Bottom Frame Repair

A PROFESSIONAL RESTORER'S VIEWPOINT

BY DON DANENBERG

I've seen many frame repairs made by simply removing an offending piece of a frame and replacing it with another piece to fill the space and create something new to screw a plank to, a graving piece or dutchman. Glue or not, this is wrong if the repair piece is larger than one third the thickness, or molded, surface measurement of the frame. It totally negates the purpose of a "frame."

Note the photo of the frame repair made by replacing the piece of frame and sistering with a piece of 3/8" plywood. Like the weak link in a chain, this frame is as strong as a 3/8" piece of plywood at this joint. This boat will depend on the planks holding the frames together here, which will not last long. This repair would almost certainly have taken longer to put together than just patterning, cutting out, and installing a new frame.

In the case of a bottom frame split on its side surface, you could try to clean the splits of oil, splinters and broken fastener pieces and glue and clamp them together. You must realize, however, that you intend to put another twenty or so fasteners right down this same, probably oil contaminated, glueline, making it almost certain to fail again. In any case, it is almost always easier and cheaper to simply unscrew the bad frame, trace it onto new framestock, make any bevels, walk over to the bandsaw and in about fifteen minutes, have a new sturdy frame to seal and install.

I replaced all the bottom and topsides frames in a very gray 22' utility. With one person removing frames and another assembling them while I patterned and cut them out, we were able to replace all bottom and topsides frame futtocks and knees in two days. In another six days, I had fabricated and installed a new stem, gripe, keel, chines, and complete transom frames and bows.

If I had been required to use glues an dutchmen to attempt to save those badly deteriorated old frame members, I'm sure it would have taken weeks to accomplish something with a very questionable lifespan, as well as questionable fairness and strength. I know I would certainly have expected popped bungs and cracked varnish in the topsides.

In short, it is up to you to decide how historically important a bad frame member is, and if this is the case, you should probably have started with a different boat. You might consider extra effort worthwhile in saving and restoring frames that contain hull numbers. You will soon learn that whatever seems, at first, to be the hardest or most expensive choice in wooden boat repair is generally the cheapest and easiest in the long run. This is due to the fact that doing it right the first time makes each of the successive procedures easier.

Assembly Tools

A decent bandsaw (1/2 hp or more).

A surface planer (small portables work well).

A hand-held power plane.

A low angle hand plane and rabbet plane.

A sturdy jigsaw.

A strong drill.

An adjustable clutch screwgun.

Correctly sized drillbits and counterbores for each size of screw you will be using.

Twelve inch drillbits from 1/4" to 3/8" with correct counterbores for boltheads and washers will be necessary for carriage bolt installation.

A divider or compass with adjustable pencil length.

An angle indicator or adjustable protractor and bevel gauge.

An eight foot straightedge and six and four foot levels.

A water level or laser level.

As many barclamps as possible from 6" to 36". I generally use about 60 per boat.

3/4 x 3/4 x 16 foot battens.

Adjustable ships curve.

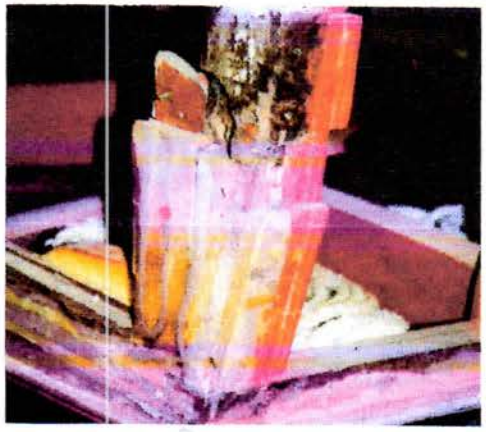
Ice picks.

Lumber

It is not really my place to decide for you what materials you will eventually choose in your restoration. I can only offer my opinions based on experience and research. I ask that you do as much research as possible on whatever

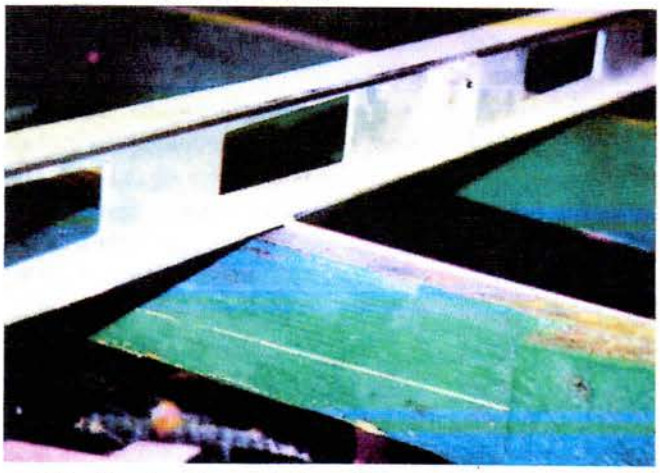
This frame is only as strong as the 3/8" plywood butt sistered to it. Better to replace it with an all-new piece.

Photos supplied by Don Danenberg



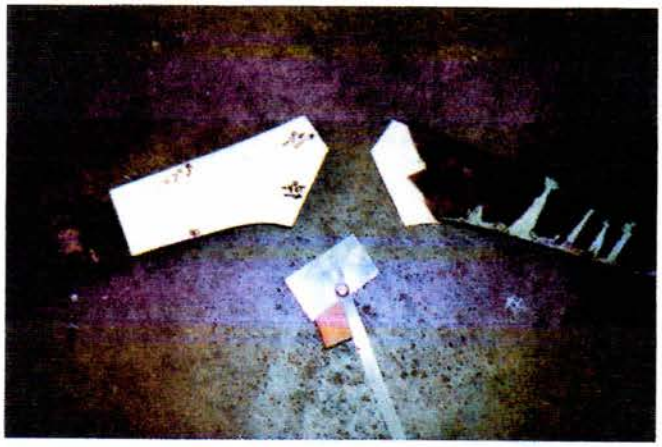
Shaped blocks were glued in to replace missing frames sections. It is up to the planks to hold this "frame" together.

NO WAY! Not the way to do things.



Adjusting the shape of a bent frame by stapling posterboard to the edge verified by battening. The new frame will be traced to this line.

When frame ends are missing or rotted away, we simply shape the missing end out of posterboard and staple it in place before removing the frame from the hull.



The angles are transferred to the pattern using an adjustable protracgtor or bevel gauge.

The endgrain of the topsides frame is sometimes only slightly affected by rot. If only a small section can be cut from the topsides frame, the shape of the bottom frame can be adjusted to compensate.

materials you might use with an emphasis on how they are properly used. This may sound redundant, but all too often, I have seen the correct materials used incorrectly.

Since you are rebuilding a wooden boat, I suggest you buy or borrow every book you can find on wood. Get to know how wood expands and contracts relative to its grain direction so you will know what to expect before you install it.

If you own a wooden boat, you simply must obtain the book *Understanding Wood* by R. Bruce Hoadley. This book not only explains wood's properties, such as stability and rot resistance, but also explains, in depth, how to work with it.

The best way to protect your investment is to use the best materials you can obtain, especially with the wood. For example, the

rot resistance of woods commonly used in classic boat frame construction relate as follows:

Very resistant
White oak (Q.alba)

Moderately resistant
Honduras mahogany
African mahogany
Douglas fir

Slightly or non-resistant
Red oak
Philippine mahogany
Ashes

Traditional plank on frame construction has, for millennia, depended mainly on white oak (quercus alba) for all frame construction. This is due to compression, shear, and tensile strength, combined with high rot resistance and unsurpassed fastener holding capabilities. Do no confuse this with red or black oaks or even with some of the lesser white oaks which do not have anywhere near the same degree of rot resistance. Your local lumberyard probably does not make these distinctions, so you will have to so some research to find the real thing. You may have to purchase and ship your lumber from a marine lumber supplier.

One method of testing the wood is to cut a small sample across the end grain, exposing the vessel structure. Very carefully, slice this surface clean with a razor blade until the vessel structures can be clearly seen with a 10-power hand lens. If the large earlywood pores appear dark, this indicates they're empty and would transport water too well for its use in boat construction, indicating that this is a type of red oak.

If the large earlywood pores appear white, then they are likely filled with bubble-like structures called *tyloses*, which make it very difficult to pass liquids and contributes significantly to rot resistance, indicating a white oak.

Please obtain the aforementioned book and another by the same author, *Identifying Wood*. I do not want to sound like an expert here, as I am not. But it sure is fun to obtain the right books and magazines, and learning from the experts.

Chris-Craft seems to be the only notable exception to the use of white oak in frame construction. While they usually used white oak for the stem and lower transom bow, only on some early models was it used for the gripe, keel, chines, and transom framing. The bottom, topsides, and deck frames were almost always Philippine mahoganies, as was the plank-stock. In replacing Chris-Craft frames with mahogany, I recommend using the American mahogany (Honduras) over Philippine for reasons of better fastener holding capabilities as well as much better rot resistance.

The true mahoganies are of the family *Meliaceae* and include the American mahoganies *(Sweitenia sp.)*, the African mahoganies *(Khaya sp.)*, and even the misnamed Spanish cedar *(Cedrela odorate)*, which was apparently, very early on, given the erroneous taxonomic name because of its cedar-like aroma. It has since been found to be of the Meliaceae family, not of Cedrela.

The so-called Philippine mahoganies *(Shorea, parashorea, Pentacme spp.)* are not related at all to the Meliaceae family and, as such, are not true mahoganies.

In my research in the Chris-Craft archives at the Mariner's Museum, I found wood orders, dating back to 1927, for millions of board feet of lumber placed with the Indiana Quartered Oak Company. The only mahoganies ordered were "good dark" or "fine wormy dark" grade "Philippine."

See, isn't it fun to learn that the only "mahogany" boats built by Chris-Craft were the Spanish cedar planked hulls built just after World War II?

If you have completed a survey of your bottom framing and marked all those places you intend to replace, it is time to add up the materials you will need to order to replace them. Lumber is sold in "board feet," which is a unit of measurement equal to one square foot, one inch thick, or 144 cubic inches.

To determine board feet, you must multiply the length in inches times the width in inches times the thickness in inches and then divide the result by 144, the number of cubic inches in one square foot of wood, one inch thick.

For example, for a board 10 feet long and 8 inches wide and one inch thick, first transfer the length to inches (10 x 12 = 120).

$$120 \times 8 \times 1 = \frac{960}{144}$$

$$= 6.67 \text{ board feet}$$

For a board 15 feet long, (15 x 12 = 180) and 10 inches wide and 1½ inches thick:

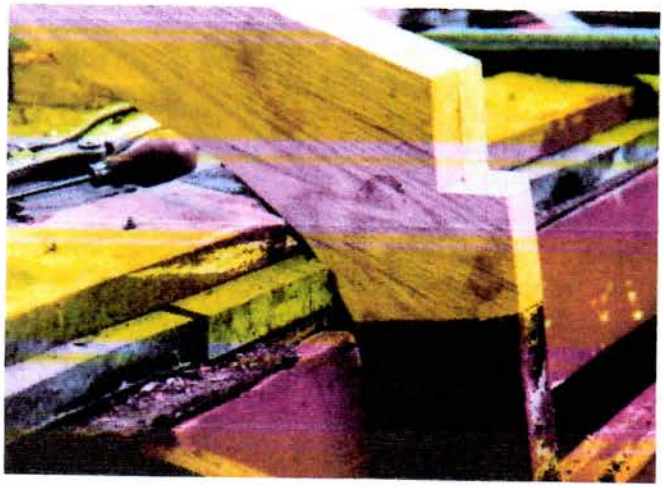
$$180 \times 10 \times 1.5 = \frac{2700}{144}$$

$$= 18.75 \text{ board feet}$$

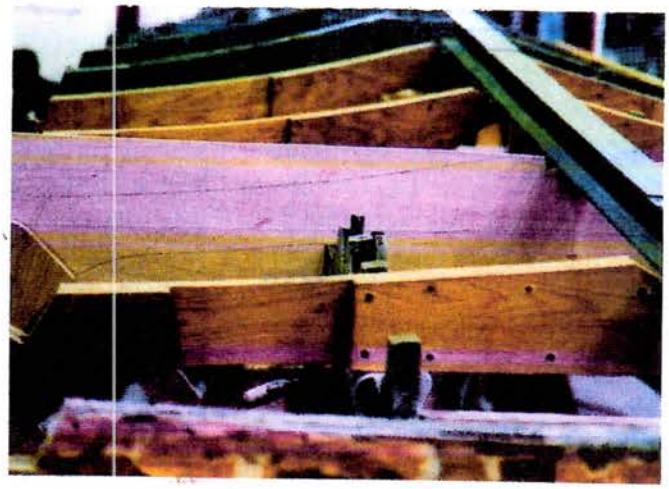
Multiply this amount by the figure the lumberyard will quote per board feet and you will know how much your lumber will cost.

The lumber is usually sold "rough sawn" and will need to be dressed to the finished thickness your boat requires with a surface planer (surfacing). If you do not own such a tool ($400 to $1000s), a good lumberyard can usually provide this service at a specified price per board feet.

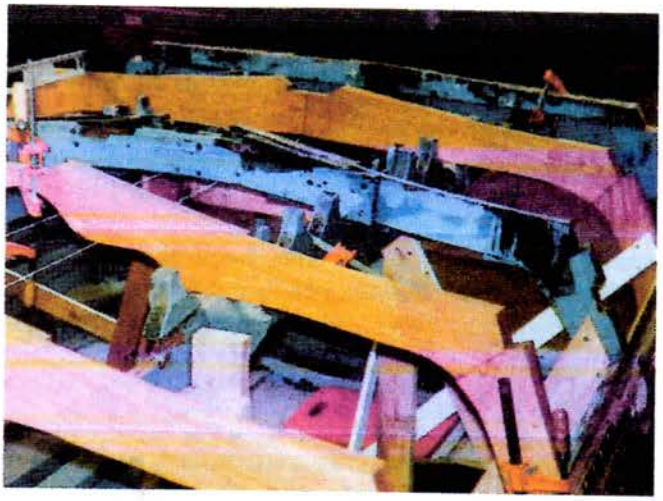
The lumberyard measures thickness in quarters of an inch: One inch thick is called 4/4, read as four-quarter. One and one-half



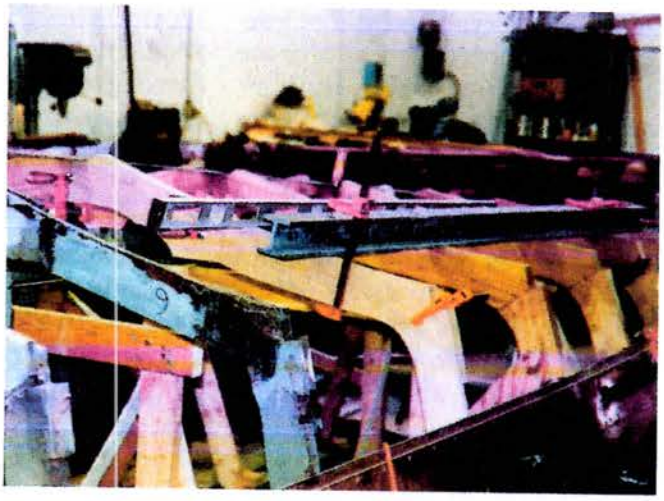
If the frame is not sound within two inches of the end, we go ahead and replace the topsides frame.



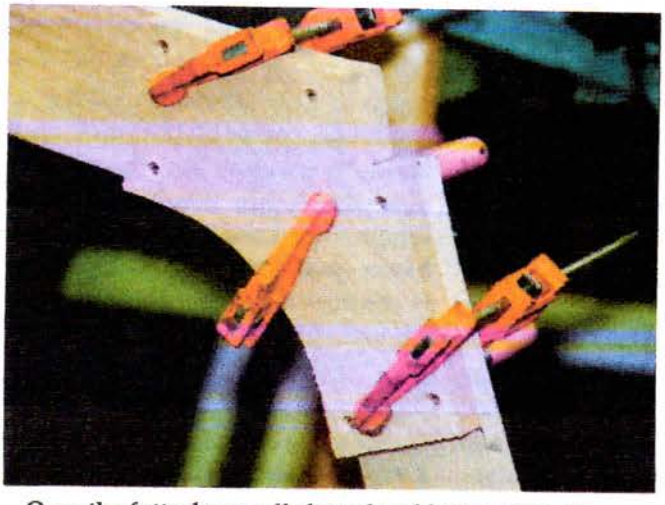
If entire frame sections are so bad that they cannot be reliably traced, sheets of plywood can be used and the shape battened from adjoining frames.



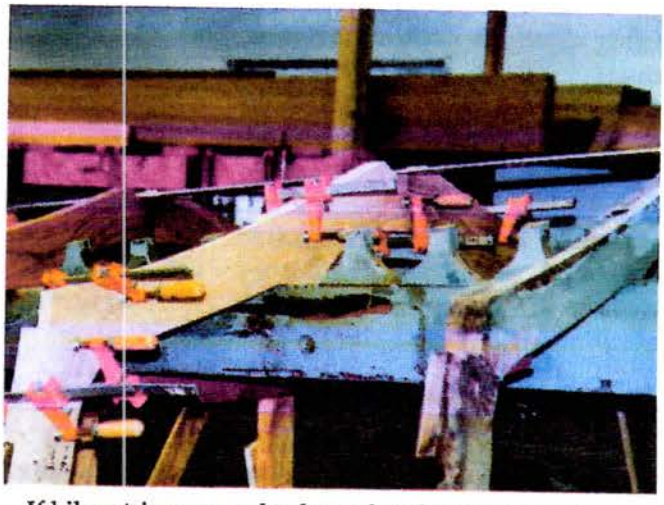
It is a good idea to replace every other frame section using the alternates to verify shape.



Frame alignment is continuously checked with battens, or straight-edges in the planing surface, to verify shape before committing to final placement.



Once the futtocks are all shaped and battened in, the locator holes can be drilled.



If bilge stringers need to be replaced, wait until all framework is done and the keel and chines are installed.

inch thick is called 6/4, read as six-quarter. Four inches thick is called 16/4, read as sixteen-quarters.

Another service your lumberyard should be able to provide is re-sawing, that is, to saw the board on edge lengthwise to change the thickness. For example, to obtain 1/2 inch thick plankstock, I usually

buy 6/4 mahogany and have it resawn and surfaced to two pieces 1/2 inch thick. This is cheaper than buying 4/4 (the smallest size usually available) and throwing away half of what you paid for in surfacing it to 1/2 inch. This also produces book-matched planks which will allow you to mirror the grain of the deck planks as you place them outboard from the king plank. This produces the most beautiful decks.

When ordering lumber, I always figure what I need and add at least 30% to the order. This allows me enough room to avoid knots or cracks or other weak or undesirable areas in the lumber. One weakness you must always watch for is wind breaks or compression failure, evidenced by very fine lines of fracture across the grain of the wood and can be seen only after the wood has been surfaced. These fractures were caused when the bole of the tree was overstressed in bending either by wind or snow load or even in felling the tree. These areas are extremely weak; sizable planks can be broken over your knee.

During the drying process, either kiln or air drying, the lumber must give up a great deal of moisture and in so doing, shrinks in size, causing considerable stresses in the structure of the wood. The planks are stacked and weighted during this process to keep them straight and flat or they would warp and crack and check and bow all over the place. These stresses do still occur and are usually confined to the ends of the planks, causing small fractures and weaknesses in at least the first six inches of either end. Do not use the first six inches of either end of the plank in your boat, throw it away and sigh, or make bookends or something of it. Check your lumber to make sure these cracks do not extend farther. Remember when you are ordering your lumber that this amount cannot be used and order lengths accordingly.

The sistered frame technique was developed hundreds of years ago in order to keep the grain direction of each futtock as straight as possible for the strength of the piece. Note the shape of the piece you are replacing and pattern your pieces accordingly. If you have a curved frame, find an appropriately curved grain in your framestock. Ideally, the grain of any piece should not be out of line more than five degrees. Short lengths of grain create weak spots in the frame. Likewise, do not include any knots.

Bedding Compounds

I've already made my position on bedding compounds and sealers very well known. One of my apprentices suggested I just get a T-shirt printed to wear to boat shows that simply read, "OK, YES, I SAID IT."

All I will say is that wood joints, especially those that contain endgrain, that can continuously exclude moisture will greatly extend the life of the boat.

Flexible adhesive bedding compounds, such as 3M 5200, allow some inevitable joint movement without losing the seal. The Trumpy Yacht Company proved this with over thirty years of service on large private yachts as well as U.S. government gun boats.

I would never use a hard glue or hard epoxy in this type of construction. I have seen many examples, even in brand new construction, where encapsulating frame members with epoxy has accelerated the rot process. This is especially pronounced when used with ash frames.

Fasteners

As far as I've seen, all of these vintage wooden boats were assembled with brass fasteners, at least until the mid sixties. There are some notable exceptions to this, but they are worse. I have restored a few late twenties Chris-Crafts that had iron fasteners in the decks only. The planks generally have to be cored with a hole-saw to remove them. In many thirties and forties Chris-Crafts, the auxiliary frames were attached to the bilge stringers with #16x5 steel screws as well as the lower transom bow attached to the sternport with a steel lag bolt. These are generally badly corroded and must all be removed and the iron-sick wood around them should be cored out and fitted with a graving piece or replaced.

You may have noted, during disassembly of the planking and keel and chines, what percentage of the old brass fasteners were broken. In one 1938 18' Gar Wood utility I restored, eight of the eleven keelbolts were broken. In one 1941 17' Chris-Craft barrelback, an astounding 60% of the topsides plank-to-frame screws were broken.

Look carefully at the ends of these broken fasteners with a magnifying glass. Does it look porous or crystallized? Is there a green or blue powdery residue of oxidized copper? If your brass fasteners are more than thirty years old, then this condition exists whether you see it or not. The old brass fasteners that haven't yet broken are also porous and crystalized and brittle and just waiting for you to make the hull tight again so that they, too, can break.

Brass is an alloy of copper and zinc (the least noble of all metals). Over time, through a process known as galvanic corrosion, the zinc leaves the alloy (dezincification), leaving behind a brittle, spongy copper so reduced in strength as to be useless.

The mass of bronze running gear below the waterline aft (propeller shaft, strut, propeller, rudder, stuffing boxes, thru hulls, etc.) is very high on the nobility table and is likely responsible for drawing the zinc from the brass alloy.

The bottom line here in our shop is that we replace every fastener in the bottom, including all of the frame screws as well as all of the carriage bolts in the keel, chines, and bilge stringers.

The question now becomes, what do you refasten with? What is nearest to bronze on the nobility table and least likely to react unfavorably with that mass of bronze that hangs below the waterline?

The answer is silicon bronze.

Stainless steel is available in many different grades: 304 (which I have personally seen bleed red rust), 308, and 316. There are also much higher aircraft grades.

These grades are available "active," which leaves them next to wrought iron, very low on the nobility table. These grades are also available with a surface treatment called passivation, which leaves them "passive," apparently to the electrical charges of galvanic corrosion. This puts these grades very high on the nobility table, between Monel and titanium. This surface treatment, however, only lasts as long as the fastener is exposed to oxygen. This is definitely not the case in a boat hull. With varnished bungs in the topsides and painted putty in the bottom planks, these fasteners are not exposed to oxygen, lose their passivity, and revert to active, bringing them back down in nobility.

I have two major suppliers for fasteners and when asked directly about the intended use of these fasteners, they both admitted that, no, they should probably not be used below the waterline. From my suppliers, silicon bronze is only 5% more expensive than the wrong kind of stainless steel.

Please go to your local library and study galvanic corrosion and electrolytic corrosion. Really, this is the fun stuff. You will learn about the nobility table: which metals are anodic (least noble), willing to give up their ionized molecules happily to a more strongly atomically charged cathodic (most noble) metal. This molecule transfer takes place in an electrolytic solution such as saltwater or mineral salt contaminated freshwater. Soaked bottom planks make a nice electrical conduit. This is, in effect, a parody of the electroplating process except there is no requirement for energy input other than the position of the components (opponents?) on the atomic chart.

Frame Replacement Procedure

I am beginning this section with the assumption that your boat is upside down with the proper supports applied to bilge stringers, sheerline, and stem. The hull should be tight, plumb, and level. The gripe, keel, and chines have been removed and all frames cleaned and degreased.

Use a taut line suspended over the hull to occasionally check your centerlines. If you have used straightedges and battens to get the bottom and planing surface back into shape and have found that some frames are still too concave in their mid-section, it is very possible that these frames could be bent of edge-set. This could very easily have happened through prolonged or improper storage, especially if they were oil-soaked. Do not duplicate bent frames.

Cardboard or very thin (doorskin) plywood can be used to pattern missing areas by stapling an appropriately shaped piece to the side of the frame to this added edge. If sections of frame ends are missing or incomplete due to rot or breakage, I staple an appropriately sized piece of cardboard pattern material to the affected end and spile the missing section, also before removal from the boat. Be sure to mark any bevels on this pattern. By using battens from surrounding frames, you can reproduce the intended shape of the missing piece.

If you really want to do the job correctly (you might as well, while everything is accessible), unscrew, degrease, seal, and pay bedding compound on all mating surfaces of all the frames and frame knees. Remember to replace the old brass fasteners with new silicon bronze.

I generally remove and repair or replace all of the even numbered frames first, leaving the odd numbered frames to hold the overall shape and give me something to batten to when assembling the new futtocks.

If sections of frame are broken in two or more places, I fasten them together with small cleats before removal, using battens across adjoining frames to insure the correct shape.

Note the inboard ends of the bottom frames where they join at the keel. It is very important that this joint be tight. Make sure that this gap is not caused by bottom spreading. I note this gap on the frame and extend the new pieces so the joint is tight. This will make the assembled frame stronger and, with proper bedding, seals the endgrain better. The outboard ends of the bottom frames can also be slightly altered to fit the chine landing better, if necessary. Note the bevel here and make it fit right.

Remember, the vast majority of these vintage runabouts were built

on assembly lines of precut parts. There were no master shipwrights on the line. You will, most likely, accidently rebuild your boat far stronger than it was originally built, especially if you are using sealers and bedding compounds that the factory did not.

If your topsides frames are sound except for the very bottom edge at the joint, you may remove the affected edge and alter the shape of the new bottom frame to compensate for the missing end. This will have to be a judgment call on your part. I would not remove more than two inches of the topsides frame, or the grain direction of the bottom frame intended to replace this piece, will be prone to failure. The remaining end of the topsides frame must be sound and absolutely free of rot or you will be doing this again in just a few years. If you go too far up the topsides frame and have to make an overlong frame knee, its grain direction will also leave it weak.

If a topsides frame needs replacement, it should be done now. Remove the bungs and plank screws in the topsides planks along this frameline and possible a fastener or two coming up from the covering board. This will leave the frame unattached except for the nail holding the plank battens to the frame. Use small wedges, and possibly a hacksaw blade, to disconnect the battens from the frame and remove the frame.

The frames can now be traced directly onto appropriately surfaced framestock. Check your boat's framework to determine the correct thickness (usually 15/16") and duplicate this thickness for the new framestock or you may have trouble correctly aligning the futtocks. If you bought wide enough framestock, you can "nest" the patterns to save on waste.

Using a protractor, or adjustable bevel gauge, transfer bevels from the original frame futtock to the new pattern. When a number of patterns are prepared, cut manageable sized portions of the framestock with a jigsaw and cut out the new frames on a bandsaw. Cut all of the 90 degree edges first and then cut the beveled edges in the order they go into the boat. This will help keep track of the bevels and insure you do not cut some of them backwards.

If you are replacing both frames in the same station, you should be able to turn one over, trace it, and cut out the mirror image. The only place this cannot be done is on some of the larger boats, such as the Chris-Craft 28' upswept, which were built slightly fuller on one side at the transom to offset the torque of a large propeller.

If your boat is a Century, all of the bottom frames are notched to accept the fore and aft plank battens. You need not cut these at this time. You can leave the frames whole until the entire bottom framework is assembled and faired in. This job can be much more accurately handled with battens and a router.

You must be careful when taking and marking bevels. You must visualize the angle from your pattern and mark whether your pattern is facing forward, aft, inboard, or outboard.

There are many areas of the hull where the frames may have changing bevels at the planking surface. Make sure you check the frame bevels every few inches along the beveled edge and mark and cut them accordingly. You will either have to get very proficient at the bandsaw or cut these out to the largest size and dress them with a handplane.

The center frame ties, or floor timbers, in the area of the engine oil pan are very thin as they pass over the keel. These are usually broken or bent out of shape due to their small size and the weight of the engine above them. I do not cut these out until I have fit the frames in those stations and verified that the originals are not bent. I generally pattern these in place by tracing their shapes directly from the correctly positioned new bottom frames.

Chris-Crafts and many other makes had a straight flat planing surface for at least eight feet at the keel forward of the transom. I use a 3" x 3" x 8' aluminum I-beam as a temporary keel to clamp the frames to during assembly of the frames in the planing surface area. I also use 6" aluminum levels, checking at many points along the frames outboard of the keel and at the chine landings in the planing surface. The frames will have varying degrees of slope as you move outboard, but should still fair in a straight line in the planing surface. Keep your straightedges parallel with the keel.

After the planing area is assembled, I replace the I-beam with a ¼" x 3" x 16' flat aluminum bar to batten the correct curvature of the keel and properly set the frames. I also replace the six-foot levels with ¾" x ¾" x 16' cedar battens in order to fair in the gentle curves of the bottom forward of the planing surface.

Trial fit these frames in the hull and trim as necessary using appropriate battens and straight edges. Clamp the bottom frames, the center frame tie, and the frame knees in each frame station together as you fit them and, when you are satisfied, drill two locator holes in each frame overlap. Drilling all of the fastener holes now will make it very messy when the bedding compound is applied.

If you do not drill the locator holes now while the frames are dry, the slippery bedding compound will make it very difficult to clamp them back into the proper position. Make sure you are using the properly sized drills and countersinks to avoid splitting the wood.

I suggest getting all of the even (or odd) numbered frame stations clamped together before drilling the locator holes. This will allow you to use battens and the odd (or even) numbered frame to ensure fairness before you commit to the shape.

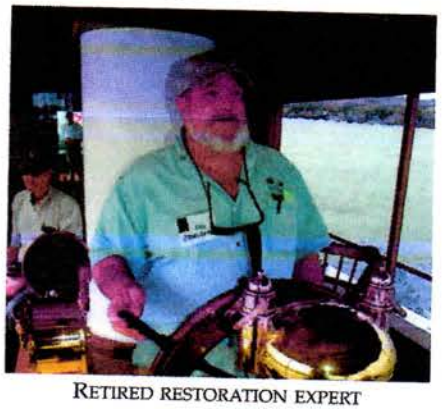
For fair forward frames, it might be wise to clamp the gripe back in place to verify the centerline and ensure proper alignment. At this point, you may need to pattern some of the frame ties in the engine area as mentioned earlier.

Once you have committed to the shape and drilled the locator holes, mark the overlaps with a pencil. This will show you where to apply the bedding compound later. You may now remove all of these frame futtocks and properly seal them. Do not use a hard plastic coating.

Once the sealer is properly set, you may apply the bedding compound at each overlap and assemble the frames. As mentioned, the bedding compound makes these pieces very slippery and difficult to clamp into position. I use ice picks to find and set the locator holes and then replace these, one at a time, with screws.

Sometimes the screw threads hang up on the top piece of wood and force the two pieces slightly apart. Watch for this especially with the first screws, as these can keep all the rest of the fasteners from seating properly. It is very often necessary to back these first screws out as you watch the wood pieces fall together and then reset them. You may now drill the remainder of the fastener holes, following the manufacturers original pattern, except where they put two screws on the same grain line. Don't do that.

Use the proper torque setting on the screwgun and watch the edges of the frame sections as you set the screws. Make sure they are bedding together tightly as the bedding compound oozes out evenly all around the joints. It is better to have a little bedding compound ooze out than leave a dry spot that water and debris can collect in. You will soon learn the proper amount to leave with your putty knife, as you are the one who has to clean up the mess. Do this carefully and you can reuse the compound on the next frame. Wipe the joints clean with a suitable solvent.



RETIRED RESTORATION EXPERT DON DANENBERG