HAYNES International HIGH-TEMPERATURE ALLOYS

HAYNES® 625 alloy

A Ni-Cr-Mo-Cb alloy with excellent strength to 1500°F (816°C), good oxidation resistance, and good resistance to aqueous corrosion.

Contents

H-3073D

PRINCIPAL FEATURES

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

HAYNES® 625 alloy 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.

Available in Convenient Forms

HAYNES 625 alloy is produced in the form of plate, sheet, strip, billet, bar, wire, pipe, and tubing.

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 most current requirements it has largely been superceded by more capable HASTELLOY alloys, such as C-22® and G-30® alloys.

Applicable Specifications

HAYNES 625 alloy is covered by the following specifications: AMS 5599 (sheet, strip and plate), AMS 5666 (bar, rings, and forgings), AMS 5837 (wire); ASTM B-443 (sheet and plate), ASTM B-446 (bar and rod), AWS A5.14 (wire). The UNS number for this material is N06625.

Nominal Chemical Composition, Weight Percent

Ni	Co	Fe	Cr	Mo	Cb+Ta	Mn	Si	Al	Ti	C
62[a]	1*	5*	21	9	3.7	0.5*	0.5*	0.4*	0.4*	0.10*

[a]As Balance * Maximum

TYPICAL TENSILE PROPERTIES

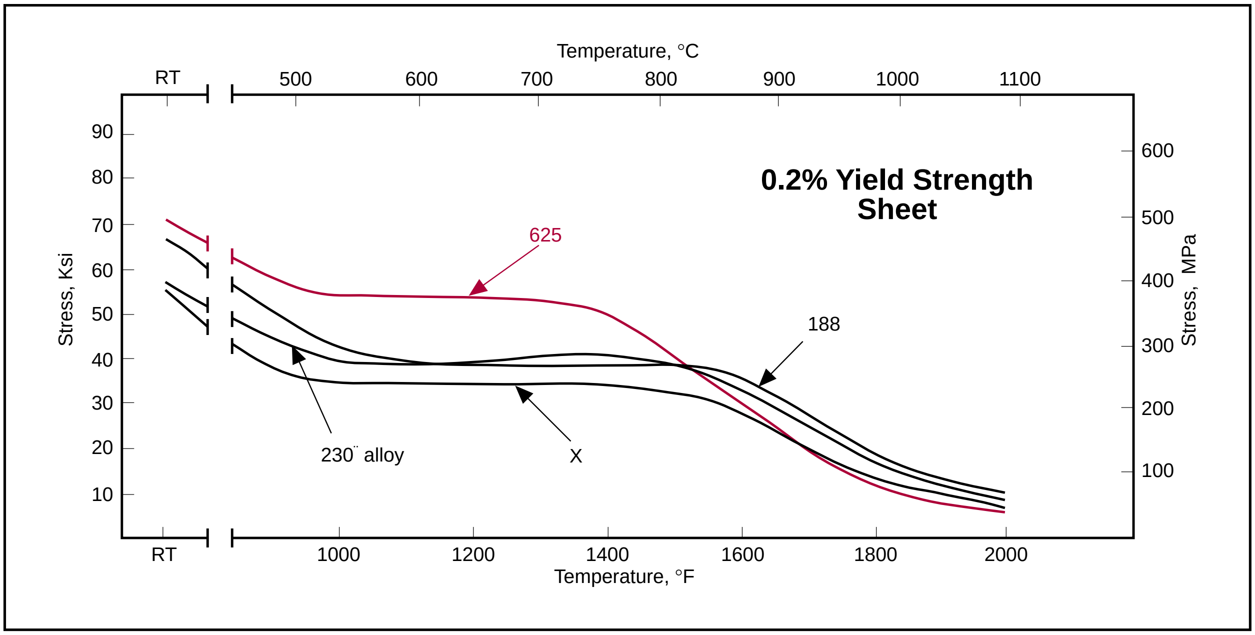
Cold-Rolled and 1925°F (1050°C) Mill-Annealed (Sheet)

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 2 in. (50.8 mm)
°F	°C	Ksi	MPa	Ksi	MPa	%
Room	Room	131.1	905	71.1	490	48.5
1000	540	111.6	770	53.7	370	54.0
1200	650	110.1	760	53.7	370	55.6
1400	760	87.2	600	50.2	345	53.1
1600	870	50.0	345	29.7	205	45.9
1800	980	24.1	165	12.1	83	43.8
2000	1095	13.7	95	5.6	39	44.7

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

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 2 in. (50.8 mm)
°F	°C	Ksi	MPa	Ksi	MPa	%
Room	Room	129.5	895	71.3	490	43.8

Comparative Elevated Temperature Yield Strengths (Sheet)

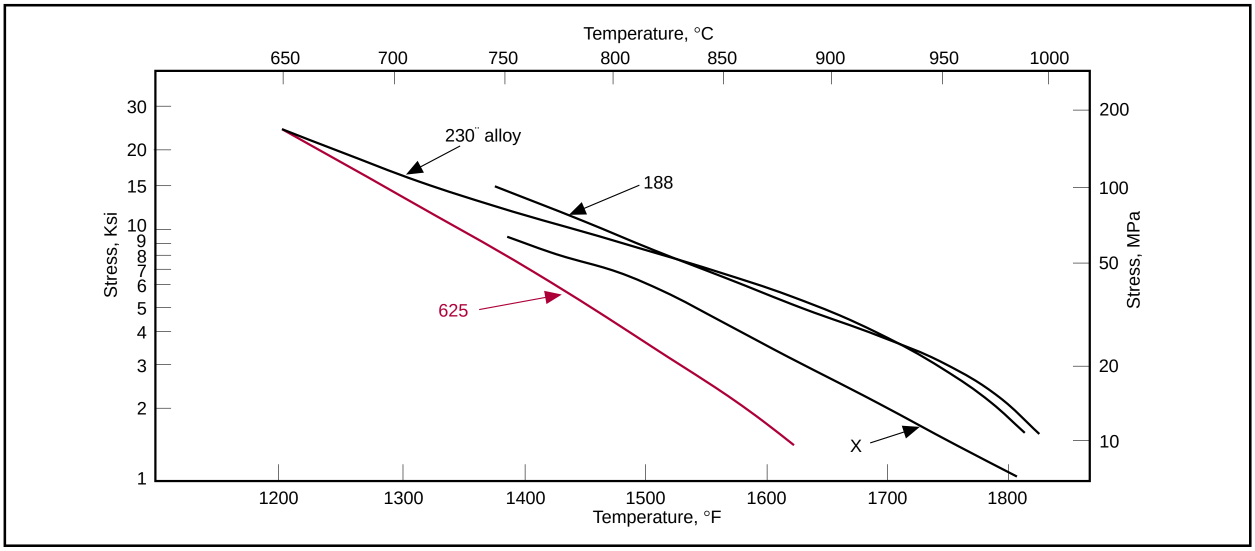


CREEP AND STRESS-RUPTURE STRENGTHS

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

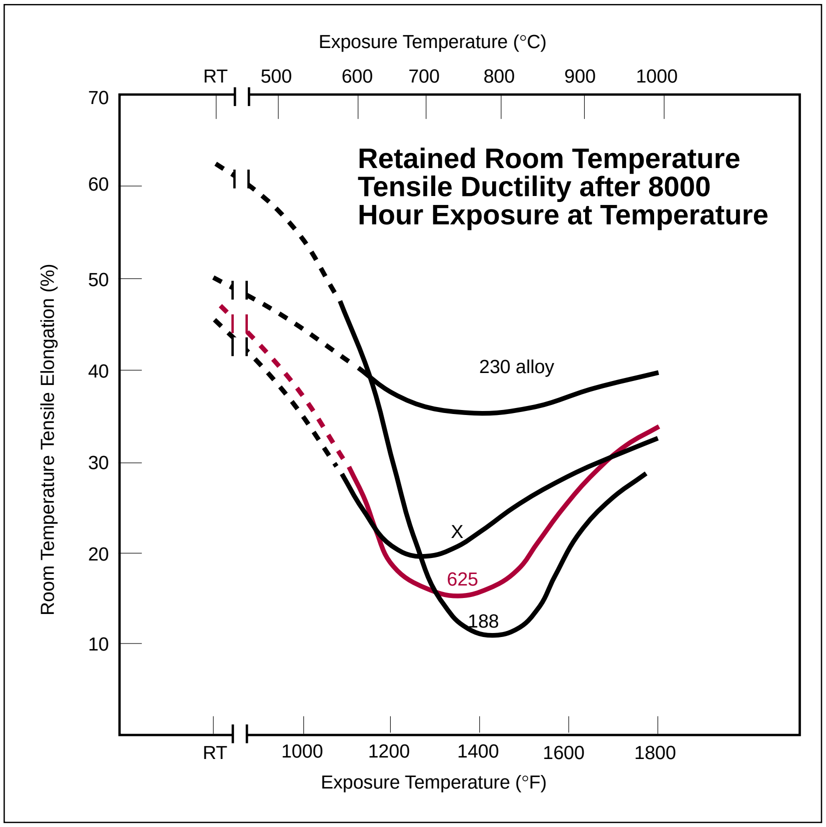
Test Temperature °F	°C	Creep, Percent	Approximate Initial Stress, Ksi (MPa) to Produce Specified Creep in 10 Hours		100 Hours		1,000 Hours	
1200	650	0.5	50.5	(350)	36.0	(250)	23.5	(160)
		1.0	58.0	(400)	40.0	(275)	25.0	(170)
		Rupture	--	--	77.0	(530)	55.0	(380)
1300	705	0.5	32.5	(225)	20.0	(140)	12.0	(83)
		1.0	35.0	(240)	22.0	(150)	13.7	(95)
		Rupture	70.0	(485)	49.5	(340)	32.0	(220)
1400	760	0.5	18.4	(125)	10.3	(71)	6.0	(41)
		1.0	20.0	(140)	12.3	(85)	7.2	(50)
		Rupture	45.0	(310)	29.0	(200)	17.8	(125)
1500	815	0.5	9.7	(67)	5.4	(37)	2.9	(20)
		1.0	11.3	(78)	6.6	(45)	3.7	(25)
		Rupture	26.5	(185)	16.2	(110)	9.1	(63)
1600	870	0.5	5.2	(36)	2.7	(19)	1.5	(10)
		1.0	6.2	(43)	3.5	(24)	1.7	(12)
		Rupture	15.3	(105)	8.6	(59)	4.2	(29)
1700	925	0.5	2.7	(19)	1.5	(10)	-	-
		1.0	3.4	(23)	1.7	(12)	-	-
		Rupture	8.3	(57)	4.1	(28)	2.7	(19)
1800	980	0.5	1.5	(10)	-	-	-	-
		1.0	1.7	(12)	-	-	-	-
		Rupture	4.1	(28)	2.7	(19)	1.7	(12)

Comparison of Stress to Produce 1% Creep in 1000 Hours (Sheet)



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_3Cb 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 °F	°C	Hours	Ultimate Tensile Strength Ksi	MPa	Yield Strength at 0.2% Offset Ksi	MPa	Elongation in 2 in. (50.8mm) %	Impact Strength ft.-lb.	Joules
As-Annealed*			127.7	880	66.2	455	46	81	110
1200	650	1000	165.0	1140	122.3	845	28	11	15
		4000	163.6	1130	117.9	815	24	8	11
		8000	164.2	1130	117.8	810	18	5	7
		16000	165.4	1140	118.5	815	12	4	5
1400	760	1000	142.9	985	95.5	660	17	5	7
		4000	145.5	1005	104.1	720	12	4	5
		8000	142.6	985	97.4	670	13	5	7
		16000	140.4	970	96.1	665	12	4	5
1600	870	1000	130.0	895	68.3	470	30	12	16
		4000	130.0	895	66.4	460	29	11	15
		8000	127.0	875	63.7	440	26	15	20
		16000	128.4	885	63.4	435	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.

	1800°F (980°C)					
	Metal Loss		Average Metal Affected		Maximum Metal Affected	
Material	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**
HAYNES® 230® alloy	0.8	20	2.8	71	3.5	89
HASTELLOY® X alloy	2.7	69	5.6	142	6.4	153
HAYNES 625 alloy	4.9	124	7.1	180	7.6	193
HAYNES 25 alloy	6.2	157	8.3	211	8.7	221
MULTIMET® alloy	11.8	300	14.4	366	14.8	376
Alloy 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.

	1800°F (980°C)				2000°F (1095°C)			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
Material	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**
230 alloy	0.3	8	0.7	18	0.5	13	1.3	33
X alloy	0.3	8	0.9	23	1.5	38	2.6	66
625 alloy	0.3	8	0.7	18	3.3	84	4.8	122
alloy 800H	0.9	23	1.8	46	5.4	137	7.4	188
25 alloy	0.4	10	0.7	18	9.2	234	10.2	259
MULTIMET alloy	0.4	10	1.3	33	8.9	226	11.6	295

TYPICAL PHYSICAL PROPERTIES

	Temperature, °F	British Units	Temperature, °C	Metric Units
Density	Room	0.305 lb/in^3	Room	8.44 g/cm^3
Melting Range	2350-2460		1290-1350	
Electrical Resistivity	Room	50.8 microhm-in.	Room	129 microhm-cm
	200	52.0 microhm-in.	100	132 microhm-cm
	400	52.8 microhm-in.	200	134 microhm-cm
	600	53.1 microhm-in.	300	135 microhm-cm
	800	53.5 microhm-in.	400	136 microhm-cm
	1000	54.3 microhm-in.	500	137 microhm-cm
	1200	54.3 microhm-in.	600	138 microhm-cm
	1400	53.9 microhm-in.	700	138 microhm-cm
	1600	53.5 microhm-in.	800	137 microhm-cm
	1800	53.1 microhm-in.	900	136 microhm-cm
			1000	135 microhm-cm
Thermal Conductivity	Room	68 Btu-in./ft.^{2} hr.-°F	Room	9.8 W/m-K
	200	75 Btu-in./ft.^{2} hr.-°F	100	10.9 W/m-K
	400	87 Btu-in./ft.^{2} hr.-°F	200	12.5 W/m-K
	600	98 Btu-in./ft.^{2} hr.-°F	300	13.9 W/m-K
	800	109 Btu-in./ft.^{2} hr.-°F	400	15.3 W/m-K
	1000	121 Btu-in./ft.^{2} hr.-°F	500	16.9 W/m-K
	1200	132 Btu-in./ft.^{2} hr.-°F	600	18.3 W/m-K
	1400	144 Btu-in./ft.^{2} hr.-°F	700	19.8 W/m-K
	1600	158 Btu-in./ft.^{2} hr.-°F	800	21.5 W/m-K
	1800	175 Btu-in./ft.^{2} hr.-°F	900	23.4 W/m-K
			1000	25.6 W/m-K
Specific Heat	Room	0.098 Btu/lb.-°F	Room	410 J/Kg-K
	200	0.102 Btu/lb.-°F	100	428 J/Kg-K
	400	0.109 Btu/lb.-°F	200	455 J/Kg-K
	600	0.115 Btu/lb.-°F	300	477 J/Kg-K
	800	0.122 Btu/lb.-°F	400	503 J/Kg-K
	1000	0.128 Btu/lb.-°F	500	527 J/Kg-K
	1200	0.135 Btu/lb.-°F	600	552 J/Kg-K
	1400	0.141 Btu/lb.-°F	700	576 J/Kg-K
	1600	0.148 Btu/lb.-°F	800	600 J/Kg-K
	1800	0.154 Btu/lb.-°F	900	625 J/Kg-K
			1000	648 J/Kg-K

Typical Physical Properties

	Temperature, °F	British Units	Temperature, °C	Metric Units
Mean Coefficient of Thermal Expansion	70-200	7.1 microinches/in.-°F	25-100	12.8 10^{-6} μm/m-°C
	70-400	7.3 microinches/in.-°F	25-200	13.1 10^{-6} μm/m-°C
	70-600	7.5 microinches/in.-°F	25-300	13.4 10^{-6} μm/m-°C
	70-800	7.7 microinches/in.-°F	25-400	13.8 10^{-6} μm/m-°C
	70-1000	8.0 microinches/in.-°F	25-500	14.2 10^{-6} μm/m-°C
	70-1200	8.4 microinches/in.-°F	25-600	14.8 10^{-6} μm/m-°C
	70-1400	8.7 microinches/in.-°F	25-700	15.4 10^{-6} μm/m-°C
	70-1600	9.2 microinches/in.-°F	25-800	16.0 10^{-6} μm/m-°C
	70-1800	9.6 microinches/in.-°F	25-900	16.7 10^{-6} μm/m-°C
			25-1000	17.4 10^{-6} μm/m-°C

DYNAMIC MODULUS OF ELASTICITY

Temperature, °F	British Units	Temperature, °C	Metric Units
Room	30.2 x 10^6 psi	Room	208 GPa
200	29.2 x 10^6 psi	100	201 GPa
400	28.8 x 10^6 psi	200	199 GPa
600	27.7 x 10^6 psi	300	192 GPa
800	26.7 x 10^6 psi	400	186 GPa
1000	25.6 x 10^6 psi	500	179 GPa
1200	24.3 x 10^6 psi	600	171 GPa
1400	22.8 x 10^6 psi	700	163 GPa
1600	21.2 x 10^6 psi	800	153 GPa
1800	18.7 x 10^6 psi	900	142 GPa
		1000	126 GPa

AQUEOUS CORROSION RESISTANCE

Media	Concentration, Percent By Weight	Test Temperature °F (°C)	Average Corrosion Rate Per Year, mils* 625 alloy	C-22® alloy	C-276 alloy	G-30® alloy
Acetic Acid	99	Boiling	<1	Nil	<1	1
Ferric Chloride	10	Boiling	7325	1	2	--
Formic Acid	88	Boiling	9	<1	1	2
Hydrochloric	1	Boiling	1	3	13	1
Acid	1.5	Boiling	353	14	32	--
	2	194 (90)	Nil	Nil	1	--
	2	Boiling	557	61	51	--
	2.5	194 (90)	72	<1	12	--
	2.5	Boiling	605	141	85	--
	10	Boiling	642	400	288	2364
Hydrochloric Acid	1	200 (93)	238	2	41	803
+ 42 g/l $Fe_2(SO_4)_3$	5	150 (66)	2	2	5	557
Hydrochloric Acid + 2% HF	5	158 (70)	123	59	26	97
Hydrofluoric	2	158 (70)	20	9	9	10
Acid	5	158 (70)	16	14	10	11
P_2O_5	39	185 (85)	1	2	9	--
(Commercial	44	240 (116)	23	21	100	--
Grade)	52	240 (116)	12	11	33	--
P_2O_5 + 2000 ppm Cl	38	185 (85)	2	1	12	--
P_2O_5 + 0.5% HF	38	185 (85)	9	7	45	--
Nitric Acid	10	Boiling	<1	<1	7	<1
	65	Boiling	21	134	888	5
Nitric Acid + 6% HF	5	140 (60)	73	67	207	--
Nitric Acid + 25% H_2SO_4 + 4% NaCl	5	Boiling	713	12	64	--
Nitric Acid + 1% HCl	5	Boiling	1	<1	8	--
Nitric Acid + 2.5% HCl	5	Boiling	<1	2	21	--
Nitric Acid + 15.8% HCl	8.8	126 (52)	>10,000	4	33	14
Sulfuric Acid	10	Boiling	37	12	19	31
	20	150 (66)	<1	<1	<1	--
	20	174 (79)	<1	1	3	<1
	20	Boiling	91	33	39	54
	30	150 (66)	<1	<1	1	<1
	30	174 (79)	<1	3	4	<1
	30	Boiling	227	64	55	60
	40	100 (38)	<1	<1	<1	<1

*To convert mils per year (mpy) to mm per year, divide by 40

Aqueous Corrosion Resistance

Media	Concentration, Percent By Weight	Test Temperature °F (°C)	Average Corrosion Rate Per Year, mils* 625 alloy	C-22® alloy	C-276 alloy	G-30® alloy
Sulfuric Acid	40	150 (66)	1	<1	1	<1
	40	174 (79)	35	9	10	2
	50	100 (38)	1	<1	Nil	<1
	50	150 (66)	25	1	4	<1
	50	174 (79)	58	16	12	10
	60	100 (38)	<1	<1	<1	<1
	70	100 (38)	<1	Nil	Nil	<1
	80	100 (38)	<1	Nil	<1	--
Sulfuric Acid + 0.1% HCl	5	Boiling	151	26	33	--
Sulfuric Acid + 0.5% HCl	5	Boiling	434	61	49	--
Sulfuric Acid + 1% HCl	10	158 (70)	121	<1	11	--
	10	194 (90)	326	94	45	--
	10	Boiling	869	225	116	--
Sulfuric Acid + 2% HF	10	Boiling	55	29	22	53
Sulfuric Acid + 200 ppm Cl-	25	158 (70)	110	11	12	--
	25	Boiling	325	215	186	101
Sulfuric Acid +1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$	11	Boiling	1815	3	42	1227
Sulfuric Acid +1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$ (ASTM G28B)	23	Boiling	2721	8	55	--
Sulfuric Acid +42 g/l $Fe_2(SO_4)_3$ (ASTM G28B)	50	Boiling	23	40	250	7

*To convert mils per year (mpy) to mm per year, divide by 40

Immersion Critical Pitting and Crevice-Corrosion Temperatures in Oxidizing NaCl-HCl

The chemical composition of the solution used in this test is as follows: 4% NaCl + 0.1% $Fe_2(SO_4)_3$ + 0.01 M HCl. This solution contains 24,300 ppm chlorides and is acidic (pH2).

In both pitting and crevice-corrosion testing the solution temperature was varied in 5°C (9°F) increments to determine the lowest temperature at which pitting corrosion initiated (observed by examination at a magnification of 40X of duplicate samples) after a 24-hour exposure period (Critical Pitting Temperature), and the lowest temperature at which crevice-corrosion initiated in a 100-hour exposure period (Critical Crevice-Corrosion Temperature).

Material	Critical Pitting Temperature		Critical Crevice-Corrosion Temperature		
	°F	°C	°F		°C
HASTELLOY® C-22® alloy	>302	>150	212	(Boiling)	102
HASTELLOY C-276 alloy	302	150	176		80
HAYNES® 625 alloy	194	90	122		50
HASTELLOY G-30® alloy	158	70	104		40
FERRALIUM® 255 alloy	122	50	95		35
Alloy 904L	113	45	68		20
Type 317LM Stainless Steel	95	35	59		15
Type 317L Stainless Steel	77	25	50		10
Alloy 825	77	25	≤23		≤-5
20CB-3® alloy	68	25	≤23		≤-5
Type 316 Stainless Steel	68	20	≤23		≤-5

Critical Pitting Temperatures in Oxidizing H_2SO_4-HCl Solution

The chemical composition of the solution used in this test is as follows: 11.5% H_2SO_4 + 1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$. This test environment is a severely oxidizing acid solution which is used to evaluate the resistance of alloys to localized corrosion. It is considerably more aggresive than the oxidizing NaCl-HCl test. Experiments were performed in increments of solution temperature of 5°C (9°F) for a 24-hour exposure period to determine the critical pitting temperature (the lowest temperature at which pitting corrosion initiated observed at a magnification of 40X of duplicate samples).

Material	Critical Pitting Temperature	
	°F	°C
HASTELLOY C-22 alloy	248	120
HASTELLOY C-276 alloy	230	110
HASTELLOY C-4 alloy	194	90
HAYNES 625 alloy	167	75

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 Haynes International publication H-3159 for further information.

Effect of Cold Reduction Upon Room-Temperature Properties

Percent Cold Reduction	Subsequent Anneal Temperature	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	Yield Strength at 0.2% Offset Ksi	Yield Strength at 0.2% Offset MPa	Elongation in 2 in. (50.8 mm) %	Hardness
None	None	133	915	70	480	46	R_B97
10	None	151	1040	113	780	30	R_C32
20		169	1165	140	965	16	R_C37
30		191	1315	162	1115	11	R_C40
40		209	1440	178	1230	8	R_C42
50		223	1540	184	1270	5	R_C45
10	1850°F (1010°C) for 5 min.	134	925	63	435	46	
20		138	950	71	490	44	
30		141	970	78	535	44	
40		141	970	82	565	42	
50		141	975	82	560	42	
10	1950°F (1065°C) for 5 min.	133	915	61	425	46	
20		137	950	71	485	45	
30		140	965	77	530	44	
40		142	975	83	575	42	
50		141	975	82	570	42	
10	2050°F (1120°C) for 5 min.	128	880	58	405	50	
20		135	930	67	460	46	
30		127	875	58	400	52	
40		137	945	72	500	44	
50		130	900	61	420	50	
10	2150°F (1175°C)	122	840	52	360	55	
20		124	850	54	370	55	
30		122	840	53	365	56	
40		122	840	52	360	55	
50		119	825	51	350	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 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. 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 (AMS 5838), or HASTELLOY W alloy (AMS 5786, 5787) welding products are suggested, depending upon the particular case. Please see publication H-3159 for more information.

Preheating, Interpass Temperatures and Post-Weld Heat Treatment

Preheat is not usually required so long as base metal to be welded is above 32°F (0°C). Interpass temperatures generally should be low. Auxiliary cooling methods may be used between weld passes, as needed, providing such methods do not introduce contaminants. Post-weld heat treatment is not normally required for 625 alloy. For further information please consult publication H-3159.

HEALTH AND SAFETY INFORMATION

Welding can be a safe occupation. However, those in the welding industry 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 and 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 affects on other organ systems.

The operation and maintenance of welding and cutting equipment should conform to the provisions 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.

Acknowledgements:

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