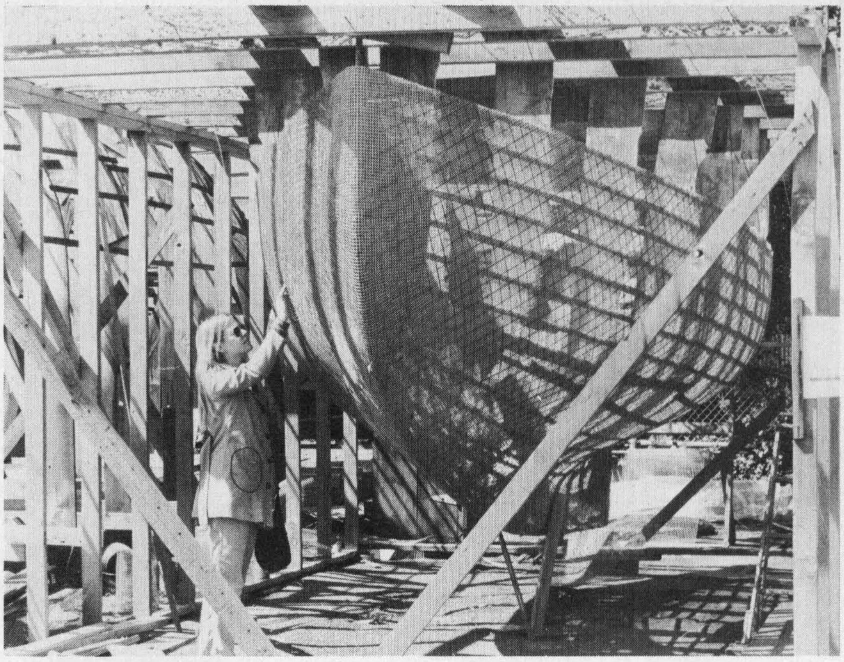
HOW TO BUILD

FLICKA

PART TWO

COMPLETE PLANS/INSTRUCTIONS
BY BRUCE BINGHAM

THE ARMATURE



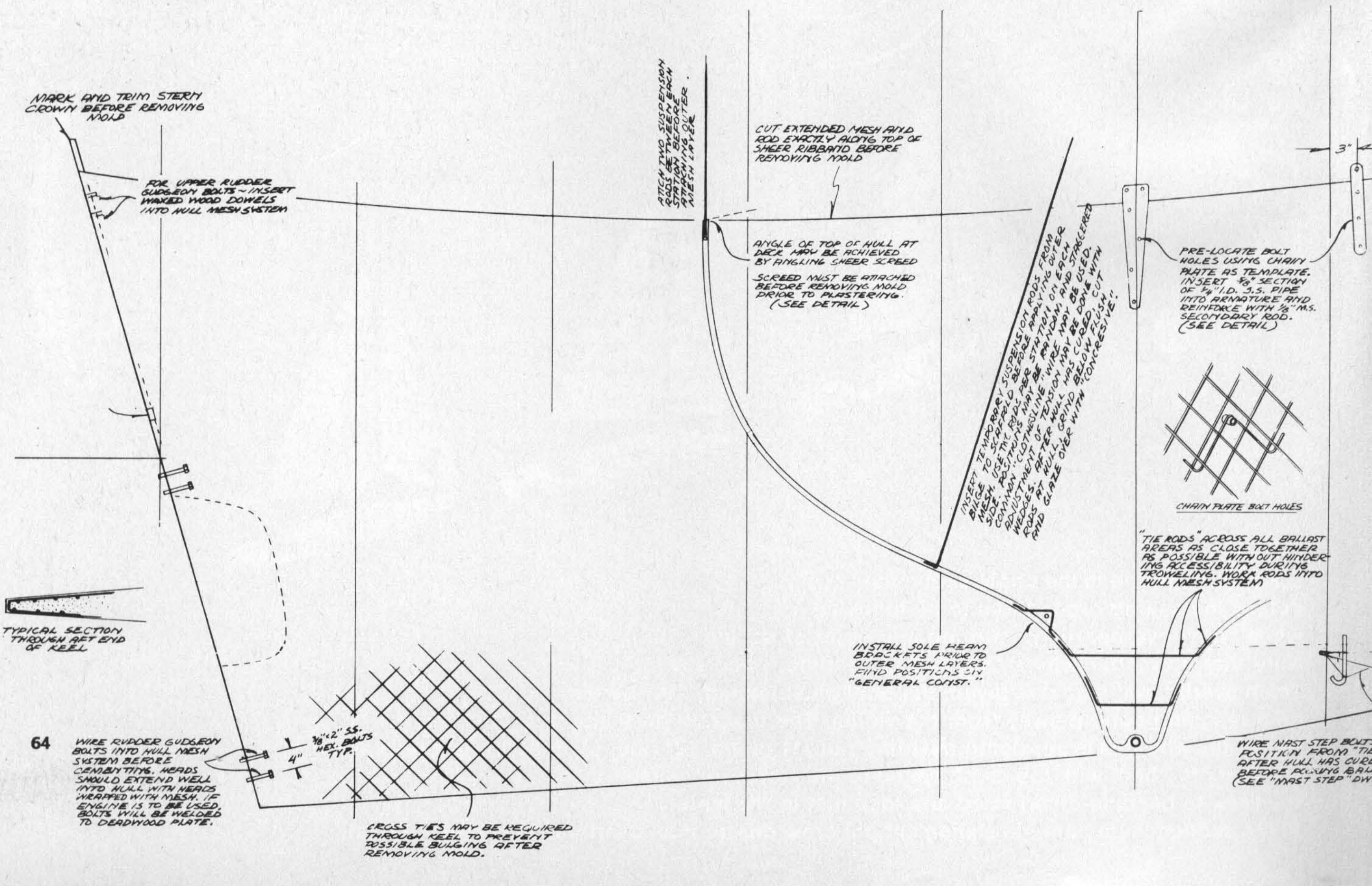
Once skeptical, Suzy can hardly believe the beauty and grace which was once rolls of wire, steel, and used lumber.

☐ I have been told by countless builders that the most difficult part of their construction was during the first week, entailing the fabrication of stations and erecting the scaffold. By now, you must surely have been driven to utter distraction by wise-crackers and passers-by saying "It'll never fly, Orville!" or "When's the flood, Noah!" This has been a thankless task with little to show in the form of a boat as an indication of the finished product.

But now, with your hull mold completed and faired, you can point with understandable pride toward the graceful figure of Flicka's emerging hull. The once pessimistic melodies played by your critics should now echo praise and admiration. You are no longer looked upon as the family outcast but with covetous surprise and envy by the neighborhood hierarchy. "Hey, it's a boat! It looks like a boat!"

But this is not the time to lay down your tools or to gloat in self-satisfaction. You have a long way to go so let's begin by rounding up the materials necessary for the completion of this installment.

The first item on the agenda will be the location of the center pipe member requiring three 10-foot lengths of ½-in. black iron pipe. Next will be



180 pounds of 10 gauge oil tempered spring steel, cold rolled or hard drawn steel wire rod (the tensile range should be in excess of 110,000 psi but not over 200,000 psi). You will also need eight rolls of ½-in., square welded, galvanized wire mesh. Each roll should be two feet wide and 100 feet in length. A heavy-duty hand staple gun is also in order with at least three boxes each of ¼-in. and ½-in. staples. Twenty-five pounds of 18 gauge soft galvanized tie wire will also be needed. Under no circumstances should these materials be substituted for cheaper or "easier" counterparts as a severe loss of strength will usually result.

MESH

Since the introduction of ferrocement to naval architecture, chicken wire (or aviary netting) has been the mesh most used throughout the field. Usually it has been applied as four layers on each side of the rod laminate and when cemented results in a shell thickness of about ¾ to ⅞-in. weighing from 10½ to 13 pounds per square foot (based on two layers of ¼-in. rod). This system, however, is totally unacceptable on two major counts. Flicka's hull shape need not exceed 9/16 of an inch or about eight pounds per square foot. While this may seem extremely thin for ferrocement it is the ultimate strength with which you must be most concerned. Based on hundreds of tests by architects, universities and independent agencies, it's become obvious that the chicken wire layup leaves a great deal to be desired in terms of bending, compression and tension yields, particularly in light hulls. The result of this testing has been in the favor of the half inch, 19 gauge welded mesh.

Comparing its attributes with chicken wire, you will find that it is manufactured of a higher tensile steel of a larger diameter. The square mesh is stiffer, both laterally and diagonally, giving it the inherent quality of lying more fairly, whereas the chicken wire is easily distorted. Because the horizontal wires of the square welded mesh are attached on the same side of their perpendicular counterparts, consecutive mesh layers may be interlocked or nested to reduce the finished thickness while increasing markedly the steel content. Because of the increased armature strength over chicken wire, a reduction in the number of mesh layers is possible.

Under no circumstances should you construct using common hardware cloth or rat wire as a substitute for the square welded mesh, nor should expanded steel be considered as an acceptable replacement.

There is a copper-coated version of the square welded mesh and it is essentially the same material. However, this copper coating is only applied for the convenience of the manufacturer and will quickly disintegrate if attacked by salt water. This probability is extremely acute in the event of the development of hairline cracks, caused by hard groundings or severe impact. Without galvanizing, the steel wires may be subject to rapid deterioration and failure.

MESH AND ROD SEQUENCE

In order to form a shell of adequate strength the following schedule should be followed to the completion of the hull armature before plastering. Install the centerpipe. Apply two layers of mesh. Attach one layer of rod followed by a single mesh layer then the second rod layer. Apply the last two layers of mesh.

Dart and jog each mesh layer individually as described under separate headings and tune the reinforcing rods in a like manner before proceeding to the next layer of rod or mesh. Follow the tying and fairing procedure to the letter to produce the highest quality finish.

BOBSTAY PLATE

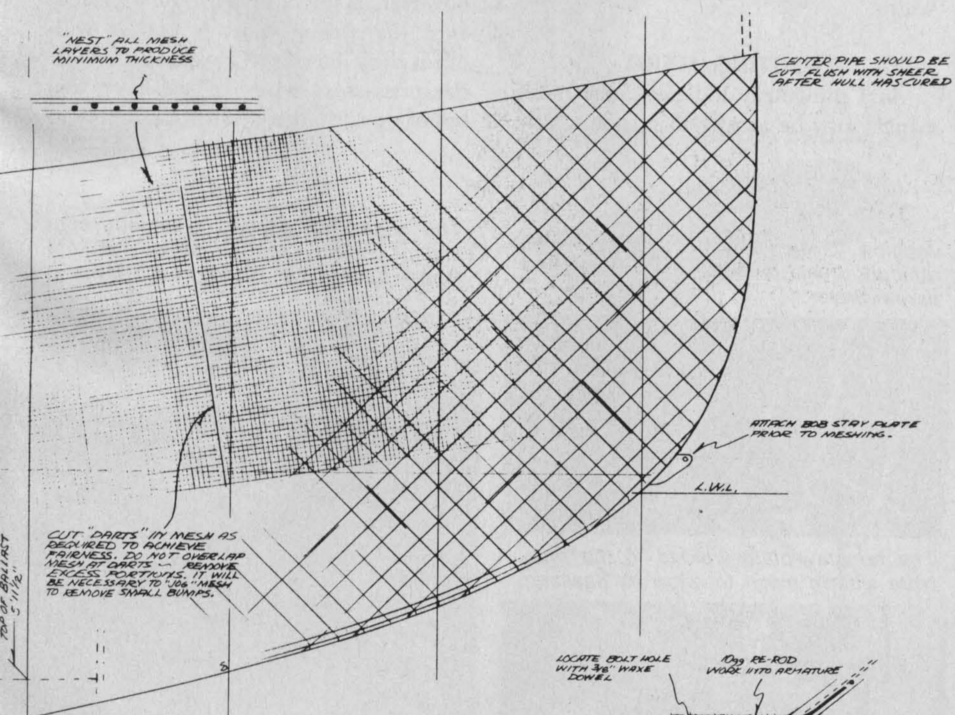
After fashioning this hardware according to the pattern, grind all cut scores smooth and slightly round all edges of the plate and hole. Have this unit heavily galvanized prior to installation.

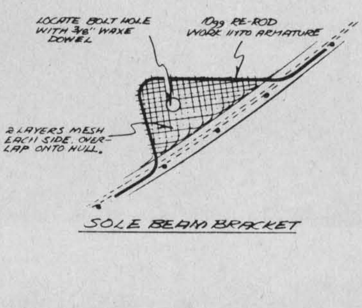
The finished piece may be welded in its proper position to the centerpipe before or after installing the pipe on the hull mold. When attaching the mesh, it will be necessary to cut a short slit to allow the mesh to be pulled over the protruding plate. Do not concern yourself with the protection of the weld as it will be thoroughly sealed upon plastering the hull.

THE CENTERPIPE

Prior to applying the first hull mesh layers, the ½-in. pipe must be bent exactly to a line 9/16-in. inside of the lofted profile. Butt and weld the pipe ends to achieve a continuous length and lightly mark the station positions.

Before attaching the pipe to the mold, install two 6-in. wide strips of mesh along the center of the mold, taking care to push them fully into the mold center notches. You may find it





SOLE BEAM BRACKET

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easier to pre-bend these mesh layers into a U section before installation. As the mesh strips are applied, staple occasionally for position.

Now the pipe is raised to the hull, inserting it into the mold notches over the mesh strips. The pipe may be held in place with wire. Bend the edges of the mesh strips back against the hull mold and staple well to prevent bulges.

THE FIRST MESH PANEL

Beginning at the sheer, pre-cut the approximate mesh length and roll it into a loose cylinder. Align the edge of the mesh with the upper edge of the sheer ribband and staple this position. Unroll the mesh along the hull, keeping it as tight as possible while stapling every six inches, or so, until you have covered the length of the hull.

Because of the stiffness of the mesh, it won't touch the hull for its entire length, but bulge outward a good part of the way. Beginning at the center of the hull, smooth the mesh against the mold and staple. With your gloved hand, push the bulges toward the ends of the hull and staple until the mesh begins to distort at the sheer. Now cut the length of the bulge. This will cause the mesh to lie flatly and result in an overlapping triangular section.

Continue to smooth successive bulges into each other, working toward the bow and stern, cutting and darting the new bulges as they reach their limits. Drive a staple as often as required to hold the mesh fairly against the hull.

The newly installed mesh panel will now look like a series of individual sections with five or six overlapping triangles. Carefully cut away these overlaps to prevent excessive thickness.

SUCCESSIVE MESH PANELS

Always work from one side of the hull to the other as this will prevent springing the mold unnecessarily. After applying the mesh at the sheer, fit the next panel so that its edge butts against the first and follow the same procedure. Continue to cover the hull until all exposed mold areas have been meshed. Occasionally, you will find a section which does not butt perfectly. This may be solved by positioning corrective mesh wedges called stealers. Use them as you wish as they will have little effect on strength.

The succeeding mesh layers are attached exactly as the first. Care must be exercised here to prevent the butt joint and darts from occurring at the same place. Stagger the mesh edges well apart, even if it requires cutting one of the mesh panels into an odd width.

NESTING MESH

As I previously indicated, the mesh panels may be arranged in such a way as to cause their wires to interlock for a reduced thickness while maintaining the same level of steel content. By observing a typical mesh sample you will notice that all of the wires running in one direction lie on the same side as their opposing counterparts. When two layers of mesh are laid together all the wires of each mesh layer which run in the same direction should face each other on the same plane. If this does not occur, simply turn your mesh panel over. The total thickness of the two mesh layers, therefore, should only occupy a width of three mesh wire diameters rather than four (illustrated).

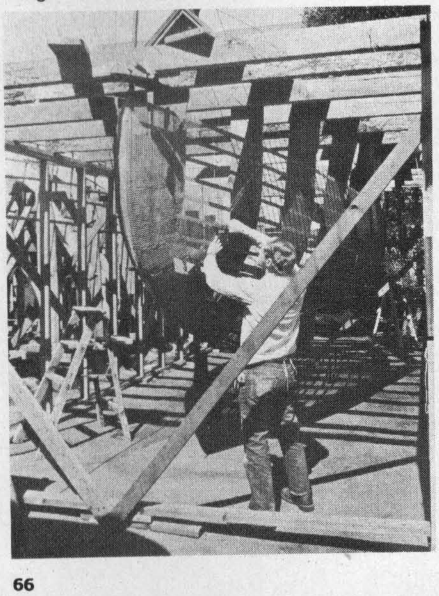
WIRE TIES AND STAPLES

Very little has been said about this seemingly insignificant subject. However, hundreds of potentially beautiful ferrocement boats have been visually ruined simply through the improper placement of these fastenings.

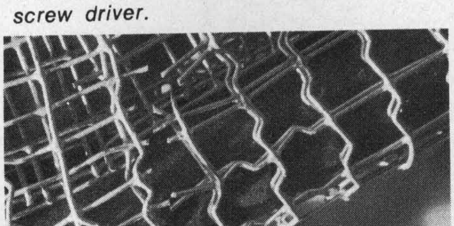
Consider once again that the very key to the strength of Flicka's shell is achieving the highest possible steel to concrete ratio within a minimum shell thickness. As I have already described, this reduced thickness is partly achieved by nesting the mesh panels properly as well as using a very strong but small diameter reinforcing rod. If, however, a staple or wire tie is placed over the wrong wire or rod it will offset these benefits. Considering either the criss-cross wires of mesh or the opposing rods, one mesh wire direction

Continued on page 82

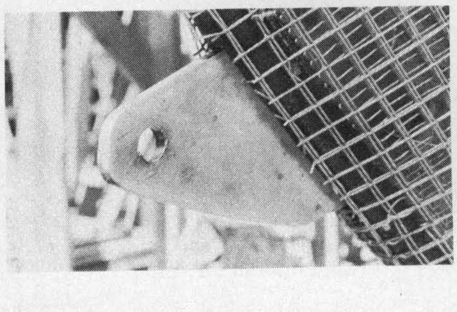
The first two mesh layers completed, Wayne Heyerly begins attaching the diagonal hull rods.



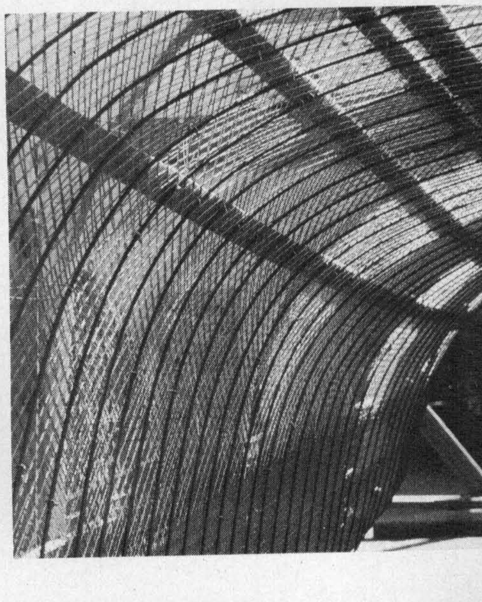
Jogging to tighten mesh in bumpy or difficult areas is done with a notched screw driver.



The bobstay plate welded to the pipe. Note slits in mesh to allow its passage.



The bilge rods portray a smooth, consistant pattern. Always strive for finished excellence during each layer.



FLICKA Continued from page 66

or rod direction will lie atop its opposing counterpart. The wire tie or staples used throughout Flicka's construction should always be placed over the lower rod or wire layer. Does this make sense? Study the illustrations and you will see that an improperly placed wire tie or staple will impede the proper nesting of the successive mesh layers. If you are inconsistent in placing your wire ties or staples it will result in slight bumps or hollows which may never be completely faired on the surface of the concrete hull.

JOGGING MESH

As each mesh panel is faired and darted to relieve the large bulges, small bumps will still be apparent. Check your work with a wood or plastic spline to detect minor discrepancies. These small bumps should be corrected by jogging.

This requires first making a tool by cutting a ⅛-in. slot into the blade of a screw driver. The screw driver is inserted over the mesh wire in the area of the bump and given a tight twist. As you do this, you will actually see the mesh flatten out a little. Continue jogging the mesh squares in all directions until the bump has completely disappeared. Jogging and tuning each mesh layer should be completed before proceeding to the next step.

ROD

Since the introduction of ferrocement to North America, mild steel rod has been the most generally used for reinforcement. This rod, however, is easily distorted, tends to scollop between fastenings, is considerably weaker than the high tensil steels and stretches markedly under tension.

Once again, we are creating a hull shell for only 9/16-in. while attempting to produce the maximum stiffness and strength. This can be accomplished only through the use of cold rolled, hard drawn or spring steel in very small diameters. As mentioned previously, 110,000 psi to 200,000 psi is the most acceptable tensile range.

APPLYING THE ROD

As you see in the armature plan, I recommend laying two layers of rod at opposing 45-degree angles rather than the normally accepted vertical and horizontal system. This will have the effect of more successfully withstanding torsional deflections of the hull as the Flicka twists its way through a sea. Any wooden boat owner knows that it is this very twisting which causes his seams to open and fastenings to shear. In ferrocement construction, a diagonally rigid unit is equally imperative to the boat's longevity.

It will make no difference which rod layer lies forward or aft, but, as with the mesh, it is important to work both sides of the hull simultaneously. I would suggest installing the first rod amidship to establish the approximate rod-angle then working forward and aft. Begin by laying the first rod under the hull and pre-bending the corner radii of the keel to proper fit. Staple the rod every foot or so up the hull, bending the rod as necessary for a snug fit at the turn of the bilge. As the rod is fastened up each side of the hull, snip its loose end at a distance of 1/16-in. below the sheer line. All successive rods will be attached in the same manner.

In the areas where the reinforcing rods turn the corner of the transom or stem, it will be necessary to bend these rods quite sharply and this may be accomplished with a homemade rod bender.

CROSS TYING

In the narrowest portion of the keel, the rods will have a tendency to flare outboard thus creating an undesirable thickness. To correct this tendency, pass a long loop of wire over the rod on one side of the hull, through the armature and over the rod on the opposing side. Twist the wire ends together and continue to turn until the reinforcing rod is pulled snugly against the inner mesh layers and mold. This procedure may be required on the first dozen, or so, rods forward of the stern.

JOGGING ROD

Occasionally, some of the more obstinate rods will tend to bulge slightly further outboard than their neighbors. This is an indication that these rods are under compression, an unacceptable condition in ferrocement. To correct this error they may be jogged in much the same manner as the mesh except that it will require the use of a homemade jogging iron (illustrated). This is nothing more than a length of pipe with two short rod dowels welded to one end. The dowels should be spaced about one inch apart. To use the jogging iron, place the dowels on each side of the reinforcing rod then pull the pipe sharply, thus creating an S shape curve at the desired position. As you do this, it will have the effect of shortening and placing tension upon the bowed rod. This tension will pull the rod against the mold and into its proper position. Always check the hull fairness by using a plastic or wooden spline as many slight bumps and hollows may not be visually apparent.

CORNERS

Because of the corners of the transom and the turn at the stem of the hull, these areas will become stress-risers or concentrations of stress lines about the hull. It is absolutely imperative that rod and mesh layers turn these corners fully and extend beyond by at least six inches. *Do not*, do not terminate or butt any of the hull rods or mesh layers on center or in any area where sharp angles are encountered.

If, for any reason, the edges of these corner rods do not line up fairly, it is possible to bend them forward or back to the correct position.

When developing the required butt joints, always stagger them from side to side and from layer to layer in order to spread out the weakening effects of these butts.

CONCRETE DECKS

As I indicated in the first installment, ferrocement decks may be constructed and should be an integral part of Flicka's hull. Assuming that you have built your deck mold in the manner illustrated in that first chapter, the mesh layers should extend over the edge of the sheer ribband and onto the deck area. The decking is covered essentially in the same way as the hull, although it is not necessary to employ the 45-degree lay of rod. It is my recommendation that only one rod layer be used, created through the extension of either the first or second hull rod layer. The deck rods should lay transversely, not longitudinally. The finished deck armature should be of the following combinations

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FLICKA

from the deck mold up: three mesh layers, one rod and two mesh. As the mesh and rod approach the cabin, hatch or cockpit carlin screed, it should be cut approximately 1/16-in. short so as not to expose the steel ends. It is very possible to include a ferrocement cockpit and this may be done by constructing a temporary form in the shape prescribed in Flicka's general construction plan.

CHAIN PLATE BOLT HOLES

Upon the completion of the mid mesh layer, provisions must be made for the attachment of the chain plates. Because it is undesirable for attachment bolts subject to shear to bear against unprotected concrete, steel bushings must be installed in the proper positions to prevent the chain plate bolts from eventually enlarging their holes. An additional precaution is recommended to alleviate the possibility of developing hairline cracks in the hull due to the concentrated stress of the shrouds. We may kill two birds with one stone in the following way: A V shaped rod (one foot each leg) is bent with short hooks at each end (one inch). A short pipe bushing (½ in. length) is welded to the pit of the V rod. One leg of the V rod is carefully pushed through the mid mesh and worked into the armature until the bushing lies in its prescribed position. The remaining leg is wire-tied through the armature while lying to the outside of the mid mesh. It is important to note that each leg of the V rod must lie parallel and on the same plane as its counterpart hull rod.

Repeat the foregoing procedure for each chain plate bolt position.

GUDGEON BOLTS

I will describe in a future installment the fabrication of the rudder gudgeon and pintles. It is only necessary at this time that fastening provisions be made within the hull armature for the rudder gudgeons. This will require only that three pairs of ⅜-in. stainless steel bolts be worked onto the meshing of the transom and deadwood in the prescribed positions on center. Working the heads of the bolts through the outer and mid mesh layers may require a little cutting. Push the bolt heads firmly against the inner mesh layers, then force the outer mesh armature through the protruding bolts. Cover the bolts with masking tape to prevent clogging during plastering. Once the hull mortar has been completely cured, you will find no tendency whatsoever for these fastenings to loosen or to crack the hull.

SOLE BEAM BRACKETS

In a future installment, I will fully describe an epoxy grout system for attaching bulkheads, joinery, sheer and deck, and sole beam brackets. While I cannot over-emphasize the unbelievable strength of the epoxy bonding system, I find that many builders refuse to trust anything but mechanical attachments. My prime recommendation is to adhere to the epoxy mounting as it is, by far, the easiest, most professionally finished and strongest. If you follow this recommendation, no attachment provisions are necessary within the armature.

If you would feel better about mechanical mounting, however, and don't mind the additional work, ferrocement sole beam brackets may be installed in the following manner: Prior to attaching the two outside layers of mesh, insert a V shaped rod from the inside of the hull, fully through the mold and armature at the prescribed beam position. Each leg of the V rod should be approximately nine inches long. Bend the protruding ends (4½-in.) against the armature so that they lie flush with the adjacent hull rods. Wire the beam bracket rods firmly into the armature. From the inside of the hull, cover the exposed V rod with two layers of mesh on each side. Allow approximately three inches of mesh to overlap onto the hull armature. Now insert a short piece of waxed ⅜-in. wood doweling through the mesh of the sole beam bracket. This will provide for a pre-located bolt hole. The bracket is now ready for plastering.

SUSPENSION RODS (FOR NO-MOLD PLASTERING)

Many builders will prefer to leave the mold inside of the hull during plastering as this appears to eliminate some of the work required for the no-mold system. I should point out, however, that it is almost impossible to prevent voids in the concrete when plastering over the mold ribbands, and chipping and filling over staples is a pain in the neck. If you are building upsidedown it is, of course, necessary that the mold remain intact until the hull has cured.

My personal recommendation is that the hull be entirely removed prior to plastering if building upright, as this will provide total accessibility of the armature from both sides of the hull, thus assuring visibility and workability when the mortar is applied.

Provisions for suspending the steel armature must be made prior to installing the outer mesh layers. As this will require the installation of 10-gauge mild steel rods (clothesline wire) which will run from the hull to the scaffold cross spans. One suspension rod will be attached at each station around the entire sheer line as well as the corners of the transom and the center of the transom camber. These extension rods should extend four or five inches down the side of the hull and should have short hooks bent into the lower ends. From the hull they will rise vertically, being bent over the cross span and down, then twisted around its standing part. The proper tension on these suspension rods may be adjusted by inserting wooden wedges under the point where they bridge the cross span.

Diagonal suspension rods are installed in much the same manner, being pushed through the hull at the flat portion of the bilge, up to and over the scaffold then back down around itself. These diagonal rods should be located within the hull at each station position.

To prevent the sheer from flexing in or outward, lengths of clothesline wire may also span the scaffold uprights just above the sheer. These horizontal wires are wire tied to the vertical sheer suspension rods.

After all of the suspension rods have been installed, the outer layers of mesh may be attached in the normal manner.

REMOVING THE MOLD (NO-MOLD PLASTERING)

Prior to removing the station molds and ribbands, make sure the hull armature is firmly wire tied together through all mesh layers at each rod intersection. As this is a long, drawn-out process it may be a good time to invite the

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TRIM TABS • TRIM TABS • TRIM TABS

FLICKA

neighbors in. Be sure that you compact all mesh layers completely with each wire tie and be sure that the twisted ends of the ties are pushed fully back into the armature so as not to snag the mason's trowel or become exposed through the finished hull.

Upon completing the wire ties, all of the attached staples must be cut loose to facilitate the removal of the lumber. This can be quickly done with a common quarter-inch wood chisel. You will find that the work procedes rapidly if you have taken the precaution of paint-spraying the staple strips with a bright color before inserting them into your staple gun.

In order to provide a working platform inside of the hull whether during the removal of the mold or while plastering, 2 by 4-in. H frames must be hung from the scaffold cross spans in order to support walking planks.

If you are careful while removing your station molds, it will be possible to pass them down to another builder. He should gladly repay you for the cost of your lumber.

THE SHEER SCREED (FOR NO-MOLD PLASTERING)

In order to facilitate a sharp, clean fair line along the upper edge of the hull, it is necessary to attach a ¾ by ¾ in. pine batten along the sheer line. Because this screed must be centered over the thickness of the armature, notches must be cut to allow its insertion over the hull suspension rods. Prior to installing, paint its underside with a light coat of melted wax. After the screed has been slipped over the suspension rods, cover the exposed slots with small pieces of scotch tape. Adjust the height of the screed so that it lies approximately 1/16-in. above the upper edge of the wire and mesh armature.

THE SHEER SCREED (FOR MOLD-IN PLASTERING)

This screed variation will require the attachment of a 1¼ by ¾-in. batten to the mold edge. Note that the long dimension must be horizontal to cause the batten to extend slightly beyond the side of the hull. Its lower face must coincide with the sheer marks on the station molds. Prior to its attachment to the molds, the side toward the armature must be painted with a light coat of melted wax.

FISH HOOKS

This is a term applied to loose wire ends along cut lines and stray ties which may impede plastering, cause exposed steel or create bumps as a result of additional thickness. If you run a gloved hand over the hull, the fish hooks can be quickly detected and should be immediately cured by tapping them into the hull or running them down with the round end of a ballpeen hammer. Keep in mind that the armature dictates the shape of the finished hull. Unfairness is rarely successfully corrected through the addition of excess mortar. Grinding and filling is a tedious procedure which should be avoided on the finished hull and every effort should be made toward perfection at this stage of construction. It is still possible to correct shallow spots by inserting wedges between the mold and armature. Exercise all of the patience you can muster at this point and do not let your anxiety get the best of you.

DIVITS

Upon completion of any layer of mesh, look for severe indentations which would exceed 1/16-in. regardless of the size of the area involved (not including dimples caused by wire ties or staples). These must not be corrected by attempting to pull the mesh outward as you will lose the advantages of wire compaction. In many instances, however, an additional layer of mesh may be secured to the divit by carefully cutting a patch somewhat smaller than the indentation. Before installing the patch, bend all of the wire ends slightly inboard so that they will not protrude above the surface or interfere with additional mesh layers or plastering. After wiring the patch in place, check this work with the fairing spline to insure against over-building. Additional wire ties in the patch area may be required to prevent excessive thickness.

JUDGING YOUR WORK

For years ferrocement proponents have ranted and raved over the superior quality of this marvelous construction technique. Concrete boat yards have mushroomed while tens of thousands of amateurs have undertaken the production of their own dream yachts. Visions have been painted of achieving quality matching the most exemplary vessels today while claiming cost and savings.

Upon objectively observing existing ferrocement examples, however, the very opposite seems to be most apparent. While I do not mean to sound overly critical, the majority of concrete yachts in existence today project a junky, bumpy and slipshod appearance when docked next to the average production vessel. While the builders' budget may be a major controlling factor as to the outcome of his efforts, the greatest failures have occurred through the lack of patience and observation.

If the ferrocement builder would only make occasional field trips to the local marinas to see how a good boat should look, he would surely return with a more healthy and considerably more critical eye toward his own standard of acceptance. There is no reason for any ferrocement hull to be apologetic for its lack of perfection nor should the material itself be used as an excuse for the builder's lack of craftsmanship.

No fiberglass, wood, steel or aluminum boat ever became smooth and shiny overnight. It has taken manufacturers countless hours and untold sweat and exertion to evolve their flawless products. They have had to overcome many of the same problems which you now encounter. The fairing and smoothing techniques described in this and other chapters must be patiently and religiously adhered to if you expect your own boat to emerge with value, pride, and the dignity she deserves.

Ferrocement, does not require the years of practice demanded of the experienced ship's carpenter, but if you think the material allows complacency or forgives sloppy work, you may be in for a rude awakening. If you are depending upon plastering over your divits and bumps at this stage, the result will require tortuous grinding and filling to cover up all that could have been solved at the outset. □