

ALLOY Data

Gall-Tough® PLUS Stainless

Identification

U.S. Patent Number

- 5,340,534

UNS Number

- S21800/S20162

Type Analysis

Carbon (Maximum)	0.15 %	Manganese	4.00 to 8.00 %
Phosphorus (Maximum)	0.040 %	Sulfur (Maximum)	0.040 %
Silicon	2.50 to 4.50 %	Chromium	16.50 to 21.00 %
Nickel	6.00 to 10.00 %	Molybdenum	0.50 to 2.50 %
Nitrogen	0.05 to 0.25 %	Iron	Balance

General Information

Description

Gall-Tough® PLUS stainless is a high silicon, high manganese, nitrogen strengthened, austenitic stainless alloy which exhibits superior self-mated galling and metal-to-metal wear resistance.

The alloy possesses higher strength than Type 316. It also exhibits chloride corrosion resistance equal to or better than Type 316, along with equivalent high temperature oxidation resistance.

Applications

Gall-Tough PLUS stainless may be considered for applications in which parts are in relative motion under load without lubricants.

Potential applications include:

- Components in food and drug processing industries
- Bolts, nuts and other fasteners for electronic and nuclear applications
- Fittings for pumps and valves in chemical process industry
- Surgical and analytical instrumentation
- Petrochemical equipment
- Bridge pins
- Aerospace
- Oil field industry

Scaling

The safe scaling temperature for continuous service is 1800°F (982°C).

Corrosion Resistance

Gall-Tough PLUS stainless is resistant to atmospheric corrosion. Its resistance to some acids and corrosive environments is comparable to that of Type 316. Its chloride corrosion resistance is equal to or better than Type 316.

Intergranular corrosion resistance may be impaired if the material is heated between 800/1650°F (427/899°C) or cooled slowly through that range.

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

Typical Corrosion Properties—Gall-Tough PLUS Stainless
 Annealed 2100°F (1150°C), water quenched and cold drawn.

Environment	Time of Test	Average Corrosion Rate (mpy)		
		Gall-Tough PLUS Stainless	Gall-Tough Stainless	Type 316
6%FeCl ₃ -RT-No Crevice	1-72h period	0.1 mg/cm ²	19.5 mg/cm ²	16.5 mg/cm ²
6%FeCl ₃ -0°C-Crevice	1-72h period	0.0 mg/cm ²	0.1 mg/cm ²	2.5 mg/cm ²
6%FeCl ₃ +1%HCl-0°C-No Crevice	72h period until pitting	25°C*	15°C*	10°C*
10 w/o H ₂ SO ₄	1-48h period	0.8 mpy	14.5 mpy	0.5 mpy
1 w/o HCl-RT	1-48h period	5 mpy	34 mpy	6 mpy
65% HNO ₃ -boiling	5-48h periods	47.5 mpy	82 mpy	37 mpy

*5°C intervals.

Properties

Physical Properties

Specific Gravity

-- 7.60

Density

-- 0.2740 lb/in³

Mean Specific Heat

120 °F, 210 °F 0.1210 Btu/lb/°F

Mean Coefficient of Thermal Expansion

77.00 °F, 122.0 °F 7.88 x 10⁻⁶ in/in/°F

77.00 °F, 212.0 °F 8.68 x 10⁻⁶ in/in/°F

77.00 °F, 302.0 °F 9.13 x 10⁻⁶ in/in/°F

77.00 °F, 392.0 °F 9.30 x 10⁻⁶ in/in/°F

77.00 °F, 482.0 °F 9.48 x 10⁻⁶ in/in/°F

77.00 °F, 572.0 °F 9.62 x 10⁻⁶ in/in/°F

77.00 °F, 662.0 °F 9.74 x 10⁻⁶ in/in/°F

77.00 °F, 752.0 °F 9.87 x 10⁻⁶ in/in/°F

77.00 °F, 842.0 °F 9.95 x 10⁻⁶ in/in/°F

77.00 °F, 932.0 °F 10.0 x 10⁻⁶ in/in/°F

77.00 °F, 1022 °F 10.2 x 10⁻⁶ in/in/°F

77.00 °F, 1112 °F 10.3 x 10⁻⁶ in/in/°F

77.00 °F, 1202 °F 10.4 x 10⁻⁶ in/in/°F

Mean coefficient of thermal expansion

Test Temperature		10 ⁻⁶ /°F	10 ⁻⁶ /K
77°F to	25°C to		
122	50	7.88	14.19
212	100	8.68	15.63
302	150	9.13	16.43
392	200	9.30	16.74
482	250	9.48	17.06
572	300	9.62	17.32
662	350	9.74	17.54
752	400	9.87	17.76
842	450	9.95	17.91
932	500	10.04	18.07
1022	550	10.17	18.31
1112	600	10.30	18.54
1202	650	10.39	18.71

Thermal Conductivity

73 °F	83.16 BTU-in/hr/ft ² /°F
212 °F	91.11 BTU-in/hr/ft ² /°F
392 °F	102.5 BTU-in/hr/ft ² /°F
572 °F	114.8 BTU-in/hr/ft ² /°F
752 °F	126.1 BTU-in/hr/ft ² /°F
932 °F	141.0 BTU-in/hr/ft ² /°F

Thermal conductivity

Test Temperature		Btu-in/ft ² ·h·°F	W/m·K
°F	°C		
73	23	83.16	12.00
212	100	91.11	13.14
392	200	102.53	14.79
572	300	114.78	16.56
752	400	126.12	18.19
932	500	141.04	20.34

Modulus of Elasticity (E)

--	26.8 x 10 ³ ksi
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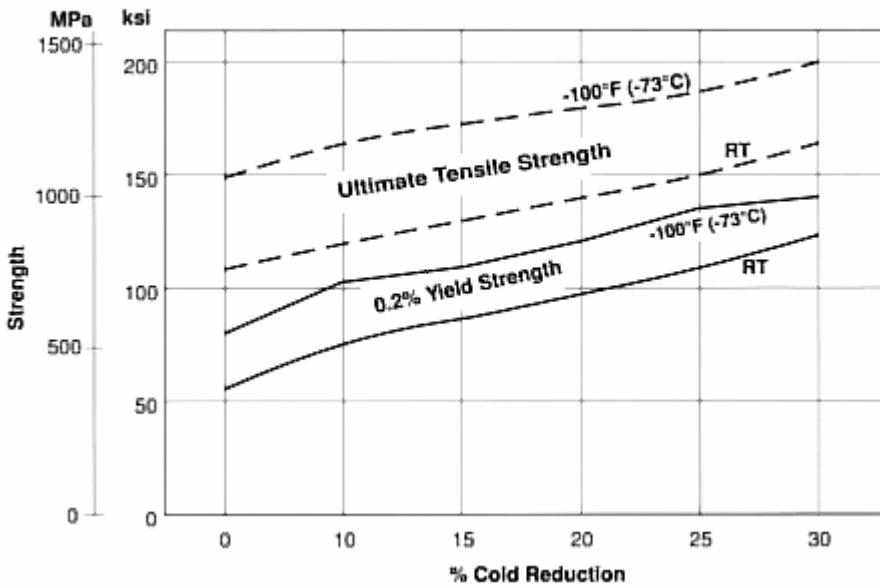
Electrical Resistivity

70.0 °F	570.0 ohm-cir-mil/ft
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Typical Mechanical Properties

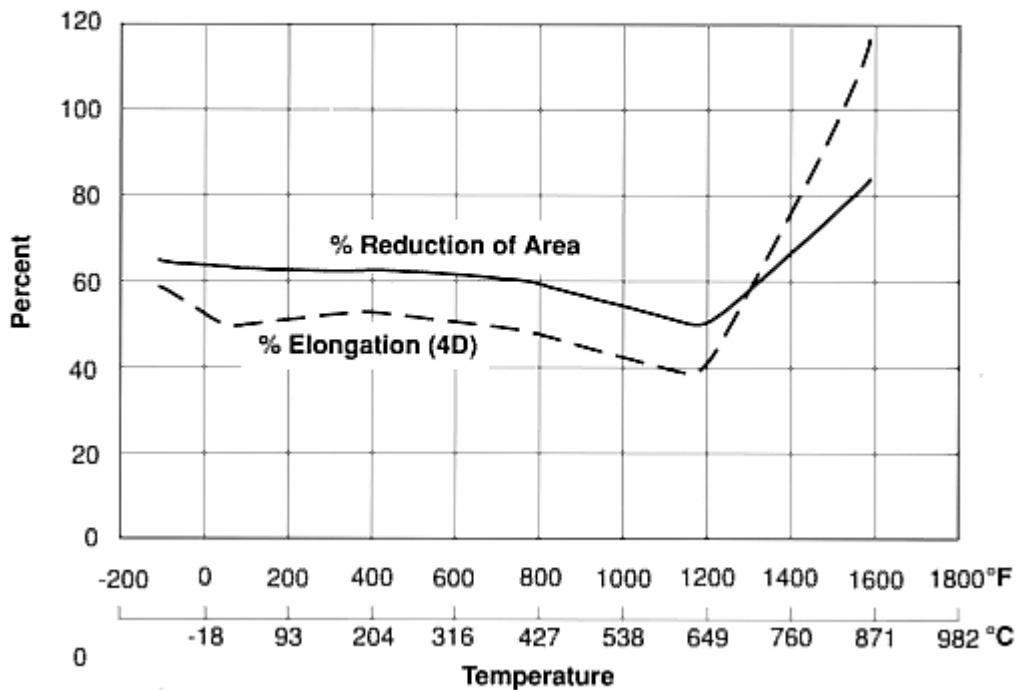
Typically, the rotating beam fatigue strength of annealed Gall-Tough PLUS stainless is 40.0 ksi (293 MPa) for 10⁷ cycles.

Effect of Cold Reduction on Tensile Properties—Gall-Tough PLUS Stainless Bar product at room temperature and -100°F (-73°F).



Percent Elongation and Reduction of Area at Various Test Temperatures—Gall-Tough PLUS Stainless

1.00" (25.4 mm) diameter bar annealed 1950°F (1066°C) 1 hour, water quenched and ground.



Typical Charpy-V-Notch Impact Strength—Gall-Tough PLUS Stainless

1.00" (25.4 mm) diameter bar annealed 1950°F (1066°C) 1 hour, water quenched.

Test Temperature		Impact Strength	
°F	°C	ft-lbs	J
Room Temperature		299	404
-100	-73	251	339

Typical Elevated Temperature Tensile Properties—Gall-Tough PLUS Stainless
 0.252" (6.4 mm) diameter tensile specimens from center of 1" diameter (25.4 mm) bar
 annealed 1950°F (1066°C) 1 hour, water quenched and ground.

Temperature		0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area
°F	°C	ksi	MPa	ksi	MPa		
	R.T.	61	423	113	783	59	72
400	204	32	222	92	638	63	73
800	427	30	208	87	603	58	70
1200	649	29	201	71	492	48	60
1600	871	21	146	23	160	124	93

Typical Room Temperature and Cryogenic Tensile Properties—Gall-Tough PLUS Stainless

Annealed 2100°F (1150°C), water quenched and cold drawn.

Percent Cold Reduction	Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area
	°F	°C	ksi	MPa	ksi	MPa		
0	Room Temp.		56	386	108	744	64	74
0	-100	-73	80	551	149	1027	68	75
10	Room Temp.		79	544	120	827	50	70
10	-100	-73	104	717	166	1144	56	69
15	Room Temp.		86	593	129	889	41	68
15	-100	-73	109	751	172	1185	49	68
20	Room Temp.		98	675	141	972	34	67
20	-100	-73	121	834	180	1241	38	66
25	Room Temp.		108	744	149	1027	30	65
25	-100	-73	136	937	184	1268	31	65
30	Room Temp.		124	855	164	1130	24	63
30	-100	-73	140	965	200	1378	23	64

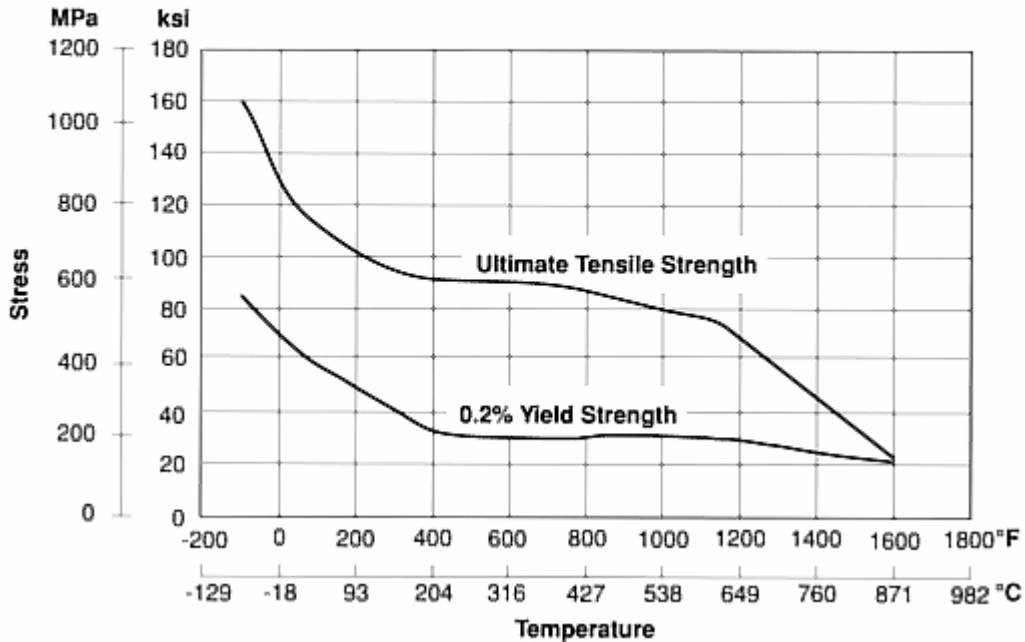
Typical Room Temperature Tensile Properties—Gall-Tough PLUS Stainless

Annealed bar 2100°F (1150°C), water quenched.

Section Size	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area
	ksi	MPa	ksi	MPa		
0.5" (12.7 mm) rd.	69	476	113	779	69	68
2.0" (50.8 mm) rd.	59	407	109	751	64	74
4.0" (101.6 mm) rd.	56	386	107	737	65	74
8.0" (203.2 mm) rd.	57	393	109	751	55	49

Typical Tensile and Yield Strengths at Various Test Temperatures— Gall-Tough PLUS Stainless

1.00" (25.4 mm) diameter bar annealed 1950°F (1066°C) 1 hour, water quenched and ground.



Heat Treatment

Annealing

Heat to 1950/2150°F (1066/1177°C) and quench in water. Typically, hardness as annealed is Rockwell B90-95.

Hardening

Gall-Tough PLUS stainless cannot be hardened by heat treatment; however, this material can be hardened through cold work.

Workability

Hot Working

Gall-Tough PLUS stainless can be readily forged, hot rolled, hot headed and upset.

For hot working, heat uniformly to 2100/2300°F (1149/1260°C). Preheating to an intermediate temperature is not required. Do not forge below 1700°F (927°C). Forgings can be air cooled without danger of cracking.

For maximum corrosion resistance, annealing after hot working is required.

Cold Working

Gall-Tough PLUS stainless is readily cold worked by conventional methods.

Strength and hardness are increased by cold working. The increase in magnetic permeability for a given cold reduction is much less than that of Gall-Tough stainless or Type 304, and equivalent to that of Type 316.

Alloy	20%CR	50%CR
Gall-Tough PLUS	<1.02	<1.20
Gall-Tough	>8	>8
Type 304	<1.2	>8

Machinability

Gall-Tough PLUS stainless machines at about 50% of the rates used for Type 304 or Type 316 stainless. Its machinability is similar to or slightly better than that of other nitrogen-strengthened alloys, like 22Cr-13Ni-5Mn stainless. A rigid setup, heavy positive feeds, and

ample coolant flow are recommended.

Weldability

Gall-Tough PLUS stainless can be satisfactorily welded by the shielded fusion and resistance welding processes. Oxyacetylene welding is not recommended since carbon pickup in the weld may occur.

When a filler metal is required, consider AWS E/ER209 welding consumables which should provide welds with strength approaching that of the base metal. If high weld strength is not necessary, then consider E/ER309.

Resistance to intergranular corrosion can be restored by a postweld annealing treatment.

Other Information

Wear Resistance

When compared to other standard stainless steels, the self-mated galling resistance and metal-to-metal wear resistance of Gall-Tough PLUS stainless are outstanding. Optimum galling resistance is obtained when both mating components are made of Gall-Tough PLUS stainless.

Galling and Wear Test Properties—Various Alloys

Galling test involves rotating a compressively loaded ½" (12.7 mm) diameter button against a block counterclockwise 360°, clockwise 360°, and counterclockwise 360° and determining the highest stress at which visible galling damage does not occur. Metal-to-metal wear tests were conducted for 40,000 cycles using crossed metal cylinders per ASTM G83.

Alloy	Galling Test		Wear Test	
	Threshold Galling Stress		Avg. Total Volume Loss, mm ³	
	ksi	MPa	100 rpm	400 rpm
Gall-Tough [®] Stainless	15*	103*	5	4
Gall-Tough PLUS Stainless	7	48	10.6	4
16Cr-8Ni-4Si-8Mn	7	48	12.1	5.2
Type 316	<1**	7**	61.3	42
Type 304	<1**	7**	29	25

* Testing at higher stress not performed

** Galled at lowest stress evaluated

Forms Manufactured

- Bar-Flats
- Bar-Rounds
- Sheet
- Wire
- Bar-Hexagons
- Billet
- Strip

Technical Articles

- Selecting Alloys for Severely Corrosive Environments
- Selecting Stainless Steels for Valves
- Two Galling Resistant Stainless Steels Used for Bridge Hinge Pins
- Unique Properties Required of Alloys for the Medical and Dental Products Industry

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