# HAYNES® 25 alloy

## Principle Features

**Excellent High-Temperature Strength and Good Oxidation Resistance**
HAYNES® 25 alloy (UNS R30605) is a cobalt-nickel- chromium-tungsten alloy that combines excellent high-temperature strength with good resistance to oxidizing environments up to 1800°F (980°C) for prolonged exposures, and excellent resistance to sulfidation. It can be fabricated and formed by conventional techniques, and has been used for cast components. Other attractive features include excellent resistance to metal galling.

**Applications**
HAYNES® 25 alloy combines properties which make it suitable for a number of component applications in the aerospace industry, including parts in established military and commercial gas turbine engines. In modern engines, it has largely been replaced by newer materials such as HAYNES® 188 alloy, and, most recently, 230® alloy, which possess improved properties. Another area of significant usage for 25 alloy is as a bearing material, for both balls and races.

## Nominal Composition

**Weight %**

| | |
|---|---|
| **Cobalt:** | 51 Balance |
| **Nickel:** | 10 |
| **Iron:** | 3 max. |
| **Chromium:** | 20 |
| **Molybdenum:** | 1 max. |
| **Tungsten:** | 15 |
| **Manganese:** | 1.5 |
| **Silicon:** | 0.4 max. |
| **Carbon:** | 0.1 |

# Creep and Stress Rupture Strength

HAYNES® 25 alloy is a solid-solution-strengthened material which possesses excellent high-temperature strength. It is particularly effective for very long-term applications at temperatures of 1200 to 1800°F (650 to 980°C). It is stronger than nickel-base solid-solution-strengthened alloys, and is the strongest of the cobalt-base materials which still have good fabrication characteristics.

**Solution-Annealed Sheet***

| Temperature | | Creep | Approximate Initial Stress to Produce Specified Creep in | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 10 h | | 100 h | | 1,000 h | |
| °F | °C | % | ksi | MPa | ksi | MPa | ksi | MPa |
| 1200 | 649 | 0.5 | 62 | 427 | 47.5 | 328 | 33.5** | 231** |
| | | 1 | 71 | 490 | 54 | 372 | 39.0** | 269** |
| | | R | 82 | 565 | 69 | 476 | 57 | 393 |
| 1300 | 704 | 0.5 | 43 | 296 | 30.0** | 207** | 21.0** | 145** |
| | | 1 | 49.5 | 341 | 35 | 241 | 23.2** | 160** |
| | | R | 64 | 441 | 50 | 345 | 38 | 262 |
| 1400 | 760 | 0.5 | 28 | 193 | 19.5 | 134 | 14.8** | 102** |
| | | 1 | 32 | 221 | 21.5 | 148 | 16.2** | 112** |
| | | R | 47.0** | 324** | 36 | 248 | 26 | 179 |
| 1500 | 816 | 0.5 | 18.5 | 128 | 14 | 97 | 10.2** | 70** |
| | | 1 | 20.2 | 139 | 15.5 | 107 | 12.3** | 85** |
| | | R | 34.0** | 234** | 24.7 | 170 | 18.1 | 125 |
| 1600 | 871 | 0.5 | 13.7 | 94 | 9.9 | 68 | 6.9** | 48** |
| | | 1 | 15.2 | 105 | 12 | 83 | 8.9** | 61** |
| | | R | 24.0** | 165** | 17.5 | 121 | 12 | 83 |
| 1700 | 927 | 0.5 | 9.7 | 67 | 6.8 | 47 | 4.5** | 31** |
| | | 1 | 12 | 83 | 8.8 | 61 | 5.6 | 39 |
| | | R | 17.3** | 119** | 11.8 | 81 | 7.2 | 50 |

*Based upon limited data
**Significant extrapolation
R= Rupture

# Creep and Stress Rupture Strength Continued

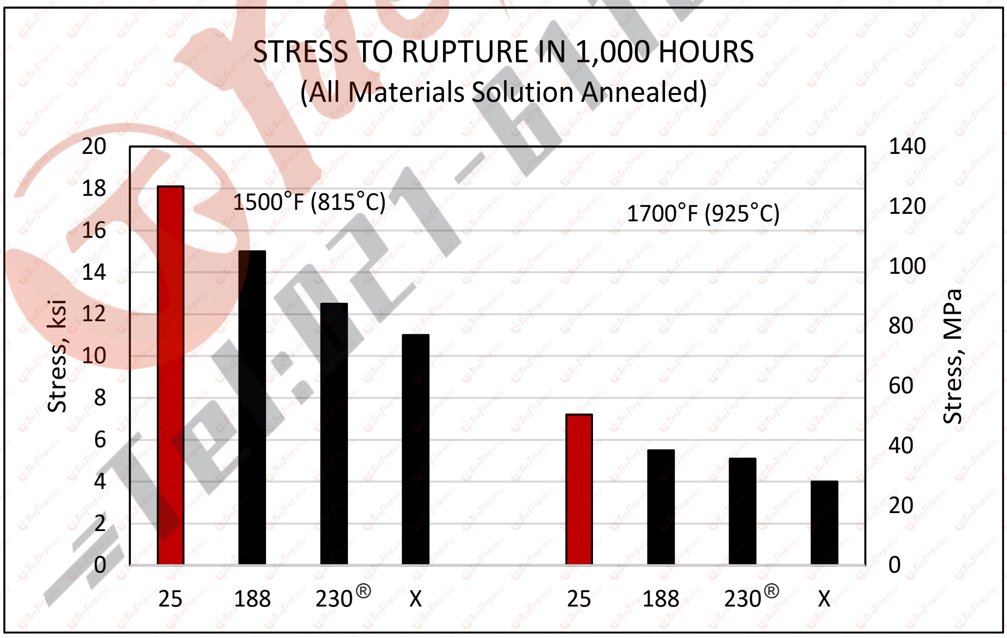
| Temperature | | Creep | Approximate Initial Stress to Produce Specified Creep in: | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 10 h | | 100 h | | 1,000 h | |
| °F | °C | % | ksi | Mpa | ksi | Mpa | ksi | Mpa |
| 1800 | 982 | 0.5 | 6.8 | 47 | 4.5 | 31 | 2.6 | 18 |
| | | 1 | 8.8 | 61 | 5.6 | 39 | 3 | 21 |
| | | R | 11.8** | 81** | 7.2 | 50 | 4 | 28 |
| 2000 | 1093 | 0.5 | 2.8 | 19 | 1.3 | 9 | - | - |
| | | 1 | 3.3 | 23 | 1.4 | 9.7 | - | - |
| | | R | 4.5 | 31 | 2 | 14 | - | - |

*Based upon limited data
**Significant extrapolation
R= Rupture

### Solution-Annealed Bar*

| Temperature | | Approximate Initial Stress to Produce Rupture in | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 h | | 100 h | | 1,000 h | |
| °F | °C | ksi | MPa | ksi | MPa | ksi | MPa |
| 1350 | 732 | 42.5 | 293 | 36.5 | 252 | 30.3 | 209 |
| 1400 | 760 | 39.2 | 270 | 31.5 | 217 | 24.1 | 166 |
| 1500 | 816 | 30.0 | 207 | 22.0 | 152 | 17.0 | 117 |
| 1600 | 871 | 23.0 | 159 | 16.5 | 114 | 12.0 | 83 |
| 1700 | 927 | 17.0 | 117 | 12.0 | 83 | 8.4 | 58 |
| 1800 | 982 | 11.5 | 79 | 7.5 | 52 | 5.0 | 34 |

### Comparative Rupture Strength, Sheet



# Tensile Properties

### Solution Heat-Treated Sheet*

| Test Temperature | | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|
| °F | °C | ksi | MPa | ksi | MPa | % |
| RT | RT | 69 | 476 | 144.5 | 996 | 54.7 |
| 1000 | 538 | 38.8 | 268 | 119 | 820 | 63.4 |
| 1200 | 649 | 37.2 | 256 | 119.3 | 823 | 54.2 |
| 1400 | 760 | 35.5 | 245 | 82.5 | 569 | 33.9 |
| 1600 | 871 | 33.5 | 231 | 46.3 | 319 | 97.8 |
| 1800 | 982 | 18.6 | 128 | 25.8 | 178 | 94.1 |
| 2000 | 1093 | 9.0 | 62 | 13.3 | 92 | 63.0 |

*Limited Data

### Solution Heat-Treated Plate

| Test Temperature | | 0.2% Offset Yield Strngth | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|
| °F | °C | ksi | MPa | ksi | MPa | % |
| RT | RT | 68.7 | 474 | 145.1 | 1000 | 58.8 |
| 1000 | 538 | 38.4 | 265 | 122.1 | 842 | 71 |
| 1200 | 649 | 33.4 | 230 | 123.5 | 852 | 64.3 |
| 1400 | 760 | 34.4 | 237 | 86 | 593 | 45.7 |
| 1600 | 871 | 32 | 221 | 48.3 | 333 | 104.7 |
| 1800 | 982 | 18.7 | 129 | 27.3 | 188 | 113.7 |
| 2000 | 1093 | 9.3 | 64 | 14.5 | 100 | 97.5 |

### Hot-Rolled and 2250°F (1230°C) Solution-Annealed Bar*

| Test Temperature | | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|
| °F | °C | ksi | MPa | ksi | MPa | % |
| RT | RT | 73 | 505 | 147 | 1015 | 60 |
| 1000 | 538 | 43 | 295 | 113 | 780 | 63 |
| 1200 | 649 | 43 | 295 | 105 | 725 | 49 |
| 1400 | 760 | 41 | 285 | 90 | 620 | 29 |
| 1600 | 871 | 34 | 235 | 54 | 370 | 29 |
| 1800 | 982 | 19 | 130 | 28 | 195 | 41 |

*Limited Data

RT- Room Temperature

*Elevated temperature tensile tests for bar 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.

# Hardness and Grain Size

| Form | Hardness, HRB | Typical ASTM Grain Size |
|---|---|---|
| Sheet | 97 | 3.5 - 5.5 |
| Plate | 99 | 3.5 - 5 |
| Bar | 98 | 3.5 - 5 |

All samples tested in solution-annealed condition

# Cold-Worked Properties

HAYNES® 25 alloy has excellent strength and hardness characteristics in the cold-worked condition. These high property levels are also evident at elevated temperature, making 25 alloy quite suitable for applications such as ball bearings and bearing races. A modest additional increase in hardness and strength can be achieved through aging of the cold-worked material.

**Typical Tensile Properties, Cold-Worked Sheet***

| Cold Reduction | Test Temperature | | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|---|
| - | °F | °C | ksi | MPa | ksi | MPa | % |
| 10 | 70 | 20 | 105 | 725 | 155 | 1070 | 41 |
| | 100 | 540 | 78 | 540 | 114 | 785 | 48 |
| | 1200 | 650 | 80 | 550 | 115 | 795 | 37 |
| | 1400 | 760 | 67 | 460 | 87 | 600 | 8 |
| | 1600 | 870 | 47 | 325 | 62 | 425 | 13 |
| | 1800 | 980 | 27 | 185 | 39 | 270 | 15 |
| 15 | 70 | 20 | 124 | 855 | 166 | 1145 | 30 |
| | 1000 | 540 | 107 | 740 | 134 | 925 | 29 |
| | 1200 | 650 | 111 | 765 | 129 | 890 | 15 |
| | 1400 | 760 | 86 | 595 | 104 | 715 | 5 |
| | 1600 | 870 | 52 | 360 | 70 | 485 | 9 |
| | 1800 | 980 | 30 | 205 | 40 | 275 | 5 |
| 20 | 70 | 20 | 141 | 970 | 183 | 1260 | 19 |
| | 1000 | 540 | 133 | 915 | 156 | 1075 | 18 |
| | 1200 | 650 | 120 | 825 | 137 | 945 | 2 |
| | 1400 | 760 | 96 | 660 | 107 | 740 | 3 |
| | 1800 | 980 | 30 | 205 | 41 | 285 | 4 |

*Limited data for cold-rolled 0.050-inch (1.3 mm) thick sheet

# Cold-Worked Properties Continued

**Typical Tensile Properties, Cold-Worked and Aged Sheet***

| Condition | Test Temperature | | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|---|
| - | °F | °C | ksi | MPa | ksi | MPa | % |
| 15% CW + Age A | 70 | 20 | 136 | 940 | 168 | 1160 | 31 |
| | 1200 | 650 | 104 | 715 | 128 | 885 | 23 |
| 20% CW + Age A | 70 | 20 | 152 | 1050 | 181 | 1250 | 17 |
| | 1000 | 540 | 129 | 890 | 151 | 1040 | 19 |
| | 1200 | 650 | 128 | 885 | 144 | 995 | 8 |
| | 1400 | 760 | 97 | 670 | 108 | 745 | 2 |
| | 1600 | 870 | 59 | 405 | 74 | 510 | 6 |
| | 1800 | 980 | 33 | 230 | 43 | 295 | 5 |
| 20% CW + Age B | 70 | 20 | 162 | 1115 | 191 | 1315 | 16 |
| | 600 | 315 | 132 | 910 | 165 | 1140 | 28 |
| | 1000 | 540 | 124 | 855 | 149 | 1025 | 23 |
| | 1200 | 650 | 119 | 820 | 140 | 965 | 13 |
| | 1400 | 760 | 92 | 635 | 116 | 800 | 7 |
| | 1600 | 870 | 50 | 345 | 71 | 490 | 9 |
| | 1800 | 980 | 31 | 215 | 42 | 290 | 12 |

*Limited data for cold-rolled 0.050-inch (1.3 mm) thick sheet.
Age A = 700°F (370°C)/1 hour
Age B = 1100°F (595°C)/2 hours

**Typical Hardness at 70°F (20°C), Cold-Worked and Aged Sheet***

| Cold-Work | Hardness Rockwell C, After Indicated Level of Cold Work and Subsequent Aging Treatment | | |
|---|---|---|---|
| | - | 900°F (480°C) | 1100°F (595°C) |
| % | None | 5 h | 5 h |
| None | 24 | 25 | 25 |
| 5 | 31 | 33 | 31 |
| 10 | 37 | 39 | 39 |
| 15 | 40 | 44 | 43 |
| 20 | 44 | 44 | 47 |

*Limited data for cold-rolled 0.070-inch (1.8 mm) thick sheet.

# Impact Strength

**Impact Strength Properties, Plate**

| Test Temperature | | Typical Charpy V-Notch Impact Resistance | |
|---|---|---|---|
| °F | °C | ft.-lbs. | J |
| -321 | -196 | 109 | 148 |
| -216 | -138 | 134 | 182 |
| -108 | -78 | 156 | 212 |
| -20 | -29 | 179 | 243 |
| RT | RT | 193 | 262 |
| 500 | 260 | 219 | 297 |
| 1000 | 540 | 201 | 273 |
| 1200 | 650 | 170 | 230 |
| 1400 | 760 | 143 | 194 |
| 1600 | 870 | 120 | 163 |
| 1800 | 980 | 106 | 144 |

# Thermal Stability

When exposed for prolonged periods at intermediate temperatures, HAYNES® 25 alloy exhibits a loss of room temperature ductility in much the same fashion as some other solid-solution-strengthened superalloys,such as HASTELLOY® X alloy or alloy 625. This behavior occurs as a consequence of the precipitation of deleterious phases. In the case of a 25 alloy, the phase in question is $Co_2W$ laves phase. HAYNES® 188 alloy is significantly better in this regard than 25 alloy; however, for applications where thermal stability is important, 230® alloy is an even better selection.

**Room-Temperature Properties of Sheet After Thermal Exposure***

| Exposure Temperature | | Exposure Time | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|---|
| °F | °C | h | ksi | MPa | ksi | MPa | % |
| None | | 0 | 66.8 | 460 | 135 | 930 | 48.7 |
| 1200 | 650 | 500 | 70.3 | 485 | 123.6 | 850 | 39.2 |
| | | 1000 | 92.3 | 635 | 140 | 965 | 24.8 |
| | | 2500 | 95.1 | 655 | 130.7 | 900 | 12 |
| 1400 | 760 | 100 | 68.9 | 475 | 115.3 | 795 | 18.1 |
| 1600 | 870 | 100 | 72.1 | 495 | 113.6 | 785 | 9.1 |
| | | 500 | 77.3 | 535 | 126.1 | 870 | 3.5 |
| | | 1000 | 81.7 | 565 | 142 | 980 | 5 |

*Composite of multiple sheet lot tests

# Physical Properties

| Physical Property | British Units | | Metric Units | |
|---|---|---|---|---|
| **Density** | RT | 0.327 lb/in$^3$ | RT | 9.07 g/cm$^3$ |
| **Melting Range** | 2425-2570°F | - | 1330-1410°C | - |
| **Electrical Resistivity** | RT | 34.9 µohm-in | RT | 88.6 µohm-cm |
| | 200°F | 35.9 µohm-in | 100°C | 91.8 µohm-cm |
| | 400°F | 37.6 µohm-in | 200°C | 95.6 µohm-cm |
| | 600°F | 38.5 µohm-in | 300 °C | 97.6 µohm-cm |
| | 800°F | 39.1 µohm-in | 400 °C | 98.5 µohm-cm |
| | 1000°F | 40.4 µohm-in | 500 °C | 100.8 µohm-cm |
| | 1200°F | 41.8 µohm-in | 600 °C | 104.3 µohm-cm |
| | 1400°F | 42.3 µohm-in | 700 °C | 106.6 µohm-cm |
| | 1600°F | 40.6 µohm-in | 800 °C | 107.8 µohm-cm |
| | 1800°F | 37.7 µohm-in | 900 °C | 101.1 µohm-cm |
| | - | - | 1000 °C | 95.0 µohm-cm |
| **Thermal Diffusivity** | 70°F | 4.4 x 10$^{-3}$ in$^2$/sec | RT | 28.3 x 10$^{-3}$cm$^2$/sec |
| | 125°F | 4.6 x 10$^{-3}$ in$^2$/sec | 100°C | 30.1 x 10$^{-3}$cm$^2$/sec |
| | 200°F | 4.8 x 10$^{-3}$ in$^2$/sec | 200°C | 32.7 x 10$^{-3}$cm$^2$/sec |
| | 400°F | 5.5 x 10$^{-3}$ in$^2$/sec | 300°C | 35.6 x 10$^{-3}$cm$^2$/sec |
| | 600°F | 6.0 x 10$^{-3}$ in$^2$/sec | 400°C | 41.2 x 10$^{-3}$cm$^2$/sec |
| | 800°F | 6.5 x 10$^{-3}$ in$^2$/sec | 500°C | 43.5 x 10$^{-3}$cm$^2$/sec |
| | 1000°F | 6.9 x 10$^{-3}$ in$^2$/sec | 600°C | 45.5 x 10$^{-3}$cm$^2$/sec |
| | 1200°F | 7.3 x 10$^{-3}$ in$^2$/sec | 700°C | 47.6 x 10$^{-3}$cm$^2$/sec |
| | 1400°F | 7.6 x 10$^{-3}$ in$^2$/sec | 800°C | 49.6 x 10$^{-3}$cm$^2$/sec |
| | 1600°F | 7.7 x 10$^{-3}$ in$^2$/sec | 900°C | 48.7 x 10$^{-3}$cm$^2$/sec |
| | 1800°F | 7.9 x 10$^{-3}$ in$^2$/sec | 1000°C | 51.6 x 10$^{-3}$cm$^2$/sec |
| | 2000°F | 8.3 x 10$^{-3}$ in$^2$/sec | - | - |
| **Thermal Conductivity** | 70°F | 72 Btu-in/ft$^2$-h-°F | 25°C | 10.5 W/m-°C |
| | 125°F | 77 Btu-in/ft$^2$-h-°F | 100°C | 12.0 W/m-°C |
| | 200°F | 83 Btu-in/ft$^2$-h-°F | 200°C | 14.0 W/m-°C |
| | 400°F | 99 Btu-in/ft$^2$-h-°F | 300°C | 15.9 W/m-°C |
| | 600°F | 114 Btu-in/ft$^2$-h-°F | 400°C | 17.7 W/m-°C |
| | 800°F | 127 Btu-in/ft$^2$-h-°F | 500°C | 19.5 W/m-°C |
| | 1000°F | 140 Btu-in/ft$^2$-h-°F | 600°C | 21.2 W/m-°C |
| | 1200°F | 152 Btu-in/ft$^2$-h-°F | 700°C | 22.9 W/m-°C |
| | 1400°F | 165 Btu-in/ft$^2$-h-°F | 800°C | 24.5 W/m-°C |
| | 1600°F | 178 Btu-in/ft$^2$-h-°F | 900°C | 26.0 W/m-°C |
| | 1800°F | 191 Btu-in/ft$^2$-h-°F | 1000°C | 27.5 W/m-°C |
| | 2000°F | 201 Btu-in/ft$^2$-h-°F | - | - |

RT- Room Temperature

# Physical Properties Continued

| Physical Property | British Units | | Metric Units | |
|---|---|---|---|---|
| Specific Heat | 70°F | 0.096 Btu/lb.-°F | 25°C | 403 J/kg-°C |
| | 125 °F | 0.098 Btu/lb.-°F | 100 °C | 424 J/kg-°C |
| | 200 °F | 0.101 Btu/lb.-°F | 200 °C | 445 J/kg-°C |
| | 400 °F | 0.106 Btu/lb.-°F | 300 °C | 455 J/kg-°C |
| | 600°F | 0.111 Btu/lb.-°F | 400 °C | 462 J/kg-°C |
| | 800 °F | 0.116 Btu/lb.-°F | 500 °C | 495 J/kg-°C |
| | 1000 °F | 0.119 Btu/lb.-°F | 600 °C | 508 J/kg-°C |
| | 1200 °F | 0.123 Btu/lb.-°F | 700 °C | 582 J/kg-°C |
| | 1400 °F | 0.128 Btu/lb.-°F | 800 °C | 592 J/kg-°C |
| | 1600 °F | 0.137 Btu/lb.-°F | 900 °C | 596 J/kg-°C |
| | 1800 °F | 0.143 Btu/lb.-°F | 1000 °C | 598 J/kg-°C |
| | 2000 °F | 0.142 Btu/lb.-°F | - | - |
| Mean Coefficient of Thermal Expansion | 70 - 200 °F | 7.1 µin/in.-°F | 25 - 100 °C | 12.8 µm/m-°C |
| | 70 - 400 °F | 7.3 µin/in.-°F | 25 - 200 °C | 13.1 µm/m-°C |
| | 70 - 600 °F | 7.5 µin/in.-°F | 25 - 300 °C | 13.3 µm/m-°C |
| | 70 - 800 °F | 7.7 µin/in.-°F | 25 - 400 °C | 13.7 µm/m-°C |
| | 70 - 1000 °F | 7.9 µin/in.-°F | 25 - 500 °C | 14.0 µm/m-°C |
| | 70 - 1200 °F | 8.2 µin/in.-°F | 25 - 600 °C | 14.6 µm/m-°C |
| | 70 - 1400 °F | 8.6 µin/in.-°F | 25 - 700 °C | 15.1 µm/m-°C |
| | 70 - 1600 °F | 8.9 µin/in.-°F | 25 - 800 °C | 15.8 µm/m-°C |
| | 70 - 1800 °F | 9.2 µin/in.-°F | 25 - 900 °C | 16.2 µm/m-°C |
| | 70 - 2000 °F | 9.5 µin/in.-°F | 25 - 1000 °C | 16.7 µm/m-°C |
| Dynamic Modulus of Elasticity | RT | $32.6 \times 10^6$ psi | RT | 225 GPa |
| | 200°F | $32.3 \times 10^6$ psi | 100°C | 222 GPa |
| | 400°F | $31.0 \times 10^6$ psi | 200°C | 214 GPa |
| | 600°F | $29.4 \times 10^6$ psi | 300°C | 204 GPa |
| | 800°F | $28.3 \times 10^6$ psi | 400°C | 197 GPa |
| | 1000°F | $26.9 \times 10^6$ psi | 500°C | 188 GPa |
| | 1200°F | $25.8 \times 10^6$ psi | 600°C | 181 GPa |
| | 1400°F | $24.3 \times 10^6$ psi | 700°C | 174 GPa |
| | 1600°F | $22.8 \times 10^6$ psi | 800°C | 163 GPa |
| | 1800°F | $21.4 \times 10^6$ psi | 900°C | 154 GPa |
| | - | - | 1000°C | 146 GPa |

RT- Room Temperature

# Wear Resistance

HAYNES 25 alloy exhibits excellent resistance to metal galling and cavitation. Metal-to-Metal Galling results shown below were generated for standard matching material room-temperature pin on disc tests. Wear depths are given as a function of applied load. Cavitation tests were performed in accordance with ASTM G 32 water at 16°C, with a frequency of 20 kHz and an amplitude of 0.05 mm. The results of the wear tests indicate that 25 alloy is superior in galling and cavitation resistance to many materials, and is surpassed only by ULTIMET® alloy and HAYNES 6B alloy. Both of these materials were specifically designed to have excellent wear resistance.

| Alloy | Galling - Degree of Damage for Various Applied Loads | | | | | |
|---|---|---|---|---|---|---|
| | 3,000 lbs. (1,365 kg) | | 6,000 lbs. (2,725 kg) | | 9,000 lbs. (4,090 kg) | |
| - | mils | µm | mils | µm | mils | µm |
| **6B** | 0.02 | 0.6 | 0.03 | 0.7 | 0.02 | 0.5 |
| **ULTIMET®** | 0.11 | 2.9 | 0.11 | 2.7 | 0.08 | 2 |
| **25** | **0.23** | **5.9** | **0.17** | **4.2** | **0.17** | **4.2** |
| **188** | 1.54 | 39.2 | 3.83 | 97.3 | 3.65 | 92.6 |
| **HR-160®** | 1.73 | 43.9 | 4.33 | 109.9 | 3.81 | 96.8 |
| **214®** | 2.32 | 59 | 3.96 | 100.5 | 5.55 | 141 |
| **556®** | 3.72 | 94.4 | 5.02 | 127.6 | 5.48 | 139.3 |
| **230®** | 4.44 | 112.7 | 7.71 | 195.8 | 8.48 | 215.5 |
| **HR-120®** | 6.15 | 156.2 | 7.05 | 179 | 10.01 | 254.2 |

| Alloy | Cavitation - Mean Depth of Erosion | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 24 h | | 48 h | | 72 h | | 96 h | |
| | mils | µm | mils | µm | mils | µm | mils | µm |
| **ULTIMET®** | 0.3 | 6.8 | 0.9 | 22.9 | 1.6 | 40.2 | 2.3 | 57.4 |
| **6B** | 0.3 | 7.7 | 0.9 | 22.3 | 1.4 | 34.8 | 1.9 | 48 |
| **25** | **1** | **24.4** | **2.1** | **53.6** | **3.4** | **85.6** | **4.5** | **115.1** |
| **625** | 3.1 | 80 | 7 | 176.6 | 10.2 | 259.2 | Not tested | Not Tested |
| **556®** | 3.3 | 83.8 | 6.9 | 175.8 | 9.6 | 244.3 | 11.4 | 289.8 |
| **230®** | 3.8 | 97.6> | 7.5 | 190.1 | 9.9 | 251.8 | 11.9 | 301.7 |

Tested in accordance with ASTM G 32 water at 16ºC, with a frequenct of 20 kHz and an amplitude of 0.05 mm

# High-Temperature Hardness

The following are results from standard vacuum furnace hot hardness tests. Values are given in originally measured DPH (Vickers) units and conversions to Rockwell C/B scale.

| | Vickers Diamond Pyramid Hardness (Rockwell C/B Hardness) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 70°F (20°C) | | 800°F (425°C) | | 1000°F (540°C) | | 1200°F (650°C) | | 1400°F (760°C) | |
| Solution Treated | 251 | 22 HRC | 171 | 87 HRC | 160 | 83 HRB | 150 | 80 HRB | 134 | 74 HRB |
| 15% Cold Work | 348 | 35 HRC | 254 | 23 HRC | 234 | 97 HRB | 218 | 95 HRB | - | - |
| 20% Cold Work | 401 | 41 HRC | 318 | 32 HRC | 284 | 27 HRC | 268 | 25 HRC | - | - |
| 25% Cold Work | 482 | 48 HRC | 318 | 32 HRC | 200 | 30 HRC | 286 | 28 HRC | - | - |

HRB = Hardness Rockwell “B”.
HRC = Hardness Rockwell “C”.

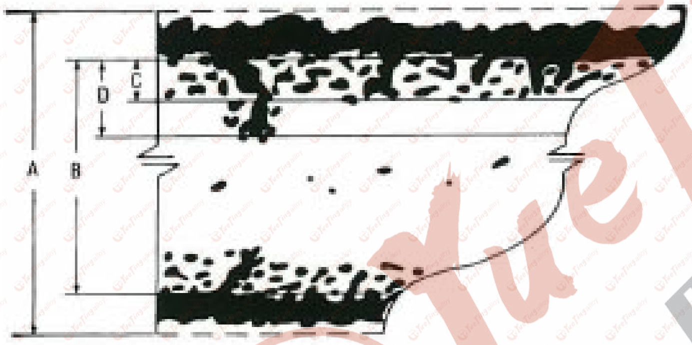
# Aqueous Corrosion Resistance

| Alloy | Average Corrosion Rate, per year | | | | | |
|---|---|---|---|---|---|---|
| | 1% HCl (Boiling) | | 10% $H_2SO_4$ (Boiling) | | 65% $HNO_3$ (Boiling) | |
| - | mils | mm | mils | mm | mils | mm |
| **ULTIMET®** | <1 | <0.03 | 99 | 2.51 | 6 | 0.15 |
| **C-22®** | 3 | 0.08 | 12 | 0.3 | 134 | 3.4 |
| **25** | **226** | **5.74** | **131** | **3.33** | **31** | **0.79** |
| **Type 316L** | 524 | 13.31 | 1868 | 47.45 | 9 | 0.23 |

HAYNES® 25 alloy was not designed for resistance to corrosive aqueous media. Representative average corrosion data are given for comparison. For applications requiring corrosion resistance in aqueous environments, ULTIMET® alloy and HASTELLOY® corrosion-resistant alloys should be considered.

# Oxidation Resistance

HAYNES® 25 alloy exhibits good resistance to both air and combustion gas oxidizing environments, and can be used for long-term continuous exposure at temperatures up to 1800°F (980°C). For exposures of short duration, 25 alloy can be used at higher temperatures. Applications for which oxidation resistance is a serious consideration normally call for newer, more capable materials such as 230® alloy or HAYNES® 188 alloy. This is particularly important at temperatures above 1800°F (980°C).




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 Burner Rig Oxidation Resistance 1000 Hour Exposure at 1800°F (980°C)**

| Alloy | Metal Loss | | Average Metal Affected | | Maximum Metal Affected | |
|---|---|---|---|---|---|---|
| | mils | µm | mils | µm | mils | µm |
| **188** | 1.1 | 28 | 3.2 | 81 | 3.9 | 99 |
| **230®** | 2.8 | 71 | 5.6 | 142 | 6.4 | 163 |
| **617** | 2.4 | 61 | 5.7 | 145 | 6.9 | 175 |
| **625** | 3.7 | 94 | 6 | 152 | 6.6 | 168 |
| **X** | 4.3 | 109 | 7.3 | 185 | 8 | 203 |
| **25** | **7.8** | **198** | **9.8** | **249** | **10.3** | **262** |
| **310SS** | 16 | 406 | 18.3 | 465 | 19.5 | 495 |
| **800H** | 22.9 | 582 | Internal oxidation through thickness | | | |

# Oxidation Resistance Continued

### Oxidation Test Parameters

Burner rig oxidation tests were conducted by exposing samples 3/8 in. x 2.5 in. x thickness (9 mm x 64 mm x thickness), in a rotating holder, to products of combustion of No. 2 fuel oil 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 fancooled to near ambient temperature and then reinserted into the flame tunnel.

### Comparative Oxidation Resistance in Flowing Air*

| Alloy | 1800°F (980°C) | | | | 2000°F (1095°C) | | | | 2100°F (1150°C) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average Metal Affected** | | Average Metal Loss | | Average Metal Affected** | | Average Metal Loss | | Average Metal Affected** | | Average Metal Loss | |
| - | mils | µm | mils | µm | mils | µm | mils | µm | mils | µm | mils | µm |
| **188** | 1.1 | 28 | 0.1 | 3 | 3.7 | 94 | 0.5 | 13 | 10.7 | 272 | 8.6 | 218 |
| **230®** | 1.5 | 38 | 0.2 | 5 | 3.3 | 84 | 0.5 | 13 | 4.4 | 112 | 1.2 | 30 |
| **25** | **2** | **51** | **0.3** | **8** | **10.2** | **259** | **9.2** | **234** | **10.7** | **272** | **8.2** | **208** |
| **X** | 1.5 | 38 | 0.2 | 5 | 4.4 | 112 | 1.3 | 33 | 6.1 | 115 | 3.6 | 91 |
| **625** | 1.9 | 48 | 0.4 | 10 | 7.8 | 198 | 3.5 | 89 | 20.2 | 513 | 18.3 | 465 |
| **617** | 2 | 51 | 0.3 | 8 | 3.8 | 97 | 0.6 | 15 | 5.2 | 132 | 1 | 25 |
| **800HT** | 4.1 | 104 | 0.5 | 13 | 11.6 | 295 | 7.6 | 193 | 15 | 381 | 11 | 279 |

* Flowing air at a velocity of 7.0 ft./min. (213.4 cm/min.) past the samples. Samples cycled to room temperature once-a-week.
** Metal Loss + Average Internal Penetration.

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

| Alloy | Average Metal Loss per Side | | Maximum Metal Affected | |
|---|---|---|---|---|
| - | mils | µm | mils | µm |
| **214®** | 1.2 | 30.5 | 1.8 | 45.7 |
| **230®** | 7.1 | 180.3 | 11.8 | 299.7 |
| **188** | 10.9 | 276.9 | 14.1 | 358.1 |
| **X** | 11.6 | 294.6 | 15.1 | 383.5 |
| **25** | **> 25*** | **>635*** | **-** | **-** |

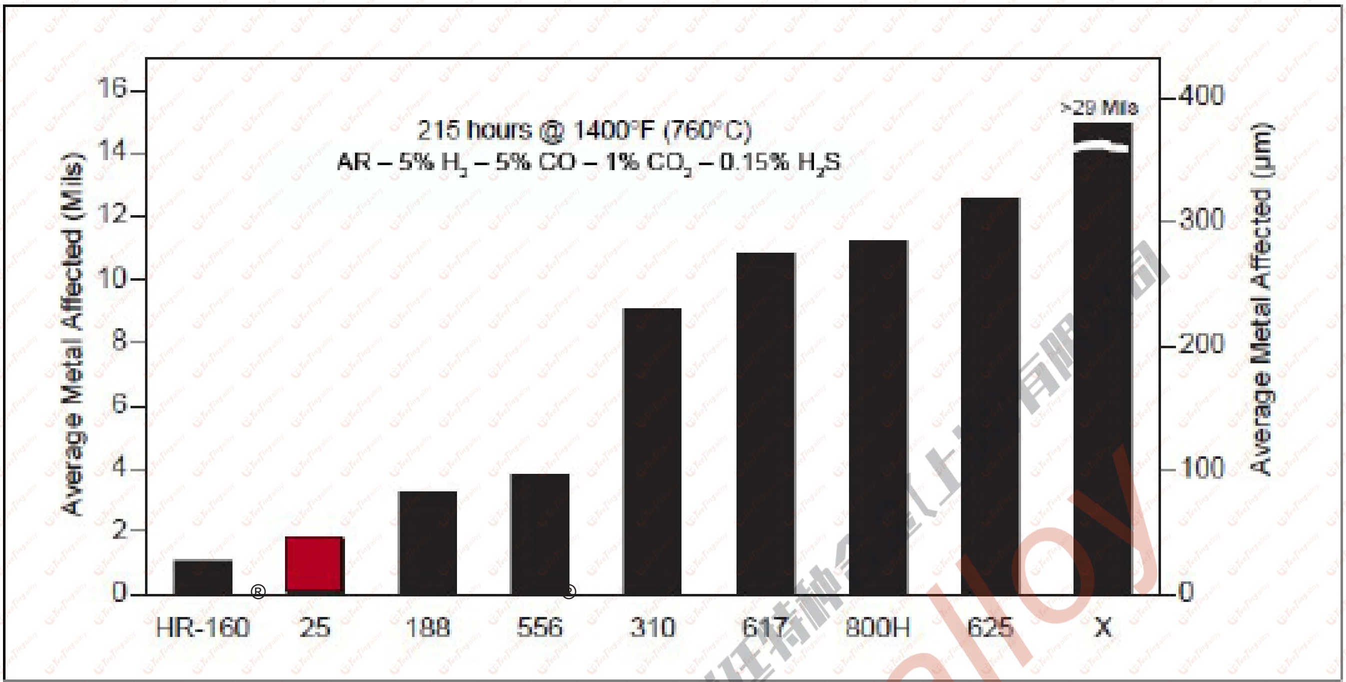
*> 25 mils (635 µm) in 165 hours

# Sulfidation Resistance

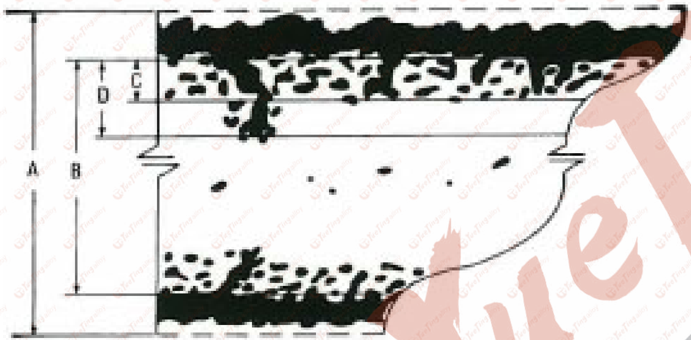
### Sulfidation Resistance at 1400°F (760°C)

HAYNES® 25 alloy has very good resistance to gaseous sulfidation environments encountered in various industrial applications. Tests were conducted at 1400°F (760°C) in a gas mixture consisting of 5 percent $H_2$, 5 percent CO, 1 percent $CO_2$, 0.15 percent $H_2S$ and 0.1 percent $H_2O$, balance Ar. Coupons were exposed for 215 hours. This is a severe test, with equilibrium sulfur partial pressure of 10-6 to 10-7 and oxygen partial pressures less than that needed to produce protective chromium oxide scales.

# Sulfidation Resistance Continued




**Schematic Representation of 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

# Fabrication

HAYNES® 25 alloy has good forming and welding characteristics. It may be forged or otherwise hot-worked, providing that it is held at 2200°F (1205°C) for a time sufficient to bring the entire piece to temperature. The alloy has good ductility, and thus also may be formed by cold working. The alloy does work-harden very rapidly, however, so frequent intermediate annealing treatments will be needed for complex component forming operations. 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 both manual and automatic welding methods, including gas tungsten arc (GTAW), gas metal arc (GMAW), shielded metal arc, electron beam and resistance welding. It exhibits good restraint welding characteristics.

# Fabrication Continued

## Heat Treatment

HAYNES® 25 alloy is furnished in the solution heat-treated condition, unless otherwise specified. The alloy is normally final solution heat-treated at 2150 to 2250°F (1175 to 1230°C) for a time commensurated with section thickness and rapidly cooled or water-quenched for optimal properties. Because annealing at temperatures less than the solution heat-treating temperature will produce some carbide precipitation in 25 alloy, which may affect the alloy's properties, annealing during fabrication may be performed at lower temperatures, but a final, subsequent solution heat treatment is needed to produce optimum properties and structure.

## Machining

For information on Machining, please refer to the machining section of Welding and Fabrication.

### Formability

| Cold Reduction | Subsequent Anneal | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation | HRC |
|---|---|---|---|---|---|---|---|
| % | | ksi | MPa | ksi | MPa | % | - |
| 0 | None | 68.4 | 470 | 144 | 995 | 58.5 | 24 |
| 10 | | 123.6 | 850 | 181.9 | 1255 | 37.1 | 36 |
| 15 | | 148.5 | 1025 | 178.2 | 1230 | 27.7 | 40 |
| 20 | | 150.9 | 1040 | 193.5 | 1335 | 18.2 | 42 |
| 25 | | 183.9 | 1270 | 232.5 | 1605 | 14.6 | 44 |
| 10 | 1950°F (1065°C) for 5 min. | 97.9 | 675 | 163 | 1125 | 39.3 | 32 |
| 15 | | 91.2 | 630 | 167.1 | 1150 | 43.8 | 30 |
| 20 | | 96.5 | 665 | 170.7 | 1175 | 40.8 | 32 |
| 25 | | 88.9 | 615 | 169.5 | 1170 | 44.3 | 32 |
| 10 | 2050°F (1120°C) for 5 min. | 74 | 510 | 156.6 | 1080 | 53.4 | 27 |
| 15 | | 78.6 | 540 | 161.2 | 1110 | 51.9 | 28 |
| 20 | | 82 | 565 | 164.8 | 1135 | 47.6 | 31 |
| 25 | | 82.9 | 570 | 165.6 | 1140 | 48 | 30 |
| 10 | 2150°F (1117°C) for 5 min. | 66.9 | 460 | 148.1 | 1020 | 62.6 | 21 |
| 15 | | 73.6 | 505 | 156.1 | 1075 | 55.4 | 26 |
| 20 | | 72.1 | 495 | 154 | 1060 | 59.3 | 26 |
| 25 | | 68.5 | 470 | 149.3 | 1030 | 61.7 | 25 |

*Based upon cold reductions taken upon 0.110-inch (2.8 mm) thick sheet.
Duplicate tests.
HRC = Hardness Rockwell "C".

# Welding

HAYNES® 25 alloy is readily welded by Gas Tungsten Arc (GTAW), Gas Metal Arc (GMAW), Shielded Metal Arc (SMAW), electron bean welding, and resistance welding techniques. Its welding characteristics are similar to those of HAYNES® 188 alloy. Submerged Arc welding is not recommended, as this process is characterized by high heat input to the base metal and slow cooling of the weld. These factors can increase weld restraint and promote cracking.

### Base Metal Preparation

The joint surface and adjacent area should be thoroughly cleaned before welding. All grease, oil, crayon marks, sulfur compounds, and other foreign matter should be removed. 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 alloy 25. For shielded metal arc welding, HAYNES® 25 alloy electrodes (AMS 5797) are suggested. For dissimilar joining of 25 alloy to nickel-, cobalt-, or iron- base materials, 25 alloy itself (AMS 5796), 230-W® filler wire(AMS 5839), HAYNES® 556® alloy (AMS 5831), HASTELLOY® S alloy (AMS 5838), or HASTELLOY® W alloy (AMS 5786) welding products are suggested, depending upon the particular case. Please see the “Welding and Fabrication” brochure or the Haynes Welding SmartGuide for more information.

### Preheating, Interpass Temperatures, and Post-Weld Heat Treatment

Preheat is not required. Preheat is generally specified as room temperature (typical shop conditions). Interpass temperature should be maintained below 200°F (93°C). Auxiliary cooling methods may be used between weld passes, as needed, providing that such methods do not introduce contaminants. Post-weld heat treatment is not generally required for 25 alloy. For further information, please consult the “Welding and Fabrication” brochure.

**Welded Tensile - Room Temperature**

| Form | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|
| | ksi | MPa | ksi | MPa | % |
| Sheet | 69 | 476 | 144.5 | 996 | 54.7 |
| Plate | 68.7 | 474 | 145.1 | 1000 | 58.8 |
| Welded Transverse, GTAW | 72.4 | 499 | 134.2 | 925 | 36.5 |
| All Weld Metal, SMAW | 88.6 | 611 | 141 | 972 | 31.5 |

# Specifications

**Specifications**

| HAYNES® 25 alloy (UNS R30605) | |
|---|---|
| **Sheet, Plate & Strip** | AMS 5537 |
| **Billet, Rod & Bar** | AMS 5759<br>MIL-C-24252D |
| **Coated Electrodes** | AMS 5797 |
| **Bare Welding Rods & Wire** | AMS 5796 |
| **Seamless Pipe & Tube** | - |
| **Welded Pipe & Tube** | - |
| **Fittings** | - |
| **Forgings** | AMS 5759 |
| **DIN** | - |
| **Others** | MIL-R-5031B Class 13 |

**Codes**

| HAYNES® 25 alloy (R30605) | |
|---|---|
| **MMPDS** | 6.4.1 |

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