INCONEL® alloy HX (UNS N06002/W.Nr. 2.4665) is a high-temperature, matrix-stiffened, nickel-chromium-iron-molybdenum alloy with outstanding oxidation resistance, and exceptional strength at up to 2200°F (1200°C).

It is used for components such as combustion chambers, afterburners and tail pipes in aircraft and land-based gas turbine engines; for fans, roller hearths and support members in industrial furnaces, and in nuclear engineering.

INCONEL alloy HX is readily fabricated and welded.

**Table 1** - Limiting Chemical Composition, % by Weight

| | |
|---|---|
| Carbon | 0.05-0.15 |
| Chromium | 20.5-23.0 |
| Cobalt | 0.5-2.5 |
| Iron | 17.0-20.0 |
| Manganese | 1.0 max. |
| Molybenum | 8.0-10.0 |
| Nickel | Balance* |
| Silicon | 1.0 max. |
| Tungsten | 0.2-1.0 |
| Phosphorus | 0.04 max. |
| Sulfur | 0.03 max |

*Reference to the balance of the alloy's composition does not guarantee this is exclusively of the element mentioned but that it predominates and others are present only in minimal quantities.

## Physical Properties

Some physical properties for INCONEL alloy HX are given in Table 2. Thermal conductivity data (Table 3) and electrical resistivity (Table 5) were determined from 5 casts of cold-rolled sheet, 0.039-0.067 in (1-1.7 mm) thick, heated-treated at 2150°F (1175°C)/rapid air cooled.

Mean coefficient of linear thermal expansion data (Table 4) are for solution-treated material. A variation of ±5% can be expected for compositional changes within the release specification, processing history and form.

The dynamic moduli data (Table 6) were obtained from cold-rolled sheet, 0.039-0.067 in (1-1.7 mm) thick, heat-treated at 2150°F (1175°C)/rapid air cooled and vibrated in the flexural mode.

**Table 2** - Physical Properties

| | |
|---|---|
| Density, g/cm³ | 8.2 |
| lb/in³ | 0.297 |
| Melting Range, °C | 1260-1355 |
| °F | 2300-2470 |
| Specific Heat, J/kg °C | 461 at 20°C |
| Btu/lb °F | 0.110 at 70°F |
| Poisson's Ratio at room temperature.. | 0.320 |

## Available Forms

INCONEL alloy HX is available as rod, bar, billet, extruded section, plate, sheet, strip, wire, pipe and tube.

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**Table 3** - Thermal Conductivity

| Temperature | | Thermal Conductivity | |
|---|---|---|---|
| °C | °F | W/m °C | Btu/ft h °F |
| 20 | 68 | 11.6 | 81 |
| 100 | 212 | 12.9 | 90 |
| 200 | 392 | 14.6 | 102 |
| 300 | 572 | 16.3 | 114 |
| 400 | 752 | 17.9 | 126 |
| 500 | 932 | 19.5 | 137 |
| 600 | 1112 | 21.1 | 148 |
| 700 | 1292 | 22.9 | 161 |
| 800 | 1472 | 24.6 | 173 |
| 900 | 1652 | 26.3 | 184 |
| 1000 | 1832 | 27.9 | 196 |

**Table 4 -** Mean Coefficient of Linear Thermal Expansion

| °C | $10^{-6}$/°C | °F | $10^{-6}$/°F |
|---|---|---|---|
| 20 -100 | 13.3 | 70 -200 | 7.40 |
| -200 | 14.0 | -600 | 7.96 |
| -300 | 14.3 | -1000 | 8.27 |
| -400 | 14.5 | -1200 | 8.53 |
| -500 | 14.7 | -1350 | 8.69 |
| -600 | 15.1 | -1500 | 8.88 |
| -700 | 15.7 | -1600 | 9.01 |
| -800 | 16.0 | | |
| -900 | 16.3 | | |
| -1000 | 16.7 | | |

**Table 5 -** Electrical Resistivity

| Temperature | | Electrical Resistivity | |
|---|---|---|---|
| °C | °F | μΩ cm | Ω circ mil/ft |
| 20 | 68 | 116 | 698 |
| 100 | 212 | 118 | 710 |
| 200 | 392 | 120 | 722 |
| 300 | 572 | 122 | 734 |
| 400 | 752 | 124 | 746 |
| 500 | 932 | 126 | 758 |
| 600 | 1112 | 127 | 764 |
| 700 | 1292 | 127 | 764 |
| 800 | 1472 | 127 | 764 |
| 900 | 1652 | 127 | 764 |
| 1000 | 1832 | 128 | 770 |

**Table 6** - Dynamic Moduli

| Temperature | | Dynamic Young's Modulus | | Dynamic Torsional Modulus | |
|---|---|---|---|---|---|
| °C | °F | GPa | $10^3$ ksi | GPa | $10^3$ ksi |
| 20 | 68 | 205 | 29.7 | 80 | 11.6 |
| 100 | 212 | 202 | 29.3 | 78 | 11.3 |
| 200 | 392 | 195 | 28.3 | 75 | 10.9 |
| 300 | 572 | 190 | 27.6 | 72 | 10.4 |
| 400 | 752 | 183 | 26.5 | 70 | 10.2 |
| 500 | 932 | 177 | 25.7 | 66 | 9.6 |
| 600 | 1112 | 168 | 24.4 | 62 | 9.0 |
| 700 | 1292 | 161 | 23.3 | 60 | 8.7 |
| 800 | 1472 | 153 | 22.2 | 56 | 8.1 |
| 900 | 1652 | 145 | 21.0 | 53 | 7.7 |
| 1000 | 1832 | 135 | 19.6 | 49 | 7.1 |

## Mechanical Properties

Room-temperature mechanical properties, typical of a single representative heat are quoted in Table 7. Data in Fig. 1 are for cold-rolled sheet, 0.039-0.067 in (1-1.7 mm) thick, heat-treated at 2150°F (1175°C)/rapid air cooled. Strain rates of 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures), and 0.1 min thereafter.

Data in Fig. 2 are for cold-rolled, welded sheet, 0.039-0.067 in (1-1.7 mm) thick, heat-treated at 2150°F (1175°C)/rapid air cooled. The sheet was welded by the gas-tungsten-arc (T.I.G.) process using INCONEL filler metal HX with argon as the shielding gas.

Creep-rupture properties of sheet (heat-treated at 2150°F (1175°C)/rapid air cooled) are shown in Fig. 3 by Larson-Miller presentation.

**Table 7 -** Mechanical Properties of Sheet at Room Temperature

| Tensile Strength | | 0.2% Proof Stress | | Elongation | Hardness |
|---|---|---|---|---|---|
| ksi | MPa | ksi | MPa | % | Rb |
| 115 | 793 | 50 | 345 | 45.5 | 90 |

**Figure 1.** Tensile properties of INCONEL alloy HX sheet.

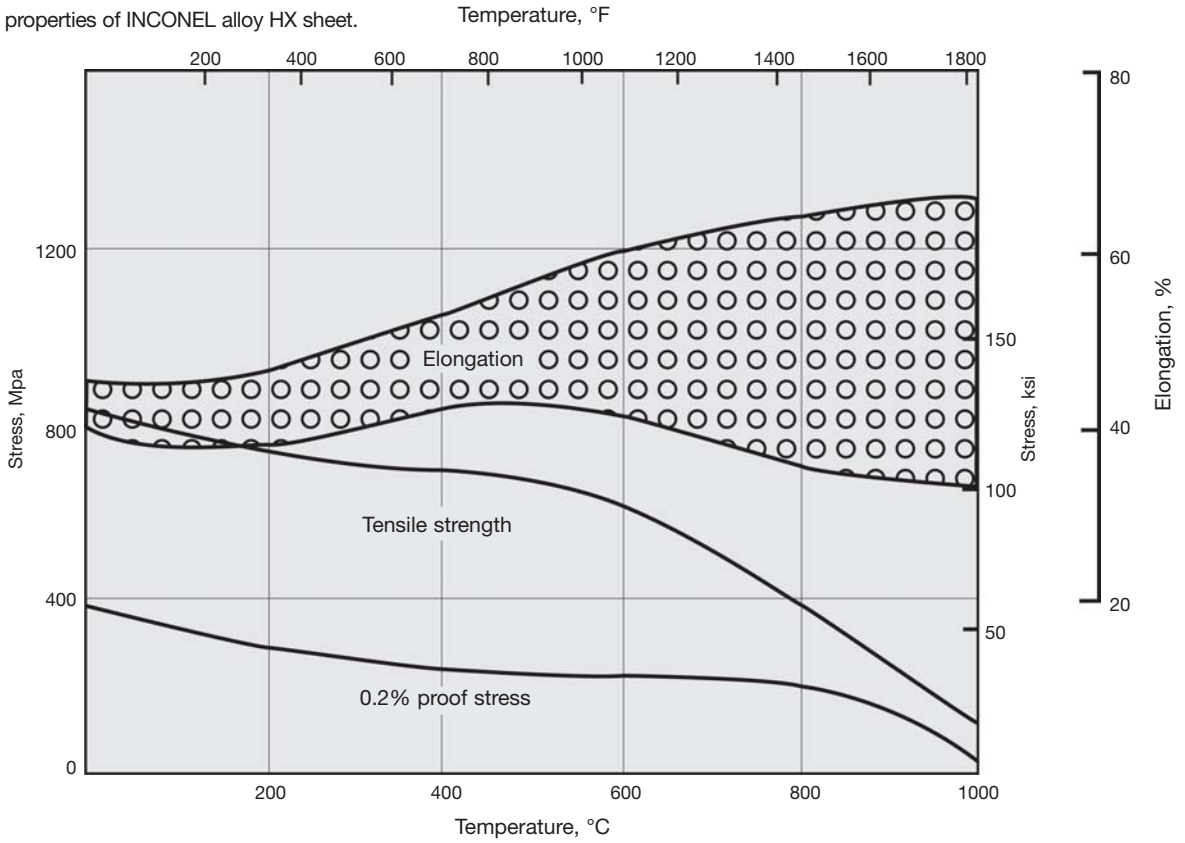



**Figure 2.** Tensile properties of INCONEL alloy HX welded sheet.

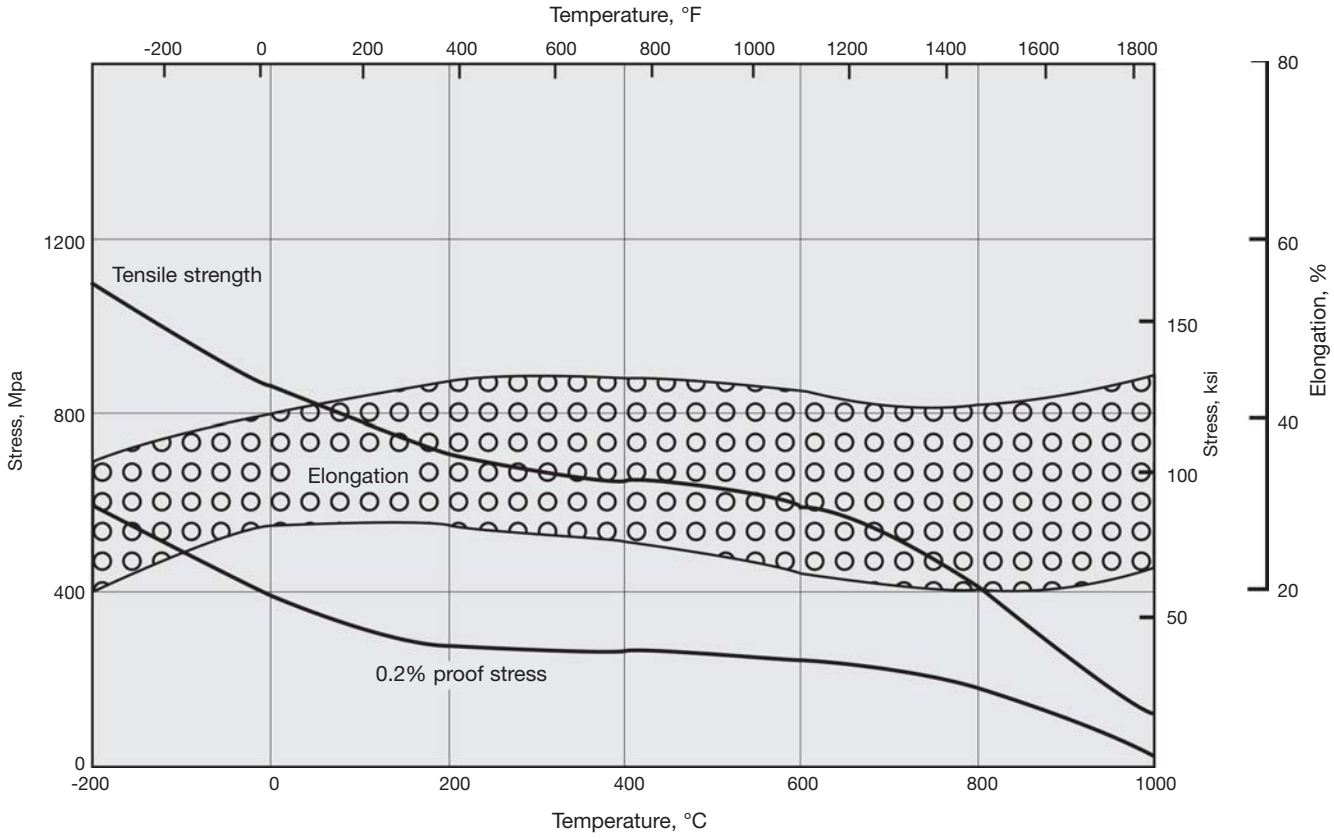
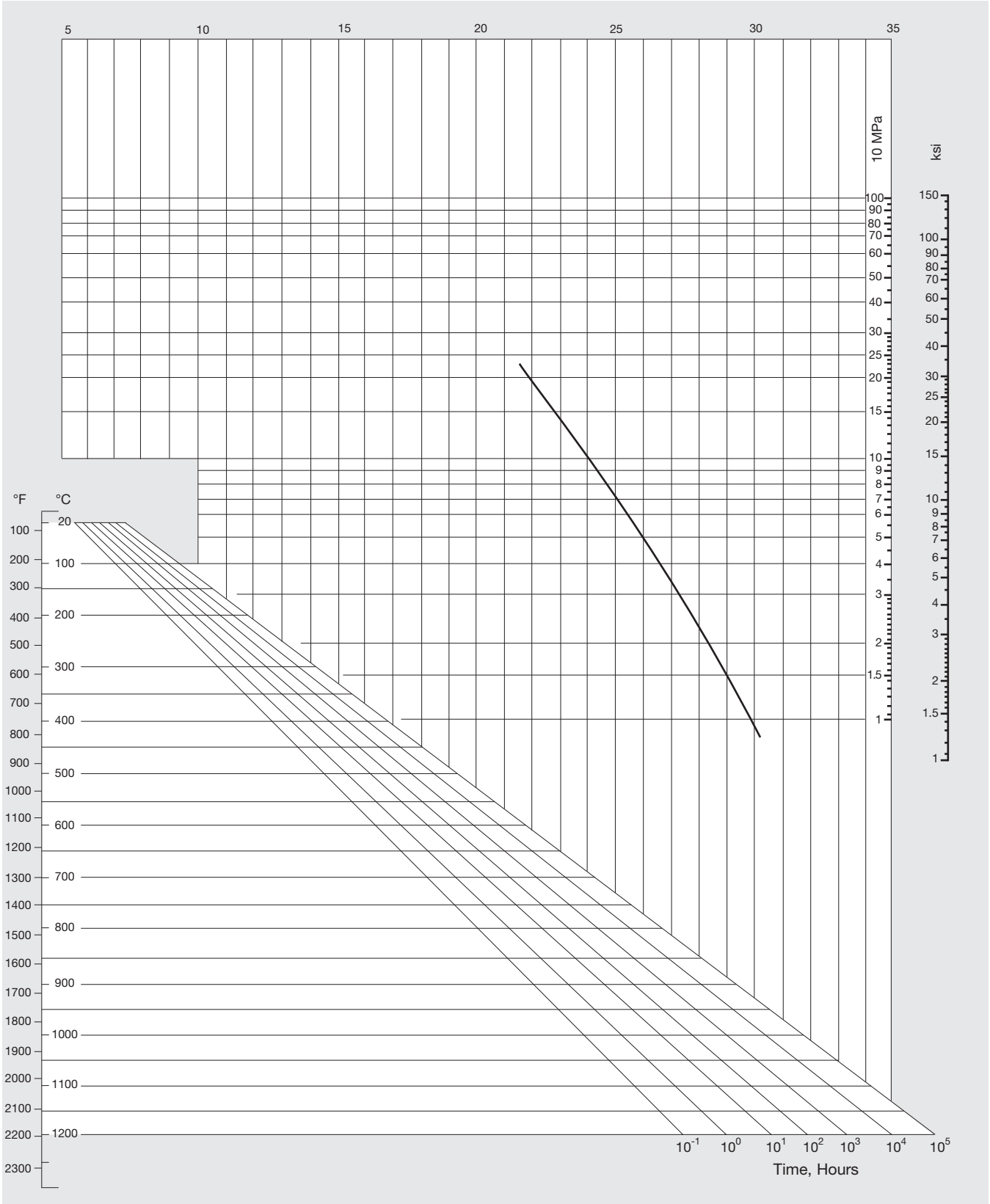


**Figure 3.** Creep-rupture properties of INCONEL alloy HX sheet.

**Larson-Miller Parameter, T(20 +log t) x $10^{-3}$, T in °K, t in hours**



## Corrosion Resistance

INCONEL alloy HX has outstanding oxidation resistance at temperatures up to 2200°F (1200°C). Test results at 1920 and 2010°F (1050 and 1100°C) for 100 hours' continuous exposure are shown in Fig. 4.

In a carburizing atmosphere of 2% methane plus 98% hydrogen flowing at 3 furnace volumes per hour for 100 hours at 1800°F (980°C), samples of a representative heat of INCONEL allow HX showed an average weight gain of 7.7 mg/cm².

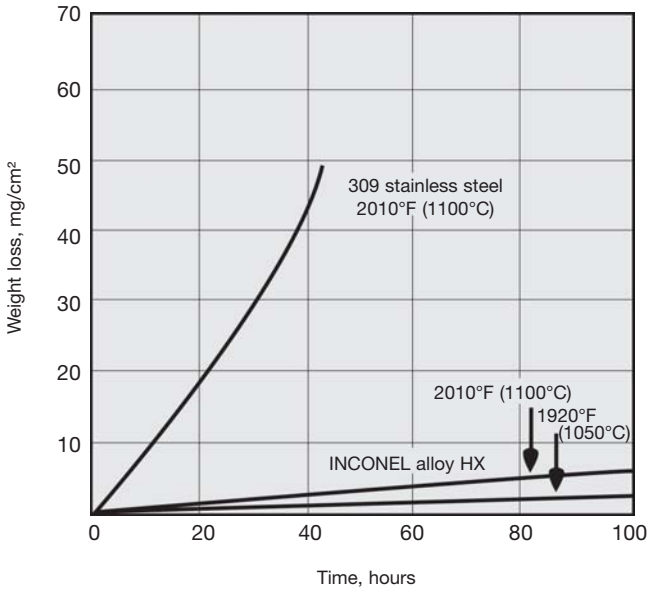



**Figure 4.** Comparative oxidation resistance of INCONEL alloy HX and AISI 309 stainless steel

# Fabrication

## Heat Treatment

The recommended heat treatment is 2150°F (1175°C), followed by rapid air cooling or water quenching. INCONEL alloy HX is normally supplied in this solution-heat-treated condition. For some applications it can be given other treatments. Consult Special Metals for further details.

## Hot and Cold Forming

INCONEL alloy HX can be readily cold formed using slightly higher power than that used for austenitic stainless steels. It is best cold formed in the solution-heat-treated condition.

For hot forming, the alloy should be heated to a starting temperature of 2150°F (1175°C). It should not be hot worked below 1800°F (980°C).

## Welding

The alloy can be welded by metal arc, gas-tungsten-arc (T.I.G.), gas-metal-arc (M.I.G.) and submerged arc processes. Welded surfaces must be thoroughly descaled and cleaned. Welding is best carried out flat since the fluidity of the alloy makes position welding difficult.

INCONEL welding electrode 117 and INCONEL filler metal 617 produce weldments that match or exceed base metal high-temperature strength and oxidation resistance. Matched composition welding consumables (INCONEL filler metal HX and INCONEL welding electrode HX) are available.

Pre-heating and post-weld heat treatments are not normally necessary. For the greatest corrosion resistance, however, solution-heat-treatment after welding may be necessary.

## Machining

INCONEL alloy HX should be machined in the annealed condition using carbide or high-speed steel tools and a copious supply of sulfur-free cutting fluid. Tools and machines should be as rigid as possible to minimize deflection and vibration. Speeds and feeds will be similar to those for NIMONIC alloy 75.

## Specifications

INCONEL alloy HX is designated as UNS N06002/ W.Nr 2.4665. Alloy HX is listed in NACE MR-01-75. The alloy is available as rod, bar, billet, extruded section, plate, sheet, strip, wire, pipe and tube. Specifications for INCONEL alloy HX include the following:

| ASTM | |
|---|---|
| B 435 | Plate, sheet and strip |
| B 366 | Fittings |
| B 572 | Rod |
| B 619 | Welded pipe |
| B 622 | Seamless pipe and tube |
| B 626 | Welded tube |
| B 751 | Tube |
| B 775 | Pipe |
| B 829 | Pipe and Tube |

| ASME | |
|---|---|
| SB 435 | Plate, sheet and strip |
| SB 366 | Fittings |
| SB 572 | Rod |
| SB 619 | Welded pipe |
| SB 622 | Seamless pipe and tube |
| SB 626 | Welded tube |
| SB 751 | Tube |
| SB 775 | Pipe |
| SB 829 | Pipe and Tube |

| SAE | |
|---|---|
| AMS 5536 | Sheet, strip and plate |
| AMS 5587 | Seamless tube |
| AMS 5588 | Welded tube |
| AMS 5754 | Bar, forgings and rings |
| AMS 5798 | Wire |

| BSI | |
|---|---|
| HR6 | Billet, bar and forgings |
| HR204 | Plate, sheet and strip |

| Deutschen Luftfahrt | |
|---|---|
| LW2.4665 Part 1 | Sheet and strip |
| LW2.4665 Part 2 | Bar and forgings |

| Ministère d'Etat de la Défense | |
|---|---|
| AIR 9165-43 | Bar, forgings and sheet |

| AECMA | |
|---|---|
| PrEN2182 | Bar |
| PrEN2182 | Forgings |
| PrEn 2183 | Forgings |
| PrEN2184 | Section for welded rings |
| PrEN2185 | Sheet, strip and plate |

| DIN | NiCr22Fe18Mo |
|---|---|
| 17744 | Composition |
| 17750 | Plate, Sheet and Strip |
| 17751 | Pipe and Tube |
| 17752 | Rod and Bar |
| 17753 | Wire |
| 17754 | Forgings |

| ISO | |
|---|---|
| 6207 | Tube |
| 6208 | Plate, Sheet and Strip |
| 9723 | Bar |
| 9724 | Wire |
| 9725 | Forgings |

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