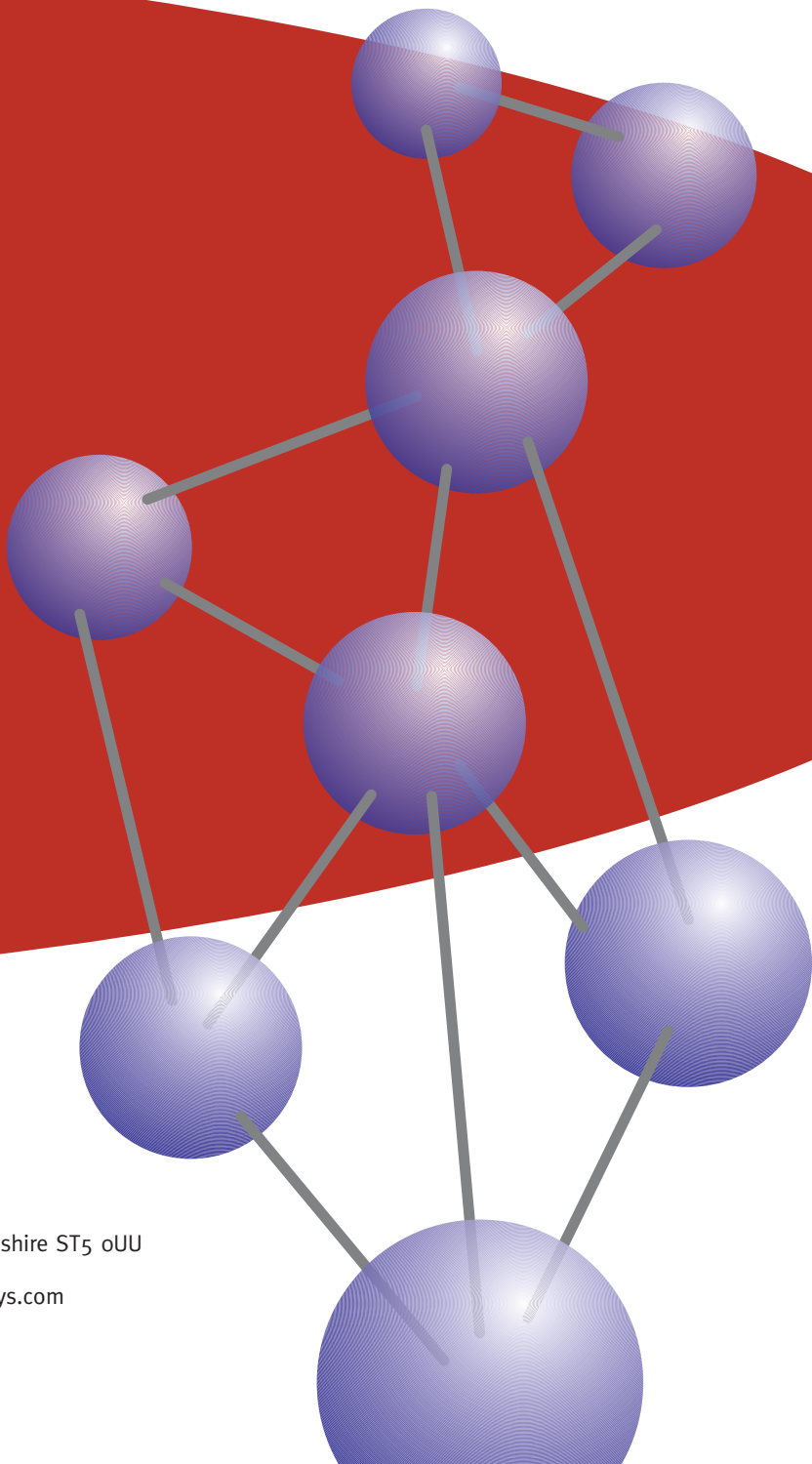
Langley Alloys

Hiduron®

Alloy 191

High strength cupronickel for marine service



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HIDURON®
alloy 191

high strength cupronickel for marine service

- Excellent general corrosion resistance in marine environments
- Superior strength, jet impingement resistance and general corrosion resistance to conventional cupronickels
- Superior combination of strength and toughness compared with aluminium bronzes
- Good anti-fouling resistance
- Low magnetic permeability
- Freedom from hydrogen embrittlement under cathodic protection and dissimilar metal coupling
- Good machineability
- Good weldability
- Good anti-galling characteristics
- Approved by Ministry of Defence (Naval)

Availability

Bar and sections

Forgings

Closed die stampings

Welding wire

Applications

Pump shafts (including submarines)
Valve Spindles
Fasteners on offshore platforms and submarines
Flanges
Hose couplings for Naval Ships
Pipework connectors for barrages
Gears
Flowmeters
Mechanical Seals
Control elements in submarines
Valve connectors
Submarine weapons handling (launch systems)
Sonar equipment components
Diverless deep water oil production equipment

Introduction

HIDURON alloy 191 is a patented high strength precipitation hardened cupronickel alloy containing about 14.5% nickel and 4.5% manganese strengthened by additions of aluminium and iron, which may be refined by controlled small amounts of chromium.

In many critical marine applications, for example on oil platforms and naval ships, the requirement for instant service following periods of inactivity favours the anti-fouling and corrosion resistance characteristics of a cupronickel; but conventional cupronickels have the disadvantage of inherently low strength. A combination of high strength with good corrosion resistance and impingement resistance is achieved with nickel aluminium bronze but the higher strength levels are only achieved at the expense of toughness with consequent limited resistance to shock.

HIDURON alloy 191 was developed to provide the best features of both kinds of alloy to meet the requirements of these demanding marine applications. Its resistance to marine corrosion is comparable with that of the conventional cupronickels, the combination of tensile strength and toughness is far superior to that available with aluminium bronzes and its properties are largely independent of section size. In addition, HIDURON alloy 191 has the relatively high modulus of elasticity of a cupronickel compared with most other bronzes.

HIDURON alloy 191 is ideal for shafts, fasteners, valve stems, flanges and other critical high strength components and finds wide application in surface and subsea naval vessels and on offshore oil and gas platforms.

The alloy has the inherent good resistance to bio-fouling of a cupronickel whilst the additional elements in its composition not only improve mechanical properties but also increase resistance to localised corrosion and to impingement attack in seawater. The alloy meets the requirements of NACE MR-01-75. HIDURON alloy 191 is virtually non-magnetic and possesses excellent sub-zero properties.

HIDURON alloy 191 has good machineability, good weldability and can also be forged, hot upset and thread rolled without difficulty. This alloy is covered by the MOD specification NES 835 (formerly DGS 357) to which it can be supplied when required.

Mechanical and physical properties

The minimum mechanical properties are shown below. Careful production control has been established to ensure that bar, forgings and stampings are suitable for the production of high integrity components and when agreed with the customer, material is subject to dye penetrant and ultrasonic inspection to ensure freedom from harmful internal and surface defects. The material is usually supplied in the heat treated condition, designed to give optimum flexibility for subsequent operations by the customer.

Minimum mechanical properties for bar and forgings (R.T.)

	Bars below 15 mm diameter	Bars of diameter 15-125 mm	Forgings, and bars of diameter above 125 mm
0.2% Proof Stress, N/mm²	430	430	400
Tensile Strength, N/mm²	725	725	710
Elongation, %, on $5.65\sqrt{S_0}$	18	18	18
Izod Impact, Joules	—	40	40
Brinell hardness		210 typical	

Typical physical properties

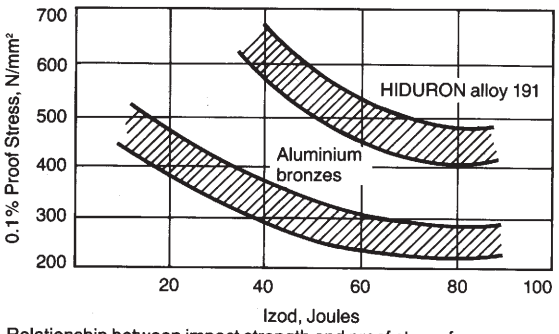
Melting range, °C	1030-1085
Coefficient of thermal expansion (20-300°C) kelvin^{-1}	16.0
Thermal conductivity at 20°C, watt/metre kelvin	25
Specific heat at 20°C, joule/kilogram kelvin	435
Electrical resistivity at 20°C ohm mm^2/m	0.35
Electrical conductivity at 20°C, m/ohm mm^2	2.85
Magnetic permeability	<1.01
Modulus of elasticity, N/mm^2	148 × 10^3
Modulus of rigidity, N/mm^2	52 × 10^3
Density at 20°C, g/cm^3	8.53

Comparison of the mechanical properties of HIDURON alloy 191 with aluminium bronzes and cupronickels is shown below, whilst figure 1 further shows its superior toughness as compared with aluminium bronzes.

Typical mechanical properties of HIDURON alloy 191 compared with some aluminium bronzes and cupronickels

	0.2% Proof Stress N/mm^2	Tensile Strength N/mm^2	Elongation on 5.65$\sqrt{S_0}$ %	Izod Impact Joules
HIDURON alloy 191	500	750	23	60
90/10 Cupronickel to BS CN102 (NES779)	120	320	38	150
70/30 Cupronickel to BS CN107 (NES780)	150	350	42	150
Nickel aluminium bronze to NES833 (DGS 1043)	310	710	28	38
Aluminium silicon bronze to NES834 (DGS 1044)	260	570	44	55

Figure 1



Relationship between impact strength and proof stress for aluminium bronzes and HIDURON alloy 191.

As with the conventional cupronickels, HIDURON alloy 191 is generally suitable for continuous service from −196°C up to 300°C, with little change in tensile properties over this temperature range. In considering applications involving continuous exposure above 250°C, some loss of strength and ductility must be anticipated and it is recommended that this should be regarded as the upper limit of service temperature on most occasions. A particular feature of HIDURON alloy 191 is that unlike many copper alloys, it may be heated to temperatures above 600°C and air cooled without loss of ductility and with only moderate loss in room temperature strength.

The thermal, electrical and magnetic properties, and modulus of elasticity of HIDURON alloy 191 are similar to those of 70/30 cupronickel. HIDURON alloy 191 is of slightly lower density however and also has about twice the hardness of conventional cupronickels in the hot worked or annealed condition.

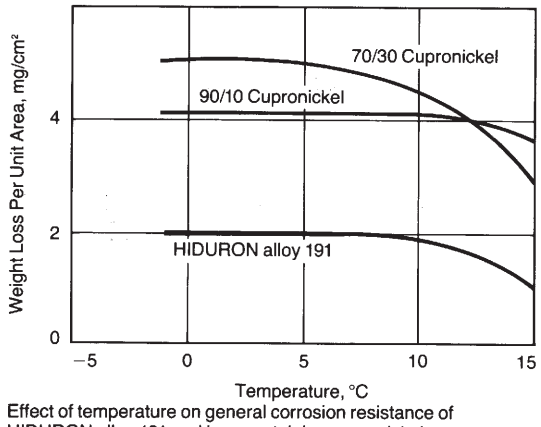
The fatigue limit at 10^8 cycles in air for HIDURON alloy 191 at 230 N/mm^2 is intermediate between the value of about 160 N/mm^2 for the conventional cupronickels in the annealed condition and 320 N/mm^2 for nickel aluminium bronze hot rolled bar.

Corrosion resistance

HIDURON alloy 191 is resistant to attack by fresh water, many polluted industrial waters, brackish waters and sea water, and shows very good resistance to biofouling, waterline corrosion, pitting and crevice corrosion. The performance of HIDURON alloy 191 in sea water in comparison with standard cupronickels is shown in figure 2.

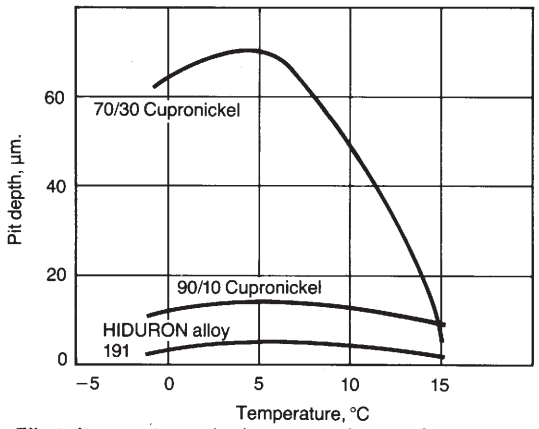
Since HIDURON alloy 191 contains aluminium, it shares with the aluminium bronzes the ability to rapidly reform its protective oxide film under conditions of corrosion/erosion. In jet impingement tests at BNF Metals Technology and the Central Dockyard laboratory resistance to impingement attack and general corrosion was similar to cast nickel aluminium bronze and superior to wrought 90/10 and 70/30 cupronickels containing 1.6 and 0.5% iron respectively. This is demonstrated in figure 3.

Figure 2



Effect of temperature on general corrosion resistance of HIDURON alloy 191 and iron-containing cupronickels in sea water containing 3% added air.

Figure 3



Effect of temperature on impingement resistance of HIDURON alloy 191 and iron-containing cupronickels in sea water containing 3% added air. The water speed at the jet was 9.2 m/s and the duration of test was 28 days.

HIDURON alloy 191 is galvanically compatible with most copper based alloys, including 70/30 cupronickel and nickel aluminium bronze, and has a potential of minus 0.19 volt (SCE). Although aluminium bronze and HIDURON alloy 191 are intrinsically less noble than the high chromium duplex and austenitic stainless steels the ability of these copper based alloys to form a passive aluminium rich oxide layer usually protects them against significant preferential corrosion when coupled with stainless steels. When dissimilar metals are present, good design can usually minimise the danger of galvanic corrosion by ensuring the more noble components are of smaller surface area.

Cupronickels, including HIDURON alloy 191, are superior to the aluminium bronzes with regard to stress corrosion in the presence of ammonia. However, in common with all copper-based alloys, at high stress the presence of ions such as ammonium and mercury could lead to SCC.

Resistance to hydrogen embrittlement

Most high strength nickel based alloys, high tensile steels, duplex stainless steels and titanium are prone to hydrogen embrittlement, the effect being usually more severe as the strength increases. Thus the high nickel or nickel based alloys in a high strength condition are much more susceptible to hydrogen embrittlement compared with the same alloy in a lower strength condition. Cathodic protection applied in the interest of a steel structure immersed in sea water will give rise to the release of nascent hydrogen at the surface of the structure. Hydrogen may also arise by the coupling of dissimilar metals, and be a problem when evolved at a more noble fastener alloy. This hydrogen can then penetrate the surface of a nickel or iron-based alloy if it is part of the immersed structure and lead to embrittlement in a relatively short space of time.

Independent slow strain rate testing by one of the major oil companies on HIDURON alloy 191 has shown freedom from hydrogen embrittlement under an imposed potential in sodium chloride solution. Results for this alloy and other bolting materials are presented below.

A clear advantage can be seen for HIDURON alloy 191, since the other alloys suffer a marked diminution in elongation and reduction of area after exposure. The nickel-copper alloy K-500 shows a fall of about a third in elongation and over a half in reduction of area. HIDURON alloy 191 exhibits little change after exposure for over twice the period.

Slow strain rate test results

Specimen exposed in 3.5% NaCl with imposed potential of −1.0v (SCE) and then tested at strain rate of 5×10^{-6}/S, potential of −1.0v was maintained during test.

	UTS N/mm²	% Elong	% Reduction of area
HIDURON alloy 191			
Before exposure	795	24	59
After exposure (2000 hrs)	812	22	61
Alloy K-500 (BS3076: NA18)			
Before exposure	1015	24	37
After exposure (915 hrs)	986	15	17
ASTM A193 B7 Alloy (Q&T)			
Before exposure	1078	19	62
After exposure (2000 hrs)	1031	12	18
Duplex Stainless Steel			
Before exposure	985	40	72
After exposure (400 hrs)	848	19	22

Presented at "Marine Engineering with Copper Nickel" Conference, London by R Butler (BP Research, Sunbury on Thames) April 1988.

Other high nickel alloys such as nickel-chromium-iron alloys (for example, alloy 925) references 1 and 2, and nickel-chromium-molybdenum alloys (for example, alloy 625) reference 3, have been shown to suffer from hydrogen embrittlement.

Ref 1. KD Barr, JA Harris and RH Moeller UK Corrosion '86, Birmingham 1986. Organised by I Corr, ST.

Ref 2. JG Erlings, HW deGroot, and JFM van Roy Materials Performance, October 1986 P28. Stress corrosion cracking and hydrogen embrittlement of high-strength non-magnetic alloys in brines.

Ref 3. NA Sorokina, VI Malkin, VI Galtsova and IV Vaganova. IZV. Akad Nauk. SSSR Met (1987), 2,133.

MARINEL™ alloy has been developed from HIDURON alloy 191 for applications where the latter alloy does not possess sufficient strength. The new extra high strength cupronickel has a 0.2% proof stress minimum of 720 N/mm².

Anti galling properties

The resistance to pickup by HIDURON alloy 191 is good. This applies to the alloy operating against itself and with other materials.

HIDURON alloy 191 operates successfully against nickel aluminium bronze and FERRALIUM® alloy 255 in the control elements of conventional and nuclear submarines.

Use is also made of HIDURON alloy in combination with the high strength duplex stainless steel to obviate galling problems in a diverless deep water oil production system and other subsea control equipment.

Fabrication

Hot working

A wide range of wrought products is supplied, including bar, forgings and stampings. If material is to be hot worked, for example, hot heading of fasteners please consult our Technical Department for details.

Welding

HIDURON alloy 191 can be welded satisfactorily using consumables of matching composition, although as with other copper-base alloys strengthened by precipitation hardening or cold work some loss of mechanical strength occurs. It should be emphasised that the mechanical properties of material in the as-welded condition and also of welds subjected to post-weld heat treatment are still much superior to conventional cupronickels in the unwelded condition.

Room temperature properties measured on 1″ diameter test bars of HIDURON alloy 191 after heating for one hour at the stated temperature and air cooled

Temperature °C	0.1% Proof Stress N/mm²	Tensile Strength N/mm²	Elongation % on $4\sqrt{S_0}$	Reduction in Area %
600	575	815	22	50
700	457	692	33	60
800	366	658	46	65
900	366	658	46	57
1000	386	663	44	43
1050	386	656	45	43

Mechanical properties of TIG welds in HIDURON alloy 191

Mechanical Property	As-deposited Weld Metal	Precipitation Hardened Weld Metal	Parent Metal Typical Properties
Tensile Strength N/mm²	470	680	750
0.2% Proof Stress N/mm²	300	410	510
Elongation on $5.65\sqrt{S_0}$, %	32	25	25
Izod Impact, J	70	40	70

Brazing and soldering

HIDURON alloy 191 should be brazed by the same procedures as for the aluminium bronzes using special fluoride-containing fluxes and silver brazing alloys of low-melting point (about 650°C). Soft soldering can also be carried out by similar procedures to those employed for the aluminium bronzes using a flux of phosphoric acid solution with a minimum specific gravity of 1.75. It should be noted that both brazing and soldering of HIDURON alloy 191 are easier than for the aluminium bronzes.

Machining

HIDURON alloy 191 can be readily machined to give an extremely good finish, using methods normally employed with high strength aluminium bronzes. If fuller details are required, please consult our Technical Department. Thread rolling in the production of fasteners can be applied satisfactorily.

Dimensional stability is good, and although normally no stress relief is required, in special cases where dimensional tolerances are critical it may be desirable to heat treat for 1 to 2 hours at 400°C.

Heat treatment

HIDURON alloy 191 is normally supplied fully heat treated to provide the optimum combination of strength and toughness. If re-forging operations are carried out by the customer subsequent heat treatment to obtain the minimum specification properties will not normally be required. However, when upsetting or welding operations are planned a final heat treatment to improve mechanical strength may be considered desirable and advice on this aspect is available from our Technical Department.

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