HAYNES® 625 alloy

Principal Features

Excellent Strength Up To 1500°F (816°C), Good Oxidation Resistance, and Good Resistance to Aqueous Corrosion

HAYNES® 625 alloy (UNS N06625) is a nickel- chromium-molybdenum alloy with excellent strength from room temperature up to about 1500°F (816°C). At higher temperatures, its strength is generally lower than that of other solid-solution strengthened alloys. Alloy 625 has good oxidation resistance at temperatures up to 1800°F (980°C) and provides good resistance to aqueous corrosion, but generally not as effectively as modern HASTELLOY® corrosion- resistant alloys.

Easily Fabricated

HAYNES® 625 alloy has excellent forming and welding characteristics. It may be forged or otherwise hot-worked providing temperature is maintained in the range of about 1800 to 2150°F (980 to 1175°C). Ideally, to control grain size, finish hot working operations should be performed at the lower end of the temperature range. Because of its good ductility, alloy 625 is also readily formed by cold working. However, the alloy does work-harden rapidly so intermediate annealing treatments may be needed for complex component forming operations.

In order to restore the best balance of properties, all hot- or cold-worked parts should be annealed and rapidly cooled.

The alloy can be welded by both manual and automatic welding methods, including gas tungsten arc (GTAW), gas metal arc (GMAW), electron beam, and resistance welding. It exhibits good restraint welding characteristics.

Heat Treatment

Unless otherwise specified, wrought HAYNES® 625 alloy is normally supplied in the mill-annealed condition. The alloy is usually mill-annealed at 1925°F plus or minus 25°F (1050°C plus or minus 15°C) for a time commensurate with section thickness and rapidly cooled or water-quenched for optimum properties. Depending on customer requirements, alloy 625 may also be supplied solution heat-treated at temperatures at or above 2000°F (1095°C), or mill annealed at temperatures below 1925°F (1050°C). Lower temperature mill annealing treatments may result in some precipitation of second phases in alloy 625 which can affect the alloy's properties.

Principal Features Continued

Applications

HAYNES® 625 alloy is widely used in a variety of high- temperature aerospace, chemical process industry, and power industry applications. It provides excellent service in short-term applications at temperatures up to approximately 1500°F (815°C); however, for long-term elevated temperature service, use of alloy 625 is best restricted to a maximum of 1100°F (595°C). Long-term thermal exposure of alloy 625 above 1100°F (595°C) will result in significant embrittlement. For service at these temperatures, more modern materials, such as HAYNES® 230® alloy, are recommended.

As a low-temperature corrosion-resistant material, alloy 625 has been widely used in chemical process industry, sea water, and power plant scrubber applications. However, in newer applications with more demanding environments, more capable HASTELLOY® alloys are preferred, such as C-22® and G-35® alloys.

Nominal Composition

Weight %

Nickel:	62 Balance
Cobalt:	1 max.
Iron:	5 max.
Chromium:	21
Molybdenum:	9
Columbium+ Tantalum:	3.7
Manganese:	0.5 max.
Silicon:	0.5 max.
Aluminum:	0.4 max.
Titanium:	0.4 max.
Carbon:	0.1 max.

Tensile Properties

Cold-Rolled and 1925°F (1050°C) Mill-Annealed, Sheet

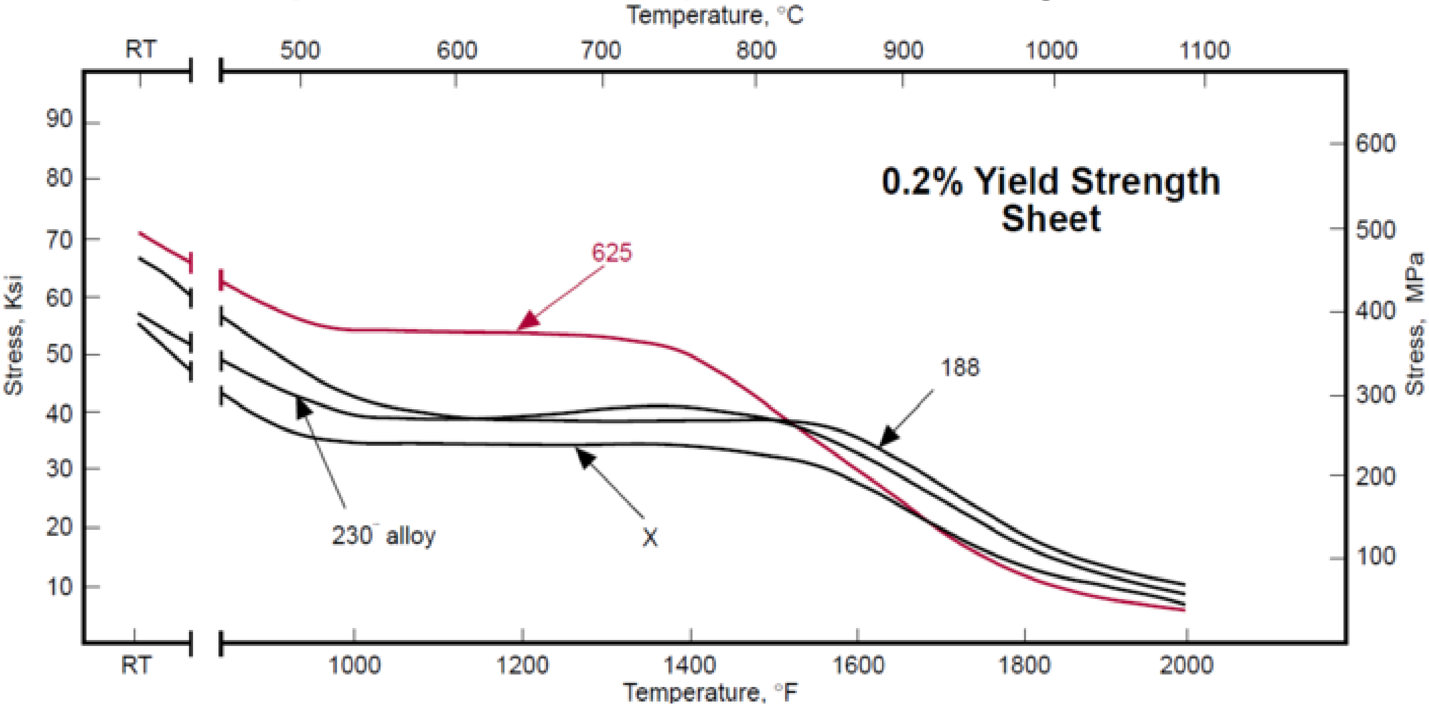
Test Temperature		Ultimate Tensile Strength		Yield Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	133.9	923	71.2	491	47.5
1000	540	118.4	816	56.3	388	54.2
1200	650	117.7	811	55.1	380	109.3
1400	760	71.0	490	53.8	371	135.0
1600	870	34.7	239	29.6	204	160.6
1800	980	15.3	106	9.9	68	154.5
2000	1095	8.7	60	5.0	35	128.3

Hot-Rolled and 1925°F (1050°C) Mill-Annealed, Plate

Test Temperature		Ultimate Tensile Strength		Yield Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	129.6	894	60.5	417	48
800*	425*	116.1	800	46.4	320	51.5
1000	540	112.3	774	44.8	309	52.1
1200	650	112.7	777	43.7	301	80.3
1400	760	71.1	490	43.7	301	102.2
1600	870	38	262	30.6	211	115.7
1800	980	17.3	119	11.8	81	120.7
2000	1095	9.3	64	5.4	37	135.1

*Average of results for only two products
RT= Room Temperature

Comparative Elevated Temperature Yield Strengths, Sheet



Creep and Rupture Properties

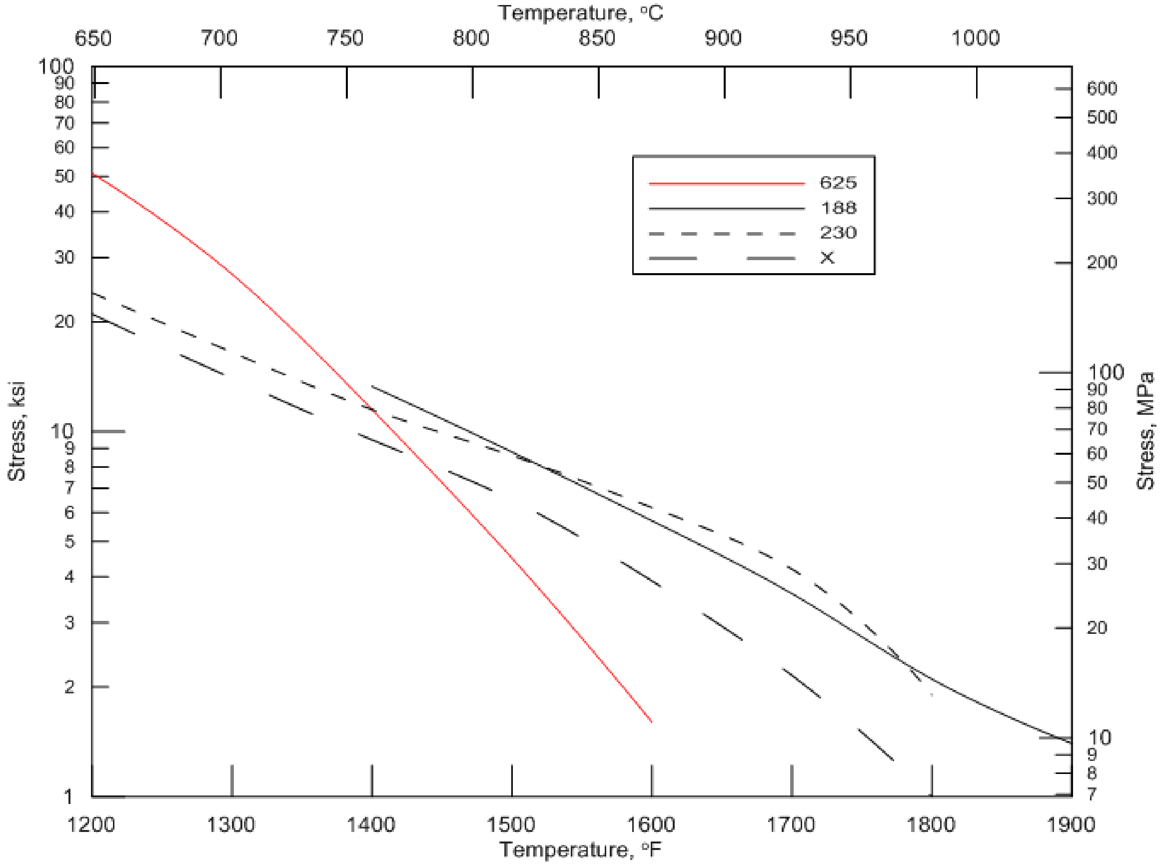
Cold-Rolled and 1925°F (1050°C) Mill-Annealed Sheet

Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in					
			10 h		100 h		1,000 h	
°F	°C	%	ksi	MPa	ksi	MPa	ksi	MPa
1100	593	0.5	75	517	69	476	64	441
		1	76	524	71	490	67	462
		R	-	-	90	621	80	552
1200	649	0.5	53	365	52	359	50	345
		1	58	400	53	365	51	352
		R	84	579	74	510	55	379
1300	704	0.5	33	228	30	207	26	179
		1	36	248	31	214	27	186
		R	68*	469*	49	338	33	228
1400	760	0.5	18.4	127	13.0	90	9.7	67
		1	20	138	14.5	100	11.5	79
		R	41	283	27	186	17.8	123
1500	816	0.5	9.7	67	5.7	39	3.2	22
		1	11.3	78	7.0	48	4.2	29
		R	24	165	15.2	105	9.9	68
1600	871	0.5	5.2	36	2.6	18	1.2	8.3
		1	6.2	43	3.3	23	1.6	11
		R	14.0	97	8.0	55	4.2	29
1700	927	0.5	2.6	18	1.1	7.6	-	-
		1	3.4	23	1.7	12	-	-
		R	8.0*	55*	4.3	30	2.7	19
1800	982	0.5	1.2	8.3	-	-	-	-
		1	1.7	12	0.5	3.4	-	-
		R	4.1	28	2.6	18	1.4	10

*Significant extrapolation

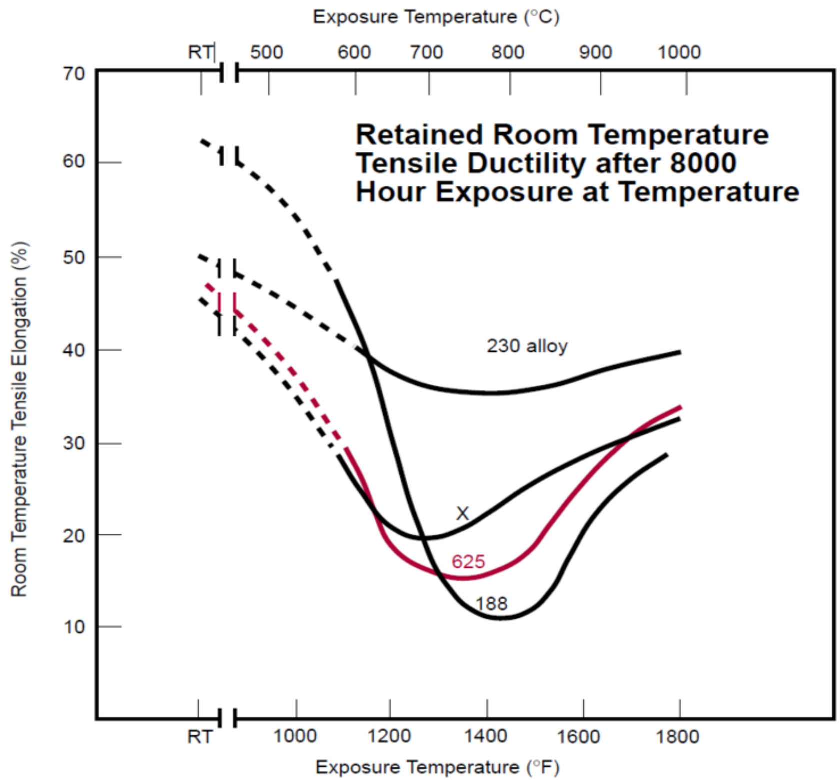
Creep and Rupture Properties Continued

Comparison of Stress to Produce 1% Creep in 1,000 Hours



Thermal Stability

HAYNES® 625 alloy is similar to the solid-solution-strengthened superalloys, such as HAYNES® 188 alloy or HASTELLOY® X alloy, which will precipitate deleterious phases upon long- term exposure at intermediate temperatures. In this case, the phase in question is Ni Cb delta- phase which serves to impair both tensile ductility and impact strength. For applications where thermal stability is important, 230® alloy is recommended.



Room Temperature Properties After Thermal Exposure, Plate

Exposure Temperature		h	0.2% Yield Strength		Ultimate Tensile Strength		Elongation	Impact Strength	
°F	°C	-	ksi	MPa	ksi	MPa	%	ft.-lb.	J
As-Annealed*		-	66.2	455	127.7	880	46	81	110
1200	650	1000	122.3	845	165	1140	28	11	15
		4000	117.9	815	163.6	1130	24	8	11
		8000	117.8	810	164.2	1130	18	5	7
		16000	118.5	815	165.4	1140	12	4	5
1400	760	1000	95.5	660	142.9	985	17	5	7
		4000	104.1	720	145.5	1005	12	4	5
		8000	97.4	670	142.6	985	13	5	7
		16000	96.1	665	140.4	970	12	4	5
1600	870	1000	68.3	470	130	895	30	12	16
		4000	66.4	460	130	895	29	11	15
		8000	63.7	440	127	875	26	15	20
		16000	63.4	435	128.4	885	32	14	19

*1875°F (1025°C), rapid cooled

Oxidation Resistance

Comparative Burner Rig Oxidation Resistance, 1000 Hours

Burner rig oxidation tests were conducted by exposing samples 3/8 in. x 2.5 in. x thickness (9 mm x 64 mm x thickness), in a rotating holder, to products of combustion of a mixture of No. 1 and No. 2 fuel oil. This was burned at a ratio of air to fuel of about 50:1 for 1000 hours. (Gas velocity was about 0.3 mach). Samples were automatically removed from the gas stream every 30 minutes, fan-cooled to near ambient temperature, and then reinserted into the flame tunnel.

Alloy	1800°F (980°C)					
	Metal Loss		Average Metal Affected		Maximum Metal Affected	
-	mils	µm	mils	µm	mils	µm
230®	0.8	20	2.8	71	3.5	89
X	2.7	69	5.6	142	6.4	153
625	**4.9**	**124**	**7.1**	**180**	**7.6**	**193**
25	6.2	157	8.3	211	8.7	221
MULTIMET®	11.8	300	14.4	366	14.8	376
800H®	12.7	312	14.5	368	15.3	389

Oxidation Resistance in Flowing Air (1008 Hours)

The following are static oxidation test rankings for 1008-hour exposures in flowing air. The samples were cycled to room temperature weekly. Average metal affected is the sum of metal loss plus average internal penetration.

	1600				1800			
	Metal Loss		Avg. Met. Aff. mils, (mm)		Metal Loss		Avg. Met. Aff. mils, (mm)	
Alloy	mils	µm	mils	µm	mils	µm	mils	µm
214®	0	0	0.1	3	0.1	3	0.3	8
188	-	-	-	-	0.1	3	1.1	28
230®	0	0	0.6	15	0.2	5	1.5	38
X	0.1	3	0.7	18	0.2	5	1.5	38
625	**0.1**	**3**	**0.6**	**15**	**0.4**	**10**	**1.9**	**48**
617	-	-	-	-	0.3	8	2.0	51
25	-	-	-	-	0.3	8	2.0	51
HR-120®	0.1	3	0.9	23	0.4	10	2.1	53
556®	-	-	-	-	0.4	10	2.3	58
800HT	0.1	3	1.0	25	0.5	13	4.1	104
HR-160®	0.2	5	3.0	79	0.7	18	5.5	140

(Cycled weekly); alloys are arranged in ascending order by the average metal affected.

Oxidation Resistance Continued

Amount of metal affected for high-temperature sheet (0.060-0.125”) alloys exposed for 360 days (8,640h) in flowing air at 1600°F (870°C) (Cycled once a month)

Alloy	Metal Loss		Avgerage Metal Affected	
	mils	μm	mils	μm
214®	0.1	3	0.2	5
625	0.3	8	1.4	36
230	0.2	5	1.4	36
617	0.3	8	1.6	41
HR-120®	0.3	8	1.6	41
25	0.3	8	1.7	43
188	0.2	5	1.8	46
556®	0.3	8	1.9	48
X	0.3	8	2.2	56
800HT	0.4	10	2.9	74

Comparative Dynamic Oxidation

Alloy	1600°F (870°C), 2000 h, 30-min cycles				1800°F (980°C), 1000 h, 30-min cycles			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
	mils	μm	mils	μm	mils	μm	mils	μm
188	1.1	28	2.9	74	1.1	28	3.2	81
230®	0.9	23	3.9	99	2.8	71	5.6	142
617	2.0	51	7.8	198	2.4	61	5.7	145
625	1.2	30	2.2	56	3.7	94	6.0	152
556®	1.5	38	3.9	99	4.1	104	6.7	170
X	1.7	43	5.3	135	4.3	109	7.3	185
HR-120®	-	-	-	-	6.3	160	8.3	211
RA330	2.5	64	5.0	127	8.7	221	10.5	267
HR-160®	-	-	-	-	5.4	137	11.9	302
310SS	6.0	152	7.9	201	16.0	406	18.3	465
800H	3.9	99	9.4	239	22.9	582	Through Thickness	

Amount of metal affected for high-temperature sheet alloys exposed for 1008h (cycled weekly) in air + 10%H_2O

Alloy	1600				1800			
	Metal Loss		Avg. Met. Aff.		Metal Loss		Avg. Met. Aff.	
	mils	μm	mils	μm	mils	μm	mils	μm
214®	0.1	1	0.3	7	0.0	1	0.2	6
188	-	-	-	-	0.1	3	1.4	36
230®	0.1	2	0.5	13	0.2	4	1.5	37
625	0.1	3	0.5	12	0.3	8	1.6	41
X	0.0	1	0.5	13	0.3	7	1.8	45
HR-120®	0.1	2	0.7	17	0.3	9	1.9	49
617	0.1	2	0.9	22	0.3	8	2.0	51

Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	0.305 lb/in³	RT	8.44 g/cm³
Melting Range	2350-2460°F	-	1290-1350°C	-
Electrical Resistivity	RT	50.8 µohm-in	RT	129 µohm-cm
	200°F	52.0 µohm-in	100°C	132 µohm-cm
	400°F	52.8 µohm-in	200°C	134 µohm-cm
	600°F	53.1 µohm-in	300°C	135 µohm-cm
	800°F	53.5 µohm-in	400°C	136 µohm-cm
	1000°F	54.3 µohm-in	500°C	137 µohm-cm
	1200°F	54.3 µohm-in	600°C	138 µohm-cm
	1400°F	53.9 µohm-in	700°C	138 µohm-cm
	1600°F	53.5 µohm-in	800°C	137 µohm-cm
	1800°F	53.1 µohm-in	900°C	136 µohm-cm
	-	-	1000°C	135 µohm-cm
Thermal Conductivity	RT	68 Btu-in/ft²-hr-°F	RT	9.8 W/m-°C
	200°F	75 Btu-in/ft²-hr-°F	100°C	10.9 W/m-°C
	400°F	87 Btu-in/ft²-hr-°F	200°C	12.5 W/m-°C
	600°F	98 Btu-in/ft²-hr-°F	300°C	13.9 W/m-°C
	800°F	109 Btu-in/ft²-hr-°F	400°C	15.3 W/m-°C
	1000°F	121 Btu-in/ft²-hr-°F	500°C	16.9 W/m-°C
	1200°F	132 Btu-in/ft²-hr-°F	600°C	18.3 W/m-°C
	1400°F	144 Btu-in/ft²-hr-°F	700°C	19.8 W/m-°C
	1600°F	158 Btu-in/ft²-hr-°F	800°C	21.5 W/m-°C
	1800°F	175 Btu-in/ft²-hr-°F	900°C	23.4 W/m-°C
	-	-	1000°C	25.6W/m-°C
Specific Heat	RT	0.098 Btu/lb.-°F	RT	410 J/Kg-°C
	200°F	0.102 Btu/lb.-°F	100°C	428 J/Kg-°C
	400°F	0.109 Btu/lb.-°F	200°C	455 J/Kg-°C
	600°F	0.115 Btu/lb.-°F	300°C	477 J/Kg-°C
	800°F	0.122 Btu/lb.-°F	400°C	503 J/Kg-°C
	1000°F	0.128 Btu/lb.-°F	500°C	527 J/Kg-°C
	1200°F	0.135 Btu/lb.-°F	600°C	552 J/Kg-°C
	1400°F	0.141 Btu/lb.-°F	700°C	576 J/Kg-°C
	1600°F	0.148 Btu/lb.-°F	800°C	600 J/Kg-°C
	1800°F	0.154 Btu/lb.-°F	900°C	625 J/Kg-°C
	-	-	1000°C	648 J/Kg-°C

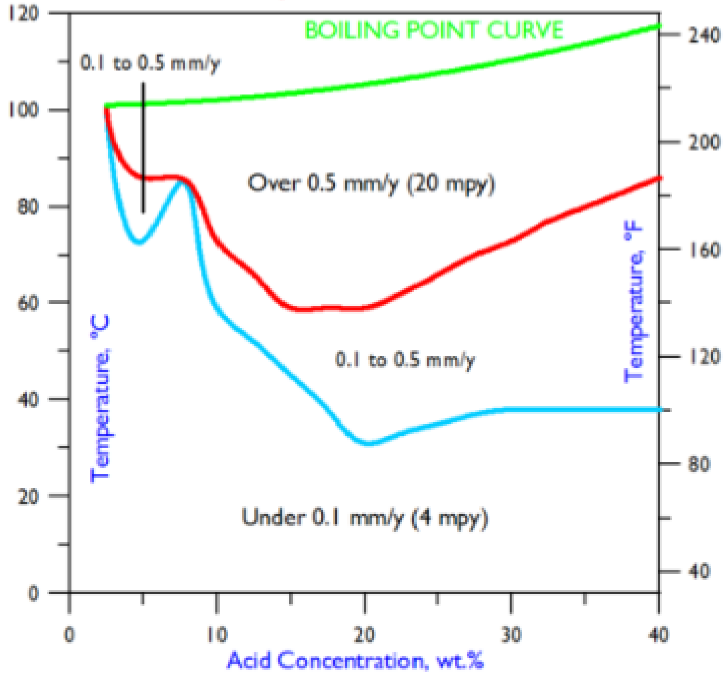
RT= Room Temperature

Physical Properties Continued

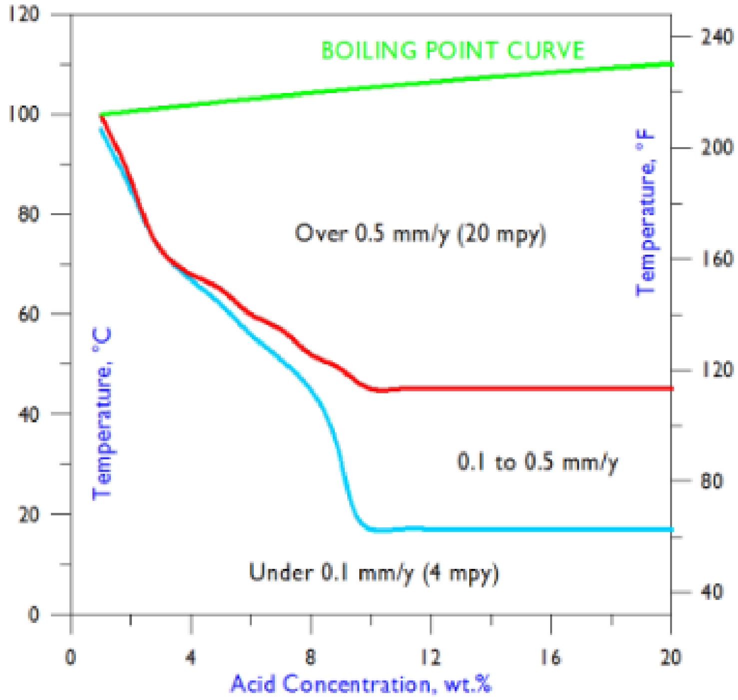
Physical Property	British Units		Metric Units	
Mean Coefficient of Thermal Expansion	70-200°F	7.1 µin/in-°F	25-100°C	12.8 x 10^{-6} µm/m-°C
	70-400°F	7.3 µin/in-°F	25-200°C	13.1 x 10^{-6} µm/m-°C
	70-600°F	7.5 µin/in-°F	25-300°C	13.4 x 10^{-6} µm/m-°C
	70-800°F	7.7 µin/in-°F	25-400°C	13.8 x 10^{-6} µm/m-°C
	70-1000°F	8.0 µin/in-°F	25-500°C	14.2 x 10^{-6} µm/m-°C
	70-1200°F	8.4 µin/in-°F	25-600°C	14.8 x 10^{-6} µm/m-°C
	70-1400°F	8.7 µin/in-°F	25-700°C	15.4 x 10^{-6} µm/m-°C
	70-1600°F	9.2 µin/in-°F	25-800°C	16.0 x 10^{-6} µm/m-°C
	70-1800°F	9.6 µin/in-°F	25-900°C	16.7 x 10^{-6} µm/m-°C
	-	-	25-1000°C	17.4 x 10^{-6} µm/m-°C
Dynamic Modulus of Elasticity	RT	30.2 x 10^6 psi	RT	208 GPa
	200°F	29.2 x 10^6 psi	100°C	201 GPa
	400°F	28.8 x 10^6 psi	200°C	199 GPa
	600°F	27.7 x 10^6 psi	300°C	192 GPa
	800°F	26.7 x 10^6 psi	400°C	186 GPa
	1000°F	25.6 x 10^6 psi	500°C	179 GPa
	1200°F	24.3 x 10^6 psi	600°C	171 GPa
	1400°F	22.8 x 10^6 psi	700°C	163 GPa
	1600°F	21.2 x 10^6 psi	800°C	153 GPa
	1800°F	18.7 x 10^6 psi	900°C	142 GPa
	-	-	1000°C	126 GPa

Iso-Corrosion Diagrams

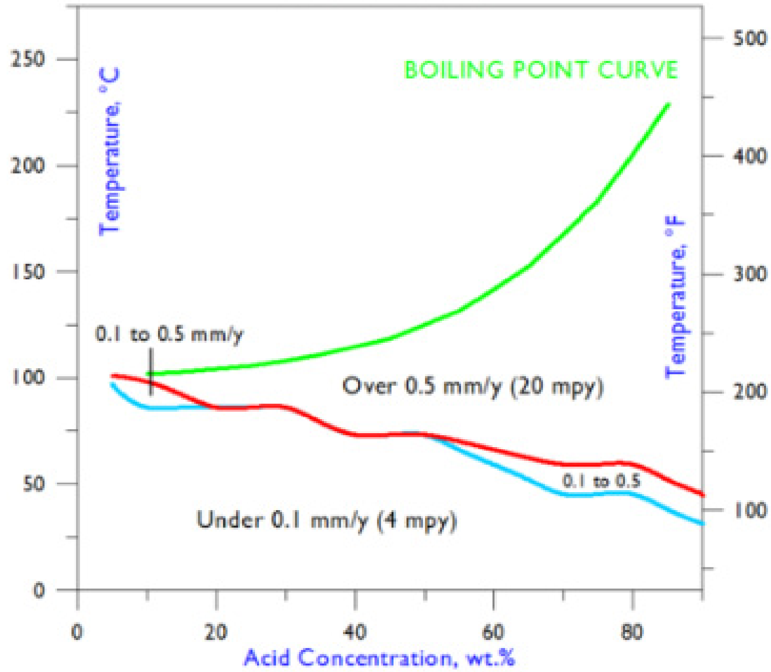
Iso-Corrosion Diagram for Alloy 625 in Hydrobromic Acid



Iso-Corrosion Diagram for Alloy 625 in Hydrochloric Acid



Iso-Corrosion Diagram for Alloy 625 in Sulfuric Acid



Iso-Corrosion Diagrams Continued

Hydrobromic Acid

Concentration	50°F	75°F	100°F	125°F	150°F	175°F	200°F	225°F	
Wt. %	10°C	24°C	38°C	52°C	66°C	79°C	93°C	107°C	Boiling
2.5	-	-	-	-	<0.01	-	<0.01	-	<0.01
5	-	-	-	-	<0.01	0.13	0.6	-	-
7.5	-	-	-	-	<0.01	<0.01	0.93	-	-
10	-	-	-	-	0.15	0.82	-	-	-
15	-	-	<0.01	0.3	0.64	-	-	-	-
20	-	0.1	0.16	0.33	0.65	-	-	-	-
25	-	-	-	-	-	-	-	-	-
30	-	-	0.11	0.21	0.34	0.72	-	-	-
40	-	-	0.08	0.15	0.25	0.42	0.79	-	-

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 17-04.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Hydrochloric Acid

Concentration	50°F	75°F	100°F	125°F	150°F	175°F	200°F	225°F	
Wt. %	10°C	24°C	38°C	52°C	66°C	79°C	93°C	107°C	Boiling
1	-	-	-	-	-	<0.01	<0.01	-	0.23
1.5	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-
2.5	-	-	-	-	-	-	-	-	-
3	-	-	<0.01	<0.01	<0.01	2.07	-	-	-
3.5	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
4.5	-	-	-	-	-	-	-	-	-
5	-	-	<0.01	<0.01	-	4.65	-	-	-
7.5	-	-	0.07	0.49	-	-	-	-	-
10	<0.01	0.15	0.3	1.16	-	-	-	-	-
15	0.06	0.19	0.4	1.06	-	-	-	-	-
20	0.06	0.16	0.36	0.82	-	-	-	-	-

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 56-97 and 3-98.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagrams Continued

Sulfuric Acid

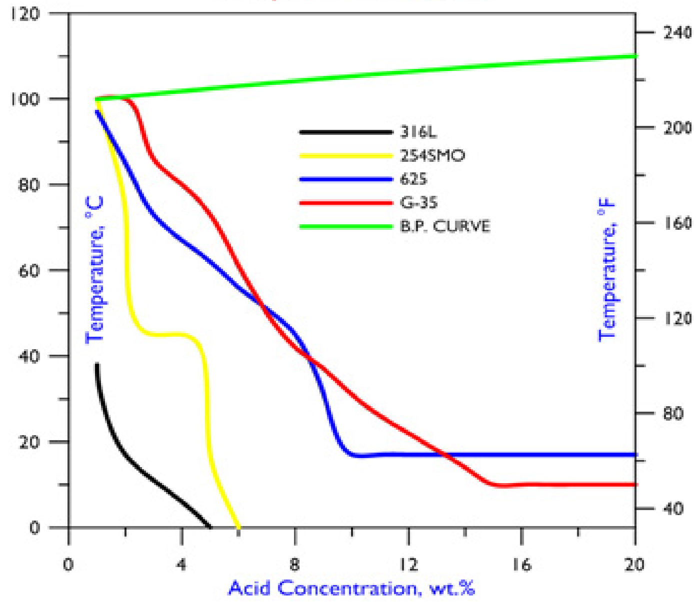
Concentration	75°F	100°F	125°F	150°F	175°F	200°F	225°F	250°F	275°F	300°F	350°F	Boiling
Wt. %	24°C	38°C	52°C	66°C	79°C	93°C	107°C	121°C	135°C	149°C	177°C	
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	<0.01	0.06	-	-	-	-	-	0.4
10	-	-	-	-	0.01	0.24	-	-	-	-	-	1.05
20	-	-	-	-	0.02	0.58	-	-	-	-	-	2.84
30	-	-	-	0.01	0.03	0.68	-	-	-	-	-	-
40	-	-	<0.01	0.02	0.58	-	-	-	-	-	-	-
50	-	-	-	0.01	0.89	-	-	-	-	-	-	-
60	-	-	<0.01	0.48	0.92	-	-	-	-	-	-	-
70	-	<0.01	0.23	0.63	-	-	-	-	-	-	-	-
80	-	0.05	0.31	0.91	2.54	-	-	-	-	-	-	-
90	<0.01	0.17	1.26	-	6.97	-	-	-	-	-	-	-
96	-	-	-	-	-	-	-	-	-	-	-	-

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 57-97 and 4-98.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

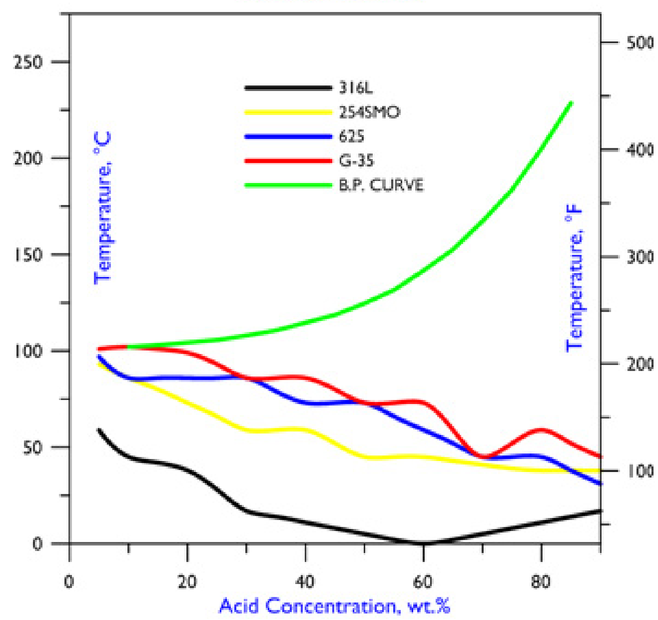
Comparative 0.1 mm/y Line Plots

To compare the performance of HAYNES® 625 alloy with that of other materials, it is useful to plot the 0.1 mm/y lines. In the following graphs, the lines for 625 alloy are compared with those of G-35® alloy, 254SMO alloy, and 316L stainless steel, in hydrochloric and sulfuric acids. The hydrochloric acid concentration limit of 20% is the azeotrope, above which corrosion tests are less reliable.

Comparison of 0.1 mm/y Lines in Hydrochloric Acid



Comparison of 0.1 mm/y Lines in Sulfuric Acid



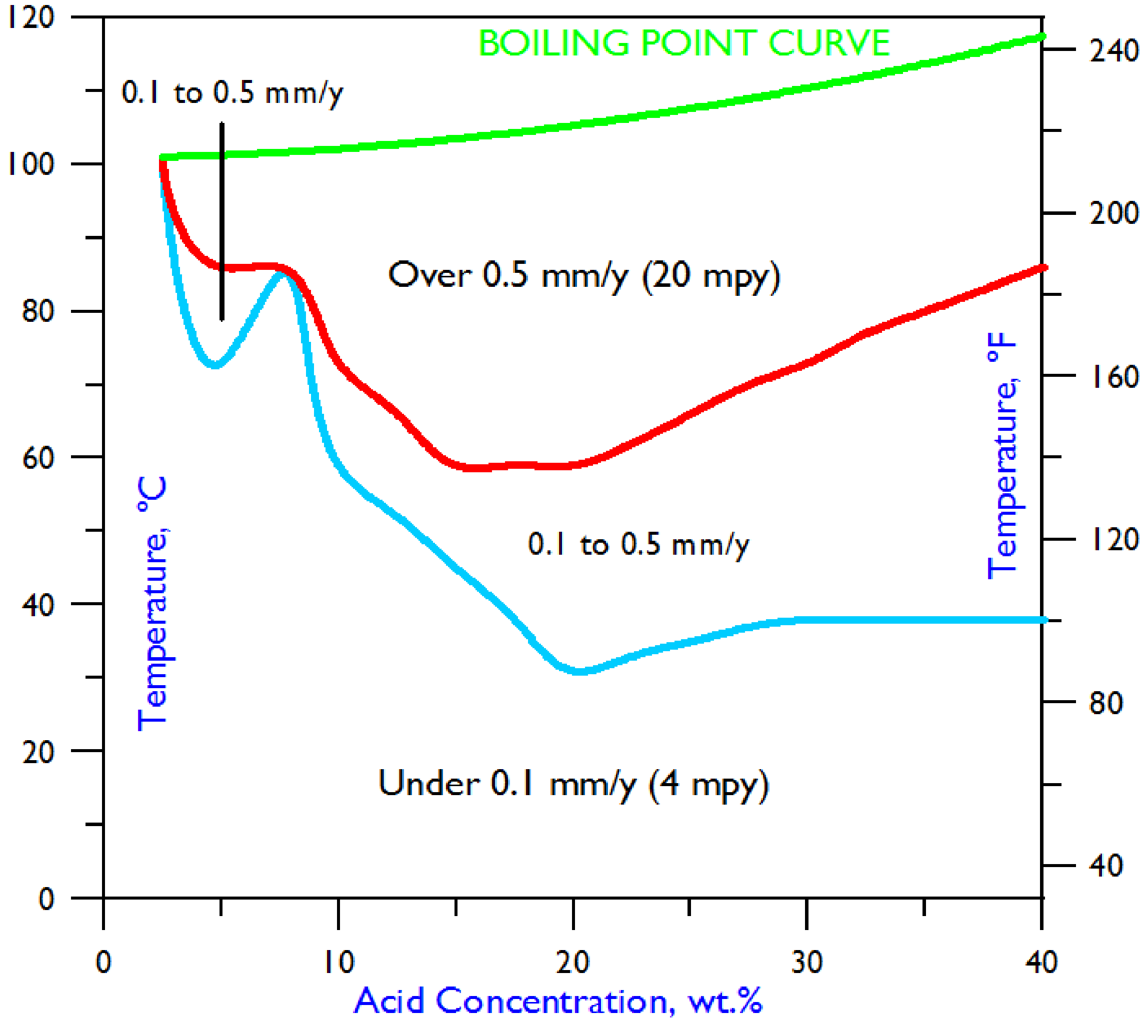
Selected Corrosion Data

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	-	-	-	-	<0.01	-	<0.01	-	<0.01
5	-	-	-	-	<0.01	0.13	0.6	-	-
7.5	-	-	-	-	<0.01	<0.01	0.93	-	-
10	-	-	-	-	0.15	0.82	-	-	-
15	-	-	<0.01	0.3	0.64	-	-	-	-
20	-	0.01	0.16	0.33	0.65	-	-	-	-
25	-	-	-	-	-	-	-	-	-
30	-	-	0.11	0.21	0.34	0.72	-	-	-
40	-	-	0.08	0.15	0.25	0.42	0.79	-	-

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 17-04.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for Alloy 625 in Hydrobromic Acid



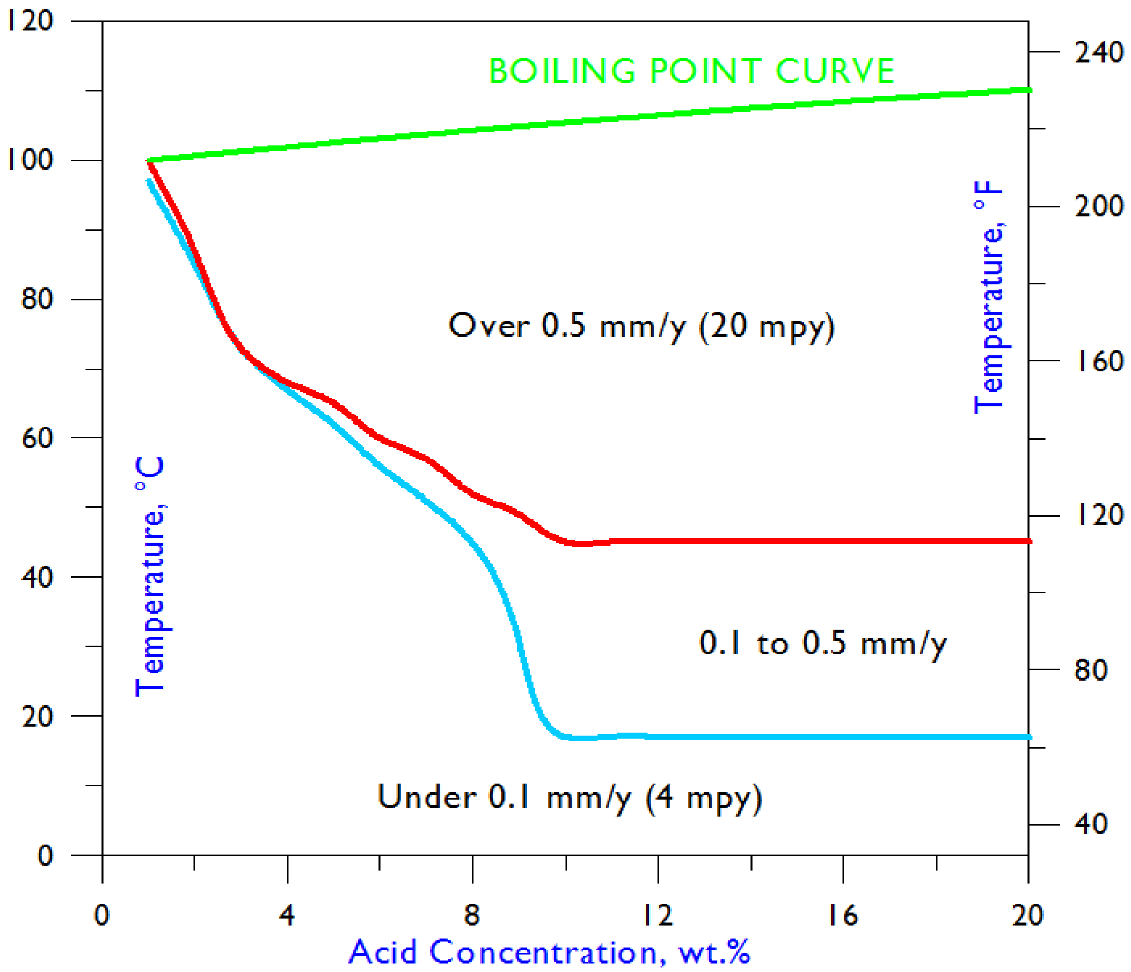
Selected Corrosion Data Continued

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	<0.01	-	0.23
1.5	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-
2.5	-	-	-	-	-	-	-	-	-
3	-	-	<0.01	<0.01	<0.01	2.07	-	-	-
3.5	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
4.5	-	-	-	-	-	-	-	-	-
5	-	-	<0.01	<0.01	-	4.65	-	-	-
7.5	-	-	0.07	0.49	-	-	-	-	-
10	<0.01	0.15	0.3	1.16		-	-	-	-
15	0.06	0.19	0.4	1.06		-	-	-	-
20	0.06	0.16	0.36	0.82		-	-	-	-

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 56-97 and 3-98.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for Alloy 625 in Hydrochloric Acid



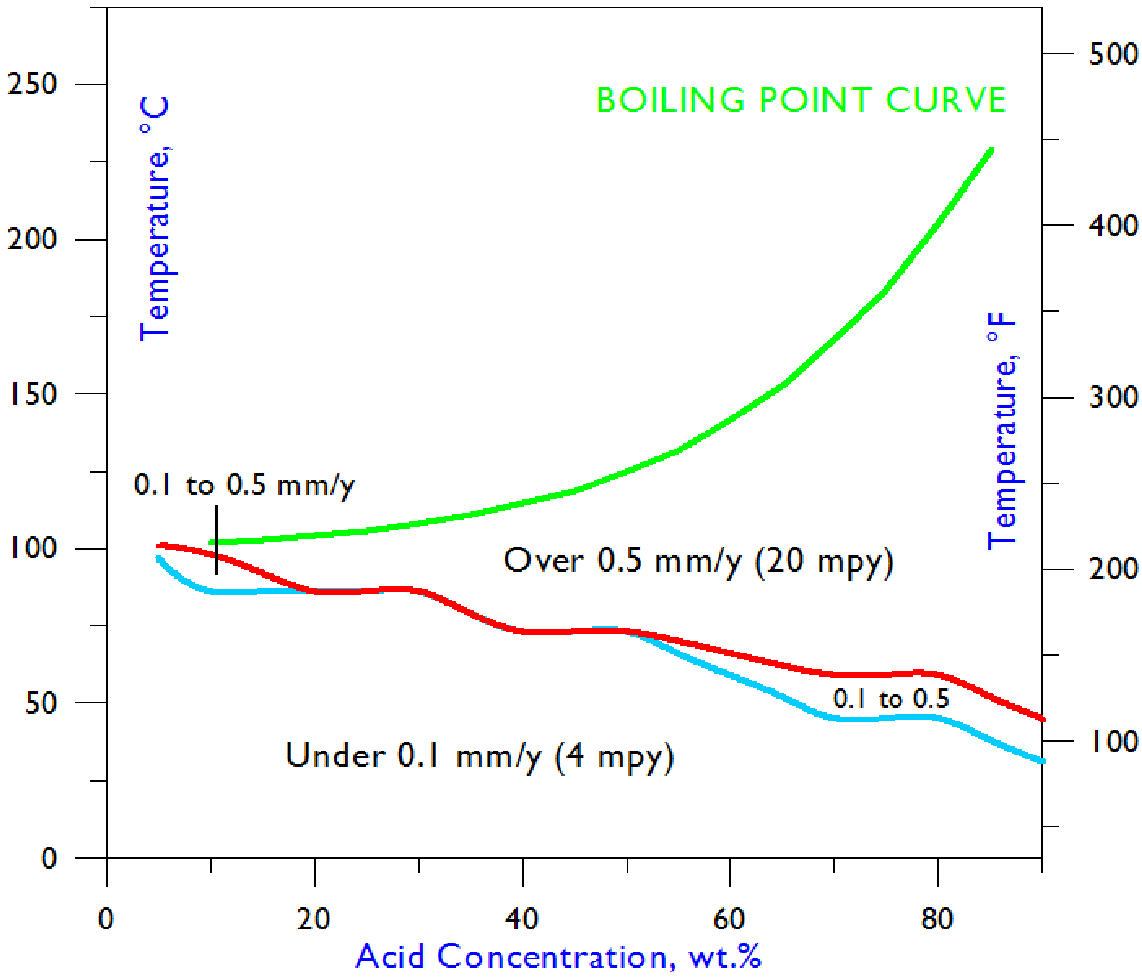
Selected Corrosion Data Continued

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	0.06	-	-	-	-	-	0.4
10	-	-	-	-	0.01	0.24	-	-	-	-	-	1.05
20	-	-	-	-	0.02	0.58	-	-	-	-	-	2.84
30	-	-	-	0.01	0.03	0.68	-	-	-	-	-	-
40	-	-	<0.01	0.02	0.58	-	-	-	-	-	-	-
50	-	-	-	0.01	0.89	-	-	-	-	-	-	-
60	-	-	<0.01	0.48	0.92	-	-	-	-	-	-	-
70	-	<0.01	0.23	0.63	-	-	-	-	-	-	-	-
80	-	0.05	0.31	0.91	2.54	-	-	-	-	-	-	-
90	<0.01	0.17	1.26	-	6.97	-	-	-	-	-	-	-
96	-	-	-	-	-	-	-	-	-	-	-	-

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 57-97 and 4-98.
All tests were performed in reagent grade acids under laboratory conditions; field tests are encouraged prior to industrial use.

Iso-Corrosion Diagram for Alloy 625 in Sulfuric Acid



Resistance to Pitting and Crevice Corrosion

HAYNES® 625 alloy exhibits good resistance to chloride-induced pitting and crevice attack, forms of corrosion to which some of 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.

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
28	113	45	64	17.5
31	163	72.5	109	42.5
G-30®	154	67.5	100	37.5
G-35®	203	95	113	45
625	**212**	**100**	**104**	**40**

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, 625 alloy is 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
28	36 h
31	36 h
G-30®	168 h
G-35®	No Cracking in 1,008 h
625	**No Cracking in 1,008 h**

Fabrication

Heat Treatment

HAYNES® 625 alloy is normally final annealed at 1925°F (1050°C) for a time commensurate with section thickness. Annealing during fabrication can be performed at even lower temperatures, but a final subsequent anneal at 1925°F (1050°C) is usually required to produce optimum structure and properties. Please see the Welding and Fabbrication brochure for further information.

Effect of Cold Reduction Upon Room-Temperature Properties

Cold Reduction	Subsequent Anneal Temperature	0.2% Yield Strength		Ultimate TensileStrength		Elongation	Hardness
%	-	ksi	MPa	ksi	MPa	%	HR B/C
None	None	70	480	133	915	46	97 HRB
10	None	113	780	151	1040	30	32 HRC
20		140	965	169	1165	16	37 HRC
30		162	1115	191	1315	11	40 HRC
40		178	1230	209	1440	8	42 HRC
50		184	1270	223	1540	5	45 HRC
10	1850°F (1010°C) for 5 min.	63	435	134	925	46	-
20		71	490	138	950	44	-
30		78	535	141	970	44	-
40		82	565	141	970	42	-
50		82	560	141	975	42	-
10	1950°F (1065°C) for 5 min.	61	425	133	915	46	-
20		71	485	137	950	45	-
30		77	530	140	965	44	-
40		83	575	142	975	42	-
50		82	570	141	975	42	-
10	2050°F (1120°C) for 5 min.	58	405	128	880	50	-
20		67	460	135	930	46	-
30		58	400	127	875	52	-
40		72	500	137	945	44	-
50		61	420	130	900	50	-
10	2150°F (1175°C) for 5 min.	52	360	122	840	55	-
20		54	370	124	850	55	-
30		53	365	122	840	56	-
40		52	360	122	840	55	-
50		51	350	119	825	58	-

Tensile results are averages of two or more tests.

*Rapid Air Cool

Welding

HAYNES® 625 alloy is readily welded by Gas Tungsten Arc (GTAW), Gas Metal Arc (GMAW), electron beam welding, and resistance welding techniques. Its welding characteristics are similar to those for HASTELLOY® X alloy. 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. These factors can increase weld restraint and promote cracking.

Base Metal Preparation

The welding surface and adjacent regions should be thoroughly cleaned with an appropriate solvent prior to any welding operation. All greases, oils, cutting oils, crayon marks, machining solutions, corrosion products, paint, scale, dye penetrant solutions, and other foreign matter should be completely removed. It is preferable, but not necessary, that the alloy be in the solution-annealed condition when welded.

Filler Metal Selection

Matching composition filler metal is recommended for joining 625 alloy. For dissimilar metal joining of 625 alloy to nickel-, cobalt-, or iron-base materials, 625 alloy itself, 230-W® filler wire, 556® alloy, HASTELLOY® S alloy (AMS5838), or HASTELLOY® W alloy (AMS 5786, 5787) welding products are suggested, depending upon the particular case. Please see the Welding and Fabrication brochure or the Haynes Welding SmartGuide for more information.

Preheating, Interpass Temperatures, and Post- Weld Heat Treatment

Preheat is not required. Preheat is generally specified as room temperature (typical shop conditions). Interpass temperature should be maintained below 200°F (93°C). Auxiliary cooling methods may be used between weld passes, as needed, providing that such methods do not introduce contaminants. Post-weld heat treatment is not generally required for X alloy. For further information, please consult the Welding and Fabrication brochure.

Nominal Welding Parameters

Details for GTAW, GMAW and SMAW welding are given in the Welding and Fabrication brochure. Nominal welding parameters are provided as a guide for performing typical operations and are based upon welding conditions used in our laboratories.

Specifications and Codes

Specifications

HAYNES® 625 alloy (N06625, W86112)	
Sheet, Plate & Strip	AMS 5599 SB 443/B 443 AMS 5869 P= 43
Billet, Rod & Bar	AMS 5666 SB 446/B 446 B 472 P= 43
Coated Electrodes	SFA 5.11/ A 5.11 (ENiCrMo-3) F= 43
Bare Welding Rods & Wire	SFA 5.14/ A 5.14 (ERNiCrMo-3) AMS 5837 F= 43
Seamless Pipe & Tube	AMS 5581 SB 444/B 444 P= 43
Welded Pipe & Tube	AMS 5581 SB 704/B 704 SB 705/B 705 P= 43
Fittings	SB 366/B 366 P= 43
Forgings	AMS 5666 SB 564/B 564 P= 43
DIN	17744 No. 2.4856 NiCr22Mo9Nb
Others	ASME Code Case No. 2468 NACE MR0175 ISO 15156

Codes

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<tr><th colspan="4">HAYNES® 625 alloy
(N06625, W86112)</th></tr>
<tr><td rowspan="12">ASME</td><td>Section I</td><td colspan="2">Grade 1
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Code Case 2632
1200°F (650°C)[2]
Grade 2
1100°F (593°C)[3]
CodeCase 1935
1000°F (538°C)[3]</td></tr>
<tr><td rowspan="3">Section III</td><td>Class 1</td><td>Grade 1
800°F (427°C)[3]</td></tr>
<tr><td>Class 2</td><td>Grade 1
800°F (427°C)[4]</td></tr>
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<tr><td rowspan="2">Section VIII</td><td>Div. 1</td><td>Grade 1
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Grade 2
1600°F (871°C)[3]
1200°F (649°C)</td></tr>
<tr><td>Div. 2</td><td>Grade 1
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Code Case 2468
800°F (427°C)[6]</td></tr>
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650°F (343°C)[7]</td></tr>
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<tr><td>B31.3</td><td colspan="2">1200°F (649°C)[6]</td></tr>
<tr><td colspan="2">MMPDS</td><td colspan="2">6.3.3</td></tr>
</table>

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