NOTE: MIL-STD-1689 has been redesignated as a Manufacturing Process Standard. The cover page has been changed for Administrative reasons. There are no other changes to this Document.

INCH-POUND

MIL-STD-1689A (SH)
23 NOVEMBER 1990
SUPERSEDING
MIL-STD-1689 (SH)
27 DECEMBER 1983
(SEE 17.5)

DEPARTMENT OF DEFENSE
MANUFACTURING PROCESS STANDARD

FABRICATION, WELDING, AND INSPECTION OF SHIPS STRUCTURE

AMSC N/A

AREA THJM

FORWARD

1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Scope. This standard contains minimum requirements for the fabrication and inspection of the hull and associated structures of combatant surface ships. The requirements for shipbuilding, materials, welding, welding design, mechanical fasteners, workmanship, inspection, forming, castings and records are included. It also applies to those submarine structures which are not high-yield strength steels. Requirements for HY-80/100 submarine structure are contained in MIL-STD-1688. Requirements for HY-130 submarine structure are contained in MIL-STD-1681.

1.2 General. This document contains both mandatory requirements and guidance information. The mandatory requirements indicated by the words "shall" or "is required" serve as standards applicable to materials, workmanship, inspection and quality control. Guidance information is indicated either by the word "should" or "may". Such information represents the latest technical guidance to assure quality but is not mandatory.

1.3 References. Reference in this document to a particular paragraph or section number shall include all applicable subparagraphs under that paragraph or section number. For example, the reference to 4.7 shall include 4.7.1, 4.7.2, 4.7.2.1, 4.7.2.2.

1.4 Requirements subject to Naval Sea Systems Command (NAVSEA) approval. Any requirements contained in this standard specifically requiring NAVSEA approval shall be forwarded to Naval Sea Systems Command, Assistant Director, Materials Engineering, Washington, DC 20362-5101. Subcontractors shall submit such items to the contracting activity in accordance with the contract or purchase order.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 17.2).

SPECIFICATIONS

FEDERAL

FF-B-584	- Bolts, Finned Neck; Key Head; Machine; Ribbed Neck; Square Neck; Tee Head.
QQ-A-200/1	- Aluminum Alloy 3003, Bar, Rod, Shapes, Tube and Wire, Extruded.
QQ-A-200/4	- Aluminum Alloy 5083, Bar, Rod, Shapes, Tube and Wire, Extruded.
QQ-A-200/5	- Aluminum Alloy 5086, Bar, Rod, Shapes, Tube and Wire, Extruded.

FEDERAL (Continued)

QQ-A-200/6	- Aluminum Alloy 5454, Bar, Rod, Shapes, Tube and Wire, Extruded.
QQ-A-200/7	- Aluminum Alloy 5456, Bar, Rod, Shapes, Tube and Wire, Extruded.
QQ-A-225/1	- Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished, 1100.
QQ-A-225/2	- Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished, 3003.
QQ-A-225/7	- Aluminum Alloy 5052, Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished.
QQ-A-250/1	- Aluminum 1100, Plate and Sheet.
QQ-A-250/2	- Aluminum Alloy 3003, Plate and Sheet.
QQ-A-250/6	- Aluminum Alloy 5083, Plate and Sheet.
QQ-A-250/8	- Aluminum Alloy 5052, Plate and Sheet.
QQ-A-250/9	- Aluminum Alloy 5456, Plate and Sheet.
QQ-A-250/10	- Aluminum Alloy 5454, Plate and Sheet.
QQ-N-281	- Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections.
QQ-N-288	- Nickel-Copper Alloy and Nickel-Copper-Silicon Alloy Castings.
QQ-S-763	- Steel Bars, Wire, Shapes, and Forgings, Corrosion Resisting.
QQ-S-766	- Steel, Stainless and Heat Resisting, Alloys, Plate, Sheet and Strip.
TT-C-1796	- Caulking Compounds, Metal Seam and Wood Seam.
WW-T-700/1	- Tube, Aluminum, Drawn, Seamless, 1100.
WW-T-700/2	- Tube, Aluminum Alloy, Drawn, Seamless, 3003.
WW-T-700/5	- Tube, Aluminum Alloy, Drawn, Seamless, 5086.

MILITARY

MIL-S-867	- Steel Castings, Corrosion Resisting Austenitic.
MIL-S-1222	- Studs, Bolts, Hex Cap Screws, Socket Head Cap Screws and Nuts.
MIL-R-5674	- Rivets, Structural, Aluminum Alloy, Titanium Columbium Alloy, General Specification for.
MIL-S-8802	- Sealing Compound, Temperature-Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High-Adhesion.
MIL-C-11796	- Corrosion Preventive Compound, Petrolatum Hot Application.
DOD-P-15328	- Primer (Wash), Pretreatment (Formula No. 117 for Metals) (Metric).
MIL-B-15382	- Bolt, Firebrick Anchor.
MIL-C-15726	- Copper-Nickel Alloy, Rod, Flat Products (Flat Wire, Strip, Sheet, Bar, and Plate) and Forgings.
MIL-S-16216	- Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100).

MILITARY (Continued)

MIL-T-16420 - Tube, Copper-Nickel Alloy, Seamless and Welded (Copper Alloy Numbers 715 and 706).

MIL-N-17163 - Nickel-Copper Alloy, Wrought; (55-60 Percent Nickel) Low Permeability.

MIL-S-17509 - Steel Castings, Austenitic, Chromium-Nickel, Low Magnetic Permeability.

MIL-E-18193 - Electrodes, Welding, Carbon Steel and Alloy Steel, Bare, Coiled.

MIL-F-18251 - Fluxes, Welding, Submerged Arc Process Carbon and Low-Alloy Steel Application.

MIL-F-19922 - Fluxes, Welding (Compositions), Submerged Arc Process with Type "B" Electrodes, Carbon and Low-Alloy Steel Application.

MIL-E-19933 - Electrodes and Rods - Welding, Bare, Chromium and Chromium-Nickel Steels.

MIL-C-20079 - Cloth, Glass; Tape, Textile Glass; and Thread, Glass and Wire-Reinforced Glass.

MIL-C-20159 - Copper-Nickel Alloy Castings (UNS No. C96200 and C96400).

MIL-E-21562 - Electrodes and Rods - Welding, Bare, Nickel Alloy.

MIL-S-21952 - Steel, (HY-80 and HY-100) Bars, Alloy.

MIL-E-22200/1 - Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium and High Tensile Steel, As Welded or Stress-Relieved Weld Application.

MIL-E-22200/2 - Electrodes, Welding, Covered (Austenitic Chromium-Nickel Steel).

MIL-E-22200/3 - Electrodes, Welding, Covered: Nickel Base Alloy; and Cobalt Base Alloy.

MIL-E-22200/4 - Electrodes, Welding, Covered, Copper-Nickel Alloy.

MIL-E-22200/5 - Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen, Low-Alloy Steel for Hardening and Tempering Heat Treatment Applications Only.

MIL-E-22200/10 - Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium, High Tensile and Higher-Strength Low Alloy Steels.

MIL-S-22664 - Steel Structural Shapes Alloy, High Yield Strength (HY-80 and HY-100) (Metric).

MIL-S-22698 - Steel Plate, Shapes and Bars, Weldable Ordinary Strength and Higher Strength: Structural.

MIL-S-23008 - Steel Castings, Alloy, High Yield Strength (HY-80 and HY-100).

MIL-S-23009 - Steel Forgings, Alloy, High Yield Strength (HY-80 and HY-100).

MIL-S-23193 - Steel, Corrosion Resistant: Castings.

MIL-S-23195 - Steel Bars and Forgings, Corrosion Resistant.

MILITARY (Continued)

MIL-S-23196 - Steel Plate, Sheet and Strip; Corrosion Resistant.
MIL-N-23228 - Nickel-Chromium-Iron Alloy Plate, Sheet, and Strip.
MIL-N-23229 - Nickel-Chromium-Iron Alloy Bars and Forgings.
MIL-P-23469 - Pin-Rivet, Grooved and Collar, Grooved Pin-Rivet, Swage-Locked (Lockpin) General Specification for.
MIL-P-23469/2 - Pin-Rivet, Grooved, Brazier Head; Straight Shank, Six Locking Grooves, Aluminum Alloy, Corrosion-Resistant and Carbon Steels.
MIL-P-23469/3 - Pin-Rivet, Grooved, Brazier, Truss and Flush Head; Straight Shank, Wide Grip Range, Multiple Locking Grooves, Aluminum Alloy and Carbon Steel.
MIL-P-23469/4 - Pin-Rivet, Grooved, Round Head; Straight Shank, Multiple Locking Grooves, Aluminum Alloy, Corrosion-Resistant and Carbon Steels.
MIL-P-23469/5 - Pin-Rivet, Grooved, Truss Head; Straight Shank, Six Locking Grooves and Multiple Locking Grooves, Aluminum Alloy, Corrosion-Resistant and Carbon Steels.
MIL-P-23469/6 - Pin-Rivet, Grooved, Flat 90° Countersunk Head; Straight Shank, Six Locking Grooves and Multiple Locking Grooves, Aluminum Alloy, Corrosion-Resistant Steel and Carbon Steels.
MIL-P-23469/7 - Pin-Rivet, Grooved, Oval 60° Countersunk Head; Tapered-Section Shank, Multiple Locking Grooves, Aluminum Alloy, Corrosion-Resistant Steel and Carbon Steels.
MIL-E-23765/1 - Electrodes and Rods - Welding, Bare, Solid and Alloyed Cored, Ordinary Strength and Low Alloy Steel.
MIL-E-23765/2 - Electrodes and Rods - Welding, Bare, Solid, or Alloyed Cored, Low Alloy Steel.
MIL-N-24106 - Nickel-Copper Alloy Bars, Rods, and Forgings.
MIL-S-24371 - Steel Plate, Alloy, Structural, High Yield Strength (HY-130).
MIL-I-24391 - Insulation Tape, Electrical, Plastic, Pressure Sensitive.
MIL-E-24403/1 - Electrodes - Welding, Flux Cored, Ordinary Strength and Low Alloy Steel.
MIL-E-24403/2 - Electrodes - Welding, Flux Cored, Low Alloy Steel.
MIL-J-24445 - Joint, Bimetallic Bonded, Aluminum to Steel.
MIL-S-24451 - Steel Heat Treated Heads, Alloy Structural, High Yield Strength (HY-80 and HY-100).
MIL-S-24645 - Steel Plate, Sheet, or Coil, Age-Hardening Alloy, Structural, High Yield Strength (HSLA-80 and HSLA-100).

STANDARDS

MILITARY (Continued)

MIL-STD-22 - Welded Joint Design.
MIL-STD-248 - Welding and Brazing Procedure and Performance Qualification.
MIL-STD-271 - Requirements for Nondestructive Testing Methods.
MIL-STD-1628 - Fillet Weld Size, Strength, and Efficiency Determination.
MIL-STE-1681 - Fabrication, Welding, and Inspection of HY-130 Submarine Hull.
MIL-STD-1688 - Fabrication, Welding, and Inspection of HY-80/100 Submarine Applications.

(Unless otherwise indicated, copies of federal and military specifications and standards are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 Other Government publications. The following other Government publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

0900-LP-003-8000 - Surface Inspection Acceptance Standards for Metals.
0900-LP-003-9000 - Radiographic Standards for Production and Repair Welds. (Except Section II Does Not Apply.)
0900-LP-006-3010 - Ultrasonic Inspection Procedure and Acceptance Standards for Hull Structure Production and Repair Welds.
0900-LP-999-9000 - Acceptance Standards for Surface Finish of Flame or Arc-Cut Material.
S9086-CH-STM-010/CH-074VI - NAVSEA Technical Manual, Welding and Allied Processes.

(Applications for copies should be addressed to the Naval Publications and Forms Center, (ATTN: NPODS) 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 17.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

B 166 - Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600 and N06690), Rod, Bar, and Wire. (DoD adopted)

B 564 - Standard Specification for Nickel Alloy Forgings. (DoD adopted)

E 155 - Standard Reference Radiographs for Inspection of Aluminum and Magnesium Castings. (DoD adopted)

E 186 - Standard Reference Radiographs for Heavy-Walled (2 to 4-1/2-in. (51 to 114-mm)) Steel Castings. (DoD adopted)

E 272 - Standard Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings.

E 280 - Standard Reference Radiographs for Heavy-Walled (4-1/2 to 12-in. (114 to 305-mm)) Steel Castings. (DoD adopted)

E 310 - Standard Reference Radiographs for Tin Bronze Castings.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

AMERICAN WELDING SOCIETY (AWS)

A2.4 - Standard Symbols for Welding, Brazing and Nondestructive Examination.

A3.0 - Standard Welding Terms and Definitions.

A5.1 - Specification for Covered Carbon Steel Arc Welding Electrodes.

A5.10 - Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods.

(Application for copies should be addressed to the American Welding Society, Inc., 550 NW LeJeune Rd., P.O. Box 351040, Miami, FL 33135.)

(Nongovernment standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 General. Except as noted herein, welding nomenclature and definitions conform to AWS A2.4 and A3.0.

3.2 Acceptable. Acceptable consists of conformance to the applicable standard or specification.

3.3 Activity. The activity is the physical plant of an organization performing work to which this standard is applicable.

3.4 Approval (approved). Approval or approved indicates the item under consideration requires acceptance by NAVSEA, or its authorized representative. Approval or approved as used herein shall be by NAVSEA authorized representative unless NAVSEA approval is specified.

3.5 Arc strike. An arc strike is any inadvertent heat-affected zone or change in the contour of the finished weld or adjacent base metal resulting from an arc or heat generated by the passage of electrical current between the surface of the finished weld or base metal and a current source such as welding electrode or magnetic particle (MT) prod.

3.6 Backgouge. A backgouge consists of the preparation of the second side of full penetration welds to the extent necessary to permit proper deposition of weld metal.

3.7 Ballistic plating. Ballistic plating is type A protective plating designed to resist the effects of ballistic penetrators (see 3.33.5).

3.8 Bulkheads.

3.8.1 Closure bulkhead (submarines). A closure bulkhead is a hull end bulkhead designed to withstand collapse depth pressure.

3.8.2 Containment bulkhead. A containment bulkhead is a bulkhead which functions to contain damage resulting from a design basis casualty within that compartment other than a watertight integrity casualty. Containment bulkheads are considered hull support structures for design and inspection requirements.

3.8.3 Holding bulkhead (submarines). A holding bulkhead is a transverse watertight bulkhead within the pressure hull envelope which forms one boundary of an escape compartment and is designed to maintain watertight integrity up to the depth prescribed in the ship's building specifications. Holding bulkheads are considered pressure hull support structure for design and inspection purposes.

3.8.4 Structural bulkhead. A structural bulkhead is a complete or partial watertight or non-watertight bulkhead which supports the hull.

3.8.5 Enclosure bulkhead. Enclosure bulkhead is an exterior bulkhead that encloses space in the superstructure.

3.8.6 Interior bulkhead. Interior bulkhead is an internal bulkhead in the superstructure.

3.9 Buildup. See 3.47.7.1.

3.10 Butt. A butt is a transverse or vertical plate edge connection in the shell, bulkhead, or deck plating (the plate butt is perpendicular to the plate seam).

3.11 Circularity. Circularity is the degree of deviation of a transverse section of the hull from a true circle.

3.12 Coamings.

3.12.1 Submarines. Coamings on submarines are compensating material surrounding holes in structure and extending through or on one side only, and are usually connected by a corner, groove tee or fillet weld and which may provide all or partial compensation for the hole.

3.12.2 Surface ships. Coamings on surface ships are perpendicular plates at the peripheries of openings.

3.13 Control surfaces. Control surfaces are those portions of ship structure external to the hull designed to provide steering, diving or stabilization capabilities, such as rudders, stabilizers and diving planes.

3.14 Corner crack. A corner crack is a crack occurring in weld metal in way of a temporary access snipe, a drain or vent opening, or at the intersection of three members (see figure 1).

3.15 Decks, main strength (surface ships). Main strength decks on surface ships are the topmost continuous deck, or decks as defined in the ship specifications for the ship involved.

3.16 Erection. Erection is the assembly of various parts or subassemblies of the ship's hull.

3.17 Fabrication. Fabrication covers construction, alteration, modification or repair operations as involved in the construction and overhaul of ships.

3.18 Foundation. A foundation is the fabricated base or support used to hold a component or part of a component or system (for example, machinery bed plates, mounting brackets, and so forth).

3.19 Fragmentation plating. Fragmentation plating is type B, C or D protective plating designed to provide protection against fragments from weapons or other sources. It may be of the same material and thickness as ballistic plating or may be of other materials such as higher strength or carbon steel, aluminum or non-metallic materials. Fragmentation plating is provided for protection against fragments (see 3.33.5).

3.20 High-hardenable materials. High-hardenable materials include special treatment steel (STS) and any structural ferritic steel with a carbon content in excess of 0.30 percent and quenched and tempered steels other than HY-80/100/130.

3.21 Higher strength steel (HSS). Higher strength steel (HSS) is steel in accordance with MIL-S-22698.

3.22 High strength low alloy steel. High strength low alloy steel (HSLA minimum yield strength) is steel in accordance with MIL-S-24645.

3.23 High yield strength steel. High yield strength steel (HY) is steel with the minimum yield strength specified.

3.23.1 HY-80/100 steel. HY-80 and HY-100 steel is steel in accordance with MIL-S-16216, MIL-S-23008, MIL-S-23009, MIL-S-21952, MIL-S-22664 and MIL-S-24451 for plate, castings, forgings, bars, shapes, and heads respectively.

3.23.2 HY-130 steel. HY-130 steel is steel in accordance with MIL-S-24371 for plate.

3.24 Inserts. Inserts are structural reinforcements welded into submarine or surface ship hull or other structure by some type of butt joint. Inserts reinforce the structure at openings or areas of high stress and maybe of the same or greater thickness than the surrounding structure.

3.25 Inspector. The inspector is the contractor, Naval shipyard and other Government agency employees, or American Bureau of Shipping (ABS) surveyor qualified as required by this standard to accept or reject materials or workmanship on the basis of specified test results.

3.26 Lamination. Lamination is an internal discontinuity in plate material consisting of oxides, sulfides, or other extraneous material and which is characterized both by layering and reasonable parallelness to the plate surface. An edge lamination is one on the edge of the plate parallel to the plate surface.

3.27 Record of accomplishment. Record of accomplishment is a record which provides objective evidence of completion, inspection of weld sand accountability of fabrication requiring inspection by this standard. Records identify the ship, applicable drawing, identification of the fabrication completed (drawing, assembly, piecemark, and so forth), and type of inspection involved. Signatures represent certification of only that portion of the structure inspected at the time.

3.28 Make-up plate. A make-up plate is a plate added at time of erection to correct discrepant materials or deviations in construction.

3.29 NAVSEA authorized representative. A NAVSEA authorized representative is any Government representative specifically authorized to approve equipment, material or procedures within the scope of this standard for NAVSEA as follows:

(a) For Government shipyards: The delegated representative of the shipyard Commander.

(b) For commercial shipyards: The delegated representative of the Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP), or the American Bureau of Shipping (ABS) when specified in the ship's specifications for a particular ship.

3.30 Ordinary strength (OS) steel. OS steel is steel is in accordance with MIL-S-22698.

3.31 Patches. Patches are plates installed to replace deleted inserts or penetrations, to correct discrepant, damaged or defective materials, or to correct errors in construction.

3.32 Penetrations. Penetrations are those items such as pipe, sleeves, or trunks welded into submarine or surface ship structure by some type of groove tee, corner, or fillet weld. Penetrations pass through and extend beyond one or both sides of the structure.

3.33 Plates (plating).

3.33.1 Access plates. Access plates are those sections of plating removed, and later reinstalled for access and installation or removal of equipment. Access plates do not involve cutting of hull frames.

3.33.2 Small access plates. Small access plates are those access plates which have a maximum diameter of 24 inches.

3.33.3 Closure plates. Closure plates are those plates left off or removed for access, wherein at least one transverse frame is cut.

3.33.4 Tank plating. Tank plating is tank boundary plating.

3.33.5 Protective plating (type A). Type A protective plating is provided for protection against ballistic shapes.

3.34 Re-entrant angle. A re-entrant angle is the angle formed between the base plate and the weld at the weld edge (see figure 2).

3.35 Rigging fittings. Rigging fittings are fittings attached to weight-handling devices such as kingposts, cranes, booms, lifting pads, and cleats.

3.36 Seam. A seam is a fore-and-aft or horizontal plate edge connection in the shell, bulkhead, or deck plating.

3.37 Shapes. Shapes are one piece hot-rolled, extruded, or high frequency welded material other than flat plate, strip, tube or bar.

3.38 Ship. A ship is any surface vessel over 100 feet in length or any submarine.

3.39 Snipe. A snipe is a small temporary or permanent opening in an abutting member to permit the deposition of a sound weld in a joint passing beneath the a butting member. A temporary snipe is closed by welding or a patch plate depending on its size. A permanent snipe is left open for use as a vent or drain hole.

3.40 Structure (submarine). Submarine structure is categorized by functions as defined in 3.40.1 through 3.40.7 (see figure 3).

3.40.1 Nonpressure hull structure. Nonpressure hull structure is structure which is not designed to withstand collapse depth pressure. This includes such items as low (soft) and intermediate pressure tanks, nonsupport structure, and foundations.

3.40.2 Nonsupport structure. A nonsupport structure is a structure not otherwise specifically categorized. This includes, but is not limited to, free flooding structure, decks and deck stanchions, control surfaces, and fairwater. Nonsupport defines the relation to the pressure hull, not the function with regard to other items.

3.40.3 Pressure hull envelope. Pressure hull envelope is structural material in boundaries maintaining watertight integrity at collapse depth. This includes such items as pressure hull plating, sea chests, trunks, hatches, missile tubes, closure bulkheads, inserts, penetrations, sonar spheres, access plates, and hard tank plating designed to withstand collapse depth pressure.

3.40.4 Pressure hull. Pressure hull is the material forming and supporting the outermost watertight boundary designed to withstand collapse depth pressure including the pressure hull envelope.

3.40.5 Pressure hull structure. Pressure hull structure is structure designed to withstand collapse depth pressure including the pressure hull envelope and supporting structure.

3.40.6 Support structure. Support structure is structure whose function is to contribute to the ability of the pressure hull envelope to withstand collapse depth pressure, but does not itself form part of the watertight boundary under normal operations. This includes items such as pressure hull frames, hard tank framing, transverse structural floors acting as frames, holding bulkheads and that portion of any internal or external bulkhead functioning as a frame.

(a) When transverse floors and bulkheads act as frames, only the first 18 inches of the pressure hull plating measured normal to the ship's axis from the surface to which the floor or bulkhead is attached is to be considered as pressure hull framing (that is, support structure).
(b) When frames have nominal depths greater than 18 inches and transition into floors and bulkheads, only the nominal depth of the frame in way of floors or bulkheads is to be considered as pressure hull framing.

3.40.7 Containment structure. Containment structure is all compartment boundary structure, not covered by other structural categories, whose function is to contain, within portions of the compartment, damage resulting from a design basis casualty within that compartment, other than a watertight integrity casualty.

3.41 Structure (surface ship). For the purposes of this standard, surface ship structure shall be construed to include those portions of the ship's structure which maintain the watertight integrity of the hull and other structures specified in section 11 except joiner and non-structural bulkheads. Additionally, it includes rudders, weight handling fittings, access trunks, ballistic doors and superstructure (see figure 4).

3.41.1 Primary structure. The primary structure is that part of the ship's structure which makes up the primary hull girder, primary support structure and primary damage control structure. The primary hull girder includes the shell, main strength decks, principal longitudinal bulkheads, vertical keel, deep web girders and stiffeners designed to withstand the ship bending stress. Primary support structure includes the collision bulkhead, main transverse and bent bulkheads, and foundations that are integral parts of the primary girder and primary support structure. Primary damage control structure includes containment structure, water and oil tight tank bulkheads, type A protective plating, and water tight vital space boundaries below the design flooding levels (V-lines).

3.41.1.1 Hull envelope. Hull envelope is structural boundary material maintaining watertight integrity at the design flood levels (V-lines). This structure includes the shell, sea chests, external decks and bulkheads below the design flooding levels (V-lines).

3.41.1.2 Containment structure. Containment structure is all compartment boundary structure, not covered by other structural categories, whose function is to contain, within portions of the compartment, damage resulting from a design basis casualty within that compartment, other than a watertight integrity casualty.

3.41.2 Secondary structure. The secondary structure includes sponsons, superstructure, trunks, air, gas and flame tight bulkheads, fragmentation plating, masts, booms, kingposts, and weight-handling rigging and fittings.

3.41.3 Miscellaneous structure. Miscellaneous structure is structure other than primary and secondary. This includes foundations, stacks, control surfaces, non-tight bulkheads, and compensation for holes.

3.42 Tanks (submarines).

3.42.1 Hard tanks. Hard tanks are tanks designed to withstand pressure equal to or greater than ship test pressure (test depth).

3.42.2 Intermediate pressure tanks. Intermediate pressure tanks are tanks designed to withstand pressure greater than 125 pounds per square inch (lb/in^2) but less than ship test pressure (test depth).

3.42.3 Low pressure tanks (soft tanks). Low pressure tanks are tanks designed to withstand pressures 125 lb/in^2 and less.

3.43 Tilting bracket. Tilting bracket is plate or shape fitted to the load carrying member to stabilize the member from going out of plane.

3.44 Underwater side protective system. An underwater side protective system is a system designed to provide a defense against underwater explosion.

3.45 Verify (verification). For the purposes of this standard, the terms verify or verification mean examination of records such as test results for the purpose of determining compliance with applicable specification requirements.

3.46 Web stiffener. Web stiffener is plate fitted to the load carrying member web to preclude web failure by buckling.

3.47 Welds.

3.47.1 Attachment weld. Attachment weld is any weld attaching an OS or HSS member (see figure 5) to HY-80/100 surface ship and submarine structure where all of the following conditions are met:

(a) Application involves: Pipe hangers, cable hangers, ventilation hangers, attachments supporting only instruments or electrical equipment where the total weight of the instruments or electrical equipment is 1 ton (2240 pounds) or less, or lifting pads designed to carry 1 ton (2240 pounds) or less.
(b) A normal cross section through the attaching member does not exceed 2 inches nominal design length in any direction.
(c) Except for solid round bar, the thickness of the attaching member does not exceed 1/2 inch.
(d) For solid round bar, the maximum design weld throat does not exceed 1/2 inch.

3.47.2 Block weld. A block weld is an increment of a continuous multiple pass weld that is completely or partially built up in cross-section before adjacent lengths are deposited.

3.47.3 Completed weld. Completion occurs when all weld metal has been deposited, the weld has cooled to ambient temperature and the weld has been visually accepted and is ready for other nondestructive test (NDT) inspections.

3.47.4 Finished weld. A finished weld is a weld which has received all required inspection and has been accepted.

3.47.5 Foundation welds. Foundation welds are welds used to fabricate foundations and to attach them to ship's structure.

3.47.6 Tank welds (submarine). A tank weld is 100 percent efficient full or partial penetration weld in tank boundary plating (such as floor to tank top, side to shell, butts and seams) or to either side of tank boundary plating where the member involved is being used primarily as a tank boundary plate stiffener. It does not include frame to hull welds internal to the tank, back up structures, foundation welds, pressure hull butt and seam welds, or attachment welds (see figure 6).

3.47.7 Weld surfacing.

3.47.7.1 Weld buildup. Weld buildup is the deposition of filler metal to restore base material or weld surface dimensions, or to interpose a layer of weld metal on the material surface of the joint prior to joining the material members together.

3.47.7.2 Weld cladding (defined in AWS 3.0) (see figure 7). For purposes of inspection, cladding deposited for O-ring or gasket seating surfaces is further subdivided into the categories of:

(a) Inboard surface (nonpressure, dry side).
(b) Outboard surface (pressure, wet side).
(c) Seating or seal area surface.

3.48 Weld contour. Weld contour is the surface profile of a weld in the as deposited condition or after preparation to meet workmanship or NDT requirements.

3.49 Weld contouring. Weld contouring is the deliberate shaping of weld surfaces for hydrodynamic or fatigue considerations or as otherwise permitted in this standard.

3.50 Weld pass. A weld pass is a single longitudinal progression of a welding bead along a joint or weld deposit for the length of one block or more and may consist of more than one start or stop.

3.51 Wormhole porosity. Wormhole porosity is an elongated cavity type discontinuity formed by gas entrapment during solidification generally where the length is three or more times greater than the width and where the alignment of the void is normal to the solidification front.

4. QUALIFICATION REQUIREMENTS

4.1 General requirements. The purpose of these qualification requirements is to ensure that qualified procedures and appropriate equipment are used by properly trained personnel. It shall be the responsibility of the

activity to ensure that personnel, procedures and NDT equipment used for fabrication and inspection comply with this standard. Procedures and personnel previously qualified or approved shall not require requalification provided the qualifications have not lapsed, and provided the qualification records or approval documentation are available. Welding procedures and techniques, NDT processes and procedures, NDT equipment, and material other than those specified in this standard or MIL-STD-248 may be used if based on procedure qualification tests approved by NAVSEA.

4.2 Welding procedure qualification. Except as specified in 4.1, before any welding is performed on structures covered by this standard, procedures shall be qualified in accordance with MIL-STD-248. Records of welding procedure qualification shall be as specified in section 5. Procedure qualification testing is not required for welding on assemblies, the possible failure of which is remote and would not result in danger to the ship, such as the following:

(a) Nonstructural or joiner bulkheads.
(b) Partitions, lockers, and grating.
(c) Nonballistic wire way and ventilation trunks, except where compensation is required for trunk penetrations in main hull structure.
(d) Galley fixtures.
(e) Label plates, name plates.
(f) Furniture.
(g) Hand railings.
(h) Operating platforms.
(i) Hand-grabs and ladders.

4.2.1 Specific qualification requirements.

4.2.1.1 Gas-metal-arc process (short circuiting transfer) qualification. Use of the gas-metal-arc (short circuiting transfer) process is not permitted for welds in ships structure except as permitted in section 13.

4.3 Welder performance qualification. Prior to performing any production welding covered by this standard, personnel shall be qualified in accordance with MIL-STD-248 except as specified in 4.1. Qualification of welders and welding operators is not required when working on assemblies for which procedure qualification is not required (see 4.2). Qualification of welders and welding operators for aluminum plate and aluminum stiffener butt welds shall be based solely on radiographic (RT) inspection of the qualification test assembly. Welding operator qualification is not required for operators of stud welding equipment.

4.4 Nondestructive testing (NDT) procedure qualification.

4.4.1 Radiographic (RT) inspection. Qualification of RT inspection procedures, including film processing procedures, shall be made in accordance with MIL-STD-271. Records of procedure qualification shall be as specified in section 5.

4.4.2 Magnetic particle (MT) inspection. MT inspection shall be performed in accordance with MIL-STD-271. Each activity shall certify that the procedure used is in accordance with these requirements.

4.4.3 Liquid penetrant (PT) inspection. PT inspection shall be performed in accordance with MIL-STD-271. Each activity shall certify that the procedure used is in accordance with these requirements.

4.4.4 Ultrasonic (UT) inspection. Qualification of UT inspection procedures shall be made in accordance with MIL-STD-271. Records of UT procedure qualification shall be as specified in section 5. Qualification of UT inspection procedures for castings shall consist of the development of inspection procedures, calibration standards, and acceptance standards by the user activity, and applications shall be subject to NAVSEA approval.

4.4.5 Visual (VT) inspection. VT inspection shall be performed in accordance with MIL-STD-271. Each activity shall certify that the procedure used is in accordance with these requirements.

4.4.6 Eddy current (ET) inspection. Qualification of ET procedures shall be in accordance with MIL-STD-271. Applications and record requirements shall be approved by NAVSEA.

4.4.7 Other NDT. NDT procedures, techniques, equipment, and materials not specified in this standard may be used provided the procedure and performance qualification is approved by NAVSEA.

4.5 Qualification of NDT Personnel. NDT personnel shall be qualified in accordance with MIL-STD-271.

4.6 NDT equipment. NDT equipment, when used by qualified NDT operators employing approved procedures, shall detect discontinuities within the limits specified in section 8. For weld inspection, UT inspection equipment shall meet the requirements of MIL-STD-271.

4.7 Vision tests.

4.7.1 Welders. Personnel, as specified in 4.3 (except tack, fillet, spot and stud welders), shall be required to pass an annual vision test in accordance with MIL-STD-248.

4.7.2 NDT personnel. Personnel, as specified in 4.5, shall be required to pass a vision test in accordance with MIL-STD-271.

4.7.3 Corrective aids. Glasses or other corrective aids used to pass the vision tests shall be used when performing production work or inspections.

4.8 Workmanship inspection requirements.

4.8.1 Workmanship procedures. Each activity shall develop written procedures to provide for documentation of the quality and completeness of workmanship for structure as required by section 6 (see 17.3). These procedures shall specify as a minimum the following:

(a) Actions required to ensure conformance to all drawing, specification and contract requirements, including actions to ensure inspections of structure are complete prior to the structure being made inaccessible for inspection.
(b) The organizational elements responsible to certify specific workmanship attributes.
(c) Signatures certifying workmanship inspections shall be based on personnal observation.
(d) Detailed documentation requirements ensuring records are maintained as required by section 5.

4.8.2 Qualification of workmanship inspection personnel. All personnel performing workmanship inspections required by section 6 shall be formally trained to use a written workmanship procedure, in accordance with a documented program.

5. RECORD REQUIREMENTS

5.1 General. Each activity shall have a quality control system consisting of written procedures which assign responsibility and provide accountability for performing fabrication and inspections as required by this standard (see 17.3).

5.2 Records. The quality control system shall also include the preparation and maintenance of written records. Records shall contain as a minimum the information described herein. Except as detailed for submarines, records for and traceable to individual items, pieces, or parts are not a requirement of this standard. Records are required only to the extent specified herein (see 17.3).

5.2.1 Welding procedure qualification. These records shall be in accordance with MIL-STD-248 (see 17.3).

5.2.2 Welder and welding operator qualification. These records shall be in accordance with MIL-STD-248 (see 17.3).

5.2.3 NDT procedure qualification. These records shall be in accordance with MIL-STD-271 (see 17.3).

5.2.4 NDT personnel qualification. Records of personnel qualification shall be in accordance with MIL-STD-271 (see 17.3).

5.2.5 Workmanship personnel qualifications. Workmanship personnel qualification records shall include the following information (see 17.3):

(a) Workmanship inspector identification (name, clock number or social security number).
(b) Method of workmanship inspection and procedure trained in.
(c) Dates of training.
(d) Signature certifying that the workmanship inspector has satisfactorily completed the required training, and is qualified to perform the method of workmanship inspection that the inspector has been trained in.

5.2.6 Material receipt inspection records.

5.2.6.1 Plates, shapes, forgings, bars, and castings. Mill or foundry records shall be required for both surface ships and submarines showing the chemical and mechanical test results as a minimum to ensure compliance of the material with the applicable material specification. The records shall also include the assurance that all required NDT was performed and the results found to be satisfactory (certificate of compliance) (see 17.3). HY-80/100 plate verification records shall be required.

5.2.6.2 Pressure hull envelope. In addition to the controls specified in 6.2.1 for submarine pressure hull envelope, records shall be maintained to trace the material from its location or use to the records specified in 5.2.6.1 (see 17.3).

5.2.6.3 Submarine support structure. Traceability shall be required from the point of fabrication, as part of the ship, through a controlled procedure back to the records specified in 5.2.6.1 by means of fabrication and utilization records or markings on the item (see 17.3).

5.2.6.4 Surface ships and other submarine material. For surface ships and submarine material not otherwise specified herein, material shall be controlled as specified in 6.2.1; however, traceability of this material to or from its location in the ship shall not be required.

5.2.7 Welding filler materials. After being verified by the receiving activity for compliance with specification requirements, manufacturers' test reports for electrodes, wire and flux shall be maintained as specified in 5.2.12 (see 17.3).

5.2.8 Welding surveillance inspection. Records of inspections as required by section 6, shall contain the following (see 17.3):

(a) Base material identification.
(b) Welding process being used.
(c) Filler metal type identification.
(d) Heat input (satisfactory or unsatisfactory).
(e) Preheat/interpass temperature of the joint being welded (satisfactory or unsatisfactory).

(f) Location on ship or assembly where welding is being performed.
(g) Type of weld; original or repair.
(h) Date of inspection and signature of inspector making check.
(i) Record of corrective actions taken in case of discrepancy.
(j) Joint preparation (satisfactory or unsatisfactory).
(k) Joint configuration and fit-up (satisfactory or unsatisfactory).
(l) Root cleaning and contour (satisfactory or unsatisfactory).
(m) Slag removal (satisfactory or unsatisfactory).
(n) Welder identification and qualification.
(o) Repair excavation contour (satisfactory or unsatisfactory).

5.2.9 NDT. Except for VT inspection records which shall be in accordance with 5.2.9.1, NDT records shall include the following data (see 17.3):

(a) Inspection method.
(b) Part or location inspected (for example, ship or hull number, name of part, frame number, compartment number, or other specific structural location).
(c) Test result (acceptable or unacceptable).
(d) Repairs - number of repair cycles prior to acceptance.
(e) For submarines, traceability and extent of inspection.
(f) Identification of person performing inspection.

5.2.9.1 VT inspection of welds. Records of inspections performed in accordance with 6.4 shall include the following (see 17.3):

(a) Reference to the written procedures controlling the inspection.
(b) The organizational element responsible.
(c) Signatures certifying VT of welds. This certification shall be based on personal observation.
(d) The location, assembly, types of welds, weld joint identification (when applicable), VT results, repairs for acceptance and re-VT (when applicable), and items (a), (b) and (c) above shall be documented by a record of accomplishment.

5.2.10 Workmanship inspection. Workmanship inspections required in section 6 shall be documented by use of a record of accomplishment or detailed records (see 17.3).

5.2.10.1 Submarines. Measurement and recording of submarine hull circularity and pressure hull frame dimensions shall be as specified in MIL-STD-1688 (see 17.3).

5.2.10.2 Surface ship dimensions. The principal ship dimensions shall be recorded on as-built or docking drawings as required by the specifications (see 17.3).

5.2.11 Record instructions. Forms shall be marked (N/A) for sections not applicable to the particular job, or a vertical arrow shall be drawn through similar items. Each activity shall be responsible for the records, including RT films, on materials or components prepared by subcontractors.

5.2.12 Maintenance of records. All required records shall be maintained by the activity and be available to the NAVSEA representative throughout the life of the contract and for 3 years after delivery of the surface ship or the submarine (see 17.3). At the expiration of the record retention period, all records, before being destroyed, shall be made available to NAVSEA or the authorized representative by written notification. If no disposition is authorized within 6 months, the records may be destroyed.

6. INSPECTION REQUIREMENTS

6.1 General. Unless otherwise specified, final inspections shall be performed in the final surface condition. Repairs to base materials or welds shall be inspected to the same requirements as the original base material or weld, respectively. Record requirements are specified in section 5 (see 17.3).

6.1.1 Inspection. Inspection shall be made when the material or weld or both is accessible for inspection to the degree necessary to confirm the material or weld or both is acceptable.

6.2 Material inspection. Material records shall be verified to assure compliance of the material with the applicable specifications. Verification shall be accomplished by checking mill or inspection reports against the applicable specification requirements and material marking, as applicable, against the material received. Additionally, for material supplied from a warehouse or jobber (not directly from the manufacturer), the user activity (construction) shall conduct periodic independent testing to establish reasonable confidence in the reliability of contractor test data in accordance with a written procedure. If the contractor's quality conformance inspection records are not available, the construction activity shall establish specification conformance of the material in accordance with a written procedure.

6.2.1 Material identification. The identification of the material shall be maintained to the point of initial fabrication in accordance with a written procedure. The identification of the material shall be visually verified at the point of initial fabrication as being the same material identification or an approved alternate material identification, as required by the installation plan.

6.2.2 Filler material inspection. Lot inspection test reports covering tests conducted by the manufacturer shall be verified by the contractor for compliance with specification requirements. If the manufacturer's quality conformance inspection records are not available, the construction activity shall establish specification conformance of the material.

6.3 Welding inspection.

6.3.1 Surveillance inspection of welding. In process monitoring of welding shall be accomplished to ensure compliance with welding procedures, and related drawing requirements. This surveillance inspection shall be accomplished in accordance with a written procedure as specified in section 4. Corrective action shall be taken upon detection of discrepancies and such action shall be recorded as specified in 5.2.8.

6.3.2 Inspection of workmanship. All structure in the process of fabrication and completed shall be inspected in accordance with written procedures as specified in section 4 to ensure compliance and completeness with detailed working drawings and this document. This inspection shall include the following:

(a) Weld joint design, weld joint preparation, flame and arc cut surfaces, plate edges for laminations, and joint fit-up in accordance with sections 11 and 14.
(b) Weld repairs for excavation contours, and full penetration welds for root cleaning and contour in accordance with section 14.
(c) HY-130 base material surfaces, after completion of fabrication, for arc strikes, weld spatter, fabrication scars, and removal of temporary attachments in accordance with section 14.
(d) Pressure hull and main ballast tank plating, welded plate in free flood areas, and structural bulkheads for plate and shape alignment, and fairness in accordance with section 12, and drawings.
(e) Specified geometrical tapers of structural material and welds in accordance with section 11, and drawings.
(f) Snipes in accordance with section 11.
(g) Penetrations and intersecting butt welds in the pressure hull envelope for weld build-up in accordance with section 11.
(h) Underwater exterior surfaces in accordance with drawings.
(i) Pressure hull frames for frame dimensional tolerances, flange curvature, spacing and butt alignment in accordance with section 12.
(j) Hull circularity of submarines in accordance with section 12.
(k) Structural castings, forgings, and shaped inserts for specified dimensions, surface conditions, and identification markings in accordance with section 16.
(l) Hard tank and main ballast tank frames for dimensional tolerances and spacing in accordance with drawings.
(m) Pressure hull penetration bore diameters in accordance with drawings.

6.4 VT inspection. All completed welds shall be VT inspected in accordance with section 7 to ensure completeness and compliance with detailed working drawings and sections 8, 13 and 14. This inspection shall include:

(a) Weld size adequacy for type of joint (B, T, PT, C, L) specified and shape of fillet weld face.
(b) Weld surface uniformity for smoothness or sharp irregularities and acceptability for other NDT when required.
(c) Weld surface cleanliness and physical defects such as cracks, burn through, melt through, oxidation and slag, slag craters, porosity, pits, arc strikes, gouges (fabrication damage), spatter, end melt and corner melt.
(d) Weld contour for re-entrant angles, unfused bead overlap and undercut.
(e) Welds in or to weight handling fittings or fixtures after proof load testing.
(f) Seal-off and wrap-around welding.
(g) Contour grinding.

6.4.1 Visual inspection of welds.

6.4.1.1 Fillet welds on primer coated surfaces.

6.4.1.1.1 Single-pass fillet welds. Single-pass fillet welds shall be VT inspected. Welds failing to meet the acceptance standards as specified in section 8 shall be treated in accordance with 6.4.1.1.2.

6.4.1.1.2 Multiple-pass fillet welds. Multiple-pass fillet welds shall be VT inspected as follows: Either the first pass deposited in multiple-pass fillet welds shall be inspected in accordance with 6.4.1.1.1 prior to deposition of subsequent passes, or multiple-pass fillet welds shall be inspected in accordance with the following sample plan, which provides multiple levels of sampling so that the amount of inspection is reduced or increased to suit the quality of the welding. A gouge shall be at least 3 inches long with the mid-third extending to the root of the weld. Wormhole and porosity limits shall be in accordance with NAVSEA 0900-LP-003-8000.

(a) To begin, gouge the weld at one place in each 5 feet of weld. Continue at this rate until 15 successive gouges have shown weld metal to be within the wormhole or porosity limits.
(b) When 15 successive gouges have shown sound weld metal, change to the rate of one gouge inspection in each 10 feet of weld. Continue at this rate until wormhole or porosity limits are exceeded, or until 15 successive gouges have shown sound weld metal. Where wormhole or porosity limits are exceeded, revert to the rate of one gouge in each 5 feet of weld.
(c) When 15 successive gouge inspections show only sound weld metal, change to the rate of one gouge in each 20 feet of weld. Continue at this rate until wormhole or porosity limits

are exceeded or until 15 successive gouge inspections show sound weld metal. When wormhole or porosity limits are exceeded, revert to the rate of one gouge in each 10 feet of weld.

(d) When 15 successive gouge inspections show only sound weld metal, change to the rate of one gouge in each 40 feet of weld. When wormhole or porosity limits are exceeded, revert to the rate of one gouge in each 20 feet of weld.

(e) Further reduction of the frequency of inspection is permitted on approval of the sampling plan, with supporting data.

(f) Where gouging reveals defects in excess of those specified in section 8, the weld on each side of the defective area shall be gouged out until the acceptance standards are met. A minimum length of 12 inches on each side of the defective area shall be gouged prior to rewelding.

6.4.2 Visual inspection of base materials. Visual inspection of plate, rolled or extruded shapes, castings, forgings, bars and formed material shall be in accordance with sections 6 and 16.

6.5 MT inspection. MT inspection shall be performed using written procedures and qualified personnel as specified in section 4. Inspection shall be performed using either the direct current (dc) prod or alternating current (ac) yoke, in accordance with section 7 to acceptance standards specified in section 8. PT inspection may be substituted for MT inspection where MT inspection is impractical. MT inspection requirements are specified in tables I and II, for surface ships and submarines, respectively.

TABLE I. MT inspection requirements, surface ship structures. 1/

Inspection category	Inspection time
I. Primary structure	
A. For HY-80/100 and high-hardenable materials:	
(1) Areas where attachment welds of over 80,000 lb/in^2 yield strength are removed and repair by welding is not required.	After removal and the surface has been prepared as specified in section 14.
(2) Areas where attachment welds of any yield strength are removed and repair by welding is required.	After repair welding and the surface has been prepared as specified in section 14.

See footnotes at end of table.

TABLE I. MT inspection requirements, surface ship structures 1/ - Continued.

Inspection category	Inspection time
I.A.	
(3) Any ferritic weld metal deposited prior to heat treatment over 500 degrees Fahrenheit (°F).	After heat treatment.
(4) Full penetration or 100 percent efficient ferritic welds (10 percent of the length of each joint). 2/	After the weld is completed and cooled to ambient temperature.
B. For HY-80/100 and high-hardenable materials and HSLA-80:	
(1) Tension surfaces of hot formed material elongated in excess of 15 percent.	After hot forming.
(2) Tension surface of cold formed material elongated in excess of 12 percent.	After cold forming.
(3) Tension surfaces of hot formed welds.	After hot forming.
(4) Tension surfaces of cold formed welds.	After cold forming.
C. HSLA-80 material over 1-1/4 inch thickness:	
(1) Full penetration or 100 percent efficient ferritic welds (10 percent of the length of each joint). 2/	After weld is completed and cooled to ambient temperature.
II. Secondary structure	
A. For HY-80/100 and high-hardenable materials:	
(1) Any ferritic weld metal deposited prior to heat treatment over 500°F.	After heat treatment.

See footnotes at end of table.

TABLE I. MT inspection requirements, surface ship structures 1/ - Continued.

Inspection category	Inspection time
II.	
B. For HY-80/100 and high-hardenable materials and HSLA-80:	
(1) Tension surfaces of hot formed material elongated in excess of 15 percent.	After hot forming.
(2) Tension surface of cold formed material elongated in excess of 12 percent.	After cold forming.
(3) Tension surfaces of hot formed welds, temporary weld sites or welded surface repairs.	After hot forming.
(4) Tension surfaces of cold formed welds, temporary weld sites or welded surface repairs.	After cold forming.
C. Welds in or to fittings or fixture supporting over 1 ton (static) that are not proof load tested.	After weld is completed and cooled to ambient temperature.
III. Miscellaneous structure	
A. For HY-80/100 and high-hardenable materials:	
(1) Any ferritic weld metal deposited prior to heat treatment over 500°F.	After heat treatment.
B. For HY-80/100 and high-hardenable materials and HSLA-80:	
(1) Tension surfaces of hot formed material elongated in excess of 15 percent	After hot forming.
(2) Tension surfaces of cold formed material elongated in excess of 12 percent	After cold forming.

See footnotes at end of table.

TABLE I. MT inspection requirements, surface ship structures 1/ - Continued.

Inspection category	Inspection time
III.C.	
(3) Tension surfaces of hot formed welds, temporary weld sites or welded surface repairs.	After hot forming.
(4) Tension surfaces of cold formed welds, temporary weld sites or welded surface repairs.	After cold forming.

1/ See 6.5.2 for exemptions.
2/ In random MT inspections where the original sample is rejectable and requires weld repair, two additional 10 percent samples shall be selected and MT inspected. If these are acceptable, the rejectable area in the first sample shall be repaired and the weld accepted. If either of these additional samples is rejectable requiring weld repair, the entire length of the weld shall be inspected and repaired where needed. After repair, additional MT shall be performed to assure that the entire rewelded length plus 6 inches of unrepaired weld at each end of each repair meets the acceptance standards specified in section 8 except that this expanded inspection is not required beyond crossing permanent attachments with joint efficiencies of 50 percent or greater.

TABLE II. MT inspection requirements, submarine structures. 1/ 2/

Inspection category	Inspection time
I. Pressure hull structure	
A. Welds in or to higher strength steel.	After weld is completed and cooled to ambient temperature.
II. Containment structure and containment bulkheads	
A. Welds in or to higher strength steel.	After weld is completed and cooled to ambient temperature.

See footnotes at end of table.

TABLE II. MT inspection requirements, submarine structures 1/ 2/ - Continued.

Inspection category	Inspection time
III. Nonpressure hull structure	
A. Intermediate pressure tanks	
(1) Welds in or to higher strength steel.	After the weld is completed and cooled to ambient temperature.
B. Low pressure tanks	
(1) Welds in or to higher strength steel in plating butt welds, tank boundary welds, closure plates and inserts subject to pressure over 15 lb/in^2.	After the weld is completed and cooled to ambient temperature.
C. Foundations	
(1) Welds in or to higher strength steel where both members are over 1/2 thick.	After the weld is completed and cooled to ambient temperature.
D. Nonsupport structure	
(1) For higher strength steel.	
a. The external surface of all skin welds in the control surfaces.	After the weld is completed and cooled to ambient temperatures.
b. Welds connecting control surfaces to hubs and stocks.	After the weld is completed and cooled to ambient temperature.
(2) Welds in or to weight handling fittings or fixtures supporting over 1 ton (static) that are not proof load tested.	After the weld is completed and cooled to ambient temperature.

1/ See 6.5.2 for exemptions.
2/ MT inspection is not required for welds in or to higher strength steels of any thickness which are RT or UT inspected.

6.5.1 Final inspection. Final inspection of ferritic material shall be performed after all required machining and grinding have been completed or may be performed within 1/32 inch of the final surface provided the dc continuous method is used. For inspection purposes, weld surface areas designed to be covered by other structural weldments (such as areas of longitudinal butt weld surfaces under frame welds or frame or stiffener weld areas covered by intercostals) are not considered as finished welds until the covering weldment has been completed. The preheat interruption MT test specified in 6.5.3 for incompleted welds shall not apply in this case to those weld surface areas designed to be covered by other structural weldments.

6.5.2 Exemptions. Exemptions to tables I and II shall be as follows:

(a) Inspection is not required for areas where percussive (capacitor discharge) stud welds which are 3/8 inch or less stud diameter, and arc stud welds which are 3/8 inch and less stud diameter, have been removed, nor for permanent automatically-timed stud welds.
(b) Inspection is not required for weld surface areas which are to be subsequently covered by other partial or full penetration welds; for example, surface areas of longitudinal butt joints under frame webs and their associated welds and welds of stiffeners crossing butt joints.
(c) Inspection is not required for arc strike removal sites, fabrication scars, nicks or gouges prior to repair welding.
(d) Inspection is not required for prepared surfaces that will be covered by weld metal, or prepared surfaces for bolts, studs or for pipe, mechanical, or electrical penetration holes less than 4 inches in diameter.
(e) Inspection is not required for attachment welds to non-pressure hull structure in submarines or to frames, bulkheads, tanks, foundations, closure plates, or inserts in surface ships (see 3.47.1).
(f) Inspection is not required for fillet welds 3/8 inch and smaller.
(g) Inspection is not required for butt joints in material 3/8 inch or less in thickness, except those in submarine low pressure tank boundary welds and intermediate tank welds.
(h) Inspection is not required for backgouged roots.
(i) Inspection is not required for clad welds used in wear-resistant applications.

6.5.3 Loss of minimum interpass temperature in HY-80/100 and high-hardenable materials. For HY-80/100 materials 1-1/8 inches thick and over and high hardenable materials, MT inspection is required when minimum interpass temperature drops below 113°F when welding with ferritic filler material (see 13.5).

6.6 PT inspection. PT inspection shall be performed using written procedures and qualified personnel as specified in section 4. Inspection shall be performed in accordance with section 7 to acceptance standards specified in section 8.

6.6.1 Surface ships. PT inspection shall be performed on all completed welds deposited with austenitic or nonferrous electrodes in weight-handling fittings or fixtures supporting over 1 ton, unless the fitting or fixture is proof load tested after installation. Overlay or clad welding deposited on primary hull structure with austenitic or nonferrous weld metal for corrosion-resistance applications shall be PT inspected.

6.6.1.1 Aluminum superstructure. PT inspection shall be performed on plate and stiffener butt welds to the following levels:

10 percent - In-progress inspection of the backgouged root.
10 percent - Final inspection. This shall be in addition to and shall not coincide with the required UT or RT sample inspection.

A 5X VT inspection in accordance with a qualified written procedure may be substituted for the PT inspection.

6.6.1.2 Exception. PT inspection is not required for clad welds used in wear-resistant applications.

6.6.2 Submarines. Completed nonferrous or austenitic stainless steel welding in or to the pressure hull envelope plating shall have the final weld surface PT inspected unless otherwise specified (see 6.6.2.1).

6.6.2.1 Exceptions. PT inspection shall not be required for nonferrous or austenitic stainless-steel fillet attachment welds which do not involve penetration through the pressure hull envelope plating. PT inspection of backgouged surfaces shall not be required. PT inspection shall not be required for clad welds used in wear-resistant applications.

6.6.3 Cold formed welds. PT inspection shall be performed on the tension side of all austenitic or non-ferrous welds which are cold formed after welding except when located in OS and HSS materials.

6.7 RT inspection. RT inspection requirements are specified in tables III and IV. RT inspection shall be performed using equipment, procedures and personnel qualified as specified in section 4. Inspection shall be performed in accordance with section 7 to acceptance standards specified in section 8.

TABLE III. UT or RT inspection, surface ship structures.

Inspection category	Inspection extent	Applicable notes (1/ through 4/ apply to all items.)
I. Primary structure		
A. Hull envelope		
(1) Intersections of butt joints in plating 1/4 inch thick and over within the midship 3/5 length.	10 percent	6/ 7/ 8/
(2) Intersections of butt joints in the sheer strake to other shell plating 1/4 inch and over within the midship 3/5 length.	All Intersections	6/ 7/ 8/ 9/
(3) Butt (transverse) joints in plating 1/4 inch and over within the midship 3/5 length.	One random location in each 20-foot length	6/ 7/
(4) Seam (longitudinal) joints in plating 1/4 inch and over within midship 3/5 length.	One random location in each 40-foot length	6/ 7/
(5) Butt (transverse) joints in the flat and vertical keel within the midship 4/5 length.	10 percent of the length of each joint	6/ 7/
(6) Butt (transverse) joints in the bilge and sheer strakes within the midship 3/5 length.	10 percent of the length of each joint	6/ 7/
(7) Butt (transverse) joints in shell plating over 1 inch outside the midship 3/5 length.	5 percent of the length of each joint	6/ 7/

See footnotes at end of table.

TABLE III. UT or RT inspection, surface ship structures - Continued.

Inspection category	Inspection extent	Applicable notes (1/ through 4/ apply to all items.)
I.A.		
(8) Full penetration butt joints in or to patches, access plates, inserts or closure plates in plating 1/4 inch and over in the main strength decks, innerbottom tank top, bottom shell, sheer strake or bilge strake within the midship 3/5 length.	25 percent of the total length	10/ 11/ 12/
(a) For eight or more patches or access plates or inserts or closure plates of 12 inches major diameter or less within one compartment or within 20 feet of each other on a given surface.	Random locations which total 25 percent of the total lengths as determined by quality assurance personnel	10/ 11/ 12/ 13/
B. Strength decks		
(1) Intersections of butt joints in the stringer strakes to other deck plating 1/4 inch and over within the midship 3/5 length of the main strength decks or innerbottom tank top.	All intersections	6/ 7/ 8/ 9/
(2) Butt (transverse) joints in the stringer strakes of main strength decks or innerbottom tank top within the midship 4/5 length.	10 percent of the length of each joint	6/ 7/

See footnotes at end of table.

TABLE III. UT or RT inspection, surface ship structures - Continued.

Inspection category	Inspection extent	Applicable notes (1/ through 4/ apply to all items.)
I.B.		
(3) Butt (transverse) joints in plating over 1 inch of main strength decks or innerbottom tank top within the midship 3/5 length.	5 percent of the length of each joint	6/ 7/
C. Containment structure and containment bulkheads		
(1) Intersections of butt-welded joints in plating 1/4 inch and over.	All intersections	8/
(2) Butt-welded joints in plating 1/4 inch and over.	10 percent of each length	7/
D. Type A protective plating and underwater protection systems		
(1) Butt joints in plating 1/4 inch and over.	One random location in each 20-foot length	
(2) Intersections of butt-welded joints in plating 1/4 inch and over.	10 percent of the intersections	8/
(3) Butt joints welded and inspected from one side only in plating 1/4 inch and over.	100 percent	

See footnotes at end of table.

TABLE III. UT or RT inspection, surface ship structures - Continued.

Inspection category	Inspection extent	Applicable notes (1/ through 4/ apply to all items.)
I.		
E. Support		
(1) Butt-welded joints in continuous supporting structure stiffening members 1/4-inch thick and over within the midship 3/5 length.	2 percent	
(2) Butt-welded joints in continuous supporting structure stiffening members 1/4-inch thick and over outside the midship 3/5 length.	1 percent	14/
(3) Butt-welded joints in longitudinal stiffeners 1/4 inch thick and over which align in a transverse plane having an offset of 6 inches or less with butt-welded joints in shell, inner bottom, and strength deck plating within the midship 3/5 length.	10 percent	
II. Secondary structure		
A. Superstructure designed for blast loading		
(1) Intersections of butt-welded joints in outside plate over 1/4 inch.	10 percent	8/

See footnotes at end of table.

TABLE III. UT or RT inspection, surface ship structures - Continued.

Inspection category	Inspection extent	Applicable notes (1/ through 4/ apply to all items.)
II.A.		
(2) Butt-welded joints in outside plating over 1/4 inch.	One random location in each 20-foot length	
(3) Butt-welded joints in supporting structure stiffening members over 8 inches in depth and over 1/4 inch thick.	10 percent of the joints	5/
B. Aluminum superstructure		
(1) Intersection of butt-welded joints in longitudinally continuous structure for plating 1/4 inch and over.	10 percent	16/
(2) Butt-welded joints in longitudinal stiffeners.	10 percent	16/
(3) Butt-welded joints in plating 1/4 inch and over.	One random location in each 20-foot length	16/
C. Kingposts, masts, booms, and weight handling equipment		
(1) Circumferential full penetration butt joints.	100 percent	15/
(2) Longitudinal (axial) full penetration butt joints.	10 percent of the length of each joint	

See footnotes at end of table.

TABLE III. UT or RT inspection, surface ship structures - Continued

Inspection category	Inspection extent	Applicable notes (1/ through 4/ apply to all items.)
II.C.		
(3) Full penetration butt welds attaching rigging fittings to decks, bulkheads, booms, king-posts or masts, provided the fitting supports or carries working loads in excess of 1 ton and is not proof tested after installation.	One random location in each attachment weld	
(4) Full penetration butt-welded joints in boat davit or crane material 1/4 inch and over.	100 percent	
D. Fragmentation plating		
(1) Intersections of butt-welded joints in plating 1/4 inch and over	10 percent of the inter-sections	8/
(2) Butt joints welded from one side only in plating 1/4 inch and over.	10 percent of the length of each joint	

1/ (a) All random or partial inspections shall be in accordance with the inspection plan developed by the activity in accordance with 6.7.2 or 6.8.1.

(b) Re-RT/UT of welds previously accepted by RT/UT is not required when the depth of repair of an MT or visually detected defect does not exceed two layers or half the thickness of the thinnest member joined, whichever is less. When additional welding is deposited on the surface of welds previously accepted by RT/UT, re-RT/UT is not required when the additional weld does not exceed two layers or half the thickness of the thinnest member joined, whichever is less.

2/ Final UT or RT inspection shall not be performed until the weld has cooled to ambient temperature.

3/ In selecting locations for inspection, a proportionately larger number of locations in thicker material shall be chosen.

4/ For material thicknesses less than 1/2 inch, the porosity acceptance standard for 1/2 inch shall be used.

5/ At least 50 percent of the length of the joint shall be inspected in joints in structural shapes.

6/ The midship length is applicable to displacement type vessels, and inspection shall be as specified for other than displacement type vessels.

7/ The length may be expanded on a case basis prior to award of contract.

8/ Unless prevented by design restrictions, this inspection shall include a minimum of 3 inches of weld on all sides of the intersection.

9/ If a riveted or mechanically fastened gunwale connection is used, the number of intersections to be inspected shall be reduced to 10 percent of the total intersections.

10/ The total sample shall include all corners and weld intersections. If the insert or closure plate is not essentially circular or elliptical, any change in the weld direction greater than 30 degrees shall be considered a corner.

11/ Closure plates for temporary accesses in new construction vessels, having an area greater than 50 square feet, essentially rectangular in shape, and which are of the same thickness as the adjoining plates in the same strake, shall be inspected at each corner; however, the remainder of the welding shall be inspected as required for the surrounding structure.

12/ When inspecting closure plates, existing welds which cross or terminate in new welds shall be inspected for a minimum of 3 inches beyond their intersection with new welds. The existing welds in new construction vessels shall meet the applicable acceptance standards. For welds in vessels undergoing conversion or repair, the extent of inspection and acceptance standards shall be in accordance with NAVSEA S9086-CH-STM-010/CH-074VI.

13/ For each patch or insert or closure plate weld found to not meet inspection criteria, two additional patch or insert or closure plate welds from the lot containing the rejected sample shall be inspected. If either of the two additional welds are rejected, the entire lot shall be inspected.

14/ Inspection shall include 15 joints minimum or 1 percent, whichever is greater.

15/ RT/UT inspection is not required when welds are covered by an approved scalloped wrapper plate fillet welded to the member, provided that:

(a) The minimum thickness of the wrapper plate equals the thickness of the member which it covers.
(b) The wrapper plate extends beyond the joint a minimum of 6 inches in both directions or twice the diameter of the member, whichever is greater.
(c) The fillet weld is of adequate size to provide 100 percent joint efficiency.
(d) The welds are MT or PT inspected.

16/ For UT inspection of welds less than 1/2 inch in thickness, special procedure and operator qualifications apply (see MIL-STD-271).

TABLE IV. UT or RT inspection, submarine structures.

Inspection category	Inspection extent	Applicable notes (1/ through 5/ apply to all items.)
I. Pressure hull structure		
A. Pressure hull envelope		
(1) Butt joints.	100 percent	
(2) Closure plates and inserts.	100 percent	
B. Support structure		
(1) Butt joints in pressure hull frame flanges.	100 percent	6/
(2) Full penetration butt joints in holding bulkhead plating.	100 percent	
(3) Closure plates and inserts.	100 percent	
II. Containment structure		
A. Full penetration butt joints in containment bulkhead boundary plating.	100 percent	
B. Closure plates and inserts.	100 percent	
III. Nonpressure hull structure		
A. Intermediate pressure tanks		
(1) Full penetration butt joints in tank boundary plating.	100 percent	

1/ Inspection of submarine structure welds shall be performed as specified in table IV, except that HY-80/100 and high-hardenable materials shall be as specified for HY-80/100 in accordance with MIL-STD-1688.
2/ Welds may be inspected as soon as the weld has cooled to ambient temperature.
3/ After repair of rejected welding, the original NDT method used to disclose that defect, that is RT or UT, shall be employed to assure that the

repair, plus 3 inches of the unrepaired weld at each end of the repair, meets the applicable acceptance standards. Re-RT/UT of welds previously accepted by RT/UT is not required when the depth of repair of an MT or visually detected defect does not exceed two layers or half the thickness of the thinnest member joined, whichever is less.

4/ When additional weld is deposited on the surface of RT/UT accepted weld, re-RT/UT is not required provided the additional weld deposited on a weld face does not exceed two layers. Subsequent weld overlay or buildup for corrosion or dimensional control which covers previously accepted welds is not subject to the foregoing, and re-RT/UT of the previously accepted welds is not required.

5/ When new welds in closure plates land on or terminate in existing welds, the existing welds shall be inspected for a minimum of 6 inches beyond their intersection with new welds and shall be free of cracks.

6/ Radiographs of flange butts are acceptable if the total length of interpretable film is equal to the flange width, less the web thickness plus one fillet size.

6.7.1 Welds. For the weld areas specified in tables III and IV, either RT or UT may be used, provided the same method is used for any required reinspections, unless otherwise approved.

6.7.2 Random or partial inspections. Where random or partial inspections are specified for the structural categories in table III, each activity shall prepare an inspection plan for the first ship of a class (to be built at its facility and for which this document is implemented) that assures, as a minimum, the following:

(a) Proper identification of all weld joints in the inspection category that may be inspected, and documentation of applicable attributes commensurate with weld joint criticality (primary structure, secondary structure and miscellaneous structure) to facilitate the exploration of welds and the selection of additional inspection sites of (c), (d) and (e) below when acceptance standards are not met.

(b) The selection of the exact inspection sites after welding has been completed.

(c) Procedures to be followed when acceptance standards are not met. Such procedures include exploration along the weld length to determine the extent of rejectable welding, additional UT or RT after repair to assure compliance with the applicable acceptance standards, and the influence of intersecting full penetration seals.

(d) Procedures to be followed for the selection of additional inspection sites for each rejected weld site.

(e) Procedures to be followed when acceptance standards are not met on any of the additional inspection sites to assure removal of all the defective welds involved.

(f) The implementation of corrective action plans to prevent defective non-conforming welding.

(g) Procedures for modification of the plan as changes evolve in fabrication attributes and ship class structural design.
(h) The participation of the NAVSEA representative in the inspection plan.

The plan and all future modifications shall be approved by the NAVSEA representative and NAVSEA prior to implementation.

6.8 UT inspection. UT inspection requirements are specified in tables III and IV. UT inspection shall be performed using equipment, procedures, and personnel qualified as specified in section 4. Inspection shall be performed in accordance with section 7 to acceptance standards specified in section 8.

6.8.1 Random or partial inspections. Where random or partial inspections are specified for the structural categories in table III, each activity shall prepare an inspection plan for the first ship of a class (to be built at its facility and for which this document is implemented) that assures, as a minimum, the following:

(a) Proper identification of all weld joints in the inspection category that may be inspected, and documentation of applicable attributes commensurate with weld joint criticality (primary structure, secondary structure and miscellaneous structure) to facilitate the exploration of welds and the selection of additional inspection sites of (c), (d) and (e) below when acceptance standards are not met.
(b) The selection of the exact inspection sites after welding has been completed.
(c) Procedures to be followed when acceptance standards are not met. Such procedures shall include exploration along the weld length to determine the extent of rejectable welding, additional UT or RT after repair to assure compliance with the applicable acceptance standards, and the influence of intersecting full penetration welds.
(d) Procedures to be followed for the selection of additional inspection sites for each rejected weld site.
(e) Procedures to be followed when acceptance standards are not met on any of the additional inspection sites to assure removal of all the defective welds involved.
(f) The implementation of corrective action plans to prevent defective non-conforming welding.
(g) Procedures for modification of the plan as changes evolve in fabrication attributes and ship class structural design.
(h) The participation of the NAVSEA representative in the inspection plan.

The plan and all future modifications shall be approved by the NAVSEA representative and NAVSEA prior to implementation.

6.8.2 Welds. Grinding or machining within the limits specified in section 14 of welds previously accepted by UT shall not require reinspection by UT.

6.8.3 Approval. Applications of UT as a substitute for MT or PT shall be subject to approval. Where UT is substituted for MT or PT inspections, baseline and final inspections shall be conducted. The criteria for a crack-free condition shall be no significant difference between the results of these inspections.

6.9 Stud welding. Automatic timed arc or percussive (capacitor discharge) welded studs for all permanent applications shall be inspected at the beginning of each set-up (diameter change) or shift duration by bending or torque testing five consecutively welded studs.

6.9.1 Bend testing. If bend testing is performed, the studs to be tested shall be welded to a piece of scrap in the vertical position unless production welding is to be limited to flat position work. Bending of production studs is prohibited. Studs shall be bent to an angle of 15 degrees (except for 5000 series aluminum, which shall be bent to 10 degrees) and return using a device similar to that shown on figure 8.

6.9.2 Tension testing by torquing. Studs may be tension tested by the use of the torque test. Any convenient means may be used for applying the tensile load axially to the stud, such as the application of a sleeve over the stud using a washer and nut with force being applied by a torque wrench. Studs shall be subjected to a torque which will develop not less than 80 percent of the yield strength of the stud material. The stud cross section at the stud base or the root of the threads (whichever is less) shall be used as the basis for testing. Requirements for torque values and axial load shall be as specified in tables V and VI for commonly used carbon steel/corrosion resistant steel stud sizes and aluminum stud sizes.

TABLE V. Axial load and torque values for steel and corrosion-resistant steel.

Stud size	UNC, NC CLASS 2A			UNF, NF CLASS 2A		
	Minor diameter	Axial load, pounds	Torque inch-pounds	Minor diameter	Axial load, pounds	Torque inch-pounds
10	0.1379	417	9	0.1508	501	11
1/4	.1876	773	22	.2052	927	29
5/16	.2431	1299	47	.2603	1490	58
3/8	.2970	1940	86	.3228	2290	111
7/16	.3485	2761	144	.3749	3091	174
1/2	.4041	3590	218	.4374	4208	276
5/8	.5119	5762	442	.5554	6784	565
3/4	.6255	8604	807	.6718	9926	1000
7/8	.7368	14939	1320	.7858	13580	1601
1	.8446	15691	1988	.8960	17654	2373
1-1/8	.9475	19743	2806	1.0210	22924	3511
1-1/4	1.0725	25295	4069	1.1460	28879	4964

TABLE VI. Axial load and torque values for aluminum (5000 series).

Stud size	UNC, NC CLASS 2A			UNF, NF CLASS 2A		
	Minor diameter	Axial load, pounds	Torque inch-pounds	Minor diameter	Axial load, pounds	Torque inch-pounds
10	0.1379	178	4	0.1508	215	5
1/4	.1876	313	9	.2052	397	12
5/16	.2431	557	20	.2603	638	25
3/8	.2970	832	37	.3228	982	48
7/16	.3485	1145	60	.3749	1325	75
1/2	.4041	1534	93	.4374	1804	118

6.9.2.1 Internally threaded studs. Internally threaded studs shall be tested to the torque valves of the screws (screwed into the studs) used in the torque testing.

6.9.3 Tension testing. Studs with mechanical joints (for example, crimped Al-Cres insulation studs) shall be tested on a piece of scrap of the same material type, thickness, and position as the production application. Studs shall be satisfactory if a tensile load will cause the mechanical joint to fail without failure in the weld.

6.9.4 Rejection procedure. If any of the five studs tested at beginning of set-ups or shifts show signs of failure, the conditions causing failure shall be rectified and the test repeated.

6.9.5 Pressure-containing applications. In addition to the testing specified in 6.9, studs used in connection with openings in watertight, oil tight, gas or air tight, or pressure-containing applications shall also be tested as follows. Ten percent of the studs, but not less than two per opening shall be torque tested in accordance with 6.9.2. The sample tested shall include the first and last studs welded for each opening. If any of the studs tested show signs of failure, all of the studs for the opening shall be tested. Studs showing signs of failure shall be removed and new studs welded and tested.

6.9.6 Nonpressure-containing applications. For permanent nonpressure-containing applications such as sound dampening, electric cables, fixtures, and so forth, the inspection requirements specified in 6.9 apply.

6.9.7 Temporary attachments. Testing is not required for temporary attachment studs.

7. NDT METHODS

7.1 Personnel qualification. Personnel performing NDT shall be qualified in accordance with section 4.

7.2 VT inspection. VT inspection procedure and technique shall be in accordance with MIL-STD-271.

7.2.1 Surface preparation.

7.2.1.1 Welds. VT inspection of welds shall be done after slag removal and with the weld in the final surface condition. Surfaces which have been cleaned and painted with one coat of primer are considered suitable for inspection.

7.2.1.2 Base material. The surfaces to be inspected shall be in a clean condition (free of scale). Surfaces which have been cleaned and painted with one coat of primer are considered suitable for inspection.

7.3 MT inspection. MT inspection procedure and technique shall be as specified in MIL-STD-271.

7.4 PT inspection. PT inspection procedure and technique shall be as specified in MIL-STD-271.

7.5 RT inspection. RT inspection procedure and technique requirements shall be as specified in MIL-STD-271.

7.6 UT inspection. UT inspection procedure and techniques for inspection of welds shall be as specified in MIL-STD-271, or the applicable material specification or the acquisition document.

8. INSPECTION ACCEPTANCE STANDARDS

8.1 General. Discontinuities that exceed the limits specified herein shall be repaired in accordance with this standard. Unless otherwise specified in this standard, materials shall be in accordance with the material specification for the intended application. Structures fabricated in accordance with this standard shall comply with all applicable drawings, specifications and standards. Personnel responsible for performance and evaluation of NDT results shall be qualified and certified in accordance with section 4.

8.2 VT inspection of completed welds. Completed welds inspected in accordance with 6.4 shall conform to the acceptance criteria detailed herein. Unless otherwise specified, the inspection zone shall include the weld face and 1/2 inch of adjacent base material. Areas beyond this weld zone shall be in accordance with the workmanship requirements of section 14.

8.2.1 Cleanliness. Welds inspected for final acceptance shall be free of slag, paint and weld metal spatter in excess of 1/8 inch length or diameter.

8.2.2 Weld surface uniformity. The weld surface shall be free of sharp irregularities deeper than 1/16 inch between beads and shall fair into the base material at the weld edges without undercut or overlap (roll over) in excess of the requirements of this standard. Surface roughness, burn through, melt through, oxidation and crater pits shall not exceed the acceptance criteria of NAVSEA 0900-LP-003-8000. Weld surfaces shall be prepared for NDT as specified in section 7.

8.2.3 Shape of fillet weld face. Fillet and fillet reinforced welds shall be essentially flat (minus 1/16 inch to plus 3/16 inch of a line drawn toe to toe). Weld concavity is acceptable provided the minimum throat thickness is at least equal to the minimum specified leg size multiplied by 0.7 (see figure 2). Excessive roughness at weld edges and re-entrant angles less than 90 degrees, as shown in figure 2, shall be corrected.

8.2.4 Arc strikes. Arc strikes shall be repaired in accordance with 14.5.

8.2.5 Cracks. Cracks shall be removed.

8.2.6 Porosity. Only pores greater than 1/32 inch in diameter shall be evaluated. No single pore shall be greater than 3/32 inch in length or diameter. The sum of pore diameters in any 2 inch weld length shall not exceed 3/16 inch. Porosity requirements for fillet welds on primer coated surfaces shall be in accordance with 8.2.6.1.

8.2.6.1 Fillet welds on primer coated surfaces. Fillet welds deposited on primer-coated surfaces shall not exhibit porosity or wormholes in excess of the following:

(a) Single-pass fillet welds. One indication 1/32 inch or greater in any 6-inch length exclusive of weld crater porosity.
(b) Multipass fillet welds. NAVSEA 0900-LP-003-8000, class 1, figure 4 medium, shall apply for gouged surfaces. If VT inspection of the first pass deposited is performed in lieu of gouging, the acceptance standard for the first pass shall be as defined in (a) above.

8.2.7 Undercut, end melt, corner melt. Undercut, end melt and corner melt shown on figure 9 shall not exceed the limitations detailed in table VII. The depth of undercut or grinding shall be measured from the unground base material adjacent to the weld.

TABLE VII. Undercut, end melt and corner melt.

Submarine pressure hull structure and surface ship primary hull structure				
Condition	Base metal thickness, inch	Maximum depth as-welded condition, inch	Maximum depth/length after grinding, inch	
			Depth	Length restriction
Undercut	Under 1/2	1/32	1/32	None
	1/2 and over	1/32	1/32	None
	1/2 and over	1/32	1/16	1/
End melt 2/	1/4 and under	1/16	3/32	Only at ends of a member (see figure 8)
Corner melt	All	1/16	3/32	Only at corners of a member (see figure 8)
Other structures				
Undercut	Under 1/2	1/16	1/16	None
	1/2 and over	1/16	1/16	None
	1/2 and over	1/16	3/32	1/
End melt 2/	1/4 and under	3/32	1/8	Only at ends of a member (see figure 8)
Corner melt	All	3/32	1/8	Only at corners of a member (see figure 8)

1/ The accumulated length does not exceed either 15 percent of the joint length or 12 inches in any 36-inch length of welding, whichever, is less.
2/ For base metal thicknesses greater than 1/4 inch, undercut requirements apply.

8.2.8 Weld size.

8.2.8.1 Groove-tee and fillet welds. Groove tee fillet reinforced welds and fillet welds shall be at least equal to the size specified on the drawing (except as allowed by 8.2.10). When fillet size must be increased as a result of excessive gap between members at the time of fit-up, the fillet size shall be increased as required by 14.3. Weld size ir excess of that required is acceptable provided the contour requirements of 8.2.3 are satisfied.

8.2.8.2 Butt welds. Butt weld surfaces shall not be below the adjacent plate surfaces, except localized weld surface indication areas and weld toes, unground or corrected by grinding, that do not exceed the depth limitations for undercut of 8.2.7. The as-deposited surfaces at the weld edge shall be satisfactory, provided they do not form a re-entrant angle less than 90 degrees with the base plate due to excessive convexity or roll-over. Butt welds ground for hydrodynamic purposes shall not extend more than 1/16 inch above the adjacent plate surfaces. Otherwise, butt weld reinforcement shall not require a maximum height limitation provided the surface condition is uniform. In the case of butt welds joining plates of unequal thickness, the weld shall taper gradually, approximately four to one, from the beveled edge of the thicker plate surface to the thinner plate. No point of the finished tapered butt weld surface shall be below a line from the edges of the weld joint preparation except for allowable undercut. Otherwise butt weld reinforcement shall not require a maximum height limitation provided all other requirements of this section are met.

8.2.9 Seal-off and wrap-around welding. Fillet and fillet reinforced partial penetration welds shall be sealed off with weld at end(s) of members (flat bars, angles, channels and tees) to form a closed loop where surfaces are to be wetted. Members which will not be wetted shall be sealed off when practical. When specified by a weld all-around symbol, the minimum weld reinforcement size shall be maintained (wrap-around) at the end(s) of attached members. When the member is located per tolerances and the full size fillet weld (wrap-around) is not obtainable, the maximum size obtainable shall be considered acceptable provided the above seal-off requirement in wetted areas is maintained.

8.2.10 Contour grinding. When required, contour ground welds shall comply with the requirements of 14.2. Contour grinding of fillet or partial penetration welds shall not be performed unless required by the ship specifications or drawings, or 14.4; in which cases, fillet size requirements shall be maintained after contouring.

8.2.11 Nicks, gouges and other fabrication scars. Nicks, gouges and other fabrication scars in the weld inspection zone shall not exceed 1/32 inches in depth and 12 inches in length for materials less than 1/2 inch thick; and 1/16 inch in depth and 12 inches in length for materials equal to or greater than 1/2 inch thick.

8.2.12 VT inspection for edge laminations.

8.2.12.1 Surface ships. Continuous laminations 8 inches or less in any 24-inch length, or discontinuous laminations in a straight line whose total length is 12 inches or less in any 24-inch length and with no single continuous laminations greater than 6 inches are acceptable. Edge laminations which exceed these limitations shall be repaired as specified in section 14, or the affected plate area replaced. Any laminations disclosed on exposed plate edges which will not be covered by welding shall be repaired by welding, in accordance with section 13.

8.2.12.2 Submarines. Edge laminations visually detected in submarine plating shall be MT inspected in accordance with 8.3.3.

8.2.13 Circularity and frame dimensional tolerances. Submarine hull circularity and frame dimensions shall meet the requirements specified in MIL-STD-1688.

8.2.14 Other NDT. Welds that conform to the requirements set forth above are considered acceptable for any other NDT.

8.3 MT inspection.

8.3.1 Welds. Welds and 1/2 inch of adjacent base material shall be inspected when specified. Indications less than 1/16 inch shall be disregarded. Relevant indications 1/16 inch and greater shall be evaluated. The following conditions shall be cause for rejection:

(a) Relevant linear indications greater than 1/8 inch in length.
(b) Two or more relevant linear indications separated by less than 1 inch.
(c) Four or more relevant linear indications in any 4 inches of weld length.

Indications that are removed by grinding to a depth of 1/32 inch or less shall be considered nonrelevant and not recorded.

8.3.2 Castings. When specified, all accessible casting surfaces shall be inspected. Indications less than 1/8 inch shall not be evaluated. Relevant indications 1/8 inch and greater shall be evaluated. The following conditions shall be cause for rejection:

(a) Relevant linear indications greater than 1/4 inch within 3 inches of surface to be welded.
(b) Relevant linear indications greater than 5/16 inch on other surfaces.
(c) Two or more relevant linear indications with an accumulated length of more than 1/2 inch and separated by less than 1 inch.

Indications which do not meet this criteria may be removed without repair welding, provided the minimum design thickness is not violated. Weld repairs and 1/2 inch of adjacent base material shall meet the requirements of paragraph 8.3.1.

8.3.3 Edge laminations in submarines. Plate edge laminations on weld joint preparations which do not exceed 1/2 inch in length or do not exceed an accumulated length of 4 inches in any 6-inch length of edge surface are acceptable. Edge laminations which exceed the above shall be repaired as specified in section 14, or the affected plate area replaced. Any laminations disclosed on plate edges which will not be covered by welding shall be repaired by welding in accordance with section 13.

8.3.4 Forgings, bars, formed materials. When MT inspection is required, forgings, bars and formed materials shall be free of linear indications in excess of 1/8 inch. Welds, and weld repairs in these materials shall meet the requirements of 8.3.1.

8.4 RT inspection.

8.4.1 Welds.

8.4.1.1 Submarine welds. Welds which require radiography in accordance with section 6 shall conform to the acceptance standards of MIL-STD-1688.

8.4.1.2 Surface ships. Welds which require radiography in accordance with section 6 shall be interpreted to the class III requirements of NAVSEA 0900-LP-003-9000. Welds that are inadvertently radiographed shall be free of cracks or relevant linear discontinuities in excess of class 3 criteria.

8.4.2 Castings. Acceptance standards for castings shall be in accordance with section 16.

8.4.2.1 Weld repair. Acceptance standards for weld repairs in castings shall be in accordance with section 16.

8.4.3 RT indications of surface imperfections. When arc strikes and weld spatter in excess of the requirements set forth in this standard are overlooked during VT and are shown as RT indications in the weld or base material, the affected area need not be re-radiographed if the presence and removal of such surface discontinuities is verified and documented.

8.5 UT inspection.

8.5.1 Welds.

8.5.1.1 Submarine welds. Welds which require UT inspection in accordance with section 6 shall meet the acceptance standards specified in NAVSEA 0900-LP-006-3010, class 2.

8.5.1.2 Surface ship welds. Welds which require UT inspection in accordance with section 6 shall meet the acceptance standards specified in NAVSEA 0900-LP-006-3010, class 3.

8.5.2 Materials.

8.5.2.1 Wrought materials. Materials shall meet the UT inspection acceptance standards of the applicable base material specification.

8.5.2.2 Cast materials. Materials shall meet the UT inspection acceptance standards of section 16. Weld repairs to castings shall also be inspected in accordance with the acceptance standards of section 16.

8.6 PT inspection.

8.6.1 Welded joints. Weld joints shall be evaluated in accordance with NAVSEA 0900-LP-003-8000, class 2.

8.6.2 Weld cladding. Weld cladding shall be evaluated in accordance with NAVSEA 0900-LP-003-8000 as follows:

(a) Inboard boundary - class 3 (see figure 7).
(b) Seating and seal areas - class 1 (see figure 7).
(c) Outboard boundary - class 2 (see figure 7).
(d) Other applications - class 2 (such as corrosion protection only).

8.6.3 Castings. Acceptance standards for castings shall be as specified in 8.3.2 for MT inspection.

8.6.4 Adjacent base material. While inspecting welds or weld cladding, indications detected in base material shall be evaluated to the acceptance criteria of the weld or the base material, whichever is less restrictive. If the base material did not originally require PT, the developer shall be removed and the area examined at 5X magnification. Linear indications in excess of 3/8 inch shall be cause for rejection.

9. FORMED MATERIALS AND WELDS

9.1 General. For materials not specified in tables VIII and IX, forming shall be as recommended by the manufacturer and procedures thereof shall be subject to NAVSEA approval prior to the start of production forming.

TABLE VIII. Cold-forming temperature requirements.

Material	Temperature (°F maximum)
OS steel	1/ 1,175
HSS steel	1/ 1,175
HSLA steel (HSLA-80)	2/ 500
High-yield strength steel (HY-80)	2/ 500
High-yield strength steel (HY-100)	2/ 500
STS steel	300
Austenitic stainless steel (CRES)	900
Nickel-copper (Monel)	1,050
5000 series aluminum alloys	175
Copper nickel	900

1/ Cold forming is not permitted between 400 and 700°F.
2/ These alloys embrittle in the temperature range of 500 to 1,100°F; hence, losing some of their toughness (see 9.3.3.4).

TABLE IX. Hot-forming temperature requirements.

Material	Temperature range (°F)
OS steel	1/ 2/ 1550-1675
HSS steel	1/ 2/ 1550-1675
HSLA steel (HSLA-80)	3/ 1600-2100
High-yield strength steel (HY-80)	4/ 1600-2100
High-yield strength steel (HY-100)	4/ 1600-2100
STS steel	4/ 1600-2100
Austenitic stainless steel (CRES)	5/ 1750-2100
Nickel-copper (Monel)	1700-2100

1/ For normalized material, the material shall be air cooled from the forming temperature.
2/ OS steel (1 inch and less in thickness) and HSS steel (less than 1/2 inch in thickness) may be heated to 2200°F maximum for hot forming. OS steel greater than 1-inch thickness and HSS steel 1/2-inch and greater thickness may be heated above 1675°F (2000°F maximum) provided that the material is normalized after hot forming.
3/ HSLA-80 shall be reheat treated in accordance with MIL-S-24645 for the specific class involved (1, 2 or 3).
4/ HY-80/100 and STS shall be reheat treated (austenitized, quenched and tempered) and retested for mechanical and impact properties in accordance with the applicable material specification after hot forming.
5/ For the austenitic stainless steels, forced air cooling or liquid quenching from the hot forming temperature is required to avoid both carbide precipitation (sensitization) and sigma phase formation.

9.2 Cold forming. Cold forming temperatures, for materials and welds, shall be in accordance with table VIII. Cold forming may be done on fully heat treated material and on welds in such material. Structural materials formed to an inside radius less than 2T shall be hot formed in accordance with 9.3 unless otherwise approved.

9.2.1 Inspection of HY-80/100, HSLA-80 and high-hardenable materials. The tension surfaces that are elongated in excess of 12 percent shall be inspected in accordance with section 6. When these tension surfaces are machined, final inspection shall be performed after finish machining. Figure 10 maybe used as an aid in determining elongation.

9.3 Hot forming. Hot forming temperatures for materials and welds shall be in accordance with table IX.

9.3.1 Contaminants. Prior to hot forming operations, the material to be formed and the surfaces of the forming equipment which will come in contact with the material to be formed shall be free of oil, grease, zinc, lead, tin, copper, substances which contain these elements, or other low melting point alloys.

9.3.2 Furnace fuels. Gas or oil fired furnace fuels used in the hot forming of nickel alloys (those alloys containing 50 percent or more nickel) and copper-nickel alloys shall have the following limitations on sulfur content:

(a) Gas: 30 grains per 100 cubic feet.
(b) Oil: 0.5 percent by weight.

9.3.3 HY-80/100, HSLA-80, and high-hardenable materials.

9.3.3.1 Base material testing. After hot forming, HY-80/100, HSLA-80 and high-hardenable materials shall be heat treated to produce properties conforming to those specified in applicable material specifications. Test specimens for determining properties shall be removed from material which is an integral part of each hot formed and heat treated piece after final heat treatment and completion of all forming operations. A separate test piece may be used provided it is from the same heat of material, is of approximately the same maximum cross-section, is subjected to the same thermal cycling, and is heat treated with the formed material.

9.3.3.2 Surface inspection. After heat treatment and cleaning, the tension surfaces of the hot formed HY-80/100, HSLA-80 and high-hardenable materials elongated in excess of 15 percent, shall be inspected in accordance with section 6. Figure 10 may be used as an aid in determining elongation. When repairs are required they shall be performed in accordance with sections 13 and 14.

9.3.3.3 Hot formed base metal repair welds. After heat treatment, weld joints, temporary weld sites or areas of welded surface repair, welded prior to heat treatment, shall be inspected in accordance with section 6. Hot formed welds and base metal repair welds inspected and accepted, after forming and heat treating in accordance with this section, shall be considered as base metal for the purpose of any further inspection requirements specified in section 6.

9.3.3.4 Forming restrictions. Forming in the temperature range between the hot and cold forming temperatures shall be prohibited due to embrittling effects.

9.3.4 Welding procedure qualification for hot formed and heat treated welds. A level 1 procedure qualification test, as specified in MIL-STD-248, shall be performed to qualify any electrode employed for weld joints, temporary welds, or weld surface repairs in material which is to be subjected to hot forming and heat treatment after such welding. The qualification test plate shall undergo heat cycling representative in magnitude and time at temperature of that employed in hot forming and subsequent heat treating operation. Hot forming shall not be performed on structures containing weld

deposits until the applicable procedure qualification has been approved. Mechanical properties and NDT of hot-formed welds shall be as specified in the procedure qualification approval. Exception may be made when the weld is to be removed after forming.

9.4 Forming of galvanized steels. Prior to forming galvanized steels at temperatures in excess of 400°F to form the strength or tightness members specified below, the galvanizing shall be completely removed from the area to be affected by forming by an acid bath followed by neutralization or by other approved methods:

(a) Surface ship primary structure or submarine pressure hull structure.
(b) Machinery and main switchboard foundations.
(c) Sea chests.
(d) Drain collecting tanks, bilge wells, and sumps.
(e) Deck seamanship installations and fittings.

The procedure for forming galvanized steels at temperatures in excess of 400°F for uses other than those specified in (a) through (e) above shall be as follows:

(a) The area to be affected by forming shall be heated with a slightly oxidizing oxyfuel gas flame to a temperature not exceeding 950°F.
(b) The molten zinc and zinc oxide shall then be removed from the area by wire brushing.
(c) The area shall be reheated in accordance with table IX and formed.

When flame cutting is required in the formed area, it shall be accomplished after the removal of the galvanizing.

10. WELDING FILLER MATERIALS

10.1 General. Unless otherwise approved, welding electrodes (bare and coated), bare filler wire, flux cored wire, and submerged-arc flux used in the fabrication of ship hulls shall be of the types specified in tables X through XVI. These tables specify acceptable filler metals, processes, and conditions that shall be used in joining specified base materials. Materials, welding filler metals, and welding processes other than those specified in the tables of this section may be employed if qualified in accordance with section 4. Base materials and filler metals not specified in tables X through XVI may be used provided they are acquired to approved Government or equivalent commercial specifications.

TABLE X. Filler materials for OS steel, HSS steel, and equivalent carbon steels.

Process	Filler material 1/2/		Base metal
	MIL-type	Specification	Specifications
SMAW	6010 4/ G6010 4/ G6011 6011 6020 6027	AWS 5.1 3/	MIL-S-22698, other S-1 materials specified in MIL-STD-248 and equivalent materials: for example, ASTM grades
	7018-M 8018-C3	MIL-E-22200/10 MIL-E-22200/1	
GTAW, GMAW, and SAW	Electrode	MIL-E-18193	
	Flux	MIL-F-18251 MIL-F-19922	
	70S-1 70S-2 70S-3 70S-4 70S-5 70S-6	MIL-E-23765/1	
FCAW	5/ 70T-1 5/ 71T-1 70T-5 70T-6 70T-8 71T-8 71T-8-Ni1 80T-1-Ni2 81T-1-Ni2	MIL-E-24403/1	

1/ Equivalent materials on the ABS approved list of filler materials may be used as alternates when approved by NAVSEA.

2/ For multipass welds, any shielded metal arc electrode below may be used for making root pass welds, regardless of which of the electrodes are used in making the final weld passes.

3/ For higher strength hull structural grades, these electrodes are for fillet welds other than in or to surface ship primary hull structure and submarine hull structure.

4/ Suitable for all welds. Primarily intended for horizontal fillets and welds over galvanizing or primer coated surfaces. See section 13 for limitations or special qualification requirements for welding over galvanized or primer-coated surfaces.
5/ These electrodes may be used on all S-1 materials, provided toughness equals 20 foot-pounds at minus 20°F. If toughness does not meet these requirements, then these electrodes are restricted to grades A, B, and AH-36 materials.

TABLE XI. Filler materials for HY-80, HY-100, HSLA-80, and STS. 1/

Process	Filler materials 2/		Application
	Type	Specification	
SMAW	3/ MIL-12018-M2	MIL-E-22200/10	HY-100 to HY-100 HY-100 to STS STS to STS STS to HY-100
	4/ MIL-10018-M1 5/ MIL-11018-M	MIL-E-22200/10 MIL-E-22200/1	HY-80 to HY-80 HY-80 to HY-100 HY-80 to STS HY-80 to HSLA-80 HSLA-80 to HSLA-80 HSLA-80 to HY-100, STS
	MIL-7018-M 5/ MIL-8018-C3	MIL-E-22200/10 MIL-E-22200/1	OS to HY-80/100, HSLA-80, STS HSS to HY-80/100, HSLA-80, STS
	5/ MIL-10018-N1	MIL-E-22200/5	Limited, subject to approval by NAVSEA
GMAW and SAW	6/7/ MIL-120S-1	MIL-E-23765/2	HY-100 to HY-100 HY-100 to STS STS to STS
	6/ MIL-100S-1 6/ MIL-100S-2	MIL-E-23765/2	HY-80 to HY-80 HY-80 to HY-100 HY-80 to STS HY-80 to HSLA-80 HSLA-80 to HSLA-80 HSLA-80 to HY-100, STS
	MIL-70S-1 through MIL-70S-6	MIL-E-23765/1	OS to HY-80/100, HSLA-80, STS HSS to HY-80/100, HSLA-80, STS

See footnotes at end of table.

TABLE XI. Filler materials for HY-80, HY-100, HSLA-80, and STS 1/ - Continued.

Process	Filler materials 2/		Application
	Type	Specification	
FCAW	MIL-110TC MIL-101TC MIL-101TM MIL-101TS MIL-100TC MIL-100TM MIL-100TS	MIL-E-24403/2	HY-80 to HY-80 HY-80 to HY-100 HY-80 to STS HY-80 to HSLA-80 HSLA-80 to HSLA-80 HSLA-80 to HY-100, STS
	MIL-7XT-1-HY MIL-7XT-X-HY MIL-7XTX-X-HY MIL-8XTX-X-HY	MIL-E-24403/1	OS to HY-80/100, HSLA-80, STS HSS to HY-80/100, HSLA-80, STS
GMAW	MIL-309 MIL-309Cb MIL-310	MIL-E-19933	STS to STS 8/9/
SMAW	MIL-309-15/16 MIL-309Cb-15/16 MIL-310-15/16	MIL-E-22200/2	STS to STS 8/9/

1/ Filler and base material combinations for other high-hardenable materials shall be as specified in an approved procedure.
2/ When welding HY-80/100 or HSLA-80 to ferritic steels (other than HY-100 or STS), the electrode specified for HY-80 or HSLA-80 shall be used unless otherwise specified in this table.
3/ MIL-11018-M may be used when the electrodes meet the requirements of MIL-12018-M2 electrodes of MIL-E-22200/10, and are specifically approved by NAVSEA.
4/ MIL-10018-M1 is approved for limited use for repair of fillet or groove tee welds in HY-100 material as permitted in section 13.
5/ MIL-8018-C3, MIL-10018-N1, MIL-11018-M type electrodes in accordance with MIL-E-22200/1 shall meet the moisture and moisture resistance requirements of MIL-E-22200/10 and shall be specifically approved by NAVSEA.
6/ Not to be used for applications requiring post weld heat treatment, including stress relief, unless approved by NAVSEA.
7/ MIL-120S-1 shall not be used for Submerged Arc Welding (SAW) unless specifically approved by NAVSEA.
8/ For existing stainless-steel welds in STS, MIL-310 type filler materials may be used for repair welding.
9/ Only for fillet, grooved tee, lap and corner welds in STS.

TABLE XII. Filler materials for welding ferrous to non-ferrous and austenitic materials, and for cladding.

Process	Filler materials		Applications
	MIL-type	Specification	
SMAW	309-15/16 309Cb-15/16	MIL-E-22200/2	For all welded joints between ferrous and stainless steel alloys and for first and second layer cladding of austenitic stainless steel on ferrous base materials.
GTAW, GMAW, and SAW	309 309Cb	MIL-E-19933	
SMAW	4N11	MIL-E-22200/3	For all welded joints between ferrous alloys and nickel, nickel-copper and copper nickel and for the cladding of nickel on ferrous base materials.
GTAW, GMAW, and SAW	EN/RN61	MIL-E-21562	
SMAW	1/ 9N10	MIL-E-22200/3	For all welded joints between ferrous alloys and nickel copper alloys and for the cladding of nickel copper on ferrous base materials.
GTAW, GMAW, and SAW	EN/RN 60	MIL-E-21562	
SMAW	1/ 8N12	MIL-E-22200/3	For all welded joints between ferrous alloys and nickel chrome iron alloys and for the cladding of nickel-chrome-iron alloys of ferrous base materials.
GTAW, GMAW, and SAW	EN/RN 82	MIL-E-21562	
SMAW	1N12	MIL-E-22200/3	For the cladding of nickel-chromium-molybdenum-columbium on ferrous-base materials.
GTAW, GMAW, and SAW	EN/RN 625	MIL-E-21562	

1/ Suitable for applications requiring post weld stress relief heat treatments.

TABLE XIII. Filler materials for austenitic stainless-steel alloys. 1/

Specification	Base metal	Base metal				
		304	310	316	321	347
QQ-S-763 QQ-S-766 MIL-S-867 MIL-S-17509 MIL-S-23193 MIL-S-23195 MIL-S-23196	304	308	308 (309) (310)	308 (316)	308 (347)	308 (347)
QQ-S-763 QQ-S-766	310	308 (310) (309)	310 (309)	310 (316)	310 (347)	310 (347)
QQ-S-763 QQ-S-766 MIL-S-867 MIL-S-23193	316	308 (316)	310 (316)	316	316 (347)	316 (347)
QQ-S-763 QQ-S-766 MIL-S-867	321	308 (347)	310 (347)	316 (347)	347	347
QQ-S-763 QQ-S-766 MIL-S-867 MIL-S-17509 MIL-S-23193 MIL-S-23195 MIL-S-23196	347	308 (347)	310 (347)	316 (347)	347	347
		Filler metal MIL-types 2/ (MIL-E-19933, MIL-E-22200/2)				

1/ The preferred fill metal is listed at the top with alternative filler metals in parentheses.

2/ Low carbon filler metals of the specified MIL-types may be used for all applications, and shall be used when both members being joined are low carbon alloys.

TABLE XIV. Filler materials for nickel base alloys.

Base material		Process	Filler material	
Alloy type	Specification		MIL-type	Specification
Nickel-copper	MIL-N-24106 MIL-N-17163 QQ-N-281 QQ-N-288 composition E	SMAW	9N10	MIL-E-22200/3
Nickel-chromium-iron	ASTM B 166 and B 564 MIL-B-15382 MIL-N-23228 MIL-N-23229	SMAW	4N1A 8N12 1N12	
Nickel-copper	MIL-N-24106 MIL-N-17163 QQ-N-281 QQ-N-288 composition E	GTAW, GMAW, and SAW	EN/RN60	MIL-E-21562
Nickel chromium-iron	ASTM B 166 and B 564 MIL-B-15382 MIL-N-23228 MIL-N-23229	GTAW, GMAW, and SAW	EN/RN62 EN/RN82 EN/RN6A EN/RN625	

TABLE XV. Filler materials for copper-nickel alloys.

Base material		Process	Filler material	
Alloy type	Specification		MIL-type	Specification
CuNi 70/30	MIL-T-16420	SMAW,	CuNi 70/30	MIL-E-22200/4
CuNi 90/10	MIL-C-20159 MIL-C-15726	GTAW, GMAW, and SAW	EN/RN67	MIL-E-21562

TABLE XVI. Filler materials for wrought aluminum alloys.

Base material 1/		Type						
Specification	Type	5083	5456	5454	5086	5052	3003	1100
QQ-A-225/1 QQ-A-250/1 WW-T-700/1	1100	2/ 5356	2/ 5356	3/ 4043	2/ 5356	3/ 4043	2/ 1100	2/ 1100
QQ-A-200/1 QQ-A-225/2 QQ-A-250/2 WW-T-700/2	3003	2/ 5356	2/ 5356	3/ 4043	2/ 5356	3/ 4043	2/ 1100	
QQ-A-225/7 QQ-A-250/8	5052	3/4/ 5356	3/4/ 5356	2/4/5/ 5356	2/4/5/ 5356			
QQ-A-200/5 WW-T-700/5	5086	3/ 5356	3/ 5356	5/ 5356	3/ 5356			
QQ-A-200/6 QQ-A-250/10	5454	3/4/ 5356	4/ 5356	2/3/ 5554				
QQ-A-200/7 QQ-A-250/9	5456	3/ 5183	3/ 5556					
QQ-A-200/4 QQ-A-250/6	5083	3/ 5183						
			Filler materials (AWS A5.10)					

1/ 6061 alloy shall not be used in structural applications.
2/ 4043 may be used.
3/ 5356, 5183, or 5556 may be used.
4/ Shall not be used where service temperature is above 150°F.
5/ 5154, 5254, 5183, or 5556 may be used.

10.2 Acquisition requirements. Welding filler materials shall be acquired in accordance with the applicable material specifications. However, proprietary filler materials qualified by procedure qualification may be acquired to the limitations and controls established in the procedure qualification.

10.3 Handling and storage. Welding electrodes shall be handled carefully to prevent damage to their coatings. Damaged containers shall have their contents examined for cracked coatings or other damage to the coated electrodes and for distorted spools or entwined winding on spooled wire. Filler material damaged to the extent that it does not meet specification requirements shall not be used for production welding.

10.3.1 Covered electrodes. Electrodes shall be stored in dry storage. Electrodes which have been in physical contact with water shall be scrapped or reconditioned in accordance with an approved procedure. Low hydrogen type ferritic covered electrodes, except those in accordance with 10.3.1.1, shall be used within 9 hours on removal from either sealed receiving containers or a vented holding oven maintained at 150 to 300°F. Electrodes not used within 9 hours after issue or otherwise exposed to ambient conditions shall be held for at least 8 hours in a vented holding oven maintained at 150 to 300°F prior to reissue.

10.3.1.1 Covered electrodes for welding HY-80/100, HSLA-80, and high-hardenable materials.

10.3.1.1.1 Conditioning and maintenance of ferritic covered electrodes for use involving HY-80/100, HSLA-80, or STS applications. Electrodes which meet the moisture and moisture resistance requirements as specified in MIL-E-22200/10 may be used directly from manufacturer's hermetically sealed containers without baking prior to initial issue. Subsequent issue shall be in accordance with 10.3.1.1.2. Where the specified moisture requirements are exceeded or where deemed necessary by the activity concerned, baking followed by storage in holding ovens shall be accomplished in accordance with 10.3.1.1.1.1 through 10.3.1.1.1.3.

10.3.1.1.1.1 Baking. The electrodes specified in 10.3.1.1.1 shall be conditioned by baking at a temperature of 800 ± 25°F using a total time at temperature of 30 minutes to 1 hour. Variations to this time and temperature may be used provided the procedure is approved. The following conditions are applicable:

(a) Loading temperature. Electrodes shall not be placed in the oven for baking while the temperature of the oven exceeds 300°F.
(b) Heating rate. During baking, the temperature of the oven shall not be raised more than 300°F per hour where oven temperatures are 500°F and above.
(c) Time above 500°F. The total elapsed time at oven temperatures above 500°F shall be kept to a minimum.
(d) Charging the oven. In charging the oven, the electrodes shall be spread on suitable trays. Electrodes may also be placed into open aluminum cans and held in the vertical position. Trays or cans shall not be fabricated using any solder or joint filler which liquifies under 1000°F.
(e) Baking oven type. Automatically controlled, forced convection or circulation ovens which bake electrodes in accordance with the requirements of this paragraph shall be used.
(f) Baking controls. Oven controls and recording instruments shall be checked at periodic intervals in accordance with an established calibration program.

10.3.1.1.1.2 Storage in holding ovens. Electrodes which have been baked shall be transferred to holding ovens without being allowed to cool below 150°F. Transfer shall be accomplished with the electrodes protected from inclement weather. Except as specified in 10.3.1.1.2, electrodes shall be stored in vented holding ovens after the containers have been opened. Holding oven temperature shall be 225 to 300°F. Holding ovens shall be used for storage of electrodes removed from the baking ovens.

10.3.1.1.1.3 Rebaking. Electrodes may be baked by the receiving activity more than once provided each electrode brand is initially tested after a maximum proposed number of baking cycles and shown to meet specifi-

cation requirements for moisture, usability, all-weld metal tensile mechanical properties and chemistry. Recertification of each electrode brand to the above requirements shall be performed annually.

10.3.1.1.2 Exposure of electrodes. Upon removal from the manufacturer's hermetically sealed containers or holding ovens, MIL-7018-M, MIL-8018-C3, MIL-10018-M1, MIL-11018-M, and MIL-12018-M2 electrodes shall not be used after being exposed to the atmosphere for a total period of more than 9 hours. During exposure, means shall be provided to protect electrodes from inclement weather.

10.3.1.1.3 Returned electrodes. Electrodes turned in after 9 hours or less shall be returned to the holding ovens for 8 hours prior to reissue. Electrodes turned in after more than 9 hours exposure shall be rebaked in accordance with 10.3.1.1.1.3.

10.3.2 Bare electrode and flux core wire or filler wire storage. Bare electrode and flux core wire or filler wire shall be stored in a dry area.

10.3.3 Submerged-arc granular flux.

10.3.3.1 Granular flux for welding HY-80/100, HSLA-80, or high-hardenable materials.

10.3.3.1.1 Storage. Granular flux shall be stored in a dry area.

10.3.3.1.2 Preparation for use. Prior to the start of any welding operation, granular flux shall be heated to 250°F minimum and used while warm to the touch. Flux shall be heated in clean, uncoated metal containers.

10.3.3.1.3 Reuse. Unfused granular flux may be reused subject to the following conditions:

(a) Flux shall be collected from clean, dry work pieces.
(b) If flux is not warm to the touch, it shall be rebaked at 250°F minimum for at least 2 hours.

10.3.3.2 Granular flux for welding other than HY-80/100, HSLA-80, or high-hardenable materials.

10.3.3.2.1 Storage. Granular flux shall be stored in a dry area.

10.3.3.2.2 Reuse. Unfused granular flux collected from clean, dry work pieces may be used.

10.4 Welding filler material identification. Electrodes, flux-cored electrodes, welding wire and flux shall be identified by type up to the point of usage.

10.4.1 Coated electrodes. Each coated electrode shall have distinguishable color code, type designation or classification number marking. If markings are destroyed by baking or other means, electrodes shall not be used until identification is restored.

10.4.2 Bare electrodes, flux core wire, or filler metal. Each spool or coil of bare electrodes shall carry an identifying label. Each piece of bare filler metal shall have distinguishable color code, type designation or classification number marking.

10.4.3 Granular flux. Each container of granular flux shall be labeled as to type.

11. WELDING DESIGN

11.1 Joint efficiency. Joint effeciency shall be based on the strength of the weaker member of a two-member joint; that is, that member which has the lowest product of thickness times ultimate tensile strength. When three members are joined such that the through member is the weakest member, the joint efficiency shall be based on the strength of the weakest intercostal member. Methods accepted by NAVSEA which account for the load directions and geometries may be used. For submarine structures, weld joints using permanent backing straps shall be considered 90 percent efficient welds. For surface ship structures, full penetration welds including those using permanent or removable backing straps (see 11.2.1), where compatible weld metal of equivalent or greater ultimate tensile strength is used as specified in section 10, are condidered to be 100 percent efficient welds, except that welds made from one side without backing shall have a maximum efficiency of 80 percent. Permanent backing straps used to obtain full penetration may be tacked, welded on one side, or welded on both sides as necessary to suit service conditions. For aluminum alloys, efficiencies of full penetration welds shall be based on the proportional strength of filler metal and annealed base metal unless otherwise approved as a result of special tests.

11.2 Design group classification. Welding joint symbols shall be in accordance with AWS A2.4. Welding joint details specified in 11.2.1 through 11.2.6 shall be in accordance with the appropriate figures and provisions specified in MIL-STD-22, except the material thickness limitation specified in MIL-STD-22 is not applicable. Except as specified in 11.2.7, welded joint types are separated into general classifications as specified in 11.2.1 through 11.2.8. Groove joints within the same design group may be interchanged without drawing change provided joint effeciencies are not reduced. Full penetration joint design may be used where partial penetration joint designs are specified. Where this is done, the inspection requirements for the partial penetration joint design may be applied.

11.2.1 Group B joints. Group B joints are butt joints as specified in MIL-STD-22. Welded butt joints may be used subject to the limitations listed below:

(a) Butt-type permanent backing strap joints welded from one side shall not be used without approval in the following locations:

(1) Submarines. Structure subject to submergence pressure.
(2) Surface ships. Bilge, sheer, and stringer strakes within the 3/5 midship length for displacement type ships and as specified for other type ships, and for type A protective plating.

(b) Welded butt joints made against removable backing and on which the root is inspected in accordance with the requirements of this standard shall be considered the equivalent of a joint welded from both sides.

(c) Butt joints in strength members, including inserts, of unequal thickness shall require chamfering of the thicker member down to the thickness of the thinner member as specified in MIL-STD-22. This requirement applies to welded butt joints in the following locations:

(1) Surface ships. Transverse or vertical welded butt joints in longitudinal strength structure within the 3/5-midship length for displacement type ships and as specified for other type ships, those welded butt joints located in normally highly stressed transverse structure such as flight deck bents; and all welded butt joints in foundation structure designed for shock.
(2) Submarines. Welded butt joints in pressure hull structure and intermediate pressure tanks.
(3) Periphery welds of insert plates and other connections, not required to be chamfered or tapered in accordance with (1) or (2) above, may be designed as corner or tee joints.

11.2.2 Group T joints. Group T joints are full penetration groove tee joints as specified in MIL-STD-22. Full penetration groove tee welds may be used subject to the limitations specified in 11.1.

11.2.3 Group PT joints. Group PT joints are partial penetration groove and fillet welded tee joints as specified in MIL-STD-22. The sizing of group PT welded joints shall be in accordance with MIL-STD-1628. Alternative methods allowed by 11.1 may be used subject to the limitations listed in 11.2.3.1 and 11.2.3.2.

11.2.3.1 Intermittent fillet welded joints. Intermittent fillet welded joints may be used subject to the limitations listed below:

(a) Intermediate fillet welded joints shall have continuous welds on both sides of the joint at the fixed ends of the attached member for 1/8 the length of the member.
(b) Intermittent fillet welded joints shall not be used in the following locations:

(1) Areas exposed to water or weather.
(2) Surface ship primary hull structure and submarine pressure hull structure and intermediate pressure tanks. Joints of stiffeners attached to surface ship primary support structure which is not part of the primary hull girder may be excluded from this requirement.

11.2.3.2 Intermittent fillet weld size. Intermittent fillet weld sizes shall be determined by increasing the continuous double fillet size required by this specification in proportion to the unwelded length of the joint. That is, if the unwelded length of the joint is half the intermittent spacing, the intermittent fillet size shall be twice the double continuous fillet size. Calculated intermittent weld sizes shall not be based on weld load capacity greater than base material load capacity. In such cases, the size of the intermittent fillet welds shall be reevaluated using a reduced weld spacing or an increased weld length. Additional restrictions applicable to intermittent welds are found in MIL-STD-22 and MIL-STD-1628.

11.2.4 Group C joints. Group C joints are corner joints as specified in MIL-STD-22. Welded corner joints may be used subject to the limitations specified in 11.1

11.2.5 Group L joints. Group L joints are plug and slot welded joints and fillet welded lap joints as specified in MIL-STD-22.

11.2.5.1 Fillet welded lap joints. The strength and efficiency of these fillet welds shall be determined in the same manner as for group PT joints specified in 11.2.3.

11.2.5.2 Plug and slot welds. These welds shall be used only upon NAVSEA approval when applied to surface ship primary hull structure, except as specified in table XVII. These welds shall be used only upon NAVSEA approval when applied to submarine structure.

TABLE XVII. Surface ship weld joint design requirements.

Item	Connection	Joint efficiency (percent)	Joint design group
Bilge keels	Plating butts and seams	100	B
	Web to plating	75	
	Connections to shell	75	
Breasthooks	Plating butts and seams	100	B
	Plating periphery to:		
	(a) shell	75	T, PT, L
	(b) Decks, longitudinals, stringers	100	B, T, PT
	(c) Intersecting bulkheads:		
	(1) Plating on both sides	100	T, PT
	(2) Plating on one side only	75	T, PT
Bulkheads, longitudinal and transverse	Plating butts and seams	100	B
	Plating periphery of:		
	(a) Main subdivision bulkheads	100	T, PT
	(b) Type A protective and side protective system bulkheads	100	T, PT, C
	(c) Transverse bent bulkheads	100	T, PT
	(d) Bulkheads designed to resist nuclear airblast	100	T, PT, C
	(e) Bulkheads designed as foundation structure	100	T, PT, C
	(f) Partial structural bulkheads:		
	(1) To side protective system	100	T, PT, C
	(2) Elsewhere	75	T, PT, C
	(g) Miscellaneous structural bulkheads:		
	(1) WT and OT	75	PT, C, L
	(2) Other	60	PT, C, L
	(h) Swash bulkheads	60	PT, L, C
	(i) Joiner and nonstructural bulkheads	50	PT, L, C
	Connections where slotted or cut out in way of through members:		
	(a) Structural bulkheads to passing member or to collar plates	100	T, PT, L
	(b) Joiner and nonstructural bulkheads to passing member or to collar plates	50	PT, L

TABLE XVII. Surface ship weld joint design requirements - Continued.

Item	Connection	Joint efficiency (percent)	Joint design group
Bulkheads, longitudinal and transverse (Continued)	Stiffeners:		
	(a) Butts of shapes	100	B
	(b) Webs to bulkhead plating (and to faceplate if built-up):		
	(1) Type A protective bulkheads	100	T, PT
	(2) Side protective system	100	T, PT
	(3) Nonprotective bulkheads:		
	a. Web to plating	60	PT
	b. Web to faceplate in way of brackets	75	PT
	(4) Joiner and nonstructural bulkheads	50	PT
	(c) End connections to decks, bulkheads, platforms and intersecting members:		
	(1) Webs	100	T, PT, C
	(2) Flanges where backed up	100	T, PT
	(3) Flanges where not backed up	75	T, PT
	(d) Tilting brackets	50	T, PT, C
	(e) Tangency chocks to web and faceplate at brackets	50	T, PT
Decks, platforms and innerbottom	Plating butts and seams	100	B
	Plating periphery of type A protective decks	100	T, PT, C
	Plating periphery of nonprotective decks not in superstructure and platforms to:		
	(a) Type A protective and side protective system bulkheads	100	T, PT
	(b) Longitudinal bulkheads	75	T, PT
	(c) Transverse bulkheads:		
	(1) Deck on both sides	100	T, PT
	(2) Deck on one side only	75	T, PT
	(d) Shell:		
	(1) Type A protective shell	100	T, PT
	(2) Shell plating in way of side protective system	100	T, PT
	(3) Nonprotective shell	75	T, PT
	(e) Sponson shell	75	T, PT, C

TABLE XVII. Surface ship weld joint design requirements - Continued.

Item	Connection	Joint efficiency (percent)	Joint design group
Decks, platforms and innerbottom (Continued)	(f) Trunks and hatches:		
	(1) In longitudinal strength decks	100	T, PT, C
	(2) Elsewhere	75	T, PT, C
	Connections where slotted or cut out in way of through members:		
	(a) Plating to through member or to collar plates	100	T, PT, L
	Longitudinals, and transverses and other stiffeners:		
	(a) Butts of shapes	100	B
	(b) Webs to deck or platform plating (and to faceplate if built-up):		
	(1) Type A protective decks	100	T, PT
	(2) In way of stanchions	100	T, PT
	(3) Nonprotective decks and platforms:		
	a. Web to plating	60	T, PT
	b. Web to faceplate in way of brackets	75	T, PT
	(c) End connections to bulkheads and to intersecting members:		
	(1) Webs	100	T, PT
	(2) Flanges where backed up	100	T, PT
	(3) Flanges where not backed up	75	T, PT
	(d) Tilting brackets	50	T, PT, C
	(e) Tangency chocks to web and faceplate at brackets	50	T, PT
Docking brackets	Connections to:		
	(a) Vertical keel, solid floors, and unlightened longitudinals	100	T, PT, L
	(b) Lightened floors and longitudinals	75	T, PT, L
	(c) Shell plating	75	T, PT, L
Foundations and machinery flats	Connections joining foundation structure	100	B, T, PT, C, L
	Connections to support structure	100	B, T, PT, C, L

TABLE XVII. Surface ship weld joint design requirements - Continued.

Item	Connection	Joint efficiency (percent)	Joint design group
Foundations and machinery flats (Continued)	Connections of support structure and framing in way of foundations	50	B, T, PT, C, L
	Penetrations:		
	(a) Water or oil tight	75	
	(b) Other	50	T, PT, C
	Tilting brackets	50	T, PT, C
Framing, shell and innerbottom, longitudinal and transverse	Plating butts and seams	100	B
	Butts of shapes	100	B
	Connections where slotted or cut out in way of through members:		
	(a) At collar plates	100	T, PT, L
	(b) Where continuous	100	T, PT, L
	(c) Where intercostal only	75	T, PT, L
	(d) Where intercostal, but supporting continuous structure	100	T, PT, L
	End connections to intersecting members:		
	(a) Deep web members (over 24 inches):		
	(1) Flanges and adjacent 25 percent of web	100	T, PT, L
	(2) Remainder of web	75	T, PT, L
	(b) Other members (24 inches and under)	100	T, PT, L
	Web connections to structure supported and to faceplate if builtup:		
	(a) Type A protective plating	100	T, PT
	(b) Nonprotective plating:		
	(1) To innerbottom plating in way of main subdivision and type A protective bulkheads	100	T, PT
	(2) Elsewhere	60	T, PT
Masts, booms, kingposts, weight handling rigging and fittings	All connections	100	B, T, PT, C, L

TABLE XVII. Surface ship weld joint design requirements - Continued.

Item	Connection	Joint efficiency (percent)	Joint design group
Rudders	Plating butts and seams	100	B
	Plating periphery	100	B, C
	Framing:		
	(a) Connections to rudder casting	100	T, PT, C
	(b) Elsewhere	75	T, PT, L
Shell plating	Groove butts and seams	100	B
	Lapped butts and seams	100	L
	Connections of appendages to the shell except bilge keels	100	T, PT
	Shell plating to uppermost strength deck	100	T, C
Sponsons	Connection to hull girder	100	B, T, PT
	Bulkheads (see bulkheads, longitudinal and transverse)		
	Decks (see decks, platforms, and innerbottom)		
	Sponson shell plating butts and seams	100	B
	Sponson shell stiffeners:		
	(a) Butts of shapes	100	B
	(b) Web connections to plating (and to faceplate where builtup):		
	(1) Type A protective plating	100	T, PT
	(2) Nonprotective plating		
	a. Web to plating	50	T, PT
	b. Web to faceplate in way of brackets	75	T, PT
	(c) End connections to bulkheads and to intersecting members:		
	(1) Webs	100	T, PT
	(2) Flanges where backed up	100	T, PT
	(3) Flanges where not backed up	75	T, PT
	(d) Tilting brackets	50	T, PT, C
	(e) Tangency chocks to web and faceplates at brackets	50	T, PT
Stanchions	Butts of shapes	100	B
	Head and heel connections	100	T, PT
	Web to flange if buildup	75	T, PT
	Elsewhere	75	T, PT

TABLE XVII. Surface ship weld joint design requirements - Continued.

Item	Connection	Joint efficiency (percent)	Joint design group
Structural compensation for openings	In plating and in attached framing of:		
	(a) Type A protective decks and bulkheads	100	T, PT, C, L
	(b) Side protective system decks and bulkheads	100	T, PT, C, L
	(c) Bulkheads and decks exposed to or designed to resist nuclear airblast	100	T, PT, C, L
	(d) Transverse bent bulkheads	100	T, PT, C, L
	(e) Sponson transverse frames	100	T, PT, C, L
	(f) Stringer strakes	100	T, PT, C, L
	(g) Shell	100	T, PT, C, L
	(h) Uppermost strength deck	100	T, PT, C, L
	(i) Nonprotective bulkheads and nonprotective decks, when:		
	(1) Watertight, oiltight or continuous structure	75	T, PT, C, L
	(2) Nontight, airtight or intercostal structure	50	PT, C, L
Superstructure	Plating butts and seams	100	B
	Connections to hull girder:		
	(a) Shell plating	100	B
	(b) Type A protective deck	100	T, PT, C, L
	(c) Nonprotective deck		
	(1) At ends for 1/8 length	100	T, PT, C, L
	(2) Elsewhere	75	T, PT, C, L
	Connections in decks and bulkheads where slotted or cut out in way of through members:		
	(a) Plating to through member or to collar plates	100	T, PT, L
	Plating periphery of:		
	(a) Type A protective bulkheads	100	T, PT, C
	(b) Bulkheads exposed to or designed to resist nuclear airblast	100	T, PT, C
	(c) Bulkheads:		
	(1) Transverse	100	T, PT, C
	(2) Longitudinal:		
	a. At ends for 1/8 length	100	T, PT
	b. Elsewhere	75	T, PT

TABLE XVII. Surface ship weld joint design requirements - Continued.

Item	Connection	Joint efficiency (percent)	Joint design group
Superstructure (Continued)	(3) Miscellaneous structural	75	PT, C, L
	(4) Joiner and nonstructural	50	PT, L
	Plating periphery of type A protective decks or levels	100	T, PT, C
	Plating periphery of nonprotective decks or levels to:		
	(a) Type A protective bulkheads	100	T, PT, C
	(b) Enclosure bulkheads	75	T, PT
	(c) Interior bulkheads:		
	(1) Deck on both sides	100	T, PT
	(2) Deck on one side only	75	T, PT
	(d) Trunks and hatches	75	T, PT
	Bulkhead stiffeners (same as under bulkheads, longitudinal and transverse)		
	Deck longitudinals, transverses, and other stiffeners (same as under decks, platforms, and innerbottom)		
Vertical Keel	Plating butts	100	B
	Connection to flat keel and rider plate	75	T, PT, L

11.2.6 Group E joints. Group E joints are edge joints as specified in MIL-STD-22. Edge welded joints shall only be used in secondary structure such as joiner bulkheads and partitions, and for purposes of joint sealing.

11.2.7 Special joints. When joint configurations other than those shown in this section are employed, the joint shall be detailed on the drawing and approved for the ship involved, or the special joint shall be specifically approved by NAVSEA as an acceptable alternative and contained in a qualified welding procedure. Such joints shall meet the efficiency and design requirements contained in this document or any approved limitations.

11.2.8 Canted tee joints. Where tee joints are formed by structural elements at an angle other than 90 degrees to one another, the joint shall be designed as follows:

(a) For all full penetration group T joints and all double-beveled or double J-grooved group PT joints, the angle of the bevel or J on the closed side of the joint shall be corrected to provide at least the minimum angle for each joint type as specified in MIL-STD-22.

(b) Partial penetration tee joint (PT2S.1) when used for submarine application. For attachment of structural members to pressure hull or tank plating subject to submergence pressure, where the angle formed between the tee member and the through plate is greater than 105 degrees on the open or obtuse angle side of the joint, a bevel shall be provided on this side of the joint sufficient to produce an included angle of 45 degrees minimum. The effect of this requirement will produce a joint similar to T2V.1 or PT2V.4.

11.3 Design requirements. The minimum required joint efficiencies and the allowable joint design groups for different connections shall be as specified in tables XVII and XVIII.

TABLE XVIII. Submarine weld joint design requirements. 1/

Structural category and connection or type of weld	Minimum joint efficiency (percent) 2/	Weld joint design group	Notes
I. Pressure hull structure			
A. Pressure hull envelope			
(1) Welds in pressure hull envelope			
a. Welds joining pressure hull envelope material (unless otherwise stated below)	100	B, T, C	
b. Compensating penetrations	100	T, PT, C	3/4/
c. Noncompensating penetrations	100	T, PT, C	4/
(2) Welds to pressure hull envelope			
a. Frame to hull			
(1) External	100	T, PT	5/
(2) Internal	100	T, PT	5/
b. Hard tank stiffeners to hard tank plating			
(1) Stiffeners on pressure side	100	T, PT	5/
(2) Stiffeners not on pressure side	75	T, PT	
c. Attachment welds (see 3.47.1)	100	T, PT	
d. Connections of foundations, tanks, bulkheads	100	T, PT	6/
e. Attachment of fairwater and superstructure	100	T, PT	7/

See footnotes at end of table.

TABLE XVIII. Submarine weld joint design requirements 1/ - Continued.

Structural category and connection or type of weld	Minimum joint efficiency (percent) 2/	Weld joint design group	Notes
f. End connection of primary and secondary stiffeners	100	T, PT	5/
g. Stiffeners of trunks, tunnels, missile tubes and seachests			
(1) External	100	T	
(2) Internal	75	T, PT	
h. Attachment of vertical keel	100	T, PT	5/
i. Attachment of nonsupport structure	75	T, PT	
B. Support structure			
(1) Welds in support structure			
a. Welds joining support structure material (unless otherwise stated below)	100	B, T, C	
b. Pressure hull envelope frame web to flange	100	T, PT	
c. Bulkhead primary stiffener			
(1) End connections	100	T, PT	
(2) Web to flange and tank or bulkhead	75	T, PT, C	
d. Bulkhead and hard tank secondary and panel stiffeners			
(1) End connections	100	T, PT	
(2) Web to flange, tank or bulkhead			
a. For 1/8 of length from ends	75	T, PT, C	
b. Remainder	50	T, PT, C	
e. Penetrations			
(1) Compensating	100	T, PT, C	4/
(2) Penetrations through special sandwich bulkheads with solid filler	100	PT	4/8/
(3) Water or oil tight	75	T, PT, C	4/
(4) Other penetrations not listed above	50	T, PT, C	4/

See footnotes at end of table.

TABLE XVIII. Submarine weld joint design requirements 1/ - Continued.

Structural category and connection or type of weld	Minimum joint efficiency (percent) 2/	Weld joint design group	Notes
(2) Welds to support structure			
a. Tilting brackets	50	T, PT, C	
b. Attachment welds	100	T, PT, C	9/
c. Connections of foundations tanks to support structure	100	T, PT, C	
II. Containment structure-joint design requirements for containment structure shall be obtained by referring to the applicable support structure in category (b)(1) above			
III. Nonpressure hull structure			
A. Intermediate pressure tanks			
(1) Welds in intermediate pressure tanks			
a. Welds joining intermediate pressure tank material (unless otherwise stated below)	100	B, T, C	
b. Penetrations			
(1) Water or oil tight	75	T, PT, C	4/
(2) Other	50	T, PT, C	4/
(2) Welds to intermediate pressure tanks			
a. Stiffener web to plating			
(1) Stiffener on pressure side	100	T, PT	5/
(2) Stiffener not on pressure side	75	T, PT	
b. End connections of stiffeners	100	T, PT	5/
c. Stiffener web to flange	75	T, PT, C	
d. Tilting brackets	50	T, PT, C	
e. Connection to structure other than pressure hull envelope	100	T, C	
f. Attachment welds	100	T, PT, C	9/

See footnotes at end of table.

TABLE XVIII. Submarine weld joint design requirements 1/ - Continued.

Structural category and connection or type of weld	Minimum joint efficiency (percent) 2/	Weld joint design group	Notes
B. Low pressure (soft) tanks			
(1) Welds in low pressure tanks			
a. Welds joining low pressure soft tank material (unless otherwise stated below)	100	B, C, T, PT	7/
b. Penetrations			
1. Water or oil tight	75	T, PT, C	4/
2. Other	50	T, PT, C	4/
(2) Welds to low pressure tanks			
a. Connection to structure other than pressure hull envelope	100	T, PT, C	7/
b. Stiffener end connections	100	T, PT	7/
c. Stiffener web to flange and stiffener web to tank plating	75	T, PT, C	
d. Tilting brackets	50	T, PT, C	9/
e. Attachment welds	100	T, PT, C	9/
C. Foundations			
(1) Welds in foundations			
a. Welds joining foundation material (unless otherwise stated below)	100	B, C, T, PT	7/
b. Penetrations			
1. Water or oiltight	75	T, PT, C	4/
2. Other	50	T, PT, C	4/
c. Attachment welds and welds to foundations	100	T, PT, C	
D. Nonsupport structure			
(1) Welds in nonsupport structure			
a. Welds joining nonsupport structure material (unless otherwise stated below)	100	B, T, PT, C	7/
b. Butt welds in vertical keel	100	B	
c. Penetrations			
1. Water or oil tight	75	T, PT, C	4/
2. Other	50	T, PT, C	4/
d. Weld in masts	100	B, T, PT	
e. Deck and platform stiffener web to deck or flange	75	T, PT, C	

See footnotes at end of table.

TABLE XVIII. Submarine weld joint design requirements 1/ - Continued.

Structural category and connection or type of weld	Minimum joint efficiency (percent) 2/	Weld joint design group	Notes
(2) Welds to nonsupport structure			
a. Stanchion butt weld and head and heel connection	100	B, T, PT, C	7/
b. Web to plating or flange connection in superstructure and fairwater	75	T, PT, C	
c. Connection of decks, floors, and platforms to structure other than pressure hull envelope	75	T, PT, C	
d. Vertical keel to structure other than pressure hull envelope	75	T, PT	
e. Tilting brackets	50	T, PT, C	
f. Welds to the masts	100	T, PT	
g. Attachment welds	100	T, PT, C	9/

1/ Where specific connections are listed, the minimum required joint efficiency and the allowed design group are shown in columns 2 and 3. Where specific connections are not listed in column 1, the joint efficiency and weld joint design group for this connection shall be the same as that required for similar connections in the same structural category.

2/ The weld joint efficiency may be reduced as specified in MIL-STD-1628 when approval is obtained on a case basis.

3/ Only joints PT2V.2 and PT2J.2 of design group PT may be used.

4/ Weld buildup is required on all penetrations containing 0.20 percent carbon or higher prior to welding into structure.

5/ Only joints PT2V.1, and PT2V.5 of design group PT may be used utilizing an automatic or semi-automatic (SAW or gas metal-arc spray mode) welding process approved by NAVSEA. Where joints PT2V.1, PT2J.1, and PT2V.5 are used in pressure hull framing and flooring applications, they shall only be used for internal floors and internal framing. No group PT joints (except for tubing connections) shall apply to welds in reactor plant tanks, or to that portion of frame to pressure hull envelope welds, interrupted by penetration (trunks and valves) within a distance of two times the frame depth from the penetration, or to the periphery joints of holding bulkheads.

6/ Design group PT shall not be used for connection to pressure hull except for joints PT2V.1, PT2J.1, and PT2V.5 for round bar or tubing connection. No group PT joints (except for tubing connections) shall appply to welds in reactor plant tanks, or to that portion of frame to pressure hull

envelope welds, interrupted by penetration (trunks and valves) within a distance of two times the frame depth from the penetration, or to the periphery joints of holding bulkheads.

7/ Joint efficiency of 90 percent is acceptable when a backing bar is required due to inaccessibility. When a backing bar joint is used, the nominal stress at the joint shall not exceed 90 percent of the normally allowable stress.

8/ See figure 11.

9/ C2S.1 joint design is also allowed for attachment welds (see 3.47.1) to category I.B, II, and III structure.

11.3.1 Composite joints. A joint which is both mechanically fastened and welded shall not be used without NAVSEA approval.

11.3.1.1 Bimetallic joints. The bimetallic bonded joints in accordance with MIL-J-24445 are intended for welded structure where steel is to be joined to aluminum alloy, such as the joining of an aluminum deck house to a steel deck on a surface ship. The joints shall be used in atmospheric and dry structural applications only, and require suitable coatings to prevent galvanic corrosion.

11.3.2 Pressure hull envelope attachment in submarines. Every effort should be made to minimize welded structure and miscellaneous attachments to the pressure hull envelope. Permanent attachments to the pressure hull envelope, which are on the opposite side of the pressure hull plating from the frames, shall be located on the frame line whenever possible. For this purpose, the frame line is defined as a width equal to the hull plate thickness on either side of the centerline of the frame web. Arc stud welds or capacitor discharge welded studs, not more than 1/4 inch in diameter, may be applied anywhere on the pressure hull.

11.3.3 Penetrations in submarines. The toes of full penetration welds connecting a penetration to the pressure hull envelope shall be separated from the toe of any other full penetration or partial penetration weld in or to the pressure hull envelope by 3/4 inch. For a fillet weld or partial penetration weld, the minimum separation shall be 1/2 inch from any other weld. Penetrations in other than the pressure hull envelope are exempt from this requirement.

11.3.3.1 Intersection. Penetrations in the pressure hull envelope shall not intersect a full penetration weld except where necessary. Where it is necessary for a penetration to intersect a welded butt joint, the penetration should preferably be centered on the weld of the butt joint or shall intersect and overlap the welded butt joint by at least 3/4 inch as shown on figure 12.

11.3.3.2 Distance. The distance between the centerline of a penetration in the pressure hull envelope and an adjacent frame, floor, or bulkhead should be a minimum $\geq$ 20 percent of the frame space, subject to noninterference with frame flanges for welding accessibility.

11.3.4 Inserts, patches, and small plates in submarines. The minimum dimension of an insert, patch, or small access plate in the pressure hull envelope shall be 4T or 6 inches, whichever is larger, where T is the thickness of the member penetrated. The minimum dimension of an insert, patch or small access plate in plating and structure other than pressure hull envelope shall be 4T or 3 inches, whichever is larger, where T is the thickness penetrated. Corners of inserts or patches and small access plates in the pressure hull envelope shall have a minimum radius as shown on figure 13 except where those inserts, patches or small access plates land on full penetration butt joints. Corners of inserts, patches, or small access plates in plating and structure other than the pressure hull envelope shall have a minimum radius as shown on figure 14.

11.3.4.1 Inserts, patches, small access plates. Inserts, patches, or small access plates in the pressure hull envelope shall not intersect any other full penetration butt welds unless they land on these welds or cross them at a 90 ± 15 degree angle as shown on figure 15. When the boundaries of inserts, patches, or small access plates in the pressure hull envelope land on existing full penetration butt welds, the common length of weld shall be not less than 12 inches. When the boundaries of inserts, patches or small access plates in the pressure hull envelope do not land on existing full penetration butt welds, the toes of the weld of the insert, patch, or small access plate shall be a minimum of 3 inches from the toe of the weld of any other full penetration butt welds, except for the following:

(a) Circular inserts.
(b) Circular patches.
(c) Circular small access plates.
(d) Penetrations.
(e) As specified in 11.3.4.2.

The above items (a) through (d) shall have weld toe-to-toe distances as specified in 11.3.3.

11.3.4.2 Terminations on full penetration butt joints. When insert, patch, or small access plate welds in the pressure hull envelope terminate on other full penetration butt joints, the existing weld shall be cut back a minimum distance of 3 inches, except where such cut-back would result in less than 2 inches of existing weld remaining between the end of the cut-back and adjacent frame web, bulkhead surface, or tank top. In such cases, the minimum cut-back shall be terminated not less than 2 inches from the adjacent frame, bulkhead surface, or tank top, but in no case shall the cut-back be less than 2 inches long. When it is anticipated that this latter situation will occur, the weld toes of insert, patch or small access plate welds shall be limited to a minimum of 4 inches from the weld toes of the adjacent frame web, bulkhead surfaces, or tank top.

11.3.5 Access and closure plates in submarines. Corners of access and closure plates in the pressure hull envelope shall have a minimum radius of 6 inches, except when a boundary lands on an existing hull longitudinal or circumferential butt joint. In the latter instances, the corners shall intersect the butt weld at an angle of 90 ± 15 degrees.

11.3.5.1 Boundaries. Boundaries of access and closure plates in the pressure hull envelope shall either land on existing hull (circumferential or longitudinal) butt joint or the weld toe-to-toe spacing from any adjacent hull butt joint shall be a minimum of 3 inches, except for the items specified in 11.3.4.1(a), (b), (c) and (d). These items shall have weld toe-to-toe distances as specified in 11.3.3. When a transverse boundary of an access or closure plate does not land on an existing butt joint, it shall be located so that the center of the weld is between 15 and 25 percent of the frame space from the face of the adjacent frame or bulkhead.

11.3.5.2 Terminations on full penetration butt joints. When access or closure plate welds in the pressure hull envelope terminate on other full penetration butt joints, one of the existing longitudinal or circumferential butt welds shall be cut back a minimum distance of 3 inches except where such cut back would result in less than 2 inches of existing weld remaining between the end of the cut back and adjacent frame web, bulkhead surface, or tank top. In such cases, the minimum cutback shall be terminated not less than 2 inches from the adjacent frame, bulkhead surface, or tank top but in no case shall the cut back be less than 2 inches long. When it is anticipated that this latter situation will occur, the weld toes of the access or closure plate welds shall be limited to a minimum of 4 inches from the weld toes of the adjacent frame web, bulkhead surface, or tank top.

11.3.6 Inserts, patches, and small access plates in surface ships. The minimum dimension of an insert, patch, or small access plate shall be 4T or 3 inches, whichever is larger, where T is the thickness of the member penetrated. Corners of inserts, patches, and small access plates shall have a minimum radius as shown on figure 14.

11.3.7 Access and closure plates in surface ships. Boundaries of access and closure plates shall be located between principal ship framing or bulkheads, and shall be at least 3 inches from any of these members. When variance from this 3-inch minimum is required by special circumstances, such variances shall be subject to approval. The boundaries of access and closure plates should land on existing butts or seams wherever practicable. No cuts shall be made in the sheet, stringer or bilge strakes, or in the flat keel, unless approved on a case basis. Welding closer than 6 inches to a mechanically fastened joint should be avoided. Corners of access or closure plates shall have a mimimum radius of 6 inches, except when a boundary lands on an existing hull longitudinal or transverse butt joint. In the latter instance, the corners shall intersect the weld at an angle of 90 ± 15 degrees (see figure 15). Closure plate weld joints shall be full penetration, 100 percent efficient welds.

11.3.8 Make-up plates. Make-up plates welded into primary structure shall have a minimum width of 6 inches.

11.3.9 Vent and drain holes. Where water or oil tightness or strength is not a consideration, use of permanent corner or scallop holes in members joining to plating shall be permitted to provide accessibility for welding and for vents and drains. The maximum allowable size for holes shall be determined by design consideration. Typical vent and drain holes are shown on figure 16. The relief or keyhole type vent and drain hole shown on figure 17 may be used as an alternate.

11.3.10 Snipes. Snipes shall be provided as necessary in all systems of intersecting full penetration welds to allow the deposition of sound weld metal at such intersections. The location of snipes shall be governed by the details of welding sequence, and snipe dimensions shall be the mimimum required to allow satisfactory completion of welding in the through joint. Bevels shall be provided on snipes to allow proper closure welding, and such welding shall be in accordance with the requirements of this section (see figures 18 and 19).

11.3.11 Water and oil stops. Water and oil stops shall be used for all tight structures. As a minimum, these stops shall be located at all through members on tight structures (bulkheads, decks and platforms). Stops shall be located on the tank side of the boundary, and for adjacent tanks, stops shall be located on both sides of the boundary. For through member nontight structures, a continuous fillet weld along the member and through the snipe may be used. The snipe should be approximately 6 inches from the intersection but shall not be located directly under a structural supporting member. Generally, oil or water stops of welded type shall be 45-degree, single V-groove welds with root not less than 1/4 inch. Where stops other than welded type are used in welding construction, the material and installation shall be such that the stops are not damaged by welding.

11.3.12 Tank boundaries. Unless otherwise approved by NAVSEA, all fillet welded joints in tank boundaries shall have a minimum of two weld layers per side.

11.3.13 Type A protective compensation. Compensation shall be required for holes and penetrations in type A protective plating and for holes and penetrations over 12 inches in diameter or equivalent area in fragmentation plating. Compensation criteria shall be as specified in the individual ship specification.

11.3.14 Protective plating other than type A. There are no welding design requirments for types of protective plating other than type A. For these types of protective plating, welding that is adequate for the structural purpose is adequate for the protective purpose of the plating.

12. ERECTION REQUIREMENTS

12.1 General. The detail specifications may require special tolerances for specific fabrication and erection applications. Where this condition exists, the tolerances specified in the detail specifications shall apply.

12.2 Assembly and erection. General allowances for shrinkage of steels are shown on figure 20. These values are for general guidance only and will depend upon factors such as fixturing, joint restraint, welding process, sequence of welding, heat input and size of welds. Unless otherwise specified, joints welded in a single pass shall not be used for joining main or strength deck plating to shell plating (shear and stringer strakes) or to gunwale bars.

12.2.1 Riveting and mechanical fastening. Riveting and other mechanical fastening shall be in accordance with section 15.

12.3 Alignment and fairness.

12.3.1 Plate and shape alignment tolerances. Where structures are bolted or tacked in preparation for welding, the deviation of alignment or surfaces in way of joints shall be so that after welding, the requirements specified in table XIX shall be met.

TABLE XIX. Butt type joints in plate and shapes.

Thickness (inches)	Maximum allowable deviation (inch)
Surface ships:	
Less than 3/8	1/16
3/8 to 3/4	1/8
Over 3/4 to 1-1/2	3/16
Over 1-1/2	1/4
Submarines:	
5/8 and less	1/16
Over 5/8	1/8

12.3.1.1 Intercostal structure (surface ships and submarines). Discontinuous members on opposite sides of a through member shall line up back to back with a limit of error in offset not exceeding one-half the thickness of the through member. Where the discontinuous member is a structural shape, both webs and flanges shall be aligned within this limit. On longitudinal framed ships, the principal longitudinal strength structure shall be continuous through transverse structure unless approved by NAVSEA.

12.3.2 Structural fairness.

12.3.2.1 Surface ships. Unfairness (deviation from the design molded line) of welded plating shall not exceed the tolerances shown on figures 21 and 22 for steel structure, and figures 23 and 24 for aluminum structure. Permissible unfairness shall result in a generally fair curve across the panel, except that for aluminum structure, and additional deviation of 1/8 inch from the fair curve is permitted in way of welded butts and seams. Sharp knuckling or joggling in way of stiffeners shall be avoided by use of fabrication techniques such as dishing, drum heading or restraint, which will minimize distortion. A procedure for measuring fairness and taking corrective actions shall be developed and shall be available for review by the authorized representative prior to construction. If aid is necessary in determining the acceptability of the fairness of welded structure, a measurement of the unfairness of plating may be made in the area of interest. In such cases, the measurement shall be made across the minor dimensions of the panel. The tolerances specified on figures 21, 22, 23 and 24 are plus or minus dimensions from a fair line.

12.3.2.1.1 Tolerances on figures 21 and 23. Tolerances shown on figures 21 and 23 apply to the following:

(a) Entire shell.
(b) Uppermost strength deck.
(c) Longitudinal strength structures within the midships 3/5 length for displacement type ships, or as specified for other types of ships, which includes innerbottom tank and the deck next below the uppermost strength deck if continuous above machinery spaces.
(d) In transversely framed ships, the permissible unfairness for structure noted in (a), (b) and (c) above is reduced by 1/8 inch.
(e) Bulwarks and exterior superstructure bulkheads.

12.3.2.1.2 Tolerances on figures 22 and 24. Tolerances shown on figures 22 and 24 apply to the following, except when the structures fall into both categories of 12.3.2.1.1 and 12.3.2.1.2; then the requirements of 12.3.2.1.1 shall take precedence:

(a) Structural bulkheads forming a boundary of a living space (stateroom, office, berthing, messing or lounge area) and passageways contiguous to such spaces.
(b) Decks within the hull and superstructure in way of the above living spaces.
(c) Decks exposed to the weather.
(d) Tanks and main transverse bulkheads.
(e) Innerbottom plate longitudinals.

12.3.2.1.3 Other structural bulkheads and decks. For other structural bulkheads and decks, and unfairness as shown on figures 22 and 24, as applicable, may be increased by 1/8 inch. For stiffener spacings greater or less than those shown on figures 21, 22, 23 and 24 respectively, the curves shall be extrapolated proportionately. For material thickness greater than 1 inch, the tolerance for 1 inch thick material is applicable.

12.3.2.1.4 Deviations. Unless otherwise specified, deviations from the molded form (surface ships) shall not exceed the following limits:

(a) Plus or minus 1/2 inch from the vertical longitudinal center plane with an additional plus 1/2 inch tolerance for ships greater than 100 feet in beam.
(b) Plus or minus 1 inch in 100 feet of length.
(c) Plus or minus 1 inch of beam with an additional plus 1 inch tolerance for ships greater than 100 feet of beam.
(d) Between-deck heights shall be within plus or minus 3/8 inch. Accumulated deviation at any deck level shall not exceed plus or minus 1 inch from the molded deck line. An additional accumulated deviation tolerance of plus 1/2 inch is permitted for ships with a depth greater than 50 feet from baseline to uppermost continuous deck.
(e) To determine compliance with the above tolerances, a procedure shall be developed describing the method used and location of measurements. The procedure and data derived shall be maintained and be available for review by the authorized representative.

12.3.2.1.5 Correction of frame, beam, and stiffener bows. Frame, beam and stiffener bows in primary strength structure or structure subject to dynamic loading shall be corrected when it varies plus or minus from the designed or molded line in excess of the following:

$$\frac{\text{Span (feet)}}{\text{Depth (inches)} \times 4} = \text{tolerances (inches)}$$

where span is the distance between the fixed ends at support structure, and depth is the depth of a stiffening member measured from the underside of the flange. The measurement shall be taken from the most distorted position of the web.

12.3.2.2 Submarines. Plate panel fairness and pressure hull frame tolerances for submarines shall be as specified in MIL-STD-1688.

12.3.3 Straightening (steel). Where preventive measures are insufficient to control distortion and fairness tolerances are exceeded, straightening shall be employed to the minimum extent necessary to bring the plating within the tolerances specified. Straightening by the use of heat

shall not be employed on stringer and shear strake plating within the 3/5 midship length for displacement type ships, or as specified for other ships. Flame straightening may be used for hull structural applications involving steel in the as-rolled or normalized condition (except as specified herein). Higher strength steels may be faired by flame straightening; however, on these materials, this method shall be kept to a minimum, due to possible degradation of mechanical properties. On the high-yield strength (HY-80/100, HSLA-80), and high-hardenable steels, flame straightening shall not be employed. After fairing operations, welds in affected areas shall be inspected in accordance with section 6.

12.3.4 Straightening (aluminum). Shrink welds may be used but flame straightening shall not be employed on aluminum alloys without the procedure being approved by NAVSEA.

12.4 Circularity (submarines). For new construction submarine work, circularity measuring requirements shall be as specified in MIL-STD-1688. For submarine repair and overhaul work, circularity measuring requirements shall be as specified in MIL-STD-1688.

13. WELDING REQUIREMENTS

13.1 Welding procedure and performance qualification. Welding procedures, welders and welding operators shall be qualified in accordance with section 4, prior to their employment in production work.

13.1.1 Vertical position, down progression. The vertical position, down progression shall be restricted to the root pass of multi-layer welds for submarine pressure hull structure, containment structure, intermediate pressure tanks, or surface ship structure. Vertical position, down progression shall be restricted to the first pass for all other applications.

13.1.2 Gas metal-arc. Gas metal-arc (short-circuiting transfer process) shall not be used for welds in submarine or surface ship structure except when approved by NAVSEA.

13.2 Joint preparation. Plate edges shall be prepared for welding in accordance with section 14. In addition to weld buildup to correct oversize root openings, weld buildup may be used on surfaces or edges of materials in way of penetrations or connections prior to making joint fit-up. As an alternative, temporary backing of compatible metallic or other approved materials may be used in the joint root to allow welding across the excessive root opening provided it is subsequently removed prior to completing the weld. In all cases involving welding to correct excessive root opening, the joint edges shall not be joined until the oversize root opening is corrected to within the requirements as specified in MIL-STD-22.

13.2.1 Joint configuration. Weld joint configurations prior to welding shall be in accordance with section 11 with the following special considerations:

(a) Unbalanced double-bevel butt joints may be welded from either side first.
(b) Unbalanced double-bevel tee joints or single-bevel tee joints may be welded from either side first.
(c) Double-bevel weld joint designs may be prepared by beveling one side prior to any welding, and the second side beveled after sufficient welding on the first side. Joint preparation technique shall be in accordance with section 14.
(d) Single- or double-bevel groove joints within the same design group may be interchanged provided joint efficiencies are not reduced. Full penetration joint designs may be substituted where partial penetration joint designs are specified. Where this is done, the inspection requirements of the partial penetration joint design applies.

13.2.2 Weld root cleaning. Unless otherwise permitted by welding procedure approval (for example, twin arc) the root of a joint to be welded from both sides and which requires complete penetration shall be chipped, ground, or gouged after sufficient welding has been done on one side and before any welding is started on the opposite side in way of the weld deposited on the first side. The weld root area shall be cleaned to sound metal and contoured so as to allow sound deposition of the root pass from the second side. Prior to deposition of any weld metal from the second side, the root area shall be VT inspected as specified in section 6.

13.2.3 Weld root and repair excavation contour. Background roots and weld repair areas shall he contoured to produce an excavation which is fully visible to the welder and allows access for welding. The excavation shall have sidewalls sloping without sharp breaks or keyholing from the surface to the bottom, with a bottom radius of 1/8 inch minimum and width sufficient to allow proper accessibility and electrode manipulation (see figure 25).

13.2.4 Additional requirements for HY-80, HY-100, and high-hardenable materials. The use of oxyfuel gas gouging shall be prohibited for HY-80, HY-100, and high-hardenable materials.

13.2.5 Removal of austenitic or nonferrous weld metal. When it is necessary to make ferritic welds over areas that previously contained austenitic or nonferrous welds, an acid etch test shall be used to ensure complete removal of the austenitic or nonferrous weld metal.

13.3 Welding materials. Welding materials shall be in accordance with the requirements of section 10.

13.4 Preheat procedures and controls.

13.4.1 Methods. Preheat may be applied by any of the following methods and in any combination:

(a) Resistance heaters.
(b) Induction.
(c) Soft gas torch (gas-air).
(d) Oxyfuel torch.
(e) Furnace.
(f) Radiant.
(g) Other approved methods.

13.4.2 Application. When the base metal is below the specific minimum temperature, it shall be preheated so that the parts on which weld metal is being deposited are at or above the specified minimum temperature.

13.5 Preheat and interpass temperatures. Preheat and interpass temperatures for production and repair welding shall be in accordance with table XX. For materials other than those listed, preheat and interpass temperatures shall be established by the procedure qualification test. If the preheat temperature drops below 113°F on uncompleted welded joints in or to HY-80/100 (1-1/8 inches and over) or high-hardenable materials, the partially completed welds shall be inspected in accordance with section 6 before resumption of welding. Reheating to within the specified temperature range prior to the resumption of welding may be done before or after this inspection.

TABLE XX. Preheat and interpass temperature for joint welding, tacking, or overlaying. 1/2/3/4/5/6/7/

Material	Thickness	Preheat and interpass Temperature for welding (°F)	
		Minimum	Maximum
8/ HY-80/100 STS 10/	1-1/8 inch and over	9/ 200	300
	Over 1/2 inch and less than 1-1/8	125	300
	1/2 inch and less	60	300
HSLA-80	1 inch and over	60	300
	Less than 1 inch	32	300
HSS steel and equivalent grades with 0.30 percent carbon maximum	1 inch and over	60	N/A
Structural steels with carbon greater than 0.30 percent	All	11/	11/

See footnotes at end of table.

TABLE XX. Preheat and interpass temperature for joint welding, tacking, or overlaying 1/2/3/4/5/6/7/ - Continued.

Material	Thickness	Preheat and interpass Temperature for welding (°F)	
		Minimum	Maximum
Austenitic stainless (CRES)	All	60	350
Nickel-copper	All	60	350
Copper-nickel	All	60	350
Bronzes (except Ni-Al bronze)	All	11/	11/
Aluminum alloys	All	11/ 12/	11/ 12/
Nickel Aluminum Bronze	All	11/	600

1/ Based on thicker member.
2/ When welding STS, HY-80, or HY-100 to OS, HSS and HSLA-80 steels, the requirements for STS, HY-80, or HY-100, respectively, shall apply.
3/ After either one or both members of a HY-80, HY-100, or STS weld joint is built up 3/16 inch minimum or two layers prior to joint welding, the 200°F minimum preheat and interpass temperature of the built-up member or members may be reduced to 150°F minimum when making any additional buildup and subsequent weld.
4/ When employing austenitic stainless steel or nonferrous filler materials specified in section 10 for overlay application on HY-80, HY-100, or STS, the 200°F minimum preheat may be reduced to 60°F.
5/ When HY-80, HY-100, or STS has been built up with austenitic stainless steel or nonferrous weld metal to 3/16 inch or two layers, welds may be made between the buildup and austenitic stainless steel or nonferrous metals, provided the HY-80, HY-100, or STS material temperature is not lower than 60°F or interpass higher than 350°F.
6/ For surface ships where nonferrous or austenitic stainless steel electrodes are used for nonstructural and miscellaneous attachments to OS, HSS and HSLA-80 steel, STS, HY-80, or HY-100, minimum preheat shall be 60°F, unless lower temperatures, as permitted above, are allowable for the thickness of material.
7/ The preheat and interpass requirements may deviate from those specified when welding in close proximity to low melting temperature materials, such as plastics or lead, when approved by NAVSEA.
8/ For attachment welds of OS and HSS steel to HY-80 material, regardless of thickness, preheat may be reduced to 60°F when using type MIL-7018-M

accordance with MIL-E-23765/1, or type MIL-71T-1-HY flux cored electrodes in accordance with MIL-E-24403/1 with equivalent diffusible hydrogen maximum specified and when using a procedure specifically approved by NAVSEA for the reduced preheat requirement.

9/ When using MIL-7018-M, MIL-8018-C3 or applicable bare wire filler materials, 150°F preheat may be used.

10/Preheat shall be 60°F minimum and interpass 350°F maximum when using austenitic stainless steel electrodes.

11/Temperature ranges for joint welding, tacking, overlaying or gouging shall be as established in procedure qualification tests.

12/For 5000 series aluminum alloys, holding in temperature range between 150 and 450°F shall be avoided insofar as practicable or feasible.

13.5.1 Use of torch heating. Torch heating for HY-80, HY-100, and high-hardenable material should be confined to tack or temporary welding or to those applications involving welding within a localized area. When torch heating is used for welding operations other than for tack welding, the base material shall slowly be brought up to preheat temperature with sufficient time allowed for heat to soak through the thickness of the parts being welded. The heated area should extend approximately 6 inches beyond the weld site in all directions. Exceptions to the above are as follows:

(a) Those instances in which torch heating is used as an accessory device to decrease the time required for reaching preheat temperature on material which is being heated with electric heaters.

(b) Those instances in which an element of a weld joint provides insufficient heat sink capacity to warrant the use of electric heaters because of the rapid increase of interpass temperature which will occur when welding is initiated. Examples of the latter are face plates or coamings on "lightening" and access openings, flanges on light stiffening members.

(c) For miscellaneous hanger and attachment welds where the 6-inch distance is impractical, the distance may be reduced to suit job conditions.

When torches are used for low temperature (60 to 125°F) preheating, moisture condensate caused by the flame may be deposited in the weld joint. This moisture should be removed by maintaining metal temperature above ambient temperature for a few minutes before welding.

13.5.2 Preheat and interpass temperature measurement. Temperatures of 113°F and above shall be measured using temperature indicating crayons or other approved means. When the ambient temperature is below the required minimum preheat or there is evidence of moisture on the material surface, preheat shall be applied until the area is warm to the touch and dry. Temperature indicating crayons shall not be used within the weld joint. Preheat temperature shall be measured on the surface of the base material on the side from which welding will be performed and within 3 inches of the area to be welded. Interpass temperature shall be measured on the surface of the

base material on the side from which welding will be performed and within 1 inch of the weld joint edge and along the joint within 3 inches of the start of the next weld pass. Weld pass shall be defined as extending for the length of a block or joint being welded, even though more than one start or stop may be required to complete the length of the block or joint.

13.6 Heat input. When welding with any process in or to HY-80, HY-100, HSLA-80 or STS, the limits for heat input as measured in joules per inch, based on the thickness of the thinner member, shall conform to the values listed below unless otherwise exempted.

Plate thickness (inch) 1/2/	Maximum joules/inch
Less than 1/2	45,000
1/2 and greater	55,000

1/ The word "maximum" shall not be interpreted as either nominal or average.
2/ For type MIL-10018-M and MIL-12018-M2 electrodes 1/8-inch and smaller, the maximum heat input in the flat welding position shall be 45,000 joules/inch for thicknesses 1/2-inch and greater and 35,000 joules/inch for thickness less than 1/2-inch.

13.6.1 Alternate heat inputs. Except as specified in 13.6.2, approval shall be required for alternate heat inputs exceeding the 45,000 and 55,000 joules per inch limitations. This shall require special procedure qualification approval by NAVSEA.

13.6.2 Root passes. Root passes which will be removed are exempt from the heat input requirements specified in 13.6.

13.6.3 Twin arc roots. When detailed on the qualified procedure, root passes of twin arc welded joints may be exempted from the requirements specified in 13.6 when the following conditions are met:

(a) The cross-sectional thickness of both passes does not exceed 3/8 inch.
(b) The joint design is such that the surface of the twin-arc beads will be not less than 3/8 inch from the completed weld surface.

13.6.4 Computation of heat input for HY-80/100, HSLA-80, or STS. For computing the heat input (joules/inch), the following formula applies:

$$\text{Heat input (joules/inch)} = \frac{\text{arc voltage x welding amperage x 60}}{\text{rate of travel (inches per minute)}}$$

13.7 Tack welds. Tack welds shall be made with the same type electrode as that to be used in the final weld (except as specified in section 10). Tack welds should be of the same quality and should be deposited so as to facilitate incorporation into the final weld. Cracked tack welds and those of

poor quality or workmanship shall be removed, except that cracked or poor quality tack welds deposited on the backside of a weld joint need not be removed prior to welding the first side if the backside is to be backgouged. Cracked single pass tack welds need not be removed provided the tacks will be fully incorporated into new weld metal by using an approved SAW process which has been demonstrated to fully consume the tack welds.

13.7.1 Block tack welds. Block tack welds which are made by qualified welders (not tack welders) in accordance with the requirements of this section and are inspected in accordance with the requirements of section 6 are considered initial increments of the final weld. Block tacks should not exceed 18 inches in length and shall be deposited to a depth of at least 1/4 of the joint thickness.

13.8 Slag removal. Slag shall be removed before starting to deposit subsequent beads and before nondestructive testing. Slag shall be removed by chipping, grinding, or other suitable mechanical means. Silicates formed during gas tungsten or gas metal-arc welding need only be removed to the extent necessary that they do not interfere with welding or required NDT.

13.9 Ferritic welds. Ferritic welds of any type shall not be deposited on austenitic or nonferrous welds or base materials.

13.10 Buttering or buildup. Where buttering or buildup by welding on the joint surface to correct oversize root opening or errors in joint preparation is accomplished, it should be done prior to joint welding, and unless specifically approved otherwise, such buildup of each joint edge shall not exceed T or 1/2 inch, whichever is less, where T is the thickness of the thinner member being welded. Where one side of a joint may not be accessible, the total of buttering or buildup (that is, 2T or 1 inch, whichever is less) may be deposited on one member. When root openings cannot be corrected within this limitation, repair shall be made using patches, make-up plates, and so forth, in accordance with section 11. Buttering or buildup may be employed for fairing or for other corrections over or adjacent to welds, provided the above restrictions are not exceeded. This buildup shall be considered part of the involved weld. The buttering or buildup shall be deposited with electrodes specified in section 10, using methods and procedures in accordance with this section. Temporary backing may be used to assist in the buttering or buildup. However, in all cases involving welding to correct excessive root opening, the joint edges shall not be joined until the oversize root opening is corrected to within the requirements specified in MIL-STD-22.

13.11 Arc stud welding. Arc stud welding shall be permitted when procedures and equipment are qualified in accordance with section 4. Inspection of production stud welding shall be in accordance with section 6. Before welding permanent studs when there is evidence of moisture on the material surface, preheat shall be applied until the area is warm to the touch and dry. There is no preheat restriction for welding temporary studs.

13.12 Weld cutback requirement. Weld cutback requirements and recommended welding sequence for plate replacements, make-up plates and closure plates shall be as shown on figure 26.

13.13 Welding over galvanized surfaces. Welding over galvanized coated surfaces using electrodes other than those conforming to types G6010 and G6011 as specified in AWS 5.1 shall be in accordance with MIL-STD-248, level I procedure qualification, in accordance with sections 4 and 14.

13.14 Welding over primer coated surfaces. Welding over primer coated surfaces of OS steel (or equivalent grades) and HSS steel (or equivalent grades) with electrodes conforming to type 6011 in accordance with AWS 5.1; and types MIL-7018-M in accordance with MIL-E-22200/10 and MIL-8018-C3 in accordance with MIL-E-22200/1, is permitted under the following conditions:

(a) The primer meets general or detailed ship specifications.
(b) The welding procedure is qualified in accordance with section 4.
(c) Production welding meets the inspection requirements as specified in section 6.

13.15 Welding of precipitation hardenable alloys. Welding of precipitation hardenable alloys, except HSLA-80, shall be prohibited unless approved by NAVSEA.

13.16 Oxyfuel gas welding. Oxyfuel gas welding shall be prohibited on quenched and tempered steels.

13.17 Repair of base materials and welds. Welding shall be done subject to all the requirements of this standard. Type MIL-10018-M1 electrodes may be used for repair of fillet or groove tee welds in HY-100 material that were originally made with other electrodes specified in section 10 provided the following requirements are met:

(a) The length of such repair does not exceed 6 inches and adjacent repairs within the same weld joint are more than 3 feet apart, or alternately,
(b) Fillet or partial penetration groove tee welds shall be resized in way of the repair area to account for any difference in strength level of the type MIL-10018-M1 electrode when compared to the electrode employed for the original weld being repaired.

13.17.1 Repair of holes. Holes may be welded closed provided the original hole diameter does not exceed 2-1/2 inches and the material is 1/4 inch or greater in thickness. The opening shall have an included angle of 20 degrees minimum and shall be open at the root greater than 1/2 inch. Partial penetration holes shall have 3/16 inch minimum remaining material or shall require visual inspection of the backside for burn through. Full penetration welds shall be used to repair through thickness holes. Through thickness holes welded against backing bars shall have the backing bars removed if

accessible and the back surface inspected in accordance with section 6. Holes greater than 2-1/2 inches original diameter or holes in plate less than 1/4 inch shall be repaired by expanding the hole size for a circular patch in accordance with section 11. Partial penetration holes greater than 2-1/2 inches diameter may be welded closed to the above requirements provided depth of the hole does not exceed 20 percent of the base material thickness.

13.17.1.1 Alternate methods of repairing holes. Alternate methods which may be used for repairing holes in surface ship secondary structures when approved are shown on figure 27.

13.17.2 Inspection of repair welding. Repair welding shall be subject to the inspection requirements as specified in section 6.

13.18 Post weld heat treatment. When specified, welded assemblies shall be heat treated for the purpose of reducing residual stresses, maintaining dimensional stability and for improving the properties of the weld or base metal. The post weld heat treatment shall be in accordance with table XXI. Post weld heat treatment other than that specified in this section shall be subject to approval.

TABLE XXI. Post weld heat treating procedure.

I. Furnace A. General	When specified, a welded structure shall be subject to post weld heat treatment for the purpose of relieving stresses, maintaining dimensional stability or improving the characteristics of the base or weld metal. When a complete weldment is to be heated in a furnace, support shall be provided to minimize the change in shape due to its weight. Extra material should be left on surfaces to be finished to allow for this movement and possible scaling caused by stress relieving. There shall be no direct impingement of flame on the material being treated.

TABLE XXI. Post weld heat treating procedure - Continued.

B. Temperature measuring equipment	Temperature measuring equipment shall be provided to indicate the temperature of the weldment. The average of the observed temperature of the weldment at different locations (or of the installed pyrometer if it has been demonstrated that the furnace has been constructed and instrumented in such a manner that the temperature of the weldment can be maintained within the required range by controlling the furnace temperature) is considered to be the temperature of the weldments. Heat treating operations shall be recorded by potentiometers furnished with autographic records.
C. Location	When used, thermocouples shall be located to measure the temperature at the anticipated hottest and coolest points on the weldment. The number of thermocouples provided shall assure complete coverage of the weldment and adequate temperature history. If more than one weldment is to be stress relieved at the same time, thermocouples shall be provided for each weldment except as permitted in B above. However, no more than six thermocouples shall be required for a furnace charge.
D. Installation	Thermocouple wires shall be electrically insulated except at their hot junctions. In order to avoid erroneous readings, thermocouples shall be so arranged that flames do not impinge on cold or hot junctions or on the wires themselves. Thermocouples shall be attached to the weldment by a method which ensures that the wires are held firmly in metallic contact with the weldment. This may be accomplished by inserting the thermocouple wires in a small pool of molten weld metal or by mechanical means.

TABLE XXI. Post weld heat treating procedure - Continued.

E. Temperatures	To avoid setting up harmful stresses due to temperature gradients within heavy sections, the rate at which the temperature of the weldment is raised and lowered shall be as follows unless otherwise specified for the material involved: The rate at which the temperature of the weldment is raised above 500°F during stress relieving shall not exceed 400°F per hour or (400/T)°F per hour whichever is the lesser (T = maximum material thickness). The rate of heating and cooling of the weldment in the furnace shall be controlled by maintaining a temperature difference of not more than 75°F between any two thermocouples attached to the weldment, when the furnace temperature is above 500°F. During the holding time at the specified stress relieving temperature, the maximum temperature difference between the two points of the weldment shall not exceed 50°F. Upon cooling, the weldment may, if desired, be removed from the furnace when the maximum temperature of the weldment has fallen to 500°F.
II. Local	
A. Heating method	Post weld heating shall be accomplished by the use of electric inductance or electric resistance devices or other approved local heating methods.
B. Heating rate	The heating rate shall not exceed 40°F per 5-minute period.
C. Holding variation and cooling rate	The holding temperature variation and cooling rate shall be as specified in I.E. of this table.

TABLE XXI. Post weld heat treating procedure - Continued.

D. Width of heating	Post weld heat treatment requires uniformly heating a band having a minimum width of six times the material thickness on each side of the weld joint.
E. Temperature measuring equipment	The temperature measuring equipment and the location and installation methods shall be as specified in I.B., I.C., and I.E. of this table.

13.18.1 Heat treatment restrictions. Stress relieving of HY-80/100, HSLA-80 and STS materials shall be prohibited. For other materials, if considered necessary, stress relieving may be employed for dimensional stability during machining or as an intermediate treatment for cold forming. Heat treatment shall be performed in accordance with table XXI. Unless approved by NAVSEA, post weld stress relief if prohibited for any weldments containing weld deposits of nonferrous or austenitic stainless steel filler metals. Nonferrous or austenitic stainless steel materials or filler metals shall not be attached or applied to any ferritic steel weldment prior to any required post heat treatment without NAVSEA approval for each application.

13.18.2 Temperatures. The specific temperatures and soak times for post weld heat treatments shall be in accordance with table XXII. References to the base material or weldment thickness in accordance with table XXII apply to the thickness of the base material immediately adjacent to the weld deposit.

TABLE XXII. Post weld heat treating parameters. 1/

Material	Temperature	Remarks
OS and HSS steel	1150 ± 50°F 2/	
Austenitic stainless steel		Weldments shall not be post weld heat treated without approval.
Nickel-copper	1150 ± 50°F	
Copper-nickel	575 ± 25°F	Heat treatment for dimensional stability only.

See footnotes at end of table.

TABLE XXII. Post weld heat treating parameters 1/ - Continued.

Material	Temperature	Remarks
OS and HSS steel	1150 ± 50°F 2/	
Aluminum		Weldments shall not be post weld heat treated without approval.
Bronze		Only heat treatable bronze alloys approved for the specific application may be stress relieved. The heat treatment shall be as established in procedure qualification testing.

1/ Holding times shall be 1 hour per inch of thickness of the weld thickness, or fraction thereof.

2/ When the 1150°F temperature is impractical, the following may be used:

Holding temperature plus 50, minus 0°F	Holding time (hour/inch thickness)
1050	2
1000	3
950	5

13.19 Environmental control. When using the gas metal arc welding (GMAW) process in the open environment for aluminum plating butt welds of superstructures, positive shielding of the weld site shall be provided to prevent disturbance of shielding gases. Rigid enclosures shall be used unless otherwise approved.

13.20 Welding equipment grounding. Welding equipment grounding requirements shall be in accordance with NAVSEA S9086-CH-STM-010/CH-074VI.

13.21 Welding in way of wetted surfaces. Welding shall be prohibited on material where preheating is required when water, oil, or similar materials are in contact with the surface opposite the side to be welded, and when less than 1/4 inch of base material is between the weld area and the side in contact with the liquid, unless a NAVSEA approved procedure is used. This restriction does not apply to materials which do not require pre-heating.

14. WORKMANSHIP REQUIREMENTS

14.1 Weld joint preparation. Plate edges shall be prepared for welding by any one or combination of the following methods:

(a) Machining (such as planing or shearing).
(b) Oxyfuel gas cutting.
(c) Carbon arc-air gouging.
(d) Chipping.
(e) Grinding or burring.
(f) Plasma arc cutting.
(g) Automatic oxyfuel gouging.

14.1.1 Weld joint surface preparation. Flame or arc cut surfaces shall be in accordance with NAVSEA 0900-LP-999-9000. Surfaces to be welded and adjacent surfaces for a distance of approximately 1/2 inch from the expected weld area shall be clean, dry and free of surface matter or defects such as paint, oil, grease, moisture, scale, oxide or rust, and objectional nicks, gouges and irregularities, to an extent that weld soundness will not be detrimentally affected.

14.1.1.1 Aluminum alloys. On aluminum alloys, surfaces to be welded shall be free of oil, grease and markings. In addition, the oxide film shall be removed from joint and faying surfaces as well as contiguous (adjacent) surfaces within 1/2 inch of the weld joint by means of a clean stainless steel wire brush or by approved chemical means. Welding shall take place within 16 hours after oxide film removal or the joint shall be recleaned.

14.1.1.2 Zinc coatings. In the following cases, metallic zinc shall be removed from all joint surfaces on which welds are to be deposited and for a distance which will be at least 1/2 inch from the edges of the finished welds:

(a) Connections of main transverse watertight bulkheads to shell.
(b) Main condenser induction and discharge sea chests and their connections to the hull.
(c) Connections of main propulsion machinery foundations to shell or innerbottom plating.
(d) Deck seamanship installations and fittings.
(e) Weight handling equipment.
(f) Attachments to the following materials: armor, stainless steel, HY-80/100, HSLA-80, high-hardenable materials or nonferrous metals except copper-zinc alloys.
(g) Other connections to be welded with electrodes other than G6010 or G6011 in accordance with AWS 5.1, unless otherwise approved.

14.1.1.2.1 Removal of zinc coating. Removal of metallic zinc may be accomplished by blasting, grinding, chemicals, or localized heating with subsequent removal of molten zinc by wire brushing. Where localized heating is

employed, a slightly oxidizing flame (oxyfuel gas) shall be used. The localized heating technique shall not be used for removing zinc coatings from HY-80/100, HSLA-80, STS or similar analysis.

14.2 Weld contour and cleaning. Where possible, mechanical means such as grinding or burring shall be used in lieu of welding to reduce surface irrregularity to an acceptable contour. When welding is required to correct improper contour, it shall be performed in accordance with section 13.

14.2.1 Weld edges. Weld edges which are undercut in excess of the acceptance standards in accordance with section 8 shall be repaired by grinding or welding. Unacceptable weld bead overlap and excessive roughness shall be corrected by mechanical means (see 14.4.4).

14.2.2 Aluminum butt welds. The toes of all plating butt welded joints in superstructure shall be ground to a smooth re-entry angle contour. For aluminum butt welded joints, there shall be no undercut at the toes of the weld.

14.3 Fillet weld. When the opening between elements of a fillet welded joint exceeds 1/16 inch but not more than 3/16 inch as a nominal condition along the joint, fillet size shall be increased by an amount equal to the excess of the opening above 1/16 inch. Where the gap between members exceeds 3/16 inch as a nominal condition along the joint fillet, weld size and weld procedure are subject to approval.

14.3.1 Fillet weld tolerances. Fillet weld tolerances shall be as specified in section 8.

14.3.2 Intermittent fillet welds. Intermittent fillet welded joints shall have continuous welds on both sides of the joint at the fixed ends for one eighth the length of the member. The length and spacing of increments specified shall be laid off between the continuous end welds.

14.3.2.1 Size and spacing of intermittent fillet welds. The size and spacing of intermittent fillets shall be as specified in section 11.

14.4 Surface preparation and correction.

14.4.1 Material surface correction. When employed for material surface correction, grinding shall produce a smooth depression blended into the surrounding surfaces. In no case shall such grinding exceed the limits specified in 8.2.7 for undercut without weld repair.

14.4.2 Surface preparation for nondestructive testing. Weld surfaces shall be prepared for NDT as specified in section 7.

14.4.3 Plate transition surface preparation. Where plates are beveled for transition from thick to thin sections, the surfaces shall meet the acceptance standards in accordance with NAVSEA 0900-LP-999-9000. Repair shall be accomplished by grinding, machining, or welding.

14.4.4 Undercut and other weld-edge corrections. Grinding should be employed to effect such repairs when the weld-edge condition can be corrected by grinding to depths not exceeding those specified in 8.2.7. The repair of undercut and other weld-edge defects (including ground areas exceeding 8.2.7 limitations) by welding shall be accomplished by depositing a bead or beads in the undercut or ground area which will fair into the existing weld.

14.5 Arc strike corrections on heat-treated materials. For all arc strikes including discoloration that occurred after final heat treatment in OSS/HSS (S-1) with carbon content greater than 0.30 percent, carbon molybdenum steel (S-3), alloy steel with chromium content not to exceed 3/4 percent and total alloy not to exceed 2 percent (S-3A), alloy steel with chromium content 3/4 percent to 2 percent and total alloy content 2-3/4 percent maximum (S-4), alloy steel with total alloy content 10 percent maximum (S-5), martensitic stainless high alloy steels (S-6), specialty martensitic stainless high alloy steels (S-6A), quenched and tempered HY-130 alloy steels (S-11B), complete removal of the heat affected zone shall be verified with an etchant that has been demonstrated to disclose heat affected zone structure in the material involved unless repair welding is required. Etchants shall be prepared and used in accordance with good metallurgical practice.

14.5.1 Arc weld metal spatter. All arc weld metal spatter greater than 1/8 inch diameter shall be removed.

14.6 Arc strikes, nicks, gouges, and other fabrication scars. Arc strikes, nicks, gouges, and other fabrication scars up to and including 1/32-inch depth is acceptable without repair. Arc strikes, nicks, gouges and other fabrication scars in excess of 1/32 inch, but within the limitations listed below shall fair smoothly into the base material or shall be repaired by mechanical means or welding. Arc strikes, nicks, gouges and other fabrication scars in excess of these limits shall be repaired by welding. Arc strikes on heat treated materials, regardless of depth of the arc strike or thickness of the base material shall be dispositioned as required by 14.5.

Base material thickness	Arc strikes, nicks, gouges and other fabrication scars limitations
Less than 1/2 inch	All indications exceeding 1/32-inch shall be repaired by welding.
1/2 inch and greater	Up to 1/16 inch is allowed.

14.7 Insert, patch, access and closure plate requirements. Deviations from the design requirements for cutback and proximity limitations as specified in section 11 shall require approval.

14.8 Peening. Peening shall be done with power-driven equipment with round or blunt nosed tools of circular or oblong cross section. Light grinding shall be employed to remove visual indications of flaking or laps. Surface slag, slag inclusions, cracks, and gas holes shall be removed before peening to prevent entrapment of foreign materials or unfused areas in the

weld. Peening of root layers is prohibited unless specifically approved by NAVSEA. If the last layer is peened, it shall be ground to remove evidence of peening.

14.9 Plate edge laminations. Laminations visually disclosed on exposed plate edges which are not included in a weld joint shall be excavated and welded as specified in 14.9.1 and 14.9.2.

14.9.1 Submarines. Plate edge laminations visually disclosed during fabrication or repair of submarine pressure hull structure shall be MT inspected to determine extent of lamination (see 8.3.3). Rejectable laminations shall be excavated to a depth of approximately 3/4 inch or 1/2 material thickness, whichever is less, from the plate edge and welded over.

14.9.2 Surface ships. Plate edge laminations disclosed during fabrication or repair of hull envelope shall be VT inspected to determine extent of lamination (see 8.2.12.1). Rejectable laminations shall be excavated to a depth of approximately 3/8 inch or 1/2 material thickness, whichever is less, from the plate edge and welded over.

14.10 Removal of welded attachments. In removal of attachments or in modifying existing hull structure, welds in materials other than HY-80/100 or high-hardenable materials shall be removed by chipping, oxyfuel gas cutting, gouging, and grinding. For HY-80/100 or high-hardenable materials, welded attachments shall be removed a minimum of 1/16 inch away from the permanent member to which they are attached by chipping, carbon arc-gouging, or oxyfuel cutting, followed by grinding or chipping to restore the plate surface. Surfaces which are exposed after removal of temporary attachments and studs shall be VT inspected in accordance with NAVSEA 0900-LP-003-8000. Surface defects shall be faired out by grinding, provided the depth limitations for weld-edge correction specified in 8.2.7 are not exceeded. Where these depth limitations will be exceeded, the defective areas shall be repaired by welding. Repairs shall be ground flush on exterior hull surfaces and on uninsulated interior living space surfaces and inspected in accordance with section 6.

14.11 Stud welds. Stud welds shall not exhibit any visual evidence of cracks when tested by bending or torquing as specified in section 6. If the base material fails before stud torque values are reached, the torque test is acceptable.

14.12 Circularity and frame dimensional tolerances. Submarine hull circularity and frame dimensions shall meet the requirements specified in MIL-STD-1688.

15. MECHANICAL FASTENERS

15.1 General. The materials, design, installation and inspection of structural riveting and other mechanical fastening of steel and aluminum alloy surface ship hull structure shall be in accordance with this section. Mechanical fastening of assemblies, the possible failure of which is remote

and would not result in failure to ship or component, may be of any safisfactory type. Mechanical fastening of assemblies, possible failure of which is remote and would not result in failure to ship or component, may be at the discretion of the designer.

15.2 Materials. Mechanical fastener materials for various applications shall be in accordance with table XXIII.

TABLE XXIII. Mechanical fastener materials.

Material joined	Application 1/	Type of fastener	Fastener material	Specification
OS steel to OS steel		Lockpin	MS	2/3/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6
		Bolt and nut	MS	MIL-P-23469/7 MIL-S-1222
HSS steel, HY-80/100, HSLA-80 or STS to OS steel		Lockpin	MS	2/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-P-23469/7
		Bolt and nut	MS	MIL-S-1222
HY-80/100 to HY-80/100 HSLA-80 STS to STS HSS steel to HSS steel		Lockpin	CRES	2/3/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-P-23469/7
		Bolt and nut	CRES	MIL-S-1222
HY-80/100 to HY-80/100 HSLA-80 to HSLA-80 STS to STS HSS steel to HSS steel	Where strength is not of special consideration	Lockpin	MS	2/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-P-23469/7
		Bolt and nut	MS	MIL-S-1222

See footnotes at end of table.

TABLE XXIII. Mechanical fastener materials - Continued.

Material joined	Application 1/	Type of fastener	Fastener material	Specification
Aluminum to aluminum	Where required for strength and where exposed to the weather, sea water, or wet spaces	Rivet Lockpin Bolt and nut	AL CRES CRES	MIL-R-5674 3/4/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/3 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-S-1222
	Where required for strength and where not exposed to the weather, sea water, or wet spaces	Lockpin Bolt and nut	MS MS	5/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-S-1222
	Where strength is not a special consideration	Rivet Lockpin Bolt and nut	AL AL AL	MIL-R-5674 5/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-S-1222
	Nonstructural applications where rivet diameter is less than 5/16 inch and material thickness does not exceed 1/8 inch	Rivet	AL	MIL-R-5674
Aluminum to steel	Where required for strength and where exposed to the weather, sea water or wet spaces	Lockpin Bolt and nut	CRES CRES	3/4/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/3 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-S-1222

See footnotes at end of table.

TABLE XXIII. Mechanical fastener materials - Continued.

Material joined	Application 1/	Type of fastener	Fastener material	Specification
Aluminum to steel (Continued)	Where required for strength and where not exposed to the weather, sea water or wet spaces	Lockpin	MS	2/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-P-23469/7
		Bolt and nut	MS	MIL-S-1222
	Where strength is not a special consideration and where exposed to the weather, sea water, or wet spaces	Rivet	AL	MIL-R-5674
	Where strength is not a special consideration and where not exposed to the weather, sea water, or wet spaces	Rivet	AL	MIL-R-5674
		Lockpin	AL	5/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6
		Bolt and nut	AL	MIL-S-1222
		Lockpin	MS	2/ MIL-P-23469 MIL-P-23469/2 MIL-P-23469/4 MIL-P-23469/5 MIL-P-23469/6 MIL-P-23469/7
		Bolt and nut	MS	MIL-S-1222

1/ Applications are general except as shown otherwise. Special restrictions applicable to the use of all mechanical fasteners other than rivets are specified in 15.3.2. If one side of the joint is exposed to the weather, sea water, or wet spaces, the pin and collar shall be corrosion-resistant steel.

2/ Classes M23469/2, type I, class 3; M23469/4, type I, class 3; M23469/6, type I, class 3; M23469/4/5/6, type II, class 3; M23469/7, type II, class 3.

3/ For seams below the waterline, use oval 60-degree countersunk head, tapered shank MIL-P-23469/7.

4/ Classes M23469/2, type I class 2; M23469/4/5, type I, class 2; M23469/6, type I, class 2; M23469/3, type I, class 2.
5/ Classes M23469/2, type I, class 1; M23469/4/5, type 1, class 1; M23469/6, type I, class 1.

15.3 Construction. Mechanical fasteners (rivets, prestressed bolts, nuts, and lockpins) shall be in accordance with the appropriate specification as specified in table XXIII. The fasteners and welding employed in the ship shall function independently of each other. NAVSEA approval will be required for composite joints (welded or mechanically fastened). The use of mechanical fasteners for joints in ballistic plating will require NAVSEA approval.

15.3.1 Application of other mechanical fasteners. Prestressed bolts and nuts, pins and collars outlined in table XXIII may be used in lieu of rivets for all joints, except:

(a) For seams below the waterline, 60 degree oval countersunk head, tapered shank, pin and collars, or prestressed bolts and nuts in accordance with MIL-P-23469 shall be used.
(b) Where satisfactory tightness of the joint cannot be obtained.
(c) Where the extension of the pin and collar or bolt and nut would be unacceptable.

15.3.2 Symbols. Drawings shall employ the designations as shown in table XXIV to indicate the use of mechanical fasteners.

TABLE XXIV. Mechanical fastener symbols.

Symbol	Meaning
No distinguishing symbol shall be used for medium steel fasteners.	
AL	Aluminum
HT	High tensile steel
B	Button heat
C	Countersunk head
T	Tap
BP	Button Point
CK	Countersunk point
CP	Cone point
/	Single fastening
//	Double fastening
///	Triple fastening
////	Quadruple fastening
/////	Quintuple fastening
//-//	Double-butt straps, double fastened
///-///	Double-butt straps, triple fastened

See footnotes at end of table.

TABLE XXIV. Mechanical fastener symbols - Continued.

Symbol	Meaning
////-////	Double-butt straps, quadruple fastened
/////-/////	Double-butt straps, quintuple fastened
CN	Chain fastening
LP	Lockpins 1/
B&N	Prestressed bolts and nuts 1/

No distinguishing symbol shall be used for zigzag fastening.

Designation of mechanical fasteners shall be in the following order:

(a) Material
(b) Diameter
(c) Type of head/type of points (rivet only)
(d) Fasteners other than rivets 1/

For example:	(a)	(b)	(c)(d)	(d)
	HT	3/4 inch	3/CK	LP 1/
	AL	1/2 inch		

1/ Where lockpins or prestressed bolts and nuts are indicated on drawings, a note shall identify the classes of pins and collars or bolts and nuts.

15.3.3 Sizes of mechanical fasteners. Fasteners shall be of sufficient strength and length to assure structural adequacy for the function required. Where other mechanical fasteners are used in lieu of rivets, their higher strength, if any, may be considered in the design of the joint and thus permit the selection of smaller sizes than those specified in tables XXV and XXVI for rivets while maintaining the edge distance and spacing specified for the rivet.

TABLE XXV. Sizes of rivets for various weights of plating (ferrous).

Rivet diameter (inches)	Nominal weight of plates and sheets (lb/ft^2)
1/4	Below 3.17
3/8	Including 3.17 to 6.37
1/2	Including 6.37 to 8.92
5/8	Including 8.92 to 12.75
3/4	Including 12.75 to 20.4
7/8	Including 20.4 to 30.6
1	Including 30.6 to 40.8
1-1/8	Including 40.8 and over

TABLE XXVI. Sizes of rivets for various weights of plating (aluminum alloys).

Nominal rivet diameter (inches)	Thickness of the thinnest plate adjacent to rivet head or point (inches)
3/32	0.045 or less
1/8	.046 to 0.062
3/16	.063 to .093
1/4	.094 to .124
5/16	.125 to .187
3/8	.188 to .249
1/2	.250 to .437
5/8	.438 to .499
3/4	.500 to .561
7/8	.562 to .687
1	.688 and over

15.3.3.1 Ferrous rivets. In general, the size of rivets shall be in accordance with table XXV. In special construction requiring the use of rivets of smaller diameters than those specified in table XXV, the smaller rivets may be used upon approval.

15.3.3.1.1 Members of different thicknesses. In connecting members of different thicknesses where strength is of primary importance, the size of rivets and the spacing shall be that required for the thicker member of the joint. If the thicker member is more than double the thickness of the thinner member, an intermediate size of rivet shall be used. In nontight structure where the plates differ in thickness from the angles or other shapes connecting thereto, the size and the spacing of rivets, in general, shall be that corresponding to the thickness of the plating. If water tightness or oil tightness is of primary importance, the size of rivets and the spacing shall be that corresponding to the thinner member of the joint.

15.3.3.1.2 Heavy castings, weldments, and forgings. Through rivets in heavy castings, weldments, and forgings shall be 1/8 inch larger in diameter than that specified in table XXV for the plates connected thereto.

15.3.3.1.3 Three-ply. Except for double strapped butts, rivets for three-ply riveting should be 1/8 inch larger in diameter than the sizes specified in table XXV. Double strapped butt joints in plating 5/8 inch thick or less may have one size smaller rivets than that specified in table XXV.

15.3.3.2 Aluminum alloy rivets. In general, the size of rivets shall be in accordance with table XXVI. To minimize the pressure required to drive cold aluminum alloy rivets, diameters shall be kept as small as is consistent with the required shear strength.

15.3.4 Arrangement of mechanical fasteners. Fastener spacing and number of rows in butt joints of surface ship primary hull structure shall be selected for maximum efficiency. Surface ship secondary hull structures may be designed with butt joint efficiencies ranging from 65 to 75 percent. Where structures are to be water or oil tight, maximum efficiency shall be reduced as little as possible commensurate with required tightness and shall be governed by the necessity for adequately caulking the joint. In no case shall the spacing in rows be less than three diameters.

15.3.4.1 Plate laps and single-strap joints. In general, plate laps or single-strap joints shall be used where tightness is a prime consideration. Since the relatively thin straps of double strapped joints are difficult to caulk, this joint shall be used only where strength is of primary importance.

15.3.4.2 Zigzag. In general, a zigzag pattern shall be used where two or more rows of fasteners are required in butts and seams of plating or in shapes. Chain patterns shall be used only with NAVSEA approval.

15.3.4.3 Scallop. For lapped joints or strapped butt joints, if alternate fasteners are omitted in the outer rows, the ends of the plates in the lapped butts or the edges of the butt straps in the strapped butts shall be scalloped.

15.3.4.4 Distance in zigzag patterns. In zigzag patterns, the distances between centers of rows shall be not less than that specified in tables XXVII and XXVIII.

TABLE XXVII. Spacing of rows in fastener diameters, zigzag pattern (ferrous).

In rows	Between rows	Between outer two rows when alternate fasteners in outer row are omitted
3-1/2	1-3/4	2-1/8
4	1-3/4	2-3/8
4-1/2	1-7/8	2-5/8
5	1-7/8	2-7/8
5-1/2	2	3-1/8
6	2	3-3/8

TABLE XXVIII. Spacing of rows in fastener diameters, zigzag patterns (aluminum alloys).

In rows	Between rows		Between outer two rows when alternate fasteners are omitted in outer row (for 70-percent efficiency)
	Lockpins, also button or cone points of rivets	Countersunk points of rivets	
3-1/2	2	2-3/16	2-1/8
4	1-7/8	2-1/16	2-1/4
4-1/2	1-7/8	1-7/8	2-3/8
5	1-7/8	1-7/8	2-1/2
5-1/2	2	2	2-9/16
6	2	2	2-5/8

15.3.4.5 Watertight and airtight joints. For watertight and airtight joints of insulated aluminum to steel connections where steel (MS or CRES) prestressed bolts and nuts or lockpins are used, a distance of 5-1/3 diameters (maximum) may be used in rows zigzagged. The spacing between rows shall be in accordance with table XXVIII for 5-1/2 inch diameters in row spacing.

15.3.4.6 Rivet centers in steel. Centers of rivets from the edge of plates or straps in steel structure shall be not less than two times the rivet diameter. For caulking edges, the centers of rivets shall be not more than 1-3/4 times the rivet diameter from the edge of a plate or strap 1/2 inch or more thick, or more than two times the rivet diameter for plates or straps less than 1/2 inch thick. For angle and other shapes, the same distances from the edge shall be maintained.

15.3.4.7 Rivet centers in aluminum. Centers of rivets in aluminum alloy structures shall be not less than two times the rivet diameter from the edge of plate or straps, except where edge caulking is required. When edge distance of less than two diameters in the direction of principal stress is used, the allowable bearing stress in the plate or shape shall be reduced in the ratio of E/2, where E is the edge distance in diameters.

15.3.4.8 Edge distance. Where steel, prestressed bolts and nuts or lockpins are used in aluminum plates and shapes, the minimum edge distance in the direction of stress shall be three diameters.

15.3.4.9 Lightweight. To save weight, flanges of angles, except those forming boundaries of watertight or oiltight structures and those contributing to the longitudinal strength of the ship, may be cut (planed or oxygen cut) and the gauge line of rivets moved toward the bosom of the bar so as to leave an edge distance of 1-1/2 diameters, provided proper fastening conditions result. If the toe of the lightened flange is to be caulked, the edge distance of the rivet shall be not less than 1-1/2 diameters after removing

the material for caulking. For bars bounding watertight or oiltight structure, the flanges shall not be cut, except for caulking, unless the plate to which the bar is attached is of such a thickness (less than bar flange) that an overall saving of weight will result and sufficient space remains for caulking the heel of the bar, if required. If the plate is required to have metal to metal contact, the flanges of the bar may be cut, as for nonboundary flanges.

15.3.4.10 Tolerance. A tolerance of plus or minus 1/16 inch on all the foregoing edge distances shall be permitted.

15.3.4.11 Aluminum alloy castings. Rivets in aluminum alloy castings shall in no case have an edge distance of less than 1-3/4 inch diameter.

15.3.5 Plate laps and butt and seam straps.

15.3.5.1 Width. The widths of laps and straps shall be not less than required by the summation of edge distances and spacing of rows, and shall not exceed these requirements by more than 1/8 inch for each row of rivets in the connections, but in no case shall the accumulation exceed 1/2 inch.

15.3.5.2 Thickness. Double straps, having a double row of rivets, shall each be the nearest commercial thickness over one-half the thickness of the connecting plate. Straps having a triple row of rivets, or more, shall each be the nearest commercial thickness over 5/8 that of the plates joined. Single steel butt and seam straps having a single or double row of rivets shall be the same thickness as the plates being connected. Single aluminum butt and seam straps, or single steel butt and seam straps having three rows or more, shall be the nearest commercial thickness over one-half times the thickness of the plates they connect. Where plates connected are of different thickness, the thickness of butt or seam straps shall be governed by that of the thinner plate, provided suitable liners are employed. Scalloping of lapped or strapped butt joints shall be required as specified in 15.3.4.3.

15.3.6 Calculation of joint efficiencies. The efficiency of a joint shall be the ratio of the load necessary to cause failure of the joint to the load necessary to cause failure of the nonperforated member. In joints of indefinite extent, efficiencies shall be based on a unit strip through the joint of width equal to a repeating strip of fasteners.

15.3.6.1 Calculation. In calculating efficiencies of joints, the unit ultimate strengths specified in 15.3.6.1.1 through 15.3.6.1.4 for tension, shear and bearing shall be used unless special materials are involved in which case NAVSEA approval is required.

15.3.6.1.1 Unit ultimate shearing strength. The unit ultimate shearing strengths of fasteners shall be taken as equal for single and double shear.

15.3.6.1.2 Rivets. For rivets, shear and bearing areas shall be based on the size of the rivet holes. In steel construction, this is the nominal rivet diameter plus 0.031 inch. In aluminum construction, it shall be, for

following amounts: 1/32 inch for fasteners less than 1/2-inch diameter; 1/16 inch for fasteners 1/2-inch but less than 7/8-inch diameter; 3/32 inch for fasteners 7/8-inch diameter and larger. In no case shall the depth of countersink be assumed as greater than the thickness of the plate. Further requirements for countersinking are specified in 15.4.10.

15.3.6.2 Medium steel. Where medium steel plates or shapes are joined by medium steel fasteners, the values as specified in table XXIX shall be used.

TABLE XXIX. Medium steel fastener strengths.

Plates and shapes of fasteners	Tensile strength (lb/in^2)	Shearing strength (lb/in^2)	Bearing strength (lb/in^2)
Plates or shapes (OS)	58,000	34,800	92,800
Rivets (medium steel)	----	48,000	----
Lockpins (medium steel)	----	60,000	----
Prestressed bolts (medium steel)	----	60,000	----

15.3.6.3 HSS, HY-80, HY-100, HSLA-80 and STS steels. Where plates or shapes of these steels are to be joined by high tensile steel rivets, the strengths as specified in table XXX shall be used. A shearing strength of 64,000 lb/in^2 shall be used for high tensile steel rivets when joining plates and shapes of these steels.

TABLE XXX. High tensile steel, HY-80, HY-100, HSLA-80 and STS fastener strengths.

Plate and shape material	Thickness (inches)	Tensile strength (lb/in^2)	Shearing strength (lb/in^2)	Bearing strength (lb/in^2)
HSS	1 and under	80,000	48,000	128,000
	Over 1	72,000	43,000	115,000
HY-80 and HSLA-80	2 and under	110,000	60,000	160,000
HY-100	2 and under	115,000	69,000	184,000
STS	2 and under	115,000	69,000	184,000

15.3.6.4 Aluminum alloy. Where aluminum plates or shapes are joined by aluminum fasteners, the values as specified in table XXXI shall be used.

TABLE XXXI. Aluminum alloy fastener strengths.

Characteristics/material	Strength (lb/in^2)
Tensile strength of plates:	
Alloy 6061-T6	42,000
Alloy 5086-H32, H116 and H117	40,000
Alloy 5456-H321, H116 and H117	46,000
Alloy 5454-H34	39,000
Tensile strength of shapes:	
Alloy 6061-T6	42,000
Alloy 5086-H112	35,000
Alloy 5456-H311	42,000
Alloy 5454-H311	31,000
Shearing strength of rivets:	
Alloy 6061-T6:	
Driven cold as received	30,000
Driven cold as quenched	24,000

TABLE XXXI. Aluminum alloy fastener strengths - Continued.

Characteristics/material	Strength (lb/in^2)
Shearing strength of lockpins:	
Alloy 6061-T6	30,000
Bearing strength of plates:	
Alloy 6061-T6	88,000
Alloy 5086-H32, H116 and H117	80,000
Alloy 5456-H321, H116 and H117	84,000
Alloy 5454-H34	78,000
Bearing strength of shapes:	
Alloy 6061-T6	80,000
Alloy 5086-H112	70,000
Alloy 5456-H311	79,000
Alloy 5454-H311	59,000

15.3.6.4.1 Thin plates or shapes. If aluminum alloy fasteners are used in relatively thin plates or shapes, the shear strength shall be reduced in accordance with the following:

(a) For double shear-percentage reduction = (13d/t) - 19.5 (where d/t is less than 1.5, percentage reduction shall be zero).
(b) For single shear-percentage reduction = (4d/t) - 12 (where d/t is less than 3, percentage reduction shall be zero).

In each formula, "d" is fastener diameter and "t" is the material thickness. The thickness used is that of the thinner material for single shear joints or of the middle piece in double shear joints.

15.3.6.5 Bimetallic joints. Where steel lockpins and bolts are used in bimetallic joints of aluminum and steel, a shearing strength value for the fastener of 70,000 (lb/in^2) shall be used.

15.3.6.6 CRES fasteners. Where CRES fasteners are used, strength values shall be based on the appropriate specification (see table XXIII). In lieu of these strength values for fasteners made of medium steel, high tensile steel or aluminum, the values may be based on the appropriate specification (see table XXIII).

15.3.7 Transition from welded to mechanically fastened structure. When required to combine welded and mechanically fastened structures, a plate joined as shown on figure 28 shall be used to make the transition. NAVSEA approval of the transition plate design shall be required.

15.4 General fabrication requirements.

15.4.1 Workmanship. Plating and shapes shall not be marred nor show any undue amount of hammer marks around fastener holes. For joints in members serving principally in compression, the edge-to-edge contact of the abutting members shall be such that all transmitted compressive loads will be taken by the actual bearing of one member on the other, and not by the fasteners in shear. Abutting members shall be in contact for at least one-third the length of the joint, and the contact shall be uniformly distributed along the joint so that the compressive stress on the abutting edges will not exceed the allowable bearing stress. The fit of the abutting for the remainder of the length of the joint shall exclude a 0.010 inch feeler. The use of caulking or shims to obtain the required contact shall not be permitted. Liners shall be fitted wherever necessary to secure proper connections of plates and shapes. Tapered liners shall take not less than two fasteners or two rows (see 15.3.5.2). In riveting heavy castings, forgings and weldments involving large rivets, the rivets shall be machined and accurately fitted to minimum clearance. The points shall be heated only when such procedure is absolutely necessary to obtain satisfactory workmanship and riveting.

15.4.2 Punching. Holes shall, in general, be punched from the side that will form the faying surface; where this is not done, they shall be punched small and reamed, as necessary, to obtain a smooth surface before the material is put in place. Burring of any kind between faying surfaces shall be removed.

15.4.3 Unfair holes. Drifting to overcome unfair holes shall not be allowed. Where unfair holes occur, they shall be reamed out and fasteners suitable for the increased sizes of holes shall be used. Where the number or the diameter of individual holes required to be reamed out to an increased size for the purpose of removing unfairness will impair the strength of the structure, new replacement structure with unfairness corrected shall be required.

15.4.4 Holes in OS steel.

15.4.4.1 Before assembly. Holes made in ordinary strength steel before assembly shall be punched or drilled small and reamed to size for the following:

(a) Watertight or oiltight structure.
(b) In structure involving main hull or local strength such as foundations.
(c) In three or more thicknesses of material and in materials of thickness 1 inch and over.

15.4.4.2 After assembly. Holes drilled after assembly may be drilled to size. Holes in a member used as a template for drilling holes through a connecting member may be drilled to size, except that widely spaced tack holes used for assembly shall be drilled or punched undersized and reamed to size.

15.4.5 Holes in HSS steel. Holes through high tensile steel shall be drilled, except that for material 5/8-inch thick and less, the holes may be punched and reamed, provided the reamer removes the material to a depth of at least 3/32 inch on the punched side and 1/16 inch on the die side of the plate, the depth being measured from the edge of the punched hole. For material 5/8-inch thick and up to and including 3/4-inch thick, punching shall be permitted, provided that the punched hole is 3/16-inch undersize. Drilled holes in high tensile steel shall be reamed to size after assembly for the same applications as listed above for medium steel.

15.4.6 Holes in galvanized plates and shapes. Holes for rivets to be driven hot in galvanized medium and high tensile steel plates or shapes shall have rounded edges of 1/8 plus 1/32 inch radius at surface contiguous to manufactured heads and points of button head type rivets. When galvanized steel members are connected by high tensile steel rivets, all joints, whether strapped or lapped, shall have the zinc coating removed from under the head and point of button head type rivets. The extent of the removal of the zinc coating shall be such as to leave the coating intact for as great a distance as practical, but not closer than 1/4 inch from the periphery of any rivet holes and expected edges of the head and point of the button type rivet. However, where driving to fill a countersunk hole, the countersinking having been done after galvanizing, the zinc need not be removed from the edges of the countersunk hole. Metallic zinc may be removed by spot facing, grinding, blasting, chemicals, or by local heating with a slightly oxidizing flame to a temperature not exceeding 950°F (faint red heat) followed by a wire brushing.

15.4.7 Holes in HY-80, HY-100, HSLA-80 and STS. Holes in these steels shall be drilled, and after erection shall be reamed to the nominal diameter of the fastener plus the allowed clearance between the nominal diameter of fastener and rivet hole.

15.4.8 Holes in aluminum alloy material. Holes in aluminum alloy material shall be subdrilled or subpunched to a size 1/16 inch less than the diameter of the fastener. After assembly, holes shall be reamed to size. Reaming of aluminum alloy plating shall proceed only fast enough to allow the necessary bolting up operation to be completed before fastening, in order to prevent creeping of plating between the reaming and fastening operations. If one drilled member is used as the template for drilling the holes in the connecting member after erection, only the tack holes need be subdrilled in either member. Chips and drillings produced by drilling and reaming shall be removed from between all faying surfaces.

15.4.9 Clearance and interference fits. Clearance fits shall be required for rivets and prestressed bolts and nuts larger than 1/2-inch diameter. For clearance fits, the differences between the nominal diameter of these fasteners and the fastener holes shall not exceed the following:

Diameter	Inch
Under 1/2 inch	1/64
1/2 inch and larger	1/32

15.4.9.1 Lockpins. Holes for lockpins shall be sized in accordance with MIL-P-23469.

15.4.10 Countersinking. The included angle of countersink shall be the same as that for the countersunk head of the fastener (see MIL-R-5674, MIL-P-23469, FF-B-584, as applicable). Countersunk points shall have the same included angle as countersunk heads. The countersunk heads and points shall not be below the surfaces of the plate or shape after fastening (driving).

15.4.10.1 Galvanized steel plate. In galvanized steel plates or shapes, the depth of countersinking shall not exceed three-fourths of the thickness of the plate.

15.4.10.2 Aluminum alloy. In aluminum plates or shapes under 3/16-inch thickness, fasteners with countersunk heads or points shall not be used.

15.4.11 Faying surface treatment.

15.4.11.1 Steel. Except as specified herein, faying surfaces shall receive two coats of primer, formula 117 in accordance with DOD-P-15328, on each surface. Faying surfaces of ballistic structure shall be thoroughly coated with rust preventative compound in accordance with MIL-C-11796. Faying surfaces in fresh water and oil tanks shall not be painted. After pickling, primer coating need not be removed other than the loose material removed by wire brushing.

15.4.11.2 Aluminum. When welded seams are made in aluminum after mechanically fastening the aluminum to steel in bimetallic joints, the seams shall stop about 1 inch above the steel and shall be left unwelded across the steel. The unwelded gap shall be approximately 1/4 inch with a radius of approximately 1/4 inch at the top of the gap (where the weld stops). The gap area shall be filled with polysulfide synthetic rubber in accordance with MIL-S-8802, class B-2 material.

15.4.12 Water and oil stops. Stops shall not be used to correct defective workmanship or materials, nor where the best practice requires metal-to-metal contact. Stops shall be used in the following places:

(a) Where a member passes through a watertight or oiltight member.
(b) In watertight or oiltight seams, including those formed by plates and shapes, in number and location as required to prevent water or oil, as applicable, traveling between faying surfaces.
(c) For ferrous fastening in watertight or oiltight joints where rivets less than 3/8 inch are driven cold.
(d) For cases where it would be impossible to secure the requisite tightness by caulking.
(e) For aluminum fastening where material is under 1/4 inch in thickness.
(f) For ferrous fastening where the material is 3/16 inch or less, packing may be used in seams, laps, and stapling to secure tightness.

15.4.12.1 Material for water and oil stops. Stops for ferrous structure shall be polysulfide synthetic rubber in accordance with MIL-S-8802, class B-2 material, or other approved materials. Where aluminum will be joined to other materials, the joints shall be treated as specified in 15.4.11. Stops for aluminum material shall be plastic insulation tape in accordance with MIL-I-24391 or other NAVSEA approved equivalent. Type I as specified in TT-C-1796 is a satisfactory gunning mixture for oil stops. Materials of stops shall be fresh, and the work in way thereof shall be fastened before the material has hardened. Stops shall be inserted not more than 1 week before fastening is started. The material of the stops shall not prevent properly drawing the members close together for tight fastening and effective caulking. Where caulking is not used, or where material is under 1/4 inch in thickness, packing compound shall be used.

15.4.12.2 Welding water and oil stops. Welding may be used to form water and oil stops as approved for the applicable design (see 11.3.11).

15.4.13 Bolting for fitup. Structural work shall be properly bolted before fastening is commenced. The bolts shall be sufficient in number and so tightened that there will be no slippage, warping or swelling of the metal. Bolting shall be such as to prevent the rivet shanks from squeezing out between parts of the joints during the driving operation. In general, the bolts should draw the material sufficiently close together to exclude a 0.015-inch feeler. For aluminum alloy fastening, bolts shall be placed in every other hole for material less than 3/16-inch, and in every third hole for thicker material, with all holes filled before bolts are removed. For oiltight work in ferrous material, bolts shall not be more widely spaced than one for every four holes. Bolts shall not be removed ahead of the fastening, except as necessary for the actual driving of fasteners. Burrs and chips shall be removed, and all buckles and lumps shall be faired out before any fastening is done.

15.4.14 Mechanical fastening. Mechanical fastening occurring within the area affected by the heat of welding shall be done after welding is completed, except:

(a) Joints in longitudinal structural members may be fastened in advance of making small attachment welds for transverse members (for example, end connections of transverse deck beams to shell), provided that fasteners for a distance of 6 inches on each side of the transverse are tested for tightness after welding.
(b) Welding of butts in structural shapes and plates may be done after fastening has been carried beyond these butts, provided fasteners are omitted for a distance of 12 inches on each butt until the butts are welded.
(c) Joints in steel, using fasteners other than rivets, may be fastened prior to making adjacent tee welds, provided fastening and associated inspection are performed in accordance with a procedure which has received qualification approval by NAVSEA.

Except as specified herein, where rivet joints are used between large monolithic welded structures, butt welds crossing these joints shall be made so that fusion between members of the joint is avoided. The use of glass cloth tape in accordance with MIL-C-20079 as backing is recommended for such application (see figure 29). In ships having riveted crack interrupter joints, welded butt joints (including welded oil or water stops) fused to faying surfaces of passing strakes shall be permitted only where such joints are located in line with welded intersecting transverse members.

15.4.15 Heating of rivets.

15.4.15.1 Heating of ferrous rivets (medium and high tensile steel). Rivets shall be heated to not more than 2200°F. Temperature of rivets shall be checked visually by experienced personnel, subject to periodic checks with optical pyrometers. Where temperature controlled furnaces are employed, periodic checks shall be made to assure that furnaces do not operate at temperatures above 2200°F.

15.4.15.2 Heating of aluminum alloy rivets. Rivets shall be driven cold in the as-received or T-temper conditions. Rivets may be stored indefinitely without change in strength or driving characteristics. Heating of aluminum alloy rivets shall be prohibited.

15.4.16 Driving of fasteners. Sizes of pneumatic hammers shall be as specified herein. The selection of tools for pulling or torquing in driving of lockpins shall be based on the recommendation of the lockpin manufacturer. If hand pneumatic machines are used, the air pressure shall be not less than 90 lb/in^2 at the machine. Machines striking regular and rapid blows shall be used by the riveters. Dolly bars shall not be used where it is practical to use pneumatic holding on machines. Riveters shall be required to use the size of plunger with each rivet hammer that the manufacturer of the hammer furnishes and recommends and shall not be permitted to insert shorter plungers or balls from other sources. The tools used to form button points shall not have their faces ground down, thus reducing the size of point below the standard. Rivet points shall be fully formed and properly centered. The shanks of the rivets shall not be bent or clinched to one side in driving. The pneumatic hammer shall generally be held in direct line with the shank of the rivet during the driving operation. Excessive rolling of the pneumatic hammer to seal the rivet to the plate is not acceptable.

15.4.16.1 Power driven ferrous rivets. The sizes of pneumatic hammers shall be not smaller than those specified in table XXXII.

TABLE XXXII. Sizes of pneumatic rivet hammers to be used for different sizes of ferrous rivets.

Hammer size number	Range of rivet diameters (inches)
1/ 3	Up to 1/2
5	3/8 to 5/8
6	1/2 to 7/8
8	3/4 to 1-1/8
9	1 to 1-1/4

1/ Chipping, caulking and light riveting hammer.

15.4.16.1.1 Power-driven rivets. In watertight or oiltight structure and structural work involving the longitudinal strength of the ship, or important local strength, and in all high tensile steel and STS steel, all rivets shall be power driven. For rivets larger than 3/4 inch, power bucking shall be used, except where light plates or shapes would be damaged thereby.

15.4.16.1.2 Driving. The driving shall be completed in one operation except when it is necessary to remove excess material from a countersunk point, in which case the driving shall be completed immediately after the removal of such excess material. When such chipping of a countersunk point is necessary, it shall be done immediately after upsetting the point, and the driving shall be completed before driving other rivets.

15.4.16.1.3 Rivet points and heads. The dies used to form button points and heads during driving shall be in accordance with figure 30. Countersunk heads and points shall be left to provide a slight margin for corrosion. Finished countersunk heads and points shall be such that a rule or straight edge will be held away from the plate, and so that it can be rocked back and forth across the rivet head or point on any diameter.

15.4.16.1.4 Cold driven rivets. Rivets less than 3/8 inch in diameter may be driven cold. In watertight joints where such riveting is used, stops in accordance with 15.4.12.1, shall be fitted to secure tightness.

15.4.16.1.5 High tensile steel rivets. High tensile steel rivets shall not be driven if excessive hardness due to rapid quench may result; for example, in wet structure or during heavy rainfall.

15.4.16.2 Power driven aluminum alloy rivets. Power riveting shall be employed where practical. To avoid hardening by cold working, pneumatic hammers shall be slightly larger than those ordinarily used for hot steel rivets of the same size. The hold on die shall have a larger diameter than the head of the rivet before driving and shall bear on the head and not on the surrounding metal.

15.4.16.2.1 Overdriving. Overdriving with accompanying hardening of rivet points, or careless driving rivets, with consequent marring and expanding of plates or shapes being riveted, shall be avoided. Cold working increases the susceptibility of aluminum to cracking.

15.4.16.2.2 Single-operation. Aluminum rivets shall be driven in one operation and no stepping back or hardening shall be permitted. Tools for chipping rivets shall have a broad blade and shall be kept sharp and smooth, free from nicks or uneven spots which cause the metal to drag away from the countersinks.

15.4.16.2.3 Underdriving. Underdriving of rivets for the purpose of preventing the bulging of plate edges, due to improper edge distances, shall not be permitted, nor will bulging edges caused by overdriving be accepted.

15.4.16.2.4 Large-diameter rivets. Driving of aluminum rivets 1/4 inch or larger in diameter by means of a heavy hand hammer or sledge shall not be permitted.

15.4.16.2.5 Rivet points and heads. The dies used to form button points and heads during driving shall be in accordance with figures 31 and 32. On weather decks, and elsewhere as necessary, edges of countersunk points may be left slightly raised above the plate to avoid scarring of the plate. Where appearance is not a factor, but only upon approval, cone points as detailed on figure 33 may be used instead of button points where button point manufactured heads are not available.

15.5 Inspection and testing of fasteners.

15.5.1 Rivets. Quality of workmanship on driven rivets shall be determined by visual inspection supplemented by rivet knife and hammer test. The rivet knife shall consist of a 3/4-inch diameter hardened steel ball attached to a 6-inch length of 1/2-inch wide strip of 0.005 inch shim stock. The test hammer shall weigh approximately 4 ounces exclusive of the handle. Rivet tightness shall be judged by holding the steel ball firmly against one side of the rivet head, by spring tension of the shim stock handle, while striking the opposite side of the head sharply with the test hammer. Tightness of rivet shall be considered satisfactory if the ball does not bounce off the head. As an alternative to the steel ball method, and where approved, qualified inspectors may use their fingers against the rivet in lieu of the steel ball on the rivet knife, judging tightness by feel of movement when striking the opposite side of the head with test hammer. Rivet head contact shall be judged satisfactory if the shim stock handle of the knife or 0.005-inch shim cannot be passed under the head at any place around the circumference between the rivet head and rivet shank radii.

15.5.1.1 Replacement of defective rivets. Where inspection and testing reveal the following types of defective rivets, they shall be cut out and replaced:

(a) Loose rivets.
(b) Burnt or overheated rivets.
(c) Countersunk rivets with points or head below plate surfaces.
(d) Rivets with incompletely formed heads or points.
(e) Rivets with eccentric heads or points.
(f) Rivets with cracked heads or points.
(g) Rivets with heads not in satisfactory contact with plate surfaces as specified in 15.5.1. Aluminum material shall be PT inspected for freedom from radial cracks.

When this standard is used for guidance for replacement of rivets in hulls which have seen service, rivet holes in ferrous material shall be MT inspected for freedom from radial cracks.

15.5.2 Lockpin (pins and collars - swage locking) and prestressed bolts and nuts. Quality of workmanship of installed lockpins and prestressed bolts and nuts shall be determined by the inspection methods and standards specified in 15.5.1. Tightness shall be determined by the same inspection methods as specified in 15.5.1 for rivets. Lack of contact between the head and the inside surface of the countersunk hole, as a result of a canted condition shall meet the same tolerance requirements as specified in 15.5.1 for rivets. The allowable projection above the plate surface for oval head countersunk lockpins in accordance with MIL-P-23469/7 shall be as specified in table XXXIII.

TABLE XXXIII. Countersink lockpin projection allowances.

Pin diameter (inch)	Projection	
	minimum (inch)	maximum (inch)
1/2	7/64	13/64
5/8	7/64	13/64
3/4	9/64	15/64
7/8	7/32	5/16
1	1/4	11/32

15.5.2.1 Replacement of defective lockpins and prestressed bolts and nuts. Where inspection and testing reveal the following types of defective lockpins or prestressed bolts and nuts, they shall be removed and replaced:

(a) Loose lockpins or prestressed bolts and nuts.
(b) Lockpins and prestressed bolts and nuts which do not meet contact requirements as specified in 15.5.1.
(c) Lockpins with cracked heads or collars or prestressed bolts and nuts with cracked heads or nuts.
(d) Oval head countersunk lockpins which do not meet the projection requirements as specified in 15.5.2.

15.5.3 Extent of inspection. Fasteners employed in the following application shall be subject to 100 percent inspection as specified in 15.5.1 or 15.5.2, as applicable:

(a) Crack arrestor or crack stopper joints.
(b) Joints located in the surface ship primary hull structure within the 3/5 midship length.
(c) Joints connecting to longitudinal framing. Fasteners used for structural applications other than those specified herein shall be subject to 100 percent VT inspection and 10 percent inspection and testing, as specified in 15.5.1 or 15.5.2, as applicable. If defective fasteners are found on the 10 percent inspection, the percent inspection shall be expanded until satisfactory assurance of quality is demonstrated to the inspector.

16. STRUCTURAL CASTINGS

16.1 General. Castings purchased or manufactured by the contractor shall be in accordance with the requirements of specified material specifications and standards. The NDT requirements shall be as specified herein. If no material specification or standards are invoked, drawings for castings which are specified in table XXXIV shall include the following information:

(a) Chemical composition of material.
(b) Required mechanical properties.
(c) Pressure test or proof test, if required.
(d) NDT requirements.
(e) Identification markings.

16.2 Casting NDT requirements. Structural castings specified in table XXXIV, regardless of material, shall be inspected by the NDT method specified.

TABLE XXXIV. Category H structural castings.

Subcategory	Applicable rules	NDT required	
		RT 1/	MT/PT 2/
H-1	Castings which form a part of the submarine pressure hull envelope or watertight boundary of the ship hull structure (for surface ships, that is part of the ship hull primary structure below the full load waterline) and those areas designed for blast loading or grade A shock.	X	X
H-2	Structural castings which by failure would prevent normal propulsion, steering, or diving of the ship, and for which there is no standby or backup capability.	X	X
H-3	Towing and rigging fitting castings designed to be stressed as outlined in subcategory H-4(a) and (b) below when the fitting is not proof load tested.	X	X
H-4	Structural castings other than subcategories H-1 through H-2 above, which are designed to be stressed in excess of: (a) 2/3-yield strength when yield is the basis of design. (b) One-half of ultimate strength when ultimate is the basis of design.	X	X
H-5	Structural castings which are to be welded into the ship hull structure (into means there must be a penetration of the structure; on or to the structure without penetration is excluded).		X

1/ When approved, UT inspection may be performed in lieu of RT for castings in both surface ships and submarines. Castings with UT indications in excess of the NAVSEA approved acceptance standards contained in the qualified procedures shall require the casting to be rejected or repair welded. Alternately the UT rejected casting may be re-inspected by RT and, if shown to meet the applicable RT acceptance standards, may be accepted.

2/ For extent of MT/PT coverage required, see 16.2.3. PT may be substituted for MT when a casting surface location or condition is such that it is inaccessible for MT or may be damaged by the MT method.

16.2.1 VT inspection. Each structural casting shall be VT inspected to the specified dimensions and surface conditions. In addition, the casting shall be visually checked to assure that identification markings have been maintained. Records of this inspection shall be as specified in section 5.

16.2.2 RT inspection. Castings as specified in table XXXIV, subcategory H-1, shall receive a minimum of 75 percent (100 percent for castings in the submarine pressure hull envelope) RT coverage in those areas of the casting forming watertight boundaries or designed for blast loading or grade A shock. Those areas specified in table XXXIV, subcategory H-2, H-3, H-4, castings requiring RT, not designed for blast loading or grade A shock, shall receive a minimum of 50 percent RT coverage. The percentages of RT coverage represent the acceptable minimum coverage and should not be construed to limit the extent of RT deemed necessary by the designer to ensure casting integrity and reliability. If geometry is such that the required percent RT coverage cannot be obtained, any lower coverage shall be justified by the designer when either drawings or radiographic shooting sketches (RSS) are developed for approval.

16.2.3 MT or PT inspection. Structural castings as specified in table XXXIV shall receive 100 percent MT or PT inspection, as applicable, of all accessible surface areas within 3 inches of the contiguous surface to which welds will be applied.

16.2.4 NDT qualification requirements. NDT inspection shall be performed using personnel and procedures qualified in accordance with section 4.

16.2.5 Designer responsibility. The casting designer shall be responsible for implementing the requirements as specified in 16.2.2 and 16.2.3 by selecting and identifying those areas requiring NDT on the engineering drawings using symbols in accordance with AWS A2.4. The designer shall specify on the engineering drawing the subcategory as specified in table XXXIV that applies.

16.2.6 RSS responsibility. The foundry or activity performing the RT shall be responsible for preparing the RSS in accordance with MIL-STD-271 based on requirements established by the designer. Prior to preparation of the RSS, the design requirements for RT shall be reviewed to ensure feasibility. If disagreement arises between the designer and the RT personnel concerning areas designated to be radiographed but considered impractical by the RT personnel, the disagreement shall be mutually resolved and the drawings modified accordingly and approved.

16.3 NDT acceptance criteria. Acceptability of castings subject to NDT shall be as specified in 16.3.1 through 16.3.5.

16.3.1 VT inspection. Acceptance criteria shall be in accordance with NAVSEA 0900-LP-003-8000, class 3.

16.3.2 RT inspection. Acceptance criteria for RT shall be in accordance with tables XXXV, XXXVI, XXXVII, and XXXVIII as applicable, and 16.3.3

TABLE XXXV. RT acceptance criteria for ferrous castings of carbon steel, corrosion-resistant steel and alloy steels (including HY-80/HY-100). 1/

Thickness	Level	Level definitions	Shrinkage			Porosity		Inclusions		Chaplets	
			ASTM standard	Type	Reference radiography	ASTM standard	Reference radiography	ASTM standard	Reference radiography	ASTM standard	Reference radiography
Less than 1 inch	1	Areas requiring 75 percent or greater RT coverage (see 16.2)	2/ E 186	1 2 3	CA 3 CB 3 CC 3	E 186	A 3	E 186	B 3	E 186	EA 3
	2	Areas requiring 50 percent min. RT coverage (see 16.2)	2/ E 186	1 2 3	CA 4 CB 4 CC 4	E 186	A 4	E 186	B 4	E 186	EA 4
	3	Areas not requiring RT but inadvertently radiographed or radiographed for information purposes	2/ E 186	1 2 3	CA 5 CB 5 CC 5	E 186	A 5	E 186	B 5	E 186	EA 5
1 inch up to 3 inches	1	Same as level 1 as defined above	2/ E 186	1 2 3	CA 4 CB 4 CC 4	E 186	A 4	E 186	B 4	E 186	EA 3
	2	Same as level 2 as defined above	2/ E 186	1 2 3	CA 5 CB 5 CC 5	E 186	A 5	E 186	B 5	E 186	EA 4
	3	Same as level 3 as defined above	2/ E 186		Engineering judgment (casting review)	E 186	Engineering judgment (casting review)	E 186	Engineering judgment (casting review)	E 186	Engineering judgment (casting review)
3 inches and over	1	Same as level 1 as defined above	E 280	1 2 3	CA 3 CB 3 CC 3	E 280	A 4	E 280	B 4	E 280	EA 3
	2	Same as level 2 as defined above	E 280	1 2 3	CA 4 CB 4 CC 4	E 280	A 5	E 280	B 5	E 280	EA 4
	3	Same as level 3 as defined above	E 280		Engineering judgment (casting review)	E 280	Engineering judgment (casting review)	E 280	Engineering judgment (casting Review)	E 280	Engineering judgment (casting review)

1/ Hull castings produced from HY-80/100 steel shall be in accordance with MIL-S-23008.
2/ Where ASTM E 186 is specified, use the following:

(a) 1- to 2-megaelectronvolts (MeV) X-Ray films for X-ray sources in the range and lower, and for iridium 192.
(b) Gamma ray films for cobalt 60 sources (and radium, if any).
(c) 10- to 24-MeV X-ray films for X-ray sources in the range.

3/ Where ASTM E 280 is specified, use the following:

(a) 10- to 24-Mev X-ray films for x-ray sources in the range; and
(b) Cobalt 60 films for other sources.

TABLE XXXVI. RT acceptance criteria for copper based castings of nickel bronze, copper-nickel, aluminum bronze, nickel-aluminum-bronze, manganese bronze, and nickel-copper.

			Shrinkage			1/ASTM E 272 Dross		Porosity		Inclusions		1/ASTM E 186 Chapters	
Thickness	Level	Level definition	Type	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source	ASTM standard	Reference radiograph
1 inch and less	1	Areas requiring 75 percent or greater RT coverage (see 16.2)	Feathery spongy linear	CD 3 CD 3 CA 3	X-ray2/ Gamma3/ Gamma3/	BB 2	X-ray2/	A 4	X-ray2/	BA 3	Gamma3/	E 186	EA 4
	2	Area requiring 50 percent min. RT coverage (see 16.2)	Feathery spongy	CD 4 CD 4 CA 4	X-ray2/ Gamma3/ Gamma3/	BB 3	X-ray2/	A 5	X-ray2/	BA 4	Gamma3/	E 186	EA 5
	3	Areas not requiring RT but inadvertently radiographed for information purposes	Feathery spongy linear	CD 5 CD 5 CA 5	X-ray2/ Gamma3/ Gamma3/	BB 4	X-ray2/	Engineering judgment (casting review)		Engineering judgment (casting review)		Engineering judgment (casting review)	
Over 1 inch	1	Same as level 1 as defined above	Feathery spongy linear	CD 4 CD 4 CA 4	X-ray2/ Gamma3/ Gamma3/	BB 4	X-ray2/	A 4	Gamma3/	BA 4	Gamma3/	E 186	EA 4
	2	Same as level 2 as defined above	Feathery spongy linear	CD 5 CD 5 CA 5	X-ray2/ Gamma3/ Gamma3/	BB 5	X-ray2/	A 5	Gamma3/	BA 5	Gamma3/	E 186	EA 5
	3	Same as level 3 as defined above	Engineering judgment (casting review)			Engineering judgment (casting review)		Engineering judgment (casting review)		Engineering judgment (casting review)		Engineering judgment (casting review)	

1/ ASTM E 272 and E 186 reference radiographs (films) shall be applied as indicated. Reference films specified in ASTM E 272 are identified by two thickness ranges, namely: (a) up to 2 inches and (b) 2 to 6 inches. Films are shown for the various discontinuity types in both thickness ranges. Three types of shrinkage are shown, designated: (a) feathery (b) spongy, and (c) linear. Only feathery is shown in the up to 2-inch thickness range, and the other two types, spongy and linear, are shown in the 2- to 6-inch thickness range. Films from both thickness ranges have been used without regard to applicable thickness indicated in the standard in order to provide the best coverage and gradation of discontinuities. Since film identification designations are duplicated in the 2-inch thickness range, they are further identified in the table by stating the source.

2/ Where X-ray appears under source in the table, this indicates that the low voltage X-ray film is applicable.

3/ Where gamma appears under source in the table, this indicates that the 2-MeV X-ray or cobalt 60 gamma ray film is applicable. The reference films indicated shall be used for all production radiography sources.

TABLE XXXVII. RT acceptance criteria for tin-bronze castings.

			1/ ASTM E 310				1/ ASTM E 186 (except as noted)	
			Shrinkage		Porosity	Inclusions	Chaplets	
Thickness	Level	Level definition	Type	Reference radiograph	reference radiograph	reference radiograph	ASTM standard	Reference radiograph
1/2 inch and less	1	Areas requiring 75 percent or greater. RT coverage (see 16.2)	Linear feathery or spongy	CA 3 CD 2	A 3	2/ B 3	E 186	EA 2
	2	Areas requiring 50 percent minimum. RT coverage (see 16.2)	Linear feathery or spongy	CA 4 CD 3	A 4	2/ B 2, B 4	E 186	EA 3
	3	Areas not requiring RT but inadvertently radiographed for information purposes	Linear feathery or spongy	CA 5 CD 4	A 5	B 5	E 186	EA 4
Over 1/2 inch	1	Same as level 1 as defined above	Linear feathery or spongy	CA 4 CD 3	A 4	2/ B 2, B 4	E 186	EA 3
	2	Same as level 2 as defined above	Linear feathery or spongy	CA 5 CD 4	A 5	B 5	E 186	EA 4
	3	Same as level 3	Linear feathery or spongy	Engineering judgment (casting review)	Engineering judgment (casting review)	Engineering judgment (casting review)	Engineering judgment (casting review)	

1/ ASTM E 310 and E 186 reference radiograph (films) are to be applied as indicated. The films indicated are to be used for all production radiography sources.

2/ For the inclusion films, the discontinuities of film B 2 are considered to be more severe than those of B 3. Those of B 3 and B 4 are considered to be approximately equal, with those of B 4 being fewer in number but larger in size.

TABLE XXXVIII. RT acceptance criteria for aluminum castings.

1/ ASTM E 155

Type of discontinuity

		Gas porosity						Shrinkage				Foreign material			
		Gas holes		Round		Elongated		Cavity		Sponge		Less dense		More dense	
Metal thickness (plan dimension for finished part)	Hot cracks, cold cracks, cold shuts, misruns	Plate (inches)	Grade	Plate (inches)	Grade	Plate (inches)	Grade	Plate (inches)	Grade	Plate (inches)	Grade	Plate (inches)	Grade	Plate (inches)	Grade
1/2 inch and less	None	1.1-1/4	3	1.21-1/4	4	1.22-1/4	4	2.1-1/4	3	2.2-1/4	4	3.11-1/4	3	3.12-1/4	3
Over 1/2 inch through 1-1/4 inches	None	1.1-3/4	5	1.21-3/4	5	1.22-3/4	5	2.1-1/4	4	2.2-3/4	4	3.11-3/4	4	3.12-3/4	4
Over 1-1/4 through 2 inches	None	1.1-3/4	6	1.21-3/4	6	1.22-3/4	6	2.1-1/4	5	2.2-3/4	5	3.11-3/4	5	3.12-3/4	5
Over 2 through 3 inches	None	1.1-3/4	7	1.21-3/4	7	1.22-3/4	7	2.1-1/4	7	2.2-3/4	6	3.11-3/4	6	3.12-3/4	6
Over 3 inches	None	1.1-3/4	8	1.21-3/4	8	1.22-3/4	8	2.1-1/4	8	2.2-3/4	8	3.11-3/4	7	3.12-3/4	7

1/ ASTM E 155 reference radiographs (films) are to be applied as indicated. The films indicated are to be used for all production radiography sources.

16.3.3 Evaluation of production radiographs. The following information and instructions shall be applied in evaluating production radiographs for compliance with acceptance criteria as specified in tables XXXV through XXXVIII.

16.3.3.1 Engineering judgment. The evaluation of production radiographs involves judgment based upon visual comparison usually with a single reference radiograph, or in any case with not more than two or three reference radiographs.

16.3.3.2 Comparison. The reference radiographs as listed provide a basis for acceptability by comparison with production radiographs. If the condition exhibited by the production radiograph is considered to be the equal of or better than the pertinent reference radiographs, that portion of the casting represented by the production radiograph shall be acceptable. If the condition exhibited is considered to be worse, that portion shall be rejected.

16.3.3.3 Size variance. The sizes of the reference radiographs in the several documents vary. An area of like size to the reference radiograph shall be the unit area by which the production radiograph is evaluated, and any such area or any adjacent film area which contains a continuing defect shall meet the requirements as stated for acceptability. When the area of interest of a production radiograph is less than the unit area, such area of interest shall be evaluated to an equivalent area exhibiting the most severe condition of the reference radiograph, provided adjacent areas requiring radiographic inspection are not rejectable when interpreted collectively.

16.3.3.4 Multiple discontinuities. If more than one discontinuity type occurs in a single production radiograph, each type shall be evaluated to the applicable reference radiograph. If the combination of the several types of discontinuities is considered to be equal to, or better than, the least restrictive applicable reference radiograph, the condition shall be considered acceptable.

16.3.3.5 Shrinkage. A multiple choice of reference shrinkage films is provided. Production radiographs exhibiting shrinkage shall be judged by the most representative reference radiograph.

16.3.3.6 Porosity or inclusions. Production radiographs exhibiting porosity or inclusions shall be evaluated by the general overall condition as regards size, number and distribution. It is not the intent that the maximum size of discontinuity shown in the reference radiograph shall be the limiting size for single production radiograph discontinuity, nor that the number of discontinuities shown on the reference radiograph shall be the limiting number for a production radiograph.

16.3.3.7 Elongated or hole-type gas discontinuities. The reference radiographs do not illustrate elongated or hole-type gas discontinuities. When this condition occurs in a production radiograph, it shall be evaluated by comparison with the applicable reference shrinkage film it most closely resembles.

16.3.3.8 Mottling. Radiographs of certain cast materials may exhibit a characteristic mottled appearance with distinct radiograph density variation between adjacent small areas, and can somewhat resemble spongy-type shrinkage. It is more pronounced for low-energy level radiography and becomes less pronounced with increasing energy level. It is most often observed in radiographs of tin bronzes, and most of the reference radiographs specified in ASTM E 310 exhibit it in varying degrees. It is not, however, confined to the tin bronzes and may occur for other copper base alloys, nickel copper and austenitic stainless steels. The condition on the radiograph shall not be cause for rejection in evaluating casting radiographs.

16.3.3.9 Hot tears and cracks. Hot tears and cracks exhibited on production radiographs are not acceptable. These indications may at times resemble linear-type shrinkage on the radiograph. When doubt exists as to whether such indications are cracks or tears, or are linear shrinkage, cast surfaces in the area of interest shall be ground and MT or PT inspected as applicable. If the indications do not appear on the ground surface, it shall be considered to be shrinkage.

16.3.3.10 Lower and upper limits. The lower limit of radiographic density shall be 1.5 for single viewing or for superimposed double viewing. The upper limit shall be that the entire area of interest on all radiographs shall be completely legible on the viewing equipment used, except that in no case shall it exceed a value of 4.0. This supersedes the film-density stipulations specified in MIL-STD-271.

16.3.3.11 Radiographic density. The radiographic density of discontinuities in comparison with the background density is a variable dependent on technique factors. It shall not be used as a criterion for acceptance or rejection in comparison with reference radiographs.

16.3.4 UT inspection. Where use of UT inspection is approved, final inspection shall be performed with the surface of the material in the condition specified in the approved procedure. Acceptance standards for cast materials shall be in accordance with the applicable material specification. Where material specifications do not include UT inspection acceptance criteria, the acceptance standards shall be part of the NAVSEA-approved inspection procedure.

16.3.5 MT and PT inspection. Final inspection shall be performed after all required machining or grinding has been completed, or in the case of MT, inspection may be performed within 1/32 inch of the final surface provided a dc continuous magnetization method is used for the inspection. Acceptance criteria shall be in accordance with 8.3.2. Indications in casting base metal adjacent to fabrication welds in or to the casting shall be evaluated to the acceptance criteria in 8.3.2.

16.4 Repair welding. Repair welding of structural castings shall be in accordance with sections 13, 14, and 16, using procedures and welders qualified in accordance with section 4. Limitations on repair are set forth below.

16.4.1 Repair by grinding. Repairs may be accomplished by grinding without repair welding, provided minimum design thickness is maintained and the final contour blends smoothly into adjacent surfaces. Final surfaces shall be inspected visually and by the originally required surface inspection acceptance standards in accordance with 16.3.5. RT/UT inspection shall be required if grinding was performed to remove unacceptable RT/UT defects.

16.4.2 Repair by welding. Defects that cannot be repaired by grinding in accordance with 16.4.1 or where a minimum design thickness cannot be established shall be repaired by welding. Only those indications which will bring the casting within the acceptance criteria need to be removed.

16.4.2.1 General limitations. Prior to repair welding, the excavated area shall be fully visible to the welder and allow access of the electrode or welding torch to all weld surfaces as specified in section 13. In addition, the following requirements shall apply:

(a) Unacceptable VT, MT, or PT indications in areas of castings that are acceptable by RT/UT inspection shall be excavated until the indication is removed or to a minimum depth of 3/8 inch or T/2, whichever is less.
(b) Unacceptable RT/UT indications shall be excavated only to the extent of bringing the indications within the applicable RT/UT acceptance standards.
(c) Unacceptable VT, MT, or PT indications in castings or areas of castings that do not require RT/UT inspection shall be excavated to the extent necessary (minor, nominal, or special repair) for the excavation to be in accordance with NAVSEA 0900-LP-003-8000 prior to welding.

16.4.2.2 Minor repairs. Minor weld repairs may be made to correct surface defects at the discretion of the activity or foundry provided:

(a) They do not exceed 1 inch in depth or 20 percent of the casting thickness, whichever is less.
(b) A weld buildup for correction of casting dimensional or machining errors not to exceed the following limitations (in the finished condition):

    (1) 3/16 inch maximum buildup for design thickness 1 inch and under;
    (2) 20 percent but not to exceed 3/8-inch maximum buildup for design thickness over 1 inch.

16.4.2.3 Nominal repairs. Repair welds in excess of those specified in 16.4.2.2 but which do not exceed one-half the casting thickness or 2 inches, whichever is less, may be made at the discretion of the activity or foundry.

16.4.2.4 Special repairs. Those in excess of 16.4.2.3 shall be subject to approval by the authorized agent. Such repairs shall be made with qualified welding procedures outlining the pre- and post-weld heat treatments for which qualification data demonstrate the ability to produce weldments which meet the required mechanical properties for the material involved. A history of all previously known special casting repairs on the affected casting and a detailed sketch or photograph showing such repairs shall be developed to enable evaluation of the proposed special repair.

16.5 Repair weld inspection. Castings which have been repaired shall be inspected as detailed below.

16.5.1 VT inspection. Each casting shall be inspected after repair for conformance to drawing dimensions, surface condition and for identification marking.

16.5.2 MT and PT inspection. MT or PT inspection, whichever was originally required, shall be performed to the requirements and acceptance standards for cast material in accordance with 16.3.5 on all weld repairs in the final repair surface condition. Final inspection of weld repaired castings that are subsequently post weld stress relieved shall be performed after the post weld heat treatment.

16.5.3 RT inspection. RT of weld repairs shall be performed to the requirements and acceptance standards in accordance with 16.3.3 for cast material. RT is not required for minor repairs as specified in 16.4.2.2. RT inspection of nominal weld repairs is required if the repair was made to correct an RT detected defect. RT inspection is required for all special weld repairs if that portion of the casting being repaired originally required RT. Repair of casting RT indications is required only to the extent of bringing such indications within the applicable RT acceptance standards.

16.5.4 UT inspection. Where UT in lieu of RT inspection is approved, acceptance criteria for repair welds shall be in accordance with an approved UT inspection procedure for cast materials.

16.6 Casting designation for fabrication. Castings which have satisfactorily passed receipt inspection requirements, or have been repaired as necessary to pass the requirements, shall be considered as wrought material for further fabrication purposes except where specified in this section. Temporary attachment sites, arc strikes and other fabrication scars shall be dispositioned as wrought material. However, the acceptance standards of section 16 for final inspection shall be applied.

16.7 Records. Records shall be maintained on all nominal and special repairs as specified in section 5 and shall include the following:

(a) Size, depth and location of the repair area. If reference points do not exist due to surface configuration, castings shall be marked as necessary to provide traceability of the repair records to the location of nominal and special repairs.
(b) Post weld heat treatment.
(c) Inspection results.

17. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

17.1 Intended use. This standard is intended to describe the minimum requirements for shipbuilding practices, standards for material, weld joint design, workmanship, welding inspection and record requirements for combatant surface ship structures and for those submarine structures which are not high-yield steels.

17.2 Issue of DODISS. When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1, and 2.2).

17.3 Data requirements. The following Data Item Descriptions (DID's) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this standard is applied on a contract, in order to obtain the data, except where DoD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
4.8.1, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.6.1, 5.2.6.2, 5.2.6.3, 5.2.7, 5.2.8, 5.2.9, 5.2.9.1, 5.2.10.2. 5.2.12, 6.1, and 16.7	DI-MISC-80711	Scientific and technical reports	- - -
5.1	DI-QCIC-80147	Quality control plan	- - -
5.2.6.1	DI-E-2121	Certificate of compliance	

The above DID's were those cleared as of the date of this standard. The current issue of DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

17.4 Subject term (key word) listing.

Arc
Backgouge
Bulkhead
Butt
Coaming
Forgings
Lamination
Seam
Web stiffener
Welds

17.5 Changes from previous issue. Marginal notes are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project THJM-N228)

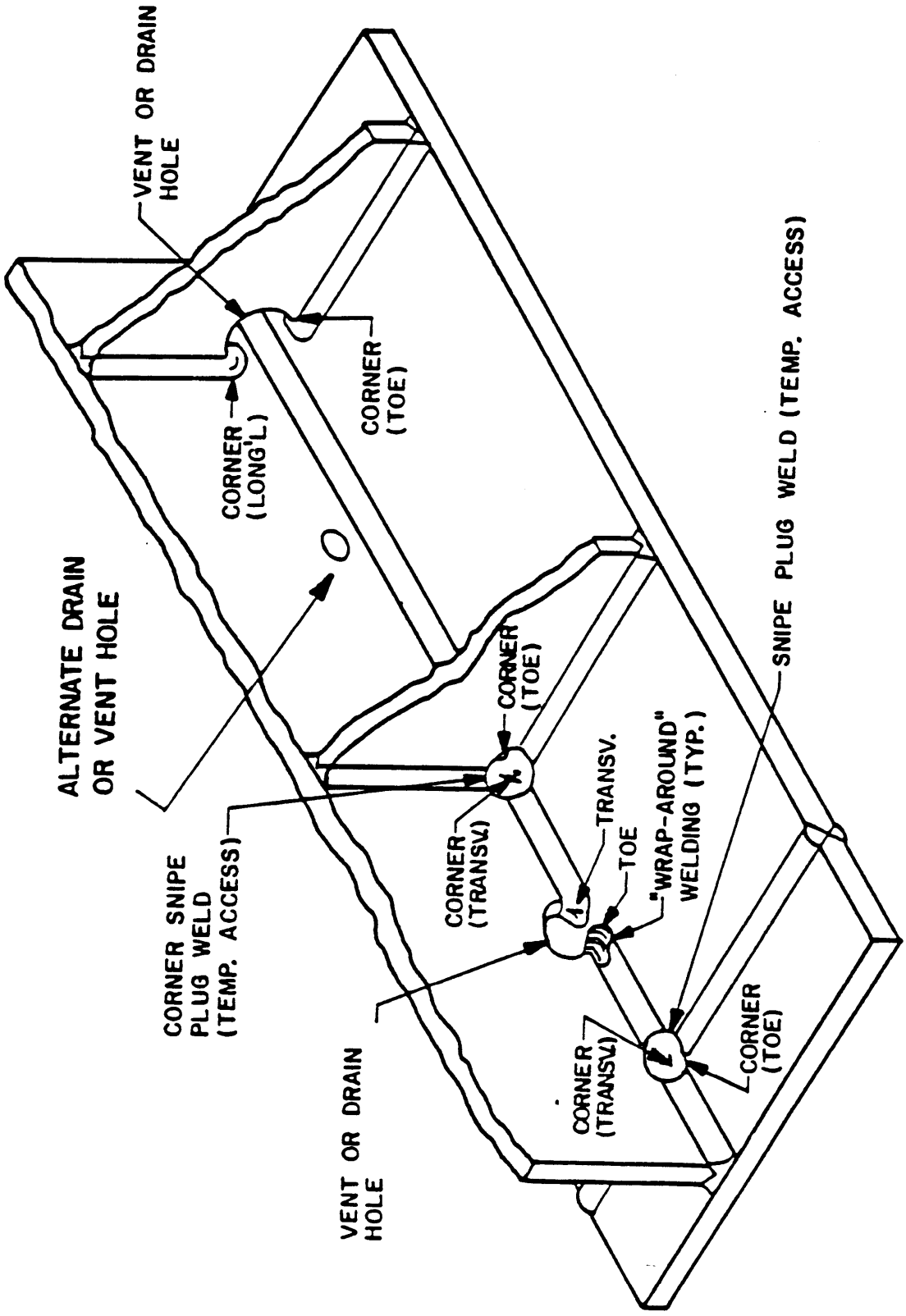
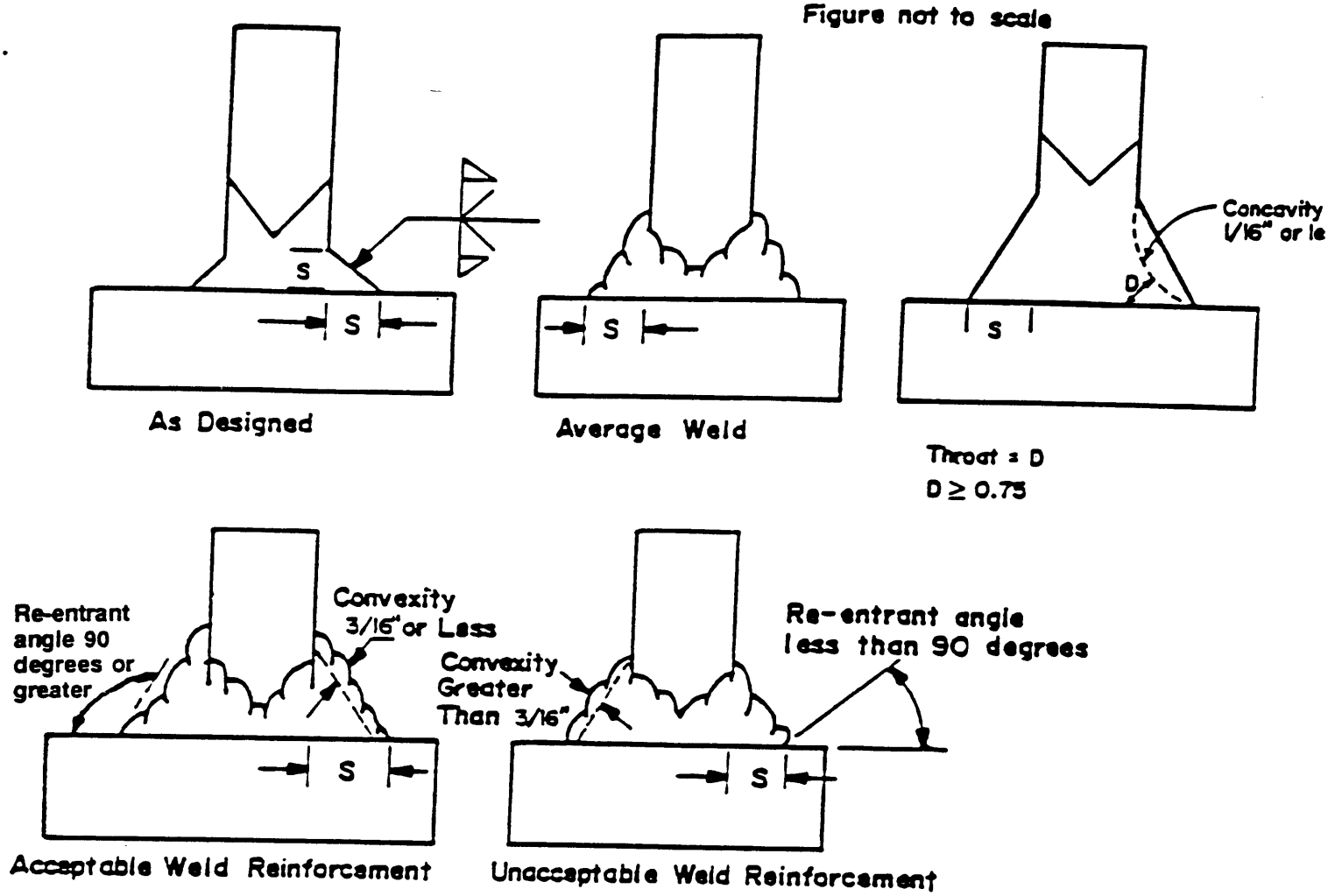


FIGURE 1. Cracks in corner welds.

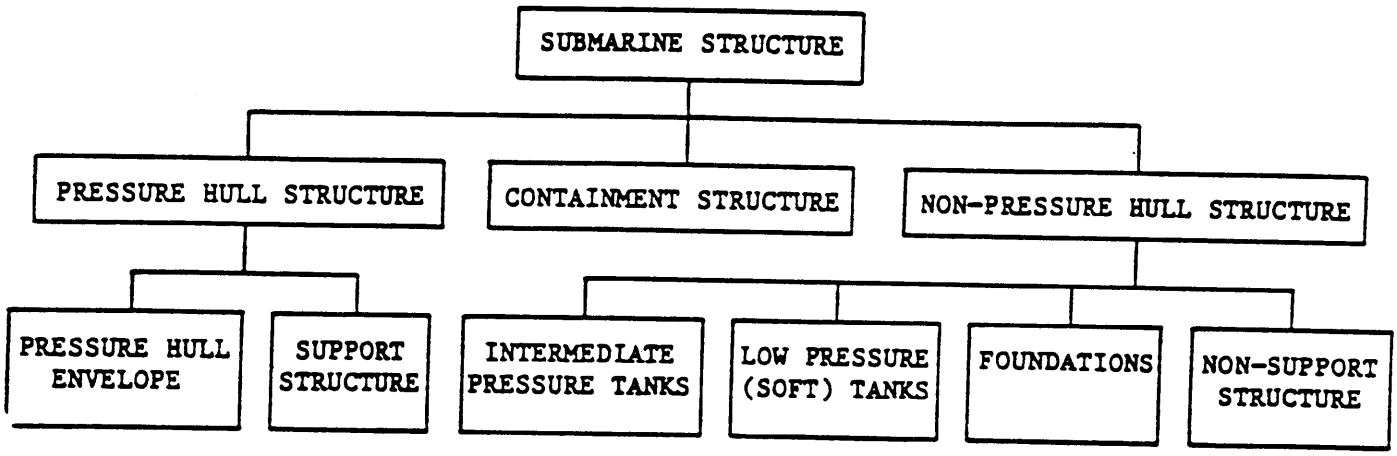


SH 4781

NOTE: S = Required fillet reinforcement.

1. Fillet reinforcement size in excess of that required by plan is acceptable provided the contour is in accordance with these figures.
2. Although the fillet contour shown in this figure is for groove tee welds, the same requirements apply for fillet welds.
3. Convexity shall not be more than 3/16 inch.
4. Concavity shall not be more than 1/16 inch; concavity is acceptable provided the minimum throat thickness is at least equal to 70 percent of required fillet reinforcement size (D = 0.75).

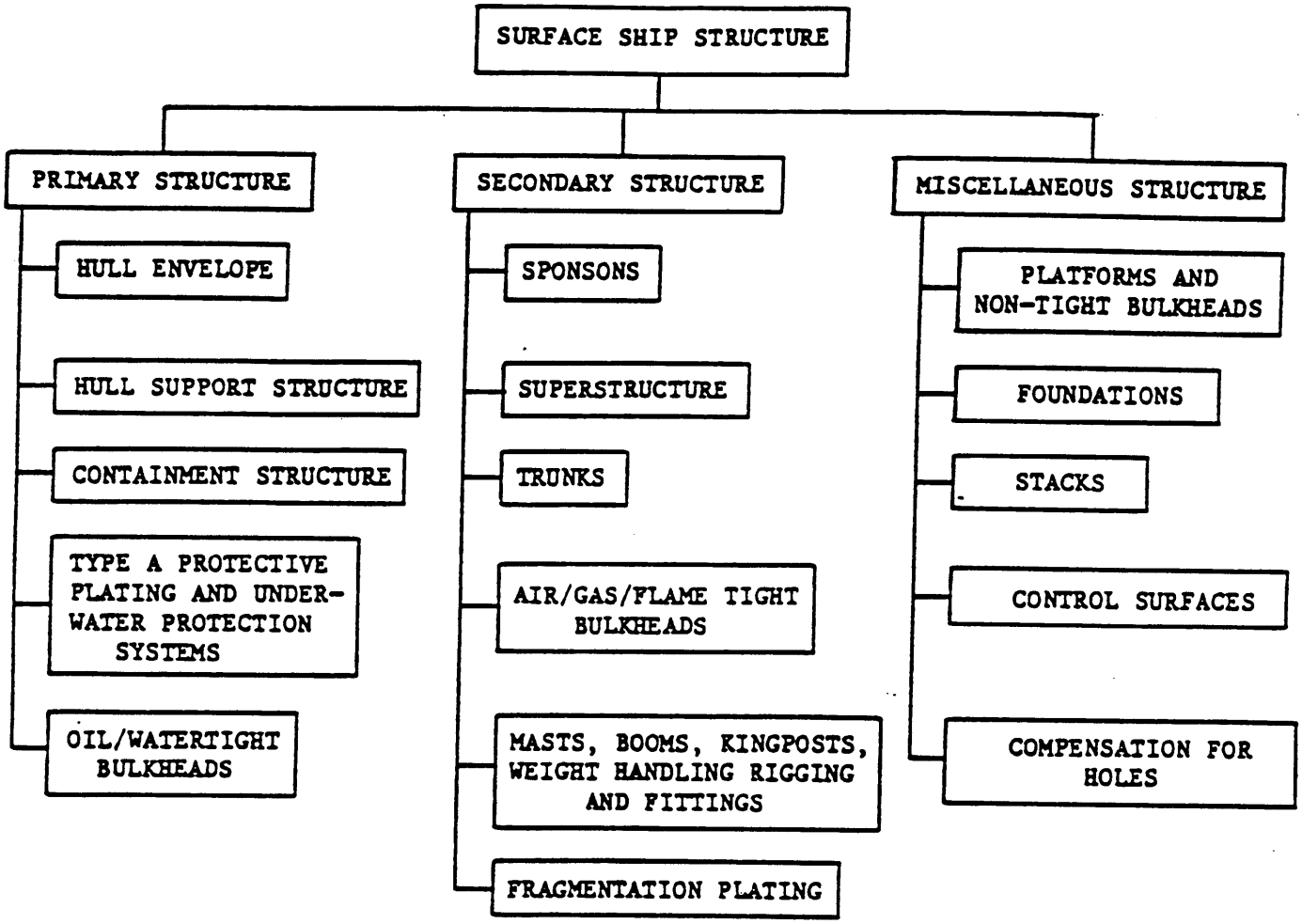
FIGURE 2. Typical contour for fillet groove tee welds and fillet welds.



NOTE:

1. Any component of submarine structure which may fall into more than one of the above categories shall be considered as belonging to that category having the more stringent design and inspection criteria.

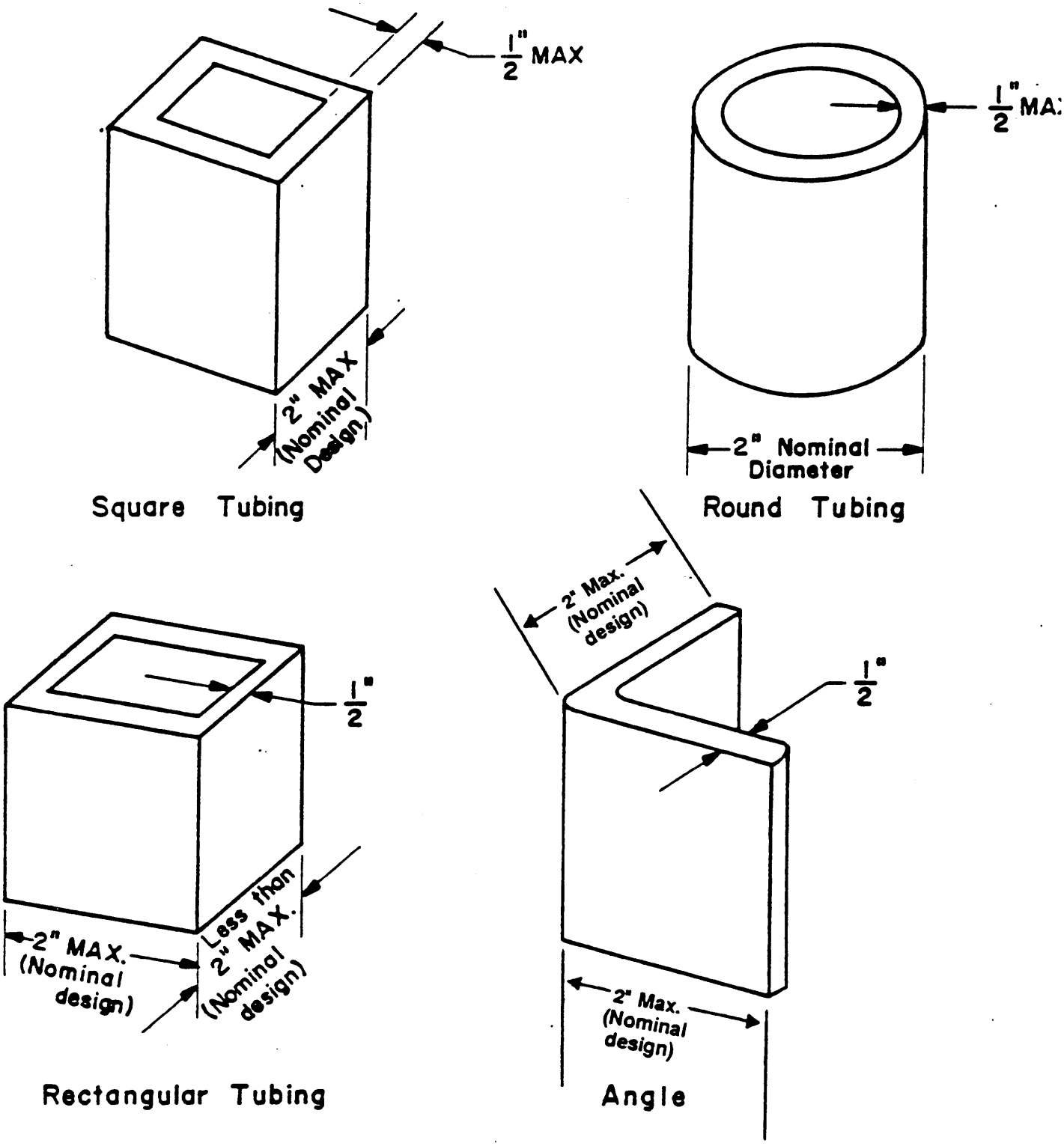
FIGURE 3. Functional diagram of submarine structure.



NOTE:

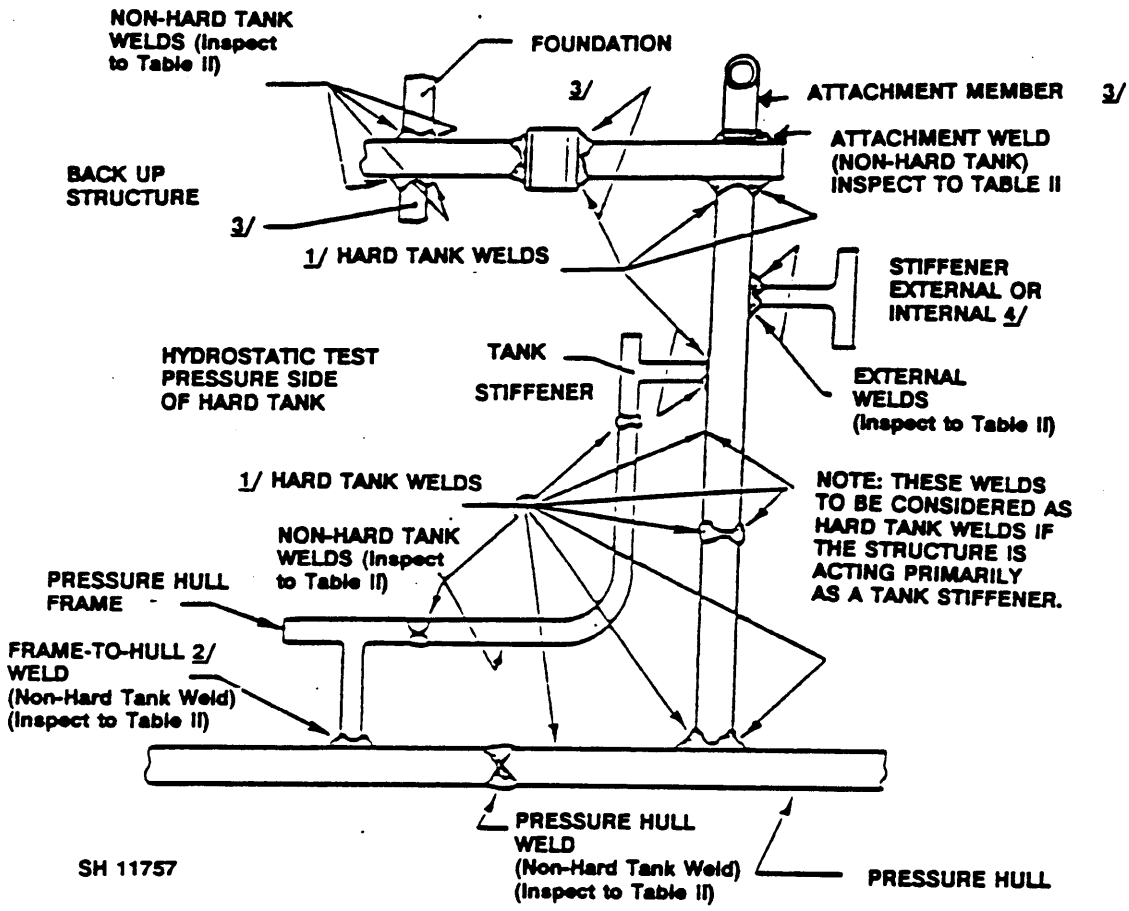
1. Any component of surface ship structure which may fall into more than one of the above categories shall be considered as belonging to that category having the more stringent design and inspection criteria.

FIGURE 4. Functional diagram of surface ship structure.



SH 131445

FIGURE 5. Attachment welds.



1/ Normally, the hydro test pressure side of the hard tank and the operational pressure side of the hard tank are the same. When exceptions exist, welds in or to both sides of the hard tank plating shall be considered hard tank welds.

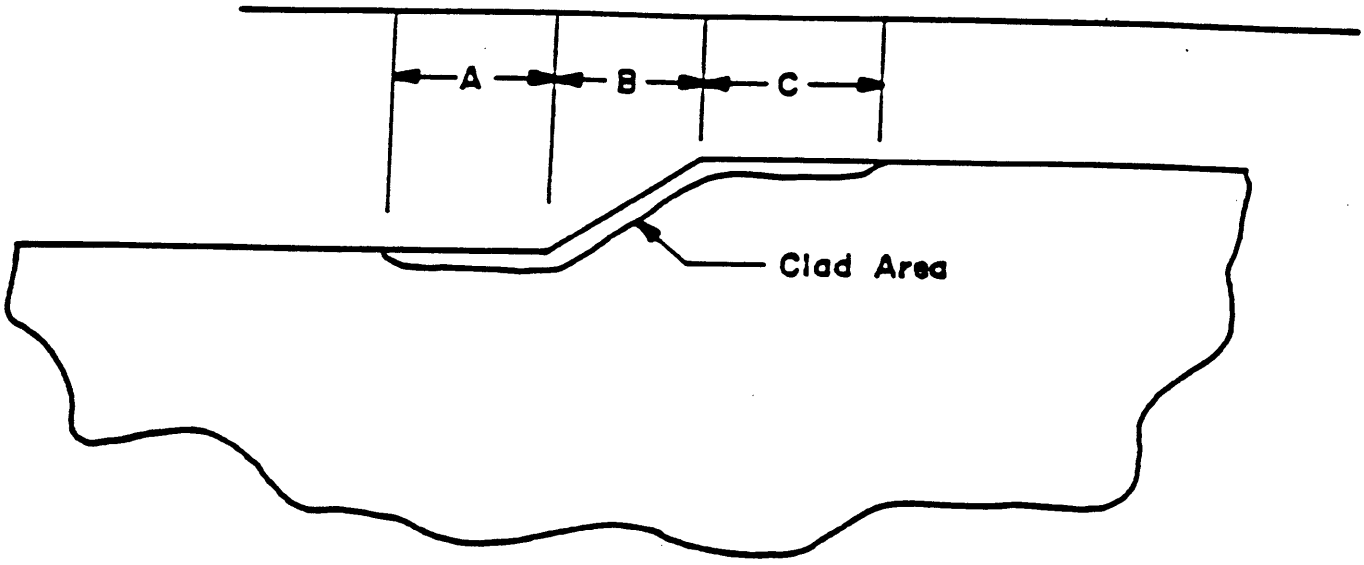
2/ Frame to pressure hull envelope welds and pressure hull welds located within the hard tank are not considered hard tank welds. If the frame to pressure hull weld acts as a tank boundary, it shall be inspected as a tank weld.

3/ Back-up structure for foundations is structure welded to the hard tank plating for the design purpose of supporting foundations and not primarily as a tank stiffener. Inspect back-up structure, foundation and attachment welds to table II.

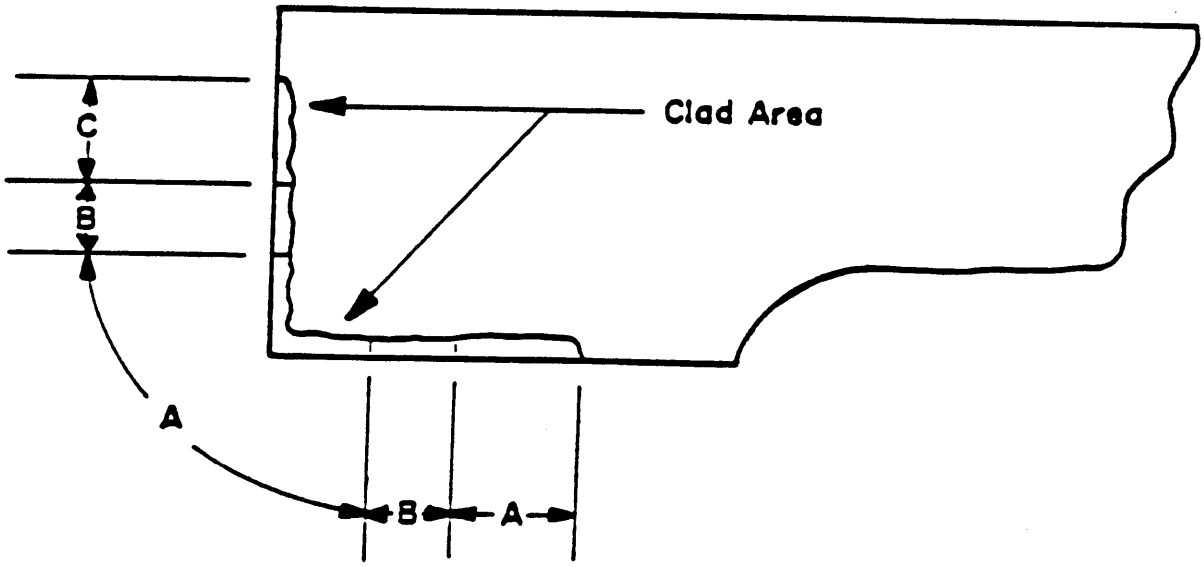
4/ Where the stiffener, external or internal, is not active as a primary tank panel stiffener, inspect the stiffener attachment weld to table II.

5/ Welds not specifically identified in this figure as tank welds are to be inspected in accordance with table II.

FIGURE 6. Hard tank welds. 5/



Typical Clad Area with Single Seating Surface



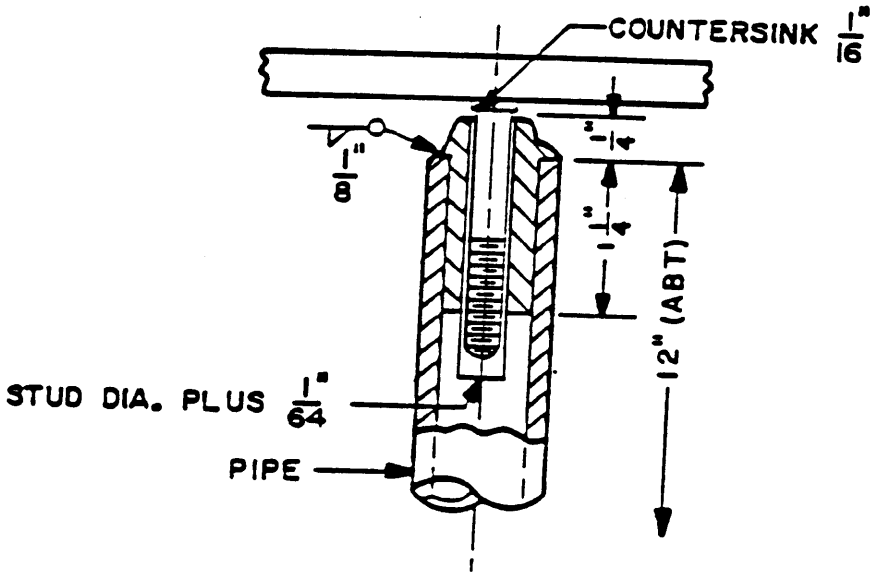
Typical clad area with double seating surface

A = Inboard surfaces	Class 3
B = Seating or seal area	Class 1
C = Outboard surfaces	Class 2

SH 12471

NOTE: The width of zone B shall be the width of the gasket retaining groove in the matching part, plus 1/8 inch.

FIGURE 7. Clad areas for O-ring or gasket seating surfaces.



SH 12469

FIGURE 8. Device for bend testing welded studs.

Figure 9A

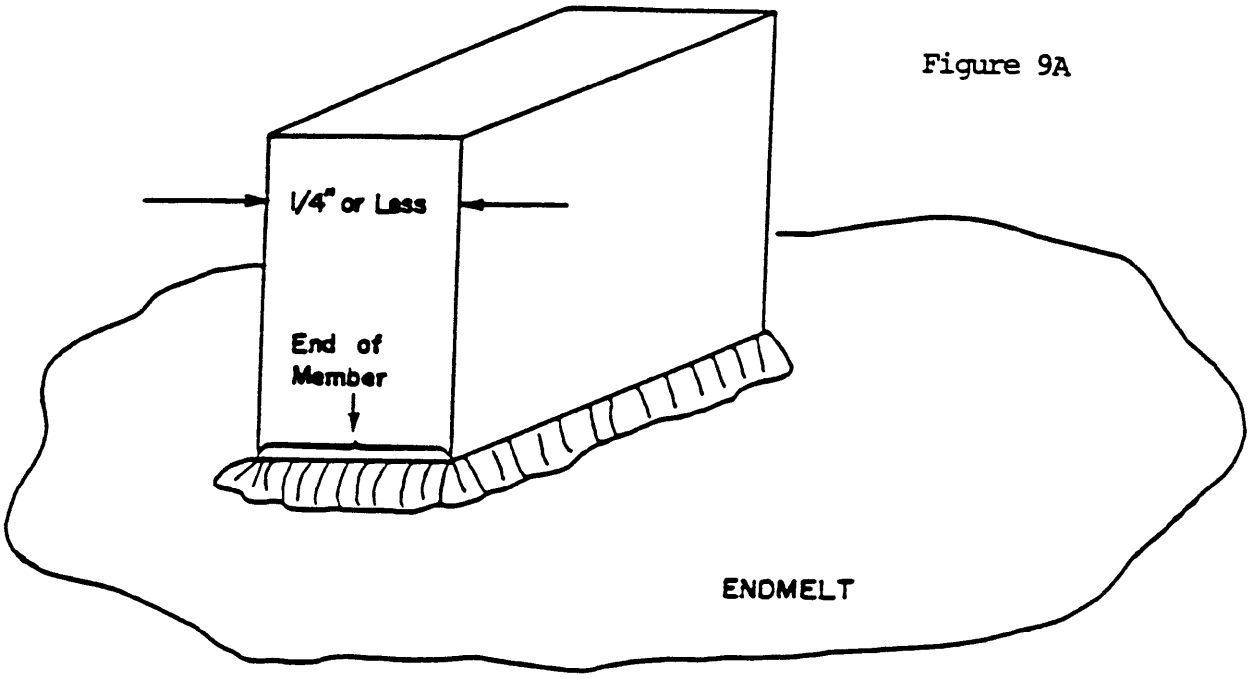


Figure 9B

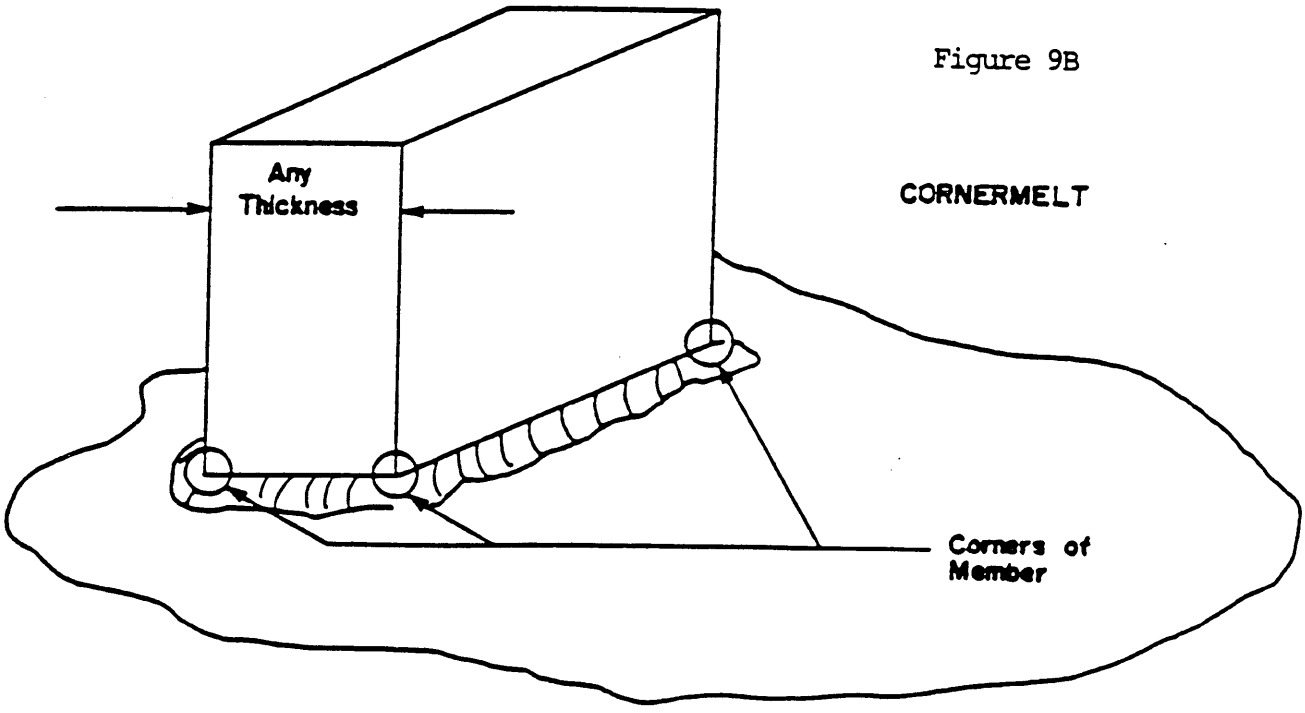
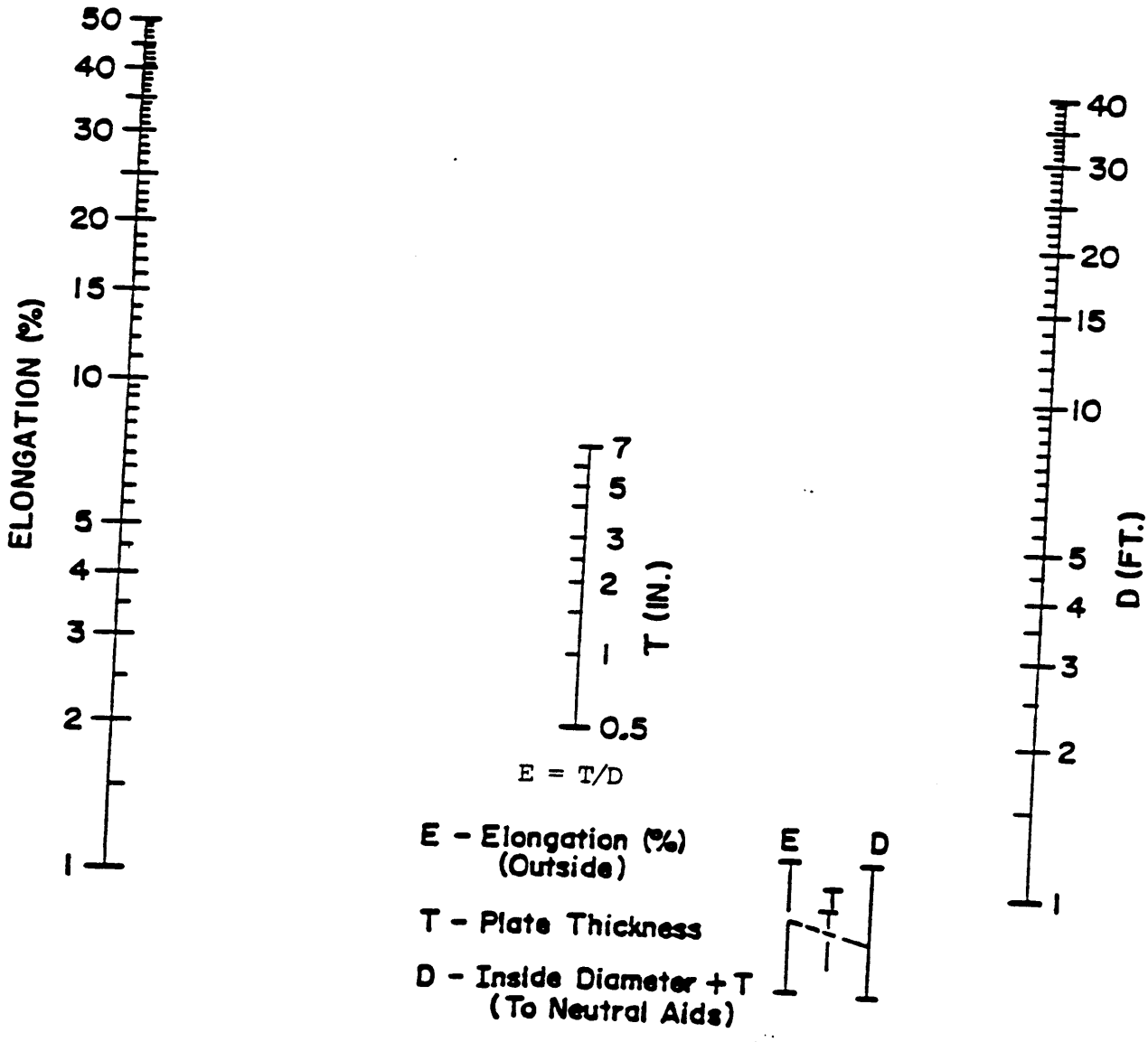
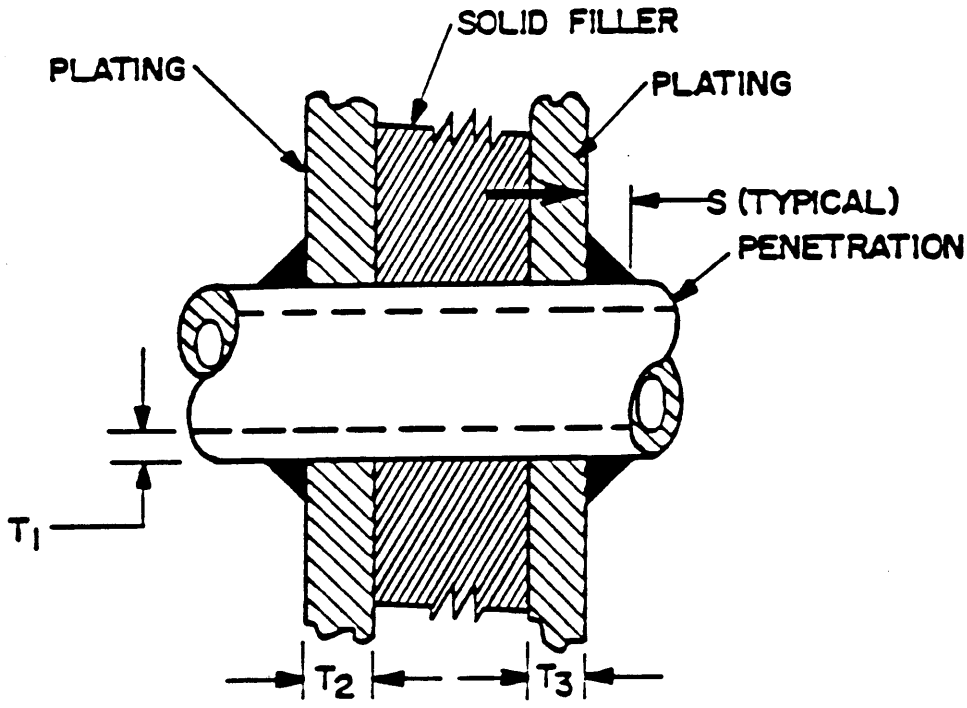


FIGURE 9. End-melt and corner-melt.



SH 12472

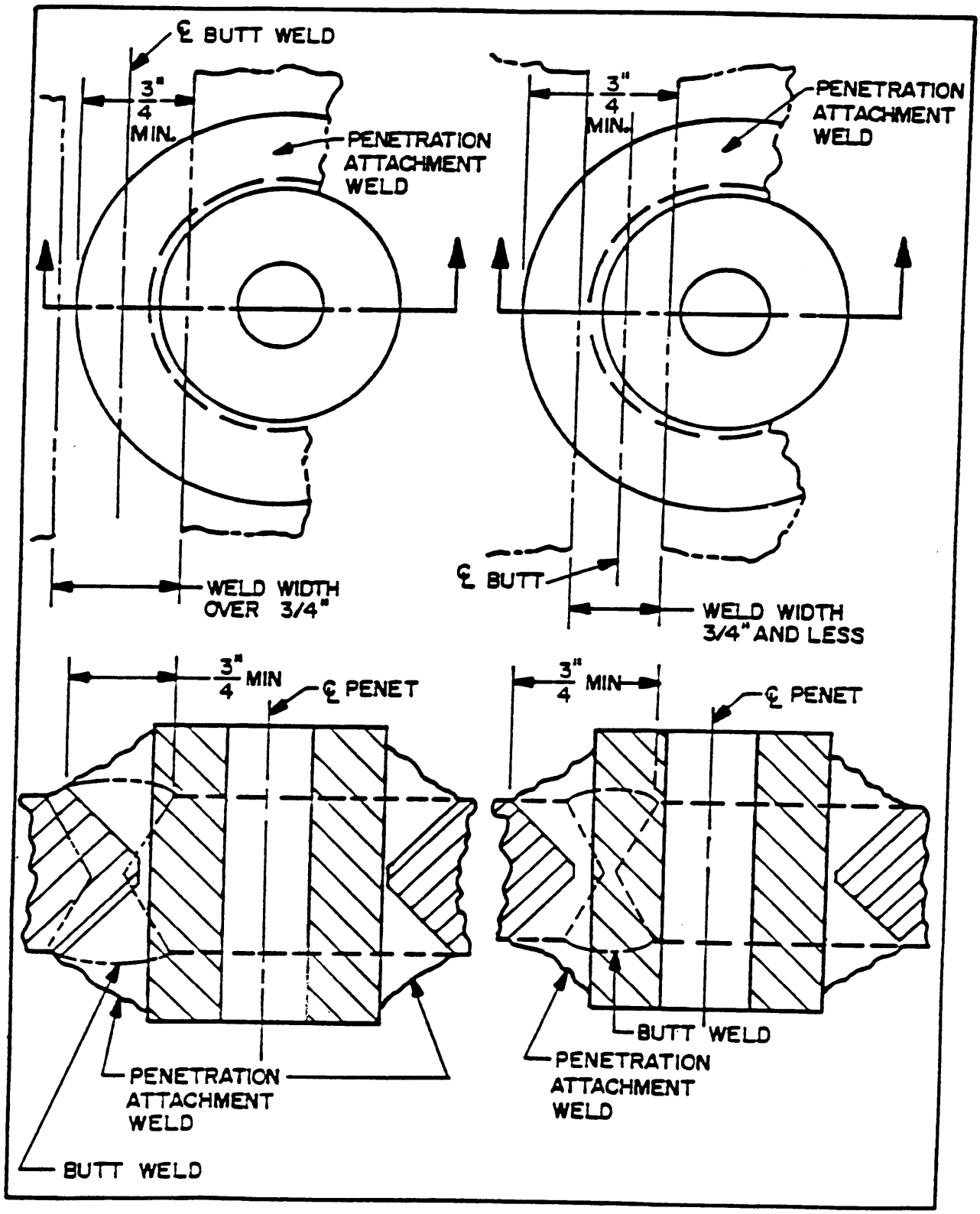
FIGURE 10. Nomograph of outside surface elongation after bending or rolling.



NOTE:
1. Sizes of fillet welds shall be determined from MIL-STD-1628 based on thickness (T1, T2 or T3) of weaker member.

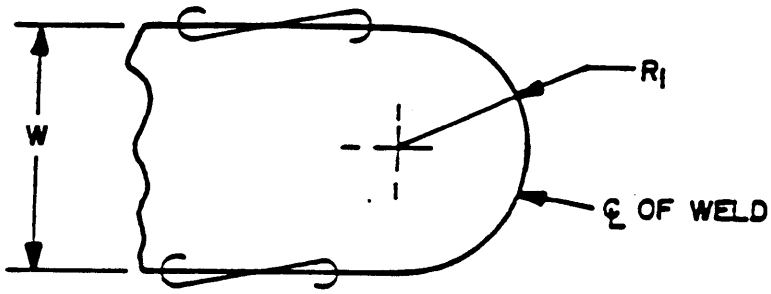
SH 12473

FIGURE 11. Penetration through special sandwich bulkhead with solid filler.

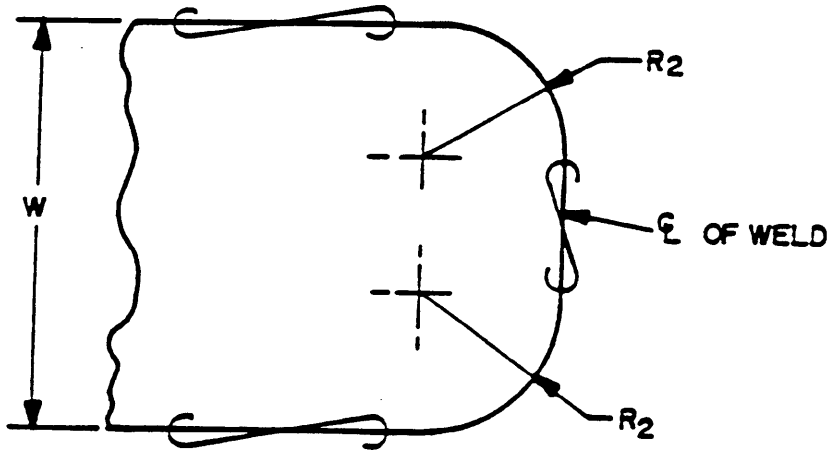


SH 12474

FIGURE 12. Location of penetration attachment welds in relation to butts and seams.



WHEN "W" = 6" MIN., 12" MAX.
THEN $R_1 = \frac{W}{2}$

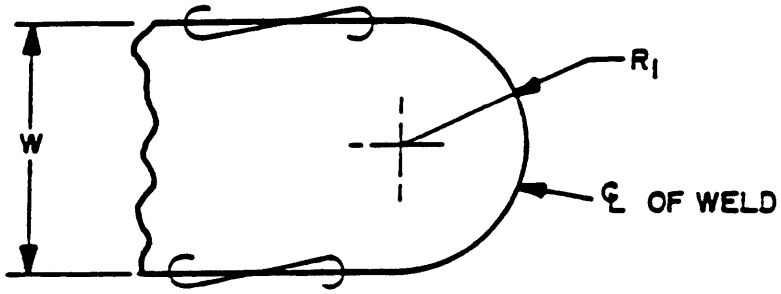


WHEN "W" = 12" MIN.
THEN R_2 = 6" OR 2T WHICHEVER IS LARGER

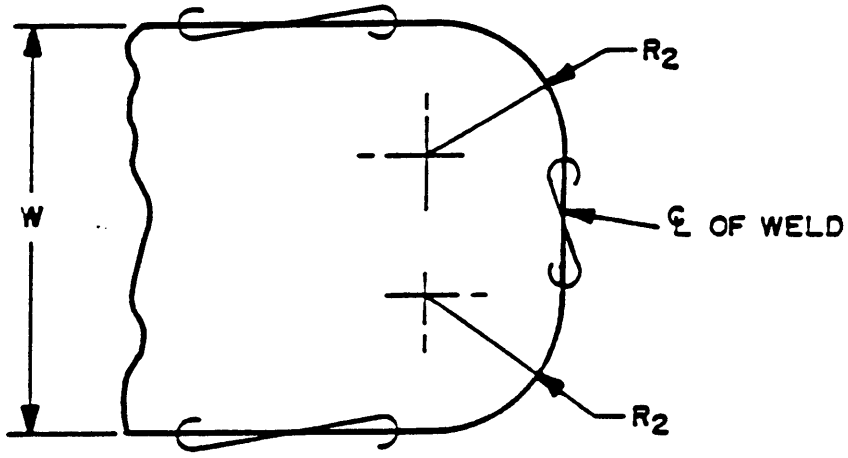
Where T equals the thickness of the member penetrated

SH 12475

FIGURE 13. Inserts, patches, and small access plates in submarine pressure hull envelope.



WHEN "W" = 3" MIN., 6" MAX
THEN $R_1 = \frac{W}{2}$

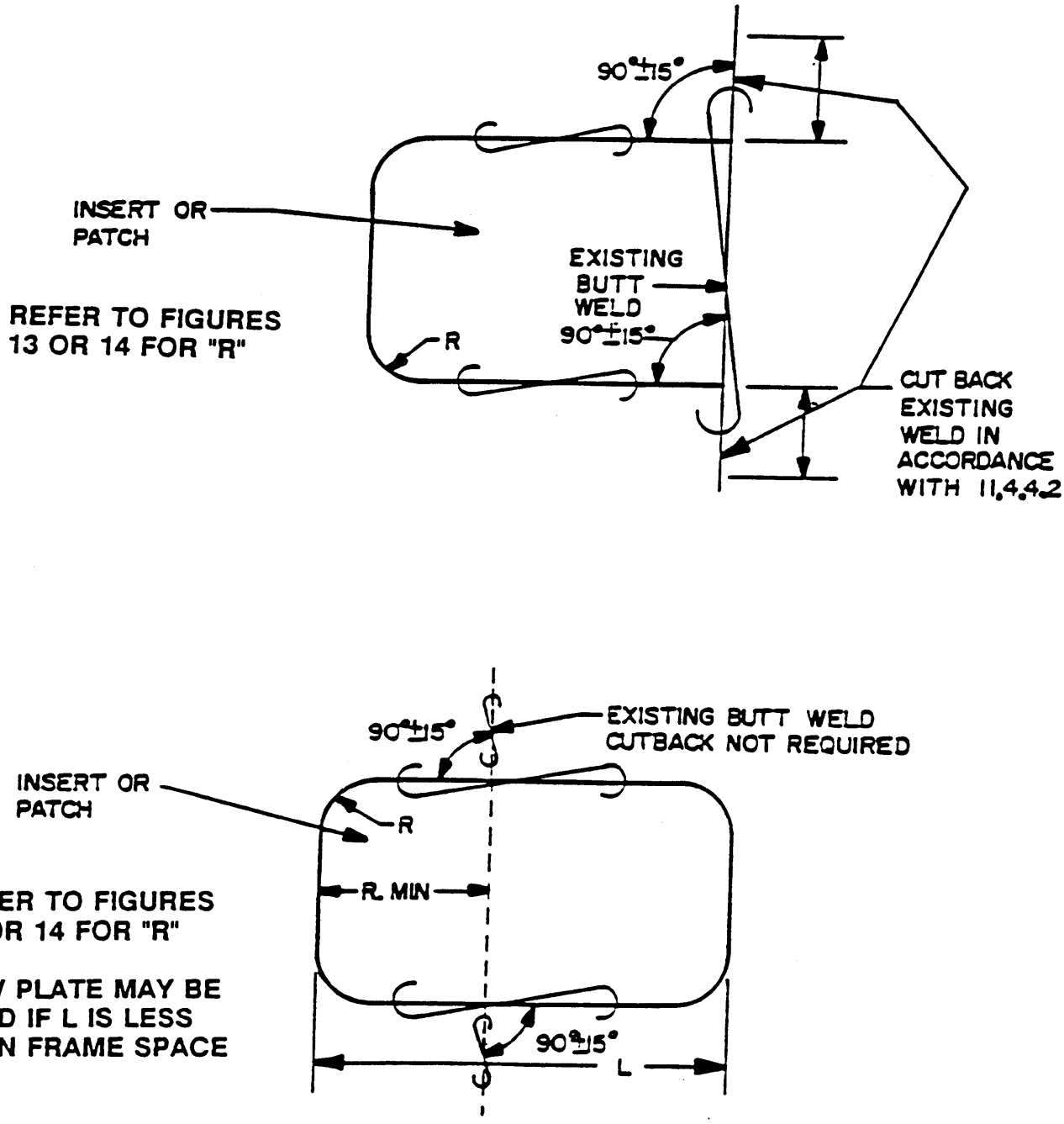


WHEN "W" = 6" MIN
THEN R_2 = 3" OR 2T WHICHEVER IS LARGER

Where T equals the thickness of the member penetrated

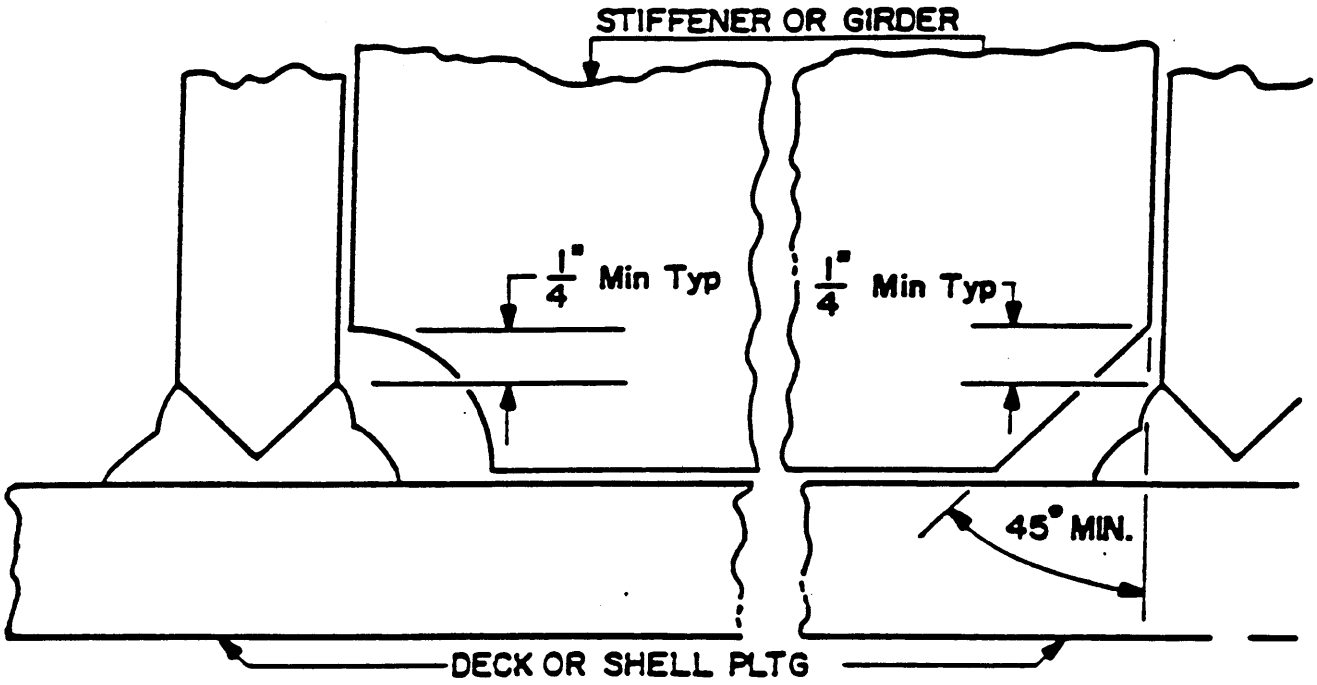
SH 12476

FIGURE 14. Inserts, patches and small access plates in plating and structure for surface ships and other than the pressure hull envelope for submarines.

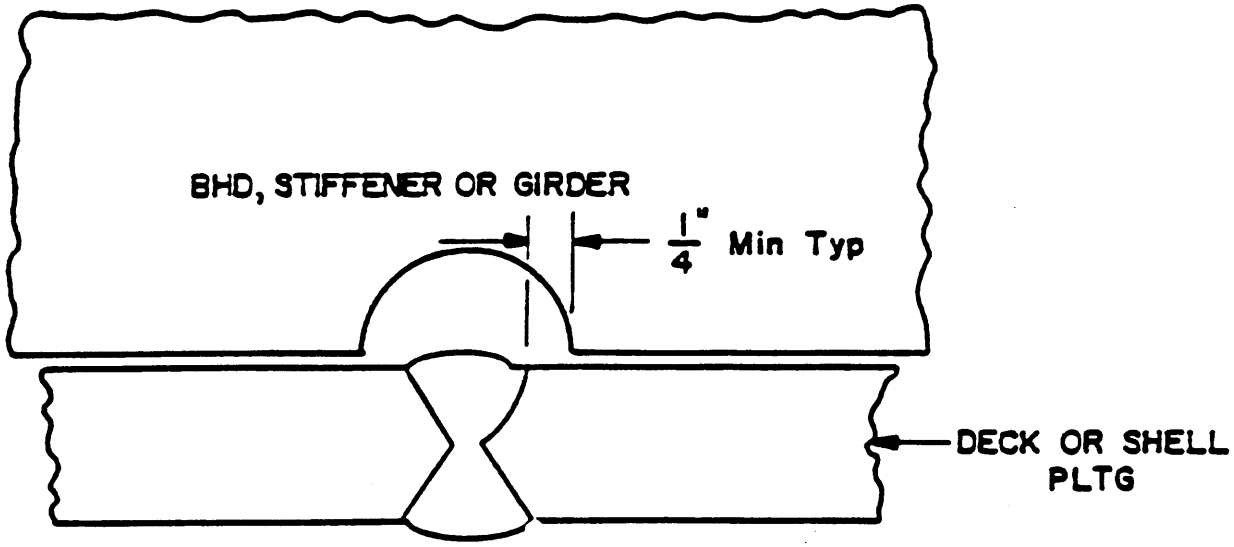


SH 12477

FIGURE 15. Relationship of inserts, patches and small access plates to existing butt welds in submarine and surface ships.



Typical vents, drains and permanent snipes in connecting member which intersect two or more other members.



SH 12478

NOTE:

1. Typical vents, drains and permanent snipes in connecting structural member crossing a butt weld. Hole may be cut smooth, free from notches or re-entrant angles from which cracks may be propagated on rough cut openings. The option of smoothing or weld repairing the objectionable irregularities is allowed.

FIGURE 16. Typical vents, drains and permanent snipes.

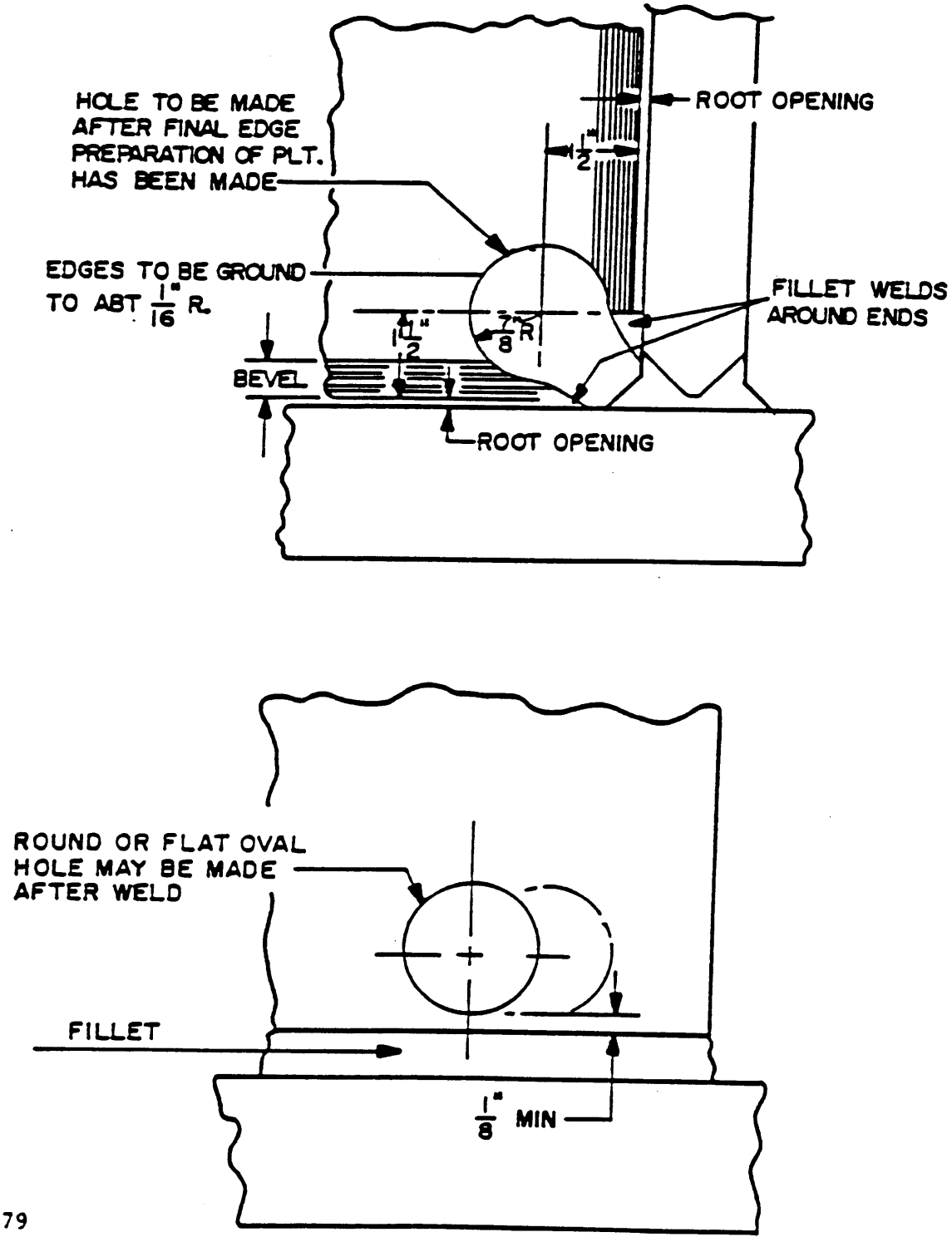
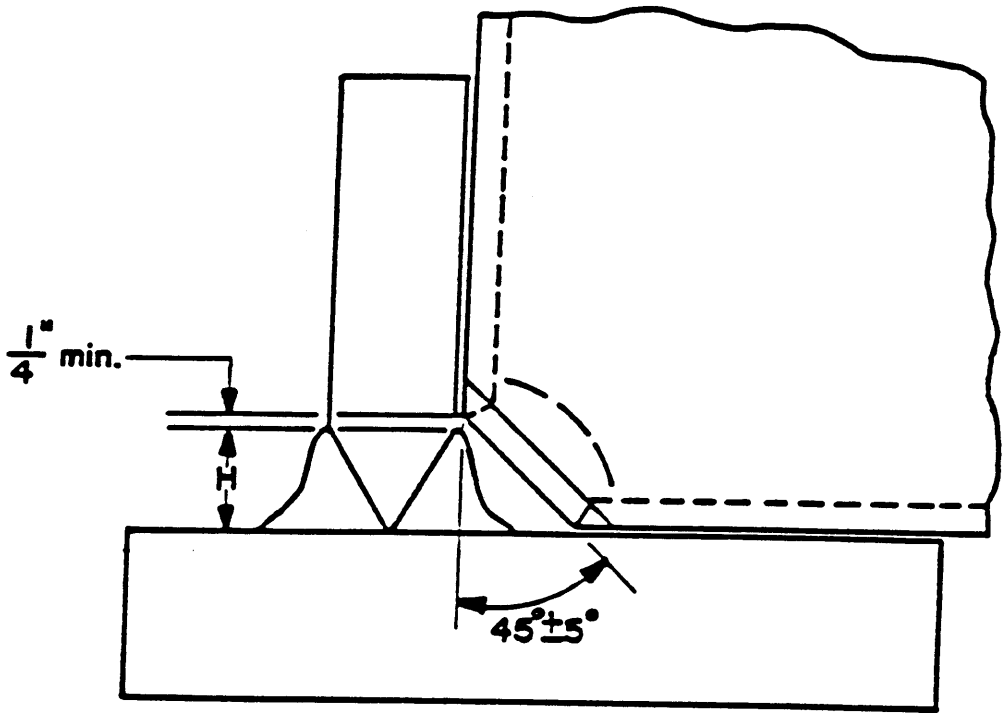


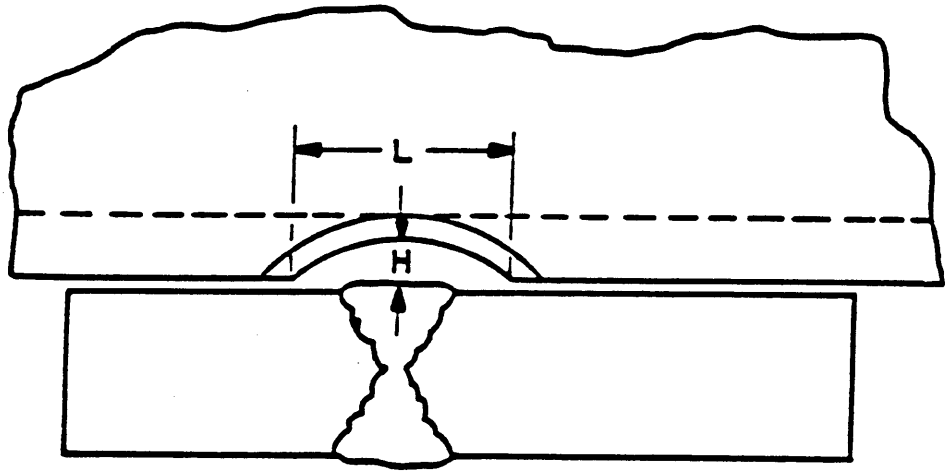
FIGURE. 17 Alternative drain or vent opening for tank structure.



SH 12486

NOTES:
1. Height of the snipe (H) shall be such that the corners of the snipe clear the intersecting weld preparation at least 1/4 inch as shown above.
2. The snipe shall be shaped and beveled as required to provide adequate accessibility for welding.
3. All access snipes shall be welded unless otherwise indicated by design requirements. The maximum buildup limitation may be increased to 1-1/2 inches for welding up snipes.

FIGURE 18. Temporary snipe in corner or connecting structural member which intersects two or more other members.



SH 12487

NOTES:

1. Length of snipe opening (L) shall be at least 1/2 inch longer than width of butt weld which it crosses.
2. Height of snipe opening (H) shall be adequate to provide accessibility for welding but not less than 3/16 inch.
3. When design of the crossing member calls for snipe edge joint preparation, the edges of the snipe shall be beveled as required to provide adequate accessibility to the butt. The edges of the snipe shall be beveled to "fair in" with the plate edge preparation bevel.
4. All access snipes shall be welded unless otherwise indicated by design requirements. The maximum buildup limitation may be increased to 1-1/2 inches for welding up snipes.

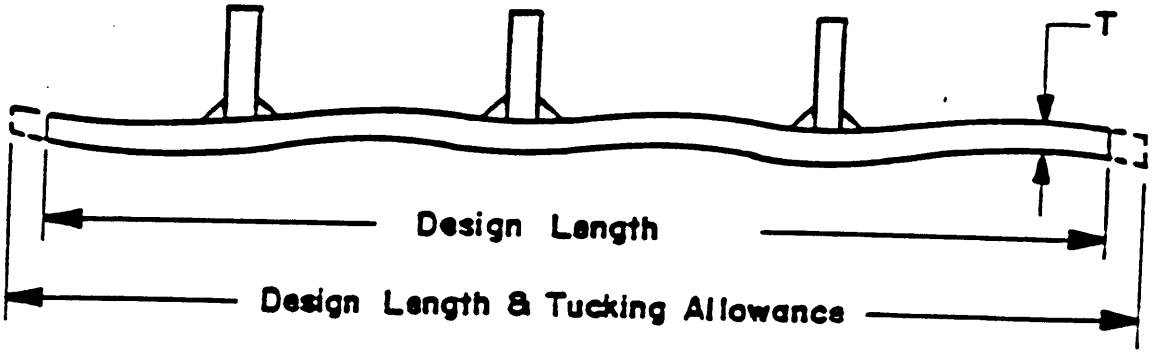
FIGURE 19. Temporary snipe in structural member connection crossing a butt weld.

BUTT WELDS (STEEL)

	Shrinkage allowance
Transverse	1/16 to 3/32 inch for all thicknesses

Longitudinal

Thickness	Shrinkage allowance
over 1/2-inch	1/32 inch in 10 feet
over 3/8- to 1/2-inch inclusive	1/32 to 1/16 inch in 10 feet
over 1/4- to 3/8-inch inclusive	1/32 to 3/32 inch in 10 feet
1/4-inch and less	1/16 to 1/8 inch in 10 feet

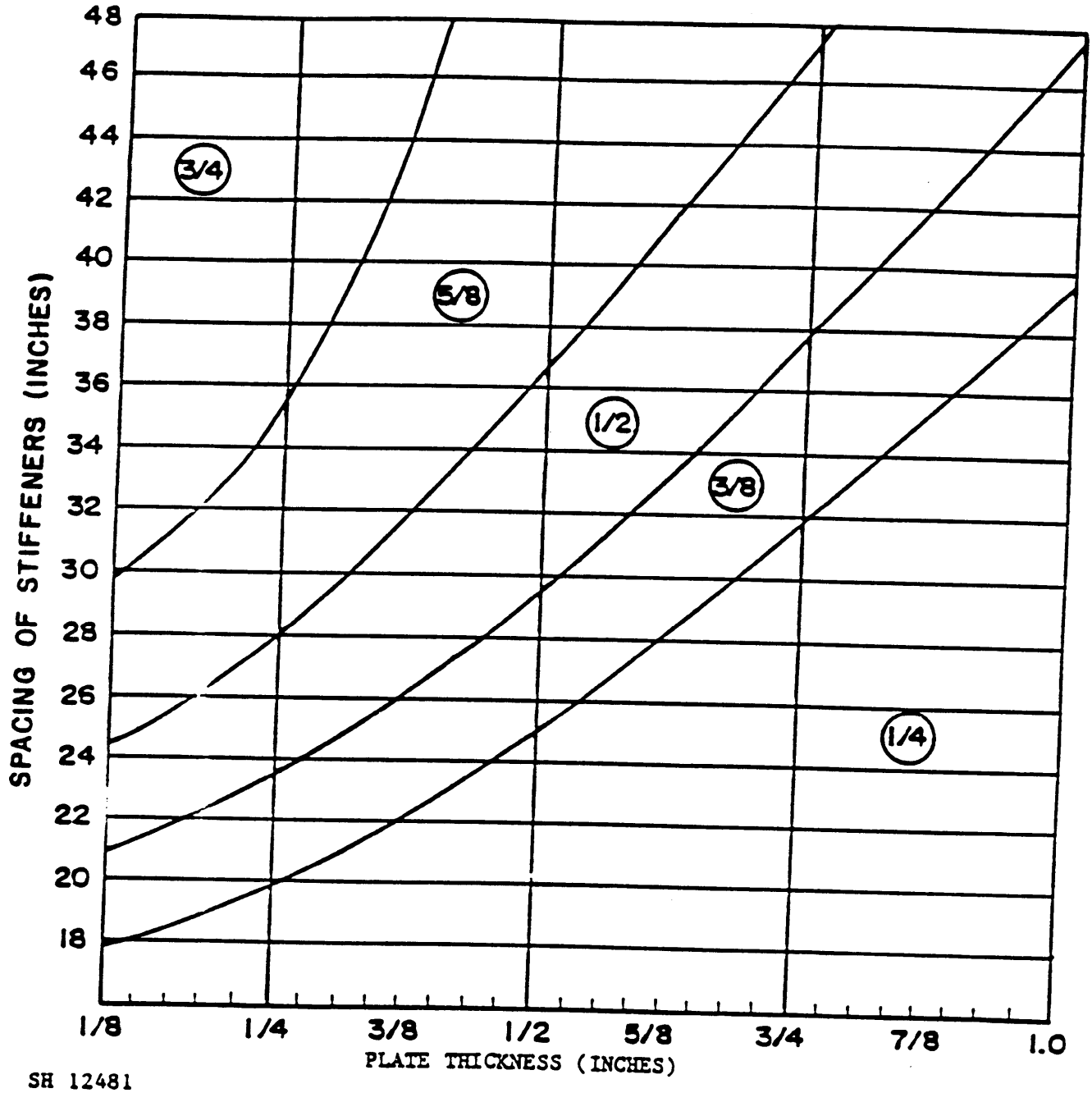


SH 12480

FILLET WELDS

Thickness	Tucking allowance
over 1/2-inch	No allowance
over 3/8- to 1/2-inch inclusive	1/64 inch per stiffener
over 1/4- to 3/8-inch inclusive	1/32 inch per stiffener
1/4-inch and less	1/16 inch per stiffener

FIGURE 20. Shrinkage allowance (for guidance only).

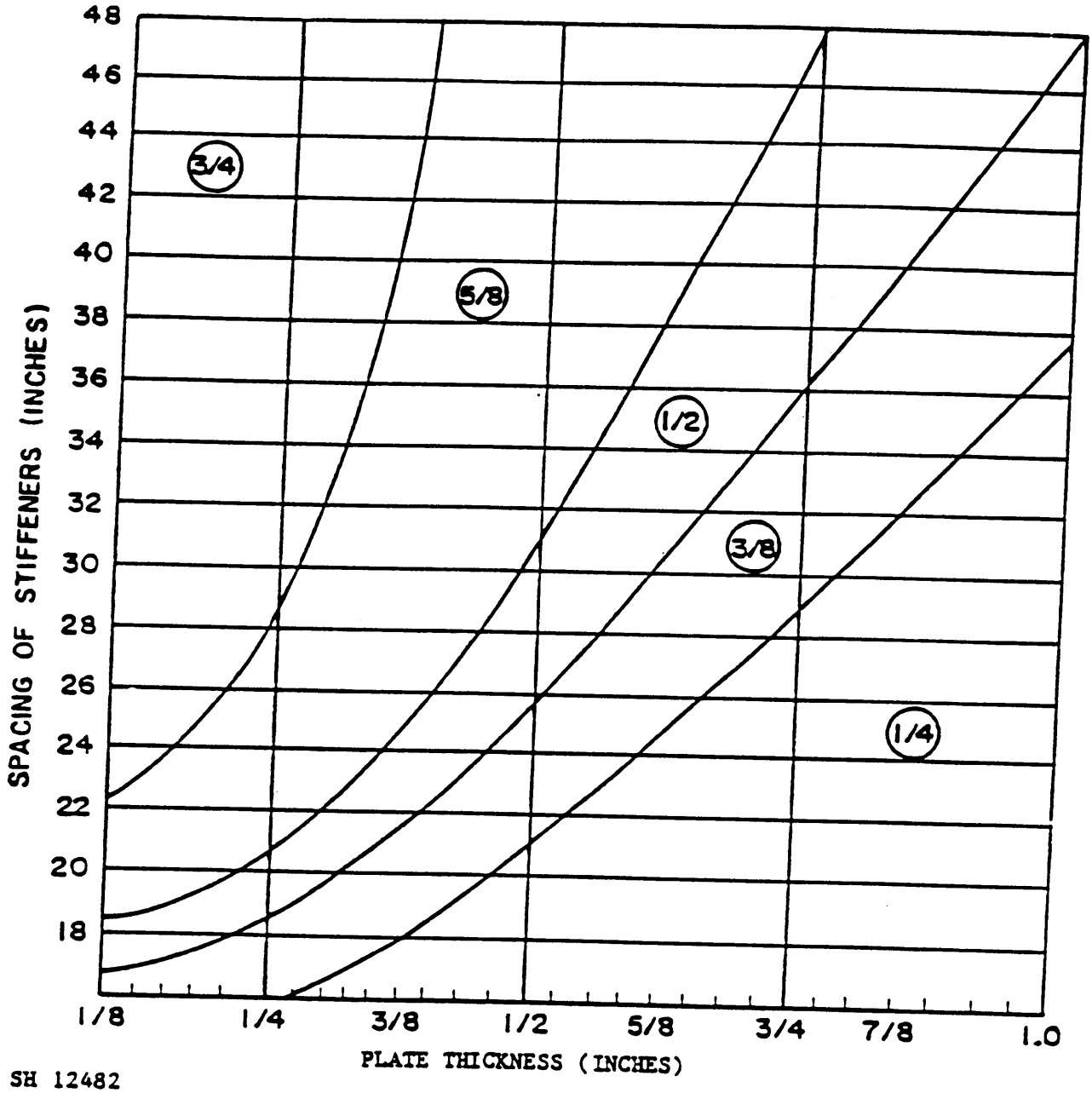


SH 12481

Applicability of tolerances:

(1) Entire shell.
(2) Uppermost strength deck.
(3) Longitudinal strength structure within the midships 3/5 length which includes inner-bottom, tank top and the deck next below the uppermost strength deck if continuous above machinery spaces.
(4) In transversely framed ships, the permissible unfairness for structure noted in (1), (2) and (3) above is reduced by 1/8 inch.
(5) Bulwarks and exterior superstructure bulkheads.

FIGURE 21. Surface ship, permissible unfairness in steel welded structure.

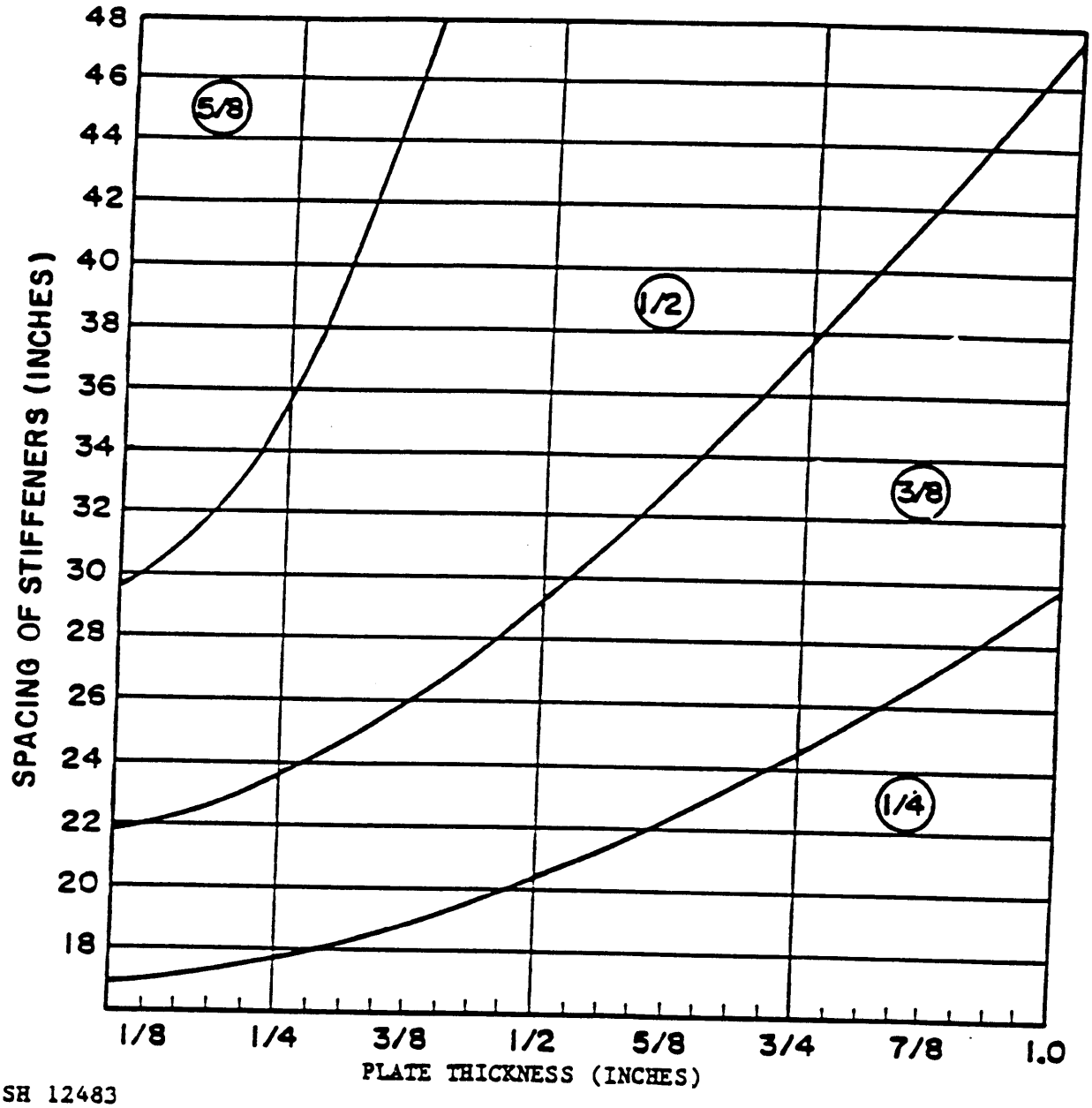


SH 12482

Applicability of tolerances:
This figure is applicable in the following areas except where figure 21 governs.

(1) Structural bulkheads forming a boundary of a living space (stateroom, office, berthing, messing, or lounge area) and passageways contiguous to such spaces.
(2) Decks within the hull and superstructure in way of the above living spaces.
(3) Decks exposed to the weather.
(4) Tank and main transverse bulkheads.
(5) Inner-bottom plate longitudinals and transverses.

FIGURE 22. Surface ship, permissible unfairness in steel welded structure.

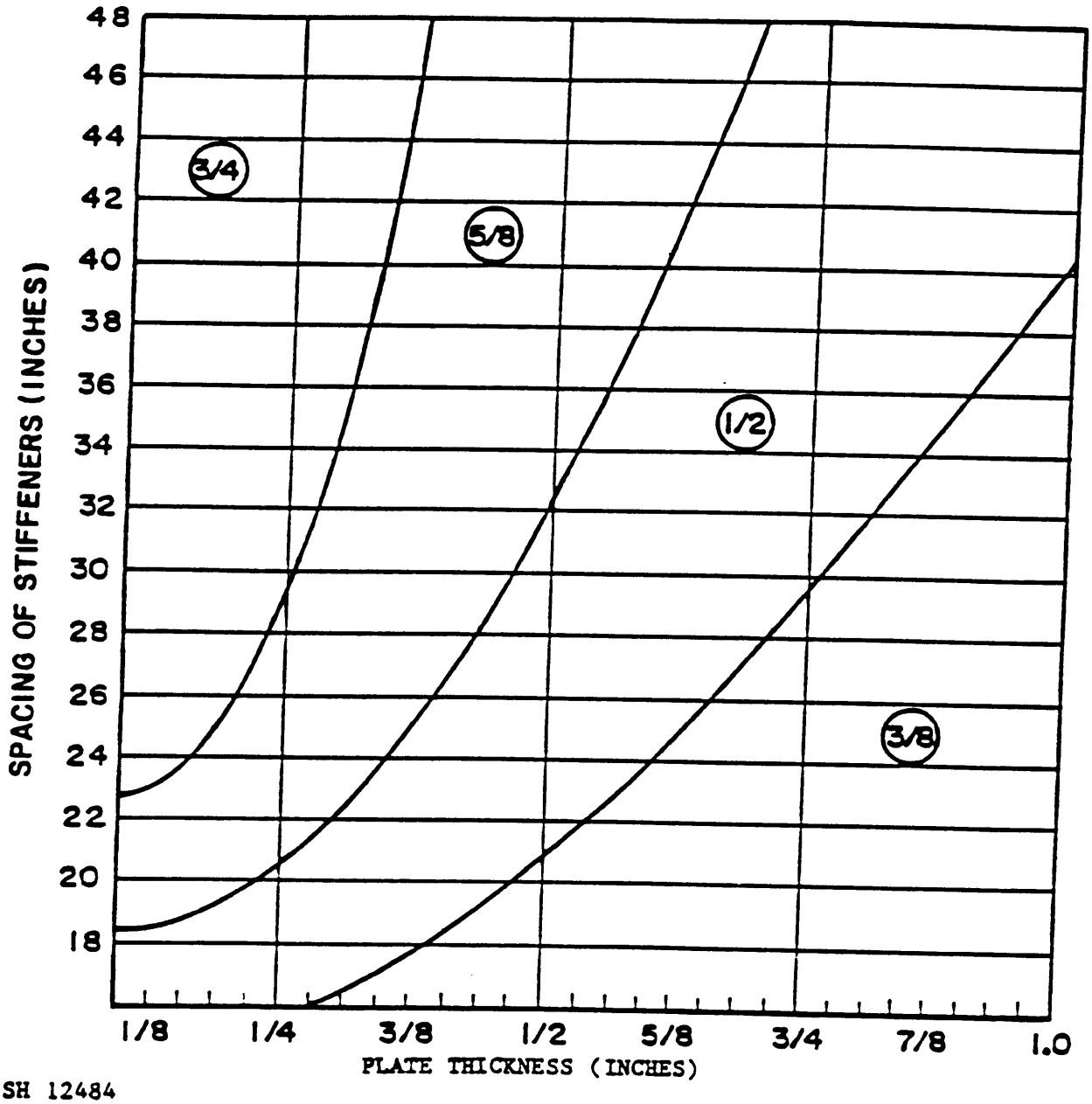


SH 12483

Applicability of tolerances:

(1) Entire shell.
(2) Uppermost strength deck.
(3) Longitudinal strength structure within the midships 3/5 length which includes inner-bottom, tank top, and the deck next below the uppermost strength deck if continuous above machinery spaces.
(4) In transversely framed ships, the permissible unfairness for structure noted in (1), (2) and (3) above is reduced by 1/8 inch.
(5) Bulwarks and exterior superstructure bulkheads.

FIGURE 23. Surface ship, permissible unfairness in aluminum welded structure.



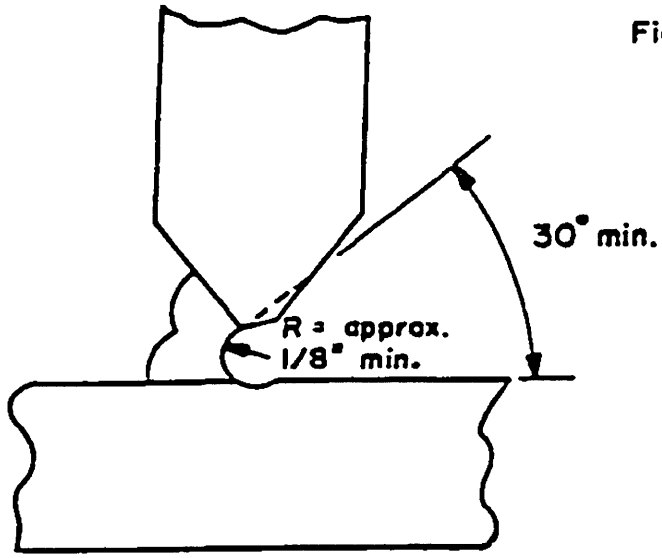
SH 12484

Applicability of tolerances:
This figure applies in the following areas except where figure 23 governs.

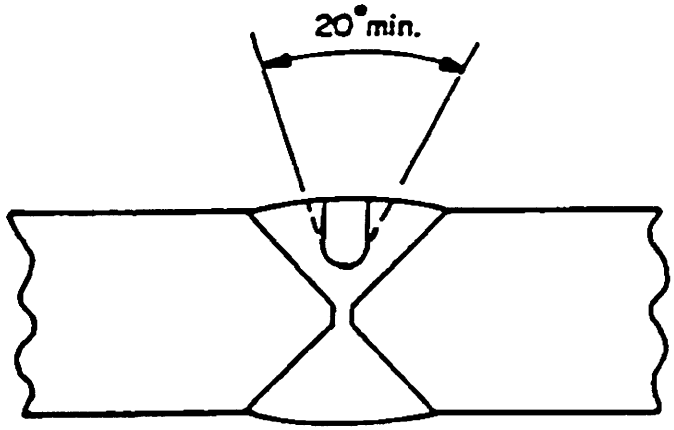
(1) Structural bulkheads forming a boundary of a living space (stateroom, office, berthing, messing, or lounge area) and passageways contiguous to such spaces.
(2) Decks within the hull and superstructure in way of the above living spaces.
(3) Decks exposed to the weather.
(4) Tank and main transverse bulkheads.
(5) Inner-bottom plate longitudinals and transverses.

FIGURE 24. Surface ship, permissible unfairness in aluminum welded structure.

Figures not to scale



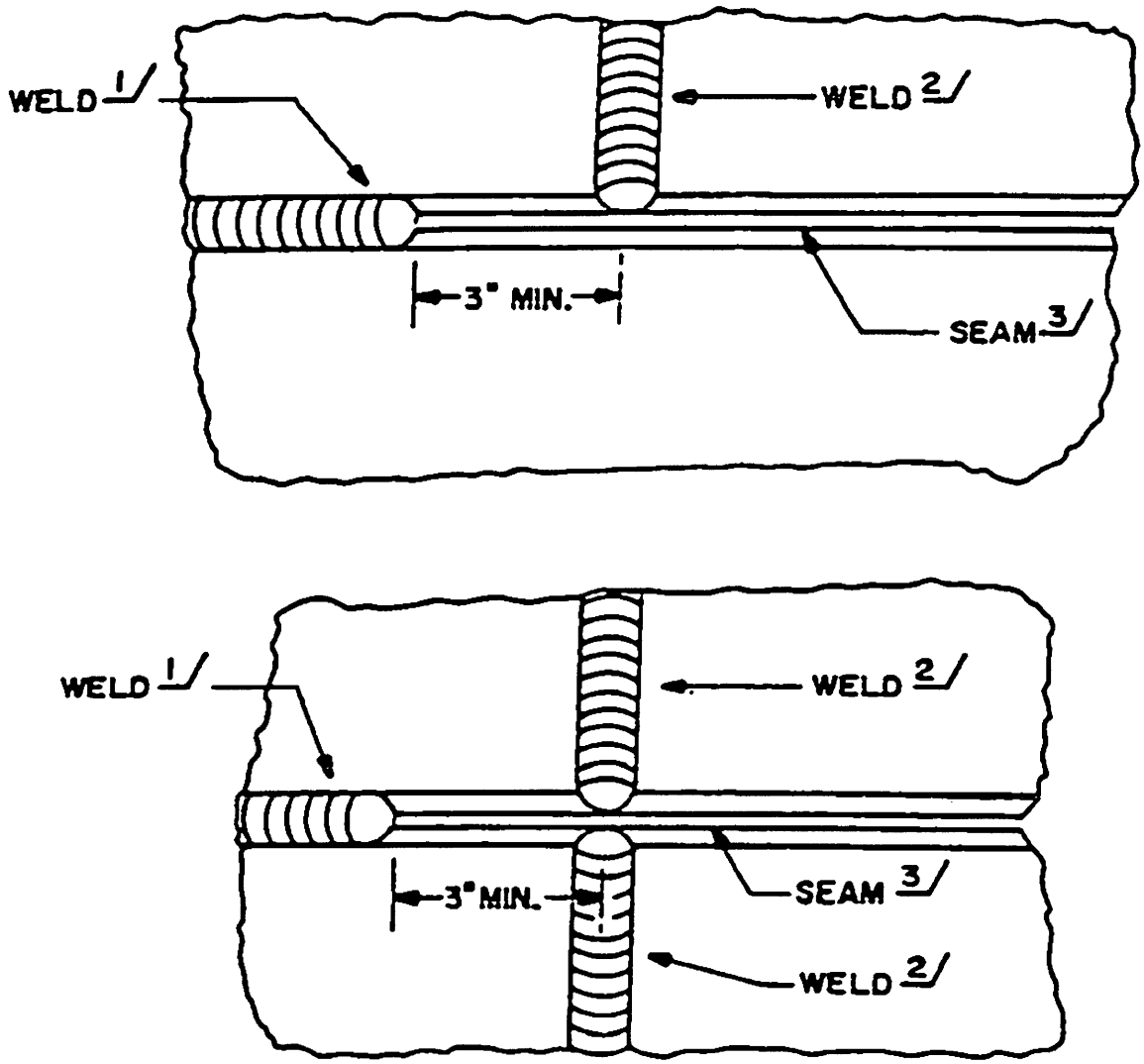
Keyholeing resulting from grinding or gouging. Additional metal should be removed as shown by dotted line to permit proper electrode accessibility and manipulation.



SR 12485

Excavation of weld metal for repair. Side walls of groove should be opened as shown by dotted lines before revelding. Radius at bottom contour = approximately 1/8 inch minimum.

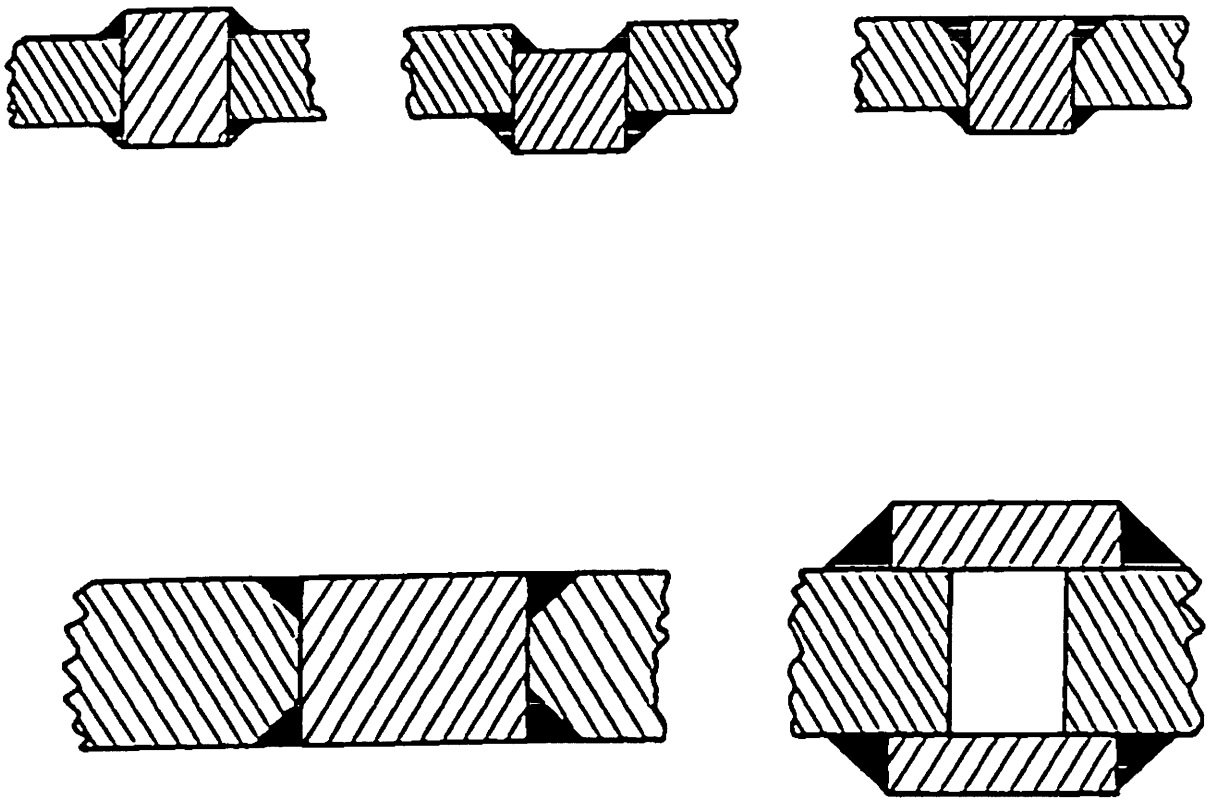
FIGURE 25. Weld root and repair excavation contours.



SH 12488

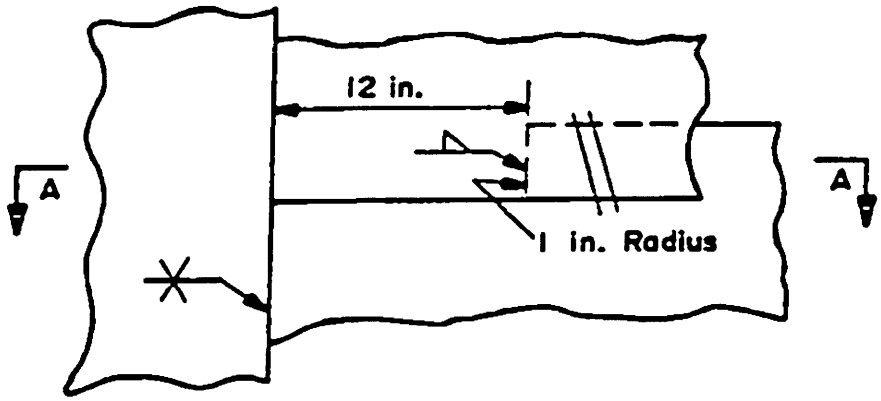
1/ Cut back weld 3 inches minimum.
2/ Weld butt weld and prepare end of weld to meet joint dimensions of seam.
3/ Complete welding of seam.

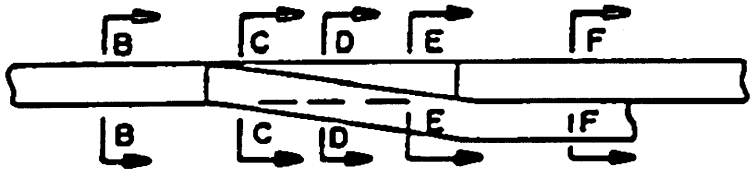
FIGURE 26. Cutback requirements.



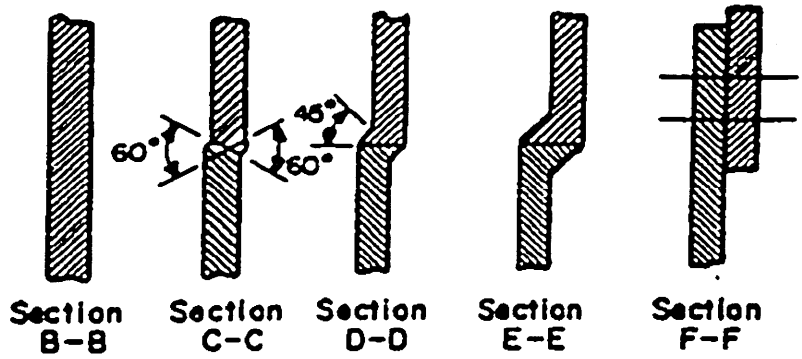
SH 12489

FIGURE 27. Alternative methods of repairing holes where tightness is the only consideration.



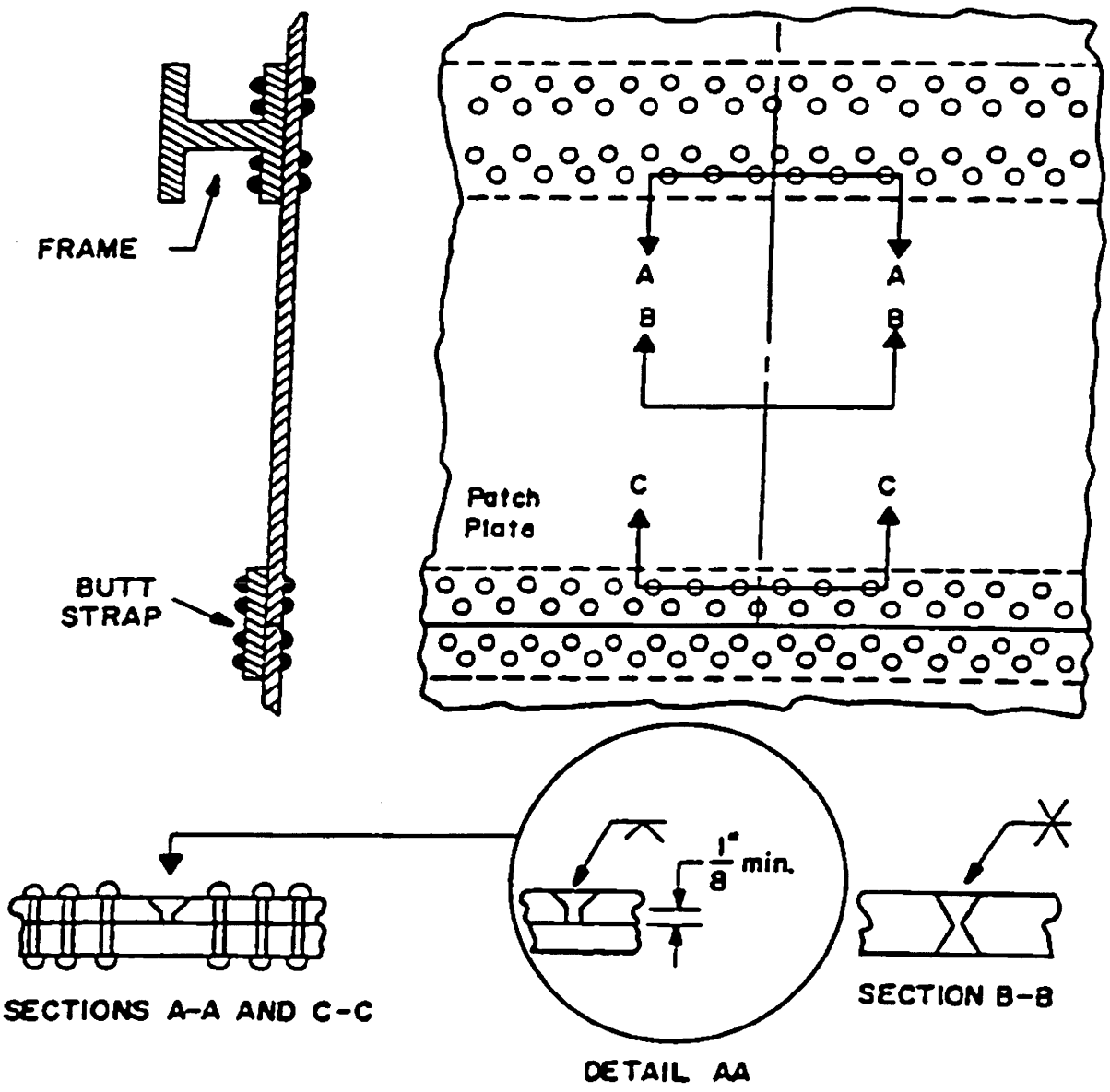


SECTION A-A



SH 12490

FIGURE 28. Transition of riveted seam to welded seam.



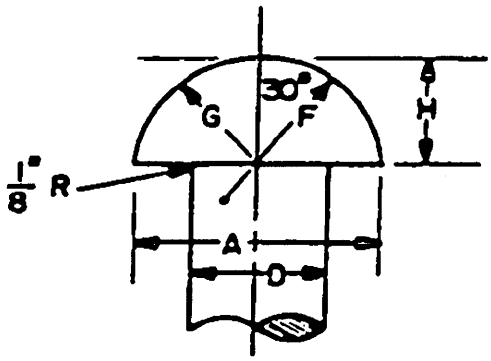
SH 12491

NOTES:
1. A backup of glass tape in accordance with MIL-C-20079 may be used to prevent fusion to the framing or rivet butt strap.
2. Do not allow weld metal to fuse through at the root and weld the two plates together.

FIGURE 29. Plate patch replacement, in riveted construction joint, requirements for welded butt.

Dimensions of dies for forming ferrous button points and heads.

D	A	H	F	G
Diameter of body (inches)	Diameter of head (inches)	Height of head (inch)	Radii of head, (inches)	
1/2	7/8	3/8	9/16	3/8
5/8	1-1/16	29/64	43/64	29/64
3/4	1-1/4	17/32	51/64	17/32
7/8	1-7/16	39/64	59/64	39/64
1	1-5/8	11/16	1-1/32	11/16
1-1/8	1-13/16	49/64	1-5/32	49/64
1-1/4	2	27/32	1-9/32	27/32

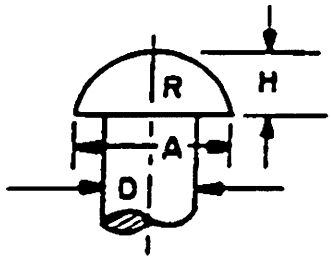


SH 12492

FIGURE 30. Button head and point dies - ferrous rivets.

Dimensions of dies for forming aluminum button points and heads (body diameter between 1/8 and 3/8 inch).

D Diameter of body (inch)	A Diameter of point (inch)	H Height of point (inch)	R Radius of point (inch)
1/8	7/32	3/32	1/8
3/16	11/32	1/8	3/16
1/4	29/64	11/64	15/64
5/16	9/16	7/32	19/64
3/8	11/16	1/4	23/64

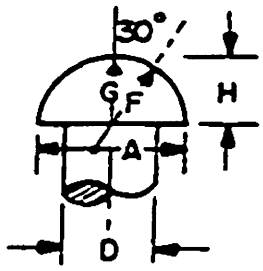


SH 12493

FIGURE 31. Button head and point dies - aluminum rivets (body diameter between 1/8 and 3/8 inch).

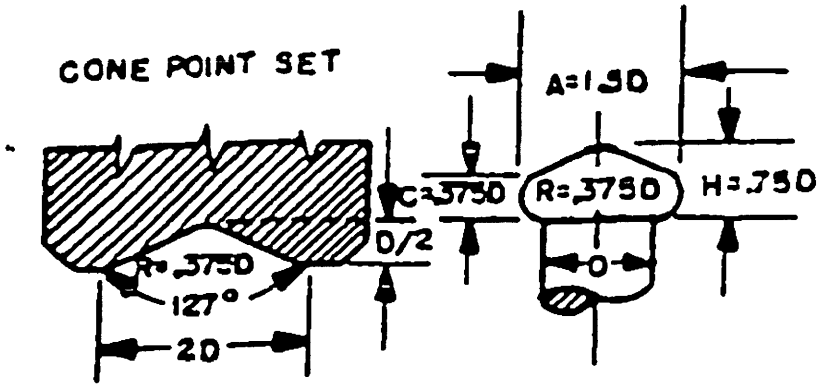
Dimensions of dies for forming aluminum button points and heads (body diameter between 1/2 and 1 inch).

D	A	H	F	C
Diameter of body (inch)	Diameter of point (inches)	Height of point (inch)	Radii of point (inches)	
1/2	7/8	3/8	9/16	3/8
5/8	1-1/16	29/64	43/64	29/64
3/4	1-1/4	17/32	51/64	17/32
7/8	1-7/16	39/64	59/64	39/64
1	1-5/8	11/16	1-1/32	11/16



SH 12494

FIGURE 32. Button head and point dies - aluminum rivets (body diameter between 1/2 and 1 inch).



SH 12502

Dimensions

D	A	H	C
Nominal diameter, inch	Diameter of head, inch	Height of head, inch	Approximate shoulder height, inch
1/4-0.250	0.375	0.188	0.094
5/16-0.313	.469	.234	.117
3/8-0.375	.562	.281	.141
1/2-0.500	.750	.375	.188
9/16-0.563	.843	.422	.211
5/8-0.625	.937	.469	.234
3/4-0.750	1.125	.563	.281
7/8-0.875	1.312	.656	.328
1-1.000	1.500	.750	.375

FIGURE 33. Cone point dies - aluminum rivets.

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	MIL-STD-1689A(SH)	901123

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4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

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