# Steel Hull Installation: Welding Requirements and Corrosion Protection Guide

This comprehensive guide provides step-by-step instructions for steel hull installation with a focus on proper welding techniques and effective corrosion protection systems. Adherence to these guidelines ensures structural integrity and longevity of marine vessels.

## Qualification Requirements for Hull Welding

Proper qualification of personnel and procedures is essential for ensuring high-quality welds in steel hull construction.

## Welder Qualification Standards

Steel hull welding must be performed by properly qualified welders in accordance with relevant standards. Welders must demonstrate proficiency through certification tests before being permitted to work on hull structures[16][19].

"Welding of hull structures is to be carried out by qualified welders, according to approved and qualified welding procedures and with welding consumables approved by the Bureau. Welding operations are to be carried out under proper supervision by the shipbuilder"[19].

Welders certified under national or international qualification standards may be engaged in hull structural steel welding, provided their certification meets the requirements established by classification societies[16]. Welding operators using fully mechanized or automatic processes generally do not need approval testing if their production welds consistently meet quality standards, though they must receive adequate training in equipment operation[19].

## Welding Procedure Qualification

Before beginning construction, welding procedures must be qualified through testing. These tests ensure that the selected materials, processes, and techniques will produce joints with the required mechanical properties[17].

Qualification tests may be required for steels used in hull construction and marine structures, as specified in various standards[17]. The tests must demonstrate that satisfactory mechanical properties can be obtained after appropriate heat treatment[17].

# Steel Hull Preparation

Proper preparation of steel components is critical before welding begins.

## Material Selection and Preparation

High-strength steel plates are commonly used for hull construction, with grades such as AH36 being popular choices due to their mechanical properties and weldability[13]. The steel must meet the requirements for strength, toughness, and corrosion resistance appropriate for marine environments[12].

Prior to welding, all steel plates and structural components must be properly cleaned and prepared. This includes removing mill scale, rust, paint, oil, and other contaminants that could affect weld quality[6]. Edges to be welded must be prepared according to approved design specifications, which may include various bevel configurations depending on plate thickness and joint type[8].

## Setting Up the Workspace

Establishing proper working conditions is essential for high-quality welds: "Provisions are to be made for proper accessibility, staging, lighting and ventilation. Welding operations are to be carried out under shelter from rain, snow and wind"[19]. This environmental control helps prevent contamination and hydrogen entrapment in welds, which can lead to defects and reduced mechanical properties[19].

# Steel Hull Welding Sequence

Following the proper welding sequence is critical to minimize distortion and stress in the hull structure.

## Step 1: Tack Welding Plate Perimeters

Begin by tack welding all plate perimeters to secure them in position. These tack welds should be the minimum necessary to fixture the plate edges without inducing significant weld shrinkage distortion[7].

"This should be a regular sequence that is the minimum to assure that the plate edges are securely fixtured, but not so much as to induce any 'weld shrinkage' distortion of the plate"[7]. For 3/8" plate, this might mean 1" tack welds every 6-8 inches around the perimeter, with the spacing adjusted according to plate thickness[7].

## Step 2: Chain Welding Longitudinal Stringers

Next, chain weld all longitudinal stringers to the hull plate. Allow adequate distance (approximately 12 inches) from any butt welds to the nearest longitudinal chain weld to accommodate shrinkage at the butt weld[7].

## Step 3: Butt Weld Fixturing

Fixture all plate butt joints both inside (with sister longitudinals if needed) and outside (with temporary longitudinals) to ensure proper alignment during welding[7]. This preparation step is crucial for maintaining the hull's structural integrity and appearance.

## Step 4: Transverse Butt Weld Execution

Execute all transverse butt welds using a measured incremental pattern across the entire vessel. The recommended approach is to work from the middle toward the perimeter, similar to the pattern used when torquing down a head[7].
"Within each butt, ordinarily it is most favorable to achieve the inside seam weld first - because the tendency is for the plate to shrink, causing an indent, but having been welded on the inside, there is some tendency to counter that force"[7]. After completing the inside weld, thoroughly back-gouge down to the weld root before performing the outside weld[7].

## Step 5: Longitudinal Butt Weld Fixturing

Properly fixture all longitudinal butt welds with internal and external fixturing as needed. This is especially important where longitudinal seam welds converge, as the welds could potentially overcome the local plate strength and cause distortion[7].

## Step 6: Insert Plate Treatment

Treat all "insert plate" welds as either "butts" or "longitudinal seams" and include them in the welding sequence accordingly. Weld the inside first, then the outside, with appropriate fixturing as needed[7].

## Step 7: Longitudinal Edge Seam Welding

After completing all plate butt welds, begin welding the lengthwise edge seams using a regular, pre-planned sequence. Start in the middle and work outward both lengthwise and vertically[7].
"It is usually best to start amidships, working toward the ends for each sequence. Ordinarily it seems best to start amidships, working toward the ends for each sequence"[7]. Implement a "back-step" sequence with welds spaced apart at appropriate intervals (e.g., 3-inch welds with 24-inch spacing between them)[7].

## Step 8: Stringer-to-Frame Welding

After completing all edge seam welds, make the welds connecting the longitudinal stringers to the frames. Introduce heat minimally at each joint to reduce the tendency of the longitudinals to collapse when heated. This may require local fixturing on the outside, particularly near any butt joints in the plating[7].

## Step 9: Plate-to-Frame Welding

As the final step, make the welds that attach the plating to the frames. This must be done carefully since these welds can cause more distortion than anticipated, and any distortion will be highly visible[7].

"It is helpful in terms of weld shrinkage/distortion to bias more of the welding toward the obtuse angle rather than the acute angle (the angle of frames to plates). This is most pronounced toward the bow and stern where the intersect between plate and frame deviates the greatest from being a 90 degree angle"[7].

## Welding Processes for Steel Hull Construction

Several welding processes are suitable for steel hull construction, with selection depending on the specific application, material thickness, and position.

## Shielded Metal Arc Welding (SMAW)

SMAW, or stick welding, is commonly used for general hull construction. E7018 electrodes are often preferred for high-strength steel welding, though they must be stored in a hotbox to ensure they are completely dry before use[18].

## Submerged Arc Welding (SAW)

SAW is particularly valuable for thick hull plate sections where minimal edge preparation is required. This process was originally developed in the early 1940s specifically for welding thick hull sections of naval ships[10].

"The process has since been used extensively in heavy fabrication industries like ship building, pressure vessel and rail industries"[10]. SAW produces high-quality welds with excellent penetration and mechanical properties, making it ideal for critical hull joints[10][15].

## Flux Cored Arc Welding (FCAW)

FCAW combined with Electro Gas welding processes can be effective for thick steel plates. Research on EH36 TMCP steel plate for hull structures has demonstrated that these combined processes can meet International Association of Classification Societies (IACS) requirements for mechanical properties[8].

## Weld Quality Standards and Inspection

Ensuring weld quality through proper standards and inspection is essential for hull integrity.

## Alignment and Profile Standards

Specific standards exist for the alignment of butt and fillet welds in hull structures. For butt welds in strength applications, misalignment should not exceed 0.15t (where t is the plate thickness) and should not exceed 3.0 mm[19].
For fillet welds in strength and higher tensile applications, alignment tolerances are typically a ≤ t1/4 measured on the median line[19]. Detailed standards also exist for weld toe angles, undercut depths, and leg lengths for both butt and fillet welds[19].

## Inspection Requirements

After welding, comprehensive inspection is necessary to ensure quality. This may include:

1. Visual inspection to verify weld size, profile, and absence of surface defects
2. Non-destructive testing such as magnetic particle, liquid penetrant, ultrasonic, or radiographic inspection depending on the criticality of the joint[17]
3. Mechanical testing for critical structural welds to verify properties meet design requirements[13]

"On completion of heat treatment the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required depending on the dimensions and nature of the original defect"[17].

## Corrosion Protection Systems for Steel Hulls

Effective corrosion protection is essential for extending the service life of steel hulls in marine environments.

## Cathodic Protection Systems

Cathodic protection is a widely used technique to prevent corrosion on metal structures, including ships and boats[45]. Two main types of cathodic protection systems are used for ships:

## Sacrificial Anode Cathodic Protection (SACP)

The SACP system uses sacrificial anodes made from a more reactive metal than the hull (typically zinc or aluminum) that corrode preferentially, protecting the hull[49].

"During installation, the anodes are either clamped or welded to the steel surface of the hull, to ensure permanent contact between the two types of metal"[9]. SACP systems are particularly advantageous for internal use and complex structures, as protection can be provided by distributing small anodes throughout the vessel[9].
Key advantages of SACP systems include:

- Simple installation
- Maintenance-free between dry dockings
- Worldwide availability
- Low cost for short-term operation[9]

## Impressed Current Cathodic Protection (ICCP)

ICCP systems use an external DC power source to provide the electrical current needed to prevent corrosion[4][9]. These systems are often preferred for larger vessels.
Key advantages of ICCP systems include:

- Smooth surface with no extra drag
- Flexibility
- Light weight for large displacement vessels
- Long lifespan
- No welding requirements
- Fully automatic operation[9]

## Protective Coatings

Coatings provide a physical barrier between the steel hull and the corrosive marine environment. An impervious coating system consists of multiple layers, each serving a specific purpose[9].

## Combined Protection Approach

The most effective approach combines both cathodic protection and coatings:
"From experience, installing the anodes at the ship building stage gives the best result for corrosion protection. The calcareous deposit formed will precipitate on uncorroded steel at once, should a defect occur"[9]. When anodes are installed after corrosion has already begun, the protective layer will be less effective[9].
"The combination of CP and coating from the construction stage is the most effective and economical corrosion protection technique"[9]. A well-applied coating system results in minimal consumption of anodes, which then serve primarily as a backup that activates only when the coating begins to deteriorate[9].

## Conclusion

Proper installation of steel hull structures requires careful attention to welding requirements and corrosion protection. By following the outlined sequence of welding operations, adhering to quality standards, and implementing effective corrosion protection systems, shipbuilders can ensure the structural integrity and longevity of steel hulls.

The combination of qualified welders, appropriate welding procedures, proper weld sequence, and comprehensive corrosion protection from the construction stage represents the most effective approach to steel hull installation. Regular inspection and maintenance of both welds and corrosion protection systems will further extend the service life of steel hull structures.

For specific applications, consultation with classification societies and adherence to relevant standards is essential to ensure compliance with all regulatory requirements while achieving optimal performance.