°C)	5.9	10.6	70 to 200°F (21 to 93°C)	5.7	10.3
70 to 400°F (21 to 204°C)	6.0	10.8	70 to 400°F (21 to 204°C)	5.9	10.6
70 to 600°F (21 to 316°C)	6.2	11.2	70 to 600°F (21 to 316°C)	6.2	11.2
70 to 800°F (21 to 427°C)	6.3	11.3	70 to 800°F (21 to 427°C)	6.4	11.5
70 to 900°F (21 to 482°C)	6.6	11.9	70 to 900°F (21 to 482°C)	6.6	11.9
H 1000			**H 1100**		
70 to 200°F (21 to 93°C)	5.7	10.3	70 to 200°F (21 to 93°C)	6.0	10.8
70 to 400°F (21 to 204°C)	6.0	10.8	70 to 400°F (21 to 204°C)	6.2	11.2
70 to 600°F (21 to 316°C)	6.2	11.2	70 to 600°F (21 to 316°C)	6.4	11.5
70 to 800°F (21 to 427°C)	6.3	11.3	70 to 800°F (21 to 427°C)	6.6	11.9
70 to 900°F (21 to 482°C)	6.6	11.9	70 to 900°F (21 to 482°C)	6.8	12.2

Thermal Conductivity (100°C, Condition A)	14.01	W/m/K

Thermal Conductivity
Condition A

Test Temperature		Btu-in/ft²•h•°F	W/m•K
°F	°C		
212	100	97.2	14.0

Modulus of Elasticity (E) (23°C, Condition H 1000, Longitudinal)	195	x 10^{3} MPa
Modulus of Rigidity (G)		
23°C, Condition H 950	76.5	x 10^{3} MPa
23°C, Condition H 1000	75.2	x 10^{3} MPa
Electrical Resistivity (100°C, Condition A)	1019	micro-ohm-mm

Electrical Resistivity
Condition A

Test Temperature		ohm-cir mil/ft	microhm-mm
°F	°C		
212	100	613	1020

Magnetic Properties

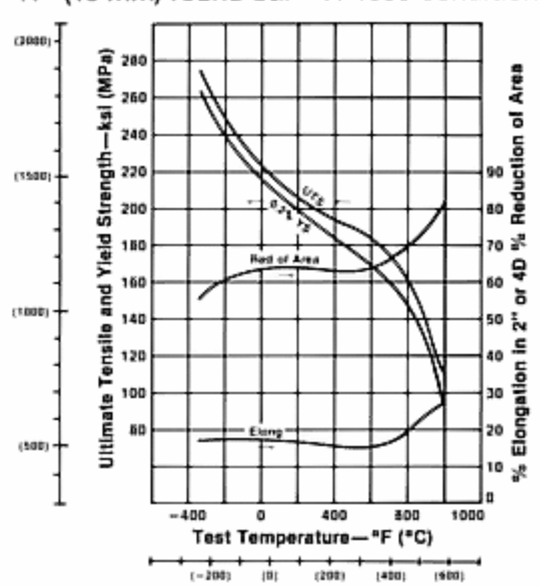
Magnetic Permeability		
Condition H 950, 836 A/m	52.000	Mu
Condition H 950, 4350 A/m	127.00	Mu
Condition H 950, 8790 A/m	85.000	Mu
Condition H 950, 13100 A/m	65.000	Mu
Condition H 950, 17300 A/m	53.000	Mu
Condition H 950, 21000 A/m	46.000	Mu

Magnetic Permeability
Condition H 950

Field Strength H (Oersteds)	Permeability
10.5	52
54.7	127
110.5	85
164.5	65
217.0	53
264.0	46

Typical Mechanical Properties

Typical Cryogenic and Elevated Temperature Tensile Properties
¾" (19-mm) round bar—H 1000 condition



Typical Cryogenic Charpy V-Notch Impact Strength
Longitudinal values

Test Temperature		Condition					
		H 950		H 1000		H 1150M	
°F	°C	ft-lb	J	ft-lb	J	ft-lb	J
Room		24	33	30	41	120+	163+
32	0	11	15	20	27	—	—
-65	-54	7	9	12	16	—	—
-110	-79	5	7	8	11	88	119
-175	-115	3	4	6	8	71	96
-220	-140	2	3	5	7	—	—
-320	-196	2	3	4	5	30	41

Typical Longitudinal Room Temperature Mechanical Properties
Center or intermediate test location

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 2" (50.8mm)	% Reduction of Area	Rockwell C Hardness	Charpy V-Notch Impact Strength		Modulus of Elasticity (E)	
	ksi	MPa	ksi	MPa				ft-lb	J	ksi	MPa
RH 950	215	1482	235	1620	12	45	48	20	27	—	—
H 950	210	1448	225	1551	12	50	47	20	27	—	—
H 1000	205	1413	215	1482	13	55	45	30	41	28.3x10³	195x10³
H 1050	180	1241	190	1310	15	55	43	50	68	—	—
H 1100	150	1034	160	1103	18	60	35	60	81	—	—
H 1150	105	724	145	1000	20	63	33	80	108	—	—
H 1150M	85	586	130	896	22	70	32	120	163	—	—

Typical Notch Tensile Strength as a Function of Notch Concentration and Test Temperature
0.750" (19.1 mm) rd. bar in H 1000 condition.

Test Temperature		Notch Factor K_t	Ultimate Tensile Strength		Notch Tensile Strength		NTS/UTS
°F	°C		ksi	MPa	ksi	MPa	
80	27	3.8	220	1517	354	2441	1.61
		5.3	220	1517	347	2392	1.57
-110	-79	3.8	234	1613	384	2648	1.64
		5.3	234	1613	373	2572	1.59

Typical Room Temperature Compressive Properties

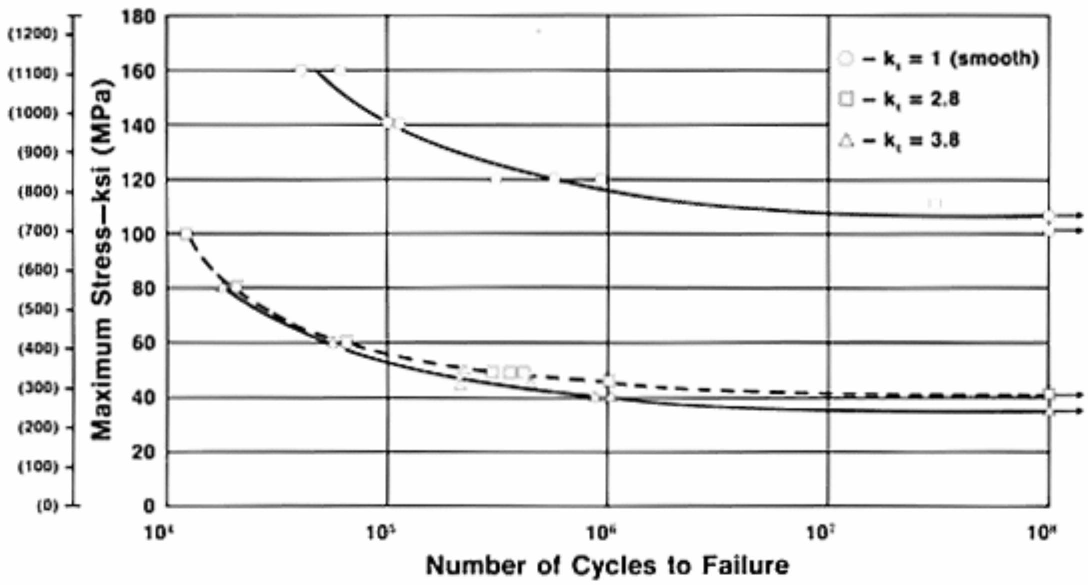
Condition	0.02% Yield Strength*		0.2% Yield Strength*		Compressive Modulus	
	ksi	MPa	ksi	MPa	ksi	MPa
H 950	181	1248	220	1517	29.4x10³	203x10³
H 1000	196	1351	220	1517	29.4x10³	203x10³
H 1050	174	2000	198	1365	29.4x10³	203x10³

*Section: 7/8" (22-mm) round bar

Typical Room Temperature Torsional Properties

Condition	Yield Strength at 0.2% Shear Strain		Yield Strength at 0.2% Normal Strain		Modulus of Rupture		Modulus of Rigidity (G)	
	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
H 950	137	945	148	1020	184	1269	11.1×10^3	76.5×10^3
H 1000	134	924	143	986	172	1186	10.9×10^3	75.2×10^3

Typical Rotating Beam Fatigue Strength
R.R. Moore specimens from ¾" (19-mm) bar—H 1000 condition



Typical Transverse Room Temperature Mechanical Properties
Center or intermediate test location

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 2" (50.8 mm)	% Reduction of Area	Rockwell C Hardness
	ksi	MPa	ksi	MPa			
H 950	210	1448	225	1551	12	40	47
H 1000	205	1413	215	1482	13	50	45
H 1050	180	1241	190	1310	15	55	43
H 1100	150	1034	160	1102	18	60	35
H 1150	105	724	145	1000	20	63	33
H 1150M	85	586	130	896	22	70	32

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

Upon aging, a predictable size change will occur.
Increasing amounts of contraction occur as aging temperature is increased.

Age-Hardening Treatment	Contraction in/in (m/m)
H 950	0.0004 to 0.0006
H 1000	0.0004 to 0.0006
H 1050	0.0005 to 0.0008
H 1100	0.0008 to 0.0012

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.

Typical Machining Speeds and Feeds – Carpenter 13-8 Stainless

The speeds and feeds in the following charts are conservative recommendations for initial setup. Higher speeds and feeds may be attainable depending on machining environment.

Turning—Single-Point and Box Tools

Depth of Cut (Inches)	Micro-Melt® Powder High Speed Tools			Carbide Tools			
	Tool Material	Speed (fpm)	Feed (ipr)	Tool Material	Speed (fpm) Uncoated	Speed (fpm) Coated	Feed (ipr)
Annealed							
.150	M48,T15	72	.015	C6	270	350	.010
.025	M48,T15	84	.007	C7	325	425	.005
Aged							
.150	M48,T15	48	.010	C6	190	250	.010
.025	M48,T15	54	.005	C7	225	290	.005

Turning—Cut-Off and Form Tools

Tool Material		Speed (fpm)	Feed (ipr)						
			Cut-Off and Form Tool Width (Inches)						
Micro-Melt® Powder HS Tools	Carbide Tools		1/16	1/8	1/4	1/2	1	1 ½	2
Annealed									
M48,T15		72	.001	.0015	.002	.0015	.001	.0007	.0005
	C6	216	.003	.005	.007	.005	.004	.0035	.0035
Aged									
M48, T15		36	.001	.001	.0015	.0015	.001	.0005	.0005
	C6	132	.003	.003	.0045	.003	.002	.002	.002

Rough Reaming

Micro-Melt® Powder HS Tools		Carbide Tools (inserts)		Feed (ipr) Reamer Diameter (inches)					
Tool Material	Speed (fpm)	Tool Material	Speed (fpm)	1/8	1/4	1/2	1	1 ½	2
Annealed									
M48, T15	72	C2	190	.003	.005	.008	.011	.015	.018
Aged									
M48, T15	36	C2	100	.001	.001	.001	.001	.001	.001

Drilling

High Speed Tools									
High Speed Tools	Speed (fpm)	Feed (inches per revolution) Nominal Hole Diameter (inches)							
		1/16	1/8	1/4	1/2	3/4	1	1 ½	2
Annealed									
M42	50	.001	.002	.004	.007	.008	.010	.012	.015
Aged									
M42	35	-	.001	.002	.003	.004	.004	.004	.004

Die Threading

FPM for High Speed Tools				
Tool Material	7 or less, tpi	8 to 15, tpi	16 to 24, tpi	25 and up, tpi
Annealed				
M2, M7, M10	5 – 12	8 – 15	10 – 22	15 – 27
Aged				
T15, M42	4 – 8	6 – 10	8 – 12	10 – 15

Milling, End-Peripheral

Depth of Cut (inches)	Micro-Melt® Powder High Speed Tools						Carbide Tools					
	Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)				Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in)			
			1/4	1/2	3/4	1-2			1/4	1/2	3/4	1-2
Annealed												
.050	M48, T15	108	.001	.002	.003	.004	C2	275	.001	.002	.004	.006
Aged												
.050	M48, T15	72	.0005	.001	.002	.003	C2	90	.001	.002	.003	.004

Tapping

High Speed Tools	
Tool Material	Speed (fpm)
Annealed	
M7, M10	12 – 25
Aged	
M7, M10 Nitrided	5 – 15

Broaching

Micro-Melt® Powder High Speed Tools		
Tool Material	Speed (fpm)	Chip Load (ipt)
Annealed		
M48, T15	9.6	.002
Aged		
M48, T15	12	.002

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
- ASME SA705
- ASTM A564 (Grade XM-13)
- ASTM A693 (Grade XM-13)
- ASTM A705 (Grade XM-13)
- MIL-S-2154

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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