# INCOLOY® alloy 25-6HN

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INCOLOY alloy 25-6HN is a super-austenitic stainless steel containing 6% molybdenum and with properties enhanced by its content of nitrogen Its high content of nickel results in thermal stability and resistance to stress corrosion cracking. Designated as UNS N08367, alloy 25-6HN directly competes with alloy AL6XN®. The same ASTM, ASME, and NACE specifications cover the alloys. Alloy 25-6HN is a new addition to Special Metals existing line of high performance, super-austenitic stainless steels, INCOLOY alloys 25-6MO and 27-7MO. The chemical compositions of these products are reported for comparison in Table 1.

Alloy 25-6HN offers significantly improved strength and corrosion resistance in most environments over conventional austenitic stainless steels such as AISI 304 or 316L. Typical applications include welded tubes for heat exchangers for chemical processing and marine applications and for desalination systems, flue gas desulfurization equipment for coal-fired power plants, and reaction vessels for pharmaceutical production.

**Table 1: Chemical Composition of 25-6HN**

| Element | **25-6HN*** | AL6XN | UNS N08367 | 25-6MO* |
|---|---|---|---|---|
| C | **0.01** | 0.02 | 0.03 max | 0.01 |
| Mn | **0.4** | 0.4 | 2.00 max | 0.7 |
| P | **0.02** | 0.025 | 0.040 max | 0.02 |
| S | **0.001** | 0.002 | 0.030 max | 0.001 |
| Si | **0.3** | 0.4 | 1.00 max | 0.3 |
| Cr | **20.6** | 20.5 | 20.00-22.00 | 20.5 |
| Ni | **24.3** | 24 | 23.50-25.50 | 25.1 |
| Mo | **6.3** | 6.3 | 6.00-7.00 | 6.7 |
| N | **0.21** | 0.22 | 0.18-0.25 | 0.21 |
| Cu | **0.25** | 0.1 | 0.75 max | 0.9 |
| Fe | **Bal.** | Bal. | Bal. | Bal. |

***Typical**

## Physical Properties

The physical properties of alloy 25-6HN are essentially the same as those reported for alloy AL6XN and are reported in Table 2. Alloy 25-6HN is non-magnetic even at very low temperatures. The low density of alloy 25-6HN enhances its value over the more dense nickel-base alloys such as C-276, 22, and 686.

**Table 2: Selected Physical Properties of 25-6HN**

| Property | **25-6HN** | AL6XN |
|---|---|---|
| Density | **8.02 g/cm3** | 8.06 g/cm3 |
| | **(0.290 lb/in3)** | (0.291 lb/in3) |
| Melting Range | **2470-2560 °F** | 2410-2550 °F |
| Magnetic Permeability (200 Oersteds at RT) | **1.003** | 1.0028 |
| Coefficient of Thermal Expansion (68-212 F) | **8.49 in/in °F x $10^{-6}$** | 8.5 x 10 –6/°F |

**Table 3: Coefficient of Thermal Expansion for INCOLOY alloy 25-6HN**

| Temp. (°F) | Coefficient of Thermal Expansion $10^{-6}$in/in•°F | Temp. (°C) | Coefficient of Thermal Expansion µm/m•°C |
|---|---|---|---|
| 77 | - | 25 | - |
| 200 | 8.66 | 100 | 15.59 |
| 400 | 8.80 | 200 | 15.83 |
| 600 | 8.90 | 300 | 15.98 |
| 800 | 9.05 | 400 | 16.23 |
| 1000 | 9.21 | 500 | 16.45 |
| 1200 | 9.53 | 600 | 16.91 |
| 1400 | 9.77 | 700 | 17.35 |
| 1600 | 9.94 | 800 | 17.72 |

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# Mechanical Properties

INCOLOY alloy 25-6HN offers higher strength than conventional austenitic stainless steels and typical of other superaustenitic stainless steels, as seen in Table 4. Even with its high level of strength, the alloy offers excellent ductility for enhanced formability.

**Table 4: Room Temperature Tensile Results**

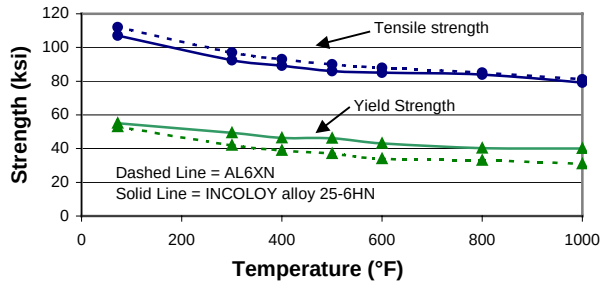
| **Property** | **25-6HN* (Plate)** | AL6XN | 25-6MO |
|---|---|---|---|
| Hardness | **90 HRB** | 90 HRB | 89 HRB |
| 2% Yield Strength | **55 ksi** | 55 ksi | 52 ksi |
| Ult. Tensile Strength | **107 ksi** | 110 ksi | 109 ksi |
| Elongation | **48%** | 45% | 47% |

***Typical**

**Table 5: Effect of Temperature on Strength of INCOLOY alloy 25-6HN**

| Temp. (°F) | Property | AL6XN | **25-6HN** |
|---|---|---|---|
| RT | Yield Strength (ksi) | 53 | **55** |
| | Tensile Strength (ksi) | 112 | **107** |
| | Elongation (%) | 50 | **48** |
| 300 | Yield Strength (ksi) | 42 | **49** |
| | Tensile Strength (ksi) | 97 | **93** |
| | Elongation (%) | 45 | **47** |
| 400 | Yield Strength (ksi) | 39 | **46** |
| | Tensile Strength (ksi) | 93 | **89** |
| | Elongation (%) | 45 | **47** |
| 500 | Yield Strength (ksi) | 37 | **46** |
| | Tensile Strength (ksi) | 90 | **86** |
| | Elongation (%) | 45 | **47** |
| 600 | Yield Strength (ksi) | 34 | **43** |
| | Tensile Strength (ksi) | 88 | **87** |
| | Elongation (%) | 45 | **46** |
| 800 | Yield Strength (ksi) | 33 | **40** |
| | Tensile Strength (ksi) | 85 | **84** |
| | Elongation (%) | 45 | **45** |
| 1000 | Yield Strength (ksi) | 31 | **43** |
| | Tensile Strength (ksi) | 81 | **80** |
| | Elongation (%) | 42 | **48** |

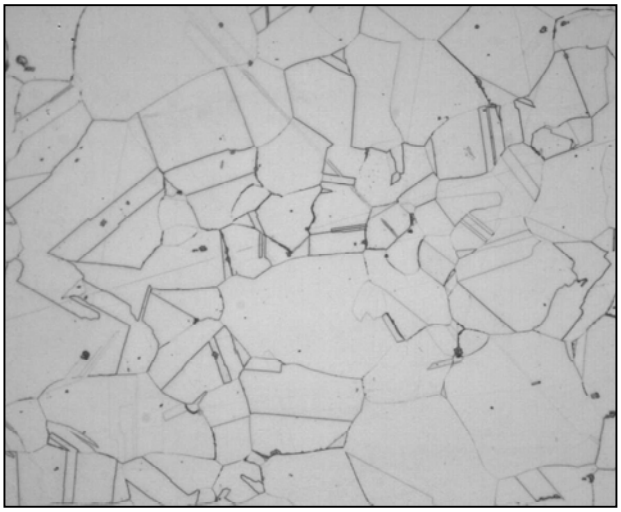
**Figure 1: Comparison between INCOLOY alloy 25-6HN and AL6XN**




# Microstructure

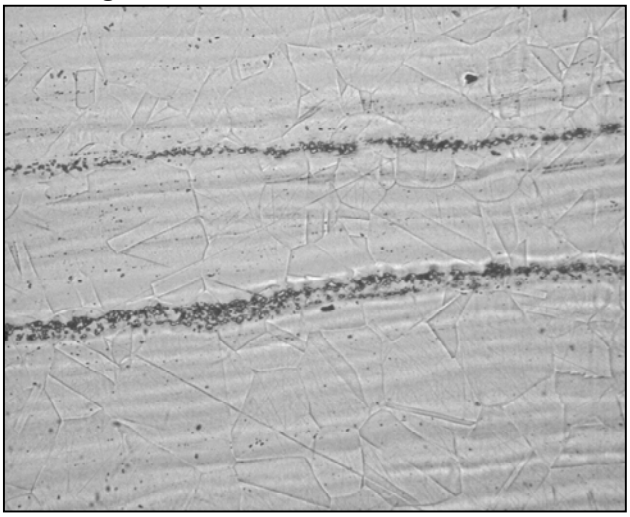
Alloy 25-6HN exhibits a fully austenitic structure. The microstructure is especially "clean" due to proprietary deoxidation practices during melting. Thus, banding and stringers in alloy 25-6HN products are minimized. The relative microcleanliness of alloys 25-6HN and AL6XN are seen in Figures 2 and 3.

**Figure 2: Microstructure of 25-6HN plate**



Etched in 2% Bromine Solution, GS: 6

**Figure 3: Microstructure AL6XN Plate**



Etched in 2% Bromine Solution, GS: 6

# Corrosion Resistance

INCOLOY alloy 25-6HN offers resistance to many modes of attack in a variety of aggressive environments. It is especially resistant to localized attack (crevice and pitting corrosion) in acid / halide media. Alloy 25-6HN also resists microbially induced corrosion. With 25% nickel, the alloy is much more resistant to chloride-induced stress corrosion cracking than austenitic stainless steels (AISI 300 grades).

Critical Pitting Temperatures (CPT) and Critical Crevice Temperatures (CCT) for SMC super-austenitic stainless steels and other grades of stainless steel and nickel-base alloys are reported in Table 6 & 7. The values for CPT and CCT of welded alloys are strongly influenced by the choice of filler material. While alloys 25-6HN is normally joined with INCONEL filler metal 625, a higher CPT results from the use of the more-resistant INCO-WELD 686CPT filler metal. Annealing after fabrication can also have a positive influence on the corrosion resistance of welded components.

**Table 6: Resistance to ASTM G48 solutions***

| Alloy | Critical Pitting Temp. per G48-C | Crevice Corrosion Temp. per G48-D | PREN |
|---|---|---|---|
| 316 Stainless | 20 C | < 0 | 20.2 |
| INCOLOY alloy 25-6MO | 70 C | 35 C | 49 |
| **INCOLOY alloy 25-6HN** | **75 C** | **35 C** | **48.3** |
| AL6XN (Allegheny) | 75 C | 35 C | 47.8 |
| Alloy 31 (VDM) | 75 C | 45 C | 54 |
| INCOLOY alloy 27-7MO | >85 C | 50 C | 56 |
| INCONEL alloy 625 | >85 C | 35 C | 51.7 |
| INCONEL alloy C276 | >85 C | 50 C | 67.2 |

**Table 7: Green Death resistance of INCOLOY alloy 25-6HN and other alloys***

| Alloy | Critical Pitting Temp. in Green Death *Duration is 72 hrs* | Crevice Corrosion Temp. in Green Death *Duration is 24 hrs* |
|---|---|---|
| INCOLOY alloy 25-6MO | 60 | 45 |
| Alloy 31 (VDM) | 55 | 50 |
| **INCOLOY alloy 25-6HN** | **70** | **50** |
| AL6XN (Allegheny) | 65 | 50 |
| INCONEL alloy 625 | 75 | 55 |
| INCOLOY alloy 27-7MO | 80 | 65 |
| INCONEL alloy C276 | >boiling | 90 |

**Table 8: G48-C Critical Pitting Test evaluation on various alloys***

| Base Metal | Filler Metal | Welded Sample CPT (°C) |
|---|---|---|
| INCOLOY 25-6MO | INCONEL 686 CPT | 55 |
| INCOLOY 25-6MO | INCONEL 625 FM | 50 |
| Allegheny AL6XN | INCONEL 686 CPT | 55 |
| Allegheny AL6XN | INCONEL 625 FM | 55 |
| **INCOLOY 25-6HN** | **INCONEL 686 CPT** | **60** |
| **INCOLOY 25-6HN** | **INCONEL 625 FM** | **55** |
| INCOLOY 27-7MO | INCONEL 686 CPT | 80 |

**Table 9: Average corrosion rate (mpy) in several mineral acid solutions at 50° C***

| Environment | 25-6MO | **25-6HN** | AL6XN | 27-7MO |
|---|---|---|---|---|
| 5% HCl | 45 | **55** | 64 | <0.1 |
| 10% H2SO4+ 2% HCl | 29 | **<0.1** | 41 | <0.1 |
| 95% H2SO4 | 18 | **20** | 28 | 14.5 |

***The above corrosion results are certainly not exhaustive and most likely do not mimic the current application. Furthermore, there is no substitute for testing in an actual process stream. If desired, please contact Special Metals Corporation for sample material to test in your application.***

# Forming/ Fabricating

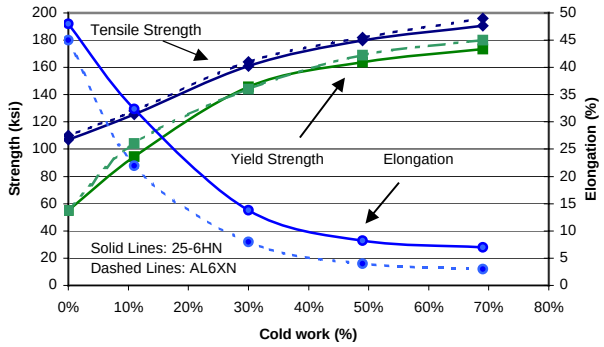
Hot working of INCOLOY alloy 25-6HN should be performed in the 1800 °F – 2250 °F temperature range. The alloy has good hot malleability, although cracking can occur at lower temperatures. Wrought material can be hot forged or hot pressed into final shapes by conventional methods.

INCOLOY alloy 25-6HN work hardens more rapidly than AISI grade 304 stainless steel or INCOLOY alloy 800 (Figure 3). To maintain a clean microstructure, after cold working, alloy 25-6HN products should be solution annealed at a temperature of 2050°F or greater. While heat treating at a lower temperature will recrystallize the deformed structure, it can also induce formation of the embrittling phase, sigma. Components with heavy cross sections should be rapidly cooled by water quenching to avoid sigma formation. Alloy 25-6HN products or components exposed to temperatures between 1100 and 1700°F during service or hot forming can form sigma phase. The presence of sigma reduces the ductility of the alloy product and reduces its resistance to localized corrosion and stress corrosion cracking. As described above, annealing at or above 2050°F will re-dissolve the sigma phase into the metal matrix and restore properties.

Like many other Fe-Ni-Cr-Mo alloys and stainless steels, alloy 25-6HN can suffer catastrophic oxidation if exposed to stagnant conditions at temperatures over 1700°F. Thus, forced gas and air flow is recommended. Stacking of plates or pieces in the furnace is to be avoided.

The same forming processes used for stainless steels can also be used for alloy 25-6HN. Due to its excellent ductility, alloy 25-6HN can be readily deformed to complex shapes and contours. However, since it is stronger than most conventional stainless steels, more power is required to form alloy 25-6HN.

**Figure 4: Cold Working 25-6HN**



# Machining

Machining characteristics of INCOLOY alloy 25-6HN are similar to those of other austenitic and super-austenitic stainless steels. Alloy 25-6HN should be machined at a slightly lower speed than 316 stainless steel due to its higher strength. Tool wear will be slightly higher than similar operations with grade 316 for the same reason. Suggested feeds and speeds for INCOLOY alloy 25-6HN are listed in Table 10. Detailed machining information is found in the SMC publication, "Machining", which is available on the company's website, www.specialmetals.com.

**Table 10: Machining Guidelines for INCOLOY alloy 25-6HN**

| Practice | Alloy | Speed (SFPM) | Depth of Cut (inches) | Feed (in/rev) |
|---|---|---|---|---|
| High Speed Steel Machining | 316 | 35 | 0.15 | 0.018 |
| | **25-6HN** | **25** | **0.15** | **0.018** |
| Carbide Machining | 316 | 375 | 0.15 | 0.018 |
| | **25-6HN** | **350** | **0.15** | **0.018** |
| High Speed Steel Drilling | 316 | 30 | --- | 0.005 |
| | **25-6HN** | **25** | **---** | **0.005** |

# Joining

INCOLOY alloy 25-6HN is readily welded using conventional processes such as gas tungsten-arc welding (GTAW/TIG), gas metal-arc welding (GMAW), shielded metal-arc welding (SMAW), submerged arc welding (SAW), and plasma arc welding (PAW). Overmatching composition welding products such as INCONEL® filler metals 625 and 622 and INCO-WELD® 686CPT® and INCONEL 112 and 122 and INCO-WELD 686CPT welding electrodes are recommended for joining alloy 25-6HN.

When autogenously welded (as in production of welded tubing) the corrosion resistance of the resulting weld is reduced. A post weld solution anneal has been shown to be effective in improving the resistance of the weld.

# Specifications

INCOLOY alloy 25-6HN is covered by a variety of specifications. Some of the common ASTM and ASME specifications are listed in Table 11. Other specifications may be applicable---Please contact Special Metals.

**Table 11: Available Specifications**

| Product form | Common Specifications |
|---|---|
| Plate, Sheet, Strip | ASTM B 688, A240 / ASME SB 688 SA 240 |
| Rod, Bar, and Wire | ASTM B 691 / ASME SB 691 |
| Forgings | ASTM B 564 / ASME SB 564 |
| Forging Stock, Billet | ASTM B472 |
| Welded Tube | ATSM B 676 / ASME SB 676 |
| Welded Pipe | ASTM B 675, B 804 / ASME SB 675 |
| Forged Flanges / Fittings | ASTM B 462 / ASME SB 462 |
| Fittings | ASTM B 366 / ASME SB 366 |

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