

Arc Welded Steel Hull Sailing Vessel



This method of construction requires intermediate skill in arc welding along with basic ability in carpentry. The jig which supports and shapes the sheet steel during fastening and welding consists of a series of wooden stations — the customary framework of wooden boats. The similarity in the two methods points to the ease with which welded sheet steel can be retrofitted to wooden designs. The difference is that in wood fabrication, the stations are a necessary and permanent part of the finished product, whereas in the steel construction, they are completely removed from the hull after supporting and shaping.

Throughout the project, the steel work consists of patterning, cutting, and fastening the sheet steel to the hull jig. The last of these steps is followed by tack welding and then by back stepping on each outside seam between the steel panels. After the work is inverted, it is completed by back stepping on inside seams and by the fabricating of the main deck, cockpit, cabin, berth and rudder.

A careful study of the offset table is necessary for the actual construction because the shape of any hull depends on the construction and positioning of stations which are derived from an offset table. After proper study has been done, jig making begins. This includes the construction of stations as per the offset table, and the construction of a stations frame, base and uprights. The latter is used to hold the stations. Once the stations are properly installed on the stations frame, the hull jig is ready for the application of the sheet steel.

Construct each station before building the stations frame to determine the overall dimensions of the craft and, the exact dimensional requirements of the stations frame.

Each station is to be plotted and drawn full scale on to a sheet of 1/8" masonite painted white to improve line visibility. (Use 4'x 8'x 1/8" masonite sheets.) Station plotting and drawing should be done in pencil so that erasing can restore blank surfaces, making the masonite reusable. The top half of the

table is used to locate points for each station along the vertical axis. The half breath schedule or bottom half of the table is used to locate station points along the horizontal axis. After a station has been plotted and drawn in half breath from the keel through the intermediate points to the sheet, it is to be made up of lengths of 5/4 x 3 No. 2 pine, joined by a 3/8" plywood gusset which is screwed into place. Set up on the same masonite template, the mirroring or sister station is now constructed in the same fashion and is gusseted to its previously constructed counterpart at the keel. The sheer points of the two are then gusseted to a length of 5/4 twice the deck specification shown in the table. This process is repeated until all the stations are fully constructed and numbered according to the plan. All the parts of the hull jig are now ready.

Resting flat on the floor of the work place, the stations support or frame need not be more elaborate than a rectangular layout duplicating the length and greatest width of the finished hull. It should be built out of 2 x 4 or 2 x 6 fir doubled on the flat and lapped and bolted together at the corners. The frame should be blocked up from the floor sufficiently for 8' lengths of 2" galvanized pipe to be inserted underneath it at intervals to make the work trailerable. It is not critical if the frame is slightly off level, as the level line by which all stations will find their exact position on the frame will be established above the keel. This line is called the *base*. All vertical distances are measured downward from it. This base is established by attaching a pole perpendicular to the center and at either end of the existing stations frame. The height of the poles must be enough to accommodate the built-up stations frame fixed at a comfortable working height, plus the height of the tallest station with approximately 4" to spare from the base line down to the work. The distance from the work to either pole should provide comfortable working room at both bow and stern. As it is possible that the stations frame will be slightly off level, it is necessary to carefully plumb both poles before attaching a line to them. Once the chord is fixed (mason chord suffices), the Y

axis of the work is established down through the middle of the work space. The X or horizontal axis is established by the sheer-to-sheer lengths of 5/4 on each full station. These lengths will not perform this function, however, until they are installed on to stations frame which, in order to serve its purpose, must be built up with horizontal supports or joists, and with uprights.



The joists for the stations frame should be constructed out of 2x4 or 2x6 fir. They should be cut to a length equal to the width of the existing frame, from outside to outside. They should be notched to interlock on end with both sides of the existing frame. By referring to a plan view of the hull, the builder will be able to pinpoint joist locations and mark them at each station on either side of the frame. Each of these locations will work out so that the 1-1/2" thickness of the upright can be added without causing its corresponding station to miss its center. It is recommended that these joists be secured with angle iron to maintain plumbness.

The uprights which are to be attached perpendicular to the joists should be cut from 2x4 material at a length which will place the hull at the most manageable height. Two uprights for each station are needed. Each pair must be plumb and bolted to the joist at approximately 18" to either side of the center line. (It is likely that at the stations closest to the bow and stern, the uprights will have to be brought in closer to the center.) It is advisable to snap a level line at deck height from bow to stern across both rows of uprights. It is also advisable to mark this line on both poles for future reference. These markings will prove helpful in leveling when the stations are installed.

In accordance with the marked deck height on each set of uprights, the stations are now to be installed onto the stations frame. Before any station is bolted into place, however, the base-line-to-keel measurement must be checked and needed adjustments made.

After the stations are properly installed, they should be strengthened and stabilized as one unit. For this reason, 1 x 2 stiffbacks are secured from bow to stern across the inside top edges of the sheer-to-sheer lengths. The installation of the bow station makes an important contribution to the stations becoming a functional hull jig; supportive horizontal bands reaching all the way from the stern tie into this station. Unlike the other

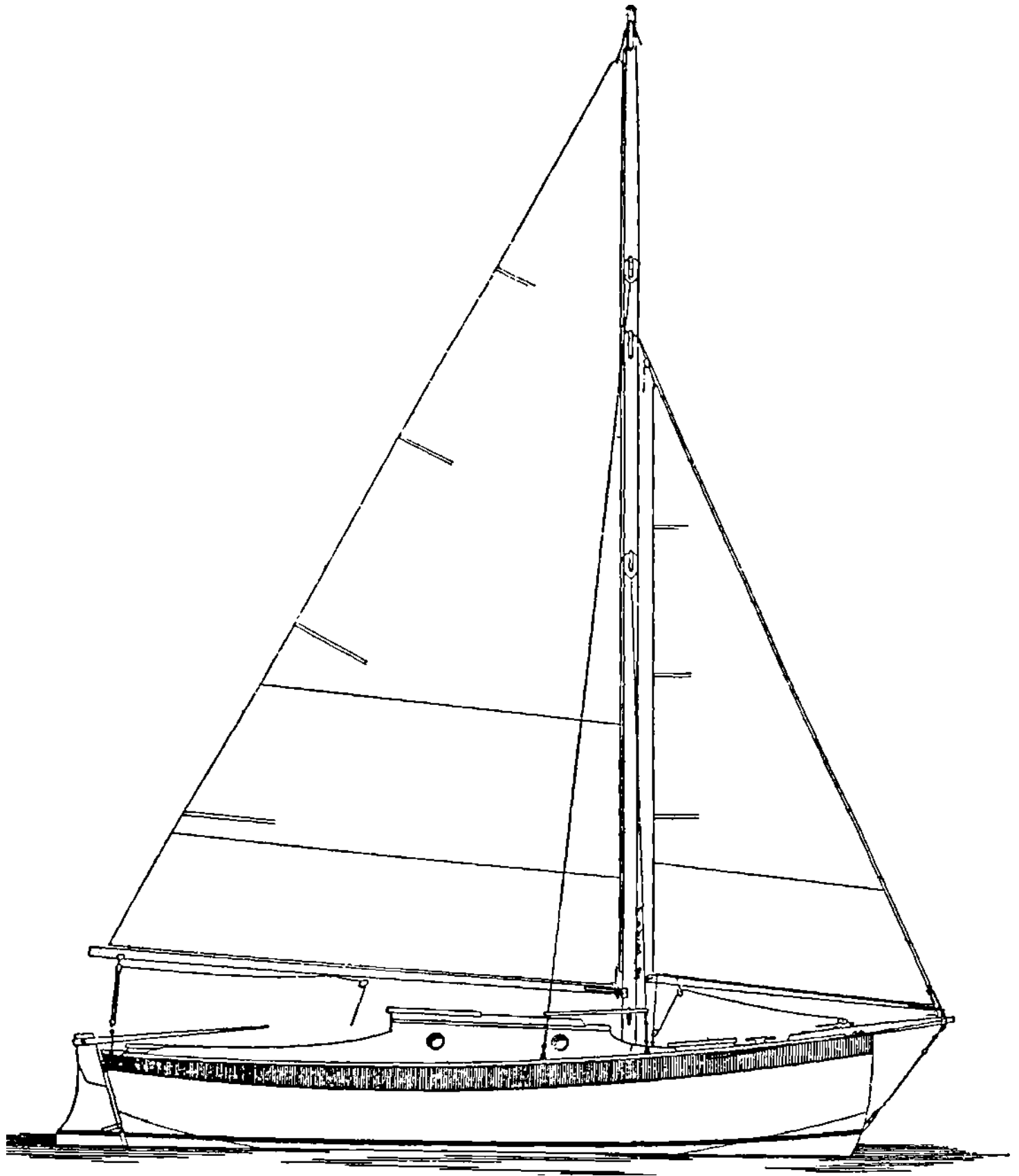
stations, the bow station is not formulated in the offset table. A study of the appropriate elevation view will yield the proper contours of the bow. Its shape is plotted and drawn on to a sheet of 3/4" plywood and is then cut out and secured to the stations frame on center and plumb. The 1 x 2 bands are installed across the outside of the stations on both sides and are then secured to the bow station. The first of these bands are positioned between keel and chine and the second directly on the chine. (It is important to check each station for plumb before securing the bands located between the keel and chine.) The final girth is installed on the sheer, but instead of being made up of 1 x 2 it is cut from 1 x 3 stock. It is essential to the proper application of the steel that all of these exterior bands be notched into the stations to keep the surface of the hull jig completely flush.

Cutting and fastening masonite patterns and counterpart sheets of steel to the hull jig is next. Approximately 50 strong backs 1/4" in diameter and 20+" in length prove to be indispensable in shaping the flat steel to the hull. These strong backs must be threaded down about 10" from one end and be made of a material which will allow them to be bent so that they can be hooked on to the inside of the jig. At the same time, however, the material must be strong enough to not give way against the

OFFSET TABLE-17-6 WATERLINE STEEL SLOOP SHEET NO. 4

STATION	A	0	1	2	3	4	5	6	7	8	9	10	11	12	S	
H E I G H T S																
L W L to Sheer	3-2¼	3-1	2-10¼	2-8½	2-6¾	2-5¾	2-4+	2-3¼-	2-2½	2-2½	2-2	2-2¼	2-2¾	2-3½	2-4+	
L W L to Wale Line	2-8½	2-9½	2-4¼	2-2	2-0	1-10¼	1-8¾	1-7¾	1-7¼	1-7½	1-7½	1-8¼	1-9¼	1-10¼	1-11½	
Base to Chine		4-0½	3-7¼	3-3¼	3-0	2-3¾	2-8¼	2-7½	2-7½	2-8¾	2-10¾	3-1	3-4½	3-9½		
Base to Keel		3-0	1-11¾	1-6½	1-3¾	1-2½	1-1¼	1-1¾	1-2	1-3¾	1-7¾	1-10¾	2-4-	2-10		
Base to Skeg						1-1		STRAIGHT						0-1¾		
Get Base to Top of Skeg from Work																
H A L F B R E A D T H S																
Deck	0-0¼	0-8¾	2-11	2-7¾	3-0¾	3-3¾	3-5¾	3-5¾	3-5¾	3-5¾	3-4	3-2¼	2-11½	2-7¾	2-5¾	
Chine		0-2½	0-10¾	1-5¼	1-10¾	2-3½	2-6¾	2-9	2-9¾	2-9½	2-8½	2-6¼	2-2¼	1-8¾		
Top of Skeg						0-1	0-1½	0-2¾	0-3	0-3¾	0-3¾	0-3	0-2	0-0¾		
Bottom of Keel	0-0¼					SAME FOR ENTIRE LENGTH										0-0¾
Bottom of Skeg						0-0¼	SAME FOR ENTIRE LENGTH								0-0¾	

DIMENSIONS TO OUTSIDE OF PLATING IN FEET AND INCHES





pressure of washer and nut working down on the outside surface of the sheet steel and shaping it to the jig.

Clamps of assorted types and sizes will help serve the same purpose, especially when temporary fastening is required. And since it is probable that there will be locations on the jig where neither strong back or clamp can be situated, it becomes necessary to add a wide variety of self-tapping screws to the fasteners list.

The builder can calculate the sheet steel sizes and quantities from dimensions and notes on the elevation and plan views in the prints or construct the hull jig and take the materials estimate directly from its measurements.

In order to avoid costly cutting errors, it is suggested that a masonite pattern can be cut and fitted to the jig before any steel segment is cut out. The same masonite used for laying out the stations may now be used for patterning the sheet steel. The 1/8" masonite used for this purpose is durable, easy to cut, and adequately flexible to fit the contours of the jig. (The masonite for a given pattern may be recycled when the steel that is cut from the pattern is found to fit the jig properly.)

Patterning should begin at the bow and along the keel. With a minimal use in the amount of clamps and screws, the masonite sheet should be fitted against the jig so that the exact shape may be scribed on to the sheet along the edges of the jig. If possible, the jig should also be marked to assist later in the fitting of the steel. The masonite is now taken off the jig, laid on a large work surface, and cut according to the scribings. The pattern is placed on top of the steel sheet which is of the appropriate thickness for the location. (At the outset of this process, 1/8" steel is used because the bottom of the hull requires the greater strength.) The pattern is clamped to the steel to prevent slipping and the steel is then scribed according to the pattern. Due to the possibility of small but critical differences between mirroring sides of the jig, the builder is cautioned against using the pattern of one side for the scribing of its counterpart. The pattern should be fitted to the opposite side first to detect any inconsistency. Where inconsistency is found, a new pattern should be made.

After the masonite template is removed from the steel and the

new scribings are found to be clearly discernible, the steel must be clamped to the work surface to minimize vibration during cutting. A heavy duty jigsaw or sawzall equipped with a 18 tooth blade should be sufficient to cut the required shape.

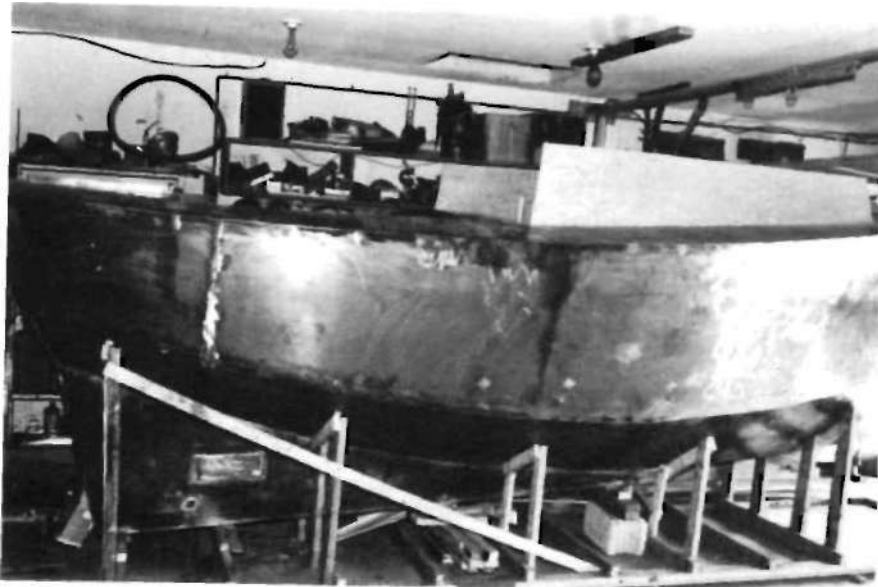
Once the sheet is in its proper position, it is clamped and then fastened. This should continue until the sheet is self-supporting. Since fitting along edges is a primary concern, the permanent securing and forming with strong backs and screws should be done evenly along chosen lines. Avoid pulling edges out of place and/or creating buckles and bubbles.

For the best weld penetration, seam openings should be set at a distance equal to the electrode diameter or steel thickness.

Tack welding begins as soon as the first counterpart sheets are properly fastened to the jig hull. A back and forth leapfrog procedure is used in tacking to prevent heat build up from distorting seam openings which will cause insufficient penetration and will necessitate refastening. The tacking is done in sets. Beginning at one end of any seam 4' or more, make the first set of tacks approximately 2' apart. The first tack of the second set is made 6" down from the first tack of the original set. The second tack of set two is made 6" down from the tack two of the first set; the remaining tacks of the second set are made in this way. Following this leapfrogging procedure through the making of a third and fourth set will result in tacking at 6" intervals along seams greater than 4'. On seams less than 4', no more than three sets of tacks are necessary. In this case, heat build up must be more carefully avoided than in the latter case. In both situations, however, it should be remembered that seam quality is directly related to sufficient cooling.

After the first sheets on either side of the keel are tack welded, remaining sheets must be put through all the steps in the process one by one. The work follows a continuous cycle of patterning, cutting, fastening and tacking until the hull is sheathed from keel to sheer.

When the work reaches this stage, back stepping on all seams is needed. The back stepping should be done with a side-to-side triangular weave on vertical seams. Neat corner beaming is called for on the keel, chine, and stern seams. Throughout the project, neatness in welding should be emphasized. The builder



is cautioned against the idea that excess welds can be removed with a grinder. Grinding often has a weakening effect on welded seams.

Before the hull can be hauled out of the work place and inverted, keel down, the skag must be patterned, cut, and welded. The skag dimensions are formed out of 1 x 2 pine, basically in the same manner the hull jig was constructed but without sheer-to-sheer lengths. The cross-sectional form of the skag can be described as an inverted "V" which is small enough in all its dimensions to be constructed on the work table.

After the steel sheet patterning and fastening are done, the skag is tacked and back stepped, stripped of its form and placed onto the hull with its ends at the proper predetermined locations. Once in place, the skag is tacked and then back stepped to the hull with a neat corner bead.

The project is now at the point where the hull must be turned keel down so that the cockpit, berth, and beams and respective sheathings can be fastened, tacked and welded. The 8" lengths of 1" iron pipe, referred to earlier under frame construction, must be inserted underneath the frame from side to side approximately every 3 feet. A pinch bar will suffice to lift the frame enough for the support blocks to be removed and the frame then set down on the piping.

Flipping the hull onto its side requires the use of a 4:1 block and tackle hooked to the gunwale and anchored up and over the hull to a very strong stationary object at a safe distance on the opposite side. Steady pulling on the block and tackle will cause the hull to reach a point where it will come to rest heeled over on its side with its weight off the stations frame. At this point, the frame should be carefully unbolted at each station. As well as making sure that the block and tackle is safely secured, it is wise to support the weight of the frame during the unbolting so that it does not put any damaging strain on the hull jig. After the frame is freed from the hull jig, the uprights are to be dismantled and the base of the frame positioned to reaccommodate the hull, keel down. Leaving the hull heeled on its side for more than a day will cause it to become misshapen by its own weight. For this reason, the work of inverting the hull should be scheduled so that it can be done without lengthy interruption.

Before jacking up and shoring the hull upright on to the frame, a wooden channel must be made up of two 2 x 4's running the length of the frame parallel to each other and about 3" off either side of the center line. The hull is then pushed to this channel and jacked up from one side and pulled from the other and gradually shored up along the way on both sides until the keel and skag are in the channel and the hull is plumb. (A plumb line extending down from off the top of the bow will aid in determining the best position.)

Now that the hull has been properly inverted it must be again secured to the frame. When the hull is properly cradled to the base, it is returned to the original work place in the same way it was removed.

Welding now resumes for the installation of the main deck beams and respective headers and carlines for hatch, cabin, and cockpit. This framing is followed by the installation of the floor beams for the cockpit and cabin and finally by thesealing off of the main deck with the deck sheets. The main deck beams are welded vertically to the inside face of the sheet at each station. As this is done, each wooden station is removed to make way for its steel replacement. Also, as the wooden stations are being removed, vertical inside seams become accessible. These should be welded and then butt blocked according to plan as soon as they are within reach. Adequate room in which to weld the remaining seams in the keel, stern, and bow is created when all of the wooden stations are stripped out.

The proper locations and dimensions, including the crowning specs of all of the above beam work for deck beams, are shown clearly in the plans.

The dimensions for the rudder should be taken from the plan and plotted on masonite. A masonite pattern is then cut and scribed on to a 1/8" steel sheet. Two patterns must be cut, clamped, and then welded together. The rudder hangers are then welded to the rudder at the prescribed stern and skag heights. Also, the corresponding female hangers are welded onto the stern and skag plates. Once these hangers are connected, the hull possesses its sense of direction and is thereby completed insofar as the major steel construction is concerned