HAYNES International

HIGH-TEMPERATURE ALLOYS

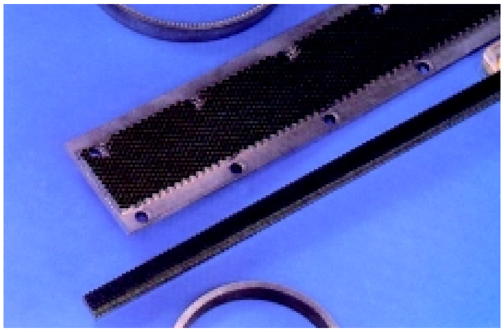
HAYNES® 214™ alloy

A nickel-chromium-aluminum-iron alloy with outstanding resistance to oxidation.

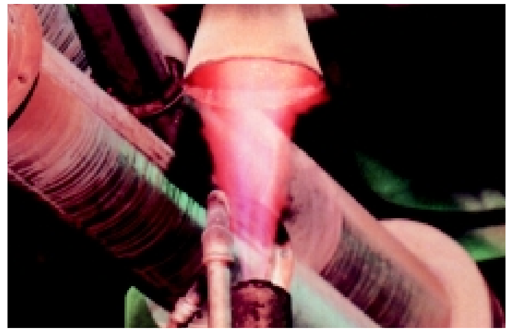
Contents

H-3008C

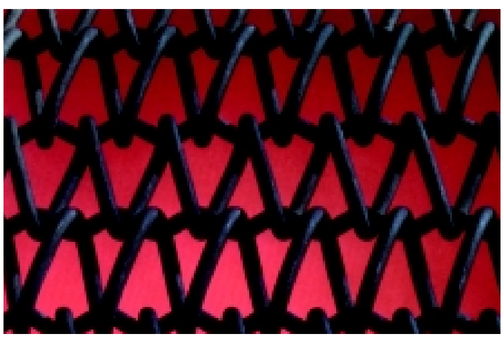
APPLICATIONS



HAYNES® 214™ alloy is gaining rapid acceptance for use in honeycomb seals because of its outstanding oxidation resistance. The seals are made of thin gage foil and are used to prevent leakage between different stages in gas turbine engines. Such seals contribute to an engines fuel efficiency.



This 214 alloy flamehood remained in service for 16 months in an application where other nickel alloy hoods required replacement every three to four months. The alloy component was subjected to direct flame impingement during the entire period in an automotive products plant.



Section of a 214 alloy belt which was removed after 3,000 hours at 1800°F (980°C) in a chinaware decorating kiln. The belt showed only minimal wear and oxidation attack. Use of 214 alloy in this application has helped reduce the time of the operation from eight or twelve hours, to less than 30 minutes.

The burner assembly at left failed after 450 cycles between minus 55 and 2000°F (minus 50 and 1095°C.) A 214 alloy burner was still in good shape after 2000 cycles in the same test. The burners were cycled from low to high temperatures in about five minutes, held for a 15-minute burn, and then rapid-air cooled.

PRINCIPAL FEATURES

Excellent Oxidation Resistance

HAYNES® 214™ alloy is a nickel-chromium-aluminum-iron alloy, designed to provide the optimum in high-temperature oxidation resistance for a wrought austenitic material, while at the same time allowing for conventional forming and joining. Intended principally for use at temperatures of 1750°F (955°C) and above, 214 alloy exhibits resistance to oxidation that far exceeds virtually all conventional heat-resistant wrought alloys at these temperatures. This is attributable to the formation of a tightly adherent Al_2O_3-type protective oxide scale, which forms in preference to chromium oxide scales at these high temperatures. At temperatures below 1750°F (955°C), 214 alloy develops an oxide scale which is a mixture of chromium and aluminum oxides. This mixed scale is somewhat less protective, but still affords 214 alloy oxidation resistance equal to the best nickel-base alloys.

The higher temperature Al_2O_3- type scale which 214 alloy forms also provides the alloy with excellent resistance to carburization, nitriding and corrosion in chlorine-bearing oxidizing environments.

Fabrication

HAYNES 214 alloy is similar in many respects to high aluminum content nickel-base alloys which are intended to be age-hardened by intermediate temperature heat treatment. If exposed at temperatures in the range of 1100-1700°F (595-925°C), 214 alloy will exhibit age-hardening as a result of the formation of a second phase, gamma prime (Ni_3Al). This also results in a significant loss of intermediate and low temperature tensile ductility. As a consequence of this, 214 alloy is susceptible to strain-age cracking when highly-stressed, highly-restrained, welded components are slowly heated through the intermediate temperature regime. This behavior is the same as that exhibited by high aluminum + titanium content superalloys, such as Waspaloy or R-41 alloys. The keys avoiding this problem are to minimize weldment restraint through appropriate component design, and/or heat rapidly through the 1100-1700°F (595-925°C) temperature range during post-fabrication heat treatment (or first-use heat up).

With the exception of the above consideration, HAYNES 214 alloy does exhibit good forming and welding characteristics. It may be forged or otherwise hot-worked, providing it is held at 2100°F (1150°C) for a time sufficient to bring the entire piece to temperature. Its room temperature tensile ductility is also high enough to allow the alloy to be formed by cold-working. All cold or hot-worked parts should be annealed and rapidly cooled in order to restore the best balance of properties.

The alloy can be welded by a variety of techniques, including gas tungsten arc (TIG), gas metal arc (MIG) or shielded metal arc (coated electrode) welding.

Heat-Treatment

HAYNES 214 alloy is furnished in the solution heat-treated condition, unless otherwise specified. The alloy is normally solution heat-treated at 2000°F (1095°C) and rapidly cooled or quenched for optimum properties. Heat treating at temperatures below the solution heat-treating temperature will result in grain boundary carbide precipitation and, below 1750°F (955°C), precipitation of gamma prime phase. Such lower temperature age-hardening heat treatments are not suggested.

Available Product Forms

HAYNES 214 alloy is available in the form of plate, sheet, strip, billet, bar, and wire.

Applicable Specifications

HAYNES 214 alloy is covered by DIN specification number 17744 No.2.4646 for all forms, and a full range of Haynes internal product specifications. Please consult Haynes International for details.

Applications

HAYNES 214 alloy combines properties which make it very suitable for service in relatively low-stress, high-temperature oxidizing environments, where the utmost in resistance to oxidation or scale exfoliation is needed. Its resistance to such environments persists to temperatures as high as 2400°F (1315°C), although strength limitations may apply. Applications can include "Clean Firing" uses such as mesh belts, trays and fixtures for firing of pottery and fine china, and the heat treatment of electronic devices and technical grade ceramics.

In the gas turbine industry, 214 alloy is used for foil construction honeycomb seals, combustor splash plates, and other static oxidation - limited parts. The automotive industry has applications for 214 alloy in catalytic converter internals, and it is used as a burner cup material in auxiliary heaters for military vehicles.

In the industrial heating market, 214 alloy is used for highly specialized applications such as refractory anchors, furnace flame hoods, and rotary calciners for processing chloride compounds. It is also used for parts in high temperature chlorine-contaminated environments, such as hospital waste incinerator internals.

Nominal Chemical Composition, Weight Percent

Ni	Cr	Al	Fe	Mn	Si	Zr	C	B	Y
75[a]	16	4.5	3	0.5*	0.2*	0.1*	0.05	0.01*	0.01

[a] As Balance * Maximum

OXIDATION RESISTANCE

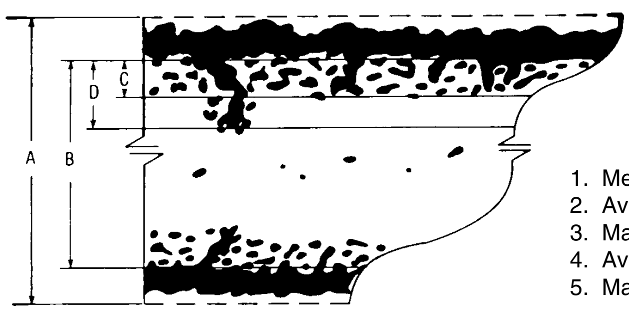
HAYNES® 214™ alloy provides resistance to oxidation at temperatures of 1750°F (955°C) and above that is virtually unmatched by any other wrought heat-resistant alloy. It can be used for long-term continuous exposure to combustion gases or air at temperatures up to 2300°F (1260°C), and, for shorter term exposures, it can be used at even higher temperatures. Useful short-term oxidation resistance has even been demonstrated at temperatures as high as 2400°F (1315°C).

Comparative Oxidation Resistance in Flowing Air*

	Average Metal Affected in 1008 Hours**							
	1800°F (980°C)		2000°F (1095°C)		2100°F (1150°C)		2200°F (1205°C)	
Material	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**
214 alloy	0.2	5	0.1	3	0.3	8	0.7	18
230® alloy	0.7	18	1.3	33	3.4	86	7.9	201
alloy 600	0.9	23	1.6	41	2.9	74	8.4	213
alloy 601	1.3	33	2.6	66	5.3	135	7.5***	191***
RA330® alloy	4.3	109	6.7	170	8.7	221	-	-
alloy 800H	1.8	46	7.4	188	8.9	226	13.6	289
Type 446 SS	2.3	58	14.5	368	>21.7	>551	>23.3	>592
Type 316 SS	14.3	363	>68.4	>1737	>105.0	>2667	>140.4	>3566

* Flowing air at a velocity of 7.0 feet/minute (213.4 cm/minute) past the samples. Samples cycled to room temperature once-a-week.
** Metal Loss + Average Internal Penetration
*** 601 Sample exhibited very large internal voids.

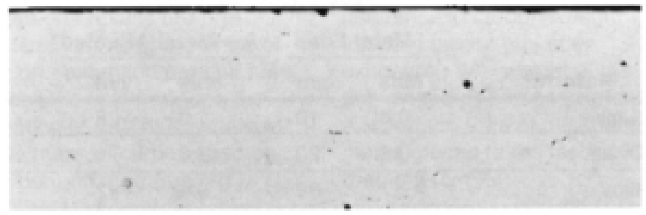
Metallographic Technique used for Evaluating Environmental Tests



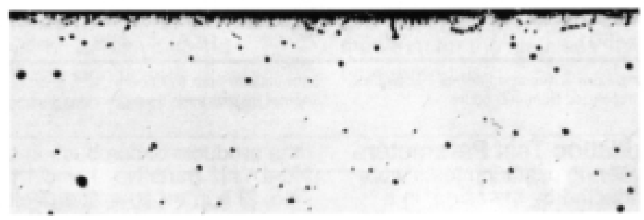
1. Metal Loss = (A - B)/2
2. Average Internal Penetration = C
3. Maximum Internal Penetration = D
4. Average Metal Affected = ((A - B)/2) + C
5. Maximum Metal Affected = ((A - B)/2) + D

Comparative Oxidation in Flowing Air 2100°F (1150°C)

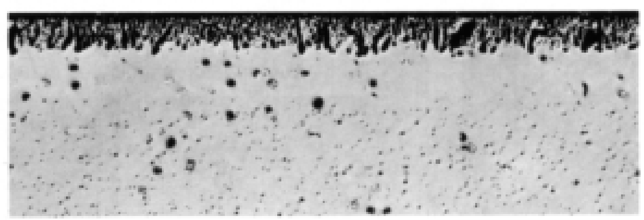
Microstructures shown are for coupons exposed for 1008 hours at 2100°F (1150°C) in air flowing at 7.0 feet/minute (213.4 cm/minute) past the samples. Samples were descaled by cathodically charging the coupons while they were immersed in a molten salt solution. The black area shown at the top of each picture represents actual metal loss due to oxidation. The data clearly show HAYNES® 214™ alloy is only slightly affected by the exposure, while other nickel-chromium alloys, such as alloys 600 and 601, and iron-nickel chromium alloys, such as RA330® alloy, all exhibit significantly more oxidation damage. Of particular importance is the almost total absence of internal attack for the 214 alloy. This contrasts markedly with the very substantial amount of internal attack evidenced by the alloy 601 and RA330 alloy tests coupons. The nature of this internal attack, as illustrated by the photomicrographs, is common for alloys containing 1-2% aluminum or silicon. Such levels of these elements do promote chromium oxide scale adherence, but do not afford improved resistance to oxide penetration below the scale.



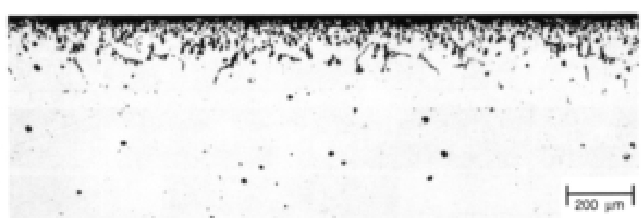
HAYNES 214 alloy
Average Metal Affected
= 0.3 Mils (8 µm)



Alloy 600
Average Metal Affected
= 2.9 Mils (74 µm)



Alloy 601
Average Metal Affected
= 5.3 Mils (135 µm)



RA330 alloy
Average Metal Affected
= 8.7 Mils (221 µm)

Comparative Burner Rig Oxidation Resistance

	1800°F (980°C)/1000 Hours				2000°F (1095°C)/500 Hours			
	Metal Loss		Av. Metal Affected*		Metal Loss		Av. Metal Affected*	
Material	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**	**Mils**	**µm**
214 alloy	0.4	10	1.0	25	0.5	13	1.2	30
230® alloy	0.8	20	2.8	71	2.2	56	5.2	132
X alloy	2.7	69	5.6	142	9.0	229	12.9	328
RA330® alloy	7.8	198	11.8	300	10.9	277	12.9	328
alloy 600	12.3[a]	312[a]	14.4[a]	366[a]	17.2	437	19.5	495
alloy 800H	12.3	312	14.5	368	30.5[b]	775[b]	33.4[b]	848[b]
Type 310 Stainless	13.7	348	16.2	411	21.2	538	23.7	602
alloy 601	3.0	76	18.8	478	10.7	272	>24.0[c]	>610[c]

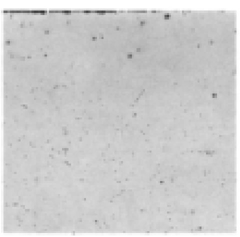
* Metal Loss + Average Internal Penetration
[b] Extrapolated from 400 hours
[a] Extrapolated from 917 hours
[c] Internal penedtration through entire thickness

Oxidation Test Parameters

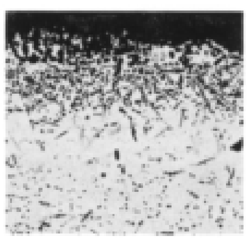
Burner rig oxidation tests were conducted by exposing, in a rotating holder, samples 0.375 inch x 2.5 inches x thickness (9.5mm x 64mm x thickness) to the products of combustion of fuel oil (2 parts No. 1 and 1 part No. 2) burned at a ratio of air to fuel of about 50:1. (Gas velocity was about 0.3 mach). Samples were automatically removed from the gas stream every 30 minutes and fan cool-ed to less than 500°F (260°C) and then reinserted into the flame tunnel.

Comparative Burner Rig Oxidation Resistance at 1800°F (980°C)/1000 Hours

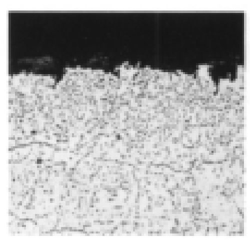
(Black areas of micros indicates actual metal loss)



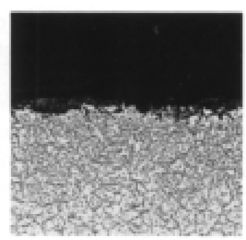
HAYNES 214 alloy
Average Metal Affected
= 1.0 Mils (25 µm)



Alloy 601
Average Metal Affected
= 18.8 Mils (478 µm)

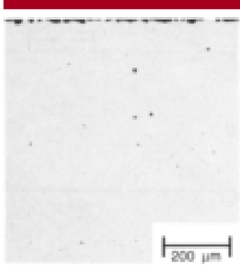


RA330 alloy
Average Metal Affected
= 11.8 Mils (300 µm)

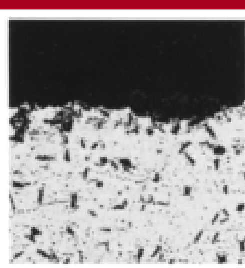


Alloy 800H
Average Metal Affected
= 14.5 Mils (368 µm)

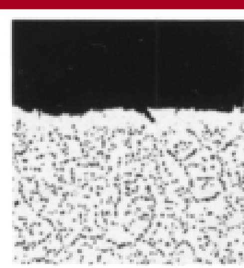
Comparative Burner Rig Oxidation Resistance at 2000°F (1095°C)/500 Hours



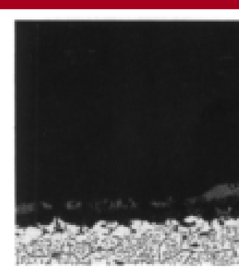
HAYNES 214 alloy
Average Metal Affected
= 1.2 Mils (30 µm)



Alloy 601
Average Metal Affected
= >24.0 Mils (>610 µm)



RA330 alloy
Average Metal Affected
= 12.9 Mils (328 µm)



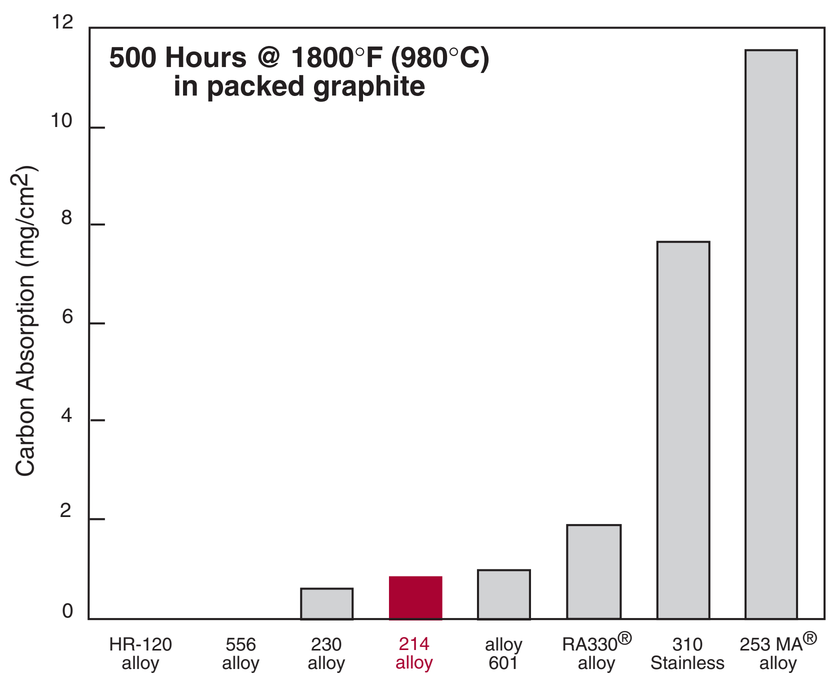
Alloy 800H
Average Metal Affected
= 33.4 Mils (848 µm)

CARBURIZATION RESISTANCE

HAYNES® 214™ alloy has very good resistance to carburization, as measured in both packed graphite exposure tests and mixed gas exposure tests. Results for these tests are presented in the following pages. All results are presented in terms of the mass of carbon absorption per unit area, which was obtained from the equation $M = C(W/A)$ where M = the mass of carbon absorption per unit area (mg/cm^2). C = difference in carbon (weight fraction) before and after exposure , W = weight of the unexposed specimen (mg) and A = surface area of the specimen exposed to the test environment (cm^2).

Packed Carburization Resistance

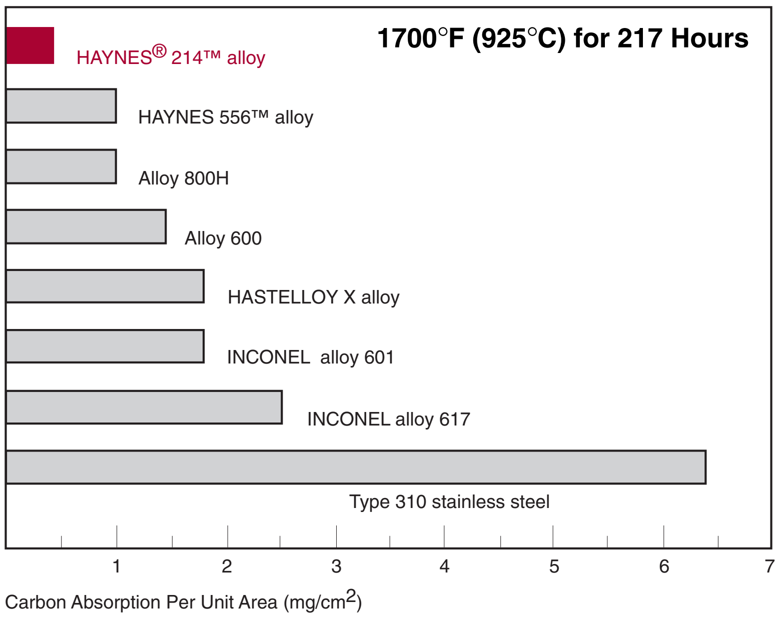
Carbon absorption observed for 214 alloy following 500 hour exposure in packed graphite at 1800°F (980°C) was very low, as shown below. While superior resistance was exhibited by HAYNES HR-120™ and 556™ alloys, other alloys tested exhibited significantly greater carbon absorption. In particular, the resistance to carburization of 214 alloy was far better than that for the stainless steel type materials.



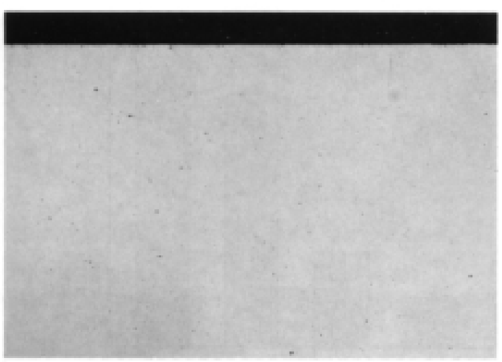
Mixed Gas Carburization Tests

Carbon absorption observed for 214 alloy following exposure at both 1700°F (925°C) and 1800°F (980°C) to a carburizing gas mixture was significantly lower than that for all other materials tested. This is shown in the graphs on the following pages. For these tests, the exposure was performed in a gas environment consisting of (by volume %) 5.0% H_2, 5.0% CO, 5.0% CH_4 and the balance argon. The calculated equilibrium composition (volume %) at 1800°F (980°C) and one atm was 14.2% H_2, 4.8%CO, 0.003% CO_2, 0.026% CH_4, 0.011% H_2O and the balance argon. The activity of carbon was 1.0 and the partial pressure of oxygen was 9×10^{-22} atm at 1800°F (980°C).

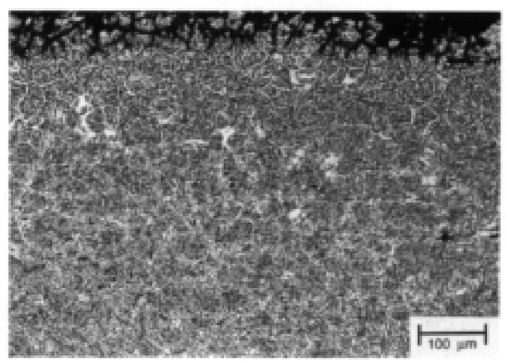
Comparative 1700°F (925°C) Mix Gas Carburization Tests



Typical Carburized Microstructures (Unetched) After Exposure For 215 Hours At 1700°F (925°C)

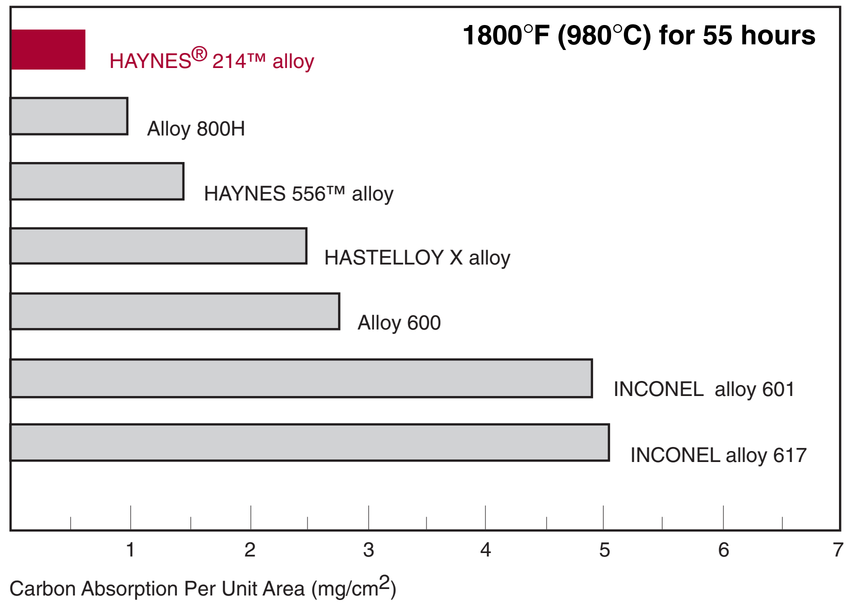


HAYNES 214 alloy

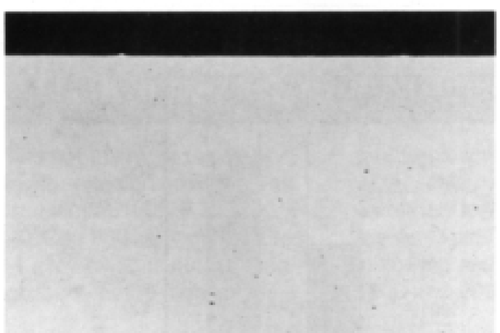


Type 310 Stainless Steel

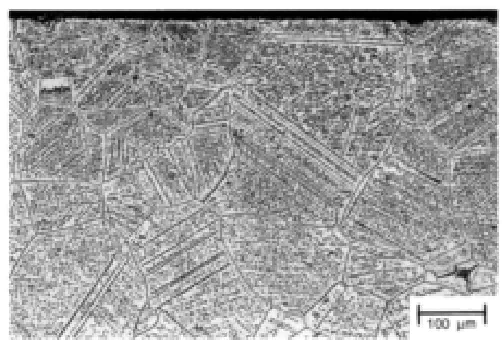
Comparative 1800°F (980°C) Mixed Gas Carburization Tests



Typical Carburized Microstructures (Unetched) After Exposure For 55 Hours At 1800°F (980°C)



HAYNES 214 alloy

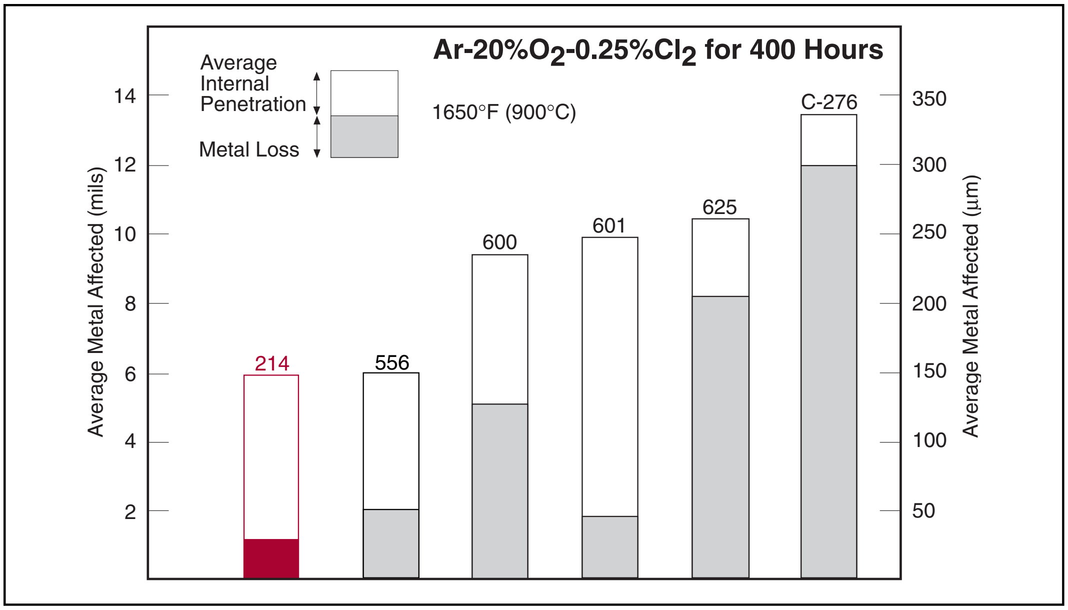


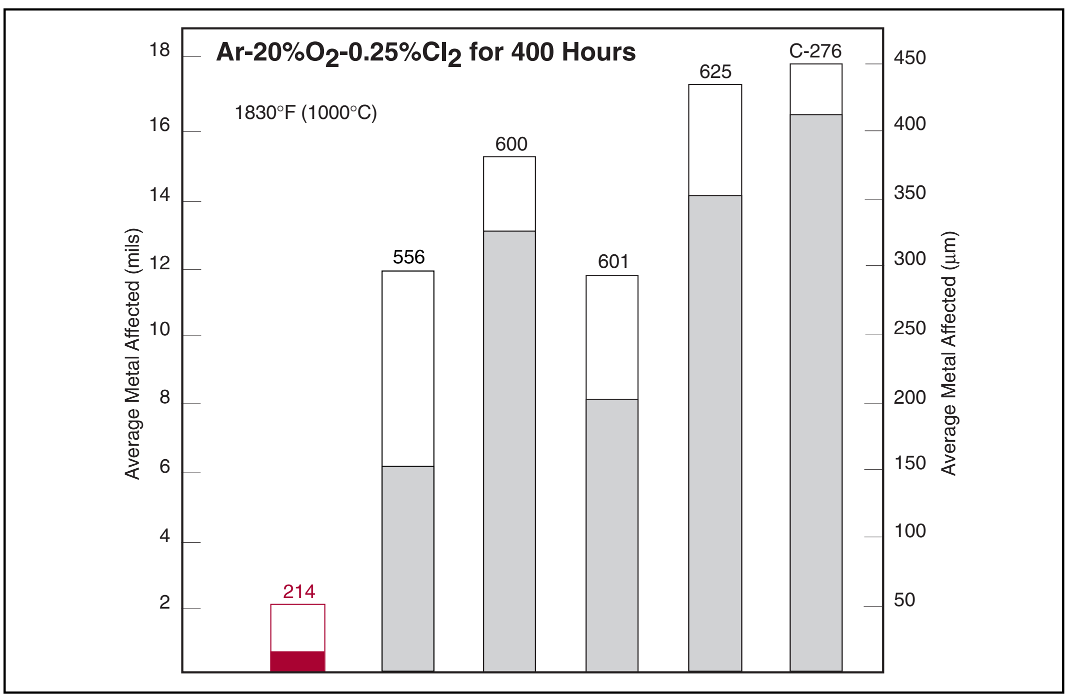
INCONEL alloy 617

Note: Alloy 617 is carburized to the center of the sample.

RESISTANCE TO CHLORINE-BEARING ENVIRONMENTS

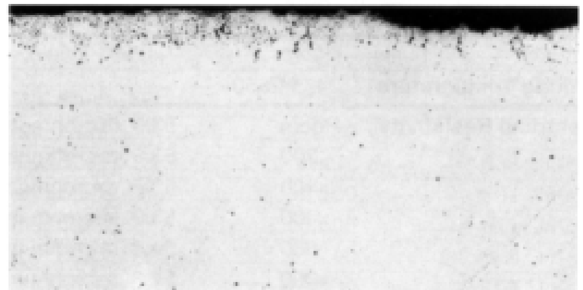
HAYNES® 214™ alloy provides outstanding resistance to corrosion in high-temperature, chlorine-contaminated oxidizing environments. This is particularly evident for exposures at temperatures at or above 1800°F (980°C), where the formation of the Al_2O_3-rich protective oxide scale is favored. Test results are shown for 400 hour exposures in a flowing gas mixture of Ar + 20% O_2 + 0.25% Cl_2. Note that the metal loss exhibited by 214 alloy is very low compared to other alloys tested.



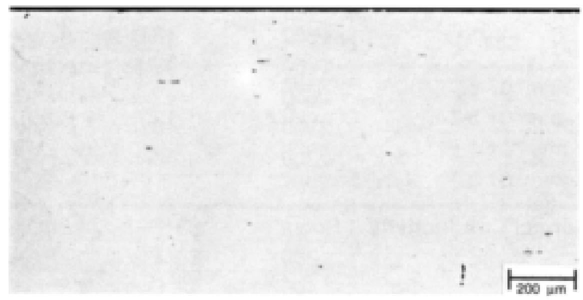


Resistance to Chlorine-Bearing Environments (continued)

HAYNES® 214™ alloy has also been tested in environments with higher levels of chlorine contamination. The photomicrographs to the right are for samples exposed to a mixture of air and 2% chlorine for 50 hours at 1830°F (1000°C). Once again, the black area at the top of each photograph represents actual metal loss experience. Alloy 601 exhibited 2.0 Mils (51 µm) of metal loss, and an average internal penetration of 6.0 Mils (152 µm), for a total average metal affected of 8.0 Mils (203 µm). Results for 214 alloy, by contrast, were 1.0 Mils (25 µm) of metal loss, 1.0 Mils (25 µm) of average internal penetration, for a total average metal affected of only 2.0 Mils (51 µm). These results are consistent with the results for lower chlorine level, longer-term tests given on the previous page.



Alloy 601



HAYNES 214 alloy

NITRIDING RESISTANCE

While not the most resistant alloy for nitriding environments at traditional 1000°F to 1200°F (540°C to 650°C) temperatures, 214 alloy exhibits outstanding resistance at the higher temperatures where its protective Al_2O_3 scale can form, even in extremely low oxygen environments. Tests were performed in flowing ammonia at 1200, 1800 and 2000°F (650, 980 and 1095°C) for 168 hours. Nitrogen absorption was determined by technical analysis of samples before and after exposure, and knowledge of the exposed specimen area.

	Nitrogen Absorption (mg/cm²)		
Material	**1200°F (650°C)**	**1800°F (980°C)**	**2000°F (1095°C)**
HAYNES 214 alloy	1.5	0.3	0.2
Alloy 600	0.8	0.9	0.3
Alloy 601	1.1	1.2	2.6
230® alloy	0.7	1.4	1.5
Alloy 625	0.8	2.5	3.3
X alloy	1.7	3.2	3.8
Alloy 800 H	4.3	4.0	5.5
Type 310 Stainless	7.4	7.7	9.5

TYPICAL PHYSICAL PROPERTIES

	Temp., °F	British Units	Temp., °C	Metric Units
Density	Room	0.291 lb/in.^{3}	Room	8.05 g/cm.^{3}
Melting Temperature	2475-2550		1355-1400	
Electrical Resistivity	Room	53.5 microhm-in.	Room	135.9 microhm-cm
	200	53.9 microhm-in.	100	136.9 microhm-cm
	400	53.9 microhm-in.	200	136.9 microhm-cm
	600	53.9 microhm-in.	300	136.9 microhm-cm
	800	54.3 microhm-in.	400	137.7 microhm-cm
	1000	54.3 microhm-in.	500	137.9 microhm-cm
	1200	53.5 microhm-in.	600	136.8 microhm-cm
	1400	51.6 microhm-in.	700	133.7 microhm-cm
	1600	49.6 microhm-in.	800	129.2 microhm-cm
	1800	48.0 microhm-in.	900	124.9 microhm-cm
	1900	47.6 microhm-in.	1000	121.6 microhm-cm
	2000	47.6 microhm-in.	1050	120.9 microhm-cm
	2100	48.0 microhm-in.	1100	121.0 microhm-cm
	2200	48.4 microhm-in.	1150	121.9 microhm-cm
			1200	122.9 microhm-cm
Thermal Conductivity	Room	83 Btu-in./ft.^{2} hr.-°F	Room	12.0 W/m-K
	200	88 Btu-in./ft.^{2} hr.-°F	100	12.8 W/m-K
	400	99 Btu-in./ft.^{2} hr.-°F	200	14.2 W/m-K
	600	112 Btu-in./ft.^{2} hr.-°F	300	15.9 W/m-K
	800	132 Btu-in./ft.^{2} hr.-°F	400	18.4 W/m-K
	1000	153 Btu-in./ft.^{2} hr.-°F	500	21.1 W/m-K
	1200	175 Btu-in./ft.^{2} hr.-°F	600	23.9 W/m-K
	1400	200 Btu-in./ft.^{2} hr.-°F	700	26.9 W/m-K
	1600	215 Btu-in./ft.^{2} hr.-°F	800	29.7 W/m-K
	1800	225 Btu-in./ft.^{2} hr.-°F	900	31.4 W/m-K
	2000	234 Btu-in./ft.^{2} hr.-°F	1000	32.7 W/m-K
	2200	255 Btu-in./ft.^{2} hr.-°F	1100	34.0 W/m-K
			1200	36.7 W/m-K

Typical Physical Properties (continued)

	Temp., °F	British Units	Temp., °C	Metric Units
Specific Heat	Room	0.108 Btu/lb.-°F	Room	452 J/Kg-K
	200	0.112 Btu/lb.-°F	100	470 J/Kg-K
	400	0.118 Btu/lb.-°F	200	493 J/Kg-K
	600	0.124 Btu/lb.-°F	300	515 J/Kg-K
	800	0.130 Btu/lb.-°F	400	538 J/Kg-K
	1000	0.136 Btu/lb.-°F	500	561 J/Kg-K
	1200	0.154 Btu/lb.-°F	600	611 J/Kg-K
	1400	0.166 Btu/lb.-°F	700	668 J/Kg-K
	1600	0.173 Btu/lb.-°F	800	705 J/Kg-K
	1800	0.177 Btu/lb.-°F	900	728 J/Kg-K
	1900	0.178 Btu/lb.-°F	1000	742 J/Kg-K
	2000	0.179 Btu/lb.-°F	1100	749 J/Kg-K
	2200	0.180 Btu/lb.-°F	1200	753 J/Kg-K
Mean Coefficient of Thermal Expansion	70-400	7.4 microinches/in.-°F	25-200	13.3 10^{-6}m/m-°C
	70-600	7.6 microinches/in.-°F	25-300	13.6 10^{-6}m/m-°C
	70-800	7.9 microinches/in.-°F	25-400	14.1 10^{-6}m/m-°C
	70-1000	8.2 microinches/in.-°F	25-500	14.6 10^{-6}m/m-°C
	70-1200	8.6 microinches/in.-°F	25-600	15.2 10^{-6}m/m-°C
	70-1400	9.0 microinches/in.-°F	25-700	15.8 10^{-6}m/m-°C
	70-1600	9.6 microinches/in.-°F	25-800	16.6 10^{-6}m/m-°C
	70-1800	10.2 microinches/in.-°F	25-900	17.6 10^{-6}m/m-°C
	70-2000	11.1 microinches/in.-°F	25-1000	18.6 10^{-6}m/m-°C
			25-1100	20.2 10^{-6}m/m-°C

DYNAMIC MODULUS OF ELASTICITY

Temp., °F	Dynamic Modulus of Elasticity, 10^6 psi	Temp., °C	Dynamic Modulus of Elasticity, GPa
Room	31.6 x 10^6 psi	Room	218 GPa
200	30.6 x 10^6 psi	100	210 GPa
400	29.6 x 10^6 psi	200	204 GPa
600	28.7 x 10^6 psi	300	199 GPa
800	27.4 x 10^6 psi	400	190 GPa
1000	25.3 x 10^6 psi	500	184 GPa
1200	23.9 x 10^6 psi	600	177 GPa
1400	22.3 x 10^6 psi	700	170 GPa
1600	20.2 x 10^6 psi	800	162 GPa
1800	19.0 x 10^6 psi	900	151 GPa
		1000	137 GPa

TYPICAL TENSILE PROPERTIES

Cold-Rolled and Solution Annealed Sheet, 0.078 to 0.125 Inches (2.0 to 3.2 mm) Thick*

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	144.2	995	87.6	605	36.8
1000	540	125.5	865	78.9	545	40.4
1200	650	118.5	815	81.1	565	25.5
1400	760	102.0	705	78.8	645	16.3
1600	870	58.2	400	45.0	310	15.4
1800	980	15.2	105	7.8	54	61.3
2000	1095	8.4	58	3.9	27	61.0
2100	1150	4.6	32	1.8	12	89.2
2200	1205	4.4	30	1.3	9	74.8

* Average of six tests for each condition

Hot-Rolled and Solution Annealed Plate, 0.500 Inches (12.7 mm) Thick*

Test Temperature		Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 1.25 in. (31.8 mm)
°F	°C	Ksi	MPa	Ksi	MPa	%
Room	Room	138.9	960	82.2	565	42.8
1000	540	120.0	825	71.5	495	47.8
1200	650	114.9	790	75.9	525	33.0
1400	760	97.4	670	73.6	505	23.1
1600	870	66.4	460	50.4	345	33.6
1800	980	16.7	115	8.4	58	86.4
2000	1095	9.0	62	4.2	29	88.6
2100	1150	6.6	46	2.1	14	99.4
2200	1205	5.0	34	1.4	10	91.5

* Average of six tests for each condition

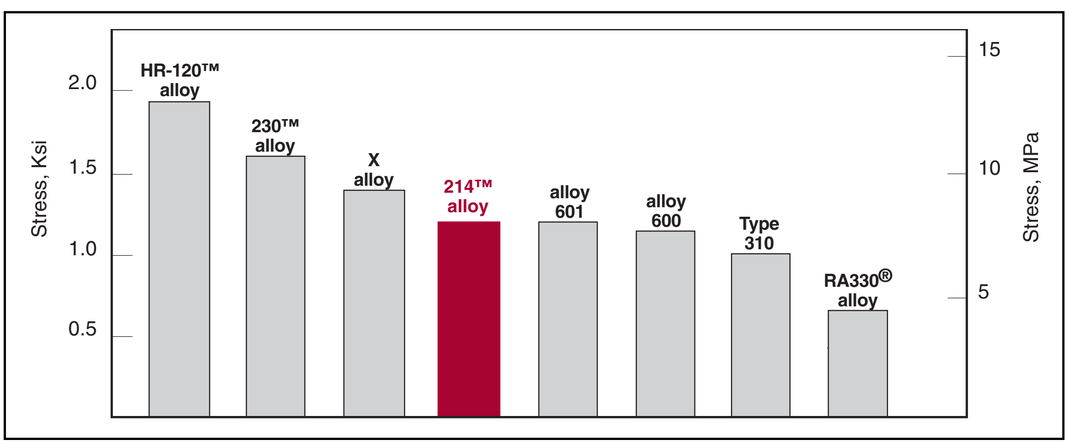
TYPICAL CREEP AND STRESS-RUPTURE PROPERTIES

Solution Annealed Sheet, Plate and Bar

Temperature °F	Temperature °C	Creep, Percent	Average Initial Stress, Ksi (MPa) to Produce Specified Creep and Rupture: 10 Hours		100 Hours		1,000 Hours		10,000 Hours*	
1400	760	0.5	37.2	(255)	27.5	(190)	20.4	(140)	15.1	(105)
		1.0	39.8	(275)	29.5	(205)	21.9	(150)	16.2	(110)
		Rupture	47.9	(330)	33.9	(235)	24.0	(165)	17.0	(115)
1500	815	0.5	23.4	(160)	17.4	(120)	12.9	(89)	9.6	(66)
		1.0	26.3	(180)	18.6	(130)	13.5	(93)	9.8	(68)
		Rupture	30.2	(210)	20.9	(145)	14.5	(100)	10.0	(69)
1600	870	0.5	13.8	(95)	9.6	(66)	6.5	(45)	4.3	(30)
		1.0	15.9	(110)	10.5	(72)	6.8	(47)	4.4	(30)
		Rupture	22.4	(155)	13.2	(91)	7.8	(54)	4.5	(31)
1700	925	0.5	7.6	(52)	4.7	(32)	2.9	(20)	1.8	(12)
		1.0	8.3	(57)	5.1	(35)	3.1	(21)	1.9	(13)
		Rupture	11.0	(76)	6.5	(45)	3.9	(27)	2.3	(16)
1800	980	0.5	2.1	(14)	1.3	(9.0)	0.87	(6.0)	0.57	(3.9)
		1.0	2.3	(16)	1.5	(10)	0.96	(6.6)	0.63	(4.3)
		Rupture	3.7	(26)	2.5	(17)	1.7	(12)	1.2	(8.3)
1900	1040	0.5	1.2	(8.3)	0.69	(4.8)	0.41	(2.8)	0.24	(1.7)
		1.0	1.4	(9.7)	0.84	(5.8)	0.50	(3.4)	0.30	(2.1)
		Rupture	3.2	(22)	2.0	(14)	1.2	(8.3)	0.76	(5.2)
2000	1095	0.5	0.72	(5.0)	0.41	(2.8)	0.24	(1.7)	0.14	(1.0)
		1.0	0.90	(6.2)	0.53	(3.7)	0.31	(2.1)	0.18	(1.2)
		Rupture	2.2	(15)	1.4	(9.7)	0.92	(6.3)	0.59	(4.1)

* Significant extrapolation for 0.5% and 1.0% creep values

Comparative Stress-Rupture Strengths, 1800°F (980°C)/10,000 Hours



THERMAL STABILITY

HAYNES® 214™ alloy exhibits reasonable room temperature ductility after long-term thermal exposure at intermediate temperatures. Precipitation of gamma prime phase occurs for exposures below 1750°F (955°C), along with minor chromium-rich carbides. Exposure at temperatures above about 1700°F (925°C) have little effect upon the properties of 214 alloy, but significant grain growth can occur above about 2000°F (1095°C).

Room-Temperature Tensile Properties of Sheet Following Thermal Exposure

Exposure Temperature			Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Elongation in 2 in. (50.8 mm)
°F	°C	Hours	Ksi	MPa	Ksi	MPa	%
1400	760	0	141.1	975	89.4	615	37.3
		32	157.5	1085	104.6	720	27.6
		100	157.8	1090	103.7	715	26.1
		1000	156.4	1080	98.3	680	27.1
1600	870	0	141.1	975	89.4	615	37.3
		32	139.7	965	81.6	565	35.0
		100	135.5	935	76.9	530	35.1
		1000	132.5	915	71.6	495	39.9
1800	980	0	141.1	975	89.4	615	37.3
		32	137.5	950	84.6	585	38.0
		100	137.7	950	84.7	585	34.2
		1000	139.6	965	87.9	605	35.2

FABRICATION CHARACTERISTICS

Heat Treatment

HAYNES 214 alloy is normally final solution heat-treated at 2000°F (1095°C) for a time commensurate with section thickness. Solution heat-treating can be performed at temperatures as low as about 1950°F (1065°C), but resulting material properties will be altered accordingly. Annealing during fabrication can be performed at even lower temperatures, but a final, subsequent solution heat treatment is needed to produce optimum structure and properties.

Typical Hardness Properties for Sheet

Condition	Rockwell C Hardness
Solution Annealed	24.3
10% Cold Reduced	33.8
20% Cold Reduced	37.6
30% Cold Reduced	40.6
40% Cold Reduced	42.4
50% Cold Reduced	43.0

Fabrication Characteristics (continued)

Effect of Cold Reduction upon Room-Temperature Tensile 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 Rc
0	None	144.7	1000	86.2	595	36.3	24.3
10		159.4	1100	121.9	840	22.5	33.8
20		176.5	1215	148.8	1025	12.9	37.6
30		194.1	1340	169.5	1170	8.1	40.6
40		208.6	1440	183.2	1265	5.3	42.4
50		219.8	1515	193.8	1335	4.0	43.0
0	1800°F (980°C) for 5 min.	-	-	-	-	-	-
10		147.2	1015	90.8	625	33.1	27.4
20		150.3	1035	89.9	620	33.7	24.9
30		155.6	1075	94.2	650	33.5	27.1
40		154.3	1065	92.5	640	33.7	27.9
50		157.9	1090	95.1	655	33.7	29.3
0	1900°F (925°C) for 5 min.	-	-	-	-	-	-
10		145.5	1005	83.6	575	36.2	24.3
20		149.5	1030	88.5	610	34.6	25.1
30		151.8	1045	91.8	635	33.3	24.0
40		154.1	1060	95.2	655	32.9	24.3
50		152.0	1050	90.3	625	32.3	24.4
0	2000°F (1095°C) for 5 min.	-	-	-	-	-	-
10		143.6	990	84.8	585	36.4	22.9
20		145.8	1005	87.2	600	34.4	24.0
30		146.2	1010	84.5	585	36.5	24.5
40		147.4	1015	86.1	595	36.5	22.5
50		148.3	1020	86.8	600	34.7	23.3

* Based upon rolling reductions taken upon 0.120-inch (3.0mm) thick sheet.
Duplicate tests

WELDING

HAYNES® 214™ alloy is readily welded by gas tungsten arc (TIG), gas metal arc (MIG), and shielded metal arc (coated electrode), welding techniques. 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 that the alloy be in the solution-annealed condition when welded.

Welding (continued)

Filler Metal Selection

Matching composition filler metal is recommended for joining 214™ alloy. For shielded metal-arc welding, HASTELLOY X electrodes (AMS 5799) are suggested. For dissimilar metal joining of 214 alloy to nickel- or cobalt-base materials, 230-W™ filler metal will generally be a good selection, but HASTELLOY S alloy (AMS 5838A) or HASTELLOY W alloy (AMS 5786B, 5787A) welding products may be used. For dissimilar welding to iron-base materials, 556 filler metal is recommended. Please see publication H-3159.

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 that such methods do not introduce contaminants. Post-weld heat treatment is not normally required for 214 alloy.

Nominal Welding Parameters

Nominal welding parameters are provided as a guide for performing typical operations. These are based upon welding conditions used in Haynes International, Inc. laboratories. For further information, please consult Haynes International.

Automatic Gas Tungsten Arc Welding

Square Butt Joint - No Filler Metal Added

	Material Thickness		
	0.040" (1.0mm)	0.062" (1.6mm)	0.125" (3.2mm)
Current (DCEN), amperes	50	80	120
Voltage	8	8.5	9.5
Travel Speed, in/min. (mm/min)	10 (254)	12 (305)	12 (305)
Electrode Size-EWTH-2, in (mm)	1/16 (1.6)	3/32 (2.4)	1/8 (3.2)
Electrode Shape	45° inc	45° inc	45° inc
Cup Size	#8	#8	#8
Shielding Gas Flow, CFH (l/min.)	30 (14.2)	30 (14.2)	30 (14.2)
Gas Type	Argon	Argon	Argon
Backing Gas, CFH (l/min.)	10 (4.7)	10 (4.7)	10 (4.7)
Gas Type	Argon	Argon	Argon

Manual Gas Tungsten Arc Welding

V-or U-Groove - All Thicknesses 1/8" (3.2 mm) or greater

Technique	-	Stringer Bead
Current (DCEN), amperes	-	120 root, 140-150 Fill
Voltage	-	11 to 14
Filler Metal	-	1/8" diameter (3.2 mm) 214 alloy
Travel Speed, ipm (mm/min)	-	4 to 6 (102-152)
Electrode Size-EWTH-2, in (mm)	-	1/8" diameter (3.2 mm)
Electrode Shape	-	30° included
Cup Size	-	#8 or larger
Gas Type	-	Argon
Shielding Gas Flow, CFH (l/min.)	-	30 to 35 (14.2 to 16.5)
Backing Gas Flow, CFH (l/min.)	-	10 (4.7) or back-gouge to sound metal and fill from root side
Preheat	-	Ambient
Interpass Temperature Maximum	-	200°F (93°C)

Gas Metal Arc Welding

	Short Circuiting Transfer Mode All Thicknesses 0.090" (2.3mm) and greater	Spray Transfer Mode All Thicknesses 0.156" (4.0mm) and greater
Wire Type	214™ alloy	214 alloy
Wire Diameter, in (mm)	0.045 (1.1)	0.062 (1.6)
Feed Speed, ipm (m/min)	170 to 190 (4.3 to 4.8)	160 to 170 (4.0 to 4.3)
Current (DCEP), amperes	100 to 110	210 to 230
Voltage	20 to 22	28 to 30
Stickout, in (mm)	1/2-3/4 (12.7 to 19.1)	3/4 (19.1)
Travel Speed, ipm (mm/min)	8 to 10 (203 to 254)	9 to 12 (229 to 305)
Torch Gas Flow, CFH (l.min.)	40 (18.9)	40 (18.9)
Gas Type	A1025 (90% He, 7.5% Ar, 2.5% CO_2) or 75% Ar + 25% He)	Argon

Shielded Metal Arc Welding

No matching chemistry SMAW electrodes are currently available for 214 alloy.

HASTELLOY X electrodes (AMS 5799) have been successfully used to join 214 alloy.

Typical parameters for X alloy electrodes (flat position) are given below.

Electrode Diameter		Voltage	Current (DCEP)	Travel Speed	
in	(mm)		amperes	ipm	(mm/min)
3/32	(2.4)	22 - 24	45 - 75	3 - 5	(76 - 127)
1/8	(3.2)	22 - 24	70 - 110	4 - 6	(102 - 152)
5/32	(4.0)	23 - 25	110 - 140	4 - 6	(102 - 152)

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.

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