HAYNES International

Corrosion-Resistant Alloys

HASTELLOY® C-22HS® alloy

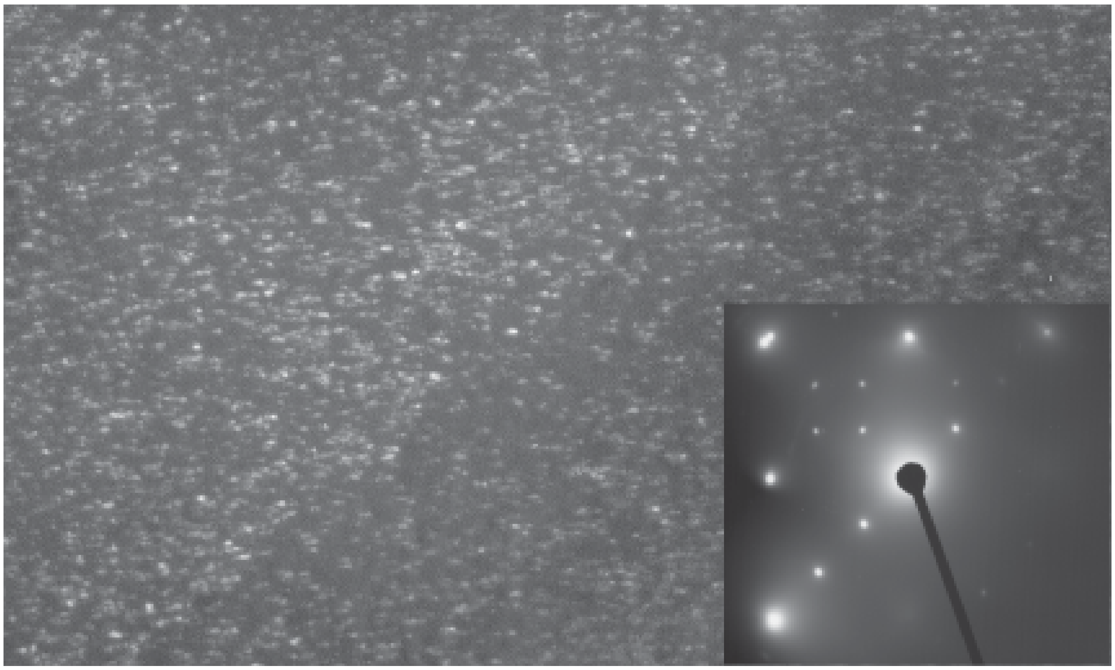
A versatile nickel-chromium-molybdenum alloy with excellent resistance to both oxidizing and reducing acids and which can be heat treated to obtain very high strength.

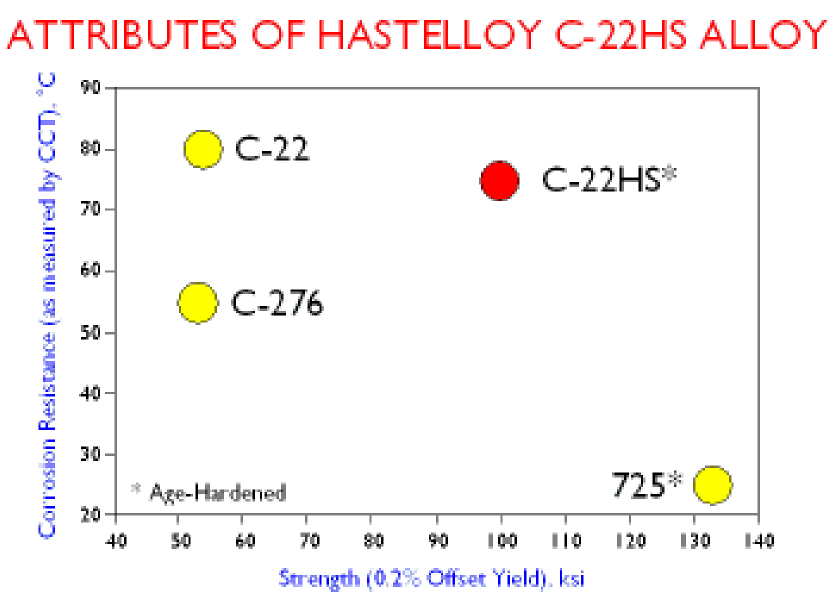
Preliminary Data

Contents

H-2122

A TEM darkfield image of C-22HS alloy in the age-hardened condition. The lighter colored particles are $Ni_2(Mo,Cr)$ precipitates on the order of 10 nm in diameter which give the alloy its high strength. Also shown (inset) is a [001] diffraction pattern indicating that the crystal structure of the precipitates is of the Pt_2Mo type.





Plot illustrating the unique combination of high strength and high corrosion resistance of C-22HS alloy.

PRINCIPAL FEATURES

Outstanding Corrosion Resistance, High Strength
HASTELLOY® C-22HS™ alloy** is corrosion-resistant, nickel-chromium-molybdenum alloy which can be heat treated to obtain a strength approximately double that of other C-type alloys. Importantly, the corrosion resistance and ductility of the alloy remain excellent when in the high strength condition. In addition to its high uniform corrosion resistance in oxidizing as well as reducing environments, the as-heat treated C-22HS alloy possesses high resistance to chloride-induced pitting and crevice corrosion attack.

Product Forms
C-22HS alloy is available in the form of plate, sheet, strip, billet, bar, wire, pipe, and tube.

Heat Treatment
The high strength of C-22HS alloy is derived from the formation of strengthening particles of $Ni_2(Mo,Cr)$ which form during the patented*** two-step age-hardening heat treatment. The approximately 48 hour heat treatment, 1300°F (705°C) FC to 1125°F (605°C)/32 hours/AC, is described in more detail on page 14.

Solution Annealed and Filler Wire Applications
C-22HS alloy may also be considered for applications which do not require the high strength imparted by the heat treatment. In the annealed condition, C-22HS alloy has even higher corrosion-resistance, particularly with regard to localized corrosive attack. This localized attack resistance also makes the alloy an attractive candidate as a general-purpose filler metal or weld overlay.

Applications

- Agitators and blenders
- Shafting
- Fan blades and hubs
- Fasteners
- Springs
- Valves
- Dies
- Screws
- Wellhead parts
- Rings and gaskets

Field Test Program
Samples of C-22HS alloy in the age-hardened condition 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.

** Covered by U.S. Patent 6,860,948
*** Covered by U.S. Patents 6,544,362 and 6,638,373

COMPOSITION

Ni	Cr	Mo	Fe	Co	W	Mn	Al	Si	C	B
BAL	21	17	2*	1*	1*	0.8*	0.5*	0.08*	0.01*	0.006*

*Maximum

PHYSICAL PROPERTIES*

Physical Property	Metric Units		British Units	
Density (annealed)	RT	8.60 g/cm.^{3}	RT	0.311 lb/in.^{3}
Density (age-hardened)	RT	8.64 g/cm.^{3}	RT	0.312 lb/in.^{3}
Electrical Resistivity	RT	0.98 µohm.m	RT	38.4 µohm.in
	100°C	1.00 µohm.m	200°F	39.3 µohm.in
	200°C	1.04 µohm.m	400°F	41.1 µohm.in
	300°C	1.08 µohm.m	600°F	42.8 µohm.in
	400°C	1.12 µohm.m	800°F	44.3 µohm.in
	500°C	1.15 µohm.m	1000°F	45.5 µohm.in
	600°C	1.17 µohm.m	1100°F	46.0 µohm.in
Thermal Conductivity	RT	11.8 W/m.°C	RT	82 btu.in/h.ft^2.°F
	100°C	13.5 W/m.°C	200°F	93 btu.in/h.ft^2.°F
	200°C	15.4 W/m.°C	400°F	107 btu.in/h.ft^2.°F
	300°C	17.1 W/m.°C	600°F	120 btu.in/h.ft^2.°F
	400°C	18.6 W/m.°C	800°F	132 btu.in/h.ft^2.°F
	500°C	20.5 W/m.°C	1000°F	147 btu.in/h.ft^2.°F
	600°C	22.4 W/m.°C	1100°F	154 btu.in/h.ft^2.°F
Mean Coefficient of Thermal Expansion	25-100°C	11.6 µm/m.°C	70-200°F	6.4 µin/in.°F
	25-200°C	12.0 µm/m.°C	70-400°F	6.7 µin/in.°F
	25-300°C	12.4 µm/m.°C	70-600°F	6.9 µin/in.°F
	25-400°C	12.7 µm/m.°C	70-800°F	7.1 µin/in.°F
	25-500°C	13.1 µm/m.°C	70-1000°F	7.3 µin/in.°F
	25-600°C	13.3 µm/m.°C	77-1100°F	7.4 µin/in.°F
Thermal Diffusivity	RT	0.0334 cm^2/s	RT	0.129 ft^2/h
	100°C	0.0362 cm^2/s	200°F	0.139 ft^2/h
	200°C	0.0398 cm^2/s	400°F	0.155 ft^2/h
	300°C	0.0427 cm^2/s	600°F	0.167 ft^2/h
	400°C	0.0454 cm^2/s	800°F	0.180 ft^2/h
	500°C	0.0489 cm^2/s	1000°F	0.194 ft^2/h
	600°C	0.0517 cm^2/s	1100°F	0.200 ft^2/h
Specific Heat	RT	412 J/kg.°C	RT	0.098 btu/lb.°F
	100°C	434 J/kg.°C	200°F	0.103 btu/lb.°F
	200°C	451 J/kg.°C	400°F	0.108 btu/lb.°F
	300°C	465 J/kg.°C	600°F	0.112 btu/lb.°F
	400°C	477 J/kg.°C	800°F	0.115 btu/lb.°F
	500°C	488 J/kg.°C	1000°F	0.118 btu/lb.°F
	600°C	504 J/kg.°C	1100°F	0.120 btu/lb.°F
Dynamic Modulus of Elasticity (Young's Modulus)	RT	223 GPa	RT	32.3 x 10^6 psi
	100°C	218 GPa	200°F	31.6 x 10^6 psi
	200°C	211 GPa	400°F	30.5 x 10^6 psi
	300°C	209 GPa	600°F	30.2 x 10^6 psi
	400°C	205 GPa	800°F	29.5 x 10^6 psi
	500°C	195 GPa	1000°F	27.6 x 10^6 psi
	600°C	181 GPa	1100°F	26.4 x 10^6 psi
Melting Range	1304 - 1368°C		2380 - 2495°F	

* Properties are for material in the age-hardened condition unless otherwise noted.

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 Critial 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.

	Critical Crevice Temperature		Critical Pitting Temperature	
Alloy	°C	°F	°C	°F
316L	0	32	15	59
725 (age hardened)	25	77	85	185
625	40	104	100	212
C-276	55	131	>120	>248
C-22HS (age-hardened)	75	167	110	230
C-22	80	176	>120	>248
C-22HS (mill annealed)	100	212	>120	>248

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. Here are the Critical Pitting Temperatures of C-22HS and other alloys in Green Death, based on tests of 24 hours.

	Critical Pitting Temperature	
Alloy	°C	°F
316L	25	77
725 (age hardened)	75	167
625	90	194
C-276	105	221
C-22HS (age-hardened)	110	230
C-22	120	248
C-22HS (mill annealed)	>130	>266

Sour Gas Testing

The testing shown below was performed on C-22HS alloy in the annealed + age-hardened condition.

Environment	Coupling	Duration	Test	Stress Level	Results
Deaerated 5% NaCl, 0.5% Acetic Acid, saturated with H_2S	Coupled with iron	30 days	TMO177 Method A, Solution A (Level III)	80% Yield	No Cracking
				100% Yield	No Cracking

Environment	NACE TMO198 Level	Temp. (°F)	RATIO Time(env) / Time(inert)	RATIO Elong.(env) / Elong.(inert)	RATIO R.A.(env) / R.A.(inert)
Deaerated 20% NaCl, 508 psig CO_2, 508 psig H_2S	Level VI	347	0.98	0.98	0.87
Deaerated 25% NaCl, 508 psig CO_2, 508 psig H_2S	Level VII	401	0.97	0.97	0.83

UNIFORM CORROSION DATA (C-22HS, C-22)

Chemical	Conc.	Temperature		Corrosion Rate					
	wt.%	°C	°F	C-22HS Annealed		C-22HS Age-Hardened		C-22	
				mm/y	mpy	mm/y	mpy	mm/y	mpy
Hydrochloric Acid	1	Boiling		0.09	3.6	<0.01	0.1	0.06	2.2
	5	79	175	0.78	30.9	2.41	94.9	1.44	56.6
	10	38	100	<0.01	<0.1	0.22	8.8	0.01	0.4
	20	38	100	0.15	5.8	0.22	8.8	0.20	7.7
Hydrobromic Acid	2.5	Boiling		<0.01	<0.1	<0.01	<0.1	0.02	0.6
	5	93	200	0.01	0.4	0.01	0.2	0.01	0.3
	7.5	93	200	0.02	0.6	0.01	0.3	0.45	17.8
	10	79	175	<0.01	0.1	<0.01	0.1	0.01	0.3
	20	66	150	0.38	14.9	0.41	16.3	0.46	18.2
Hydrofluoric Acid	1	79	175	0.31	12.3	0.35	13.7	0.21	8.2
	5	52	125	0.19	7.4	0.20	7.9	0.15	6.0
	10	52	125	0.32	12.5	0.34	13.5	0.33	13.1
	20	52	125	0.45	17.8	0.59	23.1	0.53	21.0
Sulfuric Acid	10	93	200	0.04	1.4	0.03	1.2	0.04	1.6
	20	93	200	0.06	2.2	0.05	2.0	0.28	11.0
	30	93	200	0.15	6.1	1.21	47.6	0.68	26.8
	40	79	175	0.02	0.9	0.02	0.8	0.31	12.3
	50	79	175	0.04	1.4	0.24	9.5	0.40	15.9
	60	66	150	0.01	0.4	0.01	0.3	N/T*	N/T
	70	66	150	0.11	4.2	0.17	6.7	0.28	11.0
	80	66	150	0.11	4.4	0.37	14.7	N/T	N/T
	90	66	150	0.03	1.1	0.21	8.3	0.34	13.3
Nitric Acid	20	Boiling		0.10	3.9	0.15	6.0	0.06	2.3
	40	79	175	0.06	2.3	0.06	2.4	0.03	1.2
	60	79	175	0.11	4.5	0.41	16.2	0.08	3.0
Phosphoric Acid	50	Boiling		0.03	1.2	0.04	1.4	0.03	1.3
	60	Boiling		0.11	4.2	0.10	4.0	0.56	21.9
	70	Boiling		0.21	8.1	0.16	6.2	1.04	41.0
	80	Boiling		0.27	10.5	0.46	18.2	3.02	119.0
Chromic Acid	10	66	150	0.13	5.3	0.27	10.5	0.13	5.0
ASTM G 28A**		Boiling		1.10	43.3	1.80	70.8	1.02	40.0
ASTM G 28B***		Boiling		0.17	6.8	0.70	27.6	0.20	8.0

*N/T = not tested

**G 28A = 50% H_2SO_4 + 42 g/l $Fe_2(SO_4)_3$

***G 28B = 23% H_2SO_4 + 1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$

UNIFORM CORROSION DATA (C-276, 625)

Chemical	Conc.	Temperature		Corrosion Rate			
	wt.%	°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	66	150	0.02	0.7	0.48	18.9
	70	66	150	0.05	1.8	0.63	24.7
	80	66	150	0.04	1.6	0.91	35.8
	90	66	150	0.03	1.0	N/T*	N/T
Nitric Acid	20	Boiling		0.66	25.9	0.01	0.3
	40	79	175	0.38	14.8	N/T	N/T
	60	79	175	0.82	32.3	N/T	N/T
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
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_2SO_4 + 42 g/l $Fe_2(SO_4)_3$

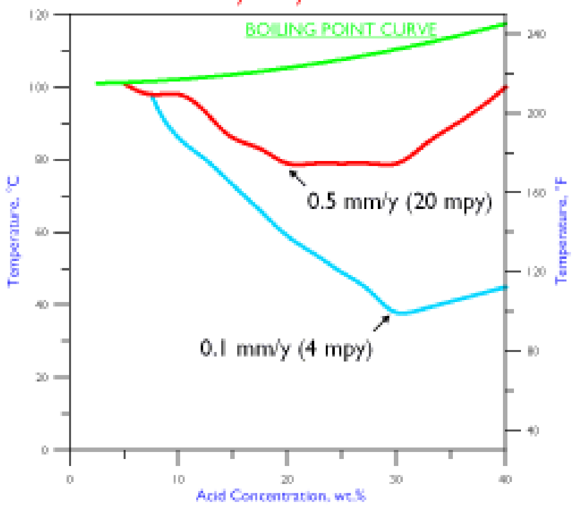
***G 28B = 23% H_2SO_4 + 1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$

ISO-CORROSION DIAGRAMS

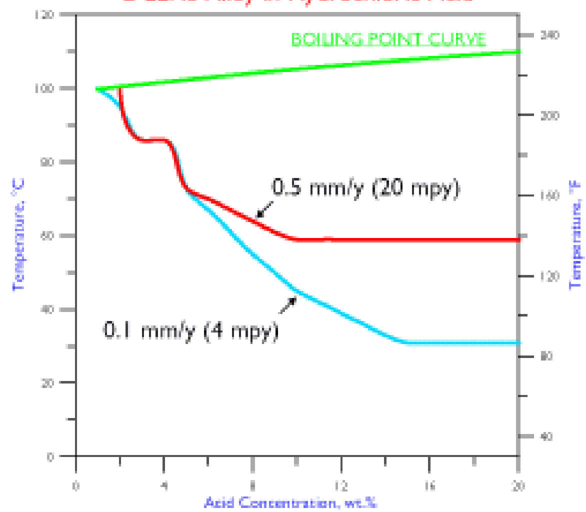
Each of these iso-corrosion diagrams was constructed using numerous corrosion rate values, generated at different acid concentrations and temperatures. The blue line represents those combinations of hydrochloric acid concentration and temperature at which a corrosion rate of 0.1 mm/y (4 mils per year) 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.

Annealed

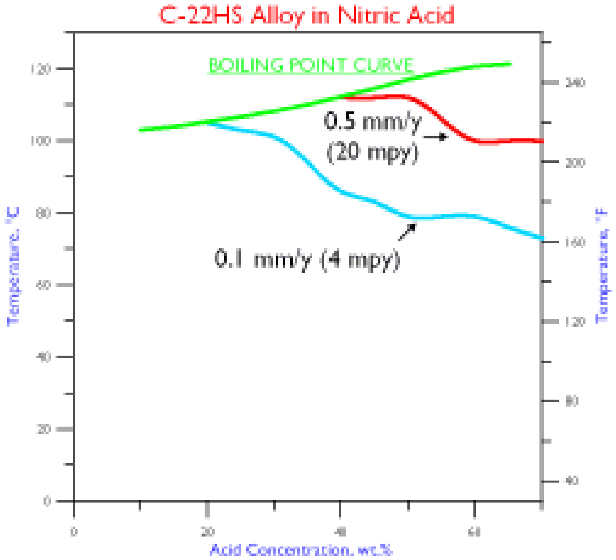
Iso-Corrosion Diagram for Annealed C-22HS Alloy in Hydrobromic Acid



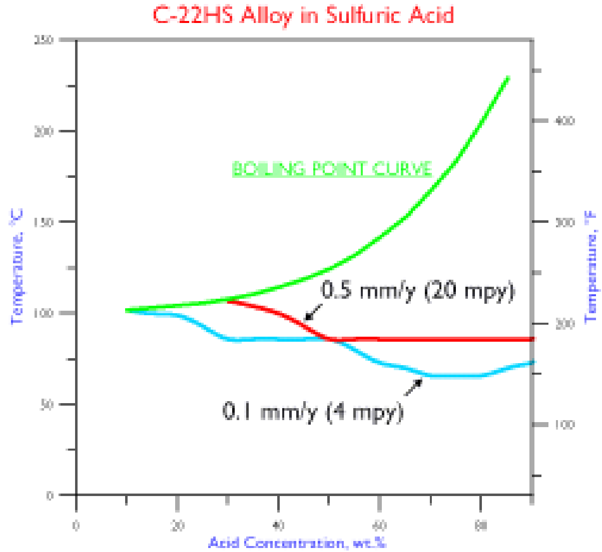
Iso-Corrosion Diagram for Annealed C-22HS Alloy in Hydrochloric Acid



Iso-Corrosion Diagram for Annealed C-22HS Alloy in Nitric Acid



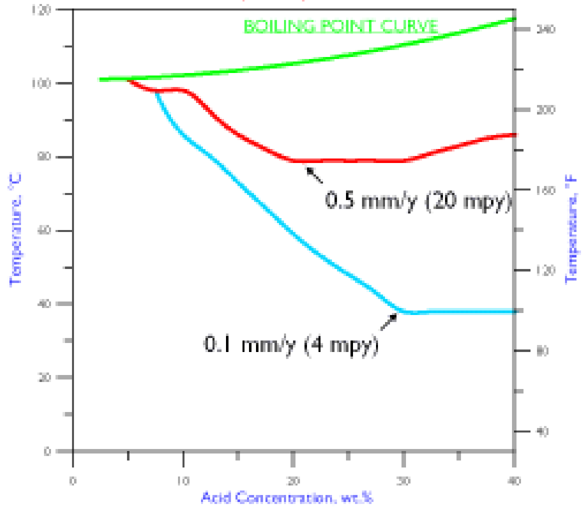
Iso-Corrosion Diagram for Annealed C-22HS Alloy in Sulfuric Acid



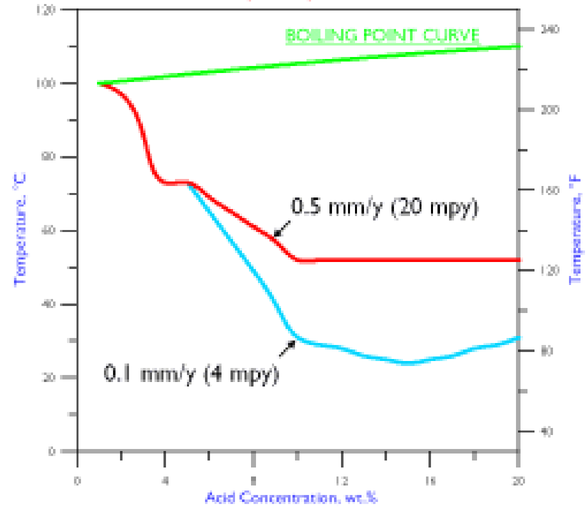
ISOCORROSION DIAGRAMS

Age-Hardened

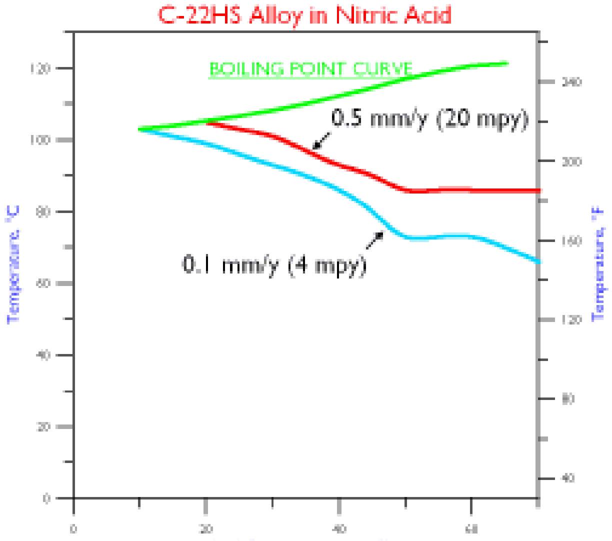
Iso-Corrosion Diagram for Age-Hardened C-22HS Alloy in Hydrobromic Acid



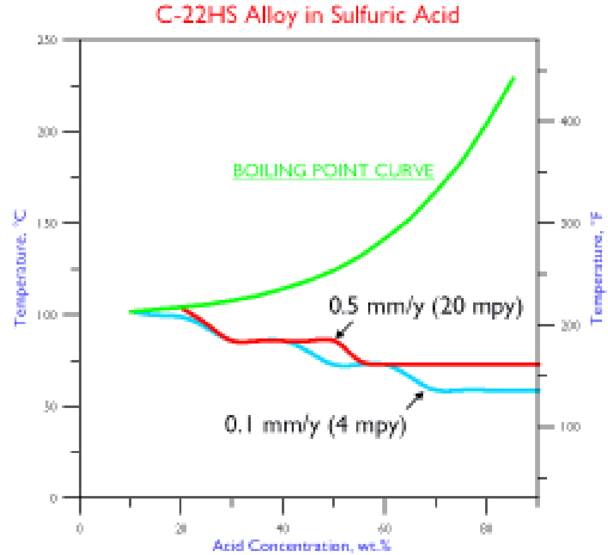
Iso-Corrosion Diagram for Age-Hardened C-22HS Alloy in Hydrochloric Acid



Iso-Corrosion Diagram for Age-Hardened C-22HS Alloy in Nitric Acid



Iso-Corrosion Diagram for Age-Hardened C-22HS Alloy in Sulfuric Acid



MECHANICAL PROPERTIES

Typical Tensile Data for Cold-Rolled and Solution Annealed Sheet

Metric Units				British Units			
Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation	Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation
°C	MPa	MPa	%	°F	ksi	ksi	%
RT	439	837	57.3	RT	63.6	121.4	57.3
100	394	807	59.9	200	57.6	117.4	60.0
200	343	754	58.6	400	49.4	108.9	58.5
300	316	734	66.8	600	45.3	106.0	68.2
400	308	718	69.6	800	44.4	103.6	70.1
500	296	691	67.8	1000	42.2	98.3	66.5
600	288	665	69.9	1200	40.1	94.8	68.5

Typical Tensile Data for Hot-Rolled and Solution Annealed Plate and Bar

Metric Units					British Units				
Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation	Reduction in Area	Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation	Reduction in Area
°C	MPa	MPa	%	%	°F	ksi	ksi	%	%
RT	376	806	62.3	77.5	RT	54.4	117.0	62.3	77.5
100	329	767	66.7	78.0	200	48.0	111.7	66.8	78.6
200	288	721	65.9	77.3	400	41.4	104.2	65.8	77.1
300	263	695	68.8	75.2	600	37.5	100.2	69.2	74.9
400	255	677	69.5	73.0	800	36.7	97.5	69.6	72.3
500	241	652	69.3	70.9	1000	34.1	93.0	69.1	70.2
600	223	628	70.6	69.1	1200	31.3	90.1	71.4	67.7

Typical Room Temperature Hardnesses

Form	Hardness	
	Mill Annealed	Age-Hardened
Plate	92 Rb	30 Rc
Sheet	90 Rb	30 Rc
Bar	88 Rb	30 Rc

MECHANICAL PROPERTIES

Typical Tensile Data for Cold-Rolled, Solution Annealed, and Age-Hardened Sheet

Metric Units				British Units			
Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation	Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation
°C	MPa	MPa	%	°F	ksi	ksi	%
RT	759	1230	40.9	RT	110.0	178.4	40.9
100	710	1190	43.6	200	103.5	173.1	43.7
200	658	1131	43.4	400	95.0	163.6	43.3
300	630	1103	47.8	600	90.7	159.5	48.5
400	590	1049	48.2	800	84.1	149.8	48.1
500	572	1003	47.1	1000	82.3	143.3	46.6
600	547	928	46.3	1100	79.8	135.2	46.4

Typical Tensile Data for Hot-Rolled, Solution Annealed, and Age-Hardened Plate and Bar

Metric Units					British Units				
Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation	Reduction in Area	Temperature	0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation	Reduction in Area
°C	MPa	MPa	%	%	°F	ksi	ksi	%	%
RT	690	1202	44.2	57.7	RT	100.1	174.2	44.2	57.7
100	627	1153	47.7	55.7	200	91.3	167.9	47.7	55.5
200	579	1089	48.3	60.0	400	83.7	157.5	48.3	60.2
300	539	1047	52.7	63.9	600	77.3	150.9	53.3	64.5
400	518	1006	52.3	63.4	800	74.3	144.4	52.3	63.0
500	507	964	50.3	63.2	1000	73.1	137.4	49.3	63.2
600	488	902	49.2	66.9	1100	70.9	131.5	49.0	66.5

Typical Charpy Impact Energy, Plate

Condition	Test Temperature		Average Charpy V-Notch Impact Energy	
	°F	°C	ft.-lbs.	Joules
Annealed	-320	-196	226	306
	Room	Room	> 260	> 353
Age-Hardened	-320	-196	73	99
	Room	Room	112	151

THERMAL STABILITY

HASTELLOY C-22HS alloy has excellent retained ductility and impact strength after long term thermal exposure at elevated temperatures. The data below shows the tensile and impact properties of samples machined from plate following long term thermal exposure at 800 and 1100°F (427 and 593°C).

Room Temperature Properties After Thermal Exposure

Original Condition	Exposure Temp.		Exposure Duration	Tensile						Charpy V-Notch Impact	
				0.2% Yield Stress		Ultimate Tensile Strength		Elong.	Reduction in Area		
	°F	°C	Hours	ksi	MPa	ksi	MPa	%	%	ft.-lbs.	Joules
Annealed	—	—	—	58.9	406	119.3	822	60.8	75.1	> 260	> 353
Annealed	800	427	1000	56.9	392	118.5	817	63.5	75.3	> 260	> 353
Annealed	800	427	4000	57.4	396	119.0	821	62.9	74.7	244	331
Annealed	800	427	8000	58.2	401	118.1	814	62.6	75	> 260	> 353
Annealed	1100	593	1000	98.6	680	173.1	1194	46.2	61.6	129	174
Annealed	1100	593	4000	113.9	785	184.0	1269	42	60.7	89	121
Annealed	1100	593	8000	114.6	790	186.2	1284	40.2	58.1	67	91
Age-Hardened	—	—	—	107.6	742	178.7	1232	40.2	49.7	112	151
Age-Hardened	800	427	1000	108.4	747	177.9	1227	44.8	57	100	136
Age-Hardened	800	427	4000	112.3	774	183.4	1265	43.2	58.1	87	118
Age-Hardened	800	427	8000	115.0	793	185.4	1278	41.3	57.2	82	112
Age-Hardened	1100	593	1000	118.3	815	185.8	1281	41.2	57.5	94	127
Age-Hardened	1100	593	4000	119.6	824	189.1	1303	36.1	43.9	48	66
Age-Hardened	1100	593	8000	119.7	826	189.7	1308	26.9	26.2	25	33

COLD-WORKED AND COLD-WORKED PLUS AGED PROPERTIES

C-22HS alloy is readily fabricated using cold-working. The data in the first row below can be used by fabricators to predict cold-forming behavior. Additionally, if a very high strength material is desired, the alloy can be given an age-hardening treatment following cold-working. The effect of such processing on the hardness is also shown below.

Room Temperature Hardness (Cold-Rolled Sheet)

Aging Time* (hours)	Hardness (Rc) for % Cold Work					
	0%	10%	20%	30%	40%	50%
0	< 20	29	35	37	40	45
1	< 20	27	33	38	41	47
4	< 20	26	33	39	41	48
10	< 20	35	40	41	45	51
24	< 20	40	43	44	48	52

* Aging was performed at 1125°F for the indicated duration.

WELDING AND FABRICATION

Welding

The weldability of C-22HS 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-22HS filler wire is suggested. For shielded metal arc welding, C-22HS covered electrodes are suggested.

Post Weld Heat Treatment

To achieve the high strength capability of the C-22HS alloy, the two step age-hardening treatment described in the heat treatment section should be given subsequent to welding. It is normally not necessary to give the welded component a full solution anneal prior to the age-hardening treatment.

Room Temperature Tensile Data for Weldments

Welding Process	Form	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
		MPa	ksi	MPa	ksi	%
Gas Tungsten Arc	Transverse Sample from Autogenously Welded 3.2 mm/0.125 in Sheet--As Welded	451	65.4	799	115.9	34.3
	Transverse Sample from Autogenously Welded 3.2 mm/0.125 in Sheet--Welded then Age-Hardened	744	107.9	1088	157.8	12.6
	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--As Welded	465	67.5	791	114.7	44
	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--Welded then Age-Hardened	759	110.1	1101	159.7	23
	All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform--As Welded	458	66.4	708	102.7	39.2
	All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform--Welded then Age-Hardened	735	106.6	1062	154.1	28.9
Synergic Gas Metal Arc	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--As Welded	442	64.1	785	113.9	46.2
	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--Welded then Age-Hardened	758	110.0	1129	163.7	27.5
	Transverse Sample from Welded Plate of Thickness 25.4 mm/1.0 in--As Welded	434	62.9	780	113.1	39.4
	Transverse Sample from Welded Plate of Thickness 25.4mm/1.0 in--Welded then Age-Hardened	763	110.6	1120	162.5	17.8
	All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform--As Welded	455	66.0	724	105.0	53.1
	All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform--Welded then Age-Hardened	712	103.3	1054	152.9	36.8

WELDING AND FABRICATION

Charpy V-Notch Impact Data for Weldments (Notch at Center Line)

Welding Process	Form	Test Temperature °C	Test Temperature °F	Impact Strength J	Impact Strength ft.lbf
Gas Tungsten Arc	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--As Welded	RT	RT	226	167
		-196	-320	171	126
	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--Welded then Age-Hardened	RT	RT	66	49
		-196	-320	46	34
Synergic Gas Metal Arc	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--As Welded	RT	RT	197	145
		-196	-320	157	116
	Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in--Welded then Age-Hardened	RT	RT	62	46
		-196	-320	46	34

Fabrication

Heat Treatment

Wrought forms of C-22HS alloy are furnished in the solution annealed condition, unless otherwise specified. The standard solution annealing treatment consists of heating to 1975°F (1080°C) followed by rapid air-cooling or water quenching. Parts which have been hot formed should be solution annealed prior to final fabrication or installation.

To use the alloy in the high-strength condition, it is necessary to age-harden using a two step treatment of 1300°F (705°C) for 16 hours, furnace cooling to 1125°F (605°C) and holding at that temperature for 32 hours, followed by an air cool. Cold or hot-worked structures should normally be given a full solution anneal prior to performing the age-hardening treatment.

Forming

C-22HS 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 on the fabrication of C-type alloys, please consult publication H-2010.

Machining

C-22HS alloy may be machined in either the solution annealed or age-hardened condition. Carbide or ceramic tools are recommended. For use in the age-hardened condition, it is suggested to rough machine in the annealed condition. After performing the age-hardening heat treatment, light machining may be performed to achieve desired final dimensions.

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 concentrations, 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.

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

Global Headquarters
1020 West Park Avenue
P.O. Box 9013
Kokomo, Indiana 46904-9013 (USA)
Phone: 1-800-354-0806 or (765) 456-6012
Fax: (765) 456-6905
www.haynesintl.com
For your local sales office or service center, please call or visit our website.

050907