Boat building

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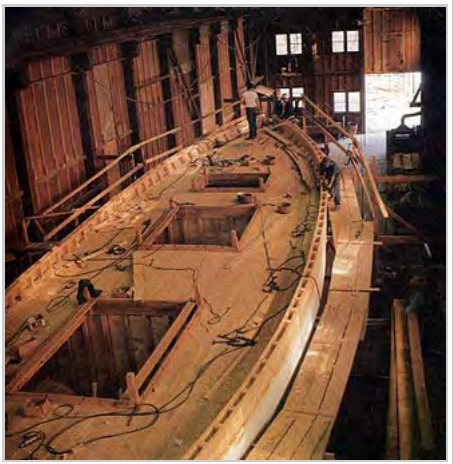
Boat building, one of the oldest branches of engineering, is concerned with constructing the hulls of boats and, for sailboats, the masts, spars and rigging.



The schooner *Appledore II* under construction.

Contents

Parts

Boat building in Greece (Hellas).

- Anchor- a heavy, pick like device, attached to a boat's stem by a warp and chain. Common types are Plow or Fisherman and Danforth. Modern anchors are made of steel but in pre-industrial societies rocks were used. The chain is added to the lower anchor end to add weight and prevent chafing of the rope warp on rocks or shellfish beds.
- Angel also virgin or maiden. A Norsemen invention used in sailing long ships from about the 10th century AD that predates blocks. They served the purpose of a block/jamb cleat in one unit. It was a flat section of wood about 150 high x 120 wide shaped like an angel/butterfly used in attaching stays to the hull. The V-shape at the lower part of the "wings" acted as a V jam cleat.
- Bitts - Two short strong posts often made of steel, located on the fore and aft side decks of a heavily built boat or ship, that are designed to take heavy mooring lines.
- Bilge - the lowest part of the hull interior, under the sole. Often water and or fuel tanks are placed in the bilges to lower the centre of gravity.
- Bilge keel - a longitudinal, external, underwater member used to reduce a ship's tendency to roll. In Britain twin bilge keels are often used on small boats moored in estuaries with a large tidal range so the

boat stay upright when dried out. With their much shallower draft yachts of this type can be sailed in shallow waters. Not as hydro dynamically efficient as a fin keel.


Side view of the wooden frame.

- Bilge pump - a pump, either manual or electric with the inlet set at the lowest point in the bilges where water will collect when the boat is upright. The inlet is protected by a screen to stop blockages
- Block a fitting with a circular wheel inside 2 cheeks designed to hold the turn of a rope. Originally made of wood, they are now made of plastic, stainless steel or carbon fibre. They are mainly used in rigging in pairs or quads to allow a single person to operate a sail that creates a lot of force. Similar to a pulley or sheave.
- Bow - The front and generally sharp end of the hull. It is designed to reduce the resistance of the hull cutting through water and should be tall enough to prevent water from easily washing over the deck of the hull.
- Bowsprit - A spar that extends forward from the foredeck, outboard of the hull proper. Common in square rigged ships where they were used to attach the outer or flying jib. In modern sailboats they are often made of lightweight carbon and used for attaching the luff of lightweight down-wind sails.
- Breasthook - A roughly triangular piece of wood fitted immediately aft of the stem and between the two inwales or sheer clamps usually in a wooden dinghy.
- Bulkhead - The internal transverse walls of the hull.
- Bulwarks - The upstanding part of the topsides, above the deck, providing safe footing when a boat is heeled.
- Cam cleat- a mechanical cleat with 2 spring-loaded cam jaws, usually made of hard plastic, that clamp onto a sheet. The sheet can be easily pulled forward and upwards to release it but is held tight in the cam jaws when unattended.
- Catsheads - A short timber(or pair of timbers) that protrudes approximately at right angles from the foredeck of a square rigged sailing ship. Its purpose is to support the weight of the anchor and keep the anchor secure and outboard of the hull to avoid damaging the hull planking.
- Capstan A vertical metal or wooden winch secured to the foredeck of a ship, used for hoisting the anchor. Capstans may be manually operated or powered hydraulically or electrically. A traditional wooden capstan is fitted with removable wooden arms fitted into sockets on which the seaman push. Seashanties were often chanted to keep the seamen together as they pushed.
- Carlin - A longitudinal strip parallel to, but inboard of, the inwale (sheer clamp). It supports the inboard edge of the side deck and the side of the cabin cladding.
- Chainplate - A strip of strong metal, often stainless steel, through-bolted to the topsides and a frame and protruding above deck level to take the load of a stay in a sail boat.
- Centre board - (also dagger board) an elongated underwater appendage that fits vertically in the slot of a centre case and extends below the hull. It can be retracted so the boat can float in very shallow water. The board has a length to breadth ratio of about 4;1. The board is tapered to a hydrodynamic (teardrop) shape in plan section to promote laminar flow of the water. This shape prevents stalling or eddying when sailing to windward. Together with the sails it lifts the hull in the windward direction. Common materials are wood often reinforced with fibreglass or carbon to obtain more stiffness and abrasion resistance. When sailing to windward the board is fully down but is retracted about half way when sailing directly down wind. When sailing to windward an efficient board prevents most leeway (sideways movement).
- Chines - Are the abrupt change of angle where the topside meets the bottom of a hull. In a power or fast sail boat the chine deflect spray down wards when the hull is travelling at speed. A multi chine hull has 4

or more chines to allow an approximation of a round bottomed shape using flat panels. It also refers to the longitudinal structural members inside the hull which support the edges of these panels. Traditionally these were called chine logs especially in Eastern USA.

- Cleat - A fitting designed to tie off ropes. Often T shaped.
- Coaming - any vertical surface on a ship designed to deflect or prevent entry of water
- Cockpit - The seating area towards the stern of a small decked vessel where the rudder controls are located.
- Counter stern - a traditional stern construction with a long overhang and a shorter, upright, end piece. The stern is rounded when in plan-view. The counter is usually decked over.
- Companion way-in a small yacht this is the short ladder that leads from the cockpit to cabin or saloon. Often it is detachable for access to the engine or storage. In a large vessel it is a permanent ladder between decks. A companion way usually has non slip treads and handholds.
- Crosstree- two short metal arms that are attached to a mast athwartwise about mid height. Mast side stays are tensioned by running through the outboard end of the arms, often forming a diamond shape. Similar to a spreader.
- Deck - The top surface of the hull keeps water and weather out of the hull and allows the crew to operate the boat more easily. It stiffens the hull. Temporary frames (or moulds) can be removed and kept for another boat.
- Deck beam - A heavy timber running athwartwise(across)from the top of a frame under the deck. It usually has a gentle convex (upward) curve for extra strength, extra head height below deck along the centre line and to allow water to run off the deck when the boat is upright.
- Dolphin striker - A short spar fitted mid-way and vertically downwards, midway along a bowsprit that holds the bobstay and prevents the outboard end of the bowsprit riding upwards under the load of a tensioned headsail.
- Dorade - A ventilation intake consisting of a cowling connected to a short vertical tube connected to a deck mounted scuppered (Dorade) box, usually made from teak. The cabin intake is offset to prevent water entering the cabin. The upper section swivels to stop breaking seas entering the dorade. Named after the 1931 yacht Dorade where it was first used.
- Epoxy resin -a chemical fluid widely used in advanced wooden boat building since the 1980s in a variety of forms, principally glue, as a filler (with a variety of powders or sawdust) and as a moisture-resistant barrier on both the interior and exterior of a wooden hull. The method was popularized by the WEST system. Sometimes used in conjunction with various cloths such as fibreglass, kevlar or carbon fibre. A thinned mixture of resin is used to penetrate the fibres of light weight woods such as Balsa and Western red cedar forming a waterproof barrier, far superior to single pot paint or varnish. In small boat and kayak construction Epoxy resin is often used in conjunction with lightweight 3 or 4 mm thick Okoume (Gaboon) plywood to form very light strong hulls. Typically few nails or screws are needed as the resin is so strong. Slow drying and far stronger but more difficult to sand than polyester resin. Typically applied with a roller, throw away brushes and radiused flat tongue depressor for coving using thickened epoxy. Softens and weakens slightly at high ambient temperatures so vessels in tropical waters should be lighter coloured.
- Fairlead-A U-shape or circular fitting often positioned near the bow that leads an anchor warp or a sheet to a cleat or winch. The anchor fairlead is usually bronze or stainless steel as it must take the regular abrasion of the warp and chain. The anchor fairlead is usually set on the change of angle between the deck and the topside to prevent wear and tear.
- Fiddle-or fiddle rail. A low rail about 40 mm high, either of solid wood or lathe-turned fiddles that is designed to stop things sliding off a table at sea when the boat is heeled.
- Foil-name for the T- or L-shaped hydroplaning appendage that lifts a hull out of the water while sailing.

The vertical component is similar to a conventional dagger board but much narrower due to the high sailing speed of foiling craft. 120 mm is typical in a foiling Moth of 3.3 m length. The vertical component is a symmetrical NASA foil shape. The main vertical foil is often angled forward to prevent air being sucked down the leading edge and creating a disturbed water flow. The winglets or blades are asymmetrical NASA foil shapes like a plane wing. In most foiling boats the whole wing can moved up or down – either automatically and/or partly controlled by a crew member to adjust the amount of lift needed. This depends mainly on wind and boat speeds. Winglets with a wider cross section give more lift at lower speeds but have more drag as speed increases whereas narrower ones have less lift but less drag at higher speed. Foils are usually made of lightweight carbon fibre because of its extreme strength and stiffness.

- Frame - the transverse structure that gives a boat its cross-sectional shape. Frames may be solid or peripheral. They may be made of wood, plywood, steel, aluminium or composite materials. They may be removed after construction to save weight or to be reused or left in-situ. In ancient shipbuilding the frames were put in after the planking but now most boats are built with the frames first. This gives greater control over the shape. "Lofting" is the process used to create life-size drawings of frames so they can be manufactured. Today frames can be cut directly from a computer programme by a robot, with extreme accuracy. In old heavily built, square rigged ships, the frames were made up of 4 individual timbers called futtocks, as it was impossible to make the shape from a single piece of wood. The futtock closest to the keel was the ground futtock and the other pieces were called upper futtocks.
- Freeboard- the distance between the water line and the deck when loaded. Boats using sheltered waters can have low free board but seagoing vessels need high freeboard.
- Furling headsail -a jib or other headsail that automatically rolls around a semi rigid forestay when a line is pulled. The lower section of the furling gear has a spring-loaded retrieval system that rolls up the headsail. These are often used in cruising boats or when a yacht is sailed short-handed. The operating lines are operated from the safety of the cockpit avoiding crew working on the exposed foredeck. On very large yachts the furling gear is attached to an electric motor for ease of use.
- Garboard - The strake immediately adjacent to the keel in a traditional wooden boat.
- Gimbaled stove/compass-a pivoting apparatus that allows a stove or compass to swing in two planes at the same time so that it remains more or less level. This makes the compass needle steady and easier to read and allows food to be cooked (carefully) in seaway.
- Gooseneck - a universal joint, usually made of stainless steel, that joins the boom to the mast. Many goose necks can be raised or lowered on a short section of track fixed to the mast.
- Grab rail- a length of strong wood, often mahogany, or stainless steel tube, with short legs, through bolted to a cabin top, so that crew making their way forward on a sloping and wet side deck have a firm handhold.
- Gudgeon- a stainless steel fitting, attached to a rudder head, in pairs, with parallel holes in which the rudder pintle pivots .
- Gunwale - The upper, outside longitudinal structural member of the hull.
- Hatch - A lifting or sliding opening into the cabin or deck for the loading of cargo or people.
- Heads - marine toilet. An abbreviation of the term catsheads which was the normal place of toileting in square rigger days. Always used in the plural.
- Horn Cleat - see cleat
- Hull - The main body of a ship or other vessel, including the bottom, sides, and deck.
- Hydrofoil-An inverted T or an L-shaped keel/dagger board device, with hydro dynamic lifting ability, that extends vertically downwards under the hull. As boat speed increases the hull lifts completely out of the water so drag is reduced and hull speed dramatically increased. The AC 72 ft catamaran New Zealand reached 40 knots in 17 knots of wind with almost no heeling, using hydrofoils in September

2012.[1] Sometimes called foiling or foil sailing. Most commonly used in 11 feet Moth sail boats. Also used in powerboats.

- Innerliner - The cockpit or deck mold of the inside or top of a GRP boat, fitted inside and joined to the (outside) hull.
- Inwale - The upper, inner longitudinal structural member of the hull, to which topside panels are fixed. In USA this is usually called the sheer clamp.
- Jib stick- A short, light spar used to hold out the jib when sailing almost directly down wind or in light airs when the jib may otherwise collapse or flap. The out board end may have a U shape to take the jib sheet or a point to go into the clew. The inboard end may be held or fastened to some convenient point such as a side stay or a purpose made fitting.
- Keel - The main central member along the length of the bottom of the boat. It is an important part of the boat's structure which also has a strong influence on its turning performance and, in sailing boats, resists the sideways pressure of the wind
- Keelson - An internal beam fixed to the top of the keel to strengthen the joint of the upper members of the boat to the keel.
- King plank - A flat, notched (nibbed) timber laid over the foredeck beams between the front of a cockpit or cabin and the stem. The notches or nibbs are designed so that the tapering deck planks do not end in a point which could be a weak point.
- Knee - A short L shaped piece of wood that joins or strengthens boat parts that meet at about 60 to 120 degrees. It may be a natural crook (e.g. apple, oak, pohutukawa) or sawn from a larger length of timber or laminated in a wooden vessel. Commonly seen on thwarts to join topsides or keelsons to join transoms. A hanging knee fits upside down e.g. underneath a thwart rather than on top. Hanging knees often support carlins where a full frame would be inconvenient.
- Locker - an enclosed space to store sails, anchors, personal effects, tools and supplies
- Mast - A vertical pole on a ship which supports sails or rigging. If a wooden, multi-part mast, this term applies specifically to the lowest portion.
- Mast step - A socket, often strengthened, to take the downward thrust of the mast and hold it in position. May be on the keel or on the deck in smaller craft.
- Moon pool - An opening in the bottom of the hull giving access to the water below, allowing access to the sea. Similar to wet porch.
- Mizzen-the permanent mast and sail set aft in a sailboat with 2 or more masts.
- Newel Post- turned wooden posts, from floor to ceiling, to one side of the cabin in a yacht. Serves as a handhold when a boat is at sea.
- Oar A wooden pole flattened at the outboard-end so it grips the water when pulled. Oars are normally used in pairs to propel a rowboat forward. Differs from a paddle by being longer and gaining leverage by passing through a rowlock which acts as a fulcrum to produce forward motion. Modern oars are often made from plastic or hollow carbon fibre in racing oars. A single oar can be leveraged against a U shape notch in the stern of a row boat to scull. The sculler stands and moves the oar in a sideways motion to produce forward motion in calm waters. A balanced oar is one that has weight added (either by extra wood or lead inside the handle)to the inboard end to balance the additional outboard length. In a rowing dinghy with 7–8 feet oars the balance point is about 12 inches outboard of the rowlocks.
- Painter-a short rope tied to the bow of a small boat, which can be held by a person. Used to control a boat while unloading from a trailer or loading/unloading from a beach.
- Parrot beak-a stainless steel fitting on the end of a spinnaker pole, consisting of a mounting with a retractable spring-loaded pin that is controlled remotely by way of a cord. When the cord is pulled it releases the spinnaker sheet so the spinnaker can be recovered by crew on deck.
- Pintle a short section of stainless steel rod, about 6-12mm in diameter, mounted on a stainless steel

bracket, that is bolted to the transom of a sail boat, so that the pin is inserted in the gudgeon hole.

- Planing Plank - a narrow, flat bottom keel about 150mm wide on a high speed deep or medium V powered planning craft. In flat water the craft would plane on this narrow plank giving increased speed. In choppy water the ride was unsettled. Steering accuracy when cornering was difficult as the craft swung wide. A concept used in power craft in the 1970s and 1980s but replaced by deeper V hulls with angles of more than 21 degrees from the 1990s.
- Prod- a very strong, light, hollow tapered pole, often made of carbon fibre, attached to the bow of a modern racing yacht, enabling it to carry a spinnaker or other down-wind sail with the luff in line with the centreline of the boat. In some yachts, such as the modern 49er, the prod is retracted through a hole in the bow when sailing upwind. Larger prods, such as on an AC72, are secured by dolphin strikers to prevent the prod bending upwards or breaking.
- Ratlines (sometimes *ratlins*) - Groups of side stays on a square rigged ship that have horizontal lines placed for feet, enabling crew to rapidly ascend to the yards.
- Rib - A thin strip of pliable timber laid athwart-wise inside the hull, from inwale to inwale, at regular close intervals to strengthen the exterior planking. The rib is often steamed to increase flexibility. The rib is traditionally fixed to the planking by rivets or copper nails bent over on the inside. This method is still used in small clinker built dinghies and similar craft. Ribs are attached after the planking is constructed. Ribs differ from frames or futtocks in being far smaller dimensions and bent in place compared to frames or futtocks which are normally sawn to shape, or natural crooks that are shaped to fit with an adze, axe or chisel.
- Rigging- wire or rod used to hold up a mast. Since the 1960s stainless steel wire has become universal in the developed world. Elsewhere galvanized wire or even rope may be used because of its availability and cheapness.3 types of stainless steel wire are commonly used. Type 1 x 19 is a non-flexible wire used for standing rigging such as stays. Type 7 x 7 is a semi flexible wire used for luff wires in sails, halyards (sometimes plastic coated) trapeze wires and light halyards. Type 7 x 19 is used for all halyards, wire sheets, vangs and strops that must run through a pulley (sheave). The common way of attaching wire is to form a small loop at the end which is fixed in place by clamping a soft metal swage over the free ends. Talurite is a common brand of swagging. The wire loop is then fastened to a rigging screw with a bow shackle to the chain plate. Kevlar rope is sometimes used in place of wire in small sailboats.
- Rowlock - Pronounced Rolick. A 'U' shaped metal device that secures an oar and acts as a fulcrum during the motion of rowing. Sometimes called an oarlock in the USA. The Rowlock is attached with a swivelling pin to the gunwale in a row boat. Commonly made from galvanized steel, bronze or plastic. Before the availability of metal the oar was normally levered against 2 wooden pins called Thole pins inserted in the gunwale. Tholepins are still used in some third world nations. In a narrow row boat the rowlocks are held well outboard in a lightweight outrigger (rigger) which is often equipped with a locking pin to hold the oar securely.
- Rudder - A steering device usually at the rear of the hull created by a turn-able blade on a vertical axis
- Sampson post - A strong vertical post used to support a ship's windlass and the heel of a ship's bowsprit.
- Scuppers - Gaps in the bulwarks which enables sea or rain water to flow off the deck.
- Shackle - a small, U shape, stainless steel or galvanized steel secured with a screw type pin at the open end of the U. Some types have spring-loaded pins that snap shut.
- Sheave box - a plastic or stainless steel box that holds a pulley that is fixed in position such as on a mast head so that the angle of the rope (halyard)is restricted.
- Sheer - The generally curved shape of the top of the hull when viewed in profile. The sheer is traditionally lowest amidships to maximize freeboard at the ends of the hull. Sheer can be reverse, higher in the middle to maximize space inside, or straight or a combination of shapes.
- Sensor - A small electronic component which can be embedded in a hull skin, keel, rudder, mast, oar or

sail of a very-high-performance craft to measure the laminar flow of air or water. Pioneered in New Zealand using technology from Formula 1 racing. Now used in rowing skiffs or racing oars to determine forces such as bending load and optimum angle of attack of the blade. Larger craft such as America Cup boats have readout displays on board so minute changes in sail angle can be related to speed and then duplicated at a later date.

- Sheet - A rope used to control the position of a sail e.g. the main sheet controls the position of the main sail.
- Skeg - A long tapering piece of timber fixed to the underside of a keel near the stern in a small boat to aid directional stability, especially in a kayak or rowboat.
- Spar - A length of timber, aluminium, steel or carbon fibre of approximately round or pear shape that is used to support sails. Such as a mast, boom, gaff, yard, bowsprit, prod, boomkin, pole or dolphin striker .
- Sole-the floor of a cabin or cockpit. Often the cabin floor is made in sections that can be lifted quickly to gain access to the bilges in the event of a leak. Cockpit floors on yachts are often self-draining so that water will drain out even when the vessel is sailing at an extreme angle. In many high speed skiffs the craft is fitted with a sole angled aft to rapidly drain the spray through an open transom. Often this type of sole is called a false floor.
- Spinnaker- sometimes called a kite in Australia or New Zealand. A large, lightweight, down-wind sail used on fore and aft rigged yachts such as sloops to dramatically increase sail area. The sail is hoisted by a halyard attached by a ring to the head of the sail. The windward, luff, corner is secured by a sheet often called a preventer. The preventer runs through a parrot beak attached to the end of a spinnaker pole. Until recently the pole was usually secured by a parrot beak to a ring on the lower mast. The leeward, clew, corner is controlled by a sheet. In double luff (parallel sided) spinnakers, the 2 sheets are interchangeable. In some very modern racing yachts the pole is replaced by a prod which is fixed in place at the bow. Some spinnakers are single luff, which are flatter and with a longer luff enabling them to be carried more easily on a reach. In small planning sailboats such as 18 ft skiffs, huge spinnakers cause dramatic increases in speed and spectacular, on the edge, sailing.
- Spreaders- two angled, metal struts, attached about mid height on a mast, for the purpose of keeping the side stays taunt. Spreaders are usually swept rearwards approximately in line of the side stay between the hounds and the chain plate. They help hold the mast straight (in column) when under heavy load such as when carrying a spinnaker on a tight reach.
- Spring - The amount of curvature in the keel from bow to stern when viewed side on. The modern trend is to have less spring in order to have less disturbance to water flow at higher speeds to aid planing.
- Stanchions - A series of narrow but strong posts, often made of marine grade stainless steel, designed to hold life lines around the outer edge of a deck. Stanchions are often attached to both the deck and a toe rail or bulwark for added strength.
- Stainless steel- mild steel to which small percentages of copper, chromium and sometimes nickel are added to make a very strong steel that is does not rust much. Marine grade stainless steel 316 containing more nickel, is even more rust resistant. Can be made into rod, tubes, sheet or pressed into a wide variety of shapes for marine fittings.
- Stays/shrouds - Standing or running rigging which hold a spar in position e.g. sidestay, forestay, backstay. Formerly made of rope, these days usually stainless steel wire.
- Stem - A continuation of the keel upwards at the front of the hull
- Stern - The back of the boat
- Stern sheets a flat area or deck, inboard of the transom in a small boat. It may contain hatches to access below decks or provide storage on deck for life saving equipment.
- Strake - A strip of material running longitudinally along the vessel's side, bilge or bottom. Sometimes called a stringer.

- Stringer-Batten in USA. A long relatively thin, knot free length of wood, running fore and aft, often used to reinforce planking on the inside of the hull, especially when thin planking is used. See strake
- Synthetic rope - There are 4 common ropes in use. Polyester, also called Dacron or Terylene, is a strong, low stretch rope, usually plaited (braided) used for running rigging. Nylon is a strong, but elastic rope, used for mooring lines and anchor warps as it resists shock loads. It is usually laid (twisted) so that it is easier to grip when hauling. Polypropylene is a light, cheap, slippery rope, that floats. It is much weaker than the previous ropes. It weakens when exposed to sunlight. It is usually laid construction. Commonly used on commercial fishing boats using nets. Kevlar is an extremely strong fibre that is now made into ropes with almost no stretch. Expensive. Suited to halyards instead of stainless steel wire. Often used on racing yachts to replace polyester when powerful winches are used. Kevlar ropes can be much smaller in diameter than polyester for the same strength. This saves windage on a racing yacht. Usually braided.
- Taff rail-a railing, often ornate, at the extreme stern of a traditional square rigged ship. In light air conditions an extra sail was set on a temporary mast from the taff rail.
- Thwart - A seat, usually transverse, that is used to maintain the shape of the topsides in a small boat.
- Tiller- A handle made of wood, steel or carbon fibre that is attached to the top of a rudder, often via a post, which enables the helmsman to steer the boat.
- Tiller extension-A long, lightweight handle attached to the forward end of the tiller which enables the helmsman to steer from a position from the side deck or outboard of a side deck on a high performance yacht. For example, from a trapeze.
- Toe rail - A upright longitudinal strip of timber fastened to the fore deck near the sheer. It is placed so that crew working on the foredeck can brace their toe or foot against it especially when the boat is heeled.
- Topping Lift-a rope running from the aft end of the boom, through a block at the masthead and down to a cleat at the foot of the mast. Used for holding the boom up when the mainsail is not being used.
- Topsides - The side planking of a boat from the waterline to the sheer.
- Transom - A wide, flat or slightly curved, sometimes vertical board at the rear of the hull, which, on small power boats, is often designed to carry an outboard motor. Transoms increase width and also buoyancy at the stern. On outboard boats the stern is often the widest point to provide displacement to carry a large outboard and to resist the initial downward thrust of a planning craft. Sometimes the term tuck is used in a sail boat.
- Trapeze- a wire and belt device allowing a crew member to lie near horizontal with their feet braced against the gunwale in order to counter act the heeling force of the wind acting on the sails of a centre board racing yacht. A thin stainless steel wire is attached to the mast at about 3/4 height and to a belt worn by the crew member via a hook. When tacking the sailor must swing in, unhook, move to the other side of the yacht and reattach the hook on the opposite tack. Agility is required. The crew holds the tail of the jib sheet for trimming and balance. In a few classes the helmsman and/or helmsman and all crew, use trapezes.
- Wand-a devise fitted to a foiling yacht to give control over the ride height and "z" factor(foil rise and fall). Consists of a carbon tube that pivots from the bow attached to an internal wire or rod that is attached to arod in the centre (main) foil. The rod runs to the main foil blades (wings)to control their angle. The wand can be set fixed but since about 2009 a dial is fitted that allow the skipper to adjust the foil blade angles/wand height. Some craft are fitted with dual wands for more precise control.
- Washboard - a panel that slides vertically in small boat's companionway acting as a removable door
- Warp-anchor rope. Traditionally made of natural fibre such as hemp, modern warps are made of stronger, lighter, synthetic fibre, often laid nylon, which is elastic so absorbing shock loads which would otherwise pull out the anchor. Warps are normally at least 3 times the depth of the water. In strong wind and/or current the warp should be at least 6 times the water depth.

- Water tank - a large irregular shaped container(s), often made of stainless steel, that is usually fitted into the bilges of a voyaging boat. The tank often has a deck mounted inlet, a vent pipe and a pump to move water to taps, showers etc. Mounted low in the hull, it adds significantly to stability when full.
- Winch-a geared mechanical device used on yachts for trimming (adjusting)sail sheets, for hoisting large sails with halyards, for hauling in an anchor or on a boat trailer for hauling a boat out of the water. The normal turret winch is set on the aft side deck for trimming headsails and or a spinnaker. Manual trimming winches are operated by grinding the handle in a circle initially, then pulling back and forwards on a short lever while a second person tails (pulls to keep tension on the sheet)to obtain optimum force. Some winches are self-tailing or the sheet can be cleated to prevent slippage. On larger yachts winches can be operated by electric motors. Typically on America's cup yachts large pedestal winches are used which can be operated by two people at the same time. Because of the force needed, especially in tacking duels, winch grinders are usually very large and strong men.
- Wind pennant-a small wind indicator balanced on a pivot, usually fitted to the mast head, to indicate wind direction. Can be made of plastic, stainless steel or sail cloth.
- Wheelhouse - a permanent, raised shelter, with large windows, often located midships or aft, from which the helmsman steers. Usually contains all the boats controls, instruments and electronics. It gives the helmsman good visibility 360 degrees and keeps them out of bad weather and spray. The wheelhouse may be open aft or have access to the side decks so when operating short-handed the helmsman can attend lines.
- Yard - A horizontal spar on a square rigged ship fitted to the forward side of a mast, holding a square sail forward of the shrouds. Each square sail hangs from its own yard. Sails are furled by seamen who bend over the yard and use both hands to haul up the sail. The sail is trimmed to the wind by braces leading from the yard arms (ends of the yard) aft (or forward) to another mast, or down to the deck. Compare to "gaff" and "boom", which attach to the aft side of the mast and hold a "fore-and-aft" sail aft of the shrouds. A square sail trims to either side of athwartships, and a fore-and-aft sail trims to either side of fore-and-aft.

Construction materials and methods

Wood

Damaged boat mid-reconstruction; carvel planking partially removed.

The traditional boat building material used for hull and spar construction. It is buoyant, widely available and easily worked. it is a popular material for small boats (of e.g. 6-metre (20 ft) length; such as dinghies and sailboats). Its abrasion resistance varies according to the hardness and density of the wood and it can deteriorate if fresh water or marine organisms are allowed to penetrate the wood. Woods such as Teak, Totara and some cedars have natural chemicals which prevent rot whereas other woods, such as Pinus radiata, will rot very quickly. The hull of a wooden boat usually consists of planking fastened to frames and a keel. Keel and frames are traditionally made of hardwoods such as oak while planking can be oak but is more often softwood such as pine, larch or cedar.

Plywood is especially popular for amateur construction but only marine ply using waterproof glues and even laminates should be used. Cheap construction plywood often has voids in the interior layers and is not suitable to boat building as the voids trap moisture and accelerate rot as well as physically weaken the plywood. No plywood is rot resistant and should be coated with epoxy resin and/or a good paint system. Varnish and Linseed

oil should not be used on the exterior of a hull for waterproofing. Varnish has about 60% of the water resistance of a good paint system. Only boiled linseed oil should be used on a boat and only in the interior as it has very little water resistance but it is very easy to apply and has a pleasant smell. Note that used linseed rags should not be left in a pile as they can catch fire. A valuable 200-year-old waka (Maori canoe)caught fire in New Zealand in June 2014 when restorers left rags piled overnight. Raw linseed oil is not suited to boats as it stays damp and oily for a long time. Mildew will grow well on raw linseed oil treated timber but not on boiled linseed oil. More recently introduced tropical woods as mahogany, okoumé, iroko, Keruing, azobé and merbau.[2] are also used. With tropical species, extra attention needs to be taken to ensure that the wood is indeed FSC-certified.[3][4] Teak or iroko is usually used to create the deck and any superstructure. Glue, screws, rivets and/or nails are used to join the wooden components. Before teak is glued the natural oil must be wiped off with a chemical cleaner, otherwise the joint will fail.

Caulking irons and oakum.

Caulking a wooden boat.

A sheet plywood sailboat during construction.

Some types of wood construction include:

- **Carvel**, in which a smooth hull is formed by edge joined planks attached to a frame. The planks may be curved in cross section like barrel staves. Carvel planks are generally caulked with oakum or cotton that is driven into the seams between the planks and covered with some waterproof substance. It takes its name from an archaic ship type and is believed to have originated in the Mediterranean. A number of boat building texts are available which describe the carvel planking method in detail.[5]
- **Clinker** is a technique originally identified with the Scandinavians and Ingveonic people in which wooden planks are fixed to each other with a slight overlap that is beveled for a tight fit. The planks may be mechanically connected to each other with copper rivets, bent over iron nails, screws or in modern boats with adhesives. Often, steam bent wooden ribs are fitted inside the hull.
- Strip planking is yet another type of wooden boat construction similar to carvel.[6] It is a glued construction method which is very popular with amateur boatbuilders as it is quick, avoids complex temporary jig work and does not require shaping of the planks.[7]
- Sheet plywood boat building uses sheets of **plywood panel**s usually fixed to longitudinal long wood such the chines, inwhales (sheer clamps) or intermediate stringers which are all bent around a series of frames. By attaching the ply sheets to the longwood rather than directly to the frames this avoids hard spots or an unfair hull. Plywood may be laminated into a round hull or used in single sheets. These hulls generally have one or more chines and the method is called Ply on Frame construction.[8] A subdivision of the sheet plywood boat building method is known as the stitch-and-glue method,[9] where pre-shaped panels of plywood are drawn together then edge glued and reinforced with fibreglass without the use of a frame.[10] Metal or plastic ties, nylon fishing line or copper wires pull curved flat panels into three-dimensional curved shapes. These hulls generally have one or more chines. Marine grade plywood of

good quality is designated "WBP" (which stands for water- and boiled-proof) or more usually BS 1088. Australian plywood manufacturers and suppliers have issued warnings that some Asian nations are selling ply stamped BS 1088 which does not meet international standards. Specifically, they say outer plies are too thin (should be 1.2 mm or 0.047 in minimum) or are very thin (less than 0.5 mm or 0.020 in) or high-grade surface ply such as Okoume is combined with a much heavier and wider inner cores. Most high-grade marine Okoume (Gaboon) ply uses lightweight poplar inner cores. Often the 1088 stamp is blurred in the poor Asian ply so it is not clear. In Australia and New Zealand a higher-grade marine ply than BS1088 is AS2272. It requires both faces to be "A" quality, with even-thickness plies. The most common plywood used for this grade is plantation-grown Hoop Pine which is fine grained, very smooth, moderately light (at 570 kg/m^3 or 36 lb/cu ft it is the same weight as Meranti ply and about 13% heavier than genuine poplar cored BS1088 Okoume). Hoop pine has a very high stress rating of F17, indicating high strength. Meranti (Lauan) ply has a stress rating of F14 and Okoume ply F8. Okoume ply is commonly coated with epoxy to increase strength and impact resistance as well as to exclude water. Both types of plywood construction are very popular with amateur builders, and many dinghies such as the Vaurien, Cherub, Tolman, Moth and P class (ply on frame construction) and FJs, FDs and Kolibris (stitch-and-glue method) have been built from it.[11][12] Another variation is tortured ply where very thin(3 mm or 0.12 in) and flexible (often Okoume)preshaped panels ply are bent into compound curves and sewn together. Little or no framework or longitudinal wood is used. This method is mainly confined to kayaks.

- Cold-Molding is a composite method of wooden boat building that uses 2 or more layers of thin wood, called veneers, oriented in different directions, resulting in a strong monocoque structure, similar to a fibreglass hull but substantially lighter. Sometimes composed of a base layer of strip planking followed by multiple veneers. Sometimes just veneers are used.[13] Cold-molding is popular in small, medium and very large, wooden super-yachts. Using different types of wood, the builder can lighten some areas such as bow and stern and strengthen other high-stress areas. Sometimes cold-molded hulls are protected either inside or out or both with fibreglass or similar products for impact resistance, especially when lightweight, soft timber such as cedar is used. This method lends itself to great flexibility in hull shape.

Steel (and before that iron)

Either used in sheet or alternatively, plate [14] for all-metal hulls or for isolated structural members. It is strong, but heavy (despite the fact that the thickness of the hull can be less). It is generally about 30% heavier than aluminium and somewhat more heavy than polyester. The material rusts unless protected from water (this is usually done by means of a covering of paint). Modern steel components are welded or bolted together. As the welding can be done very easily (with common welding equipment), and as the material is very cheap, it is a popular material with amateur builders. Also, amateur builders which are not yet well established in building steel ships may opt for DIY construction kits. If steel is used, a zinc layer is often applied to coat the entire hull. It is applied after sandblasting (which is required to have a cleaned surface) and before painting. The painting is usually done with lead paint (Pb_3O_4). Optionally, the covering with the zinc layer may be left out, but it is generally not recommended. Zinc anodes also need to be placed on the ship's hull. Until the mid-1900s, steel sheets were riveted together.

Aluminium

Aluminium is either used in sheet for all-metal hulls or for isolated structural members. Many sailing spars are frequently made of aluminium after 1960. The material requires special manufacturing techniques, construction tools and construction skills. It is the lightest material for building large boats (being 15-20% lighter than

polyester and 30% lighter than steel). Aluminium is very expensive in most countries and it is usually not used by amateur builders. While it is easy to cut, aluminium is difficult to weld, and also requires heat treatments such as precipitation strengthening for most applications. Corrosion is a concern with aluminium, particularly below the waterline. It is most commonly used in small pleasure and fishing power boats that are not kept permanently in the water.

A punt under construction.

Fiberglass (Glass-reinforced plastic or GRP)

Typically used for production boats because of its ability to reuse a female mold as the foundation for the shape of the boat. The resulting structure is strong in tension but often needs to be either laid up with many heavy layers of resin-saturated fiberglass or reinforced with wood or foam in order to provide stiffness. GRP hulls are largely free of corrosion though not normally fireproof. These can be solid fiberglass or of the sandwich (cored) type, in which a core of balsa, foam or similar material is applied after the outer layer of fiberglass is laid to the mold, but before the inner skin is laid. This is similar to the next type, composite, but is not usually classified as composite, since the core material in this case does not provide much additional strength. It does, however, increase stiffness, which means that less resin and fiberglass cloth can be used in order to save weight. Most fibreglass boats are currently made in an open mold, with fibreglass and resin applied by hand (hand-lay-up method). Some are now constructed by vacuum infusion where the fibres are laid out and resin is pulled into the mold by atmospheric pressure. This can produce stronger parts with more glass and less resin, but takes special materials and more technical knowledge. Older fibreglass boats before 1990 were often not constructed in controlled temperature buildings leading to the widespread problem of fibreglass pox, where seawater seeped through small holes and caused delamination. The name comes from the multiude of surface pits in the outer gelcoat layer which resembles smallpox. Sometimes the problem was caused by atmospheric moisture being trapped in the layup during construction in humid weather.


Wooden boats being built during the Klondike Gold Rush.

Composite material

Originally "composite" referred to a timber carvel skin fastened to iron frame and deck beams. This allowed sheet copper anti-fouling to be employed without the risk of galvanic corrosion of the hull fabric. It was employed for fast cargo vessels so that they were not slowed by marine fouling. This use is now obsolete. While GRP, wood, and even concrete hulls are technically made of composite materials, the term "composite" is often used for plastics reinforced with fibers other than (or in addition to) glass. Cold-molded refers to a type of building one-off hulls using thin strips of wood applied to a series of forms at 45-degree angles to the centerline. This method is often called double-diagonal because a minimum of two layers is recommended, each occurring at opposing 45-degree angles. "Cold-molding" is now a relatively archaic term because the contrasting "hot-molded" method of building boats, which used ovens to heat and cure the resin, has not been widely used since World War II . Now almost all curing is done at room temperature. Other composite types include sheathed-strip, which uses (usually) a single layer of strips laid up parallel to the sheer line. The composite materials are then applied to the mold in the form of a thermosetting plastic (usually epoxy, polyester, or vinylester) and some kind of fiber cloth (fiberglass, kevlar, dynel, carbon fiber, etc.), hence the finished hull is a "composite" of fiber and resin. These methods often give strength-to-weight ratios approaching that of aluminum, while requiring less specialized tools and skills.

Steel-reinforced cement (ferrocement)

Strong, long lasting and, perhaps surprisingly, not necessarily heavy. First developed in the mid 19th Century in France. Used for building warships. Extensively refined in New Zealand shipyards in the 1960s and the material became popular among amateur builders of cruising sailboats in the 1970s and 1980s, because the material cost was cheap, although the labour time element was high. The weight of a finished ferro-cement boat is higher than wooden boats only in the case of small vessels. They are suitable for traditional hull forms of types such as the gaff cutter. As such they are often built as cruisers allowing more comfortable sea passages. Hulls built properly of ferro-cement are more labor-intensive than steel or fiberglass, so there are few examples of commercial shipyards using this material. The inability to mass-produce boats in ferro-cement has led there to there being few examples around. Many ferro-cement boats built in back yards can have a rough, lumpy look, which has helped to give the material a poor reputation. The ferro-cement method is easy to do, but it is also easy to do wrong. This has led to some disastrous 'home-built' boats. Properly designed, built and plastered ferro-cement boats have smooth hulls with fine lines. Amateur builders are advised to use a professional plaster to produce a smooth finish. Most ferro-cement hulls are designed as heavy displacement. See also concrete ship, concrete canoe.

Hull types

To build a boat, the type of hull used is of vital importance; for example, going to sea requires a hull which is more stable than a hull used for sailing rivers (which can be more flat/round). Some types include:

- Smooth curve hull - As its name implies, the hulls of these vessels are rounded and don't usually have any chines or corners.
- Chined and hard chined hulls - These are hulls made up of flat panels (commonly made of plywood, or more traditionally with planking) which meet at a sharp angle known as the chine. Chined hulls range from simple flat-bottomed boats where the topsides and bottom meet at about 110 degrees (such as banks dories and sharpies) to skiffs where the bottom is arced rather than flat. Multi-chine plywood hulls allow a round hull shape to be approximated.
- Flat-bottomed hull - The flat-bottomed hull has advantages, such as the ability to travel in shallower water and being cheap and easy to build, though it is much less stable in rough waters than other hull types.
- Displacement hulls - These are hulls which have a shape which does not promote planing. Displacement hulls are often heavy and lack sufficient power -either motor or sail to achieve planning. They travel through the water at a limited rate which is defined by the waterline length.
- Planing hulls - These are hulls with a shape that allows the boat to rise higher and higher out of the water as the speed increases. They are commonly fine bowed. Sail boats that plane are flat-bottomed aft. Because sail boats sail heeled over, the flat surface can be achieved with v or arc bottom shapes. Hydroplanes are very light, flat bottomed, high powered speed boats that plane easily on flat water but quickly become unstable in any waves. Powerboats designed for rough water are usually deep V-bottomed with a deadrise angle of about 20-23 degrees. The most common form is to have at least one chine to allow for stability when cornering and for a supportive surface on which to ride while planing. Planing hulls allow much higher speeds to be achieved, and are not limited by the waterline length the way displacement hulls are. They require more energy in the form of large sails or high power motors plus light weight to achieve these speeds.

Boat building tools and use

Boat building uses many or the same tools that are common house tools such as hammers, cross cut saws, power drills, benches and vices. For building small boats under 5m some specialized tools are needed such as clamps (cramps) either G clamps or spring clamps. A minimum of 4 6inch(150mm) and 10 4inch(100mm) G clamps, plus 20 2 inch(50mm) steel spring clamps is need for ply on frame designs. More is better with clamps. Flat and round surform rasps are useful tools for shaping wood and ply. A drill set from 2-10mm, several speedbore drills for larger holes 12-25mm, (1/2inch-1 inch) rotary sanding backing pads and a range of replacement sanding pads from coarse (40grit) to fine (180grit), counter sinking drills for screws, a right angle set square, a set of manual screw drivers with blades to match screws being used are essential. A heavy craft knife, an 8m(25 ft) tape, flat and round files for metal and wood, a short(torpedo) level and a set of 3 chisels from 6 to 25mm are needed. Power tools make a job much easier and are relatively cheap. An 7 1/4inch (185mm) circular saw with a fine 40 tooth tungsten carbide blade, a jigsaw with a dust blower with a set of fine, medium and coarse tooth metal and wood blades is good for cutting plywood panels to shape, a rotary oscillating sander with medium and fine pads and a cordless drill for driving screws all save time and energy. A steam box is excellent for making planks easier to bend although hot wet rags are a messy, but easy substitute. A fine tooth hacksaw is not only essential for cutting metal such as trimming stainless steel bolts to the correct length but is handy for ultra-fine cuts in thin wood. A fine-tooth tenon saw is used to cut across the grain to produce a reasonably fine, accurate cut. Some boat builders have started using Japanese draw saws for fine cuts but while these are excellent they tend to be very expensive. A No 4 smoothing plane is essential but an electric plane is very useful (but extremely loud) for making rudder blades and centre boards. A much longer No. 7 plane is needed if the design calls for a wooden spars as used in many modern "traditional" yachts.

In boat building lots of sanding requires using either dry sandpaper, or wet and dry paper, to achieve a reasonable paint or varnish finish. Sandpaper is graded from 40 (very coarse) to 400 (ultrafine). Wet and dry sandpaper lasts longer than dry sandpaper. Wet and dry is best used on paint finishes, while dry paper is best used on dry wood. About 2 sheets of sandpaper for every foot of hull length is a good guide. Less sheet sandpaper is needed if power sanders are used. Spatula applicators, with a flexible stainless steel blade, are used to apply filler. A knife type and a flat 3"(75mm) type will cover most needs.

Silicon bronze screws are normally used in boat building but can be hard to locate. Brass fasteners are commonly available but apart from being softer and weaker the common brass alloys are much more prone to corrosion through depletion of their zinc content. Stainless steel screws may be used for attaching fittings to the hull above the water line. Type 316 stainless steel is the only stainless steel recommended. Even 316 may get stained with surface rust but this does not penetrate the surface. Staining comes from being in contact with other steels such as the anchor or incorrect cleaning in the factory. Staining near wields should be removed as it can pit. Experienced boat builders are reluctant to use even 316 below the water line in a boat permanently in salt water. This especially applied to long thin fastenings such as screws in boats that have motors. Sacrificial anodes are used to help prevent corrosion underwater but experts will inspect a sample of long thin screws or bolts annually to check for corrosion.

Epoxy resins and hardeners are universally used in boat building due to their superior holding power and ease of use.[15] In its thickened state it is used as a strong filler and for a range of joints that do away with more traditional fastenings. A large supply of cheap wooden tongue depressors is useful for mixing and applying epoxy resin. The curved ends are useful for shaping coved joints with epoxy. Silicon bronze ring nails are excellent for permanent fastening of wood and ply as they are strong and easily driven. Many small boats are almost entirely fastened by epoxy resin. In stitch and glue construction the hull panels are temporarily held together with either copper wire, nylon fishing line or plastic cable ties, until the epoxy cures, after which the stitching material is removed. Polyester filler is a quick setting (20mts), softer filler, suited to very small holes and scratches and is far more easily sanded to a fair shape than harder, stronger epoxy filler which takes 24 hours to set hard.

Boat building requires enough space, under cover, so that the builder can easily move around the hull during construction, or the boat can be built on a trailer so the hull can be moved out of the shelter for construction sessions. It also requires space at the bow and stern not only for working but for sighting down the gunwale and chine lines to check they are fair. Have the bow at the garage door end for this reason. This is especially important in stitch-and-glue construction where no jig is used, as the ply panels are very floppy until the glue sets.

Water-based paint is far easier and cheaper to apply, as undercoat, to produce a good smooth finish with a fraction of the time and effort of enamel paints, but harder and slower-drying enamel is best for the top coat on the outside of the hull, which is subject to a lot of bumps and scraps. Limit varnishing to smaller areas, such as grab rails, hatches, toe rails and trim, unless you have lots of patience and a very dust-free environment for varnishing. Use only marine gloss varnish on the outside, as interior varnish will peel off very quickly in hot sun and rain. Marine varnish has UV inhibitors to slow down peeling and fading. Never varnish a deck as it is slippery when wet. Even top-quality marine varnish is not as water-resistant as paint, so you must apply at least 4 coats. Often perfectionists will apply 8 coats or more to get a glass-like, reflective finish. Never varnish submerged parts like rudders.

Boats take a long time to build as there are almost no right angles. Amateurs working at night or in weekends commonly take a year to build a 12–16 ft (3.6–5m) craft. Builders with handyman skills will find that over time their skills will increase. For amateurs, starting with a boat built on a jig (temporary wooden frame) is useful as making the jig is all about right angles and basic carpentry skills. Sailboats require about 25% more time than a dinghy type because of the need for built-in buoyancy, centreboard case, centreboard, rudder, mast, boom and a range of special fittings such as chain plates, gudgeons, blocks cleats and tracks.

Essential safety gear needed is closed-in footwear, very high grade ear protectors (especially if using a high-revving electric plane or router), eye shields when cutting or grinding metal, disposable gloves when gluing, close-fitting clothes that will not get caught in drills. Good light is essential. Boat builders should not work when they are tired and should keep the work floor clean so they don't trip over tools or wood or electric leads. A fan is handy for extra ventilation if the work space does not have many opening windows or doors. Many boat builders like smaller tools to be bright-coloured tools so they can see them easily amongst saw dust.[16] With the recent technological advances in materials being used in modern boat building including GRP and FGRP repiratory protection masks have become essential in many workshops. The only suitable alternative being substantial dust extraction equipment by means of on-tool extraction or a fully fit out environmental cleaning workshop installation.

Other useful power tools are a belt sander, especially if using recycled timber or for finishing rough-sawn timber. A thicknesser/planer is only needed if building many boats or larger vessels, as it is usually cheaper to pay a joiner to do this for a small amount of timber. A bench saw is useful if you buy larger sectioned timber, which may be considerably cheaper and need to saw it to the correct size, but again a timber yard will do this for a small charge.[17]

Gallery

Traditional boat building in India.[18]

View of a Boat at Bheemunipatnam (being manufactured)

Traditional wooden boat building in Vietnam. Photos taken January 2009.

Small boatyard horizontal band saw, Hoi An.

Small boat using the planks first method. Hoi An.

Boat nearing completion with frames added. Hoi An.

Plank on frame construction. Quy Nhon.

Almost completed offshore fishing hull, Quy Nhon.

Plank fixing, trenails and red lead paint, Quy Nhon.

Repaired frames, barge hull. Sa
Dec, Mekong Delta.

See also

- Center for Wooden Boats
- Do it yourself
- E.G. van de Stadt
- Lofting
- Marine propulsion
- Messabout
- Outboard motor
- Propeller
- Sail
- Sailboat design and manufacturing
- Sail-plan
- Shipbuilding
- Slipway
- Spaulding Wooden Boat Center
- Stephens Bros. Boat Builders
- Sterndrive
- Stitch and glue
- Strip-built

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External links

- WoodenBoat Publications (http://www.woodenboat.com/) — publisher of construction plans and techniques for traditional boat building methods.
- A website for the home boat builder (http://www.amateurboatbuilding.com/).

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