



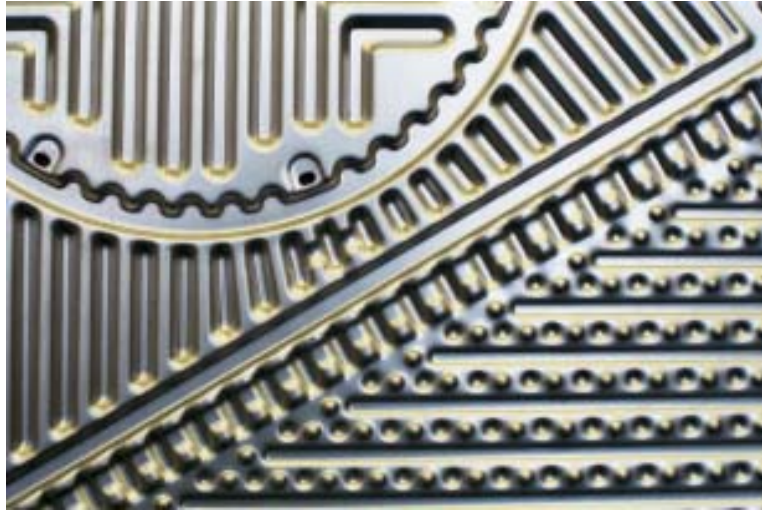
## HASTELLOY® C-2000® alloy

An extremely versatile nickel alloy resistant to corrosion in all acids and chloride solutions, over wide temperature ranges.

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HASTELLOY C-2000 alloy heat exchanger plate made for service in concentrated sulfuric acid



## Ni-Cr-Mo Alloy Application Ranges

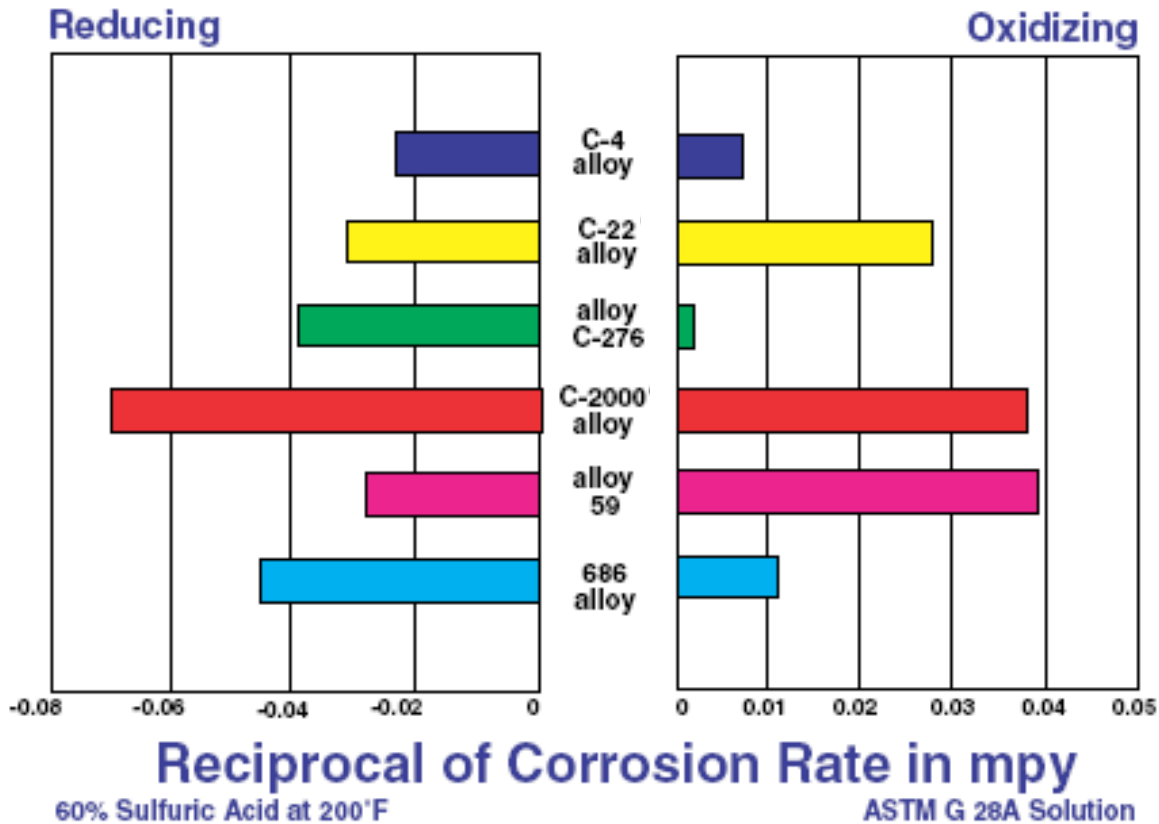


Illustration of versatility of HASTELLOY C-2000 alloy using reciprocals of corrosion rates in reducing and oxidizing acids

## PRINCIPAL FEATURES

### *Corrosion Performance*

The nickel-chromium-molybdenum (Ni-Cr-Mo) C-type alloys have a long history of use in the Chemical Process Industries and are known for their versatility. Not only do they resist all acids (especially hydrochloric, sulfuric, and hydrofluoric) over large temperature ranges, but they also resist the insidious types of attack induced by chlorides and other halide solutions, specifically pitting, crevice attack, and stress corrosion cracking.

The technical objective during the design of HASTELLOY® C-2000® alloy\* was even greater versatility, as compared with the traditional Ni-Cr-Mo alloys. This was accomplished by use of a high chromium content (23 wt.%), a high molybdenum content (16 wt.%), and a small but effective addition of copper (1.6 wt.%). The copper was found to provide enhanced temperature capability in sulfuric acid, hydrofluoric acid, and dilute hydrochloric acid.

### *Product Forms*

C-2000 alloy is available in plate, sheet, strip, billet, bar, wire, covered electrodes, pipe, and tubing.

### *Applications*

- Chemical process industry reactors, heat exchangers, columns, and piping.
- Pharmaceutical industry reactors and dryers.
- Flue gas desulfurization systems.

### *Field Test Program*

Samples of C-2000 alloy are available for field trials. Furthermore, samples can be weighed prior to delivery, and then reweighed after test by the customer, and reports provided on corrosion rates and other observations. For samples, please contact one of the Haynes International Service Centers listed on the back cover of this brochure.

### *Specifications*

C-2000 alloy is covered by ASME, ASTM, AWS, DIN, and TÜV specifications. A listing of these is provided on page 14.

## COMPOSITION, wt. %\*\*

Ni	Cr	Mo	Fe	Cu	Al	Mn	Si	C
BAL	23	16	3***	1.6	0.5***	0.5***	0.08***	0.01***

\*Covered by U.S. Patent 6,280,540

\*\* The undiluted deposit composition of C-2000 alloy covered electrodes contains up to 0.02% carbon and 0.2% silicon.

\*\*\* Maximum.

# PHYSICAL PROPERTIES

Physical Property	Metric Units		British Units	
Density	RT	8.50 g/cm. <sup>3</sup>	RT	0.307 lb/in. <sup>3</sup>
Electrical Resistivity	RT	1.28 μohm.m	RT	50.6 μohm.in
	100°C	1.29 μohm.m	200°F	50.8 μohm.in
	200°C	1.30 μohm.m	400°F	51.2 μohm.in
	300°C	1.31 μohm.m	600°F	51.6 μohm.in
	400°C	1.32 μohm.m	800°F	52.2 μohm.in
	500°C	1.34 μohm.m	1000°F	52.9 μohm.in
	600°C	1.35 μohm.m	1200°F	53.0 μohm.in
Thermal Conductivity	RT	9.1 W/m.°C	RT	63 btu.in/h.ft <sup>2</sup> .°F
	100°C	10.8 W/m.°C	200°F	74 btu.in/h.ft <sup>2</sup> .°F
	200°C	12.6 W/m.°C	400°F	88 btu.in/h.ft <sup>2</sup> .°F
	300°C	14.1 W/m.°C	600°F	99 btu.in/h.ft <sup>2</sup> .°F
	400°C	16.1 W/m.°C	800°F	114 btu.in/h.ft <sup>2</sup> .°F
	500°C	18.0 W/m.°C	1000°F	133 btu.in/h.ft <sup>2</sup> .°F
	600°C	21.6 W/m.°C	1200°F	162 btu.in/h.ft <sup>2</sup> .°F
Mean Coefficient of Thermal Expansion	25-100°C	12.4 μm/m.°C	77-200°F	6.9 μin/in.°F
	25-200°C	12.4 μm/m.°C	77-400°F	6.9 μin/in.°F
	25-300°C	12.6 μm/m.°C	77-600°F	7.0 μin/in.°F
	25-400°C	12.9 μm/m.°C	77-800°F	7.2 μin/in.°F
	25-500°C	13.2 μm/m.°C	77-1000°F	7.4 μin/in.°F
	25-600°C	13.3 μm/m.°C	77-1200°F	7.6 μin/in.°F
Thermal Diffusivity	RT	0.025 cm <sup>2</sup> /s	RT	0.10 ft <sup>2</sup> /h
	100°C	0.029 cm <sup>2</sup> /s	212°F	0.11 ft <sup>2</sup> /h
	200°C	0.033 cm <sup>2</sup> /s	392°F	0.13 ft <sup>2</sup> /h
	300°C	0.036 cm <sup>2</sup> /s	572°F	0.14 ft <sup>2</sup> /h
	400°C	0.040 cm <sup>2</sup> /s	752°F	0.16 ft <sup>2</sup> /h
	500°C	0.043 cm <sup>2</sup> /s	932°F	0.17 ft <sup>2</sup> /h
	600°C	0.047 cm <sup>2</sup> /s	1112°F	0.18 ft <sup>2</sup> /h
Specific Heat	RT	428 J/kg.°C	RT	0.10 btu/lb.°F
	100°C	434 J/kg.°C	212°F	0.10 btu/lb.°F
	200°C	443 J/kg.°C	392°F	0.11 btu/lb.°F
	300°C	455 J/kg.°C	572°F	0.11 btu/lb.°F
	400°C	468 J/kg.°C	752°F	0.11 btu/lb.°F
	500°C	486 J/kg.°C	932°F	0.12 btu/lb.°F
	600°C	536 J/kg.°C	1112°F	0.13 btu/lb.°F
Dynamic Modulus of Elasticity	RT	207 GPa	RT	30.0 × 10 <sup>6</sup> psi
	316°C	190 GPa	600°F	27.5 × 10 <sup>6</sup> psi
	427°C	177 GPa	800°F	25.6 × 10 <sup>6</sup> psi
	538°C	171 GPa	1000°F	24.8 × 10 <sup>6</sup> psi
	649°C	162 GPa	1200°F	23.5 × 10 <sup>6</sup> psi
Melting Range	1328-1358°C		2422-2476°F	

# LOCALIZED CORROSION DATA

## Critical Crevice (CCT) and Critical Pitting (CPT) Temperatures in Acidified Ferric Chloride (ASTM G 48, Methods D and C)

To assess the resistance of alloys to pitting and crevice attack, it is customary to measure their Critical Crevice Temperatures and Critical Pitting 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 crevice attack and pitting attack are encountered in acidified ferric chloride, within 72 hours.

ALLOY	Critical Crevice Temperatures		Critical Pitting Temperatures	
	°C	°F	°C	°F
316L	0	32	15	59
254SMO®	30	86	60	140
625	40	104	100	212
C-22	80	176	>120	>248
C-276	55	131	>120	>248
<b>C-2000</b>	<b>80</b>	<b>176</b>	<b>&gt;120</b>	<b>&gt;248</b>

## Critical Pitting Temperatures in Green Death Solution

Another solution commonly used for assessing the pitting resistance of nickel alloys is 11.5% sulfuric acid + 1.2% hydrochloric acid + 1% ferric chloride + 1% cupric chloride, otherwise known as Green Death. Listed are Critical Pitting Temperatures of C-2000 and other alloys in Green Death, based on tests of 24 hours.

ALLOY	Critical Pitting Temperatures	
	°C	°F
316L	25	77
625	75	167
C-4	90	194
C-22	120	248
C-276	105	221
<b>C-2000</b>	<b>110</b>	<b>230</b>

## Seawater Crevice Corrosion Results

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 industries. Listed are some recent data, generated as part of a U.S. Navy study at the LaQue Laboratories in Wrightsville Beach, North Carolina.\* Crevice tests were performed in both still (quiescent) and flowing seawater, at 29°C, plus or minus 3°C. Two samples of each alloy were tested in still water for 180 days, and two samples of each alloy were tested in flowing water for 180 days. Each sample contained two possible crevice sites.

ALLOY	QUIESCENT	QUIESCENT	FLOWING	FLOWING
	NO. OF SITES	DEPTH, mm	NO. OF SITES	DEPTH, mm
316L	2	1.80	2	0.32
254SMO	2	1.25	2	0.01
625	2	0.11	2	<0.01
C-22	0	0	0	0
C-276	1	0.12	0	0
<b>C-2000</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

\*Ref. D. M. Aylor et al, Paper No. 329, CORROSION 99, NACE International, 1999.

# UNIFORM CORROSION DATA (C-2000, C-4, C-22)

Chemical	Conc. wt.%	Temperature		Corrosion Rate					
		°C	°F	C-2000		C-4		C-22	
				mm/y	mpy	mm/y	mpy	mm/y	mpy
Hydrochloric Acid	1	Boiling		0.01	0.2	0.48	18.8	0.06	2.2
	5	79	175	<0.01	0.1	0.98	38.6	1.44	56.6
	10	38	100	<0.01	<0.1	0.19	7.3	0.01	0.4
	20	38	100	0.16	6.3	0.14	5.4	0.20	7.7
Hydrobromic Acid	2.5	Boiling		0.01	0.2	0.08	3.3	0.02	0.6
	5	93	200	0.01	0.2	0.76	29.9	0.01	0.3
	7.5	93	200	<0.01	0.1	0.76	29.9	0.45	17.8
	10	79	175	<0.01	<0.1	0.53	20.9	0.01	0.3
	20	66	150	<0.01	<0.1	0.35	13.7	0.46	18.2
Hydrofluoric Acid	1	79	175	0.18	7.0	N/T	N/T	0.21	8.2
	5	52	125	0.09	3.7	N/T	N/T	0.15	6.0
	10	52	125	0.22	8.7	N/T	N/T	0.33	13.1
	20	52	125	0.48	18.8	N/T	N/T	0.53	21.0
Sulfuric Acid	10	93	200	0.02	0.8	0.19	7.3	0.04	1.6
	20	93	200	0.03	1.0	0.38	15.1	0.28	11.0
	30	93	200	0.04	1.5	0.54	21.3	0.68	26.8
	40	79	175	0.01	0.5	0.38	15.0	0.31	12.3
	50	79	175	0.02	0.7	0.63	24.7	0.40	15.9
	60	79	175	0.02	0.9	0.67	26.4	0.67	26.4
	70	66	150	0.01	0.2	0.14	5.7	0.28	11.0
	80	66	150	0.06	2.2	0.13	5.1	N/T	N/T
	90	79	175	0.07	2.9	0.71	27.9	N/T	N/T
Nitric Acid	20	Boiling		0.02	0.7	0.38	15.0	0.06	2.3
	40	Boiling		0.24	9.5	1.27	50.0	0.26	10.4
	60	93	200	0.19	7.4	0.73	28.7	0.19	7.6
	70	93	200	0.29	11.4	0.95	37.4	0.33	13.0
Phosphoric Acid	50	Boiling		0.03	1.1	0.27	10.7	0.03	1.3
	60	Boiling		0.08	3.2	0.11	4.3	0.56	21.9
	70	Boiling		0.15	6.0	0.13	5.1	1.04	41.0
	80	Boiling		0.40	15.6	0.26	10.3	3.02	119.0
Chromic Acid	10	66	150	0.10	3.9	N/T	N/T	0.13	5.0
	20	66	150	0.61	24.1	N/T	N/T	0.68	26.7
Acetic Acid	99	Boiling		<0.01	<0.1	<0.01	0.1	<0.01	0.1
Formic Acid	88	Boiling		0.01	0.4	0.05	2.0	0.02	0.9
ASTM G 28A**		Boiling		0.67	26.3	3.52	138.6	1.02	40.0
ASTM G 28B***		Boiling		0.11	4.2	N/T	N/T	0.20	8.0

\*N/T = not tested

\*\*G 28A = 50% H<sub>2</sub>SO<sub>4</sub> + 42 g/l Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>

\*\*\*G 28B = 23% H<sub>2</sub>SO<sub>4</sub> + 1.2% HCl + 1% FeCl<sub>3</sub> + 1% CuCl<sub>2</sub>

**HASTELLOY® C-2000® alloy**

# UNIFORM CORROSION DATA (C-276, 625)

Chemical	Conc. wt.%	Temperature		Corrosion Rate			
		°C	°F	C-276		625	
				mm/y	mpy	mm/y	mpy
Hydrochloric Acid	1	Boiling		0.33	13.0	0.23	8.9
	5	79	175	0.75	29.4	4.65	183.0
	10	38	100	0.17	6.8	0.30	11.9
	20	38	100	0.14	5.4	0.36	14.1
Hydrobromic Acid	2.5	Boiling		0.13	5.0	<0.01	0.1
	5	93	200	0.15	5.8	0.60	23.7
	7.5	93	200	0.73	28.7	0.93	36.5
	10	79	175	0.51	20.0	0.82	32.3
	20	66	150	0.37	14.5	0.65	25.7
Hydrofluoric Acid	1	79	175	0.40	15.9	0.31	12.2
	5	52	125	0.34	13.4	0.70	27.4
	10	52	125	0.41	16.0	2.23	87.8
	20	52	125	0.48	18.8	4.33	170.5
Sulfuric Acid	10	93	200	0.14	5.5	0.24	9.5
	20	93	200	0.40	15.6	0.58	23.0
	30	93	200	0.42	16.4	0.68	26.9
	40	79	175	0.19	7.5	0.58	22.8
	50	79	175	0.26	10.3	0.89	35.2
	60	79	175	0.30	11.8	0.92	36.2
	70	66	150	0.05	1.8	0.63	24.7
	80	66	150	0.04	1.6	0.91	35.8
	90	79	175	0.05	1.9	6.97	274.5
Nitric Acid	20	Boiling		0.66	25.9	0.01	0.3
	40	Boiling		4.42	174.0	0.14	5.5
	60	93	200	2.03	80.0	0.06	2.4
	70	93	200	2.62	103.0	0.08	3.2
Phosphoric Acid	50	Boiling		0.18	6.9	0.02	0.9
	60	Boiling		0.28	11.1	0.16	6.2
	70	Boiling		0.13	5.2	0.89	35.2
	80	Boiling		0.31	12.3	4.90	193.0
Chromic Acid	10	66	150	0.13	5.0	0.13	5.2
	20	66	150	0.53	21.0	1.00	39.3
Acetic Acid	99	Boiling		<0.01	0.1	<0.01	0.1
Formic Acid	88	Boiling		0.04	1.4	0.24	9.3
ASTM G 28A**		Boiling		5.97	235.0	0.48	18.8
ASTM G 28B***		Boiling		1.23	48.3	N/T	N/T

\*N/T = not tested

\*\*G 28A = 50% H<sub>2</sub>SO<sub>4</sub> + 42 g/l Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>

\*\*\*G 28B = 23% H<sub>2</sub>SO<sub>4</sub> + 1.2% HCl + 1% FeCl<sub>3</sub> + 1% CuCl<sub>2</sub>

# STRESS CORROSION CRACKING

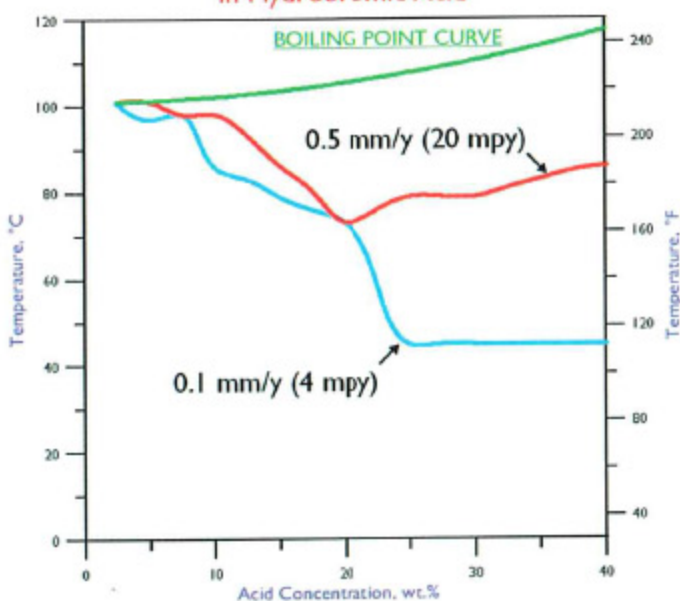
A common solution for assessing the resistance to chloride-induced stress corrosion cracking of a material is boiling 45% magnesium chloride. This table indicates the times required to induce cracking in U-bend samples of several materials. The tests were stopped after six weeks (1008 hours).

ALLOY	TIME TO CRACKING
316L	2 h
254SMO	24 h
625	No cracking in 1008 h
C-22	No cracking in 1008 h
C-276	No cracking in 1008 h
<b>C-2000</b>	<b>No cracking in 1008 h</b>

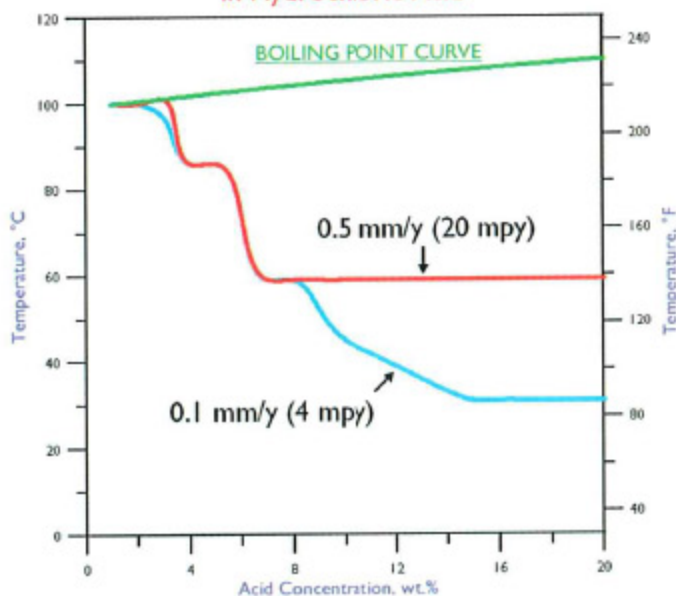
## ISO-CORROSION DIAGRAMS

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. 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 red line, rates of 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-2000 Alloy in Hydrobromic Acid



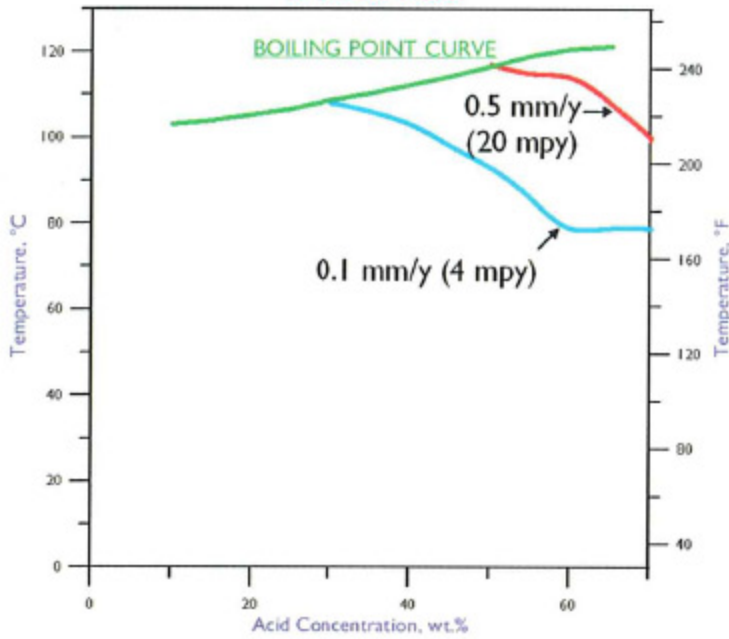
Iso-Corrosion Diagram for C-2000 Alloy in Hydrochloric Acid



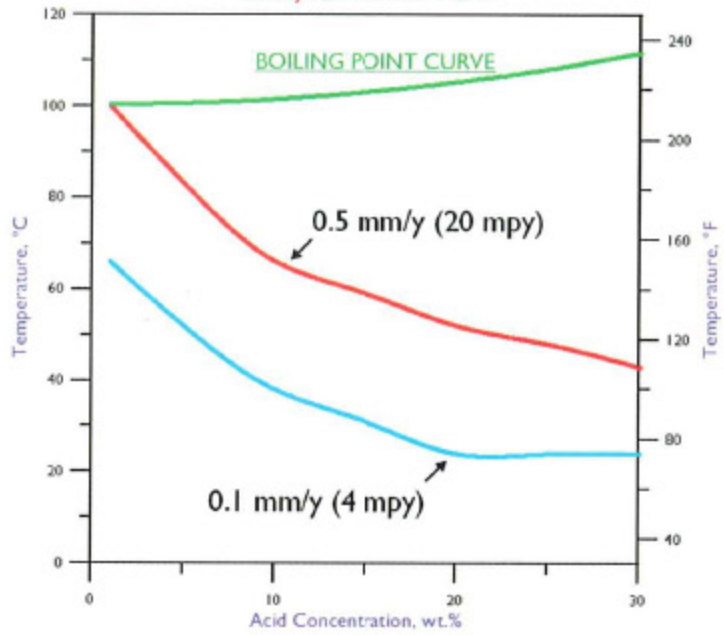


# ISOCORROSION DIAGRAMS

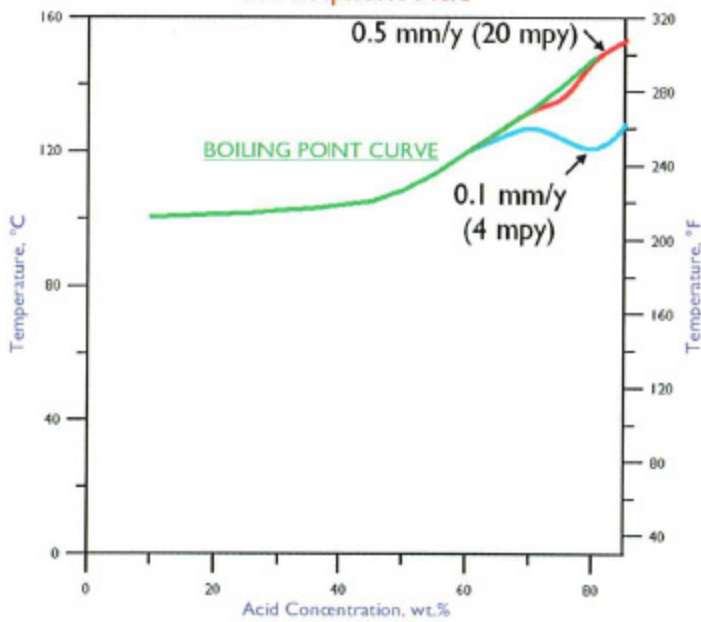
Iso-Corrosion Diagram for C-2000 Alloy in Nitric Acid



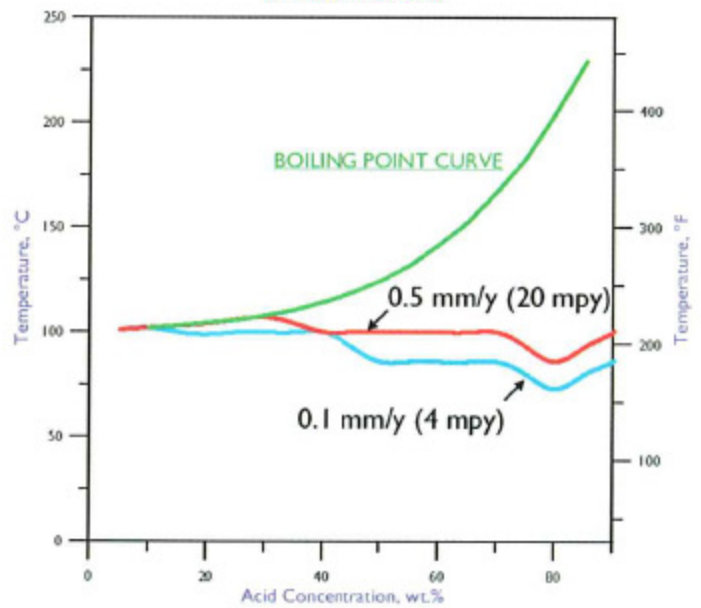
Iso-Corrosion Diagram for C-2000 Alloy in Hydrofluoric Acid



Iso-Corrosion Diagram for C-2000 Alloy in Phosphoric Acid



Iso-Corrosion Diagram for C-2000 Alloy in Sulfuric Acid



# MECHANICAL PROPERTIES

## Room Temperature Tensile Data

Form	Annealing Temperature		Thickness/ Diameter		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation %
	°C	°F	mm	in	MPa	ksi	MPa	ksi	
Sheet	1163	2125	0.6	0.025	372	54.0	752	109.0	61.0
Sheet	1163	2125	2.0	0.079	400	58.0	786	114.0	62.0
Sheet	1163	2125	3.2	0.125	359	52.0	758	110.0	64.0
Plate	1149	2100	4.8	0.188	407	59.0	745	108.0	63.0
Plate	1149	2100	6.4	0.25	393	57.0	731	106.0	63.0
Plate	1149	2100	12.7	0.5	365	53.0	731	106.0	69.0
Plate	1149	2100	25.4	1.0	359	52.0	717	104.0	71.0
Plate	1149	2100	38.1	1.5	331	48.0	696	101.0	76.0
Bar	1149	2100	9.7	0.38	331	48.0	745	108.0	67.0
Bar	1149	2100	19.1	0.75	345	50.0	738	107.0	69.0
Bar	1149	2100	25.4	1.0	379	55.0	758	110.0	68.0
Bar	1149	2100	50.8	2.0	379	55.0	724	105.0	71.0
Bar	1149	2100	88.9	3.5	386	56.0	738	107.0	71.0

## Elevated Temperature Tensile Data (Averaged for Plates and Bars)

Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
°C	°F	MPa	ksi	MPa	ksi	%
93	200	319	46.3	724	105.0	70.3
149	300	308	44.7	684	99.2	68.8
204	400	283	41.0	676	98.0	69.3
260	500	260	37.7	641	93.0	67.9
316	600	243	35.3	616	89.3	72.7
371	700	234	33.9	605	87.8	69.8
427	800	216	31.3	609	88.3	73.0
482	900	223	32.4	585	84.9	72.6
538	1000	214	31.0	586	85.0	75.3
649	1200	209	30.3	554	80.3	70.7

## Charpy V-Notch Impact Data (Plate)

Test Temperature		Condition	Impact Strength	
°C	°F		J	ft.lbf
RT	RT	Annealed	>358	>264
-196	-320	Annealed	>358	>264
RT	RT	Annealed then Aged for 100 h at 260°C/500°F	>358	>264
-196	-320	Annealed then Aged for 100 h at 260°C/500°F	342	252
RT	RT	Annealed then Aged for 100 h at 538°C/1000°F	224	165
-196	-320	Annealed then Aged for 100 h at 538°C/1000°F	174	128

# WELDING AND FABRICATION

## Welding

The weldability of C-2000 alloy is similar to that of C-276 alloy. To weld the C-type alloys, three processes are commonly used. For sheet welds and plate root passes, gas tungsten arc (GTAW) welding is favored. For plate welds, the gas metal arc (GMAW) process is preferred. For field welding, the shielded metal arc process, using coated electrodes, is favored. Submerged arc welding is not recommended as this process is characterized by high heat input to the base metal and slow cooling of the weld.

To minimize the precipitation of second phases in regions affected by the heat of welding, a maximum interpass temperature of 93°C (200°F) is recommended for the C-type alloys. Also, welding of cold-worked materials is strongly discouraged, since they sensitize more quickly and induce residual stresses. A full solution anneal, followed by water quenching, is recommended for cold-worked structures prior to welding.

### 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

For gas tungsten arc and gas metal arc welding, C-2000 filler wire (ERNiCrMo-17) is suggested. For shielded metal arc welding, C-2000 covered electrodes (ENiCrMo-17) are suggested.

## Tensile Data for Weldments

Welding Process	Form	Test Temperature		0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation %
		°C	°F	MPa	ksi	MPa	ksi	
Gas Tungsten Arc Welding (GTAW)	Transverse Sample from Welded Plate of Thickness of 12.7 mm/0.5 in	RT	RT	465	67.4	778	112.8	36.4
		260	500	326	47.3	642	93.1	42.1
		538	1000	299	43.3	558	80.6	38.9
	All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform	RT	RT	493	71.5	733	106.3	44.0
		260	500	391	56.7	614	89.0	47.4
		538	1000	365	52.9	528	76.6	46.6
Synergic Gas Metal Arc Welding (GMAW)	Transverse Sample from Welded Plate of Thickness of 12.7 mm/0.5 in	RT	RT	456	66.2	783	113.5	42.1
		260	500	352	51.1	654	94.8	43.1
		538	1000	301	43.7	582	84.4	45.6
	All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform	RT	RT	495	71.8	740	107.4	46.5
		260	500	394	57.2	620	89.9	46.4
		538	1000	377	54.7	552	80.1	50.5
Shielded Metal Arc Welding	Transverse Sample from Welded Plate of Thickness 25.4 mm/1.0 in (Flat Position)	RT	RT	364	52.8	718	104.1	58.1
	All Weld Metal Sample of Diameter 12.7 mm/0.5 in taken from Plate Weld	RT	RT	510	74.0	744	107.9	40.4
		450	842	386	56.0	565	81.9	43.9

# WELDING AND FABRICATION

## Charpy V-Notch Impact Data for Weldments

Welding Process	Form	Notch Position	Test Temperature		Impact Strength	
			°C	°F	J	ft.lbf
Synergic Gas Metal Arc Welding (GMAW)	Transverse Sample from Welded Plate of Thickness 12.7 mm./0.5 in	Mid-Weld	RT	RT	142	105
			-196	-320	106	78
Shielded Metal Arc Welding (Stick)	All Weld Metal Sample taken from Plate Weld	Heat Affected Zone	RT	RT	240	177
			-196	-320	203	150
Shielded Metal Arc Welding (Stick)	All Weld Metal Sample taken from Plate Weld	In Weld	RT	RT	71	52
			-196	-320	45	33

## Fabrication

### Heat Treatment

Wrought forms of HASTELLOY C-2000 alloy are furnished in the solution annealed condition, unless otherwise specified. The standard solution annealing treatment consists of heating to 1135°C (2075°F) followed by rapid air-cooling or water quenching. Parts which have been hot formed should be solution annealed prior to final fabrication or installation.

### Forming

C-2000 alloy has excellent forming characteristics, and cold forming is the preferred method of shaping. The alloy can be easily cold worked due to its good ductility. 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.

## Health and Safety

Welding can be a safe occupation. Those in the welding industry, however, should be aware of the potential hazards associated with welding fumes, gases, radiation, electric shock, heat, eye injuries, burns, etc. Also, local, municipal, state, and federal regulations (such as those issued by OSHA) relative to welding and cutting processes should be considered.

Nickel-, cobalt-, and iron-base alloy products may contain, in varying concentration, the following elemental constituents: aluminum, cobalt, chromium, copper, iron, manganese, molybdenum, nickel and tungsten. For specific concentrations of these and other elements present, refer to the Material Safety Data Sheets (MSDS) available from Haynes International, Inc.

Inhalation of metal dust or fumes generated from welding, cutting, grinding, melting, or dross handling of these alloys may cause adverse health effects such as reduced lung function, nasal and mucous membrane irritation. Exposure to dust or fumes which may be generated in working with these alloys may also cause eye irritation, skin rash and effects on other organ systems. The operation and maintenance of welding and cutting equipment should conform to the provision of American National Standard ANSI/AWS Z49.1, "Safety in Welding and Cutting". Attention is especially called to Section 4 (Protection of Personnel) and 5 (Health Protection and Ventilation) of ANSI/AWS Z49.1. Mechanical ventilation is advisable and, under certain conditions such as a very confined space, is necessary during welding or cutting operations, or both, to prevent possible exposure to hazardous fumes, gases, or dust that may occur.

# MACHINING

The following are guidelines for performing typical machining operations upon C-2000 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 C-2000 alloy under various conditions. For further information, please consult Haynes publication H-2010.

## Recommended Tool Types and Machining Conditions

<b>Operations</b>	<b>Carbide Tools</b>	<b>High Speed Steel Tools</b>
Drilling	C-2 grade not recommended, but tipped drills may be successful on rigid setup of no great depth. The web must be thinned to reduce thrust Use 135° included angle on point, Gun drill can be used. Speed: 50 sfm. Oil <sup>2</sup> or water-base <sup>3</sup> coolant. Coolant-feed carbide tipped drills may be economical in some setups.	M-33, M-40 series <sup>1</sup> or T-15: Use short drills, heavy web, 135° crank-shaft, grind points wherever possible. Speed: 10-15 sfm. Feed: 0.001 in. rev. 1/8 in. dia. 0.002 in. rev. 1/4 in. dia. 0.003 in. rev. 1/2 in. dia. 0.005 in. rev. 3/4 in. dia. 0.007 in. rev. 1 in. dia. Oil or water-base coolant. Use coolant feed drills if possible.
Normal Roughing; Turning or Facing	C-2 or C-3 grade: Negative rake square insert, 45° SCEA <sup>4</sup> , 1/32 in. nose radius. Tool holder: 5° neg. back rake, 5° neg. side rake. Speed: 90 sfm depending on rigidity of set up, 0.010 in. feed, 0.150 in. depth of cut. Dry <sup>5</sup> , oil, or water-base coolant.	
Finishing; Turning or Facing	C-2 or C-3 grade: Positive rake square insert, if possible, 45° SCEA, 1/32 in. nose radius. Tool holder: 5° pos. back rake, 5° pos. side rake. Speed: 95-110 sfm, 0.005-0.007 in. feed, 0.040 in. depth of cut. Dry or water-base coolant.	

- NOTES:
- 1 M-40 series High Speed Steels include M-41, M-42, M-43, M-44, M-45 and M-46 at the time of writing. Others may be added and should be equally suitable.
  - 2 Oil coolant should be a premium quality, sulfochlorinated oil with extreme pressure additives. A viscosity at 100°F from 50 to 125 SSU.
  - 3 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. Water-base coolant may cause chipping and rapid failure of carbide tools in interrupted cuts.
  - 4 SCEA - Side cutting edge angle or lead angle of the tool.
  - 5 At any point where dry cutting is recommended, an air jet directed on the tool may provide substantial tool life increase. A water-base coolant mist may also be effective.

## SPECIFICATIONS

HASTELLOY C-2000 alloy (UNS N06200)		Metal No. 2316
ASME/ASTM	SB 564/B 564	Forgings
ASME/ASTM	SB 574/B 574	Rod
ASME/ASTM	SB 575/B 575	Plate, Sheet, and Strip
ASME/ASTM	SB 619/B 619	Welded Pipe
ASME/ASTM	SB 622/B 622	Seamless Pipe and Tubing
ASME/ASTM	SB 626/B 626	Welded Tube
ASME/ASTM	SB 366/B 366	Fittings
ASME/ASTM	SB 462/B 462	Pipe Flanges, Forged Fittings
ASTM	B 472	Billets and Bars for Reforging
ASME	Section VIII, Div. I (P=43)	All Forms
ASME	Code Case 2337 (F=43)	Bare Welding Rods
ASME	Code Case 2338 (F=43)	Covered Welding Electrodes
ASME	B16.5	Pipe Flanges and Flanged Fittings
ASME	B16.34	Valves-Flanged, Threaded, and Welding Ends
AWS	A5.14 (ERNiCrMo-17)	Bare Welding Rods
AWS	A5.11 (ENiCrMo-17)	Covered Welding Electrodes
DIN	17744 No. 2.4675	All Forms
DIN	NiCr23Mo16Cu	All Forms
DIN	2.4699 (EL-NiCr23Mo16Cu)	Covered Welding Electrodes
DIN	2.4698 (SG-NiCr23Mo16Cu)	Bare Welding Rods
TÜV	Werkstoffblatt 539	All Forms
TÜV	Kennblatt 9679.00	Welding Wire
TÜV	Kennblatt 9678.00	Welding Rod
TÜV	Kennblatt 9677.00	Covered Welding Electrodes

Material Safety Data Sheets H-2071 and H-1072

## TRADEMARKS

HASTELLOY®, C-22®, and C-2000® are registered trademarks of Haynes International, Inc. 254SMO® is a registered trademark of Avesta Sheffield.

## REFERENCES

H-2010 Fabrication of HASTELLOY Corrosion Resistant Alloys

"Weldability of a Corrosion-Resistant Ni-Cr-Mo-Cu Alloy," M.D. Rowe et al, Welding Journal, Nov. 2003, American Welding Society, p. 313S

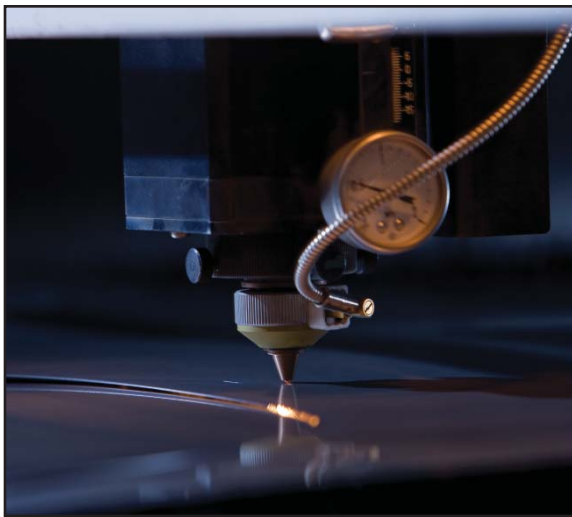
## SERVICE CENTER INFORMATION

### Service and Availability are Standard at Haynes International.

Our global service centers stock millions of pounds of high-performance corrosion-resistant and high-temperature alloys. Whether you need on-demand delivery of finished goods, end-use technical support or a partner with global presence, Haynes International provides value far beyond the alloys themselves.



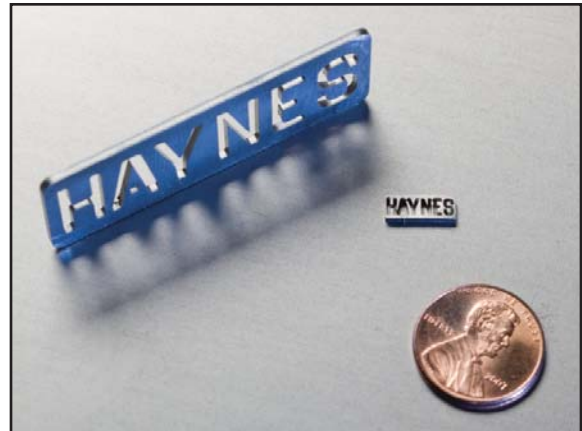
Corrosion-resistant and high-temperature alloy plate is stocked in several of our global service centers and ready for immediate delivery.



Our state-of-the-art laser is one of many of our specialized equipment that provides precision detail.



Our LaserQC® equipment accurately maps out parts for duplication.



Value-added services such as near-net shaped and laser-cut parts can be cut in various sizes to specific drawings and specifications to reduce your labor time and material waste.

# STANDARD PRODUCTS

By Brand or Alloy Designation:

# HAYNES

International

## HASTELLOY® Family of Corrosion-Resistant Alloys

B-3®, C-4, C-22®, C-276, C-2000®, C-22HS®, G-30®, G-35®, G-50®, HYBRID-BC1™, and N

## HASTELLOY Family of Heat-Resistant Alloys

S, W, and X

## HAYNES® Family of Heat-Resistant Alloys

25, R-41, 75, HR-120®, HR-160®, 188, 214®, 230®, 230-W®, 242®, 263, 282®, 556®, 617, 625, 65SQ®, 718, X-750, MULTIMET®, NS-163™, and Waspaloy

## Corrosion-Wear Resistant Alloy

ULTIMET®

## Wear-Resistant Alloy

6B

## HAYNES Titanium Alloy Tubular

Ti-3Al-2.5V

**Standard Forms:** Bar, Billet, Plate, Sheet, Strip, Coils, Seamless or Welded Pipe & Tubing, Pipe Fittings, Flanges, Fittings, Welding Wire, and Coated Electrodes

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