# 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 %**

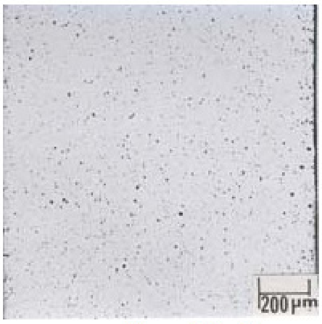
| | |
|---|---|
| **Iron:** | 31 Balance |
| **Nickel:** | 20 |
| **Cobalt:** | 18 |
| **Chromium:** | 22 |
| **Molybdenum:** | 3 |
| **Tungsten:** | 2.5 |
| **Tantalum:** | 0.6 |
| **Nitrogen:** | 0.2 |
| **Silicon:** | 0.4 |
| **Niobium:** | 0.3 max. |
| **Manganese:** | 1 |
| **Aluminum:** | 0.2 |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

# Sulfidation Resistance

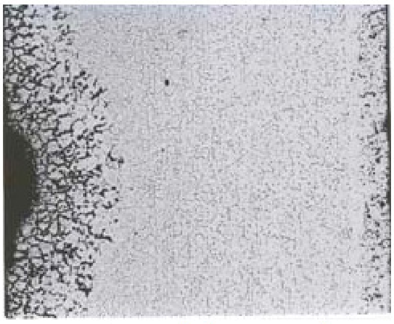
HAYNES® 556® alloy is second in resistance only to HAYNES® HR-160® alloy to the types of sulfur-bearing environments that are present in many high-temperature industrial processes. This is due partly to its comparatively low nickel content coupled with the important addition of cobalt, the high chromium 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%$H_2$+5%CO+1%$CO_2$+ 0.15%$H_2S$+0.1%$H_2O$ 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

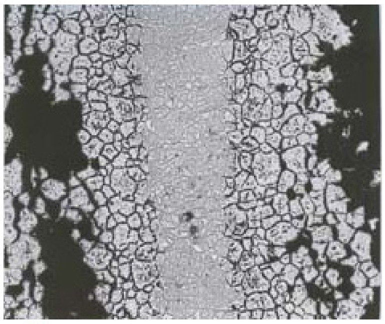
## Comparative Sulfidation Resistance at 1800°F (980°C) for 215 Hours (Width of Micros Indicates Original Sample Thickness)




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

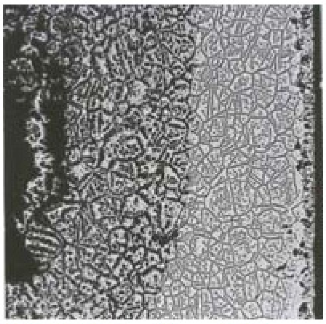


**Type 310 Stainless Steel**
Average Metal Affected =
7.4 Mils (190μm)/Side



**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

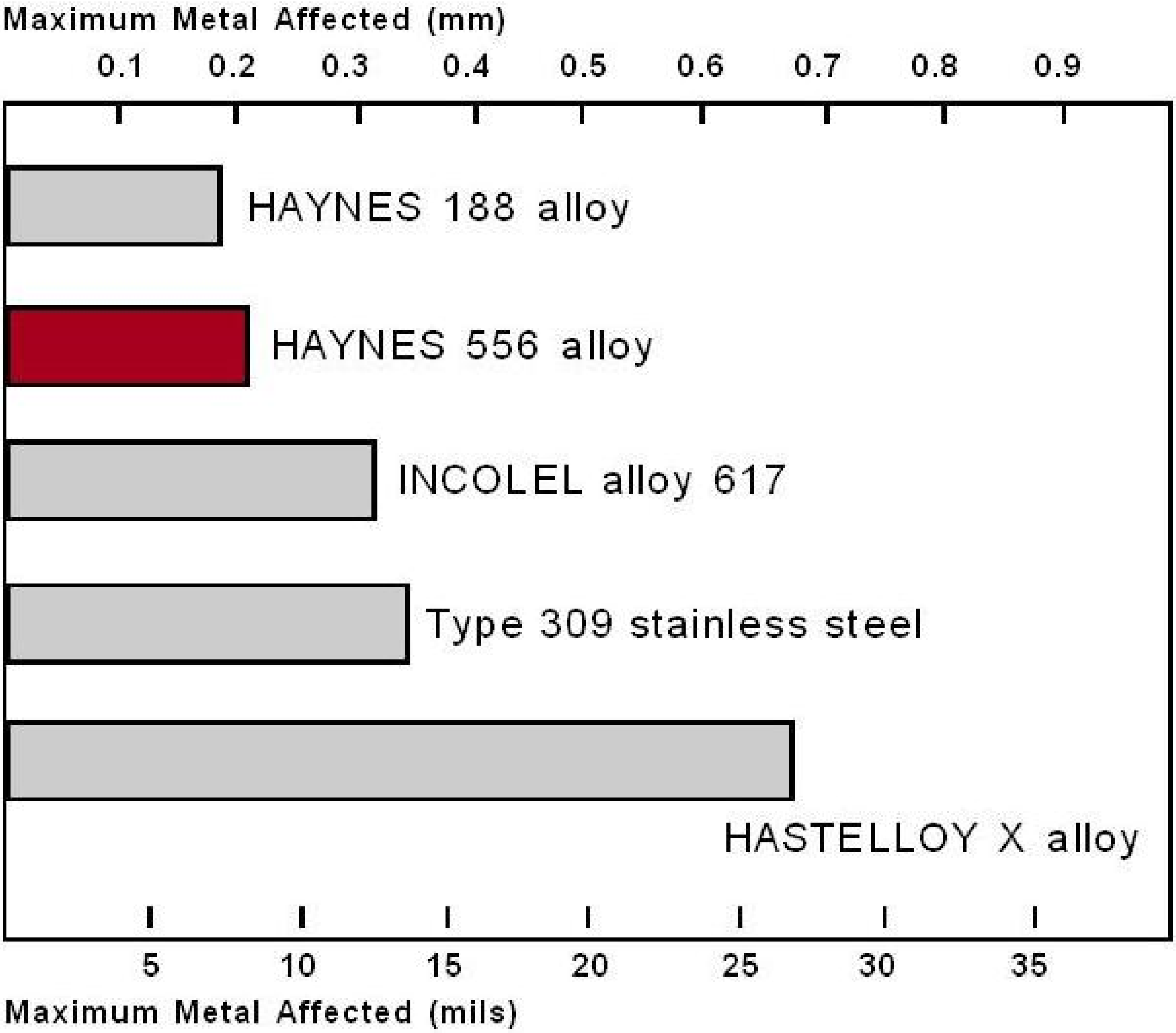
| Alloy | 1400°F (760°C) | | | | 1600°F (871°C) | | | |
|---|---|---|---|---|---|---|---|---|
| | Metal Loss | | Average Metal Affected** | | Metal Loss | | Average Metal Affected** | |
| - | mils | μm | mils | μm | mils | μm | mils | μm |
| **HR-160®** | 0.2 | 5 | 1.1 | 30 | 0.1 | 3 | 3.8 | 95 |
| **556®** | **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% $H_2$+5%CO+1% $CO_2$ +0.15%$H_2$ S+0.10%$H_2O$
**Metal Loss + Average Internal Penetration

# Sulfidation Resistance Continued

**Field Experience - Municipal Waste Incinerator**

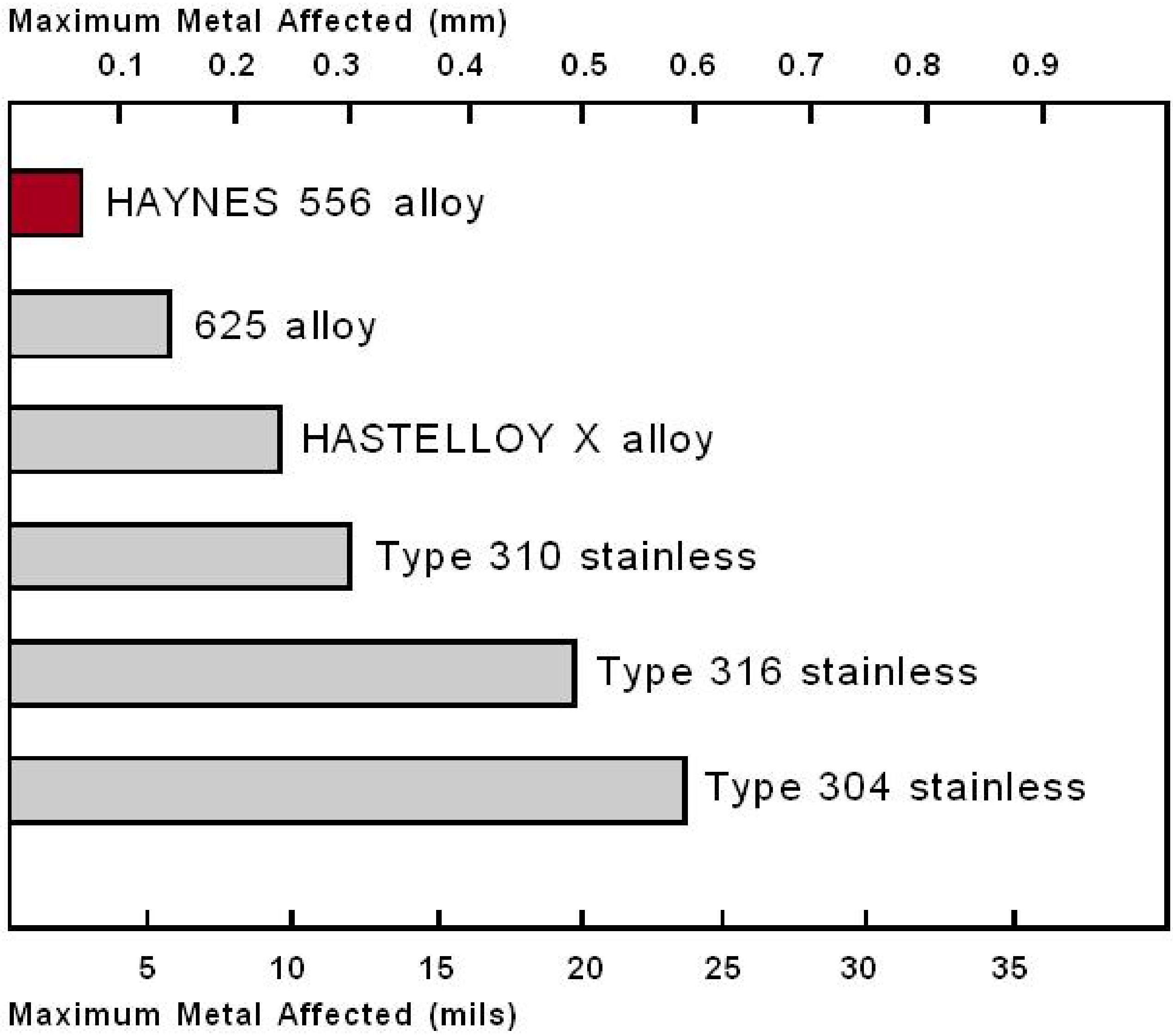
Samples were exposed for 950 hours in the superheater section of a municipal waste incinerator. Combustion gas temperatures were about 1475°F (800°C) with excursions to 1740°F (950°C). The mode of corrosion observed was oxidation/sulfidation, although alkali chloride compounds were known to be present.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



# 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.

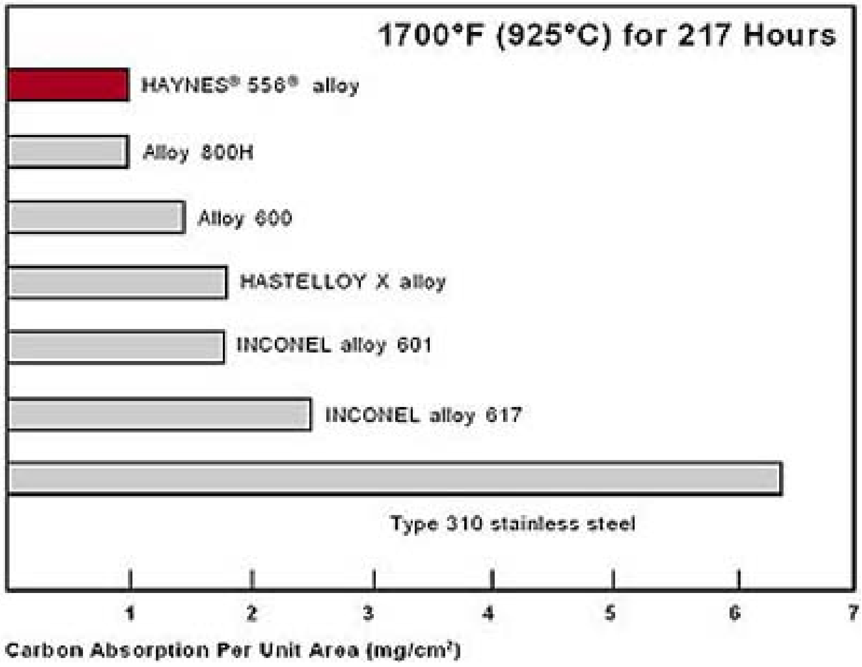


# Carburization Resistance Continued

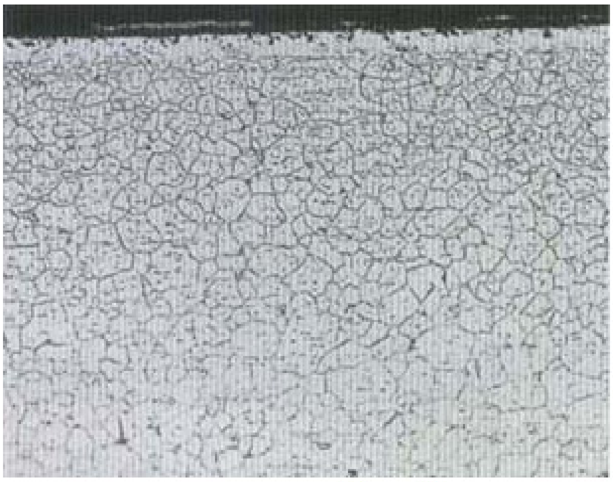
## Mix Gas Carburization Tests

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% $H_2$, 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% $H_2$, 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 x $10^{-22}$ atm at 1800°F (980°C).

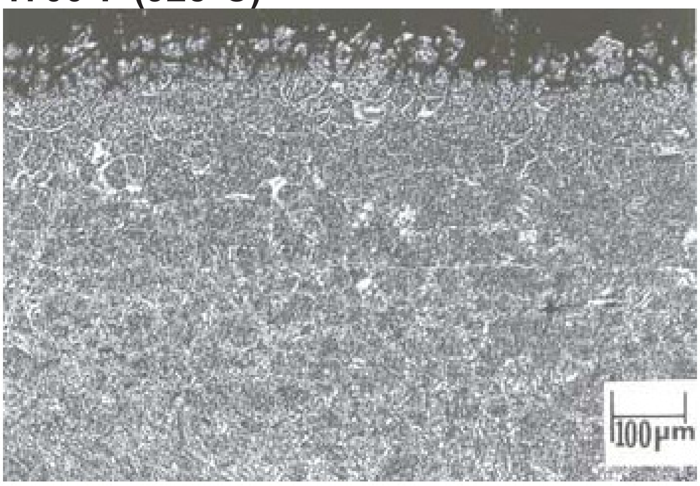
### Comparative 1700°F (925°C) Mix Gas Carburization Tests




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



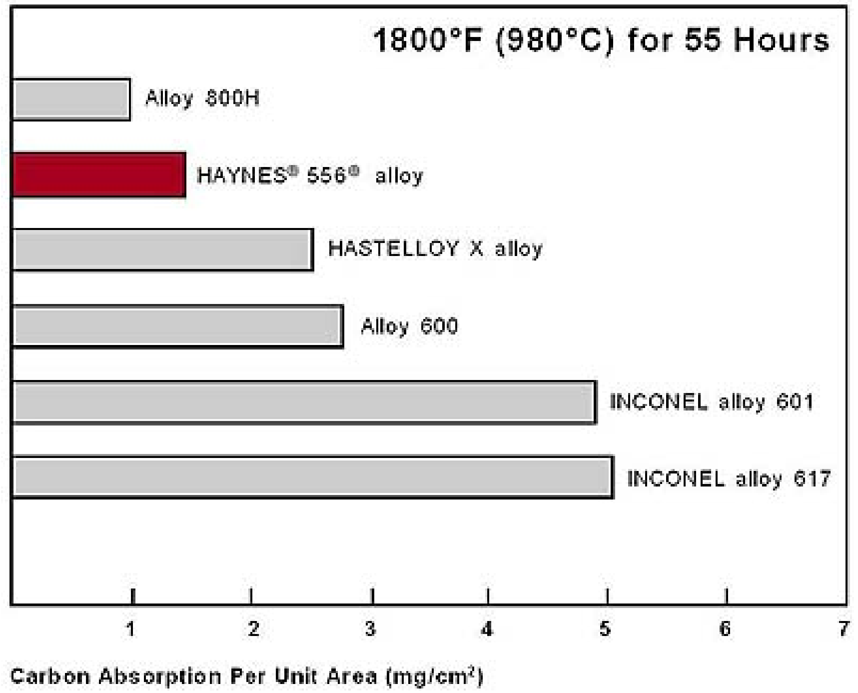
HAYNES® 556® alloy



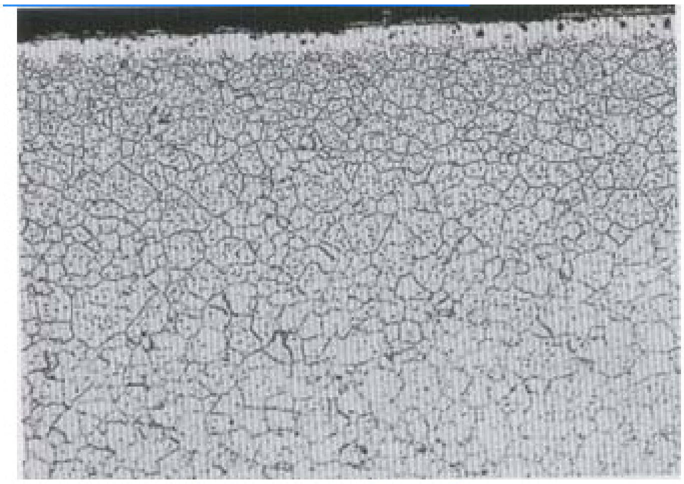

Type 310 Stainless Steel

# Carburization Resistance Continued

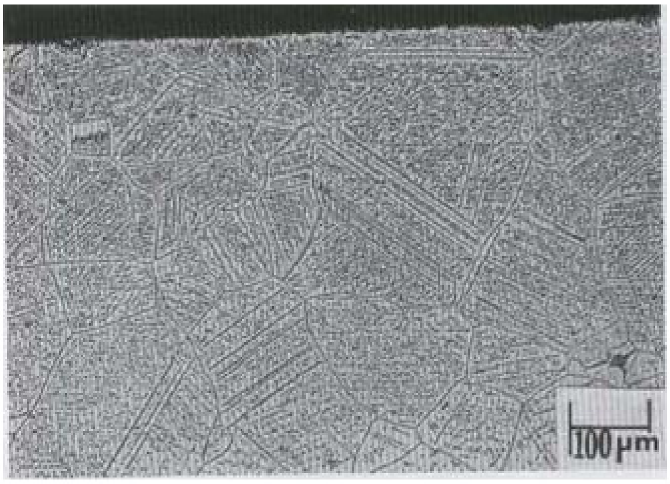
**Comparative 1800°F (980°C) Mix Gas Carburization Tests**




**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*

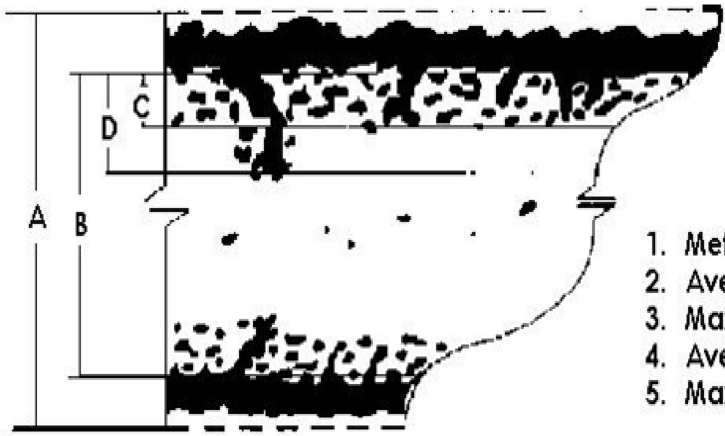
| Comparative Oxidation Resistance in Flowing Air*, 1008 Hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1800°F (980°C) | | | | 2000°F (1095°C) | | | |
| | Average Metal Affected** | | Metal Loss | | Average Metal Affected** | | Metal Loss | |
| Alloy | mils | µm | mils | µm | mils | 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

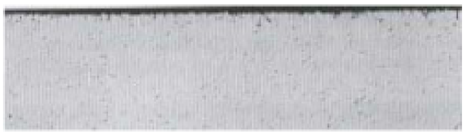



1. Metal Loss = (A - B)/2
2. Average Internal Penetration - C
3. Maximum Internal Penetration = D
4. Average Metal Affected = ((A - B)/2) + C
5. Maximum Metal Affected = ((A - B)/2) + D

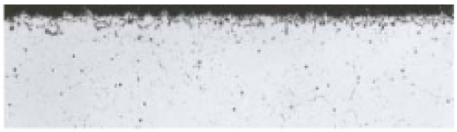
# Oxidation Resistance Continued

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

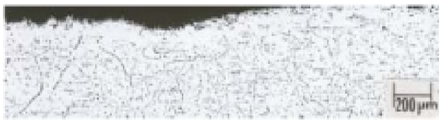
Microstructures shown are for coupons exposed for 1008 hours at 1800°F (980°C) in air flowing 7.0 feet/minute (212.0 cm/minute) past the samples. Samples were descaled by cathodically charging the coupons while they were immersed in a molten salt solution. The black area shown at the top of each picture 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 | - | - | - | - | - | - | - | - |

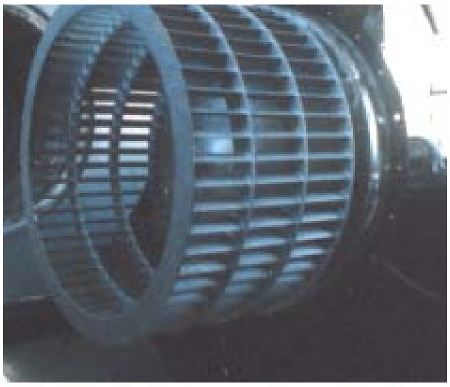
*Flowing air at a velocity of 7.0 ft/min (213.4 cm/min) past the samples. Samples cycled to room temperature once per month.

** 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

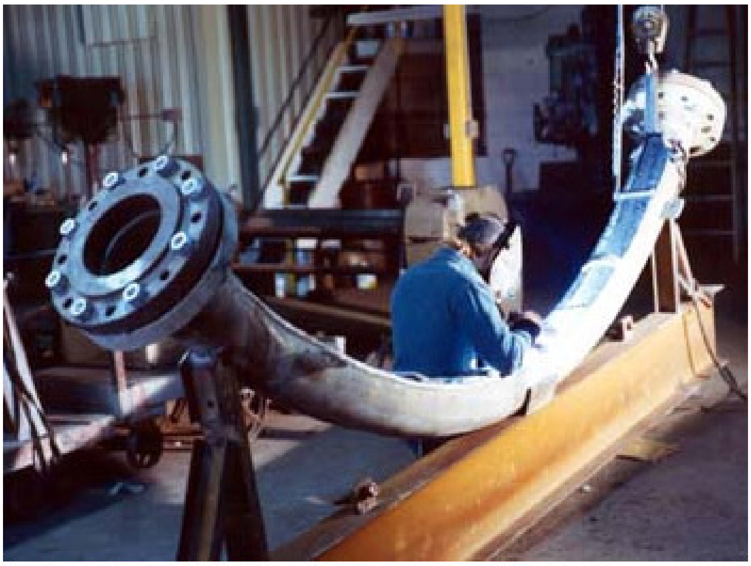
# Applications

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.



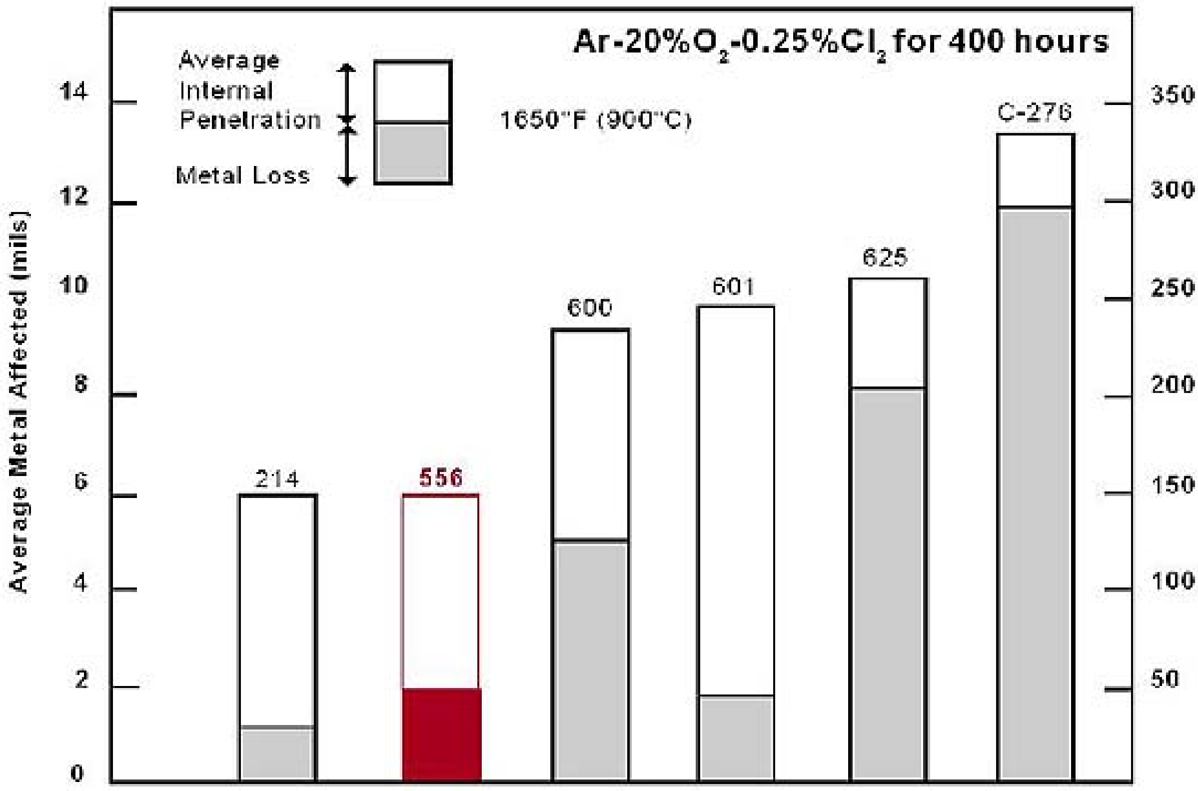
A deposit of HAYNES 556 alloy protects elbows in a piping system at a titanium dioxide plant. The elbows, coated with 556 alloy has lasted over hour times as long as those hardfaced with a cobalt-base alloy. The inside of the elbow is scoured by abrasive $TiO_2$ and corrosive $Cl_2$ at temperatures to 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%$O_2$+0.25% $Cl_2$. 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-$BaCl_2$ 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 |
| 188 | 28 | 0.7 |
| X | 38 | 1 |
| 556® | 42 | 1.1 |
| 304 SS | 74 | 1.9 |
| 310 SS | 79 | 2 |
| 600 | 94 | 2.4 |
| INCONEL® 601 | 115 | 2.9 |

## 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 |
| X | 3 | 75 |
| 556® | 6 | 150 |
| 214® | 8 | 205 |
| S | 9 | 230 |
| 188 | 9 | 230 |
| 800H | 11 | 280 |
| 304 SS | 15 | 380 |

## 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 |
| 556® | 1.6 | 41 |
| 25 | 2.3 | 58 |
| 188 | 2.5 | 64 |
| 1010 Carbon Steel | 9.2 | 234 |
| 446 SS | 9.3 | 236 |

*No internal attack noted for any of the alloys tested

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

**dissolved

# 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

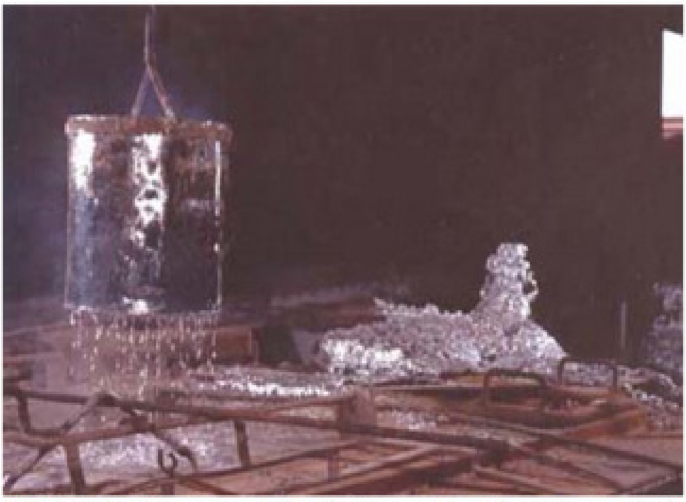
| Physical Property | British Units | | Metric Units | |
|---|---|---|---|---|
| Specific Heat | RT | 0.111 Btu/lb-°F | RT | 464 J/kg·°C |
| | 200°F | 0.113 Btu/lb-°F | 100°C | 475 J/kg·°C |
| | 400°F | 0.118 Btu/lb-°F | 200°C | 493 J/kg·°C |
| | 600°F | 0.122 Btu/lb-°F | 300°C | 508 J/kg·°C |
| | 800°F | 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 µin/in -°F | 25-100°C | 14.7 x $10^{-6}$m/m·°C |
| | 70-400°F | 8.2 µin/in -°F | 25-200°C | 14.9 x $10^{-6}$m/m·°C |
| | 70-600°F | 8.4 µin/in -°F | 25-300°C | 15.1 x $10^{-6}$m/m·°C |
| | 70-800°F | 8.6 µin/in -°F | 25-400°C | 15.4 x $10^{-6}$m/m·°C |
| | 70-1000°F | 8.8 µin/in -°F | 25-500°C | 15.7 x $10^{-6}$m/m·°C |
| | 70-1200°F | 9.0 µin/in -°F | 25-600°C | 16.1 x $10^{-6}$m/m·°C |
| | 70-1400°F | 9.2 µin/in -°F | 25-700°C | 16.4 x $10^{-6}$m/m·°C |
| | 70-1600°F | 9.4 µin/in -°F | 25-800°C | 16.7 x $10^{-6}$m/m·°C |
| | 70-1800°F | 9.5 µin/in -°F | 25-900°C | 17.0 x $10^{-6}$m/m·°C |
| | 70-2000°F | 9.6 µin/in -°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 Cotninued

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***

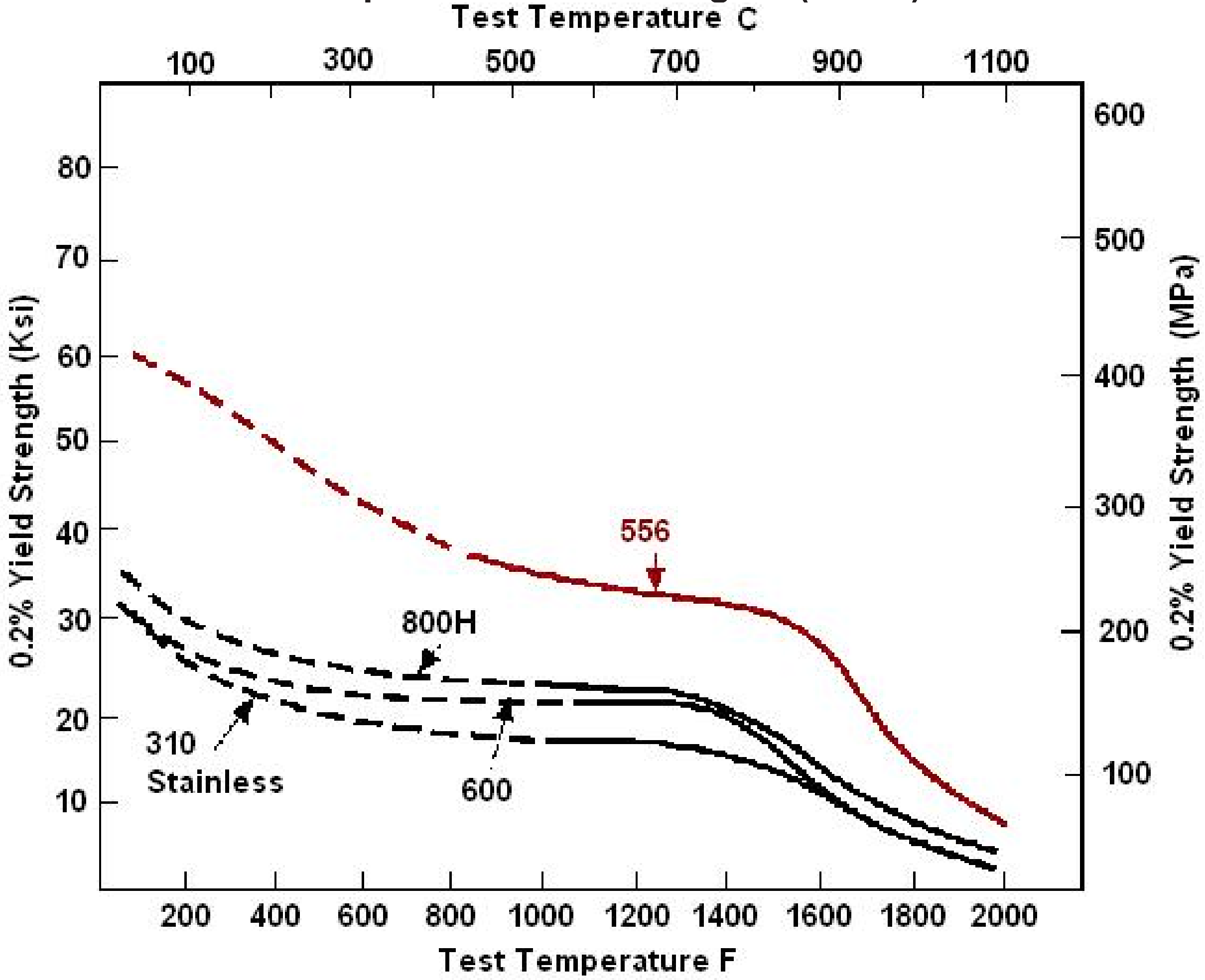
| Test Temperature | | 0.2% Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|
| °F | °C | ksi | MPa | ksi | MPa | % |
| RT | RT | 59.5 | 410 | 118.1 | 815 | 47.7 |
| 1000 | 538 | 34.9 | 240 | 93.4 | 645 | 54.4 |
| 1200 | 649 | 32.8 | 225 | 85.4 | 590 | 52.4 |
| 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 though yield and a crosshead speed of 0.05 in./minute for every inch of reduced test section from yield through failure.

**Comparative Yield Strengths (Sheet)**



# 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: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10 h | | 100 h | | 1000 h | | 10,000 h* | |
| °F | °C | % | 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 |

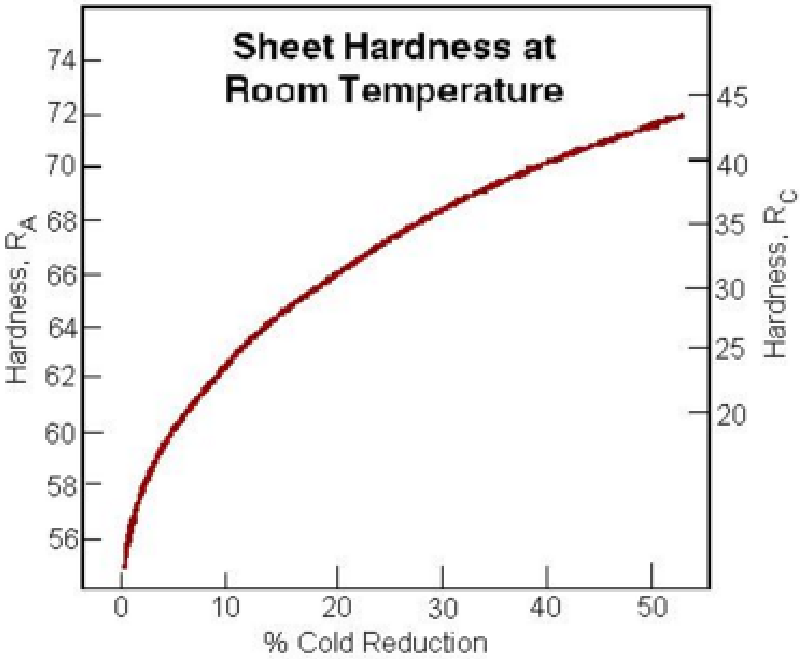
**Room-Temperature Tensile Properties of Sheet Following 1000-Hour Thermal Exposures***

| Exposure Temperature | | UltimateTensile 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"

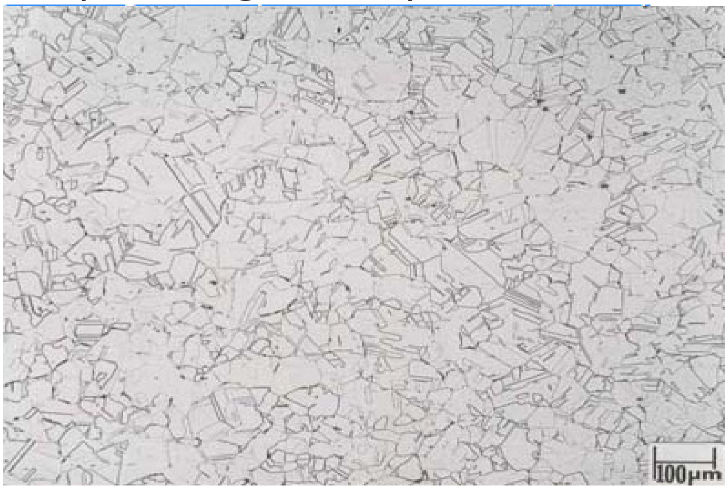
# Fabrication Characteristics Continued

**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 “Weldng and Joining Guidlines” 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<br>SB 435/B 435<br>P= 45 |
| **Billet, Rod & Bar** | AMS 5877<br>SB 572/B 572<br>B 472<br>P= 45 |
| **Coated Electrodes** | - |
| **Bare Welding Rods & Wire** | SFA 5.9/ A 5.9 (ER3556)<br>AMS 5831<br>F= 6 |
| **Seamless Pipe & Tube** | SB 622/B 622<br>P= 45 |
| **Welded Pipe & Tube** | SB 619/B 619<br>SB 626/B 626<br>P= 45 |
| **Fittings** | SB 366/B 366<br>P= 45 |
| **Forgings** | AMS 5877 |
| **DIN** | No. 1.4883<br>X10CrNiCoMoN<br>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 | - | |

[1]Approved material forms: Plate, Sheet, Bar, welded pipe/tube, seamless pipe/tube, Bolting
[2]Approved material forms: Bolting
[3]Approved material forms: Plate, Shee, Bar, welded pipe/tue, seamless pipe/tube
[4]Approved material forms: Plate, Bar
[5]Approved material forms: Plate, Sheet, Bar, fittings, welded pipe/tube, seamless pipe/tube