BOATBUILDING WITH PLYWOOD

by Glen L. Witt

CHAPTER 5 - LUMBER

It would take a good-sized book to adequately cover all aspects of lumber as it applies to boat building alone. However, a chapter devoted to lumber covering the basics that the average amateur will need to know is probably just as valuable, since the boring technicalities and scientific aspects that tend to confuse more than to clarify can be dispensed with. After all, the point in discussing lumber is to provide knowledge to help the builder select, buy, and use the proper types of lumber for the particular boat that is being built; not to provide a scientific or technical foundation. With a little practical information, the novice will be better equipped to go to his lumber dealer. To know how to ask and receive exactly what he will need for the best possible price and rest assured that his boat will be built with the most suitable materials for his special application.

It is impossible to cover all types of lumber that are available for boat construction. Each part of the country not only has certain woods that will be common to the area, but there usually will be several imported lumbers available as well. When in doubt about what type of lumber to use, a general rule to follow is that any lumber that has been proven successful in similar boats in the locale can be used. However, if the designer of the boat specifies certain types of lumber, especially where light weight, or high strength, or decay resistance characteristics may be important, try to substitute woods that will be equally matched to such requirements. For example, on a high speed runabout where a designer might specify the use of Sitka spruce (because of its light weight), it would be foolish to substitute with a wood such as white oak (which weighs nearly 65% more than Sitka spruce). Even though both woods are suitable boat building lumbers. Such a substitution would not only make the boat much heavier, but performance could be disappointing. From an economy standpoint it is usually less costly to buy those lumbers that are readily available in the general area even though the designer of the boat may have specified another type of lumber not available. Here again, woods of similar weight and strength characteristics that have been proven in use in the area can always be substituted. After all, the designer cannot be expected to specify all the suitable alternatives, especially when he may be located in another part of the country where such woods may be unfamiliar to him.

BUYING LUMBER

Probably no aspect of the boat building project causes more initial confusion for the novice than that of attempting to buy lumber. And yet, with the understanding of a few basic concepts, the process can not only be simplified, but can even be interesting. The first mistake to avoid is to grab the plans for the boat or a copy of the I bill of materials, immediately rush to the nearest lumberyard, and then give the listing to the man at the lumberyard for a quotation. This is a sure way to waste money.

First, understand how lumber is measured and sold. Lumber is usually sold by the "board foot". A board foot is a measure of size equal to 12" x 12" x 1" thick, or 144 cubic inches of wood. With every board foot of lumber charged, you will be paying for this amount of material. However, this does not mean that you will actually receive this much material. This is because that when the tree is cut down and sawn up, the lumber will be in a rather rough form. To make the lumber suitable for use, this rough board (which may be 1" in actual thickness at this point,) is decreased by the milling or surfacing process to where it will be less than the initial rough thickness. Usually such milling will remove from 1/8" to 1/4" from the board, but the customer still pays for the "sawdust" lost through milling.

Almost all hardwoods are sold as "random-random" material in the rough. This means that lengths and widths will vary. Thickness of such material is specified in "quarters", with each quarter being 1/4". Thus, "four-quarters" material is 1" in the rough state, "five-quarters" stock would be 1 1/4", etc. Commonly available rough thicknesses are 4/4, 5/4, 6/4, 8/4, and 12/4 stock, or 1", 1 1/4". 1 1/2", 2", and 3" respectively. After the rough lumber has been milled or surface planed to be smooth on two sides, it is given the designation "S-2-S", or surfaced-two-sides. In cases where completely milled lumber is available, it is given the designation "S-4-S" to show that not only have the two surfaces been milled, but the edges have been jointed square and smooth as well. Normally, S-4-S lumber will be more costly than S-2-S lumber for the same species. Lumber with the S-4-S designation will often be less in the width dimension as well, due to the fact that some material will be lost when jointing the edge. Hence, not only in such lumber more costly than the same type in the S-2-S grade, but the result will be even less wood per board foot paid for.

A deviation to the above lumber measuring system comes with softwood lumbers such as Douglas-fir. These types are commonly sold only in S-4-S grade, with both dimensions actually less than that that they are designated by. For example, a Douglas-fir member that is specified as 2" x 6" will actually net less in both dimensions by virtue of the grading standard under which softwood lumbers are measured. It would be common to find the actual net size of such a 2" x 6" member to be 1 1/2" x 5 1/2". This variation with softwood species is common for all standard size designations and should be allowed for when purchasing softwood lumber types. These lumber types are also commonly sold by the lineal foot for convenience in some lumberyards that can increase the buyer's difficulty in determining the cost per board foot in order to compare costs with hardwood lumbers. For example, a 2" x 4" Douglas-fir member priced per lineal foot contains only 2/3 board foot.

In buying lumber for the boat building project, the builder must first determine just what thicknesses of materials will be required. When the designer notes that a given member should be 1" material, does he mean that the material will actually NET 1"? Or does he mean for the builder to purchase "four-quarters" stock? The designer should note somewhere on the plans or material listing just what is meant by the noted lumber thickness. The lumber thickness is usually the first dimension noted for a given member and is often called the "sided" dimension. From a practical standpoint, as well as making the purchasing easier, the designer should preferably specify standard lumberyard dimensions. That is, 1" material will actually refer to "four quarters" stock that will be milled or "sided" as full or thick as possible. In this case, the stock could range from 3/4" to 7/8" in actual milled thickness, and the designer would have made allowances for this variation in his scantling decisions. If the lumberyard is in a position to mill all stock on order, specify that milling should be as thick as possible AND that it should be uniform. It can prove exasperating to work with, say 1" stock, that varies in net thickness by several fractions of an inch. If the lumber has already been milled, check the thicknesses when buying to assure that there is little or no variation in milled thickness.

If, on the other hand, the designer means for such 1" material to actually be 1" NET in thickness, this would mean that the lumberyard would have to take the next thickest material (in this case "five quarters" rough stock) and then mill it to the 1" NET thickness. As anyone can quickly see, this would amount to 25% more lumber (1 1/4" as opposed to 1" stock) paid for, that would be wasted as sawdust. Plus the additional cost of custom milling the thicker stock to the specified net thickness. So unless the designer specifically notes that material will be to "NET" size, assume that lumber is purchased in the standard lumberyard thickness, and specifically note this to your lumber dealer when seeking a quotation.

Another important element for saving money in buying lumber is to group similar thickness members together into larger boards and then re-saw or rip them to size using your own equipment. In other words, if the designer has specified three-l" x 2" members, group these together and purchase just one board that is 1" x 6" wide (plus a little extra allowance for the saw kerf), re-sawing them to the widths and number of pieces required. If the lumberyard does this for you, it will cost considerably more in most cases. Naturally, to re-saw such material will require a power saw, preferably a table or radial arm saw, although a portable circular saw or band saw can also be used if they have a suitable guide or "fence".

In the matter of widths of materials, usually the designer will specify the actual NET or "molded" width unless otherwise stated. This is because widths can be varied with hardwoods to virtually any dimension. Softwoods, however, are an exception to this rule. As previously noted, the width of a softwood member will be actually less than the noted size, as in the 2" x 6" member example which will net about 1 1/2" thick x 5 1/2" wide. If given a choice of widths of stock, a general rule is to purchase stock in as wide of widths as possible. In many hardwoods, widths up to and exceeding 18" are sometimes found. Not only is it possible to re-saw such a member into more pieces, but it will allow greater versatility in the laying out of frame members. For example, a sawn frame member that is 4" in width taken from a 6" wide board could make for considerable waste. However, if a board could be obtained that was a little over 8" in width, then two such members could be taken from one length. Also, when wide deeply contoured frame members are necessary, it is possible to "nest" several such frame members within one width resulting in less scrap and lower material costs (see Plate 5-A). Obviously, some planning on the part of the builder will be required to take advantage of all these

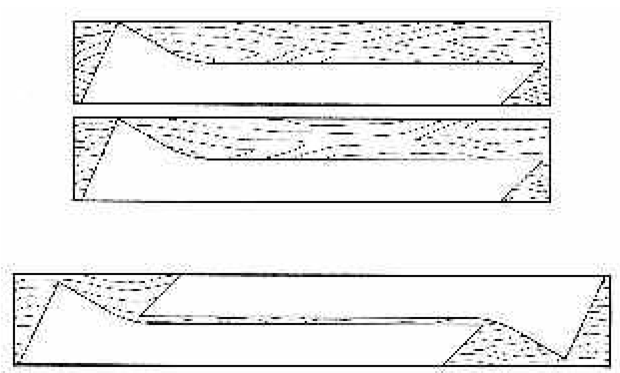

PLATE 5-A: Using material wisely can reduce costs considerably. For example, "nesting" of frame members with deep contours using wide stock will result in far less waste than using widths of stock that allow only one member from a given length of lumber. In the example, a board only slightly wider and longer yields the same number of pieces from considerably less material.

variations, but the savings in costs can be considerable. Once the builder has grouped all his lumber together and has carefully analyzed his bill of materials, or has determined what materials will be required, if the designer has not provided a bill of materials, he can go shopping. The first rule in shopping for lumber is to shop around for the best value. Note that we did NOT say shop for the best "price", since there is no such thing as a good "cheap" boat building lumber. In other words, lumber that might be half the price of other similar lumber, but that is full of defects, could wind up costing twice as much by virtue of wasted stock. This does not mean that special "close-outs" at favorable prices cannot be found and utilized, but the novice should be especially aware to avoid comparing lumber like "apples" with "oranges". He may end up with "lemons" instead.

Many boat building woods cannot be found in ordinary lumberyards. Then too, some lumberyards are more adept at merchandising lumber for boat building than others. It is easier, of course, is to find the proper lumber in areas where boat building is done. However, this does not mean that suitable sources cannot be found in other areas, even those that are far inland. This is because many boat building woods are used for other purposes. It is not uncommon, however, for lumberyards to ship lumber a considerable distance and to work on a custom-order basis, even with individuals building their own boats. When suitable sources cannot be found by utilizing the "yellow pages" or through local channels, a check with the advertising sections of the national boating magazines will usually reveal sources of boat building lumbers and related materials. However, in selecting any sources of lumber, be sure that you understand all of the cost figures, including any "hidden extras" like shipping the delivery, milling charges, bundling fees, etc., before purchasing. Experience has shown that through careful purchasing, a difference of as much as 50% in the total material cost of the hull can be realized.

SELECTING LUMBER

Once a source of lumber has been found, and a type of lumber has been decided on, the next step is the selection of the lumber or actual boards that will be used. As previously stated, wide widths are usually preferable, especially if facilities are available for re-sawing or ripping to size. Also, long lengths are desirable. But what do you do when the plans call for a member 20' long and the longest member available is 12'? As will be covered in forthcoming chapters, such long members can usually be formed from two shorter lengths by means of a scarf joint or butt joint. However, the builder must check against his plans to assure that such a joint will be located at the most appropriate location. For example, while two 10' lengths could be used to make a 20' member, utilizing a butt joint and butt block, it is possible that the joint would be located in an area of the hull with severe curvature which would make the joint more difficult to make. On the other hand, a 12' and an 8' length, which would also make up the 20' member, could be utilized that might locate the joint beyond the curvature thereby simplifying the joint. In other words, the builder should check all options against the plans in order to select the most suitable material, considering all such joints and lengths that may be required.

Ill lumber used in boat building must be seasoned, which means that the moisture from the green wood has to be removed in order to improve its serviceability. Air drying and kiln drying are the two methods used for lumber seasoning, and generally speaking, the air dried process is the best for boat building woods. However, air drying can require a year or more depending on the thickness and wood species, and consequently is seldom done. Most of the lumber available is kiln dried, which is acceptable if done properly. However, if the kiln drying process is either rushed (leaving too much moisture in the wood), or the lumber is "cooked" too long or at too high a temperature, (thereby removing too much of the moisture and making the wood brittle), the lumber will not be suitable for boat building. For most boat building lumber, the ideal moisture content ratio to lumber weight after drying (regardless of the process) is approximately 15%, with a range of from 12% to 16% being acceptable. When the wood is seasoned, it shrinks to some degree (see Plate 5-B), and if during drying too much moisture is removed, the wood will later absorb moisture and swell excessively once in use in the boat. On the other hand, if the wood is "green" or contains too much moisture after seasoning, the wood will tend to shrink and check or split while the boat is being built.

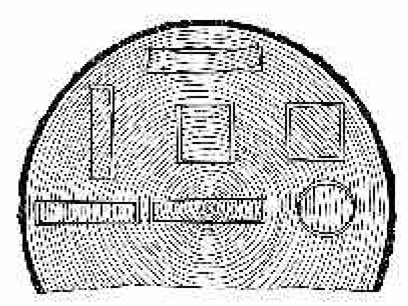

PLATE 5-b: How a piece of lumber will shrink with seasoning depends on how it is shaped in section and where it is cut from the tree. Tangential shrinkage (in the direction of the annual growth rings) is about twice as great as radial shrinkage (along the grain). The flat board at the lower left features the ideal vertical grain which makes such strinkage uniform on all faces.

But how does the average person detect lumber that has been properly seasoned and is within the range of suitable moisture content? Here it is largely a matter of depending on the integrity of the lumber dealer. However, there are tell-tale signs that one can look for when it comes to selecting suitable boards. Lumber that is "green" or unseasoned will often actually be "wet", with moisture apparent especially between boards when one is lifted. Of course, such lumber will be considerably heavier than comparable seasoned wood. Conversely, lumber that has too little moisture content may appear to be dry or even "weathered" as well as brittle.

Lumber that has been kiln dried too "hot" or quickly will often be warped, cupped, or wind severely along its length. These boards should be avoided even though the defects may only appear to a minor degree. When such boards are re-sawn after purchase, the problems are often magnified and can make it unusable.

Ihenever possible, boards should be selected that have prevalent vertical grain (also known as "edge grain" or "rift sawn" stock). Such boards will tend to expand and contract uniformly without undue distortion. When a lumberman cuts a tree, he has two ways available that he can cut the log up into boards. The easy and quick way is to simply slice up the log or "plain saw" it (see Plate 5-C). With this method, only a few of the boards will have the ideal vertical grain pattern, while most of the boards will be of flat grain (the terms "plain sawn", "slash grain", and "flat grain" are synonymous). Such flat grain boards tend to "cup" or distort, and therefore can split or check more easily. If the lumberman wants to take more care, he can cut the logs by what is called the "quarter sawn" (see Plate 5-C) method. This method results in many more boards of desirable vertical grain, but the widths will vary. Because good vertical grain wood is more desirable and quarter sawing takes more effort on the part of the lumberman, besides wasting more lumber, it is more costly. With most woods it is relatively easy for the buyer to look at the freshly cut end of a board to detect the prevalent grain structure and decide if a given board is of suitable vertical grain. While a board of obvious flat grain may look suitable in the lumberyard (otherwise flat and true), it could cup severely later, especially if not seasoned properly, and hence it is best to stick to vertical grain wood if at all possible.

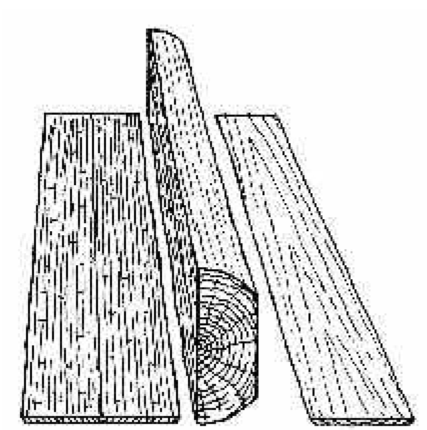

PLATE 5-c: Quarter sawed lumber results in ideal vertical or edge grained boards (at left of log), while plain sawed lumber provides boards of flat grain (to right of log) which are not as desirable for most uses in boatbuilding.

LUMBER DEFECTS

Once lumber of suitable grain structure has been selected, look for defects. Some people confuse defects with blemishes. A blemish as such does not affect the serviceability of the wood, but merely mars the appearance. A blemish can be important, however, where the natural grain appearance of the wood is desired, such as with joinerywork. A defect, however, is an irregularity in or on the wood that may lower its strength. It is often difficult for the novice to detect defects or to understand their consequences. In many cases, a defect will be limited in area and can be worked around so that it can be cut away, or will otherwise end up in a member or area where a decrease in strength is not important. So depending on the defect and its extent, don't rule out an entire board simply because of a limited defect. It is often possible to get a discounted price on such a board.

Defects usually are of two types; those caused by seasoning, and those that are caused by the way the tree grows. Seasoning defects are usually the result of shrinkage caused as the moisture is removed. Checking is a common seasoning defect, and it is a tension failure causing a split either along the surface of the board, or at the ends. An actual split in the wood is more severe than checking and is usually caused where an end check and a surface check meet. Warping is said to occur when the faces of the boards are no longer true planes. Warping defects include: bows (lumber bowing along its length), crooks (distortion of the edges of a board so they appear concave or convex), cupping (a concave or convex appearance when viewed on the end edge), and twisting (when the four comers of a board are no longer in the same plane). A major problem with bows and twists is that while the warp may be minor in the board, the problem tends to magnify when the board is re-sawn. On the other hand, cupping can be reduced if the board is re-sawn into narrow widths. Likewise, on a board warped lengthwise, shorter lengths of the same board can minimize the problem. While there are other seasoning defects, checking, splits, and warping are the ones that are most common and easily detected by the novice.

Natural defects that are a part of the lumber caused by growth can vary considerably with the species of lumber. For example, Sitka spruce is a very straight grained wood with few natural defects. However, Douglas-fir frequently contains knots to one degree or another, and it is often difficult to find the desirable dense, vertical grain type free of excessive knots. Knots are probably the most common natural defect, however, a knot in itself may be acceptable if it is minor in size in relation to the rest of the piece of wood and is tight with the surrounding wood. Whether a knot can be accepted in a given board depends not only on the soundness and size of the knot, but what the board will be used for. For example, if the board will be used for a bending member such as a sheer clamp or chine log, a knot along the length of such a member will often be unacceptable. Such a member if it does not break during installation, may fail in use at the knot.

Cross-grain in wood occurs when the fibers are not parallel with the major axis of the piece of lumber. Two types of cross-grain include diagonal grain and spiral grain. Cross-grained wood is not too commonly seen where boat building lumber is sold, partly because such wood is difficult to machine or season properly. Cross-grain wood should be avoided because such wood will fail under stress at the point of the cross-grain.

A shake is somewhat like a check or split except that shakes do not develop in seasoning or handling, but originate in the green timber. They may, however, become more apparent during seasoning. Depending on the location of the shakes, they may weaken the member. However, in boat building lumber, shakes are not too common because they occur mainly in lower grades of lumber that are not located near the heartwood of the tree.

Decay and rot can exist in wood before it has been installed in the boat and is almost always caused by fungi that grows in the wood. The decay and rot of wood after it is in the boat, its causes, and prevention is discussed later in the chapter, even though they are similar. An unusual fact of decay in wood is that all tree species are subject to heartwood decay in the living tree. However, once the heartwood lumber has been cut and seasoned, its decay resistance tends to increase, and in some cases, increases significantly depending on the species. On the other hand, rotting of sapwood in living trees is rare, but cut and seasoned, the resistance to rot is low. Therefore, decay that develops after the tree has been cut, and before use, of the lumber, is likely to be found in the sapwood. Such decay is usually easily seen and is often white or brown in color, with the surrounding wood greatly softened, punky, pocketed, brittle, collapsed, or cracked. Luckily such lumber is not commonly seen in a reputable lumberyard.

A common mistake by the novice is to confuse decay with insect damage. Insect damage is recognizable as holes in the wood and is classified as pin holes (or "pin-wormy" in some species), grub holes and powder post holes. All these insects are normally killed with kiln drying, or by wood preservative treatments. Insect damaged wood should not necessarily be automatically rejected. Much depends on the extent of the damage and where the wood will be used. Powder post damage (usually found in the seasoned sapwood of such woods as oak or ash) can destroy most of the interior of a piece of wood while the surface shows only minor holes, thereby reducing considerably the strength of the member. The other types of insect holes show up on the surface and the extent of damage thereby can be more easily determined.

ROT & WORM PROTECTION

On one hand, there seems to be a lot of talk bandied about by so-called "experts" about worm and rot "dangers" on wood boats. Yet on the other hand, finding a wood boat that is 50 years old or even older in sound condition is easy. In many cases such venerable craft seem to be unscathed by these purported "villains". Why is this so? The simple answers include using proper materials in the construction, proper construction techniques that will make the boat suitable for the conditions where it will be used, and proper maintenance.

To go into the technical aspects of this subject would not only be beyond the scope of this -book, but would also be boring to the average boat builder. All that is important from the viewpoint of the average do-it-yourselfer is how to protect his craft from possible damage from rot or worms.

Protection from worms is relatively easy on most plywood boats and is seldom a problem at all. First of all, marine wood borers (the worms that can cause damage to wood) are not found in all waters. They are usually limited to the warmer waters common to tropical areas. If worms are common to the boating area where you are located, this will usually not be a well-kept secret; the boaters in the area will know if they are there.

Wood borers tend to invade some woods and not others, so in selecting woods that will be exposed underwater, those woods that are less subject to attack should be used. If such woods are not available, they should be treated with a suitable wood preservative or pressure treating technique. However, on a plywood boat, there is usually not much solid lumber below water with the exception of skegs or deadwood keels. Unlike solid lumbers, marine borers do not seem to like plywood nearly as much as some solid lumbers. One reason that this may be so is the glue line between plies that is distasteful or even toxic to them. Another aspect is that the edge grain is more susceptible than the surface of a panel, and sealing the edge grain for protection is easy.

Of course, a plywood boat that is entirely sheathed with fiberglass or equivalent material and resin is virtually immune from worm attack, and hence this is probably the easiest method of protection where attack by worms can be expected. Worms do not seem to like or be able to penetrate surfaces covered with the resins (either polyesters or epoxies) used with these sheathings.

There are different kinds of rot and reasons for their spread, but to keep things simple, rot requires moisture, lack of air circulation, and the proper temperature to spread and grow to cause any damage. Remove any one of these factors and rot will usually not be a problem in any wood boat. As with worms, using a rot resistant wood will be the first step in rot prevention.

Most boats tend to accumulate some water in the bilge. If the boat is used in salt water, it is a common mistake to assume that this bilge water will cause rot. The rot fungi cannot grow in salt water; they need fresh water to be promoted, and consequently most rot tends to occur along the deck and cabin areas where fresh water or moisture (from rain, condensation, etc.) tends to penetrate into the structural members.

With conventionally built wood boats this is more of a problem than with plywood boats since the deck and cabin areas are likely to be covered with fiberglass or equal sheathing on the plywood boat. Nevertheless, a positive and adequate flow of air should be provided to all below-decks spaces, especially in the ends of the boat, This is not-ably important when the boat is not in use. Remember that rot can occur whether the boat is kept in the water at a mooring, or in the backyard on a trailer. So if it is kept covered regardless of where, take into consideration that air must flow inside. (Note that this rule applies to ALL boats regardless of the material used in the construction.) Temperatures should be kept down also since rot spores are not active at lower temperatures.

In building a plywood boat, the recommended technique for rot prevention, besides using suitable materials and proper maintenance, is to liberally apply wood preservative to all surfaces inside the hull. If the hull is to be sheathed with fiberglass or equal material and resin, this treatment should not be done until after the exterior of the hull has been covered since the resin will not bond to any areas where the preservative has been applied. For example, if the wood preservative liquid happens to penetrate through a joint, say along the chine, and gets onto the outside of the hull, the resin will not form a bond at this point. So apply the preservative after the hull is righted and the fiberglass covering has been completed.

There are several types of wood preservatives available under many brand names from paint dealers. Two common types are pentachlorophenol and copper napthanate, and these ingredients are usually noted on the fine print of the label. Follow the manufacturer s instructions carefully for proper protection. With most of these treatments, painting of the surfaces can be done after, but be sure to check the label.

A common mistake often is made by the amateur in assuming that if a fiberglass covering will protect the outside of the hull, why won't it do the same for the inside? The problem is not the theory in this case, but with the application. It is virtually impractical to properly apply the fiberglass cloth around all the many corners and junctions within the hull so that it will bond 100% at all areas and not lift thereby forming air bubbles. If any air bubbles at all form in such a covering and go unnoticed, they will eventually form perfect moisture traps that could lead to rot. Since the bubble where the rot will start will be a small area, it won't be noticed on the surface, but the rot could spread under the covering and do a tremendous amount of damage before it is detected. By this time it could be too late and quite a repair operation would be necessary. In short, such a procedure is not recommended; let the interior of the hull "breathe" instead, using the recommended preservative treatment and later painting the hull interior areas if desired. Note that fiberglass laminates are hygroscopic, that is, they will absorb moisture to some extent (contrary to popular belief).

SAPWOODS & HEARTWOODS

Basically, the heartwood is the middle of the tree, while the sapwood is the layer surrounding the heartwood. Actually, the heartwood consists of dead cells, and year by year the tree increases in diameter by the addition of new layers of sapwood under the bark. As the outer layer of cells increases under the bark, another layer of cells dies off in the sapwood and changes to heartwood. As previously mentioned, sapwood in practically all trees is low in decay resistance, and unless given preservative treatment, is not as durable as heartwood.

Heartwood is neither weaker nor stronger than sapwood fundamentally, but some changes in physical characteristics do occur with heartwood formation. For example, the heartwood absorbs and loses moisture more slowly than sapwood making it more dimensionally stable. However, most heartwood is more difficult to treat with preservative although many varieties are more resistant to decay in the heartwood. While the heartwood of many trees is readily distinguishable from the sapwood by virtue of a darker color, some woods show little color differential. Good all-heartwood lumber may be difficult to obtain, and it is common to find boards with both heartwood and sapwood combined, depending on the species.

SOFTWOODS & HARDWOODS

Woods are grouped into two general classes; hardwoods and softwoods. However, the terms do not necessarily mean that a hardwood is harder than a softwood. The difference between the two classes is purely genetic or botanical in nature. Hardwoods come from trees with broad leaves (called angiosperms), many that tend to drop their leaves with the seasons. Softwoods, however, come from trees that have needle or scale-like leaves (called gymnosperms), are mostly evergreens, and are often called conifers since they are cone-bearing trees. Within each classification there are considerable variations in structure and qualities. The main thing for the novice to remember is that when someone, such as a lumber dealer, refers to a wood as a "hardwood" or as a "softwood", he will be referring to woods with a botanical difference; not to a wood that may be harder than another.

LUMBER SPECIES FOR BOAT BUILDING

While there are probably thousands of different wood species throughout the world, most of them are not suitable for boat building. Many woods are unsuitable for at least one of a variety of reasons. They may be too weak, too brittle, too soft, subject to decay, will not hold fastenings well, or the trees may be too short to yield lengths of material suitable for boat building. In the following descriptions, those woods which have been proven in use in boat building over a period of literally generations in the United States are noted, as well as some which may be of only limited value or which are unsuitable, but are often confused with similar suitable types. Even though many types are imported, they are often readily available. The nomenclature of the various woods given is the commercial name. Where the wood may be known under other names, these have been listed in parentheses. Weights of each wood are given per cubic foot and per board foot at 15% moisture content on an average basis. Variations in weights, however, will occur in a given species due to variations in moisture content, heartwood to sapwood ratio, and other factors. For practical purposes a wood that weighs under 2.5 lbs. per board foot is considered light in weight. A wood that exceeds about 3.3 lbs. per board foot is considered heavy. Woods that weigh between these figures are considered medium weight woods. The descriptions are broken down into the two categories; hardwoods and softwoods. Because of their special qualities and limited uses, not all the woods listed are applicable to boat building with plywood; but they are noted since they are often sold in lumberyards specializing in boat building woods.

HARDWOODS

APITONG

44 lbs. per cubic foot, 3.67 lbs. per board foot.
Abundant in the Philippines, Indonesia, Malaysia, and New Guinea, There are many different species, however, they look very much alike. Sapwood is creamy yellow, gray, or reddish white, while heartwood is reddish purple or brown. The

grain is usually straight. The wood is slow to dry, does not take preservatives too well, is moderately low in decay resistance, and somewhat difficult to work. Apitong is very hard, strong, holds fastenings very well, and is often substituted for white oak but it is not nearly as durable.

ASH, WHITE
42 lbs. per cubic foot, 3.5 lbs. per board foot.
A domestic wood grown mainly in the Eastern states. The heartwood is brown, while the sapwood is light in color or nearly white. The wood is hard, fairly strong, straight grained, and suitable for steam bending. It can be substituted for white oak in areas that will not be continually moist. Decay resistance is low. Often used for small boat framing, oars, tillers, and joinerywork.

ELM, ROCK
44 lbs. per cubic foot, 3.67 lbs. per board foot
A domestic wood that grows in the North Central and Northern states. It has only limited use in boat building, mainly because it is suitable for steam bending. The wood is hard, strong, and shock resistant, which makes it suited well for small boats utilizing steam bent frames and laminated members. Decay resistance is fair at best and the wood tends to warp.

GREENHEART
61 lbs. per cubic foot, 5.08 lbs. per board foot
The wood is native to South America and the West Indies, however, it is imported mostly from Guiana. The heartwood is extremely decay resistant and has a reputation for being highly resistant to marine borers that may not be completely deserved when used in tropical waters. The wood was once a favorite with European builders since it is stiff and very strong. Its color varies from pale greenish-yellow to deep brownish purple, with little difference between sapwood and heartwood. The high weight can be a considerable disadvantage in some designs. Being a very hard, dense wood, it can be more difficult to work than other hardwoods.

IROKO
40 lbs. per cubic foot, 3.33 lbs. per board foot
The tree comes from tropical Africa and is much like teak, but not as strong. The heartwood is decay resistant and somewhat resistant to marine borers. The wood is hard, but moderately easy to work. Heartwood is light to greenish yellow, but darkens to brown upon exposure to light and air. Iroko is very popular for boat building in Europe.

IRONBARK
(eucalyptus)
62 lbs. per cubic foot, 5.17 lbs. per board foot
Several species of Eucalyptus called red and gray ironbark are native to

Australia where they are most used. Heartwood is red to dark brown, and sapwood is light colored. The heartwood has good decay resistance, and is resistant to some forms of marine borers. The wood is very hard, heavy, strong, and shrinks moderately. Because of its high weight, the wood can be a major disadvantage in many types of boats.

LIGNUMVITAE

(ironwood)

76 lbs. per cubic foot, 6.33 lbs. per board foot

One of the hardest and heaviest woods known, it is found in Central America and the West Indies. The wood is naturally impregnated with oils which makes it suitable for propeller and rudder shaft bearings (its major function) as long as shaft RPM is not too high. Heartwood varies from olive brown or blue to dark brown or nearly black, while sapwood is cream colored. The heartwood is very resistant to decay and abrasion. The wood is often used for keel and worm shoes, rubbing strakes, etc. It is extremely strong with regard to crushing and hardness.

MAHOGANY, AFRICAN

(khaya, utile)

32 lbs. per cubic foot, 2.67 lbs. per board foot

Very similar to genuine mahogany, it comes from Africa. Color ranges from light pink to bright red or reddish brown, but is not as variable as mahogany. The wood is hard, strong, decay resistant, of low shrinkage, and seasons well. There are several species of so-called "African" mahoganies, but those listed above are the most suitable for boat building.

MAHOGANY, HONDURAS

(Mexican mahogany)

34 lbs. per cubic foot, 2.83 lbs. per board foot

True mahogany grows in the West Indies, Central America, the northern part of South America, and some in the southern part of Florida. The types frequently used in boating are called Honduras and Mexican mahoganies. Color varies from deep red to reddish brown in the heartwood, with sapwood a pale yellow. The heartwood is decay resistant, fairly strong, and seasons well, with low and uniform shrinkage. Hardness, weight, and strength can vary depending on where the lumber is from, with the Central American variety being more variable.

MAHOGANY, PHILIPPINE

(tangile, red luan, white luan, tiaong)

39 lbs. per cubic foot, 3.25 lbs. per board foot

The many varieties of so-called "Philippine mahogany" are really types of tropical cedar common to the Philippines even though they resemble true mahogany. The dark red varieties are harder, heavier, more decay resistant, and stronger than the light red varieties that are usually limited to nonstructural joinerywork. The trees yield large, clear boards, although interlocked grain can make seasoning some times difficult.

OAK, WHITE

47 lbs. per cubic foot, 3.83 lbs. per board foot

White oak is a domestic Eastern wood often used in boat building. The problem with white oak, however, is distinguishing it from red oak that is not nearly as suitable for boat building since it is weaker and rots easily unless pressure treated with preservatives. The following characteristics should help in separating white oak from red oak. The heartwood pores will be plugged with abundant hair-like ingrowths known as tyloses, whereas red oak will contain few. The heartwood of white oak is tan or light brown, while that of red oak is reddish or pink. The pores in summer wood are very small and numerous in white oak, but with red oak they are few, large, and open. A chemical test using benzidine-sodium nitrate turns white oak heartwood dark brown or greenish brown, but that of red oak turns light orange. White oak is excellent for steam bending but should ideally be "green" for this purpose and not seasoned. It is durable, stiff, strong, hard, holds fastenings very well, is rot resistant, but is somewhat difficult to work and requires sharp tools. Because of the gallic acid in white oak, it reacts with plastic resin glue when submerged in salt water, and therefore this glue should not be used with white oak under these conditions.

OKOUME

(gaboon)

27 lbs. per cubic foot, 2.08 lbs. per board foot.

This West African wood produces large, clear logs of uniform straight grain. The heartwood is salmon pink or pale pinkish brown resembling some types of Philippine mahogany. The sapwood is grayish. It is only fairly strong considering other woods, but strong for its weight, although low in resistance to decay. The wood splinters easily and is best sawn with carbide tipped blades. It has little use in plywood boat building except in smaller boats where lightweight is more important than durability. Some imported plywood is made from this wood.

TEAK

43 lbs. per cubic foot, 3.58 lbs. per board foot

Probably the most decay resistant wood in the world, but it is not totally immune to marine borer attack. The wood grows in Burma, India, Thailand, and the East Indies. Sapwood is white to pale yellowish brown, while heartwood is a dark golden yellow that darkens with age. The wood has a rough oily feel, is straight grained and coarse, strong, hard, of low shrinkage, and easily worked but brittle, and tends to dull tools. Very commonly used for decking, joinerywork, and frequently left unfinished, it is a very durable wood. Glues used with this wood must be selected with care.

SOFTWOODS

CEDAR, ALASKA

32 lbs. per cubic foot, 2.67 lbs. per board foot

Grows along the Pacific coast from Alaska to Oregon. The heartwood is bright clear yellow, while the thin layer of sapwood, which is barely visible, is a shade lighter. The wood has a fine uniform texture with low shrinkage, and is moderately strong. Heartwood is high in decay resistance, and works and finishes well.

CEDAR, ATLANTIC WHITE

(Southern white cedar, swamp cedar, juniper)

23 lbs. per cubic foot, 1.92 lbs. per board foot

The wood is soft, brittle, weak, and splits readily. However, it is low in shrinkage even though it soaks up considerable water. Because of this and its decay resistance, the wood is frequently used for conventional planking, especially in areas where the material is grown (notably along the Atlantic seaboard and Gulf states mainly in swamps), and on boats which will. be in and out of the water frequently. It has little use in plywood boat building.

CEDAR, NORTHERN WHITE

21 lbs. per cubic foot, 1.75 lbs. per board foot

Very similar to Atlantic white cedar, but because of small trees, its use is limited to small boat construction only, especially conventional planking. It is grown mostly in the Northeastern United States, and has little use in plywood boat building.

CEDAR, PORT ORFORD

30 lbs. per cubic foot, 2.5 lbs. per board foot

Grown in limited areas of Northern California and Southern Oregon, it is the preferred species of boat building cedars. Although only moderately strong, it is the strongest cedar and the heaviest before seasoning. The heartwood is light yellow to pale brown with a distinctive spicy odor. The wood is fine and uniform in texture, moderately hard, shrinks moderately, seasons well, and is very resistant to rot.

CEDAR, WESTERN RED

23 lbs. per cubic foot, 1.92 lbs. per board foot

Grown in the Pacific Northwest, the wood has narrow white sapwood and reddish-brown heartwood. It is rather soft and weak, shrinks very little, and the heartwood has good resistance to decay. The grain is uniform and straight although somewhat coarse and brittle. While often used for conventional planking, it is not highly recommended for this use. However, for veneers for use in cold molded hull planking, the material is excellent.

CYPRESS, BALD
(red cypress, yellow cypress, white cypress)
32 lbs. per cubic foot, 2.76 lbs. per board foot
Grown along the Southeastern coastal states of the United States, often in swamps. Heartwood near salt water varies from reddish to almost black, while the heartwood from farther inland is only slightly reddish or yellowish brown. Moderately strong, it is highly decay resistant, but soaks up a lot of moisture. Its primary use is in conventional planking, and therefore has little use in plywood boat building.

DOUGLAS-FIR
(yellow fir, Oregon pine)
34 lbs. per cubic foot, 2.83 lbs. per board foot
This boat building lumber comes from the coastal areas of the Pacific Northwest. It is not a true fir, thus the hyphenated name. Unseasoned green lumber is common and should be avoided. The heartwood tends to be pinkish to yellow in color, with mature growths being of straight, uniform, and dense grained. Younger trees tend to have more knots. The wood is strong, moderately hard, moderately decay resistant in the heartwood, splits relatively easily, does not bend or steam bend readily, and is fairly easy to work. Douglas-fir is sometimes used for making spars in place of Sitka spruce, and in these applications, the wood should be free of defects, well seasoned, and of vertical grain for strength.

LARCH, EASTERN
(hackmatack, tamarack)
30 lbs. per cubic foot, 2.5 lbs. per board foot
The species grows mainly in the Northern and Northeastern coastal states, but is related to western larch. The heartwood is yellowish brown, while the sapwood is nearly white. In boat building, the crooks of the trees (usually in the roots) are used to form natural knees and stems. The wood is moderately decay resistant, tough, moderately strong, and durable.

LARCH, WESTERN
39 lbs. per cubic foot, 3.25 lbs. per board foot
Grown in the Pacific Northwest and frequently harvested and shipped, with Douglas-fir. While not a common boat building lumber, there is no reason that it cannot be used if suitable stock is selected. It resembles Douglas-fir except the heartwood is russet brown instead of pinkish or reddish. It is strong (actually stronger than Douglas-fir), stiff, has moderate decay resistance, splits easily, and has moderately large shrinkage. Knots are frequent but usually tight and small.

PINE, WHITE
(Eastern white, Western white, ponderosa, & sugar pine)
25 to 28 lbs. per cubic foot, 2.08 to 2.33 lbs. per board foot
The several types of white pine are available in most of the United States, and grow in many sections of the country. While some types were once popular in boat building, their scarcity and the fact that only second growth stock is sometimes available makes most pine too weak and not durable for boat use. Decay resistance is moderate at best, and its use is best relegated to nonstructural interior joinerywork. These varieties are described to avoid confusion with the longleaf yellow pine type.

PINE, LONGLEAF YELLOW
(Southern pine)
41 lbs. per cubic foot, 3.42 lbs. per board foot
Grown in the Southern, Atlantic, and Gulf states, there are several varieties of Southern pine. However, the "longleaf" type is best for boat use. The wood is an orange to reddish brown in color, but all species are similar and difficult to differentiate. The dense heartwood is considered almost as decay resistant as white oak. The wood is strong, straight grained, and hard, however this can vary. The sapwood can be easily treated to improve its decay resistance. Often substituted for white oak.

REDWOOD
28 lbs. per cubic foot, 2.33 lbs. per board foot
Grown along the Northern California coast, the heartwood is light cherry to dark mahogany in color, while sapwood is nearly white or pale yellow. The heartwood is extremely decay resistant, but sapwood is not. The wood is fairly straight grained and free of defects, especially if heartwood. It shrinks and swells little, is easy to work, but tends to be brittle and does not hold fastenings well. The strength is moderate, it does not bend well, and has little use in plywood boat building.

SPRUCE, EASTERN
(red spruce, black spruce, white spruce)
28 lbs. per cubic foot, 2.33 lbs. per board foot
The three species, which are grown in the North and Northeastern states, have similar properties. The wood is light in color with little difference between sapwood and heartwood. It is easily worked, moderate in strength, stiffness, hardness, and toughness. It is not resistant to decay, and is used only where weight is important, and durability is not, or for non-structural work. It has little use in plywood boat building.

SPRUCE, ENGELMANN
(white spruce, Arizona spruce, silver spruce, balsam, mountain spruce)

23 lbs. per cubic foot, 1.92 lbs. per board foot
These varieties are described only to avoid confusion with the Sitka type of spruce. Grown mainly in the Rocky Mountain states, they are not suited to boat use due to softness, low strength, low resistance to decay, and lack of shock resistance. The sapwood and heartwood are hard to differentiate, and the wood is nearly white in color. It can be used in non-structural joinerywork, however, if not subjected to moisture.

SPRUCE, SITKA 28 lbs. per cubic foot, 2.33 lbs. per board foot
Grows along the Pacific Coast from Alaska to California. Because the trees grow tall, and the material is exceptionally strong for its weight, it is the ideal spar building lumber, even though rot resistance is low. The wood shrinks little and is moderately strong in bending. The heartwood is light pinkish brown and the sapwood creamy white. Where lightweight and strength are important, it is ideal.

WOOD USE AND CHARACTERISTICS CHART

The Wood Characteristics chart (see Plate 5-D) is presented as a general guide only, and the qualities listed should be taken with a grain of salt. The reason for this is that there are many variables that must be considered in the application and usage of various wood types. For example, the fact that white oak may be excellent for frame members does not mean that each and every piece of white oak lumber will be suitable for such service. Then too, in some parts of the country, a wood that may be suitable in one area may not be suitable in another for various reasons, such as the quality or quantity available, local practices of seasoning, or any number of other variables. In other words, the recommendations are all relative not only to the locale, but to the services to which the lumber will be applied. Again, the emphasis is made that this listing is general in nature, and the guide to follow is to use those woods that are proven in boat building use in the locale. Also, when selecting a wood from the chart, be sure to look over the adjoining text for that particular species.

PLATE 5-D: Wood Use & Characteristics Chart

	Weight	Strength	Decay & Rot Resistance	Fastening Ability	Comments
Hardwoods					
Apitong	Heavy	Strong	Poor	Good	Difficult to work
Ash, white	Heavy	Fairly strong	Poor	Fair	High shock resistance
Elm, rock	Heavy	Strong	Fair	Good	Good for steam bending
Greenhart	Very Heavy	Very strong	Very good	Very good	For heavy, durable construction
Iroko	Heavy	Strong	Good	Good	Can be used in place of teak in many parts
Ironbark	Very Heavy	Very strong	Good	Good	For heavy, durable construction

(eucalyptus)					
Mahogany, African	Medium	Fairly strong	Good	Good	
Mahogany, Honduras	Medium	Fairly strong	Good	Good	Best of mahoganies
Mahogany, Philippine	Medium	Fairly strong	Fairly good	Good	Use dark red variety in boats
Oak, white	Heavy	Strong	Good	Very good	Don't confuse with red oak
Okoume	Light	Not strong	Poor	Fair	Suitable for light, small boats
Teak	Heavy	Strong	Very good	Good	Hard on tools, can remain unfinished
Softwoods					
Cedar, Alaska	Medium	Fairly strong	Good	Good	Heartwood & sapwood look similar
Cedar, Port Orford	Light	Strong	Very good	Good	Preferred boat building cedar
Cedar, Western red	Light	Not strong	Very good	Fair	Suitable for veneers in cold mold planking and for light, small boats
Douglas-fir	Medium	Strong	Fairly good	Good	Use only clear, vertical grain
Larch, Eastern	Light	Fairly strong	Fairly good	Good	Traditionally used for natural knees & stems
Larch, Western	Medium	Strong	Fairly good	Good	Similar to Douglas-fir
Pine, longleaf yellow	Heavy	Strong	Good	Very good	Substitute for white oak
Spruce, Sitka	Light	Fairly strong	Poor	Fair	High strength to weight ratio