High-Strength Marine Metals - Part 2
Copper & Nickel Alloys

High Strength with High Corrosion Resistance

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Bronze Kranz Iron, Anchor Roller, and Hawse Holes, with Stainless Steel Stanchions and Rod Rigging

In the previous article we examined stainless steel. We saw what alloys are appropriate for marine use and what stainless steel's weak points are. Here, we'll take a look at copper and nickel alloys suitable for applications on boats. Though frequently (not always) somewhat more expensive than stainless steels, copper- and nickel-based alloys have much to recommend them.

Bronze

It's really is a shame that stainless has become the "standard" metal for so many marine fittings recently. It wasn't always so. Unlike stainless, good-quality marine bronze doesn't suffer from pitting, crevice corrosion, or weld corrosion cracking. Many bronzes are as strong as stainless, and bronze can be more easily cast and worked into complex shapes than stainless. Even better, bronze is more ductile (it stretches and gives more) which provides an additional margin of strength and safety—more energy absorbed before failure.

Perhaps the most important question is: What's the difference between bronze and brass? Once, this was relatively simple—brasses were of copper alloyed with zinc, and bronzes were of copper alloyed with tin, with very little or no zinc at all. Either brass or bronze could have a variety of other elements stirred in to adjust strength, elongation, and machineability. Over the past several hundred years or so, "new" varieties of bronzes have been developed. The old standard bronzes are usually called "tin bronzes." Now, these may also have phosphorus added and so are sometimes called "phosphor bronzes." The alternatives are "aluminum bronzes," which have 5 to 8 percent aluminum, while "silicon bronze" has . . . you'll never guess . . . silicon added.

Keel bolts, for lead keels on fiberglass or wooden hulls, shouldn't be of stainless. Such bolts are (as we saw in the previous article) in exactly the worst environment for stainless underwater—in stagnant water (when any water gets in and it will). I once had a young engineer at a major

keel manufacturer solemnly explain that bronze wasn't strong enough for keel bolts?! I managed not to laugh. Not only does bronze have nearly the same tensile strength as stainless, but bronze's corrosion resistance is infinitely superior in this application. Bronze keel bolts are *the* standard and have been for over 150 years.

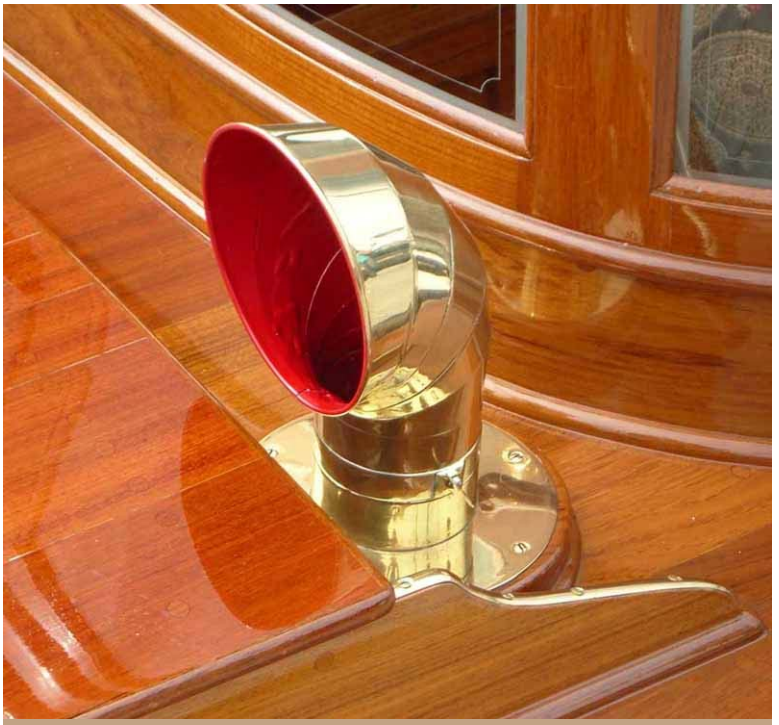
Bronze Windlass, Cleats, Chain Pipe, Stanchions

The best known silicon bronze is probably Everdur, a trademark bronze generally of 95% or higher copper, with about 3% silicon, and 1% manganese. Silicon bronze (Everdur) is about my all-around favorite marine metal. The top pick for most marine screws and bolts, it has a tensile strength of 90,000 psi in hard temper and 55,000 psi in soft temper. It'll never corrode (unless you're foolish enough to fasten it directly to steel or aluminum, where it will cause corrosion in the aluminum or steel). It can be cast, welded, rolled, bent and otherwise formed without harm. If I had my way, every fitting on a boat would be made from silicon bronze. (Of course, this is on fiberglass or wood/wood-epoxy hulls. Aluminum or steel boats should use proper marine stainless to minimize galvanic corrosion.) A silicon bronze rudder stock will simply never fail from corrosion.

If you don't like polishing bronze deck hardware (and don't want to just let it "go green," which is harmless) get it chrome plated. Now that's Bristol fashion! (This must be proper, marine-grade, high-quality chrome plating. Careful preparation over 2 or 3 nickel base coats, and multiple chrome coats are required. Cheap chrome plating will peel off and look awful in a very short time.) Phosphor and aluminum bronzes are also exceptional for almost all marine applications.

Cast Bronzes and Zinc

There's a bit of a conundrum when it comes to casting bronze. Though, say, true silicon bronze can be cast successfully, it is more difficult to cast cleanly with defined edges as well as more difficult to machine after casting. Adding zinc greatly improves bronze's castability. The question is, are such "bronzes" really bronze or are they brass. There doesn't seem to be a clear delineation on this, but copper alloys with less than 15% zinc are unlikely to suffer from dezincification. The lower the zinc content the better. Generally, alloys of copper, with less than 6% zinc content can be considered bronzes and immune from dezincification. Some of these alloys, however, are called brasses. A good example is 115 Red, C83600 Cast Leaded Red Brass. Its composition is 85% copper, 5% tin, 5% lead, and 5% zinc. Though called a brass, with such low zinc content, it's effectively a bronze. 115 Red is a good alloy for casting many marine fittings.



Polished Brass Sheet Metal Cowl Vent

Nickel Aluminum Bronze

Both bronze (including so-called manganese bronze) and stainless steel are used for propellers. Such bronzes are the low-cost approach for propellers that aren't highly loaded. Stainless propellers are high strength and can have thin blades, which are ideally suited for high-speed, high-stress applications. Such stainless propellers, however, can suffer from the same pitting and crevice corrosion that all stainless steels can experience in saltwater. Nickel aluminum bronze is the answer for high strength plus high corrosion resistance in props. NiBrAl is about

80% copper, 9% aluminum, and 5% nickel. Tensile strength is 90,000 psi, with tensile yield of 40,000 psi.

Fake Bronze That's Really Brass

As, we've seen, where bronze is copper alloyed with tin (or silicon, or phosphorus, or aluminum) brasses are copper alloyed primarily with zinc. Most brasses should not be used for structural purposes on a boat. The reason is that the zinc is so far apart from the copper on the galvanic scale that the brass will suffer from severe corrosion called *dezincification*. The zinc will literally dissolve away leaving a brittle spongy mass with no strength at all. Brass can and does make fine interior hardware and low-strength deck fitting, however.

Composition of Nickel Based Alloys

Alloy	Ni	Cu	Fe	Mn	C	Si	S	Co	Al	Ti	Cr	Mo	W	V	P	Nb+Ta
Monel 400	63.0 min	28.0-34.0	2.50 max	2.00 max	0.30 max	0.50 max	0.024 max	-	-	-	-	-	-	-	-	-
Monel K-500	63.0 min	27.0-33.0	2.00 max	1.50 max	0.25 max	0.50 max	0.01 max	-	2.30-3.15	0.35-0.85	-	-	-	-	-	-
Inconel 600	72.0 min	0.50 max	6.00-10.00	1.00 max	0.15 max	0.50 max	0.015 max	-	-	-	14.0-17.0	-	-	-	-	-
Inconel 601	58.0-63.0	1.00 max	Bal.	1.00 max	0.10 max	0.50 max	0.015 max	-	1.00-1.70	-	21.0-25.0	-	-	-	-	-
Inconel 625	58.0 min	-	5.00 max	0.50 max	0.10 max	0.50 max	0.015 max	1.00 max	0.40 max	0.40 max	20.00 - 23.00	8.00-10.00	-	-	0.015 max	3.15-4.15
Hastalloy C-276	Bal.	-	4.00-7.00	1.00 max	0.01 max	0.08 max	0.03 max	2.50 max	-	-	14.50 - 16.50	15.00-17.00	3.00-4.50	0.35 max	0.04 max	-

Values are percentages

There are some brasses which masquerade as bronzes, however. The four most common of these fakers are manganese bronze, Tobin bronze, commercial bronze, and naval brass. Manganese bronze is a complete misnomer (though it is the correct name for some unknown reason). In fact, manganese bronze is 58% copper and 39% zinc (with 0.8% manganese)—a true brass. Tobin bronze is 60% copper, 39.2% zinc, and 0.7% tin, a true brass again. Commercial bronze is 90% copper and 10% zinc—too much zinc to be a true bronze, but—in this case, at under 15% zinc—moderately resistant to dezincification. Naval brass is at least properly named as a brass. It is 60% copper and 37.5% zinc. Because it has the word "naval" in it, however, there's a tendency to think it can be used for marine applications underwater. It shouldn't be. It should be limited to use on deck and in the interior.

Bronze Rudder Stock, Rudder Stop, and Straps

Interestingly, manganese bronze, Tobin bronze, and commercial bronze are widely employed for not only fittings like cleats, and chocks, and portlights, but even for propellers and struts. The reasons is that they are strong (initially), easy to cast, and easy to machine. In fact, they give adequate service on deck and excellent service in the interior, but are potential problems below the waterline. When used for propellers or propeller struts—which is surprisingly common—care must be taken to protect these manganese-, Tobin- or commercial-bronze (really brass) fittings with zinc anodes. These anodes have to be inspected and renewed regularly. Proper silicon bronze is much better. The best propeller material, as we've seen, is nickel aluminum bronze, usually called NiBrAl or nibral.

A common comment regarding bronze is that it's difficult to find. Two sources of bronze in all shapes and in plates are:
Atlas Metal www.atlasmetal.com
Anchor Bronze & Metals, Inc. www.anchormetals.com
Sources for bronze fasteners are:
Jamestown Distributors www.jamestowndistributors.com
Aarons Silicon Bronze Fasteners
www.aaronssiliconbronzefasteners.com
Bristol Bronze www.bristolbronze.com

Monel

The real king of all marine metals is Monel. It's drawback is higher cost, but whether it's fuel or water tanks, keel bolts, fasteners, or custom hardware, no other metal provides the combination of high strength and corrosion resistance that Monel offers. Monel is nickel and copper alloyed with other elements. Monel 400 is 63% nickel, 28% to 34% copper, 2.5% iron max., 2% manganese max., 0.024% sulfur max.,

0.3% carbon max., and 0.5% silicon max. Tensile strength is 80,000 psi, and tensile yield strength 35,000 psi. Monel K-500 has a somewhat different chemical composition with incredibly high strength: 100,000 psi tensile strength and 70,000 psi tensile yield strength. Monel is also the best keel bolt material. Though silicon bronze is excellent, Monel is better still. Interestingly—and somewhat counterintuitively—Monel is the ideal keel-bolt material for cast-iron keels—highest strength, high corrosion resistance, and galvanically compatible with the cast iron.

Cast Brass Side Light

Copper-Nickel

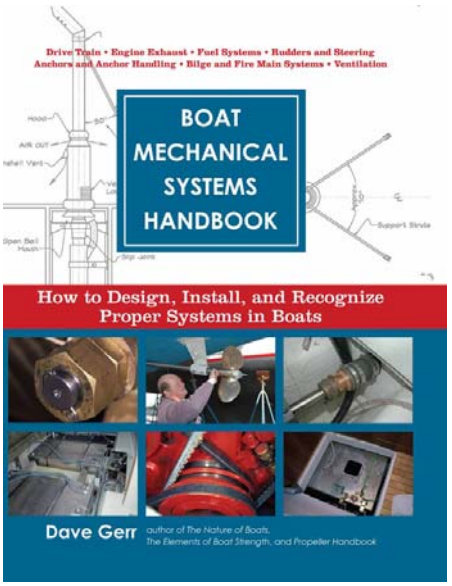
A lesser known metal is copper nickel. Obviously, this is primarily copper alloyed with nickel. Copper-nickel CA-706 is 90% copper and 10% nickel, with a tensile strength of 40,000 psi or 55,000 psi in one-quarter hard. CA-715 is 70% copper and 30% nickel, with a tensile strength of 45,000 psi. The very special characteristic of copper-nickel is that it's non-fouling without any bottom paint. Yes, almost completely and virtually forever. A few workboats have been fabricated with all copper-nickel hulls. Though their initial cost is very high, the payback—over several years of operation—is in savings from no haul-outs or bottom painting, as well as increased fuel economy from always having a clean bottom. Still, that's not the primary use for copper nickel. It's most common application is in keel coolers for boats with dry exhaust. It also makes excellent sea strainers.

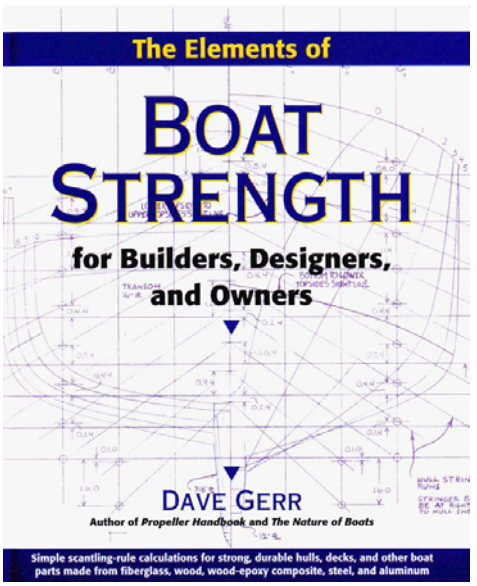
Inconel and Hastalloy C

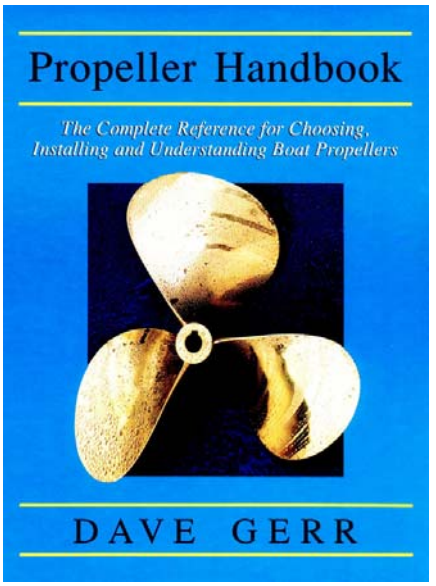
The least know of the nickel-based alloys are Inconel and Hastalloy C. These alloys are so corrosion resistant they can withstand acid at boiling temperatures. You wouldn't think there was call for such materials on boats, but there is in one specific use—exhaust piping. Though stainless (316L or 317L) can be used for custom dry exhaust risers and exhaust pipes, nothing beats the corrosion resistance of Inconel and Hastalloy C for this purpose. These metals are also very strong with tensile strengths from 80,000 psi to 130,000 psi depending the alloy. If you are specifying custom dry exhaust risers, Inconel and Hastalloy C—though pricy—are worth every penny.

Steel and Aluminum

We haven't discussed steel and aluminum in these two articles. Steel is certainly high strength, but it is far too prone to rust and corrosion for use in most marine hardware or fittings. Aluminum—proper marine aluminum—is widely used for all sorts of hardware and fittings, from window frames, to sail tracks, to cleats, to spars, and much more. Aluminum—compared to stainless, bronze, Monel—however, is both weaker and softer. It's thus not a high-strength metal. Of course, both steel and aluminum make excellent boat hulls. We'll take a look at them in a future article.







Books by Dave Gerr, available from Amazon.com