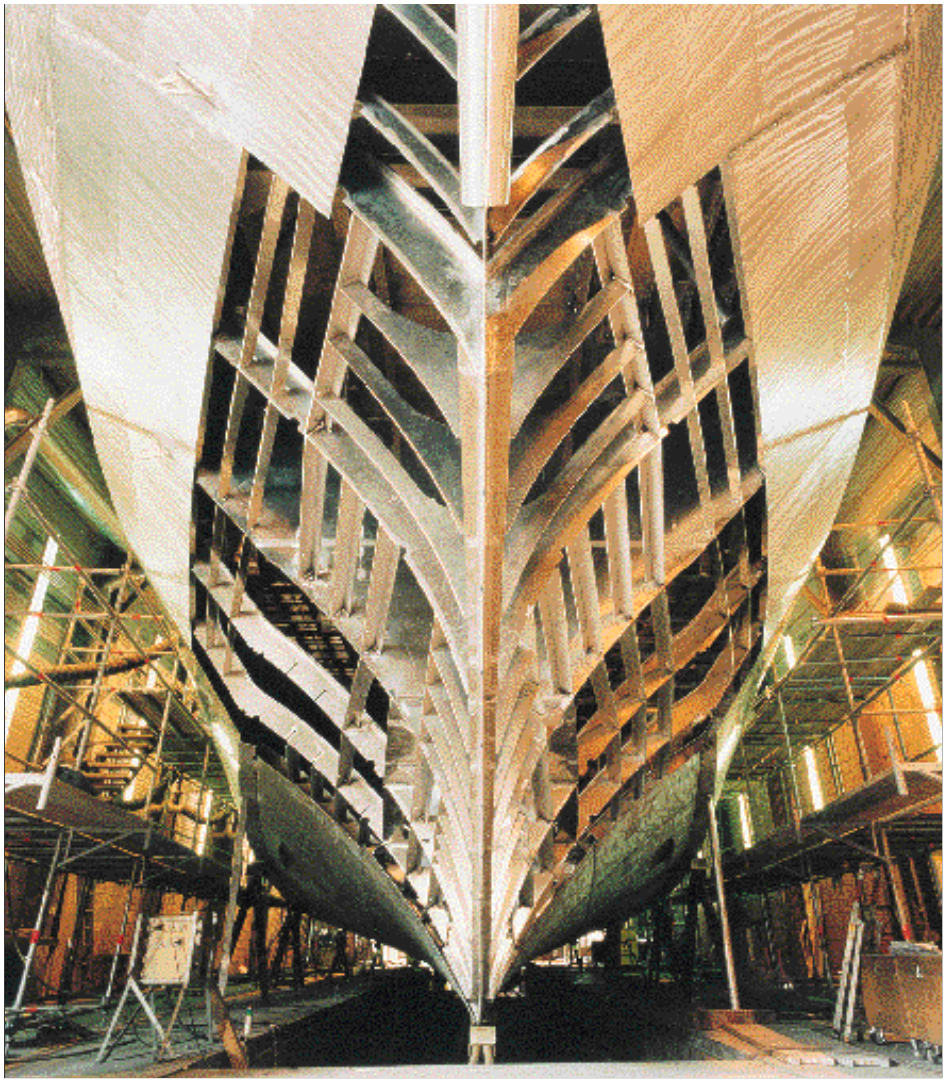
ALUMINUM ALLOY BOATBUILDING

The first aluminum pleasure boat, a 40 ft motor yacht, "Le Mignon", was reportedly built in France in 1891. Forty years later in England, the 55 ft motor yacht named "Diana II" was the first hull built with modern, high strength aluminum alloys. This vessel was successfully operated by the Royal Navy during World War II and was still in commission well into the 1960's.



Today this material is widely used throughout the world, notably in the US and Holland for the construction of motor yachts of all sizes. Today, it is mainly used for the building of one-off yachts, as fiber reinforced plastic (FRP) remains the leading material for the manufacture of production boats.

Aluminum alloys used by the marine industry have high mechanical properties and a good resistance to corrosion. They are produced in a wide variety of sheets and plates of different thickness, and extrusions of various shapes. After 100 years in existence, the possibilities in aluminum boat building guarantee new developments in the years to come.

Construction Files...

Boatbuilding aluminum alloys

The most frequently used aluminum alloys in the shipbuilding industry belong to the 5000 and 6000 series which have a magnesium content of 3 to 4 percent, in addition to other metals in lesser quantities. While the copper content is much lower than other aluminum alloys with higher mechanical properties, these alloys possess a lower resistance to sea water damage.

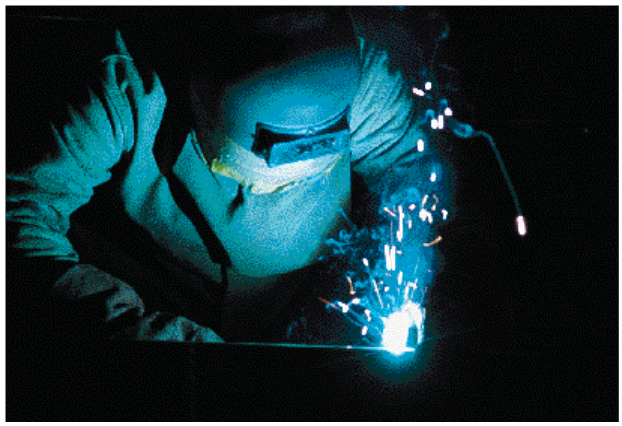
The mechanical properties of the standard 5083, 5086 and 6061 alloys can be further improved by various mechanical and/or heat treatments which are classified by designations such as H111, H32, H34 or T4, T6. These designations indicate the alloy degree of temper and hardness. However it is important to know that these alloys have different mechanical properties after having been exposed to the heat of the welding process. The 6061T6 alloy, widely used for extruded shapes such as sailboat masts, is particularly sensitive to heat.

	Tensile Properties (in psi)			
	Ultimate		Yield	
Alloy	Parent	Welded	Parent	Welded
5083 H111	40000	39000	24000	21000
5083 H321	43500	40000	30500	24000
5083 H341	50000	40000	39000	24000
5086 H111	36000	38000	21000	18000
5086 H32	40000	35000	28000	19000
5086 H34	44000	35000	34000	19000
6061 T6	38000	24000	35000	20000

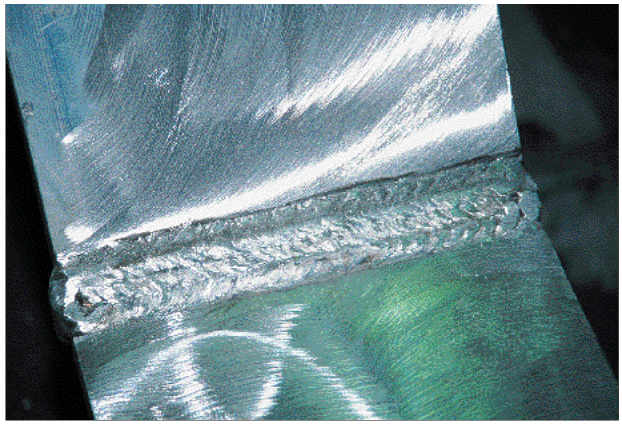
Source: Lloyd's Register of Shipping

Fabrication and joining techniques

Because of the specific gravity and mechanical properties of aluminum alloys, this boatbuilding material does not require heavy tools or equipment for forming and shaping. Subassemblies of fairly large sizes can be prebuilt and handled without heavy lifting equipment. Several modules can be fabricated at the same time before being fitted together. This dramatically reduces the overall building time for large vessels. The first aluminum boats were built with riveted joints. Today, the developments of

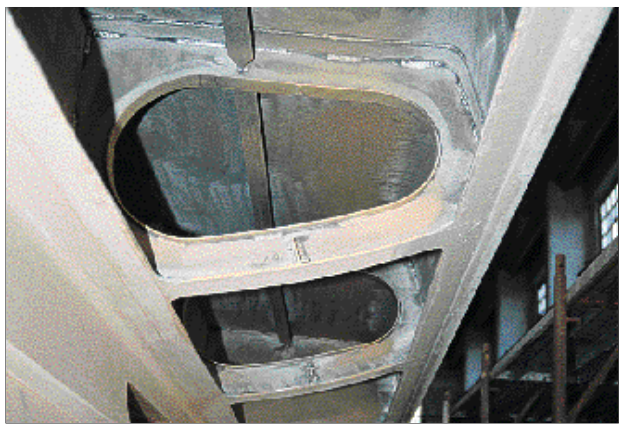


Welding has superseded riveting.



This type of work tells a lot about the quality.

Substantial weight saving can be achevied by using aluminum.



Building and assembly time can be reduced by using standard extrusions.

new techniques and inert gas welding equipment make it possible to weld even thin sheets. The welding of aluminum alloys is usually made under a shield of inert gas (argon and/or helium) to stop the formation of an oxide film which would lower the metal penetration and the weld strength. The two main welding methods are known by their acronyms T.I.G. (Tungsten Inert Gas) and M.I.G (Metal Inert Gas). T.I.G. welding is mainly used for thin sheets and other thin joints. The welder uses a hand-held filler metal rod brought to fusion with the electric arc of a tungsten electrode. M.I.G. welding is the most commonly used technique and is also the most efficient when used for large structures. A consumable aluminum electrode is used to transfer metal to the joint and the arc is enveloped within a shield of inert gas. The welders must be skilled and experienced so as to avoid the numerous weld defects that can occur (lack of penetration, lack of fusion, inclusions, porosity etc ...). The welding sequence must be carefully defined and followed to minimize local distortions, especially since thermal stresses can generate severe bending and/or twisting deformations, sometimes several inches over the length of a hull.

Mechanical assembly by bolting or riveting is commonly practiced on aluminum yachts. However they must be carried out in strict observance of certain rules and principles to guard against galvanic corrosion.

Apart from all aesthetic consideration, an aluminum structure can remain unpainted. It is in fact protected by an oxide film which appears as soon as the metal is exposed to the air.

Owners' and builders' demands have triggered the development of high performance coating and paint systems, that provide a perfect finish to aluminum alloys structures. A typical treatment program generally contains the following steps:

1. Clean and degrease thoroughly
2. Abrade or sandblast to eliminate oxide
3. Apply anticorrosive epoxy primer
4. Apply and sand lightweight fairing compound where needed
5. Apply two coats of epoxy primer
6. Apply 2 or 3 coats of Linear Polyurethane topcoat on topsides
7. Apply 2 coats of antifouling on the bottom

Prevention and protection against corrosion.

The design, construction, maintenance and life expectancy of an aluminum alloy hull require a good understanding of metal corrosion and prevention rules by the designers and builders. There are two main types of corrosion: galvanic corrosion and electrolytic corrosion.

Galvanic corrosion

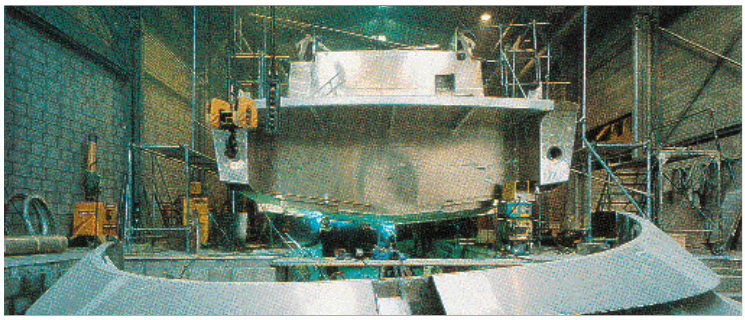
Galvanic corrosion is created by the voltage potential difference between two metals immersed in sea water (the electrolyte) that create a galvanic cell. The metal with the lower voltage potential (the anode) will corrode to protect the higher potential metal (the cathode). This phenomenon can only appear when the two metals are connected, thereby closing the electric circuit. The voltage potential is measured in relation to a constant reference electrode immersed in sea water and connected to an accurate millivoltmeter. The other lead is then connected to the metallic component to be measured (seacock, through-hull fitting, strut or hull plating). Marine surveyors use this type of equipment and procedure to carry out corrosion surveys onboard boats with galvanic corrosion problems.
The following table shows the voltage potentials of various metals immersed in sea water and measured against a silver/silver chloride (Ag/AgCl) half cell used as a reference electrode.

Easy to cut and weld, an aluminum structure is easier to repair than FRP.

From fishing trawlers to yachts, any boat can be build in aluminum.

METALS	VOLTAGE POTENTIAL
Graphite	0.27
Titanium	0.02
316 stainless (passive)	-0.03
Monel	-0.06
304 stainless (passive)	-0.06
Silver	-0.10
Nickel	-0.13
Aluminum bronze	-0.16
Lead	-0.20
Cupro-Nickel	-0.25
Brass	-0.30
Copper	-0.31
Tin	-0.31
316 stainless (active)	-0.39
304 stainless (active)	-0.49
Mild steel	-0.63
Alumnium alloys	-0.87
Zinc	-1.00
Galvanized steel	-1.10
Magnesium	-1.60

A metal is efficiently protected by the cathodic protection system when its voltage potential, measured in relation to the reference electrode, measures 0.20V to 0.25V less than the negative value listed in the table, i.e. about 1.00V for aluminum alloys. Too efficient a protection can result in the formation of alkali and oxygen which can attack the paint. So one must either respect the rules and/or seek the help of a specialist to tackle these problems.



Even on steel hulls, supertructures are often build in aluminum.

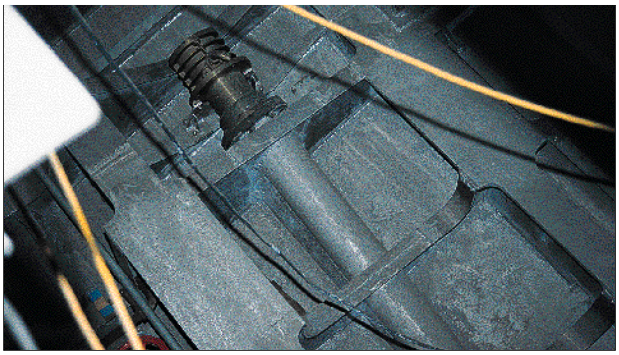
Furthermore, it is essential to follow very carefully some basic principles in the selection and joining of other metals onboard aluminum boats to minimize the risks of galvanic corrosion. For instance, bronze or stainless steel through-hulls, seacocks and/or pumps must be properly electrically insulated from the aluminum hull structure by non metallic materials washers, gaskets or sleeves. Better still, they can be replaced by similar equipment made of synthetic material when available.

Cathodic protection

The basic type of cathodic protection is well known. It is achieved by the installation of sacrificial anodes in various locations of a hull and its appendages. These anodes are usually made of zinc, used because of its low voltage potential in relation to most of the other metals used in boatbuilding. Its voltage potential is around -1.0V (see table). The placement and installation of anodes must follow some rules in order to achieve an efficient protection. Furthermore, their wastage and the efficiency of their installation and connection have to be checked on a regular basis. Anodes number and weight depends mainly on the size and the geometry of the hull. The excessive consumption of anodes over a short period of time indicates a problem which must be identified and corrected as soon as possible.

The cathodic protection of an aluminum alloy structure can be as effectively achieved by an impressed-current cathodic protection system. The basic principle remains the same but it basically transforms the item or structure to be protected into a cathode. The counter electrical current is generated by a battery or a transformer via an inert anode. Its flow is adjusted to give the optimum protection.

Aluminum sub-assemblies can easily be built.



Proper insulation and bonding of a stuffing box is needed to eliminate corrosion.

Electrolytic corrosion

Electrolytic corrosion is caused by a current from an external source, it can be the boat's own AC or DC systems or the shore power supply. On any boat, but even more so on those built in aluminum, poor electrical installations, "do it yourself" add-ons, and a general lack of preventive maintenance can have dramatic consequences. Electrolytic corrosion is usually created by stray currents. To eliminate or minimize the consequences of this type of corrosion, the yacht's electric installation must comply with some strict rules. All wiring should be of the two-wire ungrounded type. Conductors are to be properly insulated, supported and secured, preferably in conduits or the equivalent. All circuit breakers and switches are ideally two-pole, trip-free types and shore supply is to be made to an isolation transformer.

Many yards building in aluminum have acquired a impressive mastering of the various techniques of construction, finishing, and protection against corrosion. And they are building larger and better engineered aluminum alloy yachts which continues to offer numerous advantages in construction.

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Photos : Jules Malrieux & D.R.