Gall-Tough® Stainless

Identification

U.S. Patent Number

- 4,814,140

UNS Number

- S20161

Type Analysis

Carbon (Maximum)	0.15 %	**Manganese**	4.00 to 6.00 %
Phosphorus (Maximum)	0.040 %	**Sulfur (Maximum)**	0.040 %
Silicon	3.00 to 4.00 %	**Chromium**	15.00 to 18.00 %
Nickel	4.00 to 6.00 %	**Nitrogen**	0.08 to 0.20 %
Iron	Balance		

General Information

Description

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

This alloy displays higher strength and high temperature oxidation resistance than Type 304 stainless with comparable corrosion resistance, depending on the environment.

Applications

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

Potential applications include:

- Chain link conveyer belts and other 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

- Bridge pins

- Aerospace

- Oil field industry

Scaling

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

Corrosion Resistance

Gall-Tough stainless is resistant to atmospheric corrosion. Its resistance to some acids and corrosive environments is comparable to that of Type 304 stainless and superior to that of Type 430 stainless.

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

Typical Corrosion Properties—Gall-Tough Stainless
Annealed condition

Environment	Time of Test	Average Corrosion Rate (mpy)		
		Gall-Tough Stainless	Type 304	Type 430
5 w/o H_2SO_4–RT	1-48h period	18	12	1300
50 w/o acetic acid–boiling	1-48h period	0	0	8
1 w/o HCl–RT	1-48h period	34	7	246
5 w/o formic acid–176°F(80°C)	1-48h period	41	0	694
65 w/o HNO_3–boiling	5-48h periods	82	59	46

Properties

Physical Properties

Specific Gravity	
--	7.65
Density	
--	0.2760 lb/in³
Mean Specific Heat	
130 °F, 220 °F	0.1230 Btu/lb/°F
Mean Coefficient of Thermal Expansion	
77.00 °F, 212.0 °F	9.60 x 10^{-6} in/in/°F
77.00 °F, 302.0 °F	9.66 x 10^{-6} in/in/°F
77.00 °F, 392.0 °F	9.74 x 10^{-6} in/in/°F
77.00 °F, 482.0 °F	9.85 x 10^{-6} in/in/°F
77.00 °F, 572.0 °F	9.93 x 10^{-6} in/in/°F
77.00 °F, 662.0 °F	10.0 x 10^{-6} in/in/°F
77.00 °F, 752.0 °F	10.1 x 10^{-6} in/in/°F
77.00 °F, 842.0 °F	10.2 x 10^{-6} in/in/°F
77.00 °F, 932.0 °F	10.3 x 10^{-6} in/in/°F
77.00 °F, 1022 °F	10.4 x 10^{-6} in/in/°F
77.00 °F, 1112 °F	10.5 x 10^{-6} in/in/°F
77.00 °F, 1202 °F	10.5 x 10^{-6} in/in/°F
77.00 °F, 1292 °F	10.6 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		
212	100	9.60	17.28
302	150	9.66	17.38
392	200	9.74	17.54
482	250	9.85	17.73
572	300	9.93	17.87
662	350	10.01	18.02
752	400	10.13	18.24
842	450	10.23	18.41
932	500	10.29	18.53
1022	550	10.36	18.65
1112	600	10.46	18.83
1202	650	10.54	18.98
1292	700	10.63	19.14

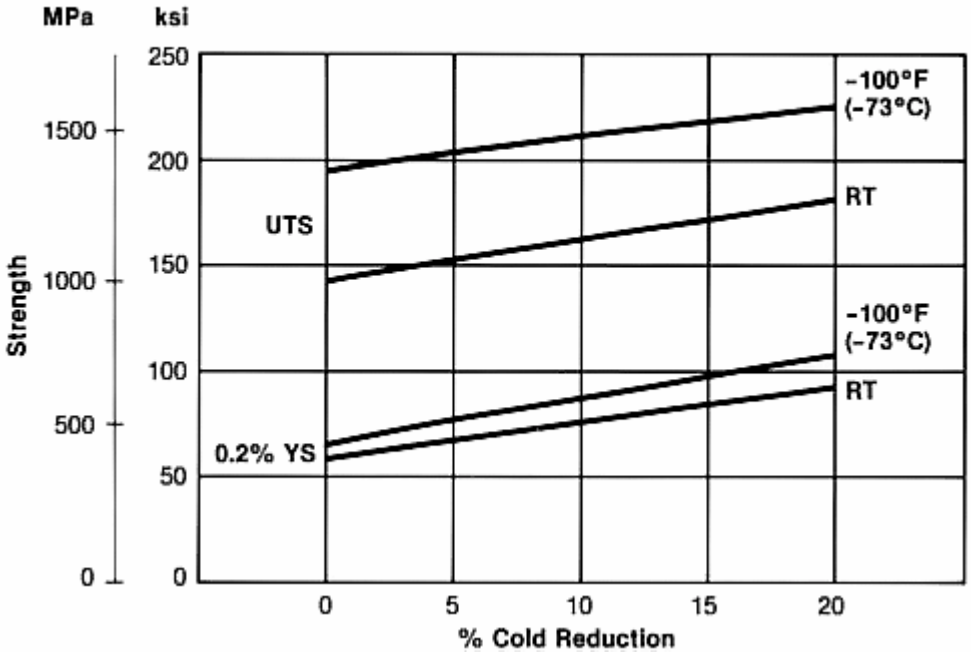
Thermal Conductivity	
122 °F	84.72 BTU-in/hr/ft²/°F
212 °F	93.56 BTU-in/hr/ft²/°F
392 °F	106.3 BTU-in/hr/ft²/°F
572 °F	118.1 BTU-in/hr/ft²/°F
752 °F	128.9 BTU-in/hr/ft²/°F

Thermal conductivity

Test Temperature		Btu·in/ft²•h•°F	W/m•K
°F	°C		
122	50	84.72	12.22
212	100	93.56	13.49
392	200	106.25	15.33
572	300	118.10	17.03
752	400	128.93	18.60

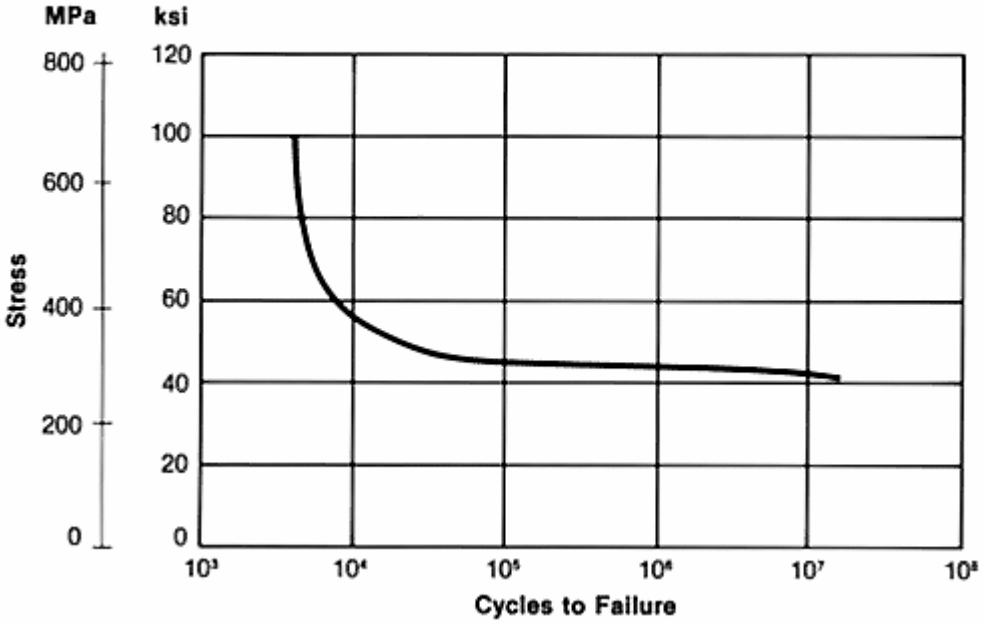
Modulus of Elasticity (E)	
--	24.8 x 10^3 ksi
Electrical Resistivity	
70.0 °F	431.0 ohm-cir-mil/ft
Typical Mechanical Properties	

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



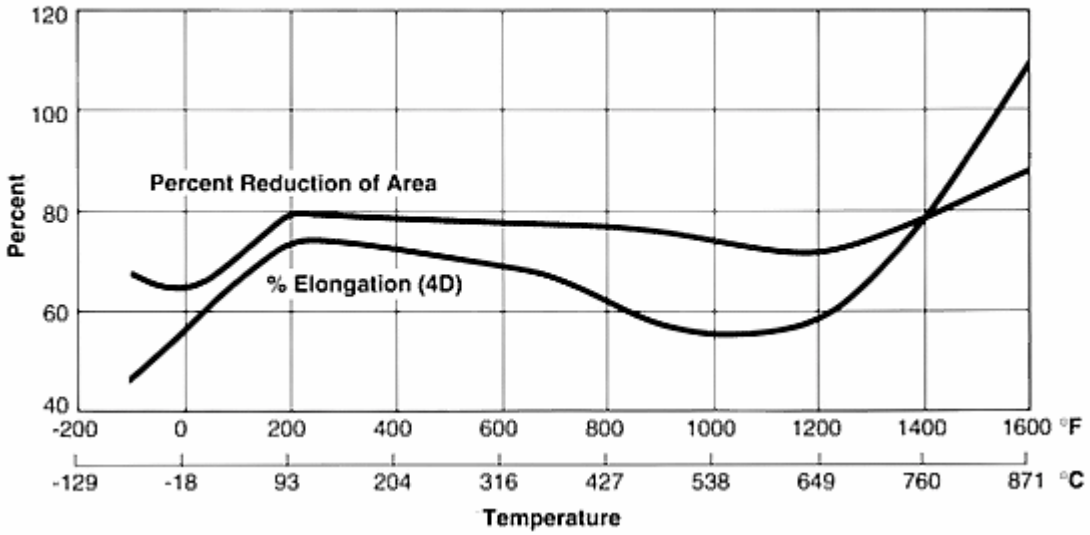
Fatigue Data—Gall-Tough Stainless

Typically, the rotating beam fatigue strength of annealed Gall-Tough stainless is 42.5 ksi (293 MPa) for 10^7 cycles.



Percent Elongation and Reduction of Area – Gall-Tough Stainless

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



Typical Elevated Temperature Mechanical Properties – Gall-Tough 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.		60	414	161	1110	63	67
200	93	45	310	105	724	74	80
300	149	39	269	96	662	70	78
400	204	34	234	88	608	68	77
500	260	31	214	86	593	69	76
600	316	30	207	84	579	69	76
700	371	30	207	82	565	67	77
800	427	29	200	79	545	62	77
900	482	28	193	77	531	56	76
1200	649	25	172	59	407	58	70
1600	871	19	131	20	138	109	90

Typical Room Temperature and Cryogenic Mechanical Properties – Gall-Tough Stainless

Annealed and cold drawn bar.

Percent Cold Work	Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	Charpy V-Notch Impact Strength	
	°F	°C	ksi	MPa	ksi	MPa			ft-lb	J
0	Room Temp		55	379	142	979	59	59	240	325
0	-100	-73	65	448	195	1344	47	68	240	325
10	Room Temp		75	517	160	1103	45	54	90-165	122-224
10	-100	-73	85	586	209	1441	41	60	152-240	206-325
20	Room Temp		89	614	181	1248	35	50	101-240	137-325
20	-100	-73	107	738	223	1538	36	64	85-109	115-148

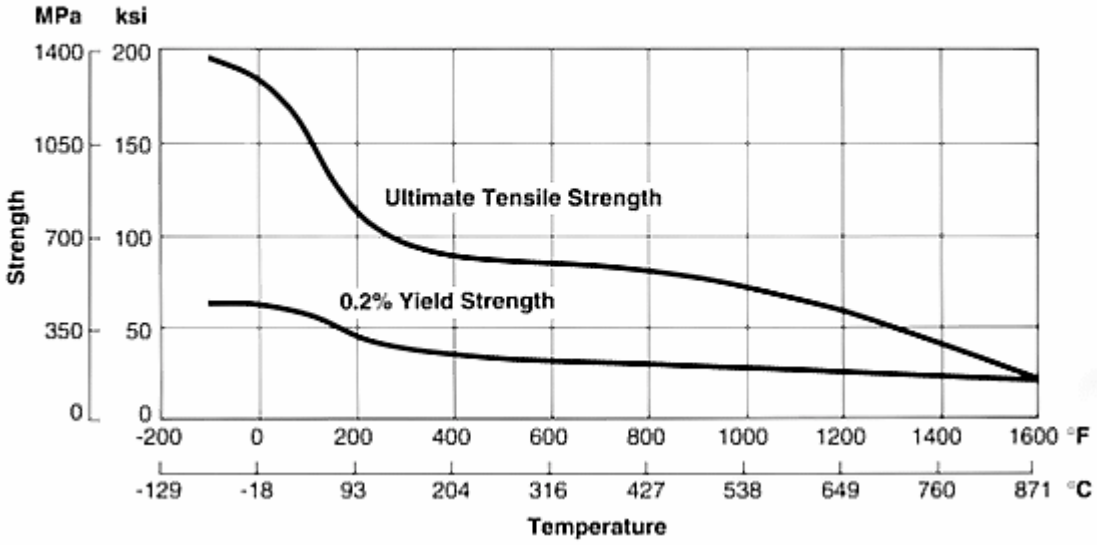
Typical Room Temperature Mechanical Properties – Gall-Tough Stainless

Annealed bar and wire

Section Size	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	Rockwell B Hardness
	ksi	MPa	ksi	MPa			
1" (25.4 mm) rd.	53	365	145	1000	59	64	93
.250" (6.35 mm) rd.	66	455	156	1076	70	73	93

Typical Tensile and Yield Strengths – Gall-Tough Stainless

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



Heat Treatment

Annealing

Heat to 1900/2000 °F (1038/1093 °C) and quench in water. Typically, hardness as annealed is Rockwell B95.

Hardening

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

Workability

Hot Working

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

Cold working causes martensitic transformation in Gall-Tough stainless, resulting in a significant increase in magnetic permeability.

Because of its metastability, Gall-Tough stainless is characterized by a high tensile strength in both annealed and cold worked conditions.

Machinability

Gall-Tough stainless machines at about 50% of the rates used for Type 304 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 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/ER240 welding consumables which should provide welds with strength approaching that of the base metal. If high weld strength is not necessary, then consider E/ER308.

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 stainless are outstanding. Optimum galling resistance is obtained when both mating components are made of Gall-Tough stainless.

Galling and Wear Test Properties—Various Alloys

Galling test involves rotating a compressively loaded 1/2″ (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,mm³	
	ksi	MPa	100 rpm	400 rpm
Gall-Tough Stainless	15*	103*	5	4
16Cr-8Ni-4Si-8Mn	7	48	12.1	5.2
Type 440C (HRC 56)	2	14	1.3	1.1
Type 304	<1**	7**	29	25
Type 430	<1**	7**	230	172

*Testing at higher stress not performed
**Galled at lowest stress evaluated

Applicable Specifications

- ASTM A240
- ASTM A276
- ASTM A314
- ASTM A479
- ASTM A580

Forms Manufactured

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

Technical Articles

- Selecting Alloys for Severely Corrosive Environments
- Selecting Stainless Steels for Valves
- Specialty Stainless Solves Galling, Contamination Problems of Threaded Parts for

Semiconductor Industry

- 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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Edition Date: 11/01/1993

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