

HAYNES® 556® alloy

Principle Features

High Strength and Resistance to High-Temperature Corrosion

HAYNES® 556® alloy (UNS R30556) is an iron-nickel-chromium-cobalt alloy that combines effective resistance to sulfidizing, carburizing and chlorine-bearing environments at high temperatures with good oxidation resistance, fabricability, and excellent high-temperature strength. It has also been found to resist corrosion by molten chloride salts and other salts, and is resistant to corrosion from molten zinc.

Ease of Fabrication

HAYNES® 556® alloy has excellent forming and welding characteristics. It may be forged or otherwise hot-worked, providing that it is held at 2150°F (1175°C) for a time sufficient to bring the entire piece to temperature. As a consequence of its good ductility, 556® alloy is also readily formed by cold working. All hot- or cold-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 (GTAW), gas metal arc (GMAW), shielded metal arc (coated electrode), and resistance welding.

Heat-Treatment

HAYNES® 556® alloy is furnished in the solution heat-treated condition, unless otherwise specified. The alloy is normally solution heat-treated at 2150°F (1175°C) and rapidly cooled or water-quenched for optimum properties. Heat treatments at temperatures lower than the solution heat-treating temperature may cause precipitation of secondary phases.

Applications

HAYNES® 556® alloy combines properties which make it highly useful for service at elevated-temperature in moderately to severely corrosive environments. Applications can include tubing and structural members in municipal and industrial waste incinerators, rotary calciners and kilns for minerals processing, and non-rotating components in industrial gas turbines burning low-grade fuels.

In the chemical process industry, 556® alloy is used for applications in rotary calciners, carbon regenerators, and in processes involving high-sulfur petroleum feedstocks.

In the metallurgical process industry, 556® alloy is widely used for hot-dip galvanizing fixtures, spinners and baskets, and for high speed furnace fans. 556® alloy is also employed in air preheaters of diesel engines, the inner covers of coil annealing furnaces, and in various high-temperature applications in the aerospace industry.

Nominal Composition

Weight %

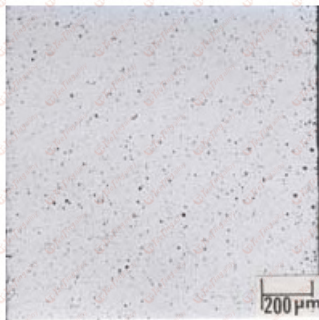
Iron:	31 Balance
Nickel:	20
Cobalt:	18
Chromium:	22
Molybdenum:	3
Tungsten:	2.5
Tantalum:	0.6
Nitrogen:	0.2
Silicon:	0.4
Niobium:	0.3 max.
Manganese:	1
Aluminum:	0.2
Carbon:	0.1
Boron:	0.02 max.
Lanthanum:	0.02
Zirconium:	0.02

Sulfidation Resistance

HAYNES® 556® alloy is second in resistance only to HAYNES® HR-160® alloy to the types of sulfur-bearing environments that are present in many high-temperature industrial processes. This is due partly to its comparatively low nickel content coupled with the important addition of cobalt, the high chromium level, and the carefully balanced minor elements. For comparison, data illustrating the relative sulfidation resistance of INCONEL® alloy 601, HASTELLOY® X alloy, alloys 600 and 800H, and Type 310 stainless steel are shown in the accompanying photomicrographs. 556® alloy had little sulfide penetration or wastage after 215 hours of exposure in an Ar+5%H₂+5%CO+1%CO₂+ 0.15%H₂S+0.1%H₂O test gas at 1800°F (980°C). By contrast, alloys such as INCONEL alloy 601 were completely destroyed, while other materials suffered severe wastage and sulfide penetration or pitting.

Sulfidation Resistance Continued

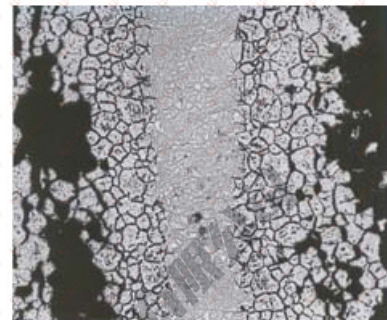
Comparative Sulfidation Resistance at 1800°F (980°C) for 215 Hours
(Width of Micros Indicates Original Sample Thickness)



HAYNES® 556® alloy
Average Metal Affected =
2.0 Mils (50 µm)/Side



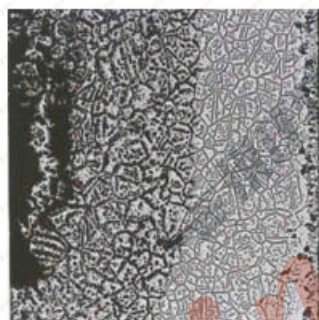
Type 310 Stainless Steel
Average Metal Affected =
7.4 Mils (190µm)/Side



Alloy 800H
Average Metal Affected =
23.2 Mils (590µm)/Side



HASTELLOY® X alloy
Average Metal Affected =
> 22 Mils (560 µm)/Side



INCONEL alloy 601
Average Metal Affected =
> 22 Mils (560 µm)/Side



alloy 600
Average Metal Affected =
> 22 Mils (560 µm)/Side

Sulfidation Resistance at Other Temperatures

Alloy	1400°F (760°C)				1600°F (871°C)			
	Metal Loss		Average Metal Affected**		Metal Loss		Average Metal Affected**	
	mils	µm	mils	µm	mils	µm	mils	µm
HR-160®	0.2	5	1.1	30	0.1	3	3.8	95
556®	2.5	65	3.8	95	5.2	130	11.7	295
310 SS	6.2	155	9.2	230	9.5	240	13.5	345
800H	7.1	180	11.2	285	11.7	295	19.2	490
X	>29.5	>750	Perforated		>21.7	>550	Consumed	
600	>21.7	>560	Perforated		>21.7	>550	Consumed	
601	>29.5	>750	Perforated		>21.7	>550	Perforated	

*215 Hour Exposure in Ar+5% H₂+5%CO+1% CO₂ +0.15%H₂ S+0.10%H₂O

**Metal Loss + Average Internal Penetration

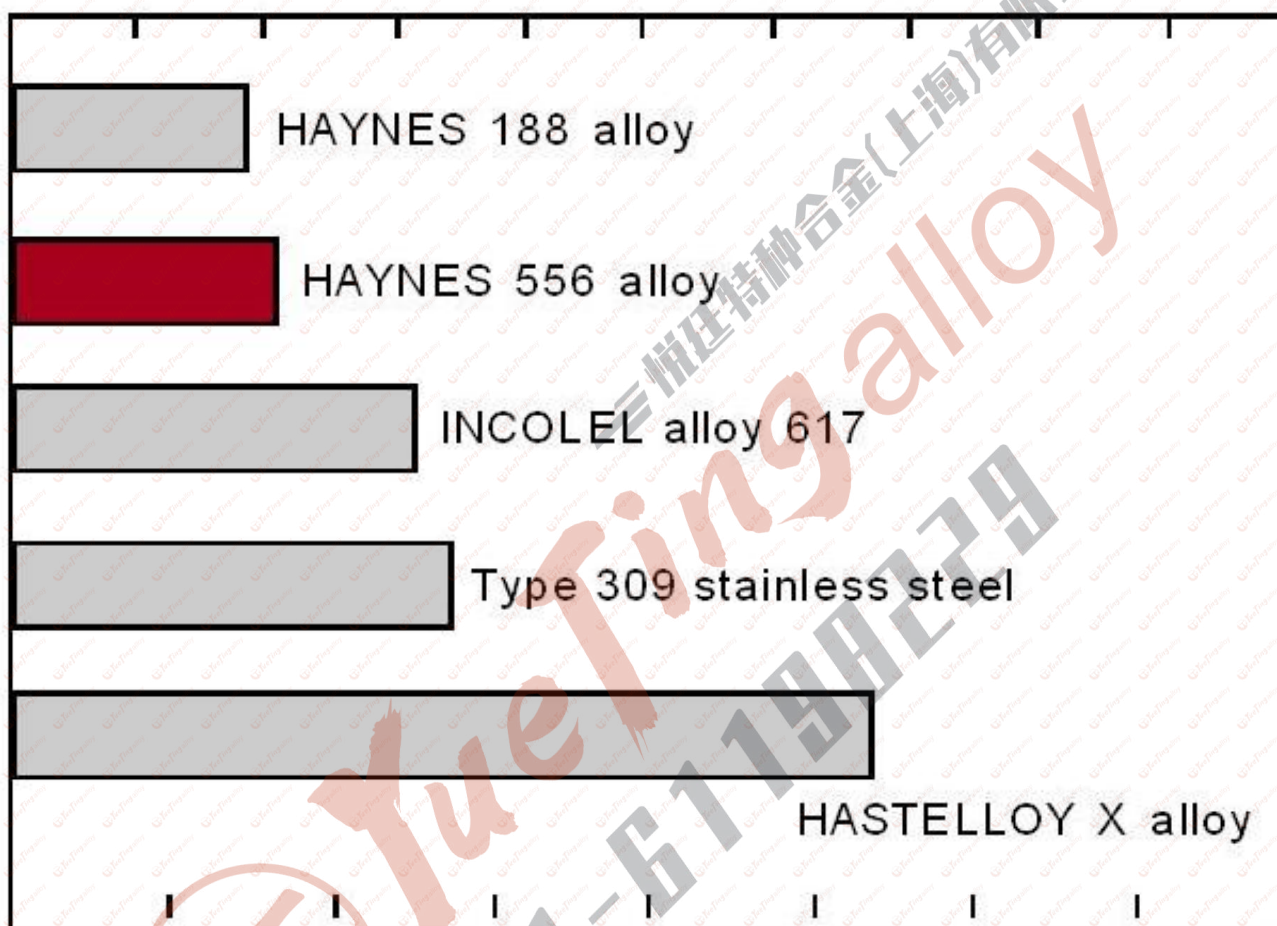
Sulfidation Resistance Continued

Field Experience - Municipal Waste Incinerator

Samples were exposed for 950 hours in the superheater section of a municipal waste incinerator. Combustion gas temperatures were about 1475°F (800°C) with excursions to 1740°F (950°C). The mode of corrosion observed was oxidation/sulfidation, although alkali chloride compounds were known to be present. HAYNES® 556® alloy was found to be one of the best alloys for resisting this highly corrosive environment.

Maximum Metal Affected (mm)

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9



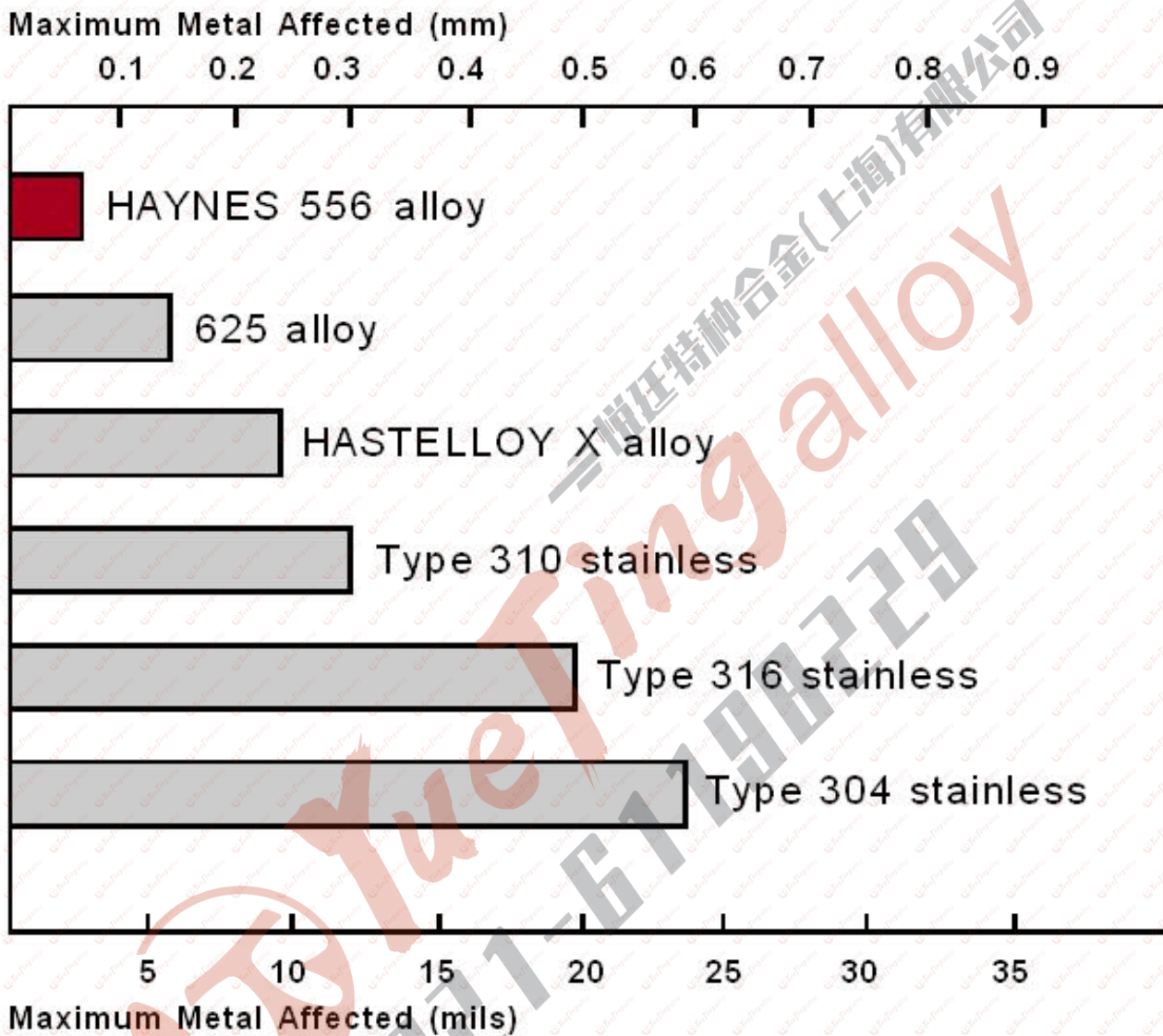
Maximum Metal Affected (mils)

5 10 15 20 25 30 35

Sulfidation Resistance Continued

Field Experience - Aluminum Remelting Furnace

Samples of tubing were exposed for 1150 hours in the recuperator of an aluminum remelting furnace producing 1250°F (675°C) flue gases. The tube samples were internally cooled by combustion preheat air the same as the operating recuperator tubes. The mode of corrosion observed was combined attack by alkali sulfates and chlorides together with oxidation. HAYNES® 556® alloy exhibited outstanding resistance to corrosion in this environment.

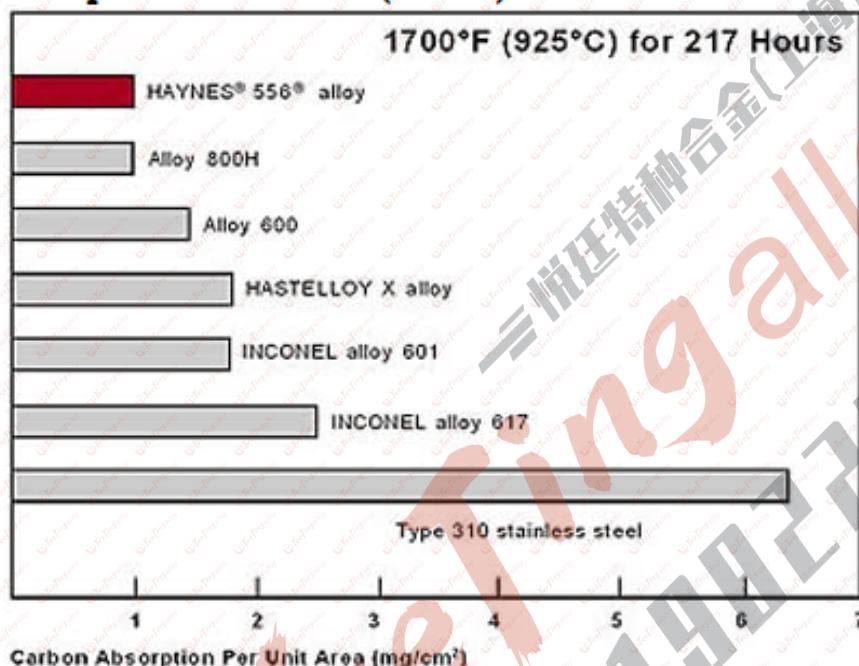


Carburization Resistance Continued

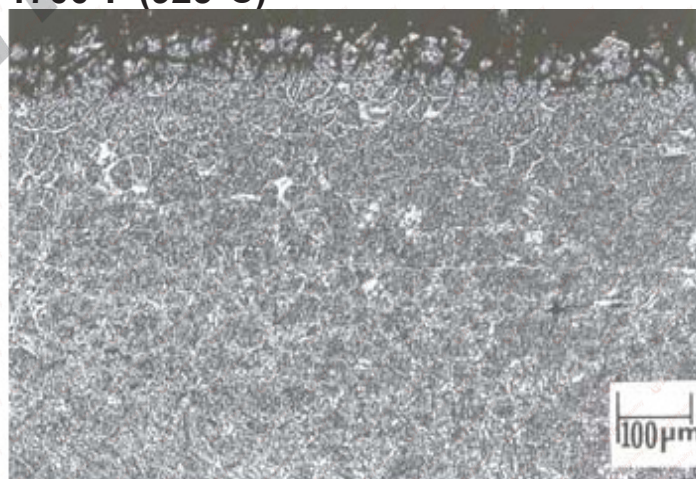
Mix Gas Carburization Tests

Carbon absorption observed for 556® 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 most 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% H₂, 5.0% CO, 5.0% CH₄ and the balance argon. The calculated equilibrium composition (volume %) at 1800°F (980°C) and one atm was 14.2% H₂, 4.8% CO, 0.003% CO₂, 0.026% CH₄, 0.011% H₂O 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

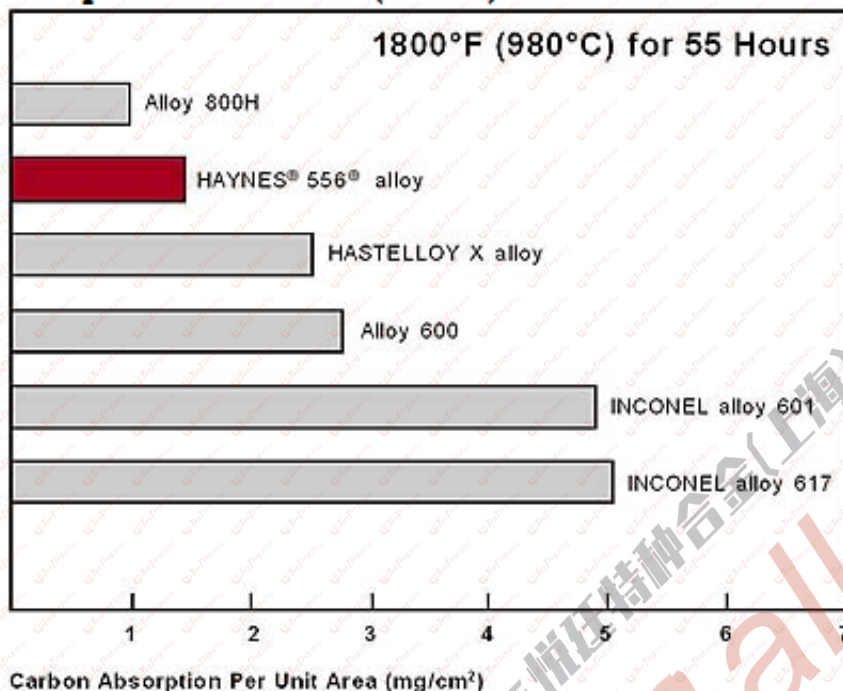


Typical Carburized Microstructures (Unetched) After Exposure For 215 Hours at 1700°F (925°C)



Carburization Resistance Continued

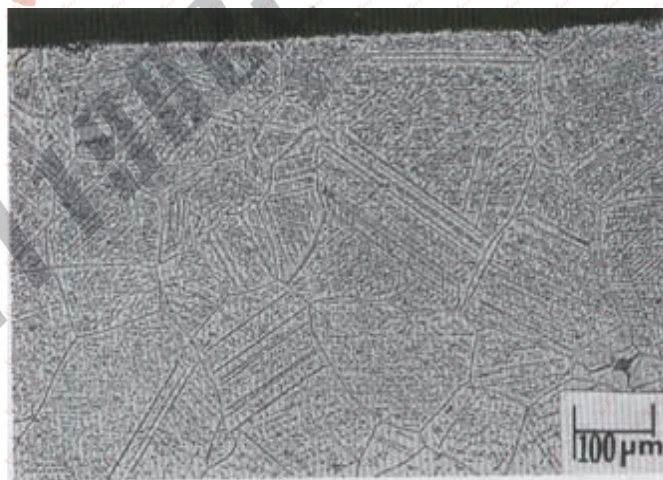
Comparative 1800°F (980°C) Mix Gas Carburization Tests



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



HAYNES® 556® alloy



INCONEL alloy 617

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

Oxidation Resistance

HAYNES® 556® alloy exhibits good resistance to both air and combustion gas oxidizing environments, and can be used for long-term exposure at temperatures up to 2000°F (1095°C). For exposures of short duration, 556® alloy can be used at higher temperatures.

Comparative Oxidation Resistance in Flowing Air*

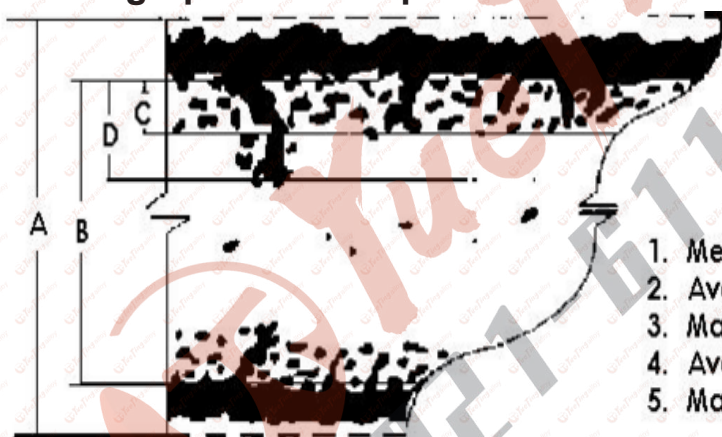
Comparative Oxidation Resistance in Flowing Air*, 1008 Hours								
Alloy	1800°F (980°C)				2000°F (1095°C)			
	Average Metal Affected**		Metal Loss		Average Metal Affected**		Metal Loss	
	mils	µm	mils	µm	mils	µm	mils	µm
X	1.5	38	0.2	5	4.4	112	1.3	33
601	1.7	43	0.4	10	3.8	97	1.3	33
556®	2.3	58	0.4	10	6.9	175	1.5	38
446 SS	2.3	60	1.3	35	14.4	366	13	330
RA330®	3	76	0.3	8	6.7	170	0.8	20
800HT	4.1	104	0.5	13	11.6	295	7.6	193
304 SS	8.1	206	5.5	140	> 19.6	> 498	N/A	N/A
316 SS	14.2	361	12.3	312	> 17.5	> 445	N/A	N/A

Samples cycled to room temperature once-a-week

* Flowing air at a velocity of 7.0 feet/minute (212.0 cm/minute) past the samples.

** Metal Loss + Average Internal Penetration

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 = $((A - B)/2) + D$

Oxidation Resistance Continued

Comparative Oxidation in Flowing Air 1800°F (980°C) for 1008 Hours

Microstructures shown are for coupons exposed for 1008 hours at 1800°F (980°C) in air flowing 7.0 feet/minute (212.0 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® 556® alloy to be superior to both RA330® alloy and Type 304 stainless steel as well as the other iron-base alloys shown in the table on the previous page.



HAYNES® 556® alloy

Average Metal Affected
= 2.3 mils (58 μm)



RA330 alloy

Average Metal Affected
= 3.0 mils (76 μm)



Type 304 Stainless Steel

Average Metal Affected
= 8.1 mils (206 μm)

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 cooled to less than 500°F (260°C) and then reinserted into the flame tunnel.

Oxidation Resistance Continued

Comparative Dynamic Oxidation

Alloy	1600°F (870°C), 2000 h, 30-min cycles				1800°F (980°C), 1000 h, 30-min cycles				2000°F (1090°C), 500 h, 30-min cycles				2100°F (1150°C), 200 h, 30-min cycles			
	Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected		Metal Loss		Average Metal Affected	
	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm
188	1.1	28	2.9	74	1.1	28	3.2	81	10.9	277	13.1	333	8	203	9.7	246
230	0.9	23	3.9	99	2.8	71	5.6	142	7.1	180	9.9	251	6.4	163	13.1	333
617	2	51	7.8	198	2.4	61	5.7	145	13.3	338	20.9	531	13.8	351	15.3	389
625	1.2	30	2.2	56	3.7	94	6	152	-	-	Consumed		-	-	-	-
556®	1.5	38	3.9	99	4.1	104	6.7	170	9.9	251	12.1	307	11.5	292	14	356
X	1.7	43	5.3	135	4.3	109	7.3	185	11.6	295	14	356	13.9	353	15.9	404
HR-120®	-	-	-	-	6.3	160	8.3	211	-	-	-	-	-	-	-	-
RA330®	2.5	64	5	127	8.7	221	10.5	267	15.4	391	17.9	455	11.5	292	13	330
HR-160®	-	-	-	-	5.4	137	11.9	302	12.5	-	18.1	460	8.7	221	15.5	394
310SS	6	152	7.9	201	16	406	18.3	465	-	-	-	-	-	-	Consumed	
800H	3.9	99	9.4	239	22.9	582	Through Thickness		-	-	Consumed after 300 h		-	-	Consumed	

Amount of metal affected for high-temperature sheet (0.060-0.125") alloys exposed for 360 days (8,640h) in flowing air.*

Alloy	1600°F (870°C)				1800°F (980°C)				2000°F (1090°C)			
	Metal Loss**		Average Metal Affected***		Metal Loss**		Average Metal Affected***		Metal Loss**		Average Metal Affected***	
	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm	mils	µm
230®	0.2	5	1.4	36	0.1	3	2.5	64	3.4	86	11	279
HR-120®	0.3	8	1.6	41	0.5	13	3.3	84	18.1	460	23.2	589
188	0.2	5	1.8	46	-	-	-	-	-	-	-	-
556®	0.3	8	1.9	48	0.5	13	6.2	157	15	381	24.1	612
X	0.3	8	2.2	56	0.2	5	2.8	71	17.1	434	26.2	665
800HT	0.4	10	2.9	74	-	-	-	-	-	-	-	-

*Flowing air at a velocity of 7.0 ft/min (213.4 cm/min) past the samples. Samples cycled to room temperature once per month.

** Metal loss was calculated from final and initial metal thicknesses; i.e. ML = (OMT – FMT) / 2

***Average Metal Affected is sum of Metal Loss and Average Internal Penetration

Applications



HAYNES® 556® alloy was chosen for components of this waste ash handling system operating at 1650°F (900°C). It has more than doubled the life of the previously used stainless steel.



This high-temperature fan for a heat-treat furnace of HAYNES 556 alloy was selected to resist a number of atmospheres at 1700 to 1800°F (925 to 980°C).



HAYNES 556 refractory anchors have outperformed other alloys in this tailgas burner which removes high-sulfur gases from effluent of refining operations.



A deposit of HAYNES 556 alloy protects elbows in a piping system at a titanium dioxide plant. The elbows, coated with 556 alloy has lasted over hour times as long as those hardfaced with a cobalt-base alloy. The inside of the elbow is scoured by abrasive TiO_2 and corrosive Cl_2 at temperatures to 1600°F (870°C).

Resistance to Chlorine-Bearing Environments

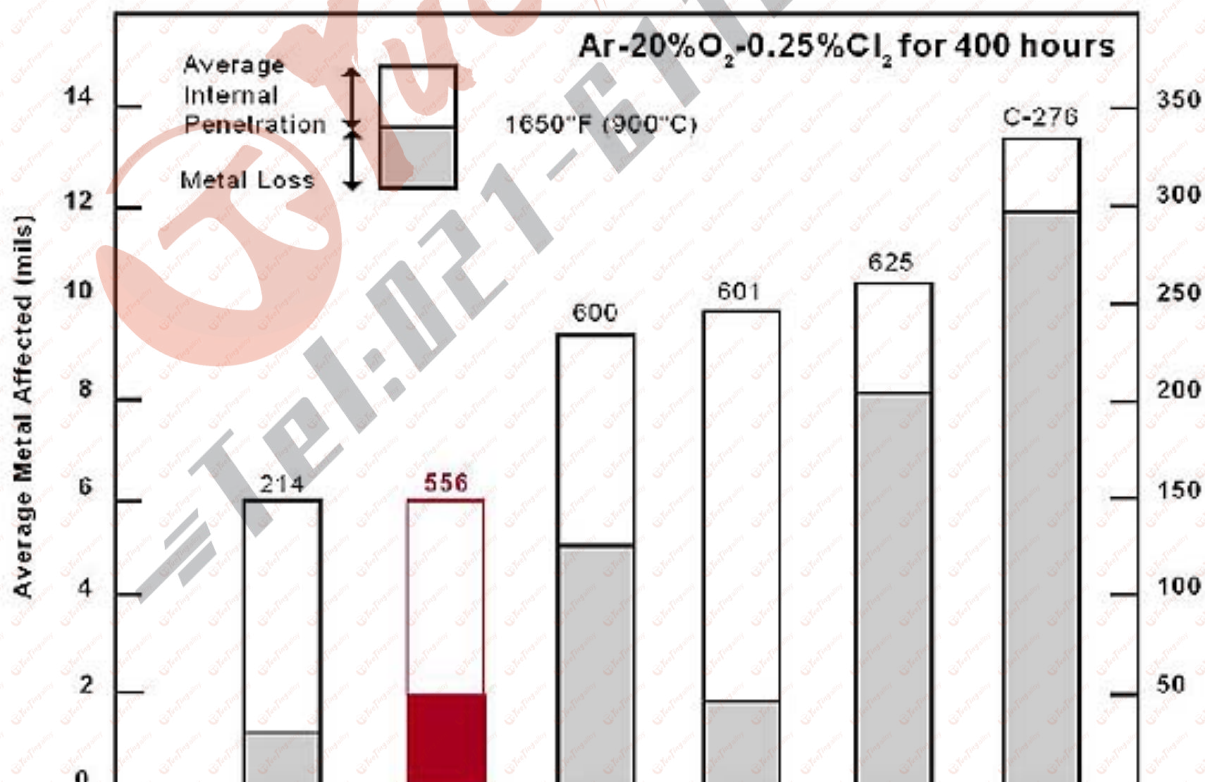
HAYNES® 556® alloy can be considered resistant to high-temperature oxidizing environments containing chlorine. Although not as resistant as HAYNES® 214® alloy at temperatures above 1650°F (900°C), 556 alloy has resistance comparable to that of 214 alloy at temperatures at or below 1650°F (900°C). This is shown by the test results given for 400 hour exposures at 1650°F (900°C) in a flowing gas mixture of Ar+20%O₂+0.25% Cl₂. Note that 556® alloy shows very low metal loss compared to most of the alloys tested, which included alloys 600, 625, INCONEL alloy 601 and HASTELLOY® C-276 alloy.



Alloy 600



HAYNES 556 alloy



Other Environments

Molten Chloride Salts

HAYNES® 556® alloy exhibits reasonable resistance to neutral NaCl-KCl-BaCl₂ type heat-treating salts at temperatures up to 1550°F (845°C) based upon actual field tests in a molten salt pot heat treating facility. Coupons were exposed for 30 days.

Alloy	Average Metal Affected	
	mils	mm
-	28	0.7
188	38	1
X	42	1.1
556®	74	1.9
304 SS	79	2
310 SS	94	2.4
600	115	2.9
INCONEL® 601		

Phosphorus-Bearing Combustion Environment

Based upon field tests performed in the combustion chamber of a fluid bed dryer used to dry sodium tripolyphosphate compounds, HAYNES® 556® alloy exhibits very good resistance to corrosion caused by formation of low-melting point eutectics involving phosphorus. Samples were exposed 30 days at a temperature of about 1475°F (800°C).

Alloy	Maximum Metal Affected	
	mils	µm
-	3	75
X	6	150
556®	8	205
214®	9	230
S	9	230
188	11	280
800H	15	380
304 SS		

Molten Zinc

Resistance to molten zinc is an important consideration for structural components in galvanizing operations. Laboratory tests were performed at 850°F (455°C) for 50 hours in molten zinc to determine suitability for such operations. Results are given below:

Alloy	Metal Loss*	
	mils	µm
-	1.6	41
556®	2.3	58
25	2.5	64
188	9.2	234
1010 Carbon Steel	9.3	236
446 SS		

Alloy	Metal Loss*	
	mils	µm
-	11	280
800H	14.1	358
304 SS	>24.0**	>610**
625	>24.0**	>610**
X		

**dissolved

*No internal attack noted for any of the alloys tested

Physical Properties

Physical Property	British Units		Metric Units	
Density	RT	0.297 lb/in ³	RT	8.23 g/cm ³
Melting Range	2425-2580°F	-	1330-1415°C	-
Electrical Resistivity	RT	35.7 µohm-in	RT	95.2 µohm-cm
	200°F	38.7 µohm-in	100°C	98.6 µohm-cm
	400°F	40.5 µohm-in	200°C	102.6 µohm-cm
	600°F	42.1 µohm-in	300°C	106.5 µohm-cm
	800°F	43.5 µohm-in	400°C	109.5 µohm-cm
	1000°F	44.7 µohm-in	500°C	112.5 µohm-cm
	1200°F	45.7 µohm-in	600°C	115.1 µohm-cm
	1400°F	46.6 µohm-in	700°C	117.2 µohm-cm
	1600°F	47.3 µohm-in	800°C	119.0 µohm-cm
	1800°F	48.0 µohm-in	900°C	120.7 µohm-cm
	2000°F	48.6 µohm-in	1000°C	122.3 µohm-cm
	-	-	1100°C	123.7 µohm-cm
Thermal Diffusivity	RT	4.5 x 10 ⁻³ in ² /s	RT	28.7 x 10 ⁻³ cm ² /s
	200°F	4.8 x 10 ⁻³ in ² /s	100°C	31.2 x 10 ⁻³ cm ² /s
	400°F	5.3 x 10 ⁻³ in ² /s	200°C	34.2 x 10 ⁻³ cm ² /s
	600°F	5.8 x 10 ⁻³ in ² /s	300°C	37.0 x 10 ⁻³ cm ² /s
	800°F	6.3 x 10 ⁻³ in ² /s	400°C	39.7 x 10 ⁻³ cm ² /s
	1000°F	6.7 x 10 ⁻³ in ² /s	500°C	42.3 x 10 ⁻³ cm ² /s
	1200°F	7.1 x 10 ⁻³ in ² /s	600°C	44.8 x 10 ⁻³ cm ² /s
	1400°F	7.5 x 10 ⁻³ in ² /s	700°C	47.0 x 10 ⁻³ cm ² /s
	1600°F	7.7 x 10 ⁻³ in ² /s	800°C	48.8 x 10 ⁻³ cm ² /s
	1800°F	8.0 x 10 ⁻³ in ² /s	900°C	50.3 x 10 ⁻³ cm ² /s
	2000°F	8.2 x 10 ⁻³ in ² /s	1000°C	51.6 x 10 ⁻³ cm ² /s
	-	-	1100°C	52.8 x 10 ⁻³ cm ² /s
Thermal Conductivity	RT	77 Btu-in/ft ² -hr-°F	RT	11.1 W/m-°C
	200°F	90 Btu-in/ft ² -hr-°F	100°C	13.1 W/m-°C
	400°F	107 Btu-in/ft ² -hr-°F	200°C	15.4 W/m-°C
	600°F	122 Btu-in/ft ² -hr-°F	300°C	17.3 W/m-°C
	800°F	135 Btu-in/ft ² -hr-°F	400°C	19.0 W/m-°C
	1000°F	148 Btu-in/ft ² -hr-°F	500°C	20.8 W/m-°C
	1200°F	160 Btu-in/ft ² -hr-°F	600°C	22.4 W/m-°C
	1400°F	173 Btu-in/ft ² -hr-°F	700°C	24.0 W/m-°C
	1600°F	185 Btu-in/ft ² -hr-°F	800°C	25.5 W/m-°C
	1800°F	197 Btu-in/ft ² -hr-°F	900°C	27.2 W/m-°C
	2000°F	210 Btu-in/ft ² -hr-°F	1000°C	28.9 W/m-°C
	-	-	1100°C	30.4 W/m-°C

RT= Room Temperature

Physical Properties Continued

Physical Property	British Units		Metric Units	
Specific Heat	RT	0.111 Btu/lb-°F	RT	464 J/kg·°C
	200°F	0.113 Btu/lb-°F	100°C	475 J/kg·°C
	400°F	0.118 Btu/lb-°F	200°C	493 J/kg·°C
	600°F	0.122 Btu/lb-°F	300°C	508 J/kg·°C
	800°F	0.126 Btu/lb-°F	400°C	523 J/kg·°C
	1000°F	0.130 Btu/lb-°F	500°C	538 J/kg·°C
	1200°F	0.133 Btu/lb-°F	600°C	552 J/kg·°C
	1400°F	0.135 Btu/lb-°F	700°C	561 J/kg·°C
	1600°F	0.140 Btu/lb-°F	800°C	570 J/kg·°C
	1800°F	0.147 Btu/lb-°F	900°C	595 J/kg·°C
	2000°F	0.152 Btu/lb-°F	1000°C	618 J/kg·°C
	-	-	1100°C	638 J/kg·°C
Mean Coefficient of Thermal Expansion	70-200°F	8.1 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-100°C	14.7 x 10 ⁻⁶ m/m·°C
	70-400°F	8.2 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-200°C	14.9 x 10 ⁻⁶ m/m·°C
	70-600°F	8.4 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-300°C	15.1 x 10 ⁻⁶ m/m·°C
	70-800°F	8.6 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-400°C	15.4 x 10 ⁻⁶ m/m·°C
	70-1000°F	8.8 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-500°C	15.7 x 10 ⁻⁶ m/m·°C
	70-1200°F	9.0 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-600°C	16.1 x 10 ⁻⁶ m/m·°C
	70-1400°F	9.2 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-700°C	16.4 x 10 ⁻⁶ m/m·°C
	70-1600°F	9.4 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-800°C	16.7 x 10 ⁻⁶ m/m·°C
	70-1800°F	9.5 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-900°C	17.0 x 10 ⁻⁶ m/m·°C
	70-2000°F	9.6 $\mu\text{in/in} \cdot ^\circ\text{F}$	25-1000°C	17.1 x 10 ⁻⁶ m/m·°C
	-	-	25-1100°C	17.1 x 10 ⁻⁶ m/m·°C
Dynamic Modulus of Elasticity	RT	29.7 x 10 ⁶ psi	RT	205 GPa
	200°F	29.1 x 10 ⁶ psi	100°C	200 GPa
	400°F	28.2 x 10 ⁶ psi	200°C	195 GPa
	600°F	26.9 x 10 ⁶ psi	300°C	187 GPa
	800°F	25.6 x 10 ⁶ psi	400°C	179 GPa
	1000°F	24.4 x 10 ⁶ psi	500°C	172 GPa
	1200°F	23.1 x 10 ⁶ psi	600°C	164 GPa
	1400°F	21.8 x 10 ⁶ psi	700°C	155 GPa
	1600°F	20.9 x 10 ⁶ psi	800°C	148 GPa
	1800°F	20.1 x 10 ⁶ psi	900°C	143 GPa
	-	-	1000°C	138 GPa

RT= Room Temperature

Applications Continued



This salt pot heat-treat basket of HAYNES 556 alloy for heat treating aircraft components at 1600°F to 600°F (870°C to 315°C) in molten salt has outperformed stainless steels 3 times because of 556 alloys excellent ductility, thermal fatigue resistance and improved strength levels at 1600°F (870°C).



556 alloy vacuum carburizing furnace retort.



HAYNES 556 spinner baskets are continually cycled through molten zinc at 850°F (455°C) for hot dip galvanizing. After 16 months of operation the 556 baskets showed no measureable metal loss from the molten zinc exposure.



556 alloy upgrades MULTIMET® alloy stator vanes in industrial turbines.

Tensile Properties

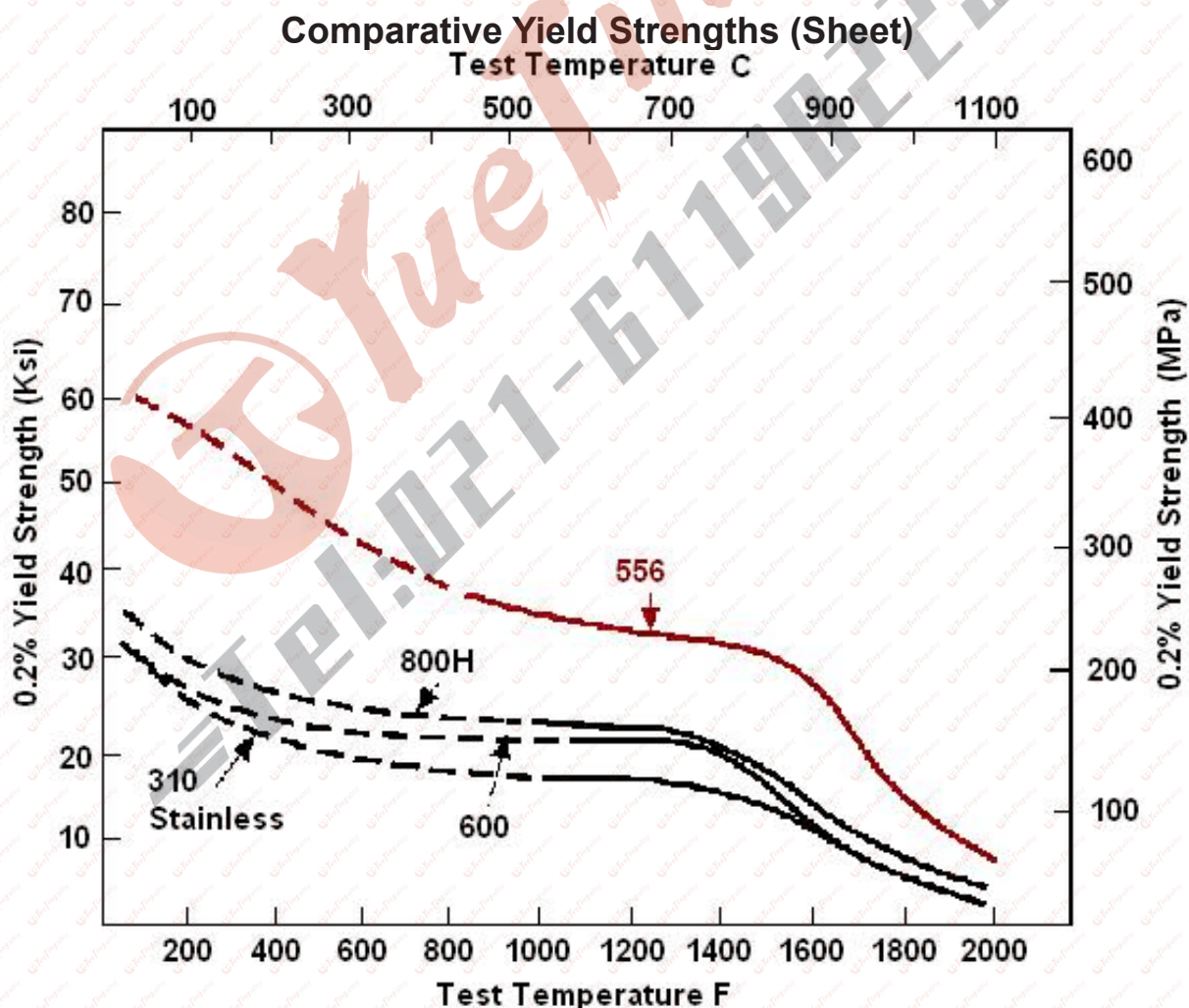
Cold-Rolled and Solution Annealed Sheet, 0.033 to 0.109 in. (0.8 to 2.8 mm) Thick*

Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	59.5	410	118.1	815	47.7
1000	538	34.9	240	93.4	645	54.4
1200	649	32.8	225	85.4	590	52.4
1400	760	32	220	68.5	470	49.1
1600	871	28.6	195	47.6	330	52.6
1800	982	15.5	105	28	195	63.3
2000	1093	8	55	14.8	100	55.4

* Based upon 10 or more Tests per condition

RT= Room Temperature

Elevated temperature tensile tests for sheet were performed with a strain rate that is no longer standard. These results were from tests with a strain rate of 0.005 in./in./minute through yield and a crosshead speed of 0.5 in./minute for every inch of reduced test section from yield through failure. The current standard is to use a strain rate of 0.005 in./in./minute through yield and a crosshead speed of 0.05 in./minute for every inch of reduced test section from yield through failure.



Tensile Properties Continued

Hot-Rolled and Solution-annealed Plate

Test Temperature		Ultimate Tensile Strength		0.2% Yield Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
RT	RT	114.6	790	54.1	373	51.3
1000	538	95.6	659	33.7	232	58.2
1200	649	87.2	601	33.2	229	55.1
1400	760	63.1	435	34	234	57.4
1600	871	37.4	258	26.9	185	87.9
1800	982	20.3	140	13.2	91	96.2
2000	1093	11.2	77	6.7	46	90.3

RT= Room Temperature

Creep and Rupture Properties

Solution Annealed Sheet, Plate and Bar

Test Temperature		Creep	Approximate Initial Stress to Produce Specified Creep in:								
°F	°C		%	10 h		100 h		1000 h		10,000 h*	
				ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
1200	650	0.5	44	305	32	220	24	165	-	-	
		1	49	340	35	240	25.5	175	18.5	130	
		Rupture	-	-	53	365	38	260	27.5	190	
1300	705	0.5	29	200	21	145	15	105	-	-	
		1	33	230	24	165	17.5	120	12.5	86	
		Rupture	52	360	37	255	26	180	17	115	
1400	760	0.5	19	130	13.5	93	9.4	65	-	-	
		1	22	150	16	110	11.5	79	8.5	59	
		Rupture	35	240	25	170	17.5	120	11.9	82	
1500	815	0.5	13	90	9	62	6.5	45	-	-	
		1	15	105	11	76	8.2	57	6	41	
		Rupture	25	170	17	115	11.8	81	7.6	52	
1600	870	0.5	8.9	61	6.4	44	4.6	32	-	-	
		1	10	69	7.5	52	5.5	38	4.1	28	
		Rupture	17	115	11.5	79	7.5	52	4.9	34	
1700	925	0.5	6.2	43	4.5	31	3.2	22	-	-	
		1	7.2	50	5	34	3.5	24	2.5	17	
		Rupture	12	83	7.6	52	4.8	33	3	21	
1800	980	0.5	4.4	30	3	21	2	14	-	-	
		1	5	34	3.4	23	2.3	16	1.6	11	
		Rupture	7.5	52	4.8	33	3	21	1.9	13	

Impact Properties

Alloy	V-Notch Impact Strength ¹ Room Temperature	
	ft.-lbs.	J
-		
800H	239 ²	324 ²
600	180	244
556®	177 ²	240 ²
188	143	194
S	140	190
625	81	110
X	54	73

1 Average of 4 or more tests

2 Samples did not break

Thermal Stability

HAYNES® 556® exhibits reasonable retained ductility after long term thermal exposure at intermediate temperatures. It does not exhibit significant sigma phase formation even after 16,000 hours exposure at 1000 to 1600°F (540 to 870°C). Principal phases precipitated from solid solution are carbides and carbonitrides.

Room-Temperature Tensile Properties of Bar Following Thermal Exposure*

Test Temperature		-	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	h	ksi	MPa	ksi	MPa	%
1200	650	0	62.5	430	113.4	780	46.5
		1000	59.7	410	120.5	830	36
		4000	57.4	395	121.2	835	33
		8000	59.8	410	127.3	880	29.4
1400	760	0	62.5	430	113.4	780	46.5
		1000	60.8	420	128.7	885	24.8
		4000	57.4	395	127.1	875	25.8
		8000	54.6	375	125.1	865	24.7
1600	870	0	62.5	430	113.4	780	46.5
		1000	52.3	360	112.9	780	32.8
		4000	42.8	295	111.5	770	29
		8000	43.9	305	108.1	745	29.5

* Average of three tests for each condition

Elevated-Temperature Tensile Properties of Bar Following 16,000-Hour Thermal Exposures*

Test Temperature		0.2% Yield Strength		Ultimate Tensile Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
1000	537	37.4	260	95.7	660	48
1200	648	37.8	260	88.8	610	23.4
1400	760	35.1	240	72.3	500	25.3
1600	871	21.9	150	42.1	290	29.5

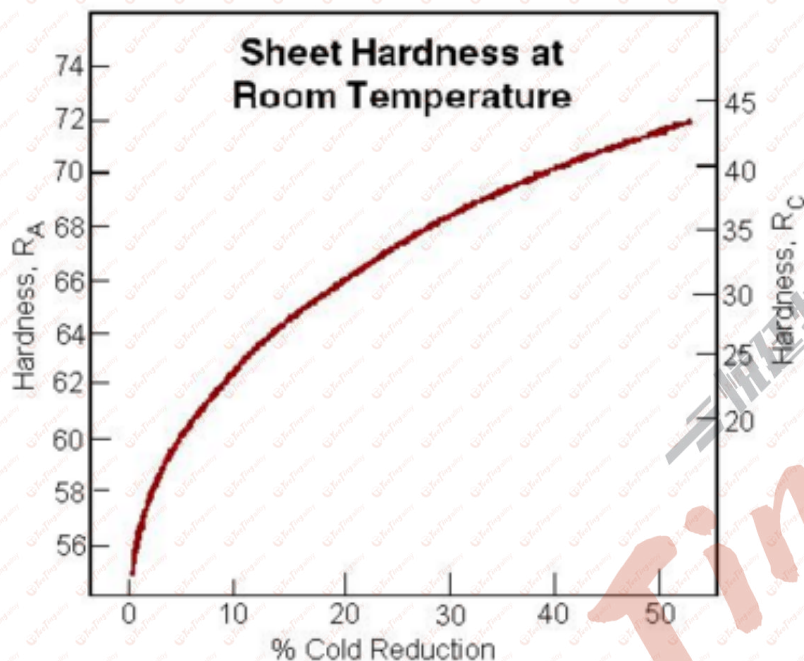
Room-Temperature Tensile Properties of Sheet Following 1000-Hour Thermal Exposures*

Exposure Temperature		Ultimate Tensile Strength		0.2% Yield Strength		Elongation
°F	°C	ksi	MPa	ksi	MPa	%
None	None	118.1	815	59.5	410	47.7
1200	648	118.4	815	53.4	370	37.9
1400	760	118.8	820	53.8	370	17
1600	871	111	765	46.6	320	20.4

Fabrication Characteristics

HAYNES® 556® alloy is normally final solution heat-treated at 2150°F (1175°C) for a time commensurate with section thickness. Solution heat-treating can be performed at temperatures as low as about 2125°F (1165°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 properties and structure. Please refer to the "Welding and Fabrication" brochure for additional information.

Typical Hardness Properties



Form	Hardness, HRB	Typical ASTM Grain Size
Sheet	91	4 - 6.5
Plate	92	3.5 - 6.5
Bar	89	3 - 5.5

All samples tested in solution-annealed condition.

HRB= Rockwell Hardness "B"

Fabrication Characteristics Continued

Effect of Cold Reduction upon Room-Temperature Tensile Properties*

Cold Reduction	Subsequent Anneal Temperature	0.2% Yield Strength		Ultimate Tensile Strength		Elongation
%		ksi	MPa	ksi	MPa	%
0	None	52.9	365	115	795	50.7
10		93.3	645	127.8	880	34.8
20		113.3	780	142.1	980	23.5
30		144.1	995	172.6	1190	12
40		155.8	1075	189.3	1305	10.1
50		169.7	1170	204.2	1410	8
0	1850°F (1010°C) for 5 min.	52.6	365	114.7	790	44.8
10		76.9	530	121.6	840	34.3
20		88.8	610	127	875	30.3
30		92.7	639	135.2	930	26.6
40		80	550	133.3	920	30.6
50		83	570	135	930	31.7
0	1950°F (1065°C) for 5 min.	52.9	365	115.8	800	45.2
10		76.8	530	122.2	845	36.9
20		76.8	530	124.7	860	34.8
30		66	455	125.1	865	38.3
40		71.4	490	128.1	885	36.7
50		77.9	535	131	905	33.4
0	2050°F (1121°C) for 5 min.	54.3	375	117	805	47
10		55.3	380	117.4	810	48
20		58.4	405	120.1	830	45.4
30		63.5	440	123.6	850	43
40		66.9	460	124.7	860	42.4
50		70.8	485	126.6	875	35

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

Typical Microstructure (ASTM 5 grain size) Annealed at 2150°F (1175°C)



Etchant: 95ml
HCL plus 5gm oxalic acid, 4 volts

Welding

HAYNES® 556® alloy is readily welded by Gas Tungsten Arc (GTAW), Gas Metal Arc (GMAW), Shielded Metal Arc (SMAW), and resistance 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. Contact with copper or copper-bearing materials in the joint area should be avoided. 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 556® alloy. For shielded metal-arc welding, MULTIMET® electrodes (AMS 5795) are suggested. For dissimilar metal joining of 556® alloy to nickel- or cobalt-base materials, 556® filler metal will generally be a good selection, but HASTELLOY® S alloy (AMS 5838) or HASTELLOY® W alloy (AMS 5786, 5787) welding products may be used. For dissimilar welding to iron-base materials, 556® filler metal is recommended. Please refer to 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 556® alloy. For further information, please refer to the “Welding and Joining Guidelines” brochure.

Welding Continued

Typical Tensile Properties

Condition	Test Temperature		Ultimate Tensile Strength		0.2% Yield Strength		Elongation
	°F	°C	ksi	MPa	ksi	MPa	
Transverse Tensile	RT	RT	120.6	832	63.6	439	42.8
	1000	540	95.6	659	41.1	283	50.3
	1200	650	84.8	585	38.3	264	47.6
	1400	760	63.1	435	34.1	235	44.8
All Weld Metal	RT	RT	107.3	739	67.3	464	43.1
	1200	650	71.4	492	44.6	308	39.4
	1400	760	55.2	381	42.4	292	55.2



Typical crack-free face and root bends for welded HAYNES® 556® alloy 0.5 inch (13 mm) plate and matching filler metal. Bend radius was 0.75 inch (19 mm).

Specifications and Codes

Specifications

HAYNES® 556® alloy (R30556)	
Sheet, Plate & Strip	AMS 5874 SB 435/B 435 P= 45
Billet, Rod & Bar	AMS 5877 SB 572/B 572 B 472 P= 45
Coated Electrodes	-
Bare Welding Rods & Wire	SFA 5.9/ A 5.9 (ER3556) AMS 5831 F= 6
Seamless Pipe & Tube	SB 622/B 622 P= 45
Welded Pipe & Tube	SB 619/B 619 SB 626/B 626 P= 45
Fittings	SB 366/B 366 P= 45
Forgings	AMS 5877
DIN	No. 1.4883 X10CrNiCoMoN 22 20 18
Others	-

Codes

HAYNES® 556® alloy (R30556)			
ASME	Section I	-	
	Section III	Class 1	-
		Class 2	-
		Class 3	-
	Section IV	HF-300.2	-
	Section VIII	Div. 1	1650°F (899°C) ¹
		Div. 2	800°F (427°C) ²
	Section XII	650°F (343°C) ³	
	B16.5	1500°F (816°C) ⁴	
	B16.34	1500°F (816°C) ⁴	
	B31.1	1200°F (649°C) ⁵	
	B31.3	-	

¹Approved material forms: Plate, Sheet, Bar, welded pipe/tube, seamless pipe/tube, Bolting

²Approved material forms: Bolting

³Approved material forms: Plate, Sheet, Bar, welded pipe/tube, seamless pipe/tube

⁴Approved material forms: Plate, Bar

⁵Approved material forms: Plate, Sheet, Bar, fittings, welded pipe/tube, seamless pipe/tube

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