CORROSION-RESISTANT ALLOYS

LION® G-30® ALLOY

cial phosphoric, sulfuric, nitric/hydrochloric, nitric/hydrofluoric acids and other complex environments containing highly oxidizing acids.

Contents

H-2028D

PRINCIPAL FEATURES

Superior Corrosion Resistance to Commercial Phosphoric Acids and Oxidizing Acid Mixtures

LIONG-30® alloy is a high chromium nickel-base alloy which shows superior corrosion resistance over most other nickel- and iron-base alloys in commercial phosphoric acids as well as many complex environments containing highly oxidizing acids such as nitric/hydrochloric, nitric/hydrofluoric and sulfuric acids.

The resistance of G-30 alloy to the formation of grain boundary precipitates in the heat-affected zone makes it suitable for use in most chemical process applications in the as-welded condition.

Product Forms

LION G-30 alloy is available in the form of plate, sheet, strip, billet, bar, wire, covered electrodes, pipe and tubing.

Some Typical Applications

- Phosphoric Acid Service
- Sulfuric Acid Service
- Nitric Acid Service
- Nuclear Fuel Reprocessing
- Nuclear Waste Processing
- Pickling Operations
- Petrochemicals
- Fertilizer Manufacture
- Pesticide Manufacture
- Gold Ore Extraction

Field Test Program

Samples of G-30 alloy are readily available for laboratory or inplant corrosion testing. Analysis of corrosion resistance of the tested material can also be performed and the results provided to the customer as a free technical service. Try testing LION G-30 alloy. Just contact any of the convenient locations shown on the back cover of this brochure.

ASME Boiler and Pressure Vessel Code

LION G-30 alloy plate, sheet, strip, pipe, tubing and fittings are covered by ASME product specifications SB581, SB582, SB619, SB622, SB626 and SB366 under UNS number N06030.

CHEMICAL COMPOSITION, PERCENT*

Ni[a]	Co	Cr	Mo	W	Fe	Si*	Mn	C*	Others
43	5.0**	28.0-31.5	4.0-6.0	1.5-4.0	13.0-17.0	0.8**	1.5**	0.03**	Cb + Ta = 0.3-1.5 Cu = 1.0-2.4 P = 0.04** S = 0.02**

*The undiluted deposited chemical composition of G-30 alloy covered electrodes has 0.04 percent carbon and 1.0 percent silicon.
**Maximum.
[a] As-balance

TYPICAL APPLICATIONS

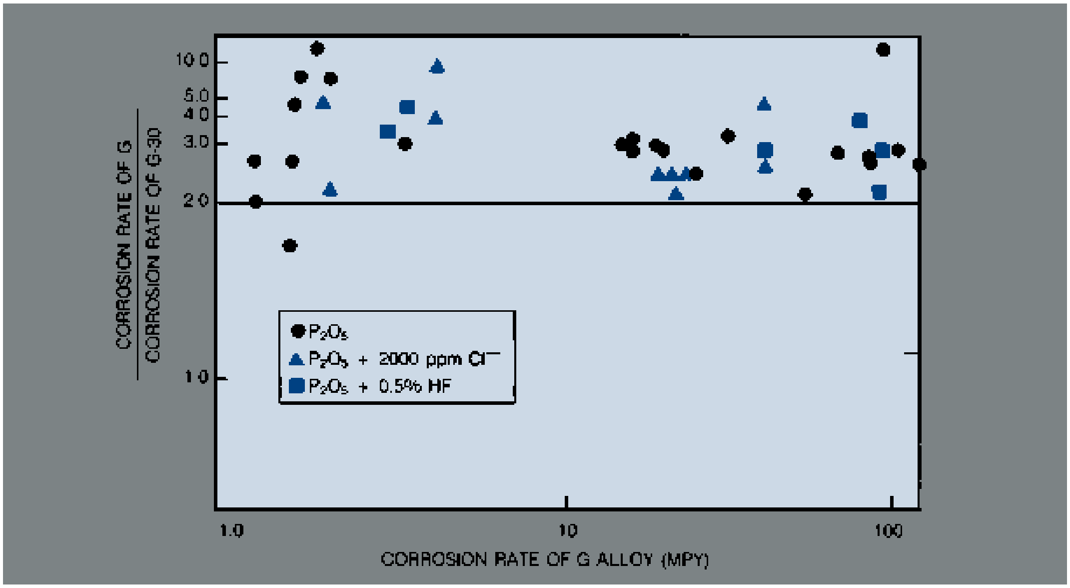
LION® G-30® alloy has outstanding resistance to hydrofluoric/nitric acid mixtures such as employed in the pickling of stainless steel. This particular operation involves aerated, 15% HNO_3 and 5% HF at 140 deg. F. (60 deg. C)

LIONG-30 alloy exhibits excellent resistance to commercial phosphoric acid. Its use is growing in the fertilizer industry for acid evaporators.

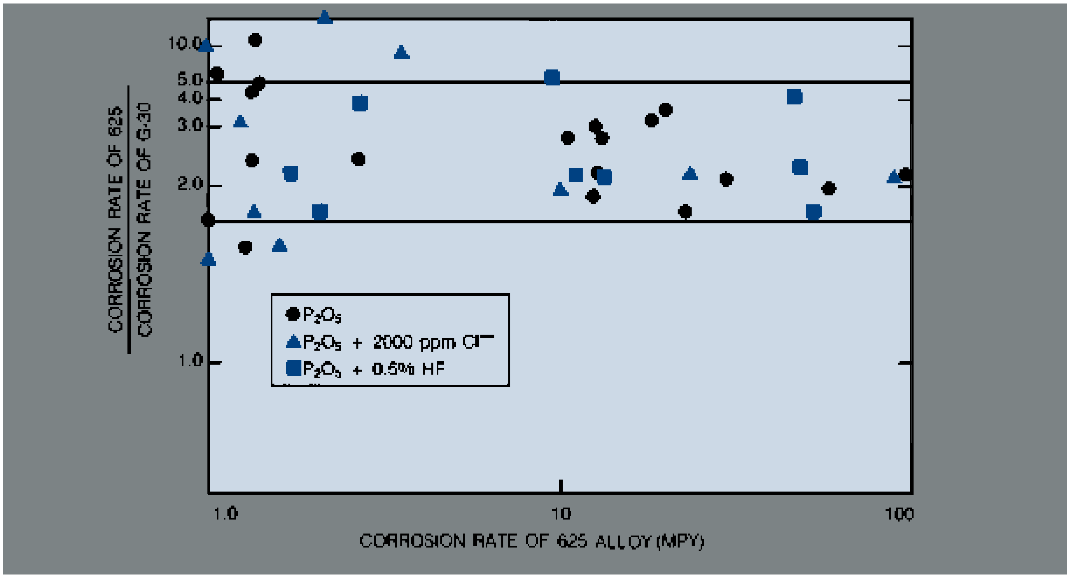
COMPARATIVE CORROSION RESISTANCE IN COMMERCIAL PHOSPHORIC ACID

The comparative corrosion resistance of LION G-30 and G alloys or 625 alloy in commercial phosphoric acid, is shown below. The corrosivity of commercial phosphoric acid is a function of several variables such as concentration, temperature, impurity levels and origin of the phosphate rock. Wide variations in corrosion rates are possible in acids of the same concentration but from different sources. Hence, corrosion tests were conducted in acids from a number of suppliers and the performance of G-30 alloy relative to LION G alloy and 625 alloy is shown as a function of the corrosion rate of G alloy and 625 alloy respectively. In general, G-30 alloy performs 2-10 times better than G alloy or 625 alloy in acids of corrosivity corresponding to corrosion rates in the range of one to one hundred mils per year.

RATIO OF CORROSION RATES OF G ALLOY/G-30 ALLOY FOR VARIOUS CONDITIONS



RATIO OF CORROSION RATES OF 625 ALLOY/G-30 ALLOY FOR VARIOUS CONDITIONS



COMMERCIAL PHOSPHORIC ACID* CORROSION DATA

Media	Temp., °F (°C)		Average Corrosion Rate per year, mils**			
			G-30® alloy	625 alloy	G-3 alloy	Sanicro 28
28% P_2O_5 + 2000 ppm $C1^-$	185	(85)	1.0	1.5	0.9	31
42% P_2O_5 + 2000 ppm $C1^-$	185	(85)	0.9	1.3	11	121
44% P_2O_5	241	(116)	7.0	23	22	—
44% P_2O_5 + 2000 ppm $C1^-$	241	(116)	7.7	25	22	—
44% P_2O_5 + 0.5% HF	241	(116)	16	60	49	—
52% P_2O_5	241	(116)	3.9	12	11	48
52% P_2O_5	300	(149)	28	79	64	248
54% P_2O_5	241	(116)	8	16	16	55
54% P_2O_5 + 2000 ppm $C1^-$	241	(116)	7	15	16	92

*Acid obtained from several plant sites. **To convert mils per year (mpy) to mm per year, divide by 40.

COMPARATIVE ACID CORROSION DATA

Media	Concen-tration, percent by weight	Test Temp., °F (°C)	Average Corrosion Rate per year, mils*		
			G-30 alloy	G-3 alloy	625 alloy
Acetic Acid	99	Boiling	1	0.6	<1
Formic Acid	88	Boiling	2	5	9
Nitric Acid	10	Boiling	0.4	0.9	1
	60	Boiling	5.3	8.5	16
	65	Boiling	5	11	20
Nitric Acid + 1% HF	20	176 (80)	31	74	123
Nitric Acid + 6% HF	20	176 (80)	177	540	2400
Nitric Acid + 1% HF	50	176 (80)	192	420	—
Nitric Acid + 0.5% HF	56	230 (110)	47	110	—
Nitric Acid + 0.5% HF + 2000 ppm Cl^-	56	230 (110)	50	113	—
Sulfuric Acid + 10% Nitric Acid	50	Boiling	16	30	—
Sulfuric Acid	2	Boiling	8	6	6
	10	Boiling	31	19	46, 25
	20	Boiling	54	30	124, 91
	50	225 (107)	37	37	223
	80	125 (52)	12	23	33
	99	266 (130)	43	74	—
	99	284 (140)	46	57	—
Sulfuric Acid + 42 g/l $Fe_2(SO_4)_3$ (ASTM G28A)	50	Boiling	7	11	23,17
Sulfuric Acid + 5% Nitric Acid	70	Boiling	133	240	—
Sulfuric Acid + 5% Nitric Acid	60	Boiling	45	84	105
Sulfuric Acid + 8% Nitric Acid + 4% HF	77	129 (54)	0.4	1.5	—
Nitric Acid + 8% HCl	18	176 (80)	2	18	6
Nitric Acid + 11% HCl	25	176 (80)	23	914	126
Nitric Acid + 3% HCl	59	176 (80)	5	34	20

*To convert mils per year (mpy) to mm per year, divide by 40.

EFFECT OF AGING ON CORROSION RESISTANCE

Aging Temp.,		Average Corrosion Rate in 20% HNO_3 + 6% HF at 176°F (80°C) per year, mils*					
		Aging Time					
		1 Hour			10 Hours		
°F	(°C)	G alloy	G-3 alloy	G-30® alloy	G alloy	G-3 alloy	G-30 alloy
1200	(649)	860	438	223	3890	575	272
1400	(760)	12000	860	230	19000	2660	1600
1600	(871)	19000	2145	177	20000	4375	454
1800	(982)	19000	577	338	19000	640	427

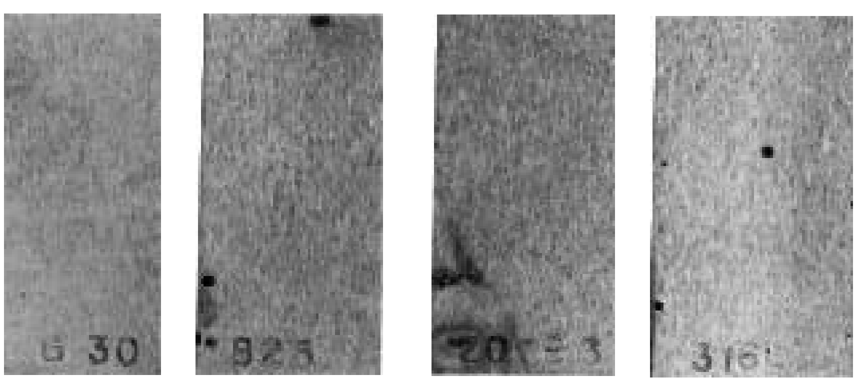
Base line corrosion rates on annealed samples from the same heat are alloy G—1075, alloy G-3—634, alloy G-30—230.
*To convert mils per year (mpy) to mm per year, divide by 40.

COMPARATIVE IMMERSION PITTING TEMPERATURES IN OXIDIZING ACIDIC CHLORIDE SOLUTION

The chemical composition of the solution used in this test is as follows: 4% NaCl + 0.1% $Fe_2(SO_4)_3$ + 0.01 M HCl. This solution contains 24,300 ppm chlorides and is acidic (pH2). The solution temperature was varied in 5°C increments to determine the lowest temperature at which pitting corrosion initiated (observed by examination at a magnification of 40X on duplicate samples) after a 24-hour exposure period (Critical Pitting Temperature).

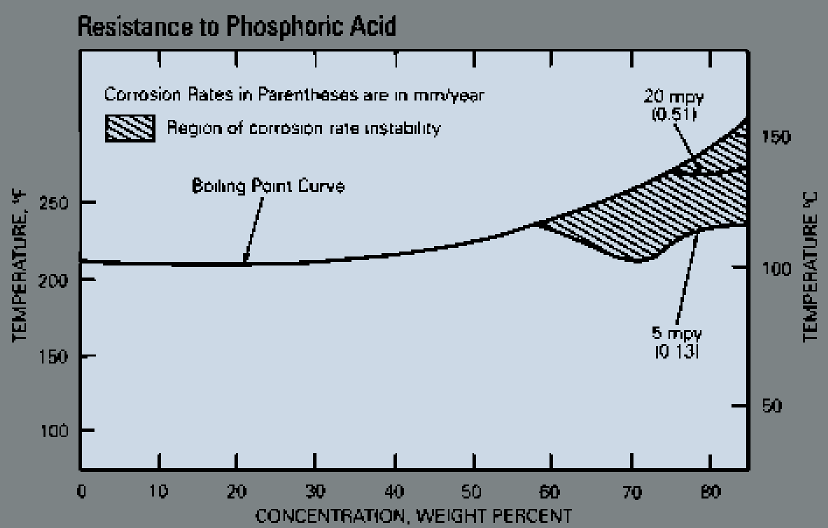
Alloy	Critical Pitting Temperature, °C	(°F)
LION® G-30® alloy	70	(158)
LION G-3 alloy	70	(158)
Alloy No. 904L	45	(113)
Type 317LM Stainless Steel	35	(95)
Type 317L Stainless Steel	25	(77)
Alloy 825	25	(77)
20 Cb-3* alloy	20	(68)
Type 316 Stainless Steel	20	(68)

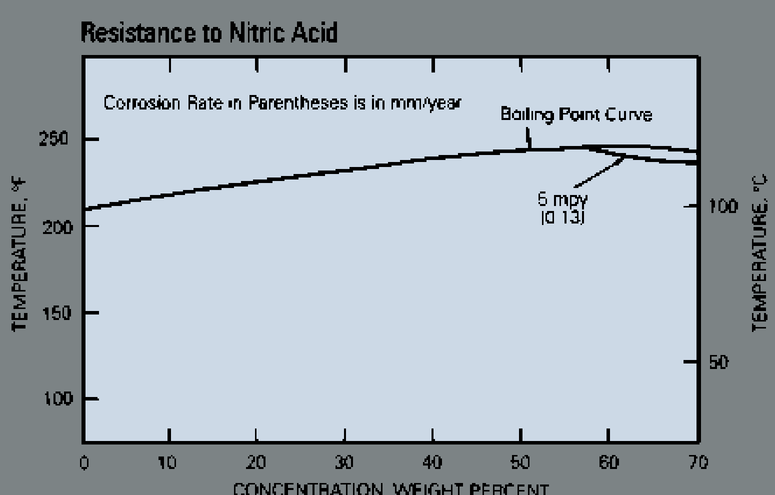
*Trademark of Carpenter Technology Corporation.



All four of these alloys were immersed in 4% NaCl + 0.1% $Fe_2(SO_4)_3$ + 0.01M HCl at 122 deg. F (50°C) for 48 hours. LION G-30 alloy was the only one not to pit.

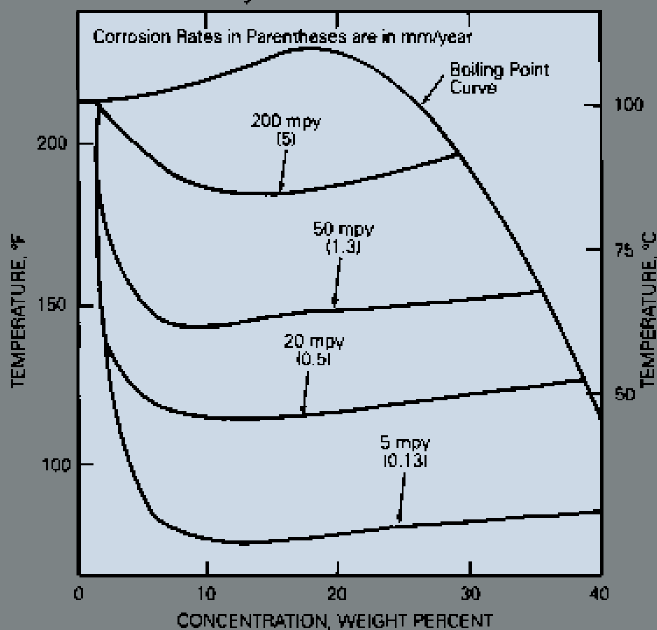
The isocorrosion diagrams shown on this and subsequent pages were plotted using data obtained in laboratory tests in reagent grade acids. These data should be used only as a guide. It is recommended that samples be tested under actual plant conditions.



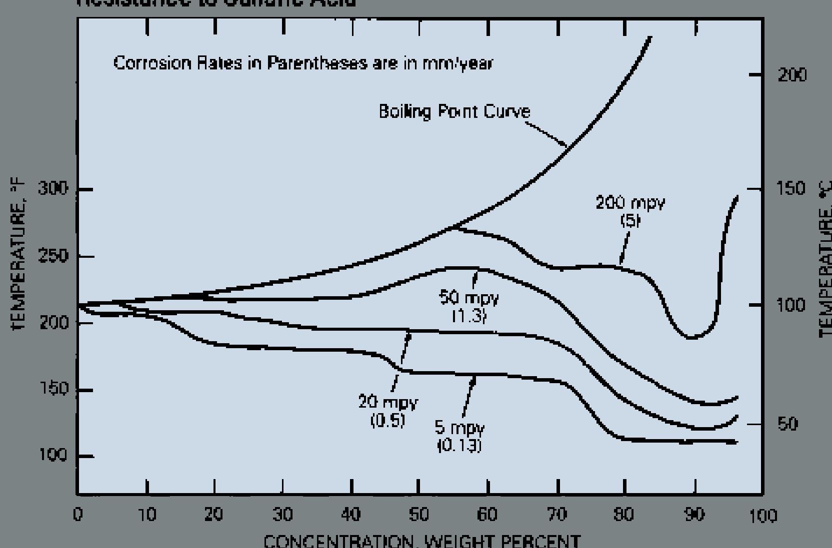


*All test specimens were heat-treated at 2150°F (1177°C), rapid quenched and in the unwelded condition.

Resistance to Hydrochloric Acid



Resistance to Sulfuric Acid



PHYSICAL PROPERTIES

	Temp., °F	British Units	Temp., °C	Metric Units
Density	70	0.297 lb./in.^{3}	22	8.22 gm/cm^3
Electrical Resistivity	75	45.7 microhm-in.	24	1.16 microhm-m
	212	46.1 microhm-in.	100	1.17 microhm-m
	392	46.9 microhm-in.	200	1.19 microhm-m
	572	47.6 microhm-in.	300	1.21 microhm-m
	752	48.4 microhm-in.	400	1.23 microhm-m
	932	48.8 microhm-in.	500	1.24 microhm-m
	1112	49.2 microhm-in.	600	1.25 microhm-m
Thermal Conductivity	75	71 Btu-in./ft.^{2}-hr.-°F	24	10.2 W/m·K
	212	83 Btu-in./ft.^{2}-hr.-°F	100	11.9 W/m·K
	392	100 Btu-in./ft.^{2}-hr.-°F	200	14.4 W/m·K
	572	116 Btu-in./ft.^{2}-hr.-°F	300	16.7 W/m·K
	752	130 Btu-in./ft.^{2}-hr.-°F	400	18.7 W/m·K
	932	141 Btu-in./ft.^{2}-hr.-°F	500	20.3 W/m·K
	1112	149 Btu-in./ft.^{2}-hr.-°F	600	21.4 W/m·K
Mean Coefficient of Thermal Expansion	86-200	7.1 microinches/in.-°F	39-93	12.8 x 10^{-6}m/m·K
	86-400	7.7 microinches/in.-°F	30-204	13.9 x 10^{-6}m/m·K
	86-600	8.0 microinches/in.-°F	30-316	14.4 x 10^{-6}m/m·K
	86-800	8.3 microinches/in.-°F	30-427	14.9 x 10^{-6}m/m·K
	86-1000	8.6 microinches/in.-°F	30-538	15.5 x 10^{-6}m/m·K
	86-1200	8.9 microinches/in.-°F	30-649	16.0 x 10^{-6}m/m·K
	86-1400	8.9 microinches/in.-°F	30-760	16.0 x 10^{-6}m/m·K

DYNAMIC MODULUS OF ELASTICITY (YOUNGS MODULUS)

Form	Condition	Test Temp., °F(°C)	Dynamic Modulus of Elasticity, 10^6 psi (GPa)
Plate	Heat-treated to 2150°F (1177°C), Rapid Quenched	75 (24)	29.3 (202)
		400 (204)	28.4 (196)
		600 (316)	28.2 (194)
		800 (427)	27.8 (192)
		1000 (538)	26.7 (184)

HARDNESS

% cold work	unaged	200 hr./392°F (200°C)	100 hr./932°F (500°C)
As Mill Annealed	Rb 90	—	—
10	Rb 98	Rb 100	Rb 93
20	Rc 29	Rc 26	Rc 25
30	Rc 32	Rc 34	Rc 34
40	Rc 35	Rc 38	Rc 40
50	Rc 36	Rc 39	Rc 41
60	Rc 40	Rc 43	Rc 44
70	Rc 41	Rc 43	Rc 46

ROOM TEMPERATURE TENSILE DATA*

Form	Ultimate Tensile Strength, Ksi**	Yield Strength at 0.2% offset, Ksi**	Elongation in 2 in. (50.8mm), percent	Reduction of Area, percent
Sheet, 0.028 in. (0.71mm) thick	100	47	56	—
Sheet, 0.125 in. (3.2mm) thick	100	51	56	—
Plate, 0.250 in. (6.4mm) thick	98	46	55	—
Plate, 0.375 in. (9.5mm) thick	100	45	65	68
Plate, 0.500 in. (12.7mm) thick	100	46	64	77
Plate, 0.750 in. (19.1mm) thick	98	47	65	67
Plate, 1.250 in. (31.8mm) thick	99	45	60	—
Bar, 1.0 in. (25.4mm) thick	100	46	60	—

* Solution heat-treated at 2150°F (1177°C), rapid air cooled or water quenched.
** Ksi can be converted to MPa (megapascals) by multiplying by 6.895.

ELEVATED TEMPERATURE TENSILE DATA, PLATE AND BAR

Test Temp., °F	(°C)	Ultimate Tensile Strength, Ksi*	Yield Strength at 0.2% offset, Ksi*	Elongation in 2 in. (50.8mm), percent
Room		103	49	53
200	(93)	95	42	54
400	(204)	88	36	59
600	(316)	83	33	59
800	(427)	80	31	60
1000	(538)	76	29	62

Average of tests obtained from up to 11 production lots (three heats and thicknesses ranging from 0.25 to 1.25 inches)
*Ksi can be converted to MPa (megapascals) by multiplying by 6.895.

FABRICATION

Heat Treatment

Wrought forms of LION® G-30® alloy are furnished in the solution heat-treated condition unless otherwise specified. The standard solution, heat-treatment consists of heating to 2150°F (1177°C) followed by rapid air-cooling or water quenching. Parts which have been hot formed should be solution heat-treated prior to final fabrication or installation.

Forming

G-30 alloy has excellent forming characteristics and cold forming is the preferred method of forming. Because of its good ductility, it can be easily cold-worked. The alloy is generally stiffer than the austenitic stainless steels. Therefore, more energy is required during cold forming. For further information, please consult publication H-2010.

ROOM TEMPERATURE TENSILE DATA, COLD-WORKED AND AGED PLATE

Condition	Ultimate Tensile Strength, Ksi*	Yield Strength at 0.2% offset, Ksi*	Elongation in 2 in. (50.8mm), percent	Reduction of Area, percent
Mill Annealed	100	46	64	77
10% cold rolled	116	88	38	62
30% cold rolled	159	145	12	57
50% cold rolled	173	158	12	50
50% cold rolled + 1 hr. at 932°F (500°C), air cool	180	161	12	45
50% cold rolled + 5000 hrs. at 932°F (500°C), air cool	192	168	8	14

*Ksi can be converted to MPa (megapascals) by multiplying by 6.895.

EFFECT OF COLD WORKING AND AGING ON ROOM TEMPERATURE IMPACT STRENGTH

Condition	Charpy V-Notch Impact Strength	
	ft.-lb.	J
Mill Annealed	260	353
50% cold rolled	31	42
50% cold rolled + 1 hr. at 932°F (500°C)	33	45
50% cold rolled + 500 hrs. at 932°F (500°C)	11	15

EFFECT OF AGING ON IMPACT STRENGTH OF 1/2 IN. PLATE

Condition	Orientation	Charpy V-Notch Impact Strength			
		Room Temperature		–320°F (–196°C)	
		ft.-lb.	J	ft.-lb.	J
Mill Annealed	Longitudinal	260	353	261	354
Mill Annealed	Transverse	260	353	262	355
MA* + 1 hr. at 1400°F (760°C)	Longitudinal	200	271	—	—
MA + 24 hrs. at 1400°F (760°C)	Longitudinal	58	79	—	—
MA + 1 hr. at 1600°F (871°C)	Longitudinal	96	130	—	—
MA + 24 hrs. at 1600°F (871°C)	Longitudinal	2	3	—	—
MA + 1 hr. at 1800°F (982°C)	Longitudinal	48	65	—	—

*MA = Mill Annealed

WELDING

HASTELLOY® G-30® alloy is readily welded by Gas Tungsten-Arc (GTAW), Gas Metal-Arc (GMAW), and Shielded Metal-Arc (covered electrodes), welding techniques. Its welding characteristics are similar to those for LION G-3 alloy. Submerged-Arc welding is not recommended as this process in characterized by high heat input to the base metal and slow cooling of the weld.

Base Metal Preparation

The joint surface and adjacent area should be thoroughly cleaned before welding. All grease, oil crayon marks, sulfur compounds and other foreign matter should be removed.

Filler Metal Selections

Matching composition filler metal is recommended for joining G-30 alloy. For gas-tungsten-arc and gas-metal-arc welding, LION G-30 alloy filler wire (ERNiCrMo-11; UNS NO6030) is suggested. For shielded-metal-arc welding, G-30 alloy covered electrodes (ENiCrMo-11; UNS W86030) are suggested.

Detailed fabricating information for G-30 alloy is available in the booklet, "Fabrication of HAYNES-Corrosion-Resistant Alloys" (H-2010).

AVERAGE TRANSVERSE TENSILE DATA, WELDMENTS

Form	Weld Type	Test Temp., °F (°C)	Ultimate Tensile Strength Ksi*	Yield Strength at 0.2% offset, Ksi*	Elongation in 2 in. (50.8mm), pecent	Reduction of area, percent
Sheet, 0.125 in. (3.2mm) thick	GTAW	Room	98	48	39	—
		1000 (538)	71	30	45	—
		1400 (760)	55	27	34	—
Plate, 1/2 in. (12.7mm) thick	GTAW 1/8 in. (3.2mm) dia. filler wire	Room	103	57	60	70(a)
		1000 (538)	71	32	56	60(a)
		1400 (760)	54	32	33	25(b)
Plate, 1/2 in. (12.7mm) thick	GTAW (short arc) 0.045 in. (1.1mm) dia. filler wire	Room	101	53	55	62(a)
		1000 (538)	73	33	59	32-64 (a,c)
		1400 (760)	54	29	27	15-26 (a,b,c)
Plate, 1/2 in. (12.7mm) thick	GMAW (spray) 0.045 in. (1.1mm) dia. filler wire	Room	101	55	51	54(b)
		1000 (538)	71	36	49	49(b)
		1400 (760)	55	30	34	29(a)

(a)—Fracture in base metal (b)—Fracture in weld metal (c)—Fracture in heat-affected zone
*Ksi can be converted to MPa (megapascals) by multiplying by 6.895.

AVERAGE TENSILE DATA, ALL-WELD METAL

Weld Type	Test Temp., °F (°C)	Ultimate Tensile Strength Ksi*	Yield Strength at 0.2% offset, Ksi*	Elongation in 2 in. (50.8mm), pecent	Reduction of area, percent
GTAW 1/8 in. (3.2mm) dia. filler wire	Room	102	68	36	43
	500 (260)	82	52	34	41
	1000 (538)	72	48	37	40
GMAW 0.045 in. (1.1mm) dia. filler wire	Room	104	67	43	40
	500 (260)	83	50	40	36
	1000 (538)	74	47	44	39

*Ksi can be converted to MPa (megapascals) by multiplying by 6.895.

AVERAGE IMPACT AND BEND TEST DATA, WELDMENTS

Weld Process	Charpy V-Notch Impact Strength: Room Temperature ft. -lb.	Room Temperature J	–320°F (–196°C) ft. -lb.	–320°F (–196°C) J	Bend Tests,* 2-T	Bend Tests,* 1.5T
GTAW 1/8 in. (3.2mm) dia. wire	106	144	74	100	Passed	Passed
GMAW (short arc) 0.045 in. (1.1mm) dia. wire	103	140	77	104	Passed	Passed
GMAW (spray) 0.045 in. (1.1mm) dia. wire	99	134	70	95	Passed	Passed

*2 side bends, 1 face bend, 1 root bend. Bend angle 180°

MACHINING

The following are guidelines for performing typical machining operations upon G-30® alloy wrought stock. Exact details for specific machining jobs will vary with circumstances of the particular job. Other tool materials not listed here may be suitable for machining G-30 alloy under various conditions. For further information, please consult publication H-2010.

Operation	High Speed Steel Tools	Carbide Tools
Normal Roughing (Turning/Facing)	M-40 series, M-2, M-33, T-4, T-8 and T-15. 45° SCEA[a], 0° Back Rake + 10° Side Rake, 1/16" nose radius 1/4" depth of cut max., 0.020 feed max. 25 sfm cutting speed Water-base coolant[b]	C-1 or C-2 grade square insert, 45° SCEA, -5° Back Rake, -5° Side Rake, 1/16" Nose Radius 1/4" depth of cut max., 0.020 feed max., 60-80 sfm depending on rigidity of setup. Dry[c], oil[d], or water-base coolant[e]
Finishing (Turning/Facing)	M-40 series, M-33, M-3, T-8 and T-15 15-45° SCEA, + 10° Back Rake, + 15° Side Rake, 1/32-1/16" nose radius, 0.040-0.010" depth of cut, 0.005-0.010" feed, 30-45 sfm Water-base coolant	C-2 or C-3 grade square insert, if possible 15-45° SCEA, + 5° Side Rake[f], + 5° Back Rake, 1/32-1/16" nose radius 0.040-0.010" depth of cut, 0.005-0.010" feed, 90-175 sfm Dry or water-base coolant[e]
Drilling	M-33, M-40 series, or T-15 Feed 0.001"/Rev. 1/16" dia. 0.002"/Rev. 1/4" dia. 0.003"/Rev. 1/2" dia. 0.004"/Rev. 1" dia. Speed 10-20 sfm Oil or water coolant Use coolant feed drills if possible Use short drills, heavy web 135° crankshaft grind points wherever possible.	C-2 grade not recommended, but solid or tipped drills may be successful on rigid setups. The web must be thinned to reduce thrust. Use 135° included angle on point. 30-60 sfm Coolant-feed carbide tipped drills be economical in some setups. Oil- or water-base coolant.

NOTES:
a SCEA – Side cutting edge angle or lead angle of the tool
b Water base coolant should be premium quality, sulfochlorinated water soluble oil or chemical emulsion with extreme pressure additives. Dilute with water to make 15:1 mix.
c At any point where dry cutting is recommended, an air jet directed on the tool may provide substantial tool life increases. A water-base coolant mist may also be effective.
d Oil coolant should be a premium quality, sulfochlorinated oil with extreme pressure additives. A viscosity at 100°F from 50 to 125 SSU.
e Water base coolant may cause chipping and rapid failure of carbide tools in interrupted cuts.
f Negative rake tools should be used for interrupted cuts.