HASTELLOY® G-30® alloy

HASTELLOY® G-30® alloy (UNS N06030) is a nickel-chromium-iron material highly resistant to “wet process” phosphoric acid (P_2O_5). P_2O_5 is one of the most important industrial chemicals, being the primary source of phosphorus for agrichemical fertilizers. G-30® alloy is also moderately resistant to chloride-induced localized attack. Furthermore, G-30® alloy is less susceptible to chloride-induced stress corrosion cracking than the stainless steels.

Principal Features

30 years of proven performance in “wet process” phosphoric acid

HASTELLOY® G-30® alloy (UNS N06030) is a nickel-chromium-iron material highly resistant to “wet process” phosphoric acid (P_2O_5). P_2O_5 is one of the most important industrial chemicals, being the primary source of phosphorus for agrichemical fertilizers. G-30® alloy is also moderately resistant to chloride-induced localized attack, which can be a problem beneath deposits in the evaporators used to concentrate P_2O_5. Furthermore, G-30® alloy is less susceptible to chloride-induced stress corrosion cracking than the stainless steels.

As a result of its high chromium content, G-30® alloy is also very resistant to other oxidizing acids, such as nitric, and mixtures containing nitric acid. It possesses moderate resistance to reducing acids, such as hydrochloric and sulfuric, as a result of its appreciable molybdenum and copper contents.

HASTELLOY® G-30® alloy is available in the form of plates, sheets, strips, billets, bars, wires, pipes, tubes, and covered electrodes. Applications include P_2O_5 evaporator tubes and nitric acid-based, metal pickling hardware.

Nominal Composition

Weight %

Nickel:	Balance
Chromium:	30
Iron:	15
Molybdenum:	5.5
Tungsten:	2.5
Copper:	2
Niobium:	0.8
Cobalt:	5 max.
Manganese:	1.5 max.
Silicon:	0.8 max.
Carbon:	0.03 max.

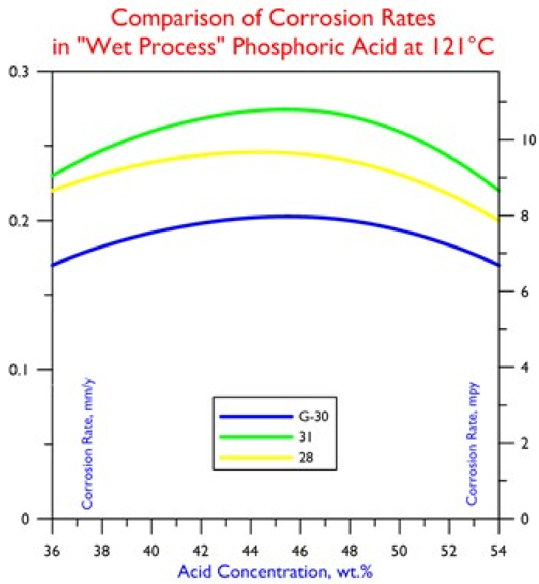
Resistance to "Wet Process"

Phosphoric Acid

"Wet process" phosphoric acid (P_2O_5) is made by reacting phosphate rock with sulfuric acid. As produced, it contains many impurities, and has a P_2O_5 concentration of only about 30%, because of the large amount of rinse water needed to separate it from the other main reaction product, calcium sulfate. Typical impurities include unreacted sulfuric acid, various metallic ions, fluoride ions, and chloride ions. The fluoride ions tend to form complexes with the metallic ions, and are therefore less of a problem than the chloride ions, which strongly influence electrochemical reactions between "wet process" phosphoric acid and metallic materials. Particulate matter (for example, silica particles) can also be present in "wet process" acid.

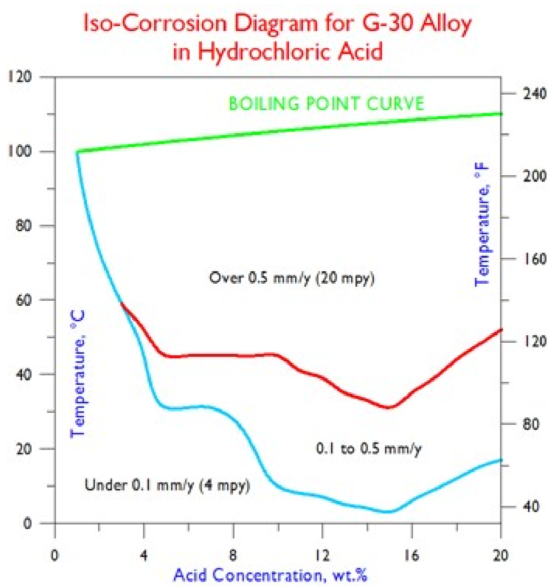
The main use of metallic materials is in the concentration process, where the "wet process" acid is taken through a series of evaporation steps, involving metallic tubing. Typically, the P_2O_5 concentration is raised to 54% during this process. The concentration effect upon the corrosivity of the acid is somewhat offset by the fact that the impurity levels drop as the concentration increases.

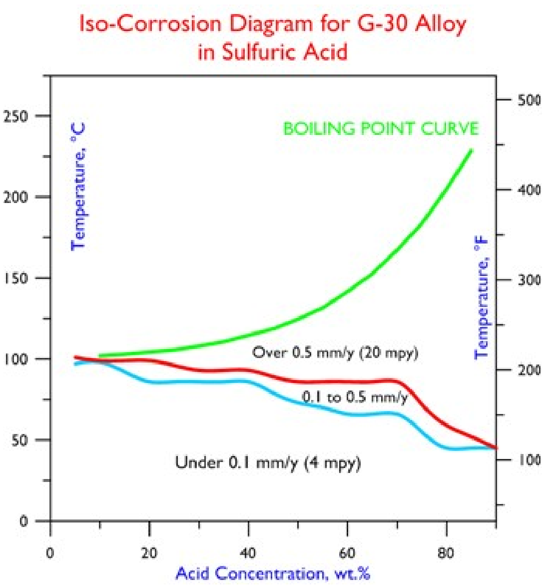
The following chart, comparing HASTELLOY® G-30® alloy with competitive stainless steels, is based on tests in three concentrations (36, 48, and 54%) of "wet process" phosphoric acid (supplied by a producer in Florida, USA) at 121°C (250°F).



Iso-Corrosion Diagrams

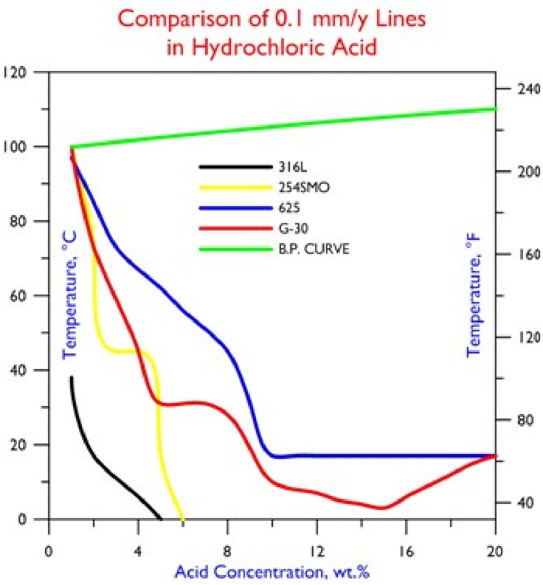
Each of these iso-corrosion diagrams was constructed using numerous corrosion rate values, generated at different acid concentrations and temperatures. The blue line represents those combinations of acid concentration and temperature at which a corrosion rate of 0.1 mm/y (4 mils per year) is expected, based on laboratory tests in reagent grade acids. Below the line, rates under 0.1 mm/y are expected. Similarly, the red line indicates the combinations of acid concentration and temperature at which a corrosion rate of 0.5 mm/y (20 mils per year) is expected. Above the line, rates over 0.5 mm/y are expected. Between the blue and red lines, corrosion rates are expected to fall between 0.1 and 0.5 mm/y.

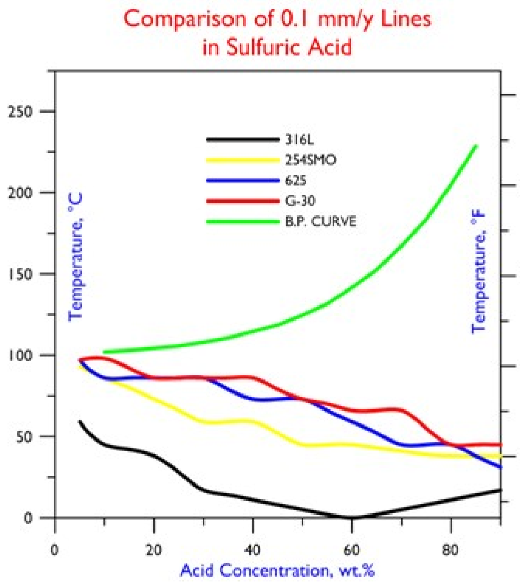




Comparative 0.1 mm/y Line Plots

To compare the performance of HASTELLOY G-30 alloy with that of other materials, it is useful to plot the 0.1 mm/y lines. In the following graphs, the lines for G-30 alloy are compared with those of 625 alloy, 254SMO alloy, and 316L stainless steel, in hydrochloric and sulfuric acids. Note that the line for G-30 alloy is slightly higher than that for 625 alloy in sulfuric acid. The hydrochloric acid concentration limit of 20% is the azeotrope, above which corrosion tests are less reliable.



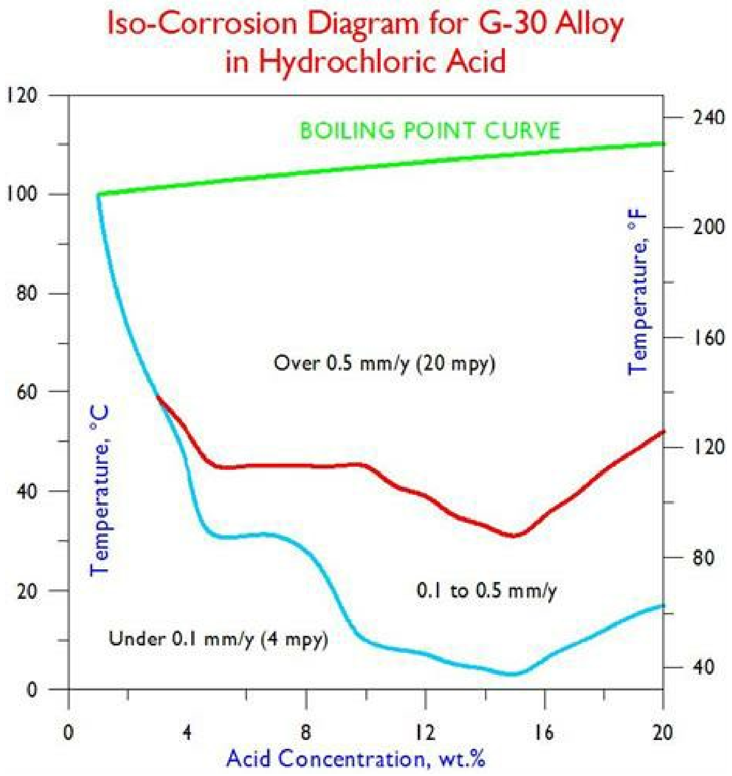


Selected Corrosion Data

Hydrochloric Acid

Conc. Wt.%	50°F 10°C	75°F 24°C	100°F 38°C	125°F 52°C	150°F 66°C	175°F 79°C	200°F 93°C	225°F 107°C	Boiling
1	-	-	-	-	<0.01	<0.01	<0.01	-	0.01
1.5	-	-	-	-	-	-	-	-	-
2	-	-	-	<0.01	<0.01	-	-	-	9.47
2.5	-	-	-	<0.01	1.04	2.06	4.23	-	12.67
3	-	-	<0.01	<0.01	-	-	-	-	-
3.5	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
4.5	-	-	-	-	-	-	-	-	-
5	-	<0.01	0.33	0.71	1.33	2.65	9.06	-	-
7.5	<0.01	0.05	-	-	-	-	-	-	-
10	0.08	0.19	0.44	0.64	1.48	3.96	15.21	-	-
15	0.13	0.31	0.66	1.87	1.47	-	11.98	-	-
20	-	0.13	0.30	0.55	1.24	-	10.90	-	-

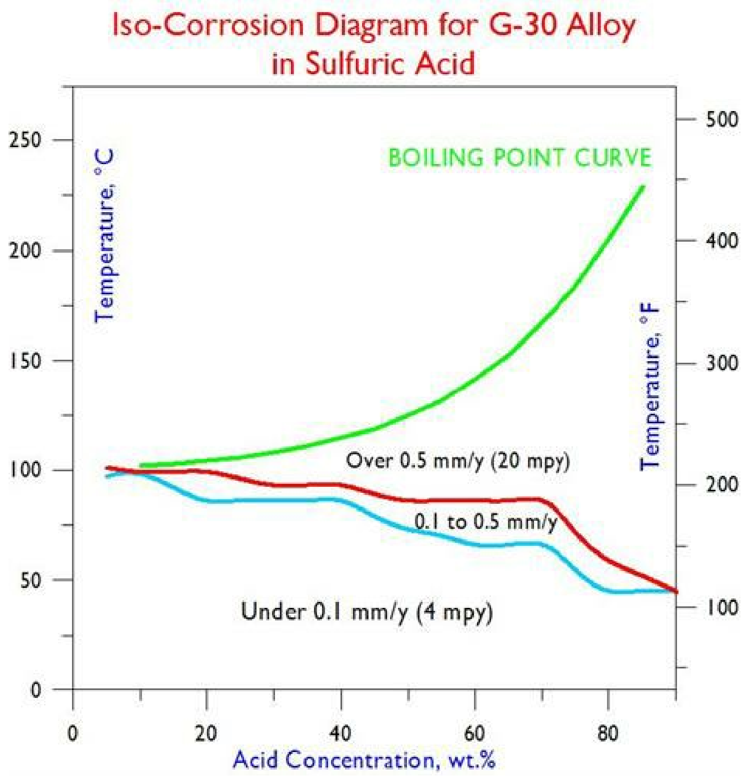
Data are from Corrosion Laboratory Jobs 446-82, 168-89, and 66-96.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.



Sulfuric Acid

Conc. Wt.%	75°F 24°C	100°F 38°C	125°F 52°C	150°F 66°C	175°F 79°C	200°F 93°C	225°F 107°C	250°F 121°C	275°F 135°C	300°F 149°C	350°F 177°C	Boiling
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	<0.01	<0.01	-	-	-	-	-	0.47
10	-	-	-	-	<0.01	<0.01	-	-	-	-	-	0.78
20	-	-	-	-	<0.01	0.36	-	-	-	-	-	1.35
30	-	-	-	-	0.01	0.55	-	-	-	-	-	1.53
40	-	-	-	0.02	0.05	0.54	-	-	-	-	-	1.95
50	-	<0.01	<0.01	0.01	0.26	0.56	0.93	-	-	-	-	3.68
60	-	-	<0.01	0.09	0.27	0.73	1.07	-	-	-	-	8.46
70	-	<0.01	0.01	0.11	0.36	0.98	1.38	-	-	-	-	-
80	-	-	0.31	1.13	2.62	4.52	4.70	-	-	-	-	-
90	-	<0.01	0.67	2.01	3.25	6.55	6.25	-	-	-	-	-
96	-	-	0.45	1.86	2.04	1.86	1.52	-	-	-	-	-

All corrosion rates are in millimeters per year (mm/y); to convert to mils (thousandths of an inch) per year, divide by 0.0254.
Data are from Corrosion Laboratory Job 449-82.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.


Iso-Corrosion Diagram for G-30 Alloy
in Sulfuric Acid
Temperature, °C
Temperature, °F
BOILING POINT CURVE
Over 0.5 mm/y (20 mpy)
0.1 to 0.5 mm/y
Under 0.1 mm/y (4 mpy)
Acid Concentration, wt.%
0
20
40
60
80
50
100
150
200
250
300
400
500

Reagent Grade Solutions, mm/y

Chemical	Conc.	100°F 38°C	125°F 52°C	150°F 66°C	175°F 79°C	200°F 93°C	Boiling
Acetic Acid	99	-	-	-	-	-	0.03
Chromic Acid	5	-	-	0.02	-	-	0.40
	10	-	-	0.14	-	-	1.23
Formic Acid	88	-	-	-	-	-	0.05
Hydrochloric Acid	1	-	-	<0.01	<0.01	<0.01	0.01
	2	-	<0.01	<0.01	-	-	9.47
	2.5	-	<0.01	1.04	2.06	4.23	-
	3	<0.01	<0.01	-	-	-	-
	5	0.33	0.71	1.33	2.65	-	-
	10	0.44	0.64	1.48	3.96	-	-
	15	0.66	1.87	1.47	-	-	-
	20	0.30	0.55	1.24	-	-	-
Nitric Acid	50	-	-	-	-	-	0.08
	60	-	-	-	-	-	0.14
	65	-	-	-	-	-	0.16
Phosphoric Acid (Reagent Grade)	50	-	-	-	-	<0.01	0.01
	60	-	-	-	-	-	0.14
	70	-	-	-	-	0.01	0.35
	80	-	-	-	-	-	0.61
	85	-	-	-	-	-	0.84
Sulfuric Acid	10	-	-	-	<0.01	<0.01	0.78
	20	-	-	-	<0.01	0.36	1.35
	30	-	-	-	0.01	0.55	1.53
	40	-	-	0.02	0.05	0.54	1.95
	50	<0.01	<0.01	0.01	0.26	0.56	-
	60	-	<0.01	0.09	0.27	0.73	-
	70	<0.01	0.01	0.11	0.36	0.98	-
	80	-	0.31	1.13	2.62	4.52	-
	90	<0.01	0.67	2.01	3.25	6.55	-
	96	-	0.45	1.86	2.04	1.86	-

Resistance to Pitting and Crevice Corrosion

Various chloride-bearing environments, notably Green Death (11.5% H_2SO_4 + 1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$) and Yellow Death (4% NaCl + 0.1% $Fe_2(SO_4)_3$ + 0.021M HCl), have been used to compare the resistance of nickel alloys to pitting and crevice attack (using tests of 24 hours duration). In Green Death, the lowest temperature at which pitting has been observed in G-30® alloy is 55°C, and the lowest temperature at which crevice corrosion has been observed is 45°C. In Yellow Death, the corresponding temperatures are 55°C and 25°C.

Resistance to Stress Corrosion Cracking

One of the chief attributes of the nickel alloys is their resistance to chloride-induced stress corrosion cracking. A common solution for assessing the resistance of materials to this extremely destructive form of attack is boiling 45% magnesium chloride (ASTM Standard G 36), typically with stressed U-bend samples. As is evident from the following results, G-30 alloy is much more resistant to this form of attack than the comparative, austenitic stainless steels.

Alloy	Time to Cracking
316L	2 h
254SMO	24 h
28	36 h
31	36 h
G-30®	**168 h**

Corrosion Resistance of Welds

To assess the resistance of welds to corrosion, Haynes International has chosen to test all-weld-metal samples, taken from the quadrants of cruciform assemblies, created using multiple gas metal arc (MIG) weld passes. Notably, the resistance of all-weld-metal samples of G-30 alloy to key, inorganic acids is close to that of the wrought, base metal in several cases.

Chemical	Concentration	Temperature		Corrosion Rate			
	wt.%	°F	°C	Weld Metal		Wrought Base Metal	
				mpy	mm/y	mpy	mm/y
H_2SO_4	30	150	66	<0.4	<0.01	<0.4	<0.01
H_2SO_4	50	150	66	0.4	0.01	0.4	0.01
H_2SO_4	70	150	66	5.5	0.14	4.3	0.11
H_2SO_4	90	150	66	102.4	2.60	102.8	2.61
HCl	5	100	38	<0.4	<0.01	13.0	0.33
HCl	10	100	38	27.6	0.70	17.3	0.44
HCl	15	100	38	25.2	0.64	26.0	0.66
HCl	20	100	38	20.5	0.52	11.8	0.30
HNO_3	70	Boiling		5.5	0.14	5.5	0.14

Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	2.97 lb/in^3	RT	8.22 g/cm^3
Electrical Resistivity	RT	RT	RT	1.16 µohm.m
	200°F	200°F	100°C	1.17 µohm.m
	400°F	400°F	200°C	1.19 µohm.m
	600°F	600°F	300°C	1.21 µohm.m
	800°F	800°F	400°C	1.23 µohm.m
	1000°F	1000°F	500°C	1.24 µohm.m
	-	-	600°C	1.25 µohm.m
Thermal Conductivity	RT	RT	RT	10 W/m.°C
	200°F	200°F	100°C	12 W/m.°C
	400°F	400°F	200°C	14 W/m.°C
	600°F	600°F	300°C	17 W/m.°C
	800°F	800°F	400°C	19 W/m.°C
	1000°F	1000°F	500°C	20 W/m.°C
	-	-	600°C	21 W/m.°C
Mean Coefficient of Thermal Expansion	86-200°F	86-200°F	30-100°C	12.8 µm/m.°C
	86-400°F	86-400°F	30-200°C	13.8 µm/m.°C
	86-600°F	86-600°F	30-300°C	14.3 µm/m.°C
	86-800°F	86-800°F	30-400°C	14.8 µm/m.°C
	86-1000°F	86-1000°F	30-500°C	15.3 µm/m.°C
	86-1200°F	86-1200°F	30-600°C	15.8 µm/m.°C
Dynamic Modulus of Elasticity	RT	RT	RT	202 GPa
	400°F	400°F	200°C	196 GPa
	600°F	600°F	300°C	195 GPa
	800°F	800°F	400°C	192 GPa
	1000°F	1000°F	500°C	187 GPa

RT= Room Temperature

Impact Strength

Plate Thickness		Test Temperature		Impact Strength*	
in	mm	°F	°C	ft.lbf	J
0.5	12.7	RT	RT	260	353
0.5	12.7	-320	-196	262	355

*Transverse Charpy V-Notch Samples
RT=Room Temperature

Tensile Strength and Elongation

Form	Thickness/ Bar Diameter		Test Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
	in	mm	°F	°C	ksi	MPa	ksi	MPa	%
Sheet	0.028	0.71	RT	RT	47	324	100	689	56
Sheet	0.125	3.2	RT	RT	51	352	100	689	56
Plate	0.250	6.4	RT	RT	46	317	98	676	55
Plate	0.375	9.5	RT	RT	45	310	100	689	65
Plate	0.500	12.7	RT	RT	46	317	100	689	64
Plate	0.750	19.1	RT	RT	47	324	98	676	65
Plate	1.250	31.8	RT	RT	45	310	99	683	60
Bar	1.000	25.4	RT	RT	46	317	100	689	60
Plate & Bar*	Various		200	93	42	290	95	655	54
Plate & Bar*	Various		400	204	36	248	88	607	59
Plate & Bar*	Various		600	316	33	228	83	572	59
Plate & Bar*	Various		800	427	31	214	80	552	60
Plate & Bar*	Various		1000	538	29	200	76	524	62

*Average results from tests of 11 plate and bar products of thickness/diameter 6.4 to 31.8 mm
RT= Room Temperature

Hardness

Form	Hardness, HRBW	Typical ASTM Grain Size
Sheet	81	1.5 - 4
Plate	80	0 - 3
Bar	78	0 - 2

All samples tested in solution-annealed condition.
HRBW = Hardness Rockwell “B”, Tungsten Indentor.

Welding and Fabrication

HASTELLOY® G-30® alloy is very amenable to the Gas Metal Arc (GMA/MIG), Gas Tungsten Arc (GTA/TIG), and Shielded Metal Arc (SMA/Stick) welding processes. For matching filler metals (i.e. solid wires and coated electrodes) that are available for these processes, and welding guidelines, please click here.

Wrought products of HASTELLOY® G-30® alloy are supplied in the Mill Annealed (MA) condition, unless otherwise specified. This solution annealing procedure has been designed to optimize the alloy's corrosion resistance and ductility. Following all hot forming operations, the material should be re-annealed, to restore optimum properties. The alloy should also be re-annealed after any cold forming operations that result in an outer fiber elongation of 7% or more. The annealing temperature for HASTELLOY® G-30® alloy is 1177°C (2150°F), and water quenching is advised (rapid air cooling is feasible with structures thinner than 10 mm (0.375 in). A hold time at the annealing temperature of 10 to 30 minutes is recommended, depending on the thickness of the structure (thicker structures need the full 30 minutes). For more details concerning the heat treatment of HASTELLOY® G-30® alloy, please click here.

HASTELLOY® G-30® alloy can be hot forged, hot rolled, hot upset, hot extruded, and hot formed. However, it is more sensitive to strain and strain rates than the austenitic stainless steels, and the hot working temperature range is quite narrow. For example, the recommended start temperature for hot forging is 1149°C (2100°F) and the recommended finish temperature is 927°C (1700°F). Moderate reductions and frequent re-heating provide the best results, as described here. This reference also provides guidelines for cold forming, spinning, drop hammering, punching, and shearing of the HASTELLOY® alloys. G-30® alloy is stiffer than most austenitic stainless steels, and more energy is required during cold forming. Also, G-30® alloy work hardens more readily than most austenitic stainless steels, and may require several stages of cold work, with intermediate anneals.

While cold work does not usually affect the resistance of HASTELLOY® G-30® alloy to general corrosion, and to chloride-induced pitting and crevice attack, it can affect resistance to stress corrosion cracking. For optimum corrosion performance, therefore, the re-annealing of cold worked parts (following an outer fiber elongation of 7% or more) is important.

Specifications and Codes

Specifications

HASTELLOY® G-30® alloy (N06030, W86030)	
Sheet, Plate & Strip	SB 582/B 582 P= 45
Billet, Rod & Bar	SB 581/B 581 B 472 P= 45
Coated Electrodes	SFA 5.11/ A 5.11 (ENiCrMo-11) F= 45
Bare Welding Rods & Wire	SFA 5.14/ A 5.14 (ERNiCrMo-11) F= 45
Seamless Pipe & Tube	SB 622/B 622 P= 45
Welded Pipe & Tube	SB 619/B 619 SB 626/B 626 P= 45
Fittings	SB 366/B 366 SB 462/B 462 P= 45
Forgings	SB 462/B 462 P= 45
DIN	No. 2.4603 NiCr30FeMo
TÜV	-
Others	NACE MR0175 ISO 15156

Codes

HASTELLOY® G-30® alloy (N06030, W86030)		
ASME	**Section I**	-
	Section III	**Class 1**
		Class 2
		Class 3
	Section VIII	**Div. 1**
		Div. 2
	Section XII	650°F (343°C)[1]
	B16.5	800°F (427°C)[2]
	B16.34	800°F (427°C)[3]
	B31.1	-
	B31.3	-
VdTÜV (doc #)		-

[1] Plate, Sheet, Bar, fittings, welded pipe/tube, seamless pipe/tube, Bolting
[2] Plate, Forgings, fittings
[3] Plate, Bar, Forgings, seamless pipe/tube

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