HASTELLOY® C-22® alloy

Principal Features

Enhanced versatility and exceptional resistance to chloride-induced pitting
HASTELLOY® C-22® alloy (UNS N06022) is one of the well-known and well-proven nickel-chromium-molybdenum materials, the chief attributes of which are resistance to both oxidizing and non-oxidizing chemicals, and protection from pitting, crevice attack, and stress corrosion cracking. Its high chromium content provides much higher resistance to oxidizing media than the family standard, C-276 alloy, and imparts exceptional resistance to chloride-induced pitting, an insidious and unpredictable form of attack, to which the stainless steels are prone.

Like other nickel alloys, HASTELLOY® C-22® alloy is very ductile, exhibits excellent weldability, and is easily fabricated into industrial components. It is available in the form of plates, sheets, strips, billets, bars, wires, pipes, tubes, and covered electrodes. Typical chemical process industry (CPI) applications include reactors, heat exchangers, and columns.

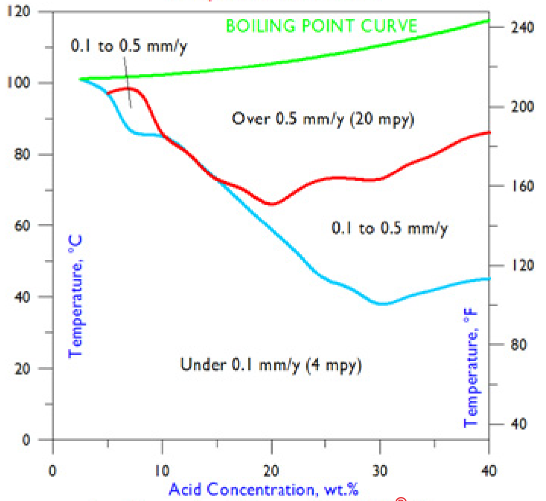
Nominal Composition

	Weight %
Nickel:	56 Balance
Chromium:	22
Molybdenum:	13
Iron:	3
Cobalt:	2.5 max.
Tungsten:	3
Manganese:	0.5 max.
Silicon:	0.08 max.
Carbon:	0.01 max.
Vanadium:	0.35 max.
Copper:	0.5 max.

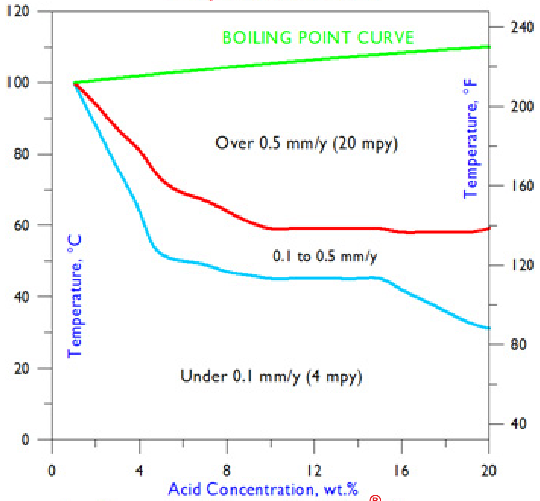
Iso-Corrosion Diagrams

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.

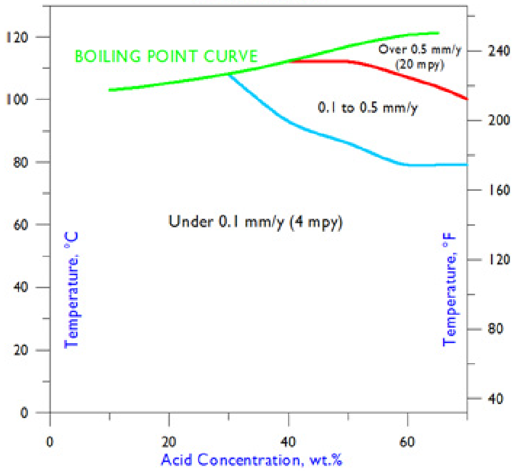
Iso-Corrosion Diagram for C-22® Alloy in Hydrobromic Acid



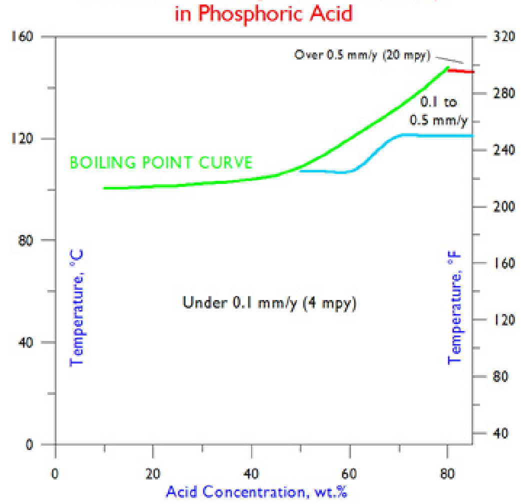
Iso-Corrosion Diagram for C-22® Alloy in Hydrochloric Acid



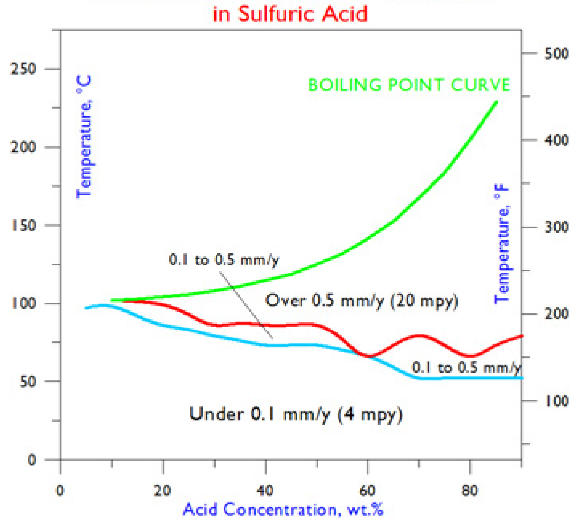
Iso-Corrosion Diagram for C-22® Alloy in Nitric Acid



Iso-Corrosion Diagram for C-22® Alloy in Phosphoric Acid

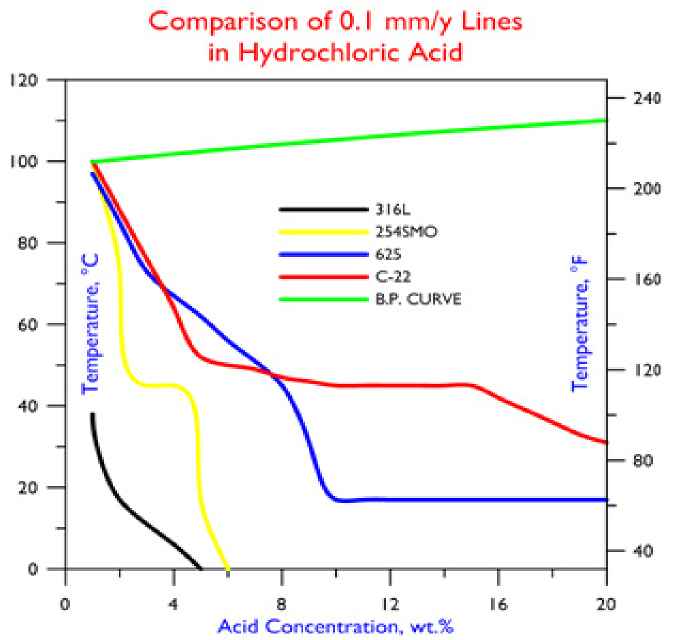


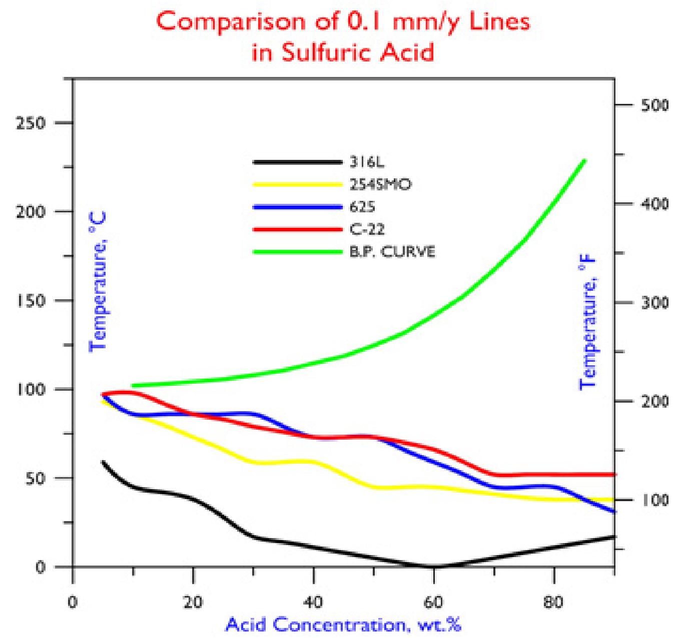
Iso-Corrosion Diagram for C-22® Alloy in Sulfuric Acid



Comparative 0.1 mm/y Line Plots

To compare the performance of HASTELLOY® C-22® alloy with that of other materials, it is useful to plot the 0.1 mm/y lines. In the following graphs, the lines for C-22® alloy are compared with those of two popular, austenitic stainless steels (316L and 254SMO), and a lower-molybdenum nickel alloy (625), in hydrochloric and sulfuric acids. The tests in hydrochloric acid were limited to a concentration of 20% (the azeotrope). At hydrochloric acid concentrations above about 5%, C-22® alloy provides a quantum improvement over the stainless steels, and offers much greater resistance hydrochloric acid than 625 alloy in the concentration range 8 to 20%.





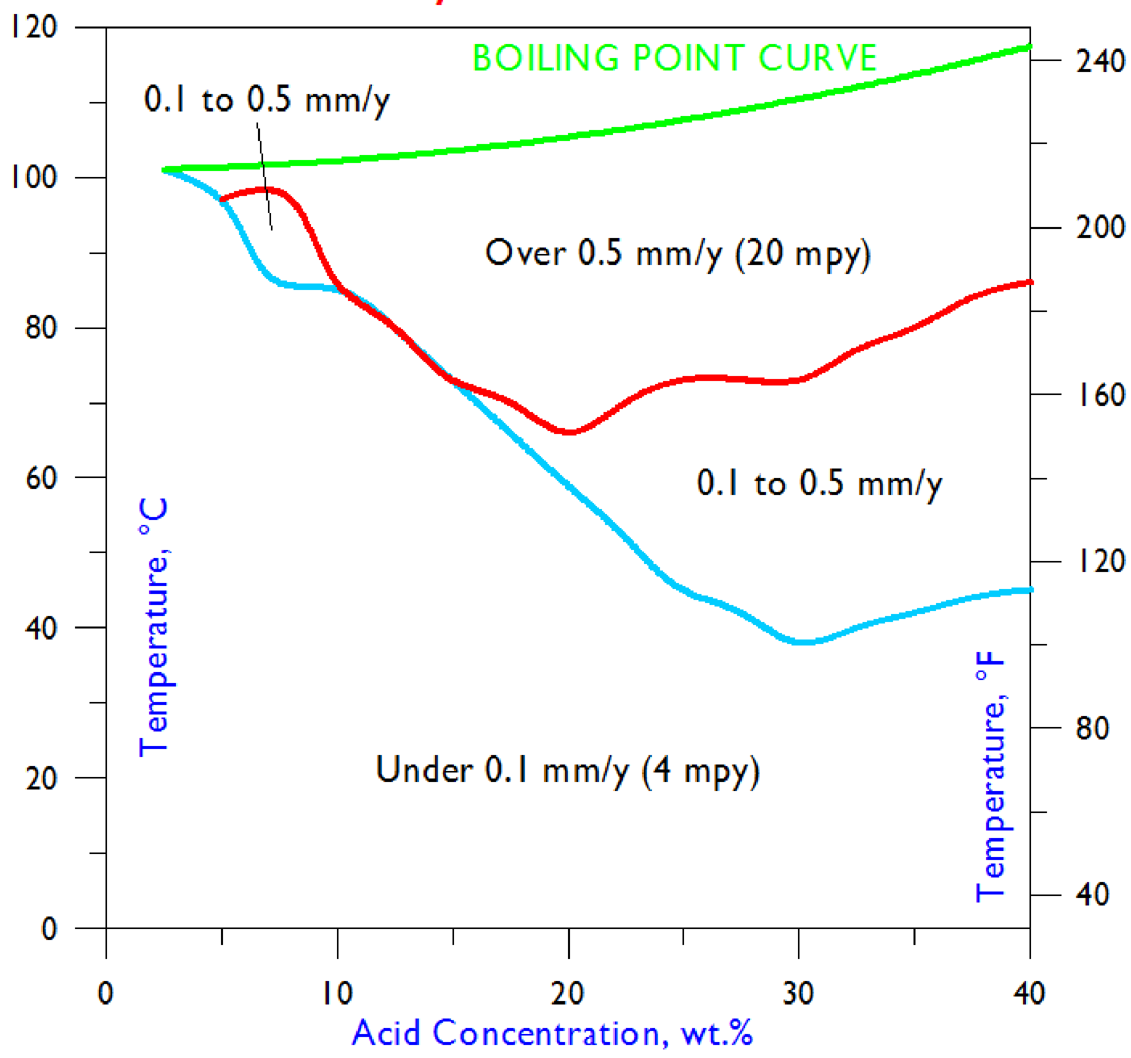
Selected Corrosion Data

Hydrobromic 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
2.5	-	-	-	-	-	-	-	-	0.02
5	-	-	-	-	-	-	0.01	-	0.76
7.5	-	-	-	-	-	0.01	0.45	-	-
10	-	-	-	-	-	0.01	1.5	-	-
15	-	-	-	0.01	<0.01	0.88	-	-	-
20	-	-	-	0.01	0.46	0.8	-	-	-
25	-	-	<0.01	0.2	0.29	0.58	0.97	-	-
30	-	-	0.11	0.23	0.29	0.59	1.12	-	-
40	-	-	0.07	0.13	0.21	0.34	0.66	-	-

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 Jobs 15-02, 27-02, and 37-02.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for C-22® Alloy in Hydrobromic Acid



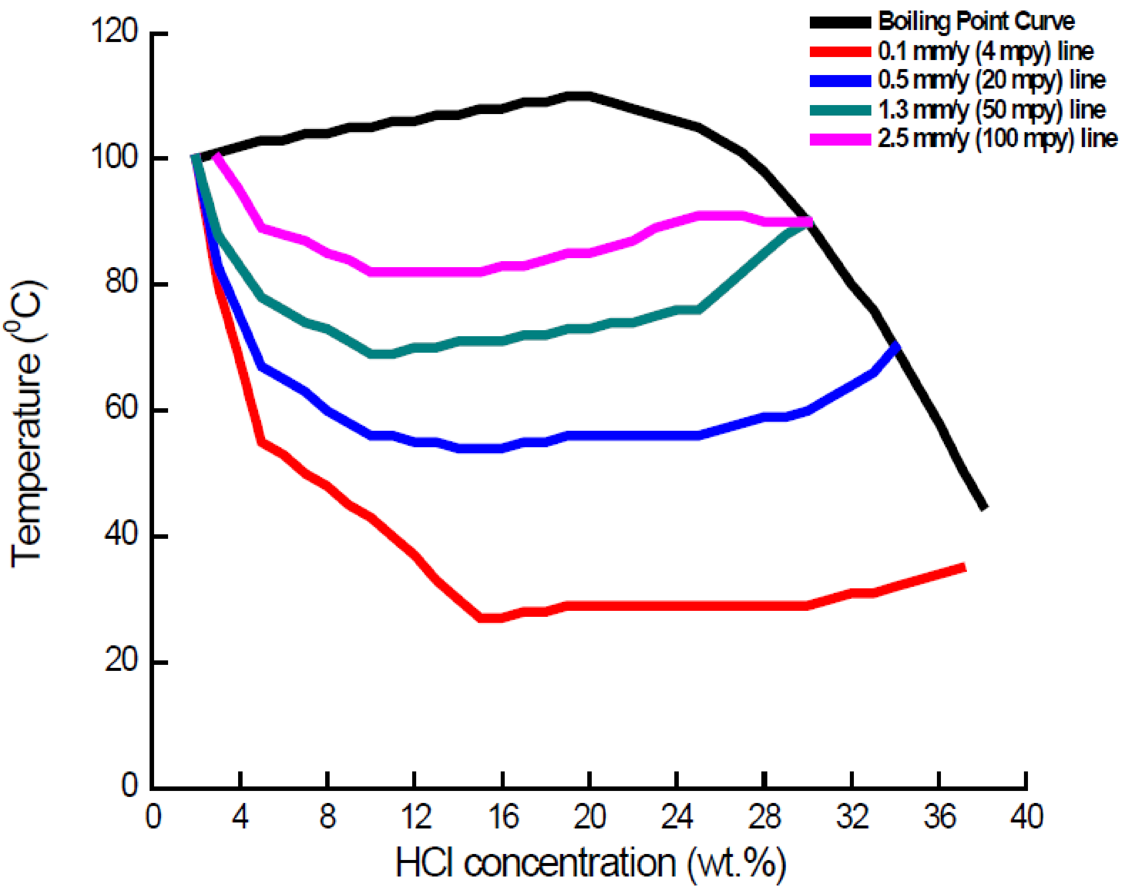
Selected Corrosion Data Continued

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	-	0.06
1.5	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-
2.5	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-
3.5	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
4.5	-	-	-	-	-	-	-	-	-
5	-	-	<0.01	-	0.44	1.44	3.02	-	8.99
7.5	-	-	-	-	-	-	-	-	-
10	-	-	0.01	0.28	0.98	1.99	4.39	-	11.68
15	-	-	-	-	0.98	1.91	-	-	11.02
20	-	-	0.2	0.32	0.9	1.72	3.38	-	9.73

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 Jobs 442-82 and 176-83.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for C-22® Alloy in Hydrochloric Acid



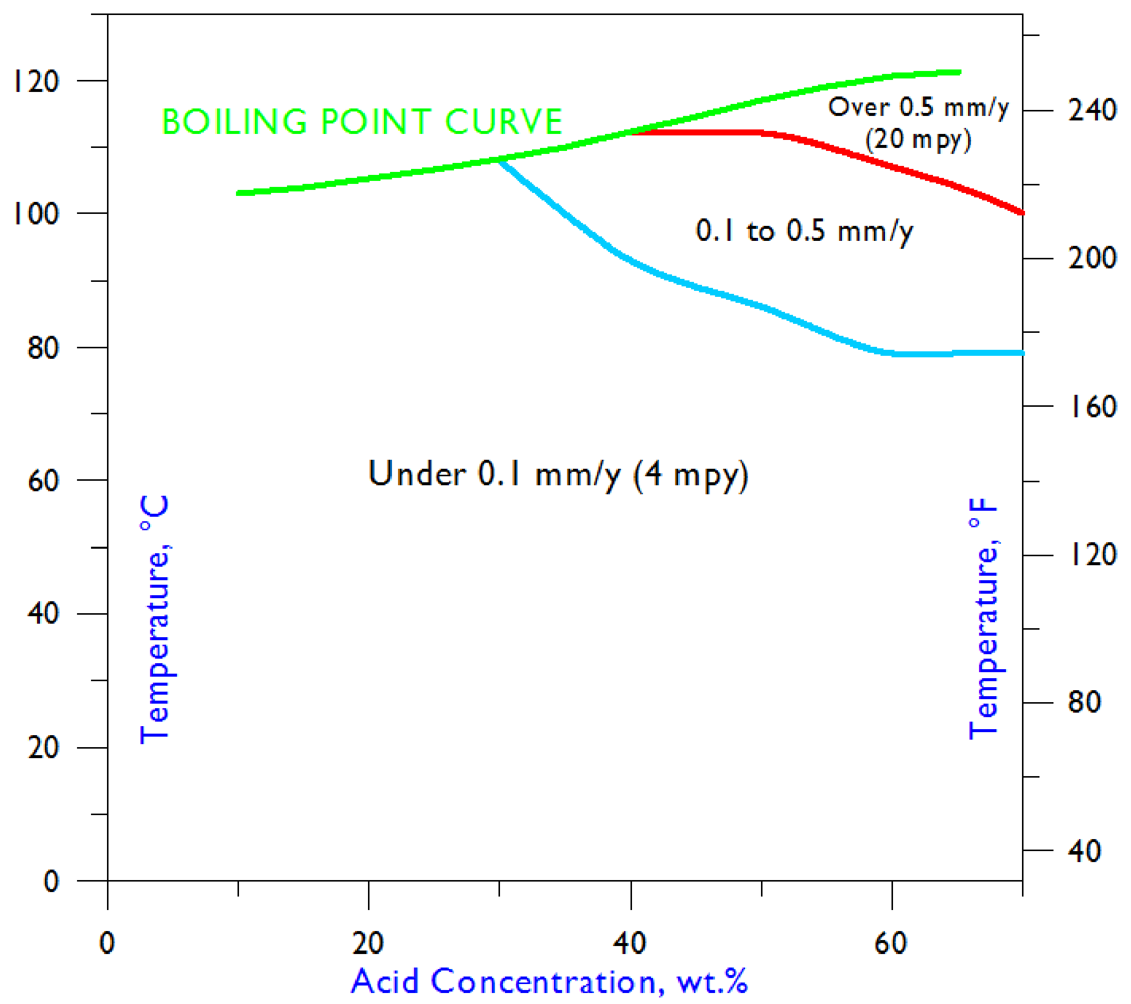
Selected Corrosion Data Continued

Nitric 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
10	-	-	-	-	<0.01	-	0.01	-	0.01
20	-	-	-	-	0.01	-	0.02	-	0.06
30	-	-	-	-	0.01	-	0.02	-	0.13
40	-	-	-	-	0.02	0.03	0.09	-	0.26
50	-	-	-	-	-	0.05	0.14	0.33	0.59
60	-	-	-	-	0.06	0.08	0.19	0.57	1.09
70	-	-	-	-	0.05	0.11	0.33	0.71	2.53

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 Jobs 443-82 and 47-04.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for C-22® Alloy in Nitric Acid



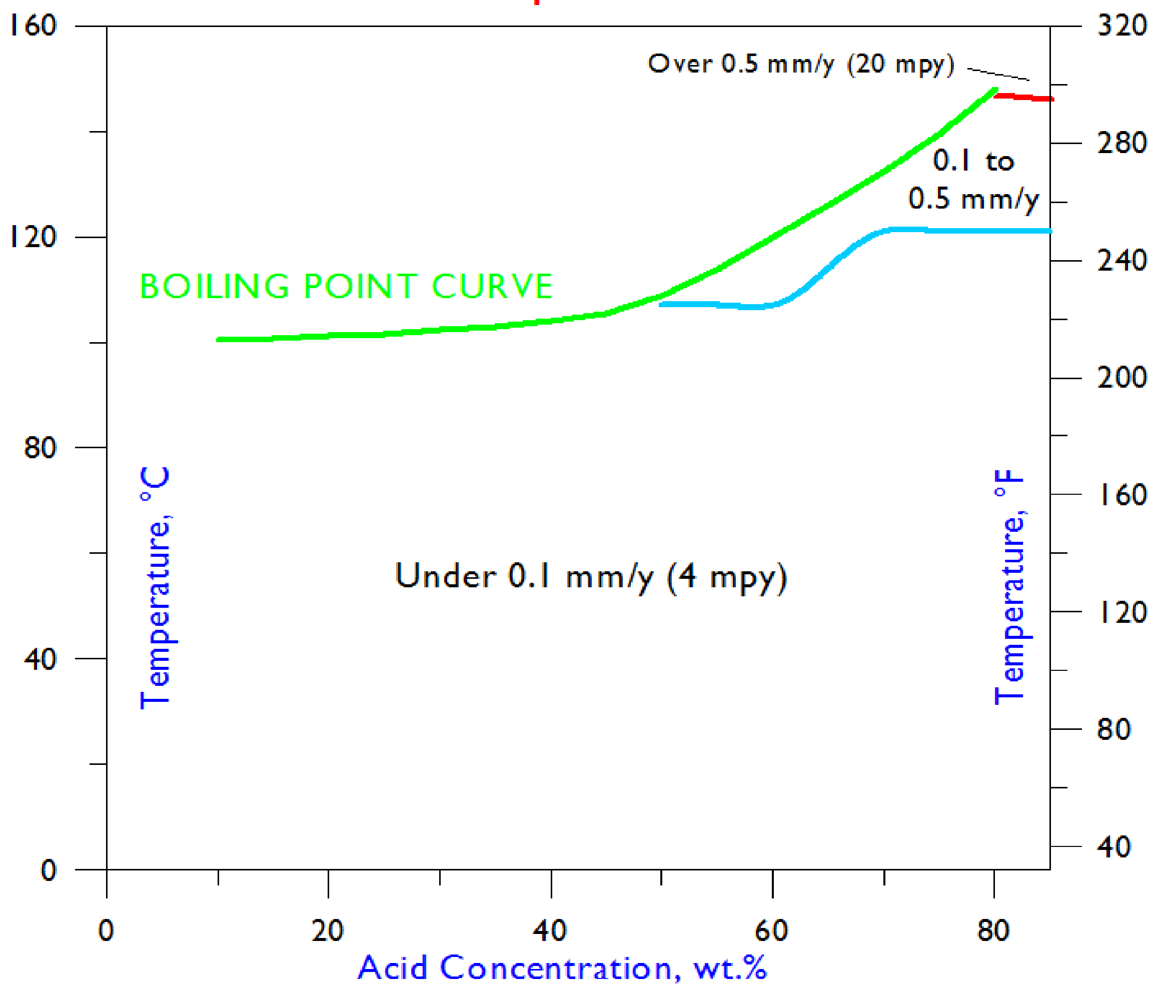
Selected Corrosion Data Continued

Phosphoric Acid

Conc. Wt.%	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	Boiling
50	-	-	-	-	-	-	-	-	0.07
60	-	-	-	-	0.08	-	-	-	0.16
65	-	-	-	-	-	-	-	-	-
70	-	-	-	-	0.07	0.13	-	-	0.23
75	-	-	-	-	0.05	0.12	-	-	0.19
80	-	-	-	-	0.06	0.12	0.16	-	0.25
85	-	-	-	-	0.07	0.12	0.2	-	0.66

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 Jobs 444-82 and 46-04.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for C-22® Alloy in Phosphoric Acid



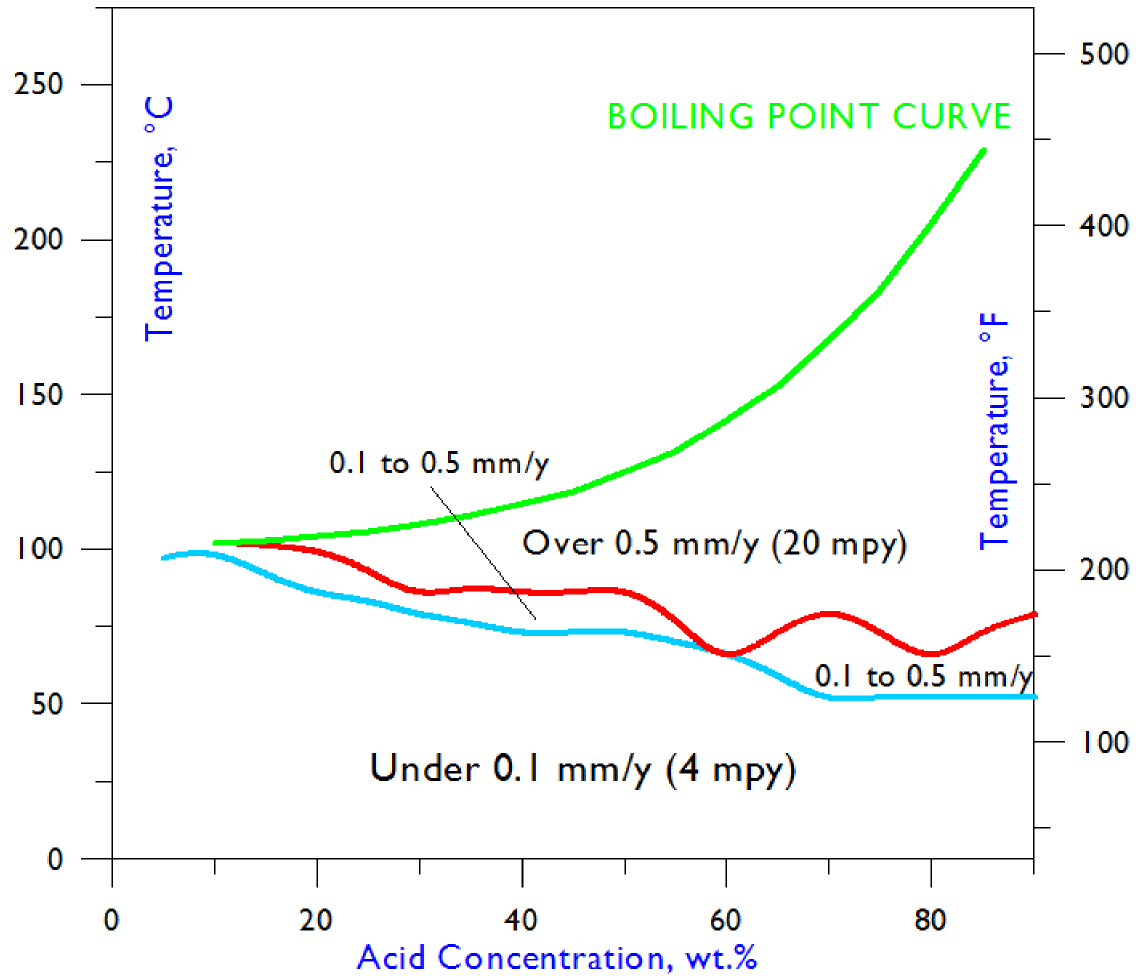
Selected Corrosion Data Continued

Sulfuric Acid

Conc.	75°F	100°F	125°F	150°F	175°F	200°F	225°F	250°F	275°F	300°F	350°F	
Wt.%	24°C	38°C	52°C	66°C	79°C	93°C	107°C	121°C	135°C	149°C	177°C	Boiling
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	0.01	-	-	-	-	-	0.13
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	<0.01	0.01	0.03	-	-	-	-	-	0.23
10	-	-	-	-	0.02	0.04	-	-	-	-	-	0.29
20	-	-	-	0.01	0.03	0.28	-	-	-	-	-	0.83
30	-	-	-	0.01	0.09	0.68	-	-	-	-	-	1.89
40	-	-	0.01	0.01	0.31	0.87	-	-	-	-	-	3.99
50	-	-	-	0.02	0.40	0.77	2.18	-	-	-	-	9.98
60	-	-	0.01	-	0.67	0.95	2.69	7.62	-	-	-	-
70	-	-	-	0.28	0.56	0.94	3.07	14.94	-	-	-	-
80	-	-	0.09	-	1.44	2.16	3.68	3.58	-	-	-	-
90	-	-	-	0.34	0.89	1.80	6.27	4.24	-	-	-	-
96	-	-	-	0.10	-	1.10	-	-	-	-	-	-

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 Jobs 319-82, 445-82, and 19-14.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for C-22® Alloy in Sulfuric Acid



Selected Corrosion Data (Reagent Grade Solutions, mm/y)

Chemical	Concentration wt.%	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
Formic Acid	88	-	-	-	-	-	<0.01
Hydrobromic Acid	2.5	-	-	-	-	-	0.02
	5	-	-	-	-	-	0.76
	7.5	-	-	-	0.01	-	-
	10	-	-	-	0.01	-	-
	15	-	0.01	<0.01	0.88	-	-
	20	-	0.01	0.46	0.8	-	-
	25	<0.01	0.2	0.29	0.58	-	-
	30	0.11	0.23	0.29	0.59	-	-
	40	0.07	0.13	0.21	0.34	-	-
Hydrochloric Acid	1	-	-	-	-	0.01	0.06
	5	<0.01	-	0.44	-	-	-
	7.5	-	-	-	-	-	-
	10	0.01	0.28	0.98	-	-	-
	15	-	-	-	-	-	-
	20	0.2	0.32	0.9	-	-	-
Hydrofluoric Acid*	5	0.04	0.15	0.47	0.58	-	-
	10	0.09	0.33	0.64	0.78	-	-
	20	0.22	0.53	0.95	1.65	-	-
Nitric Acid	10	-	-	<0.01	-	0.01	0.01
	20	-	-	0.01	-	0.02	0.06
	30	-	-	0.01	-	0.02	0.13
	40	-	-	0.02	-	0.09	0.26
	50	-	-	-	-	0.14	0.59
	60	-	-	0.06	-	0.19	1.09
	65	-	-	-	-	-	-
	70	-	-	0.05	-	0.33	2.53
Phosphoric Acid	50	-	-	-	-	-	0.07
	60	-	-	-	-	-	0.16
	70	-	-	-	-	-	0.23
	75	-	-	-	-	-	0.19
	80	-	-	-	-	-	0.25
	85	-	-	-	-	-	0.66

Selected Corrosion Data (Reagent Grade Solutions, mm/y)

Chemical	Concentration wt.%	100°F 38°C	125°F 52°C	150°F 66°C	175°F 79°C	200°F 93°C	Boiling
Sulfuric Acid	10	-	-	-	0.02	0.04	0.29
	20	-	-	0.01	0.03	0.28	0.83
	30	-	-	0.01	0.09	0.68	-
	40	-	-	0.01	0.31	0.87	-
	50	-	-	0.02	0.4	0.77	-
	60	-	-	-	0.67	0.95	-
	70	-	-	0.28	0.56	0.94	-
	80	-	-	-	1.44	2.16	-
	90	-	-	0.34	0.89	1.8	-
	96	-	-	0.1	-	1.1	-

*Hydrofluoric acid can also induce internal attack of nickel alloys; these values represent only external attack.

Resistance to Pitting & Crevice Corrosion

HASTELLOY® C-22® alloy exhibits very high resistance to chloride-induced pitting and crevice attack, forms of corrosion to which the austenitic stainless steels are particularly prone. To assess the resistance of alloys to pitting and crevice attack, it is customary to measure their Critical Pitting Temperatures and Critical Crevice Temperatures in acidified 6 wt.% ferric chloride, in accordance with the procedures defined in ASTM Standard G 48. These values represent the lowest temperatures at which pitting and crevice attack are encountered in this solution, within 72 hours. For comparison, the values for 316L, 254SMO, 625, C-22® and C-276 alloys are as follows:

Alloy	Critical Pitting Temperature in Acidified 6% $FeCl_3$		Critical Crevice Temperature in Acidified 6% $FeCl_3$	
	°F	°C	°F	°C
316L	59	15	32	0
254SMO	140	60	86	30
625	212	100	104	40
C-276	>302	>150	131	55
C-22®	**>302**	**>150**	**176**	**80**

Other 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 various 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 C-22® alloy is 120°C (considerably higher than that of C-276, i.e. boiling). In Yellow Death, C-22® alloy has not exhibited pitting, even at the maximum test temperature (150°C).The Critical Crevice Temperature of C-22® alloy in Yellow Death is 75°C (as compared with 60°C for C-276 alloy).

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, the three nickel alloys (C-22®, C-276 and 625) are much more resistant to this form of attack than the comparative, austenitic stainless steels. The tests were stopped after 1,008 hours (six weeks).

Alloy	Time to Cracking
316L	2 h
254SMO	24 h
625	No Cracking in 1,008 h
C-276	No Cracking in 1,008 h
C-22®	**No Cracking in 1,008 h**

Resistance to Seawater Crevice Corrosion

Seawater is probably the most common aqueous salt solution. Not only is it encountered in marine transportation and offshore oil rigs, but it is also used as a coolant in coastal facilities. Listed are data generated as part of a U.S. Navy study at the LaQue Laboratories in Wrightsville Beach, North Carolina (and published by D.M. Aylor et al, Paper No. 329, CORROSION 99, NACE International, 1999). Crevice tests were performed in both still (quiescent) and flowing seawater, at 29°C, plus or minus 3°C. Two samples (A & B) of each alloy were tested in still water for 180 days, and likewise in flowing water. Each sample contained two possible crevice sites. The results indicate that C-22® alloy is very resistant to crevice corrosion in seawater.

	Quiescent		Flowing	
Alloy	**No. of Sites Attacked**	**Maximum Depth of Attack, mm**	**No. of Sites Attacked**	**Maximum Depth of Attack, mm**
316L	A:2, B:2	A:1.33, B:2.27	A:2, B:2	A:0.48, B:0.15
254SMO	A:2, B:2	A:0.76, B:1.73	A:2, B:2	A:0.01, B:<0.01
625	A:1, B:2	A:0.18, B:0.04	A:2, B:2	A:<0.01, B:<0.01
C-276	A:1, B:1	A:0.10, B:0.13	A:0, B:0	A:0, B:0
C-22®	**A:0, B:0**	**A:0, B:0**	**A:0, B:0**	**A:0, B:0**

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. Predictably, the inhomogeneous nature of weld microstructures leads to higher corrosion rates (than with homogeneous, wrought products). Nevertheless, HASTELLOY® C-22® alloy exhibits excellent resistance to the key, inorganic acids, even in welded form, as shown in the following table:

	Concentration	Temperature		Corrosion Rate			
				Weld Metal		Wrought Base Metal	
Chemical	**wt.%**	**°F**	**°C**	**mpy**	**mm/y**	**mpy**	**mm/y**
H_2SO_4	30	150	66	0.6	0.02	0.4	0.01
H_2SO_4	50	150	66	9.3	0.24	0.8	0.02
H_2SO_4	70	150	66	10.3	0.26	11	0.28
H_2SO_4	90	150	66	18.5	0.47	13.4	0.34
HCl	5	100	38	<0.1	<0.01	<0.1	<0.01
HCl	10	100	38	<0.1	<0.01	0.4	0.01
HCl	15	100	38	11.1	0.28	9.4	0.24
HCl	20	100	38	10.2	0.26	7.9	0.2

Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	0.314 lb/in³	RT	8.69 g/cm³
Electrical Resistivity	RT	44.9 µohm.in	RT	1.14 µohm.m
	200°F	48.0 µohm.in	100°C	1.23 µohm.m
	400°F	48.8 µohm.in	200°C	1.24 µohm.m
	600°F	49.3 µohm.in	300°C	1.25 µohm.m
	800°F	49.7 µohm.in	400°C	1.26 µohm.m
	1000°F	50.1 µohm.in	500°C	1.27 µohm.m
	-	-	600°C	1.28 µohm.m
Thermal Conductivity	100°F	69 Btu.in/h.ft².°F	50°C	10.1 W/m.°C
	200°F	76 Btu.in/h.ft².°F	100°C	11.1 W/m.°C
	400°F	94 Btu.in/h.ft².°F	200°C	13.4 W/m.°C
	600°F	110 Btu.in/h.ft².°F	300°C	15.5 W/m.°C
	800°F	125 Btu.in/h.ft².°F	400°C	17.5 W/m.°C
	1000°F	139 Btu.in/h.ft².°F	500°C	19.5 W/m.°C
	-	-	600°C	21.3 W/m.°C
Thermal Diffusivity	RT	0.004 in²/s	RT	0.027 cm²/s
	200°F	0.005 in²/s	100°C	0.030 cm²/s
	400°F	0.005 in²/s	200°C	0.035 cm²/s
	600°F	0.006 in²/s	300°C	0.039 cm²/s
	800°F	0.007 in²/s	400°C	0.042 cm²/s
	1000°F	0.007 in²/s	500°C	0.046 cm²/s
	-	-	600°C	0.048 cm²/s
Mean Coefficient of Thermal Expansion	75-200°F	6.9 µin/in.°F	24-100°C	12.4 µm/m.°C
	75-400°F	6.9 µin/in.°F	24-200°C	12.4 µm/m.°C
	75-600°F	7.0 µin/in.°F	24-300°C	12.6 µm/m.°C
	75-800°F	7.4 µin/in.°F	24-400°C	13.1 µm/m.°C
	75-1000°F	7.7 µin/in.°F	24-500°C	13.7 µm/m.°C
	75-1200°F	8.1 µin/in.°F	24-600°C	14.3 µm/m.°C
	75-1400°F	8.5 µin/in.°F	24-700°C	14.9 µm/m.°C
	75-1600°F	8.8 µin/in.°F	24-800°C	15.5 µm/m.°C
	75-1800°F	9.0 µin/in.°F	24-900°C	15.9 µm/m.°C
Specific Heat	100°F	0.098 Btu/lb.°F	50°C	414 J/kg.°C
	200°F	0.101 Btu/lb.°F	100°C	423 J/kg.°C
	400°F	0.106 Btu/lb.°F	200°C	444 J/kg.°C
	600°F	0.111 Btu/lb.°F	300°C	460 J/kg.°C
	800°F	0.114 Btu/lb.°F	400°C	476 J/kg.°C
	1000°F	0.118 Btu/lb.°F	500°C	485 J/kg.°C
	-	-	600°C	514 J/kg.°C

RT= Room Temperature

Physical Properties Continued

Physical Property	British Units		Metric Units	
Dynamic Modulus of Elasticity	RT	29.9×10^6 psi	RT	206 GPa
	200°F	29.4×10^6 psi	200°C	197 GPa
	400°F	28.5×10^6 psi	300°C	191 GPa
	600°F	27.6×10^6 psi	400°C	185 GPa
	800°F	26.6×10^6 psi	500°C	179 GPa
	1000°F	25.7×10^6 psi	600°C	174 GPa
	1200°F	24.8×10^6 psi	700°C	168 GPa
	1400°F	23.6×10^6 psi	800°C	160 GPa
	1600°F	22.4×10^6 psi	900°C	152 GPa
	1800°F	21.1×10^6 psi	1000°C	144 GPa
Melting Range	2475-2550°F	-	1357-1399°C	-

RT= Room Temperature

Impact Strength

Test Temperature		Impact Strength	
°F	**°C**	**ft-lbf**	**J**
RT	RT	419	568
-320	-196	346	469

Impact strengths were generated using Charpy V-notch samples, machined from mill annealed plate.

Tensile Strength & Elongation

Form	Test Temperature		Thickness/ Bar Diameter		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
	°F	°C	in	mm	ksi	MPa	ksi	MPa	%
Sheet	RT	RT	0.028-0.125	0.7-3.2	59	407	116	800	57
Sheet	200	93	0.028-0.125	0.7-3.2	54	372	110	758	58
Sheet	400	204	0.028-0.125	0.7-3.2	44	303	102	703	57
Sheet	600	316	0.028-0.125	0.7-3.2	42	286	98	676	62
Sheet	800	427	0.028-0.125	0.7-3.2	41	283	95	655	67
Sheet	1000	538	0.028-0.125	0.7-3.2	40	276	91	627	61
Sheet	1200	649	0.028-0.125	0.7-3.2	36	248	85	586	65
Sheet	1400	760	0.028-0.125	0.7-3.2	35	241	76	524	63
Plate	RT	RT	0.25-0.75	6.4-19.1	54	372	114	786	62
Plate	200	93	0.25-0.75	6.4-19.1	49	338	107	738	65
Plate	400	204	0.25-0.75	6.4-19.1	41	283	98	676	66
Plate	600	316	0.25-0.75	6.4-19.1	36	248	95	655	68
Plate	800	427	0.25-0.75	6.4-19.1	35	241	92	634	68
Plate	1000	538	0.25-0.75	6.4-19.1	34	234	88	607	67
Plate	1200	649	0.25-0.75	6.4-19.1	32	221	83	572	69
Plate	1400	760	0.25-0.75	6.4-19.1	31	214	76	524	68
Bar	RT	RT	0.5-2.0	12.7-50.8	52	359	111	765	70
Bar	200	93	0.5-2.0	12.7-50.8	45	310	105	724	73
Bar	400	204	0.5-2.0	12.7-50.8	38	262	96	662	74
Bar	600	316	0.5-2.0	12.7-50.8	34	234	92	634	79
Bar	800	427	0.5-2.0	12.7-50.8	31	214	89	614	79
Bar	1000	538	0.5-2.0	12.7-50.8	29	200	84	579	80
Bar	1200	649	0.5-2.0	12.7-50.8	28	193	80	552	80
Bar	1400	760	0.5-2.0	12.7-50.8	29	200	72	496	77

Values are averages from numerous tests
RT= Room Temperature

Hardness

Form	Hardness, HRBW	Typical ASTM Grain Size
Sheet	88	3.5 - 5.5
Plate	88	0 - 4.5
Bar	84	1 - 3.5

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

Welding & Fabrication

HASTELLOY® C-22® alloy is very amenable to the Gas Metal Arc (GMA/MIG), Gas Tungsten Arc (GTA/TIG), and Shielded Metal Arc (SMA/Stick) welding processes. Matching filler metals (i.e. solid wires and coated electrodes) are available for these processes, and welding guidelines are given in our "Welding and Fabrication" brochure.

Wrought products of HASTELLOY® C-22® 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® C-22® alloy is 1121°C (2050°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). More details concerning the heat treatment of HASTELLOY® C-22® alloy are given in our "Welding and Fabrication" brochure.

HASTELLOY® C-22® 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 1232°C (2250°F) and the recommended finish temperature is 954°C (1750°F). Moderate reductions and frequent re-heating provide the best results, as described in our "Welding and Fabricaiton" brochure. This reference also provides guidelines for cold forming, spinning, drop hammering, punching, and shearing. The alloy is stiffer than most austenitic stainless steels, and more energy is required during cold forming. Also, HASTELLOY® C-22® 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® C-22® 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 & Codes

Specifications

HASTELLOY® C-22® alloy (N06022, W86022)	
Sheet, Plate & Strip	SB 575/B 575 P= 43
Billet, Rod & Bar	SB 574/B 574 B 472 P= 43
Coated Electrodes	SFA 5.11/ A 5.11 (ENiCrMo-10) DIN 2.4638 (EL-NiCr21Mo14W) F= 43
Bare Welding Rods & Wire	SFA 5.14/ A 5.14 (ERNiCrMo-10) DIN 2.4635 (SG-NiCr21Mo14W) F= 43
Seamless Pipe & Tube	SB 622/B 622 P= 43
Welded Pipe & Tube	SB 619/B 619 SB 626/B 626 P= 43
Fittings	SB 366/B 366 SB 462/B 462 P=43
Forgings	SB 564/B 564 SB 462/B 462 P= 43
DIN	17744 No. 2.4602 NiCr21Mo14W
TÜV	Werkstoffblatt 479 Kennblatt 4635 Kennblatt 4636 Kennblatt 4534
Others	NACE MR0175 ISO 15156 ASME Code Case No. 2226-2 Case No. N-621-1

Codes

HASTELLOY® C-22® alloy (N06022, W86022)			
ASME	Section I		1250°F (677°C)[1] Code Case 2226 1250°F (677°C)
	Section III	Class 1	800°F (427°C)[1] Code Case N-621-1
		Class 2	1250°F (677°C)[2]
		Class 3	1250°F (677°C)[2]
	Section VIII	Div. 1	1250°F (677°C)[1] 800°F (427°C)[3]
		Div. 2	1250°F (677°C)[1] 800°F (427°C)[3]
	Section XII		650°F (343°C)[4]
	B16.5		1250°F (677°C)[5]
	B16.34		1250°F (677°C)[6]
	B31.1		800°F (427°C)[7]
	B31.3		800°F (427°C)[8]
VdTÜV (doc #)			844°F (450°C)[9], #479

[1]Approved material forms: Plate, Sheet, Bar, Forgings, fittings, welded pipe/tube, seamless pipe/tube
[2]Approved material forms: Plate, Sheet, Bar, Forgings, welded pipe/tube, seamless pipe/tube
[3]Approved material forms: Bolting
[4]Approved material forms: Plate, Sheet, Bar, fittings, welded pipe/tube, seamless pipe/tube, Bolting
[5]Approved material forms: Plate, Forgings, fittings, Bolting
[6]Approved material forms: Plate, Bar, Forgings, seamless pip/tube, Bolting
[7]Approved material forms: Plate, Sheet, fittings, welded pipe/tube, seamless pipe/tube
[8]Approved material forms: Plate, Sheet, Forgings, fittings, welded pipe/tube, seamless pipe/tube
[9]Approved material forms: Plate, Sheet, Bar, Forgings