PREVENTING BIOFOULING WITH COPPER-NICKEL

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Long-term protection against biofouling on marine structures can be afforded by copper and copper alloys, particularly 90-10 copper-nickel, in the form of sheet or as a variety of composite products, hence avoiding costly removal of fouling by mechanical means or periodic re-application of antifouling paints.

Marine biofouling is commonplace on marine structures including pilings, offshore platforms, boat hulls and even occurs inside piping and condensers. For steel, polymer and concrete constructions, biofouling can be a severe problem, resulting in unwanted excess drag on structures and marine craft, and causing blockages in pipe systems. Regular removal is required often by expensive, mechanical means, such as by divers using high pressure water on offshore platforms, or costly prevention methods must be employed including chlorination of pipework systems or antifouling coatings.

Copper-nickel alloys and copper itself have a high natural resistance to biofouling. Copper-nickel has proved its performance over many years in applications such as sea water pipework and intake screens, water boxes, and for cladding of offshore structures and boat hulls. Other metals such as steel, titanium and aluminium foul readily.

Exposure Trials

Panels from 55 week exposure trials conducted at Langstone Harbour showing effects of cathodic protection on biofouling resistance of copper-nickel. Panels are, left to right, *steel, copper-nickel cladding on steel, copper-nickel panels with aluminium anodes*, and, on the far right, *freely exposed copper-nickel.*

Copper Mariner

One of the early solid copper-nickel hulled vessels.
After 16 years, it had not required lifting for hull cleaning.

For optimum biofouling resistance of copper-nickel

- Insulate from less noble materials
- Avoid surface contamination
- Avoid extended exposure in stagnant and polluted water

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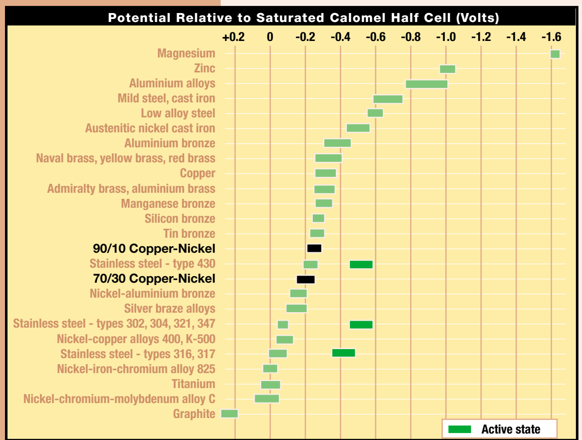
GOOD ANTIFOULING PROPERTIES....



Galvanic Series

To maintain optimum fouling protection copper-nickel must not be galvanically coupled to less noble alloys

90-10 Copper-Nickel Sheathing on Platform Legs in Morecambe Field

After 17 years sheathing is still performing well. Although sheathing is cathodically protected, it carries less than one third of the fouling that adheres to adjacent steel below the water line.

Copper-nickel alloys for boats and marine structures resist biofouling most effectively in open seas where the low biofouling adherence does not allow the slime layer to build up sufficiently to support macrofouling. Two early solid copper-nickel hulled vessels, the Asperida and Copper Mariner, when last located, had been in service for 29 and 16 years respectively. Both had experienced negligible fouling.

Under long term quiet conditions, fouling may eventually build up but it is not strongly adherent as on other surfaces. It can easily be removed by a light scraping action and has been observed to slough away periodically. On boat hulls, experience suggests that a self-cleaning mechanism exists as service velocities of 3-8 knots have been found to be sufficient to remove accumulations which have become attached during extended moorings.

For optimum resistance the copper-nickel must be freely exposed and not cathodically or galvanically protected. This means that ideally it should be electrically insulated from the structures it is cladding. However, even when cathodic protection has been applied, the level of fouling has been found to be much less than on adjacent unclad steel. For example, in the case of welded sheathing on the legs of platforms built for Stage 1 of the Morecambe Field, the level of fouling was less than one third of that on adjacent bare steel and was far more easily removed.

Biofouling Mass on 90-10 Copper-Nickel Sheathed Pilings after 10 Year Exposure

LaQue Centre For Corrosion Technology, North Carolina

Piling	Biofouling Mass kg m^{-2}	Percentage Area Covered %
Bare Steel Control	12	100
Concrete Insulated	0.14	1.2
Directly Welded	4.43	36.8
Rubber Insulated	0.62	5.3

Note the importance of electrical insulation between the copper-nickel sheathing and the steel.

ANTIFOULING MECHANISMS

The reason for the antifouling behaviour of copper-nickel alloys is still not fully understood. Initially, it was thought to be due to copper ions leaching from the surface. This has been disputed as copper-nickel has a lower corrosion rate than copper and still exhibits a similar level of fouling resistance. Also, even when cathodically protected, some level of biofouling resistance is retained over long exposure times. Current theories are that the protective surface film, which forms naturally in sea water, plays a part in the antifouling mechanism.

....AND GOOD CORROSION RESISTANCE TOO

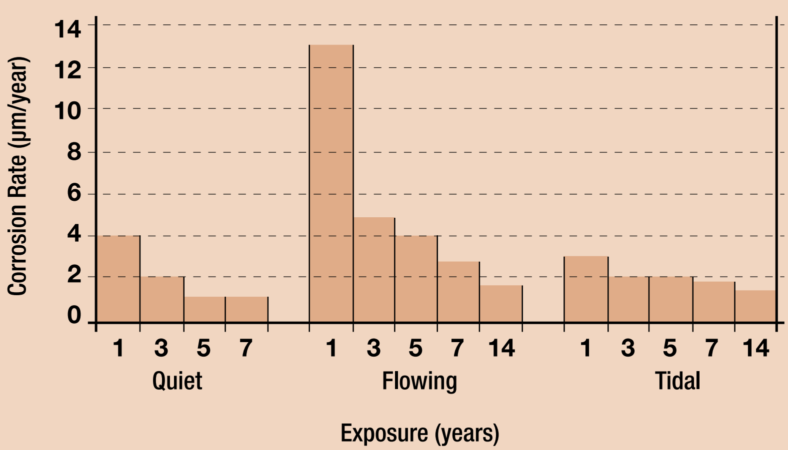
Copper and copper-nickel alloys also have a high resistance to corrosion in sea water. Copper-nickels were originally developed for sea water condenser and pipework service and this is still one of their major fields of application. General corrosion rates for copper-nickels tend to decrease with time. Once the protective surface films have matured, corrosion rates are lower than for copper and can be of the order of 1-2 microns per year. Copper-nickel alloys have a good inherent resistance to chloride pitting and crevice corrosion seldom occurs. They are also resistant to chloride and sulphide stress corrosion cracking and have not been found to suffer cracking due to ammonia in sea water service.

Copper-nickels give optimum performance in clean sea water because under these conditions a highly protective surface film forms. In polluted water, where sulphides are present, a film which is less protective may eventually form, and this can lead to higher corrosion rates. Initial exposure to clean aerated sea water to build up the correct surface film will provide a degree of protection from subsequent exposure to sulphides. For example, adequate protection is provided for the duration of normal turn-around times for ships in polluted harbours.

Fluid flow rates of up to 3.5-4m/sec are normally recommended for copper-nickel pipework. These values are now considered to be conservative, but such guidelines have worked well because they take into account normal velocity raisers within pipework systems such as bends which can cause areas of high local flow rate. Nevertheless, extreme turbulence has to be avoided. It is now thought that, at high water velocities, the shear stress acting on the protective surface film on the metal exceeds a critical value and breakdown of the film occurs, leading to high corrosion rates. The hydrodynamics around a boat hull or an offshore structure are somewhat different from those in pipework systems and greater fluid velocities can be tolerated. Experience with boat hulls has shown minimal corrosion occurs after 14 months at 24 knots (12m/s) and the highest recorded fluid velocity tolerated is 38 knots (19m/s). This was on a patrol boat which showed no measurable loss of hull thickness after 200 hours at maximum operating speed.

The Change in Corrosion Rate with Time for 90-10 Copper-Nickel in Quiet, Flowing (0.6m/sec) and Tidal Sea Water

Data was measured at LaQue Centre for Corrosion Technology, North Carolina



COMMERCIAL PRODUCTS ARE AVAILABLE

Besides weldable sheet and plate, innovative products involving composite forms of copper-nickel are now available. These are easily applied and offer a promising, long-term alternative to the use of antifouling paints. Unlike the paints in common use, they do not require replacement every 2-5 years and their use does not pose the environmental threat which has been recognised to exist with toxic organo-tin copolymer coatings.

PRODUCTS FOR BIOFOULING RESISTANCE OFFSHORE

Sheet can be welded to the structure but, in order to achieve maximum biofouling resistance, there must be electrical insulation between the copper-nickel and the steel substructure. This can be achieved by filling the space between the sheathing and steel with cement and epoxy or, more simply, by using an elastomer or rubber-based insulator.

Composite products include copper-nickel on an insulated substrate. The metal can be in the form of granules, particles, wire mesh or foil.

One composite product which has been successfully used for splash zone protection of structural legs, cross bracings and riser pipes consists of discrete granules of copper-nickel, 1mm in diameter and 1mm long, bonded into the surface layer of 3mm polychloroprene rubber sheet *(see photo - top right)*. The processing of the layer ensures that the granules are distributed and exposed over the surface so that 30% of the surface is copper-nickel and the granules are sufficiently close to allow complete surface protection. This product can be hot bonded on to elastomeric coatings or cold bonded directly on to steel. The density of the layer has been developed so that the copper-nickel will convey an estimated life expectancy of 40 years. The type of product was originally developed in 1984 with 25,000 square metres supplied worldwide.

The sheathing product has been more recently developed to provide subsea markers which can be attached to pipelines, offshore platforms and other marine structures and components. The markers maximise the effective use of diver, ROV, AUV and DSV time during inspection, repair and maintenance. They can be installed on offshore steel or concrete structures, templates, manifolds, Christmas trees, well heads, spool pieces, pipelines and umbilicals. The markers can be made in large or small sizes and are pigmented with a yellow background and black characters to allow high visibility *(see photo - centre right)*. They can be bonded, strapped, bolted or clipped in position.

Another type of composite system can also be applied to boat hulls, with the added advantage that it can prevent osmosis in fibreglass hulls as well as provide a high resistance to biofouling. This involves applying a matrix of small 5mm square tiles, 150 microns thick, aligned together by a tough, high bond, waterproof acrylic adhesive, insulating membrane. The surface to be exposed to the water has a protective cover that is only removed when the hull is completely sheathed. The narrow areas between the tiles are filled with an epoxy grout prior to launching. Durability well in excess of 20 years is predicted.

There are two methods of application. For the first, the matrix requires only a roller action at moderate temperatures to apply and can be used for new build or retrofit. A further development of this product can be integrated into the moulding of new hulls.

Courtesy of Dunlaw Engineering

Early trials with Cuproprene (previously known as Avonclad) off the California coast

Courtesy of Dunlaw Engineering

Cupromark subsea marker

Hull sheathed with Cupro FF self-adhesive 90-10 copper-nickel

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