T9074-AD-GIB-010/1688

0910-LP-112-6087 **REVISION 1**

NAVSEA TECHNICAL PUBLICATION

REQUIREMENTS FOR FABRICATION, WELDING, AND INSPECTION OF SUBMARINE STRUCTURE

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Title: REQUIREMENTS FOR FABRICATION, WELDING, AND INSPECTION OF SUBMARINE STRUCTURE

CHANGES AND REVISIONS

Purpose: The ORIGINAL issue of this document replaced MIL-STD-1688A, MIL-STD-1681, and, for submarine applications only, MIL-STD-1689A. It combines in one publication all requirements for fabrication, welding, and inspection of submarine structure. This Revision (Rev 1) updates the ORIGINAL issue and incorporates new technical developments, such as requirements for HSLA-80/100 steels, and lessons learned since the ORIGINAL issue.

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Continue on reverse side or add pages as needed

CERTIFICATION STATEMENT

This is to certify that responsible NAVSEA activities have reviewed the above identified document for technical adequacy and suitability for the intended use. This form is for internal NAVSEA management use only, and does not imply contractual approval or acceptance of the technical publication by the Government.

Name	Signature	Organization	Code	Date
Joseph M. Blackburn	Joseph M. Blackburn	NAVSEA	05P2	13 Jul 12

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FOREWORD

Revision 1 corrects certain inconsistencies, omissions, and errors in the Original issue of this document. This Revision also updates the Original issue with regard to specification improvements, technology developments, and lessons learned. The changes included in Revision 1 reflect input from NAVSEA as well as from public and private shipbuilders. The table below is a description of each change.

PARAGRAPH	DESCRIPTION OF CHANGE
N/A	Identified Rev 1.
N/A	Added a new Table of Contents.
1.6	Updated NAVSEA 05P24 address.
1.7	Updated paragraph to reflect issuing of Rev 1.
2.1.1	Updated MIL-SPECs for HY/HSLA steel base metals and filler metals to reflect NAVSEA Technical Publications, replaced superseded MIL-SPECs.
2.1.2	Added reference to NAVSEA Technical Publications for high strength plate and filler metals, and updated Code 07Q and updated parenthetical source statements.
2.2	Updated addresses for obtaining ASTM and AWS documents.
3.31.2	Added NAVSEA Base Metal Technical Publication to replace cancelled MIL-SPEC.
3.31.3.1	Added NAVSEA Base Metal Technical Publication to replace cancelled MIL-SPECs.
3.31.3.2	Added NAVSEA Base Metal Technical Publication to replace cancelled MIL-SPECs.
3.39.1	Added another criterion for defining an attachment weld.
3.44	Added definition of normal supervisory controls.
4.3	Clarified first sentence to ensure that procedures are qualified prior to production welding and added clarifications regarding the applicability of qualified HY steel welding procedures to welding HSLA-80.
5.2.1	Added the term normal supervisory controls.
5.5.2	Revised wording to clarify measurements to be recorded and records required by 5.5.2.c. Added frame flange curvature to measurements. Regarding frame flange curvature, added that confirmation of requirements of 12.3.2.2 may be provided in lieu of actual measurements.
5.6.f	Added requirement for specifying the date and time when it was determined that the weld has cooled to ambient temperature for use in subsequent MT inspections.
5.7.4	Clarified hard tank plating materials traceability requirements.
6.1.1	Added sentences to clarify surface inspection requirements for welding ferromagnetic and non-ferromagnetic materials.
6.3.2.p	Added subparagraph for inspection of cold formed materials in accordance with Sections 8 and 14 and specified the inside radius shall be per the drawing.

PARAGRAPH	DESCRIPTION OF CHANGE
6.5.2.a	Clarified inspection requirements for inspection of permanent automatically timed arc stud welds, capacitor discharge stud welds, and resistance spot welds during installation and removal operations; and added exception as noted.
6.5.2.f	Deleted requirement to perform 5X VT inspection of the inside surfaces of holes in welds in pressure hull structure that are less than 4 inches in diameter. Added acceptance criterion for the 5X VT inspection.
6.5.2.j	Added low pressure tanks to foundations and non-support structural members not requiring inspection for welds attaching coamings, non-compensating penetrations, and label plates (signs) to these members.
6.5.2.m	Clarified the types of partial penetration joint designs where MT inspection may be exempted for fillet welds 3/8 inch and smaller.
6.5.2.o	Added conditions for not requiring inspection of web to flange welds in certain low pressure soft tanks.
6.5.4	Clarified the meaning of the term “subsequent work” in the second sentence; added a new subparagraph 6.5.4.1, which identifies operations that do not require re-hydrostatic testing of hard tanks.
6.5.5.c	Clarified the requirement for re-hydrostatic testing and referred back to new paragraph 6.5.4.1 for exceptions to re-hydrostatic testing.
6.5.5.1	Clarified second sentence defining re-inspection requirements to be consistent with revised 6.5.4.
6.6.1.1	Clarified weld repair inspection requirements for excavations of non-ferrous and austenitic welds.
6.9.1	Clarified acceptance criteria for inspection of stud welds.
6.9.3.2.1	Specified that the internal major thread diameter of the stud shall be used for testing internally threaded studs as opposed to the diameter of the stud base.
6.11.1.1	Clarified inspection requirements on finished tension surfaces of HY80/100 materials when cold formed to an inside radius of 2T and greater.
7.2	Modified first sentence to change “following NDT methods” to “following NDT/inspection methods”.
7.2.g	Added hardness measurements to the listing of acceptance standards.
7.4.2.1	Added exclusion for VT inspection of surfaces with high solids paint systems applied.
7.5.1.1	Revised last sentence to clarify examination requirements.
7.6.1	Changed word “non-ferritic” to “non-ferromagnetic”.
7.7.3	Revised words in parentheses in the last sentence.
7.8.1	Added a new sentence to the end of the paragraph identifying criteria for evaluating inadvertent rejectable RT indications observed within the base material.
7.10.2.a	Deleted plate from material product forms where hardness tests can be used to verify adequacy of heat treatment.

PARAGRAPH	DESCRIPTION OF CHANGE
8.4.1	Clarified that all surfaces of wrought base materials, including all formed surfaces, shall be inspected for surface defects.
8.4.5	Deleted plate from material product forms where hardness tests can be used to verify adequacy of heat treatment.
8.7.1.3	Clarified requirements for submerged arc welding consumables testing.
9.2	Deleted HSLA-80 from materials that require NAVSEA approval for cold forming and added HSLA-80 cold forming temperature requirements to Table 9-1.
9.3.1	Added HSLA-80 to materials other than HY not requiring NAVSEA approval for cold forming to be consistent with change in 9.2.
9.3.1.1	Added new paragraph with requirements and restrictions for the cold forming of Ni-Cr-Fe and Ni-Cr-Mo-Cb base materials.
9.3.2	Clarified the restriction on cold forming of HY-base materials to an inside radius less than 2T. Added that forming HY base materials to an inside radius less than 2T must be performed hot and in accordance with 9.4.
9.3.3	Added a new paragraph that specifies forming limits on HSLA-80.
10.2.1	Deleted MIL-7018 electrode from listing of electrodes for welding OSS or HSS, since only MIL-7018-M is purchased and used. Clarified that moisture requirements shall be those in MIL-DTL-22200/1H or later revision instead of MIL-E-22200/10. Indicated that the use of MIL-8018-C3 shall require NAVSEA approval.
10.5	Deleted MIL-7018 electrode from listing of electrodes.
10.6	Deleted MIL-7018 electrode from listing of electrodes.
10.6.2	Revised title of paragraph to better reflect the requirement.
10.9.4	Added new paragraph requiring control procedures to ensure moisture requirements for MIL-100S-2F flux are met.
11.3.1	Specified that applications involving welding of OSS and HSS material, other than attachment welds, to HY steel pressure hull envelope and support structure (also added HY-80) shall use high strength filler materials per Table 10-1.
11.4.1	Clarified the inspections required when a full penetration joint design is substituted for a PT2V.5 joint using the NAVSEA approved process for welds to the pressure hull envelope.
11.4.4	Inserted PT joint sizing requirements for members (such as round, square or rectangular tubing) which can be welded on one side only (PT1S.1).
11.4.7	Added language clarifying class specific non-standard weld joint drawing.
11.5.3	Added that exceptions to the corner cut minimum radius requirements in Figure 25 must have NAVSEA approval.
11.5.3.2	Added reference to Figure 26.
11.5.4.2	Added reference to Figure 26.
11.5.9	Clarified reference to Table 13-1.
12.3.1.1.2.a	Added frame welds to the pressure hull to the listing of major welding requiring circularity measurements.

PARAGRAPH	DESCRIPTION OF CHANGE
12.3.1.1.2.c	Added new paragraph to define the extent of weld repairs that are not considered major welding relative to circularity and hull fairness measurements.
12.3.1.2.h	Clarified acceptance procedures for circularity and hull fairness measurements.
12.3.1.5.1.a	Clarified major welding definition for spherical closure bulkheads.
12.3.2.1	Clarified the frame dimensional measurement requirements. Added definition for when weld repairs require measurement to be retaken.
12.3.2.3	Clarified where frame spacing measurements can be performed. Added definition for when weld repairs require measurement to be retaken.
12.3.2.6.a	Clarified limits for end bay frame deviations.
13.6.1	Clarified requirements for welding preheat and interpass temperatures in multi-material joints.
13.6.1.1	Revised Example b to specify MIL-7018-M instead of MIL-7018 electrodes.
13.8	Clarified inspection required for repair welded and adjacent base materials.
13.9.3	Clarified that the 2-inch weld buildup limitation applies also where only one member is involved.
14.2.5	Provided exceptions to where temporary snipes are required.
14.6.3	Clarified requirements associated with removal of welds and welded attachments from an HY or HSLA member.
14.6.3.1	Added clarification with regard to inspection procedures required for temporary removal and replacement of a non-ferrous attachment on pressure hull structure.
15.4.2.1	Deleted MIL-11018 electrodes from those approved for minor, nominal, and special casting repairs.
15.4.2.2	Added clarifications regarding inspection procedures to be used for repairs on casting surfaces.
15.4.5.f	Deleted MIL-11018 electrodes for consistency with 15.4.2.1.
15.5	Revised 15.5 to add exceptions related to repair of casting defects; added a new subparagraph 15.5.1 and a new subparagraph 15.5.2 to clarify requirements for minor repairs or weld buildup and other repair or weld buildup operations in castings released for fabrication. Revised and renumbered Original paragraph 15.5.1 and renumbered Original paragraph 15.5.2.

FIGURE	DESCRIPTION OF CHANGE
2	Revised functional diagram to include extended pressure hull and interface structure.
4	Added line to clarify a non-hard tank weld; Clarified that inspection requirement pertains to a hard tank weld in Note 2.
9	In Note 2, rounded decimal equivalent of measurement to two decimal places to be consistent with best practices for reporting measurements.
10	Corrected title on the sample record sheet in the figure from “Welding Specifications” to “Record of Frame Dimensions”.

FIGURE	DESCRIPTION OF CHANGE
11	Revised Notes 3 and 4 regarding requirements for MT/PT inspection of each layer.
14A	Added new figure to clarify the meaning of 3-inch toe-to-toe distance requiring expansion inspection.
14B	Added new figure to clarify the re-inspection requirements for welds within 6 inches of a new weld.
21	Revised Note 1 to specify that welds be sized in accordance with 11.4.4, and for clarification changed (A -1/16 inch) to (A minus 1/16 inch) in Note 2.
26	Modified note to clarify cut back requirement.
All	Added to each title the paragraph number(s) in which the figure is referenced.

TABLE	DESCRIPTION OF CHANGE
6-1	Extended the exception of the expansion inspection requirements for relatively thin full penetration hull butt welds in Note 2 to include corner and tee welds in the pressure hull envelope. Added new Figure 14B to clarify Note 3 subparagraph b) (3) regarding re-inspection of welds that are not contiguous to the new weld. Added clarification to Note 4 regarding the 3-inch toe-to-toe distance requiring expansion inspection and a new Figure 14A was added. Added acceptance criterion for PT or 5X VT when substituted for MT to Note 10. Clarified Note 11 to identify examples that typically do not exceed 1/32 inch and added removal of punch marks.
6-3	Revised Inspection Category (2) to eliminate MT inspection of HY-80 and HY-100 cold formed in excess of 12 percent total elongation. Revised Note 4 to provide an acceptance criterion for PT or 5X VT inspection when substituted for MT.
6-4	Revised Note 1 wording to eliminate potential conflict with paragraph 6.8.1 and added preference for UT when either UT or RT may be used. Added Note 5c to add over grinding as a defect not requiring re-RT when the depth does not exceed two layers or half the thickness of thinnest member joined, whichever is less. Clarified the thickness of 2 layers as being 1/4 inch in Notes 5b, 5c, and 6.
9-1	Added maximum cold forming temperature for HSLA-80. Added new Note 3 referring to new paragraph 9.3.3 that specifies cold forming limits for HSLA-80. Added maximum cold forming temperature for Inconel 600 and Inconel 625, and added related Note 4.

TABLE	DESCRIPTION OF CHANGE
10-1	Updated specifications referenced to include NAVSEA T9074-BC-GIB-010/0200.
	Separated applications for MIL-11018-M from MIL-10718-M and deleted MIL-11018-M from electrodes approved for joining HY/HSLA100 to HY/HSLA-100.
	Deleted MIL-7018 electrode since it is no longer procured and is not included in MIL-DTL-22200/1H.
	Made editorial correction to list all S-type electrodes under "GMAW, SAW, GTAW" process.
	Deleted several flux cored electrodes that have never been qualified.
	Added welding of OSS/HSS to HSLA-100 when using MIL-10018-M1 and welding of "HSLA-100 to All" when using MIL-10718-M, MIL-11018-M and MIL-100S-1 to list of approved applications.
	Revised Note 6 to reference NAVSEA Technical Publication in favor of VIRGINIA/NSSN Class PPD.
	Revised Note 7 to include MIL-10018-M1 in electrodes qualified for welding OSS and HSS to HY-80/100/130 pressure hull envelope and support structure (other than attachment welds).
	Revised Notes 8 and 10 to reflect revised requirements in MIL-DTL-22200/1H.
	Revised Note 9 to delete MIL-11018-M from electrodes allowed for joining HY-100/HSLA-100 to HY-100/HSLA-100 and clarified requirements for application of under-matched welding of HY-100.
	Revised Note 10 to delete reference to MIL-7018 and to require MIL-8018-C3 to be in accordance with MIL-DTL-22200/1H or later and its use be specifically approved by NAVSEA.
	Revised Note 11 to add HY-80 pressure hull envelope and SUBSAFE support structure to applications where MIL-70 and MIL-80 electrodes may not be used for joining to OSS and HSS steels, other than for attachments or when a high strength joint is required by 11.3.1.
	Added MIL-100S-2F to fluxes permitted in Note 15.
	Added Note 18 redefining applications for MIL-11018-M electrodes.
10-4	Revised Note 2 to clarify applications of aluminum alloy 6061; and added filler metal Type 5356 to applicable material for welding base metal Type 5052 to 5052.

TABLE	DESCRIPTION OF CHANGE
11-1	Revised requirement to only require NAVSEA approved procedures for PT2V.5 welds of stiffeners to the pressure hull envelope. Incorporated detailed requirements for joint design of connections to the pressure hull envelope. Added requirements for design of connections of non-support structure to the pressure hull envelope. Revised requirements for support structure bulkhead stiffeners to be consistent with revised end connection requirements (see revised Notes 6 and 7). Clarified weld joint design requirements for low pressure tank stiffener to plating connections and for welds to foundations, specifically connections to non-support structure. Revised and clarified Note 6 by deleting inappropriate reference to solid bar and tubing and clarifying procedures for sizing certain PT2V.5 pressure hull frame welds. Revised Note 7 to allow and detail the procedures for design of fillet welded solid bar and tubing connections of foundation structure to the pressure hull envelope and to permit the use of double plate connection to hard tanks where the cyclic loading is less severe than for pressure hull plate and frames.
13-1	Added requirements for S-1 and S-2 carbon steels as Part I of table and included other base materials and filler materials in a new Part II. Revised Note 3 to Part II to add repair of base plate to butt and corner weld joint designs where it is not permitted to use reduced minimum welding preheat for HY-80 and HSLA-80/100 when welding member thicknesses is 1/2 inch and less. Deleted reference to Note 3 to Part II for HY-100. Revised Note 4 to Part II to clarify that austenitic or non-ferrous filler materials may be used with reduced preheat for welding member thicknesses 1/2 inch and less for joint designs other than butts and corners. Revised Note 5 to Part II to remove the preheat and interpass restrictions for MIL-10018, MIL-10718, and MIL-100S when welding HY-100 to HY-100 for consistency with Table 10-1, and to address MIL-11018-M electrode minimum preheat requirements. Deleted reference to Note 5 to Part II for MIL-100S electrode. Added new Note 8 to Part II, which permits reduced minimum preheat/interpass for OSS and HSS attachment welds to HY-80.
13-2	Deleted existing Note 3, which further restricted welding heat input on thin section welding with MIL-10018-M1. Added a new Note 3 that establishes new maximum heat input requirements for weld repair or buildup in HY-100 base material 1/2 inch or greater in thickness.
15-1	Added "(see 15.3)" to end of Note 4.
15-2	Revised and updated ASTM specifications referenced in the table to reflect current ASTM reference film designations, and to allow usage of common conveniently available X-ray sources.
16-1	Deleted "1.0" (typo) in the row GMAW spray t > 0.875.

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1. SCOPE

1.1 Scope. This document contains minimum requirements for fabrication and inspection of submarine and non-combatant submersible structure, including shipbuilding practices, specifications for materials, weld joint design, workmanship, welding, inspection, and record requirements. Minor structure (as defined in 3.33.3.1) is exempt from the requirements listed herein. Such structure shall be fabricated using good shipbuilding practices and may be performed using AWS, ASTM, or other commercial standards.

1.1.1 HY-130 and HSLA steels. Use of HY-130 and HSLA steels shall be as specifically permitted by the applicable ship specification or contract requirements. Use of HY-130 and HSLA steels for other applications requires NAVSEA approval on a case basis. For non-pressure hull structure, this document contains a set of requirements for fabrication, welding, and inspection of HY-130 and HSLA materials that shall be used as a baseline for each specific application. Modifications to this baseline may be necessary for the specific application and will be addressed in conjunction with the specific NAVSEA approval. Requests for specific NAVSEA approval of HY-130 and HSLA applications should address whether any modifications are needed, and provide appropriate modifications and justifications. For pressure hull and containment structure, this document is not intended to, and does not, specify requirements for fabrication, welding, and inspection of HY-130 and HSLA steels. Such requirements must be developed, justified, and approved by NAVSEA for the intended application.

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

1.3 Castings. Unless otherwise noted herein, requirements for castings, such as NDT, acceptance criteria, and repair are contained in Section 15.

1.4 Special requirements for MIL-120 and MIL-140 series welding filler materials. Additional and modified requirements for MIL-120 and MIL-140 series welding filler materials are contained in Section 16.

1.5 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 6.6 shall include 6.6.1 and 6.6.1.1.

1.6 Requirements subject to Naval Sea Systems Command (NAVSEA) approval. Any requirements contained in this document specifically requiring NAVSEA approval shall be forwarded to Naval Sea Systems Command, SEA 05P2, 1333 Isaac Hull Ave SE Stop 5142, Washington Navy Yard, DC 20376-5142. Subcontractors shall submit such items to the contracting activity in accordance with the contract or purchase order.

1.7 Changes from superseded documents. Marginal notations are not used in this Revision to identify changes due to the extensiveness of the changes. This Revision replaces the Original document dated 1 May 1997, which replaced MIL-STD-1688A dtd 09 February 1990, MIL-STD-1681 dtd 29 March 1976 and MIL-STD-1689A dated 27 December 1990 for submarine structure applications. This Revision does not replace MIL-STD-1689 for surface ship structure applications.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEFENSE SPECIFICATIONS

MIL-E-19933	-	Electrodes and Rods - Welding, Bare, Chromium and Chromium-Nickel Steels.
MIL-E-21562	-	Electrodes and Rods - Welding, Bare, Nickel Alloy.
MIL-E-22200	-	Electrodes, Welding, Covered: General Specification for.
MIL-DTL-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-22200/9	-	Electrodes, Welding, Mineral-Covered, Low-Hydrogen or Iron-Powder, Low-Hydrogen, Nickel-Manganese-Chromium-Molybdenum Alloy Steel for Producing HY-130 Weldments for As-Welded Applications.
MIL-S-22698	-	Steel Plate, Shapes and Bars, Weldable Ordinary Strength and Higher Strength: Structural.
MIL-E-23765	-	Electrodes and Rods - Welding, Bare, Solid and Alloyed Cored, General Specification for.
MIL-E-23765/1	-	Electrodes and Rods - Welding, Bare, Solid and Alloyed Cored, Ordinary Strength and Low Alloy Steel.
MIL-E-24355	-	Electrodes, Welding, Bare, Solid, Nickel-Manganese-Chromium-Molybdenum Alloy Steel for Producing HY-130 Weldments for As-Welding Applications.
MIL-E-24403	-	Electrodes - Welding, Flux Cored, General Specification for.
MIL-E-24403/1	-	Electrodes - Welding, Flux Cored, Ordinary Strength and Low Alloy Steel.

DEFENSE STANDARDS

MIL-STD-22	-	Welded Joint Design.
MIL-STD-1628	-	Fillet Weld Size, Strength, and Efficiency Determination.
MIL-STD-2035	-	Nondestructive Testing Acceptance Criteria.

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

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

NAVSEA 0924-062-0010	-	Submarine Safety (SUBSAFE) Requirements Manual.

(Copies of this document should be addressed to the Naval Sea Systems Command (Code 07Q), 1333 Isaac Hull Ave SE, Washington Navy Yard, DC 20376.)

NAVSEA S9074-AQ-GIB-010/248	-	Requirements for Welding and Brazing Procedure and Performance Qualification.
NAVSEA T9074-AS-GIB-010/271	-	Requirements for Nondestructive Testing Methods.
NAVSEA T9074-BC-GIB-010/0200	-	Filler Materials for Critical Applications: Requirements for Flux-Cored Welding Electrodes, Bare Welding Electrodes and Fluxes, and Covered Welding Electrodes for Low-Alloy Steel Applications.
NAVSEA T9074-BD-GIB-010/0300	-	Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY-80/100/130 and HSLA-80/100.
NAVSEA S9086-CH-STM-010/CH-074V1	-	NSTM Chapter 074; Volume 1, Welding and Allied Process.

(Copies of these documents are available online at https://nll1.ahf.nmci.navy.mil. These publications can be located by searching the Navy Publications Index for the TMIN without the suffix.)

2.2 Non-Government publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL (ASTM)

ASTM A240	-	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
ASTM A276	-	Standard Specification for Stainless Steel Bars and Shapes.
ASTM B166	-	Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617), and Nickel-Iron-Chromium-Tungsten Alloy (UNS N06674) Rod, Bar, and Wire. (DoD adopted)
ASTM B564	-	Standard Specification for Nickel Alloy Forgings. (DoD adopted)
ASTM E155	-	Standard Reference Radiographs for Inspection of Aluminum and Magnesium Castings. (DoD adopted)
ASTM E186	-	Standard Reference Radiographs for Heavy-Walled (2 to 4½-inch) (50.8 to 114-mm)) Steel Castings. (DoD adopted)
ASTM E272	-	Standard Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings. (DOD adopted)
ASTM E280	-	Standard Reference Radiographs for Heavy-Walled (4½ to 12-inch (114 to 305-mm)) Steel Castings. (DoD adopted)
ASTM E310	-	Standard Reference Radiographs for Tin Bronze Castings. (DOD adopted)
ASTM E446	-	Standard Reference Radiographs for Steel Castings up to 2 inch (50.8 mm) in thickness. (DoD adopted)

(Copies of these documents are available from ASTM International, 100 Barr Harbor Dr., P.O. Box C700, West Conshohocken, PA 19428-2959 or online at www.astm.org.)

AMERICAN WELDING SOCIETY (AWS)

AWS A2.4	-	Standard Symbols for Welding, Brazing, and Nondestructive Examination. (DOD adopted)
AWS A3.0	-	Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting and Thermal Spraying . (DoD adopted)
AWS A5.1	-	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.
AWS A5.4	-	Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding.
AWS A5.9	-	Specification for Bare Stainless Steel Welding Electrodes and Rods.
AWS A5.10	-	Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods.

AMERICAN WELDING SOCIETY (AWS) (CONTINUED)

AWS A5.11 - Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielding Metal Arc Welding.

AWS A5.14 - Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods.

AWS B4.0 - Standard Methods for Mechanical Testing of Welds, US Customary Only. (DoD adopted)

AWS C4.1 - Criteria for Describing Oxygen-Cut Surfaces and Oxygen Cutting Surface Roughness Gauge.

(Copies of these documents are available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126 or online at www.aws.org.)

(Non-Government 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 shall conform to AWS A2.4, AWS A3.0, and NAVSEA S9074-AQ-GIB-010/248.

3.2 Acceptable. Acceptable, as used herein, complies with or conforms to the applicable standard or specification.

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

3.4 Ambient temperature. A workpiece is considered to have cooled to ambient temperature when it is cool enough to place a hand on the material (typically less than 125 °F).

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

3.6 Arc strikes. 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 a welding electrode or magnetic particle (MT) prod.

3.7 Backgouge. Backgouge is the preparation of the second side of full penetration welds welded from both sides to the extent necessary to permit proper deposition of weld metal.

3.8 Bulkheads.

3.8.1 Closure bulkhead. Closure bulkhead is the hull end bulkhead designed to withstand collapse depth pressure.

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

3.8.3 Holding bulkhead. 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 specification. Holding bulkheads are considered pressure hull support structure for design and inspection requirements.

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

3.9 Buildup. Buildup is defined under weld buildup (see 3.39.7.1).

3.10 Butt. A butt is a transverse or vertical plate edge connection in the pressure hull, bulkhead, foundation member, 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. Coamings are compensation material surrounding holes in structure which extend through or on one side only of the hole. They are usually connected by a corner, groove tee, or fillet weld, and may provide all or partial compensation for the hole. Non-compensating coamings are material surrounding holes or the perimeter of structures (e.g., decks, foundations, etc.) for the purpose of containing loose objects or liquid from adjacent areas only.

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

3.14 Fabrication. The term fabrication covers construction, alteration, modification, or repair operations involved in the building of submarines.

3.15 Fairness. Fairness refers to the “flatness” or “smoothness” across a weld joint or plating surface. Weld distortion is a major cause of unfairness; however, other conditions such as plate misalignment or mismatch can also impact the local fairness profile. The fairness requirements noted herein refer to structural fairness.

3.16 Heat. Heat is a quantity of metal that was molten simultaneously in the same container or process just preceding solidification.

3.17 Heat soak. An operation to promote hydrogen removal from high yield strength welds by heating the weld metal for a specified time and temperature.

3.17.1 Interlayer heat soak. An operation to promote hydrogen removal from high yield strength welds by heating the weld metal for a specified time and temperature after deposition of each layer of weld metal.

3.17.2 Intraweld heat soak. An operation to promote hydrogen removal from high yield strength welds by heating the weld metal for a specified time and temperature after deposition of specified intervals during the welding of the joint.

3.17.3 Excavation heat soak. An operation to promote hydrogen removal from an excavation of high yield strength metal by heating the repair area for a specified time and temperature after metal removal is complete but prior to repair welding.

3.17.4 Post weld heat soak. An operation to promote hydrogen removal from high yield strength welds by heating the weld metal for a specified time and temperature after all weld metal has been deposited.

3.18 Inserts. Inserts are those structural reinforcements welded into the pressure hull envelope or other structure by some type of butt joint. Inserts reinforce the structure at openings or areas of high stress and may be of the same or greater thickness than the surrounding structure.

3.19 Inspector. Inspector is the contractor, naval shipyard, or other Government agency employee qualified as required by this document to accept or reject materials or workmanship based on specified test results.

3.20 Lamination. Lamination is an internal planar 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.

3.21 Liners. Liners are structural reinforcements around a hole in plates welded by some type of tee or corner joint.

3.22 Load. Load is a quantity of steel from the same heat that is heat treated in the same furnace or oven at the same time. (A load and a heat may not be identical quantities of steel.)

3.23 NAVSEA authorized representative. NAVSEA authorized representative is any Government representative specifically authorized to approve equipment, material, or procedures within the scope of this document for NAVSEA. These are as follows:

a. For naval shipyards: The delegated representative of the Shipyard Commander.

b. For commercial shipyards: The delegated representative of the Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP).

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

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

3.26 Plates (plating).

3.26.1 Access plates. Access plates are sections of plating which are removed for access, installations, or removal of equipment, and are later reinstalled. Access plates do not involve cutting of pressure hull frames.

3.26.2 Small access plates. Small access plates are sections of plating removed and later reinstalled having a maximum diameter of 24 inches.

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

3.26.4 Tank boundary plating. Tank boundary plating is all material used in the fluid boundary of a tank.

3.27 Record of accomplishment. A record which provides objective evidence of completion and inspection of welds or accountability of other fabrication requiring inspection by this document.

3.28 Re-entrant angle. Re-entrant angle is the angle formed between the base plate and the toe of the weld (see Figure 1).

3.29 Seam. A seam is a fore-and-aft or horizontal plate edge connection in the pressure hull, bulkhead, foundation member, or deck plating.

3.30 Shape. Shape, as used herein, is one piece of hot-rolled or extruded material other than flat plate, strip, tube, or bar, having a cross-section in the shape of a Tee, L, angle, Zee, Channel, I, or H.

3.31 Steel. When S-numbers are provided, they define the base material group number per NAVSEA S9074-AQ-GIB-010/248.

3.31.1 Higher strength steel. Higher strength steel (HSS) refers to a group of steels (S-1 and S-2), intended for general structural use that have minimum yield strengths in excess of 46,000 psi. HSS are steels in accordance with MIL-S-22698 or other equivalent military, ASTM, or other commercial standards specified in the applicable ship specifications, unless otherwise approved by NAVSEA.

3.31.2 High strength low alloy steel. High strength low alloy (HSLA) steels refer to a group of steels (S-11C and S-11D) that have specified minimum yield strengths. The higher strengths are achieved by the intentional addition of small amounts of alloying elements such that the required strength is reached in the hot rolled, hot rolled and aged, normalized or quenched, and aged conditions (depending on strength and thickness). HSLA-80 and HSLA-100 are specific types of HSLA steel in accordance with NAVSEA T9074-BD-GIB-010/0300.

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

3.31.3.1 HY-80/100 steel. HY-80 and HY-100 steel (S-11A) is steel in accordance with NAVSEA T9074-BD-GIB-010/0300 for plate, castings, forgings, bars, shapes, and heads.

3.31.3.2 HY-130 steel. HY-130 steel (S-11B) is steel in accordance with NAVSEA T9074-BD-GIB-010/0300, for plate, and forgings.

3.31.4 HY and/or HSLA material. HY and HSLA material refers to the family of high yield strength (HY-80/100/130) and/or high strength low alloy (HSLA-80/100) steels.

3.31.5 Ordinary strength steel. Ordinary strength steel (OSS) refers to a group of steels (S-1) intended for general structural use that typically have minimum yield strengths in excess of 34,000 psi. OSS are steels in accordance with MIL-S-22698 or other equivalent military, ASTM, or other commercial standards specified in the applicable ship specifications, unless otherwise approved by NAVSEA.

3.32 Stress corrosion cracking. Weld cracking caused by the presence of both tensile stress of sufficient magnitude and a corrosive medium.

3.33 Structure. Submarine structure is categorized by function (see Figure 2).

3.33.1 Foundation. Foundation is a base or support used to hold a component or part of a component or system. For example, machinery bed plates and mounting brackets are foundations.

3.33.1.1 Special foundation structure. Special foundation structures will be defined in the ship's detailed specifications or other contract documents and shall meet the requirements for foundations and the additional requirements for special foundation structure.

3.33.2 Non-pressure hull structure. Non-pressure hull structure is a structure which is not designed to withstand collapse depth pressure. This includes such items as low (soft) and intermediate pressure tanks, non-support structure, and foundations.

3.33.3 Non-support structure. Non-support structure is all structures not otherwise specifically categorized. This includes, but is not limited to, free flooding structure, decks, deck stanchions, control surfaces, fairwaters, padeyes, weight handling fitting or fixtures and hangers supporting pipe, cable, ventilation, and electrical items, unless otherwise specified. Non-support defines the relation to the pressure hull, not the function with regard to other items.

3.33.3.1 Minor structure. Minor structure is structure involving materials other than HY and HSLA, the possible failure of which is remote and would not result in danger to ship personnel, shipboard components or equipment, or other submarine structure. This includes items such as:

a. Non-structural or joiner bulkheads.
b. Partitions, lockers, and grating.
c. Galley fixtures.
d. Label plates and name plates.
e. Furniture.
f. Hand railings.
g. Operating platforms.
h. Hand grabs and ladders.

Minor structure shall be treated as non-support structure when welded to other submarine structure (e.g., to non-support structure, foundations,

etc.). Fabrication, welding, and inspection requirements of these attaching welds shall be in accordance with this document.

3.33.4 Pressure hull envelope. Pressure hull envelope is all structural material in boundaries maintaining watertight integrity at collapse depth. This includes items or portions of items such as pressure hull plating, sea chests, trunks, hatches, missile tubes, closure bulkheads, inserts, penetrations, sonar spheres, access plates, bridge access trunk, and hard tank plating.

3.33.5 Pressure hull structure. Pressure hull structure is all structures whose function is to withstand collapse depth pressure, including the pressure hull envelope and supporting structure.

3.33.6 Support structure. Support structure is all 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 conditions. This includes items such as pressure hull frames and hard tank frames. It also includes the portions of haunched frames, transverse structural floors, internal or external bulkheads and tanks, which function as frames; the boundaries of these portions shall be clearly identified on the drawing and are coincident with the SUBSAFE boundary at these locations. Where the extent to which items such as haunched frames, floors, and bulkheads function as support structure has not been otherwise specified or designated, the following applies:

a. When transverse floors and bulkheads act as frames, only the first 18 inches off 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 (i.e., support structure), unless otherwise specified.

b. When frames have nominal depth 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, unless otherwise specified.

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

3.33.8 Extended pressure hull structure. Extended pressure hull structure is that structure of a submarine or deep submergence vehicle (e.g., ASDS/DSRV)/structure (e.g., DDS) which only becomes subject to submergence pressure when the submarine and the deep submergence vehicle/structure are mated. Extended pressure hull structure includes pressure hull envelope structure and may include pressure hull support structure such as stiffeners. Examples of extended pressure hull structure are the mating skirt for a deep submergence vehicle and the DSRV mating seat and cofferdam on TRIDENT Class submarines.

Extended pressure hull structure shall be subject to the same requirements as pressure hull structure.

3.33.9 Interface structure. Interface structure is that structure whose function is to maintain a deep submergence vehicle/structure in a secured condition with a host submarine under design loading conditions. Interface structure is further classified as follows:

a. Interface support structure is that structure where failure of a single load path between the host submarine and the deep submergence vehicle/structure would compromise ability to maintain a secured condition under design loads and could lead to a casualty condition or loss of either the deep submergence vehicle/structure or the host submarine. Interface support structure shall be subject to the same requirements as pressure hull support structure.

b. Interface foundation structure is that structure where failure of a single load path between the host submarine and the deep submergence vehicle/structure would not compromise ability to withstand design load conditions. Interface foundation structure shall be subject to the same requirements as foundations.

All interface structure shall be considered to be classified as interface support structure unless that structure has specifically been designated or approved as interface foundation structure by NAVSEA.

3.34 Snipe. 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 abutting 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.

3.35 Tanks.

3.35.1 Hard tanks. Hard tanks are tanks designed to withstand pressure equal to or greater than ship test pressure (test depth). Hard tanks are considered as pressure hull structure (e.g., hard tank plating as pressure hull envelope and hard tank stiffeners as support structure).

3.35.2 Intermediate pressure tanks. Intermediate pressure tanks are tanks designed to withstand pressure greater than 125 pounds per square inch but less than ship test pressure (test depth).

3.35.3 Low pressure tanks (soft tanks). Low pressure tanks or soft tanks are those tanks designed to withstand pressures of 125 pounds per square inch and less.

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

3.37 Technical work document (TWD). A document which defines specific fabrication/installation instructions, and provides assurance (via certification signatures) that the work was performed in accordance with specified requirements. Examples: job tickets, key-ops, task group instructions, trade work instructions, etc.

3.38 Web stiffener. Web stiffener is a plate fitted to a load carrying member web to preclude web failure by buckling.

3.39 Welds.

3.39.1 Attachment weld. An attachment weld is any weld attaching the end of a member to submarine structure where all of the following conditions are met (see Figure 3 for examples):

a. Application involves: foundations, non-support structure, or minor structure (e.g., electrical foundations, hangers, hand grabs, etc.) designed to support 1 ton (2240 pounds) or less (total static weight).

b. The normal cross-section through the attaching member does not exceed 2½ inches nominal design length in either direction. (Note: When the member is welded at an angle of 30 to 90 degrees, the footprint at the end of the attaching member may exceed the 2½ by 2½ inch limit.)

c. The maximum design weld throat of the attaching weld does not exceed 1/2 inch.

d. The attachment does not involve welding of or to HY-130 material.

e. The application does not have multiple attachments which are rigidly (welded) connected to pressure hull structure. For example, a member which meets the requirements of a through d above, but rigidly spans between two pressure hull frames, is not considered an attachment weld. The design yard may approve other multiple attachment structural welds as attachment welds such as (but not limited to) hand grabs, ladder rungs, and manhole cover handles, based on fatigue considerations. In addition, other multiple attachment structures that have mechanical connections, such as a two-legged hanger that is connected by a mount or other bolted connections, does meet the attachment weld definitions.

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

3.39.3 Completed weld. Completion occurs when all weld metal has been deposited, required weld soaks are completed, preheat is removed, the weld has cooled to ambient temperature, and the weld is ready for other nondestructive test (NDT) inspections.

3.39.4 Finished weld. Finished weld is a weld which has received all required final inspections and has been accepted.

3.39.5 Foundation weld. Foundation weld is a weld used to fabricate a foundation or to attach it to the submarine.

3.39.6 Tank weld. A 100 percent efficient full or partial penetration weld in the tank boundary or to either side of the tank boundary where the member involved is being used primarily as tank boundary stiffener. It does not include frame to hull welds internal to the tank, backup structures, foundation welds, pressure hull butt and seam welds, or attachment welds (see Figure 4).

3.39.7 Weld surfacing.

3.39.7.1 Weld buildup. Weld buildup is the deposition of filler metal to restore base material or weld surface dimensions or to interpose a layer

of metal on the material surface of the joint prior to joining the material members together.

3.39.7.2 Weld cladding. Weld cladding is defined in AWS A3.0. For purposes of inspection, cladding deposited for O-ring or gasket seating surfaces is further subdivided into the following categories as shown in Figure 5:

a. Inboard surface (non-pressure, dry side).

b. Outboard surface (pressure, wet side).

c. Seating or seal area surface.

3.40 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.

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

3.42 Weld location. For purposes of distinguishing weld locations and classification with respect to specific requirements for design, fabrication, welding, and inspection, the terms "welds in" and "welds to" are used. These terms suggest the relative location of a weld to its boundaries, and the relationship to the general structure and function. They are not restricted to any particular joint design, see Figure 38 for examples. For tank welds, see definition 3.39.6.

3.42.1 Welds in. "Welds in" refers to all welds which are used to fabricate a selected submarine structure of a specific design category or application (e.g., welds in pressure hull structure include welds joining pressure hull envelope material, welds between pressure hull envelope and support structure material, and welds joining support structure material).

3.42.2 Welds to. "Welds to" refers to all welds which are used to attach submarine structure of a specific design category or application to another (e.g., welds attaching a foundation to pressure hull envelope).

3.43 Weld pass. 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, which may consist of more than one start and stop.

3.44 Normal supervisory controls. Controls imposed by a trade supervisor or a lead tradesman who exercises welding or workmanship inspection technical supervision.

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4. QUALIFICATION REQUIREMENTS

4.1 Scope. This section covers the requirements necessary for the qualification of welding procedures, welders and welding operators, nondestructive test (NDT) procedures, NDT personnel, NDT equipment, workmanship inspection procedures, and workmanship inspection personnel for submarine structure fabrication. Special requirements for qualification of welding procedures, welders, and welding operators, using MIL-120 and MIL-140 series filler materials, are contained in Section 16.

4.2 General requirements. The purpose of these qualification requirements is to insure that qualified procedures are used with adequate equipment by properly trained personnel. It shall be the responsibility of the activity to insure that only qualified personnel, procedures, and NDT equipment are used for fabrication and inspection to comply with this document. For applications involving filler materials other than MIL-120 or MIL-140 series, 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. Procedures and personnel previously qualified for welding MIL-120 or MIL-140 series filler materials, which do not meet the requirements noted herein, shall require approval prior to use in production. Welding procedures and techniques, NDT processes and procedures, NDT equipment, and material, other than those specified in this document or NAVSEA S9074-AQ-GIB-010/248, may be used if based on procedure qualification tests approved by NAVSEA.

4.3 Welding procedure qualification. Prior to production welding, procedures for welding covered by this document shall be qualified in accordance with NAVSEA S9074-AQ-GIB-010/248. If the applicable design provides for the use of weld metal having a lower tensile yield strength than specified in the applicable electrode specification, the lower all-weld metal tensile yield strength shall be met. Procedure qualification testing is not required for welding of minor structure (see 3.33.3.1). Qualified HY welding procedures may be used for welding HSLA-80 to other ferritic materials in accordance with TABLE III to NAVSEA S9074-AQ-GIB-010/248. Qualified HY welding procedures for other dissimilar metal welding, weld cladding, and stud welding applications shall not be extended to HSLA-80 materials and will require qualification in accordance with NAVSEA S9074-AQ-GIB-010/248.

4.3.1 Special qualification requirements. Use of welding procedures for applications listed in 13.2.2 is not permitted unless specifically approved by NAVSEA.

4.4 Welder performance qualification. Prior to performing any production welding, personnel shall be qualified in accordance with NAVSEA S9074-AQ-GIB-010/248. Qualification of welders and welding operators is not required when working on minor structure (3.33.3.1). Qualification of welders and welding operators for aluminum structural assemblies 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.

4.5 NDT procedure qualification. All NDT procedures specified in this document shall be qualified in accordance with NAVSEA T9074-AS-GIB-010/271, except as modified herein. Each activity shall certify that the procedures used are in accordance with these requirements. Records of procedure qualification shall be as specified in Section 5.

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

4.6 Qualification of NDT personnel. NDT personnel shall be qualified and certified in accordance with NAVSEA T9074-AS-GIB-010/271.

4.7 NDT equipment qualification. All NDT equipment, when used by qualified NDT operators employing approved procedures, shall detect flaws within the limits specified in Section 7. For weld inspection, UT inspection equipment shall meet the requirements of NAVSEA T9074-AS-GIB-010/271. Typical gages for VT inspection are shown in Figure 18.

4.8 Vision tests. Personnel, as specified in 4.4 (except tack, spot and stud welders) and 4.6, shall be required to pass an annual vision test. The test shall be conducted by a trained technician using standard test methods for determining visual acuity. The standard of acceptance for the vision test shall be natural or corrected near-distance acuity such that the individual is capable of reading J1 letters on the standard Jaeger type chart for near vision. Other equivalent visual tests may be substituted for the Jaeger chart. Personnel, as specified in 4.6, shall be required to pass a vision test in accordance with NAVSEA T9074-AS-GIB-010/271. Glasses or other corrective aids used to pass the vision tests shall be used when performing production work or inspections.

4.9 Workmanship inspection and inspection of materials. Each activity shall develop written procedures for workmanship inspection and inspection of materials. Training for workmanship inspection and inspection of materials shall be determined by the activity.

5. QUALITY CONTROL AND RECORD REQUIREMENTS

5.1 Scope. This section contains general quality control requirements and describes the records required for submarine structure fabrication.

5.2 General. Each activity shall have a quality control system consisting of written procedures which assign responsibility and provide accountability for performing work and inspections as required by this document.

5.2.1 Inspection monitoring. In addition to 6.3.1 and 6.3.2, when VT inspection or workmanship inspection certification signatures (respectively) are based on other than personal observation, the inspection adequacy shall be monitored using normal supervisory controls, surveillance and/or re-inspection programs, which review a representative sample of in-process and completed inspections. Results of surveillance and re-inspections shall be periodically reviewed in accordance with written procedures for quality of work, adequacy of the sampling program, and effectiveness of the inspections.

5.2.2 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 verified at the point of initial fabrication as being the same material identification or an approved alternate material identification, as required by the drawing.

5.3 Records. The quality control system shall include the preparation and maintenance of records. Records shall contain, as a minimum, the information noted herein. Vendor inspection or mill certificate records will fulfill the requirements of this section for that portion of the required information contained therein. Each activity shall be responsible for the records, including RT films, on materials or components furnished by subcontractors.

5.3.1 Record of accomplishment. A record of accomplishment is a record that can be traced to an application. A record of accomplishment may take several different forms at an activity, including a detailed record, a technical work document, or a separate log. A record of accomplishment may be used for inspections when allowed by this specification. A record of accomplishment shall include at least the following items:

a. Item and location of inspection: The location description may refer to drawings, assemblies, piece marks, purchase or item numbers, serial numbers, TWD items, or other records that uniquely identify what is being inspected.

b. A method to identify the written procedures used to perform the inspection.

c. The organizational element responsible for the inspection.

d. Certification signatures based on normal supervisory controls or personal observation. Signatures based on normal supervisory controls may only be used as allowed by this document.

5.3.2 Record instructions. Records shall be marked "N/A" for sections not applicable to the particular job or a vertical arrow drawn through similar items, unless otherwise noted in the activity's procedures.

5.3.3 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 submarine, or as specified in NAVSEA 0924-062-0010 or in the ship's detailed specifications, whichever is longer. At the expiration of the record's retention period, all records shall be made available to NAVSEA or its authorized representative by written notification. If no disposition is authorized within 6 months, the records may be destroyed.

5.4 Qualification records.

5.4.1 Welding procedure qualification. These records shall comply with NAVSEA S9074-AQ-GIB-010/248.

5.4.2 Welder and welding operator qualification. These records shall comply with NAVSEA S9074-AQ-GIB-010/248.

5.4.3 NDT procedure qualification. These records shall comply with NAVSEA T9074-AS-GIB-010/271.

5.4.4 NDT personnel qualification. These records shall comply with NAVSEA T9074-AS-GIB-010/271.

5.5 Workmanship inspection records. Workmanship inspections required in 6.3.2 shall be documented by use of a record of accomplishment or detailed records. Workmanship inspection certification signatures shall be based on normal supervisory controls or personal observation. The individual providing the inspection certification signature is responsible for ensuring that workmanship inspections have been accomplished and associated technical requirements have been met.

5.5.1 Circularity, sphericity and hull fairness inspection. Records shall be kept of all final circularity, sphericity and hull fairness measurements as required by Section 12. These records shall include the method of taking the final measurements and the records of training and certification for personnel responsible for taking these measurements. For sphericity, the records shall include the radius and mismatch measurements (when required by the ship's detailed specifications) and the analysis of these data required to show that the closure bulkheads are within the specified tolerances. Record forms used for final checks shall be in a format similar to:

a. For circularity - Figures 6, 7, and 8.

b. For hull fairness - Figure 9.

c. For sphericity - as approved by NAVSEA.

5.5.2 Pressure hull frame dimensions inspection. These records, as required by 12.3.2, shall be in a format similar to Figure 10 and shall contain the following:

a. Ship or hull number.

b. Frame number.

c. Dimensions, including web and flange tilt, flange width and unbalance, frame flange curvature, and frame depth. For frame flange curvature, confirmation that the requirements of 12.3.2.2 were met may be provided in lieu of the actual measurements.

d. Station number.

e. Distance between frames.

5.6 Weld records. Weld records are required for all welds in or to the pressure hull envelope, and for all welds which require volumetric (RT/UT) inspection. Weld records are not required for weld repairs that do not exceed 1/3 of the base material thickness, unless volumetric (RT/UT) inspection is required. Each weld record may be self-contained, or controlled by a formal records procedure at the activity in such a manner as to ensure all required attributes can be identified. Weld records shall include at least the following items:

a. Weld location (e.g., ship, assembly, and joint identification).

b. Weld joint design.

c. Base material type (e.g., OSS, HSS, HY-80).

d. NAVSEA T9074-AS-GIB-010/271 records for each required NDT inspection, unless this document allows using a record of accomplishment or no record for the specific inspection.

e. Size and location of rejectable indications and description and date of repairs, unless this document allows using a record of accomplishment or no record for the specific inspection.

f. Date and time when it was determined that the weld is at ambient temperature, for welds requiring MT inspection time delays (i.e., 24 hours or 7 days).

5.6.1 VT inspection. For welds which do not require weld records, VT inspection records shall be in accordance with NAVSEA T9074-AS-GIB-010/271 or recorded on a record of accomplishment. Welds that require 100 percent inspection using an NDT method other than VT shall have the VT inspection certification signatures based on personal observation. All other welds shall have VT inspection certification signatures based on normal supervisory controls or personal observation. The individual providing the inspection certification signature is responsible for ensuring that inspections have been accomplished and all associated technical requirements have been met.

5.7 Material records.

5.7.1 Welding filler material and flux control inspection. Records of inspection required by Section 8 shall contain the following:

a. Manufacturer’s certification and test results for compliance with the applicable defense specification referenced in Section 2.

b. Records of inspection verification of filler materials and flux conformance as required by Section 8.

c. Records of moisture content of electrodes and flux in use as required by Section 10 (laboratory test results).

d. Date of inspection and signature of inspectors.

5.7.2 Base materials. Records shall show compliance with all applicable inspection and test requirements and acceptance criteria (see 8.2 and 8.4). For castings, also see 15.4.5.

5.7.2.1 HY and HSLA base material. Records for HY and HSLA base material shall contain the following (for base material used in the pressure hull envelope, also see 5.7.4):

a. Heat, load, and slab number (mill source). For castings, the serial number (must be unique identification).

b. Chemistry and mechanical properties as required by the applicable base material specification.

c. Soundness (e.g., RT, UT, MT, as applicable).

d. Dimensional inspection, as applicable.

e. Size and location of rejectable indications and description and date of repairs.

f. For HY-80/100/130 material, Brinell hardness measurements and location where measurements were taken.

g. Date of inspections and tests and signature of inspectors.

5.7.2.1.1 Hot formed HY materials. In addition to the record requirements for base materials, records of HY hot formed materials shall include the following:

a. Certified mechanical and impact test results (as required by Section 9).

b. Surface inspection for defects (including MT, as required by Section 6).

c. Thickness and soundness (UT) inspection (as required by the applicable material specification).

d. RT results of hot formed welds, as applicable (as required by Section 6).

e. Record of contractor repairs.

5.7.3 NDT inspection of base materials. Records for required NDT inspections of base materials shall be in accordance with NAVSEA T9074-AS-GIB-010/271 for the specific method used and shall include the size and location of rejectable indications and description of repairs, with the following exceptions:

a. NAVSEA T9074-AS-GIB-010/271 records are not required when this document allows using a record of accomplishment, or no record.

b. Except for HSS used in pressure hull structure, HY/HSLA, or when specifically required by the contract or purchase order, vendors and subcontractors may provide certificates of compliance in lieu of NAVSEA T9074-AS-GIB-010/271 records.

5.7.4 Material traceability requirements for base material used in pressure hull structure. All base material used in the pressure hull envelope shall be traceable from the required base material records to the specific location or use in the submarine, and from the specific location or use in the submarine back to the required base material records. However, hard tank plating (and penetrations and inserts therein), which can be isolated from the differential between sea pressure and internal atmospheric pressure by a double boundary (i.e., hull and backup valve or equivalent), may be treated as pressure hull support structure for the purpose of material traceability. All base material used in pressure hull support structure shall be traceable from the point of fabrication, as part of the submarine (i.e., plate cutting of a specific end use part, or the point of installation into an identifiable subassembly, assembly, or system, whichever occurs first), through a controlled procedure back to the required base material records. Traceability may be accomplished by an appropriate cross-reference system such as fabrication and utilization records, markings on the item, or by an automated database.

5.8 Monitoring records.

5.8.1 Welding in-process monitoring. Records of in-process monitoring, as required by Section 6, shall contain the following attributes as applicable at the time monitoring is performed:

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).
p. Heat soak (satisfactory or unsatisfactory).

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6. INSPECTION REQUIREMENTS

6.1 Scope. This section contains requirements for inspection of materials used in, and welds in or to, submarine structure. Where more than one inspection category applies, the most restrictive category's requirements shall be used. Use of alternate inspections or methods shall require NAVSEA approval. Where the term VT is used in this document, it refers to visual inspection of welds and is a specific type of NDT method. VT, workmanship inspections, and inspections of materials are three separate types of inspections, and are so treated by this document.

6.1.1 General. Qualification requirements for inspection procedures and personnel are contained in Section 4. Inspection record requirements are contained in Section 5. For ferromagnetic materials (e.g., S-1, S-11) or ferromagnetic welds joining ferromagnetic materials to each other, surface inspection requirements, other than VT, shall be in accordance with 6.5, as applicable. For non-ferromagnetic materials (e.g., S-8, S-34, S-43) and non-ferromagnetic welds regardless of materials being joined, surface inspection requirements, other than VT, shall be in accordance with 6.6, as applicable. Inspection acceptance criteria are contained in Section 7. NDT inspection methods shall be in accordance with NAVSEA T9074-AS-GIB-010/271.

6.1.2 Surface preparation and adjacent material. Activities shall plan to perform inspections when the inspection area is accessible. When adjacent base material or an expansion area is required to be inspected as part of the weld inspection zone, only the accessible areas, at the time of inspection, need be inspected. When performing inspections, surface preparation of welds and base material shall be in accordance with NAVSEA T9074-AS-GIB-010/271, unless otherwise approved.

6.1.3 Repairs. Correction of rejectable defects shall be accomplished by repairing to the extent necessary to meet the applicable acceptance criteria. Unless otherwise allowed by this document, correction of rejectable defects shall be verified as follows:

a. Re-inspection using the inspection method that rejected the defect.

b. When a surface inspection method will be used to verify correction of the rejectable defect and weld metal will be deposited over the affected area, the inspection shall be performed prior to welding.

6.2 Inspection of material. Inspection of material shall be in accordance with this section and Sections 8 and 15, as applicable.

6.3 Workmanship inspection.

6.3.1 In-process monitoring of welding. In-process monitoring of welding shall be accomplished to ensure compliance with welding procedures and related drawing requirements. In-process monitoring shall be accomplished in accordance with a written procedure. Corrective action shall be taken upon detection of discrepancies, and such action shall be recorded as specified in Section 5.

6.3.2 Inspection of workmanship. All structures 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. Tack welds in accordance with Section 13.

c. Weld repairs for excavation contours, and full penetration welds for root cleaning and contour in accordance with Section 14.

d. Base material surfaces, after completion of fabrication, for arc strikes, weld spatter, fabrication scars, and removal of welds and welded temporary attachments in accordance with Section 14.

e. 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.

f. Specified geometrical tapers of structural material and welds in accordance with Section 11 and drawings.

g. Snipes in accordance with Section 14.

h. Penetrations and intersecting butt welds in the pressure hull envelope for weld buildup in accordance with Section 13.

i. Underwater exterior surfaces in accordance with drawings.

j. Pressure hull frames for frame dimensional tolerances, flange curvature, spacing, and butt alignment in accordance with Section 12.

k. Hull circularity, sphericity, and hull fairness in accordance with Section 12.

l. Structural castings, forgings, and shaped inserts for specified dimensions, surface conditions, and identification markings in accordance with Sections 8 and 15 and drawings.

m. Hard tank, bridge access trunk, and main ballast tank frames for dimensional tolerances and spacing in accordance with drawings.

n. Pressure hull penetration bore diameters in accordance with drawings.

o. The radius of spherical transitions in accordance with drawings.

p. The tension surface of cold formed material in accordance with Sections 8 and 14. The specified inside radius of formed material in accordance with drawings.

6.4 VT inspection.

6.4.1 VT inspection of welds. All completed welds shall be VT inspected to ensure completeness and compliance with detailed working drawings and Section 7.

6.4.1.1 Fillet welds on primer coated surfaces. When fillet welds over primer coated surfaces are permitted by 13.2.6, the welds shall be inspected as follows:

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 7.4.9 shall be gouged and evaluated in accordance with 6.4.1.1.2(f). The

gouge shall include the VT indication and be at least 3 inches long with the mid-third extending to the root of the weld.

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 of the welding 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. Acceptance criteria shall be in accordance with 7.4.9.

a. To begin, gouge the weld at one place in each 5 feet of the weld. Continue at this rate until 15 successive gouges have shown weld metal to be within the acceptance criteria.

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 the acceptance criteria are exceeded, or until 15 successive gouges have shown sound weld metal. Where the acceptance criteria 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 acceptance criteria are exceeded or until 15 successive gouge inspections show sound weld metal. When the acceptance criteria 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 the acceptance criteria 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 the supporting data.

f. Where gouging reveals defects in excess of those specified in 7.4.9, 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.

g. All gouges shall be weld repaired.

6.5 MT inspection.

6.5.1 General. MT inspection requirements are specified in Tables 6-1, 6-2, and 6-3, with exemptions noted in 6.5.2. Either DC prod or AC yoke may be used. Eddy current test inspection (ET) may be substituted for MT as noted in Tables 6-1 and 6-2. PT inspection, or when approved, ET inspection, shall be substituted for MT inspection where MT inspection is impracticable.

TABLE 6-1. MT INSPECTION REQUIREMENTS FOR HY AND HSLA MATERIALS.

Inspection category	Time of inspection	Notes
I. Pressure hull structure		
A. Pressure hull envelope.		
(1) Full penetration butt, corner and groove tee weld in pressure hull envelope. Partial penetration tee welds in the pressure hull envelope. Full penetration tee weld to the pressure hull envelope, except as noted below in categories (2) and (4).	Final inspection shall be made no sooner than the same shift 7 days (160 hours minimum) after the weld is completed and has cooled to ambient temperature.	1/ 2/ 3/ 4/ 5/ 6/
(2) Full penetration tee welds to the pressure hull envelope where the tee member is less than or equal to 1/4T or 1/2 inch, whichever is less (where T is thickness of pressure hull envelope in way of the attachment).	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 2/ 4/ 5/
(3) Hard tank welds.		
(a) Non-pressure surfaces of full and partial penetration tee and corner welds.	If final inspection is made prior to the first hydrostatic test, the time of inspection shall be in accordance with requirement of category I.A.(1), (2) or (4) of this table, as applicable. If final inspection is made after the first hydrostatic test, the requirements of category I.A.(3)(b) of this table apply.	1/ 2/
(b) All other welds.	Inspect the hard tank welds in accordance with 6.5.5.	1/
(4) Partial penetration welds to the pressure hull envelope and partial or full penetration tee welds of internal frame webs to the pressure hull envelope.	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 2/ 4/ 5/
(5) Full penetration welds in the pressure hull envelope, including welds of penetrations or hull liners greater than 4 inches in diameter, which cannot be RT or UT inspected as required by Table 6-4. (see Figure 11)	In addition to the applicable final inspection requirements of this table, inspection shall be performed after deposition of each layer, or 3/8 inch thickness, whichever is greater.	1/ 8/

TABLE 6-1. MT INSPECTION REQUIREMENTS FOR HY AND HSLA MATERIALS – CONT'D.

Inspection category	Time of inspection	Notes
I. Pressure hull structure – Cont'd		
A. Pressure hull envelope – Cont'd.		
(6) Repair of holes. (a) Depth of repair is 3/4T or less (where T is thickness of base material involved).	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 5/ 8/
(b) Depth of repair is greater than 3/4T (where T is thickness of base material involved).	Final inspection shall be made no sooner than the same shift 7 days (160 hours minimum) after the weld is completed and has cooled to ambient temperature.	1/ 5/
(7) Hot formed welds.	After heat treatment and the weld has cooled to ambient temperature.	1/ 5/ 8/
(8) Cold formed full penetration welds in or to the pressure hull envelope.	Final inspection shall be made no sooner than the same shift 7 days (160 hours minimum) after the weld is completed and has cooled to ambient temperature, after forming.	1/ 2/ 3/ 4/ 5/ 8/
(9) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair welding is not required.	After removal and after the surface has been prepared as required in Section 14.	9/ 10/
(10) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 9/
(11) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	After removal and after the surface has been prepared as required in Section 14.	9/
(12) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	After removal of any slag, scale, or surface roughness which would interfere with interpretation of indications.	9/
(13) Prepared surfaces. (see 6.5.2.d)	After final surface preparations.	5/ 8/ 11/

TABLE 6-1. MT INSPECTION REQUIREMENTS FOR HY AND HSLA MATERIALS – CONT'D.

Inspection category	Time of inspection	Notes
I. Pressure hull structure – Cont'd		
B. Support structure.		
(1) Full or partial penetration butt, corner and tee welds in or to support structure.	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 5/ 8/
(2) Repair of holes.		
(a) Depth of repair is 3/4T or less (where T is thickness of base material involved).	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 5/ 8/
(b) Depth of repair is greater than 3/4T (where T is thickness of base material involved).	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 5/ 8/
(3) Hot formed welds.	After heat treatment and the weld has cooled to ambient temperature.	1/ 5/ 8/
(4) Cold formed full penetration welds in or to support structure.	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature, after forming.	1/ 5/ 8/
(5) Ground areas where arc strikes, fabrications scars, weld defects and areas where attachments are removed and repair by welding is not required.	After removal and after surface has been prepared as required in Section 14.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	After repair welding.	1/ 9/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	After removal and after the surface has been prepared as required in Section 14.	9/
(8) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	After removal of any slag, scale or surface roughness which would interfere with interpretation of indications.	9/
(9) Prepared surfaces.	Inspection not required.	N/A

TABLE 6-1. MT INSPECTION REQUIREMENTS FOR HY AND HSLA MATERIALS – CONT'D.

Inspection category	Time of inspection	Notes
II. Containment structure and containment bulkheads		
A. Inspection requirements for containment structure and containment bulkheads shall be as specified for support structure (Category I.B.).		
III. Non-pressure hull structure		
A. Intermediate pressure tanks.		
(1) Full or partial penetration butt, corner, and tee welds in or to intermediate pressure tanks.	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 5/ 8/
(2) Repair of holes.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/
(3) Hot formed welds.	After heat treatment and the weld has cooled to ambient temperature.	1/ 8/
(4) Cold formed full penetration welds in or to intermediate pressure tanks.	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature after forming.	1/ 5/ 8/
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed, and repair by welding is not required.	After removal and after the surface has been prepared as required by Section 14.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	After repair welding.	1/ 9/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	After removal and after the surface has been prepared as required in Section 14.	9/
(8) Root area of full penetration butt, corner and groove tee welds after backgouging; weld repair excavation sites.	After removal of any slag, scale, or surface roughness which would interfere with interpretation of indications.	9/
(9) Prepared surfaces.	Inspection not required.	N/A

TABLE 6-1. MT INSPECTION REQUIREMENTS FOR HY AND HSLA MATERIALS – CONT'D.

Inspection category	Time of inspection	Notes
III. Non-pressure hull structure – Cont'd		
B. Low pressure (soft) tanks.		
(1) Full or partial penetration butt, corner and tee welds in or to low pressure (soft) tanks.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(2) Repair of holes.		
(a) Repair of full penetration holes through the tank boundary.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(b) All other hole repairs.	Inspection not required.	N/A
(3) Hot formed welds.	After heat treatment and the weld has cooled to ambient temperature.	1/ 8/
(4) Cold formed full penetration welds in or to low pressure (soft) tanks.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature, after forming.	1/ 5/ 8/ 7/
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair by welding is not required.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required except those defects that were detected by MT inspection and subsequently repair welded shall be re-inspected by MT after repair welding.	1/ 9/ 7/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required.	N/A
(8) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(9) Prepared surfaces.	Inspection not required.	N/A

TABLE 6-1. MT INSPECTION REQUIREMENTS FOR HY AND HSLA MATERIALS – CONT'D.

Inspection category	Time of inspection	Notes
III. Non-pressure hull structure – Cont'd		
C. Foundations.		
(1) Full or partial penetration butt, corner and tee welds in or to foundations.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(2) Repair of holes.	Inspection not required.	N/A
(3) Hot formed welds.	After heat treatment and the weld has cooled to ambient temperature.	1/ 8/
(4) Cold formed full penetration welds in or to foundations.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature after forming.	1/ 5/ 8/ 7/
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair by welding is not required.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required except those defects that were detected by MT inspection and subsequently repair welded shall be re-inspected by MT after repair welding.	1/ 9/ 7/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required.	N/A
(8) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(9) Prepared surfaces.	Inspection not required.	N/A
D. Non-support structure.		
(1) Full or partial penetration butt, corner, and tee welds in or to non-support structure.	Inspection not required.	N/A
(2) Repair of holes.	Inspection not required.	N/A
(3) Hot formed welds.	Inspection not required.	N/A
(4) Cold formed full penetration welds in or to non-support structure.	Inspection not required.	N/A

TABLE 6-1. MT INSPECTION REQUIREMENTS FOR HY AND HSLA MATERIALS – CONT'D.

Inspection category	Time of inspection	Notes
III. Non-pressure hull structure – Cont'd		
D. Non-support structure – Cont'd.		
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair by welding is not required.	Inspection not required.	N/A
(6) Outside surfaces of welds in or to control surfaces and welds to the hub of control surfaces. Other interior welds of control surfaces do not require inspection.	Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required.	N/A
(8) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required.	N/A
(9) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(10) Prepared surfaces.	Inspection not required.	N/A
(11) Welds of head and heel connections of stanchions, and transverse welds in stanchions.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/
(12) The attaching welds of permanent padeyes, and weight handling fittings or fixtures to structure.	Final inspection shall be made after load testing.	1/ 8/ 7/

TABLE 6-2. MT INSPECTION REQUIREMENTS FOR HIGHER STRENGTH STEEL (HSS).

Inspection category	Time of inspection	Notes
I. Pressure hull structure		
A. Pressure hull envelope.		
(1) Full or partial penetration butt, corner and tee welds in or to the pressure hull envelope.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 6/ 12/
(2) Repair of holes.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 12/
(3) Hot formed welds.	Inspection not required.	N/A
(4) Cold formed full penetration welds in or to the pressure hull envelope.	Inspection not required.	N/A
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair welding is not required.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required except those defects that were detected by MT inspection and subsequently repair welded shall be re-inspected by MT after repair welding.	1/ 9/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/
(8) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(9) Prepared surfaces.	Inspection not required.	N/A

TABLE 6-2. MT INSPECTION REQUIREMENTS FOR HIGHER STRENGTH STEEL (HSS) – CONT'D.

Inspection category	Time of inspection	Notes
I. Pressure hull structure		
B. Support structure.		
(1) Full or partial penetration butt, corner and tee welds in or to support structure.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 12/
(2) Repair of holes.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 12/
(3) Hot formed welds.	Inspection not required.	N/A
(4) Cold formed full penetration welds in or to support structure.	Inspection not required.	N/A
(5) Ground areas where arc strikes, fabrications scars, weld defects and areas where attachments are removed and repair by welding is not required.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required except those defects that were detected by MT inspection and subsequently repair welded shall be re-inspected by MT after repair welding.	1/ 9/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/
(8) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(9) Prepared surfaces.	Inspection not required.	N/A
II. Containment structure and containment bulkheads		
A. Inspection requirements for containment structure and containment bulkheads shall be as specified for support structure (Category I.B.).		

TABLE 6-2. MT INSPECTION REQUIREMENTS FOR HIGHER STRENGTH STEEL (HSS) – CONT'D.

Inspection category	Time of inspection	Notes
III. Non-pressure hull structure		
A. Intermediate pressure tanks.		
(1) Full or partial penetration butt, corner, and tee welds in or to intermediate pressure tanks.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 12/
(2) Repair of holes.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 12/
(3) Hot formed welds.	Inspection not required.	N/A
(4) Cold formed full penetration welds in or to intermediate pressure tanks.	Inspection not required.	N/A
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed, and repair by welding is not required.	Inspection not required except those defects that were detected by MT inspections and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required except those defects that were detected by MT inspection and subsequently repair welded shall be re-inspected by MT after repair welding.	1/ 9/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required except those defects that were detected by MT inspections and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/
(8) Root area of full penetration butt, corner and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(9) Prepared surfaces.	Inspection not required.	N/A

TABLE 6-2. MT INSPECTION REQUIREMENTS FOR HIGHER STRENGTH STEEL (HSS) – CONT'D.

Inspection category	Time of inspection	Notes
III. Non-pressure hull structure – Cont'd		
B. Low pressure (soft) tanks.		
(1) Full or partial penetration butt, corner and tee welds in the boundary of low pressure (soft) tanks subjected to pressure over 15 psi. In addition, for Main Ballast Tanks only full or partial penetration tee welds to the tank boundary when the member's primary function is to provide tank stiffening. Foundation back-up structure or attachment welds do not require MT inspection.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(2) Repair of holes.		
(a) Repair of full penetration holes through the tank boundary subjected to pressure over 15 psi.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 7/ 8/
(b) All other hole repairs.	Inspection not required.	N/A
(3) Hot formed welds.	Inspection not required.	N/A
(4) Cold formed full penetration welds in or to low pressure tanks.	Inspection not required.	N/A
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair by welding is not required.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/ 10/
(6) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required except those defects that were detected by MT inspection and subsequently repair welded shall be re-inspected by MT after repair welding.	1/ 9/ 7/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required.	N/A
(8) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(9) Prepared surfaces.	Inspection not required.	N/A

TABLE 6-2. MT INSPECTION REQUIREMENTS FOR HIGHER STRENGTH STEEL (HSS) – CONT'D.

Inspection category	Time of inspection	Notes
III. Non-pressure hull structure – Cont'd		
C. Foundations.		
(1) Full or partial penetration butt, corner and tee welds in or to foundations where both members are over 1/2 inch thick.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(2) End intersection welds of, or transverse welds in, beam type or built-up members in special foundation structure, regardless of member thickness (see Figure 12)	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(3) Repair of holes.	Inspection not required.	N/A
(4) Hot formed welds.	Inspection not required.	N/A
(5) Cold formed full penetration welds in or to foundations.	Inspection not required.	N/A
(6) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair by welding is not required.	Inspection not required except those defects that were detected by MT inspection and subsequently removed by grinding shall be re-inspected by MT after grinding.	9/ 10/
(7) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required except those defects that were detected by MT inspection and subsequently repair welded shall be re-inspected by MT after repair welding.	1/ 9/ 7/
(8) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required.	N/A
(9) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(10) Prepared surfaces.	Inspection not required.	N/A

TABLE 6-2. MT INSPECTION REQUIREMENTS FOR HIGHER STRENGTH STEEL (HSS) – CONT'D.

Inspection category	Time of inspection	Notes
III. Non-pressure hull structure – Cont'd		
D. Non-support structure.		
(1) Full or partial penetration butt, corner, and tee welds in or to non-support structure.	Inspection not required.	N/A
(2) Repair of holes.	Inspection not required.	N/A
(3) Hot formed welds.	Inspection not required.	N/A
(4) Cold formed full penetration welds in or to non-support structure.	Inspection not required.	N/A
(5) Ground areas where arc strikes, fabrication scars, weld defects, and areas where attachments are removed and repair by welding is not required.	Inspection not required.	N/A
(6) Outside surfaces of welds in or to control surfaces and welds to the hub of control surfaces. Other interior welds of control surfaces do not require inspection.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(7) Areas where automatically timed arc welded studs over 3/8 inch in diameter have been used and removed.	Inspection not required.	N/A
(8) Weld repair of fabrication scars, arc strikes and areas where attachments are removed and repair by welding is required.	Inspection not required.	N/A
(9) Root area of full penetration butt, corner, and groove tee welds after backgouging; weld repair excavation sites.	Inspection not required.	N/A
(10) Prepared surfaces.	Inspection not required.	N/A
(11) Welds of head and heel connections of stanchions, and transverse welds in stanchions.	Final inspection shall be made after the weld is completed and has cooled to ambient temperature.	1/ 8/ 7/
(12) The attaching welds of permanent padeyes, and weight handling fittings, or fixtures to structure.	Final inspection shall be made after load testing.	1/ 8/ 7/

Notes to Tables 6-1 and 6-2:

1/ If weld repairs are necessary, the repaired area shall be re-inspected as required for the original weld.

2/ Extent of inspection of repairs made to welds referenced to this note is based on the depth of repair, as measured from the plate surface, and as follows:

Depth of repair (T equals thickness of thinner member being repaired)	Inspection
a) Less than or equal to 1/3 T	Inspect the weld repair and a minimum of 6 inches beyond each end of the repair on the repair face.
b) Greater than 1/3 T to and including 2/3 T	Perform the inspection in (a) above for both the repair and opposite face. (see Figure 13)
c) Greater than 2/3 T	Perform the inspection in (b) above. In addition perform the inspection required by 3/ below. (see Figure 14)

The expansion inspection on a full penetration hull butt, corner and tee welds in the pressure hull envelope need only be extended to include an intersecting full penetration 100 percent efficient weld to the pressure hull, when the intersecting member is 1/4 the hull thickness or greater, and falls within the 6-inch requirement. The weld surfaces which have been covered by other full or partial penetration weld (see 6.5.2.b) or faying pads are not subject to the expansion inspection requirements above.

3/ All previously inspected full penetration welds in or to the pressure hull envelope that are within 6 inches of:

a) Newly installed full penetration welds in the pressure hull envelope, or

b) Weld repairs in the pressure hull envelope which exceed a total excavation depth of 2/3 T (see Note 2)

shall be re-inspected by MT or ET for a distance within 6 inches of the new or repair weld except re-inspection is not required if the previously inspected weld:

(1) has been heat treated (that is, quenched and tempered) as part of the base material.

(2) was previously contoured in accordance with Section 14 and MT inspected.

(3) is in a member that is not contiguous to the new weld (that is, is in an intersecting or attached member) (see Figure 14B for illustration of requirements).

Notes to Tables 6-1 and 6-2: (Cont'd)

4/ When full penetration tee welds other than attachment welds are made to the pressure hull envelope, all previously inspected full penetration welds in or to the pressure hull envelope (as noted below) shall be re-inspected by MT or ET to the following extent:

Tee member thickness (T represents thickness of the pressure hull at the attachment site)	Extent of re-inspection
Less than or equal to 1/2 T	Re-inspection not required.
Greater than 1/2 T	Re-inspect both sides of those portions of all other full penetration welds in or to the pressure hull envelope within 3 inches toe-to-toe distance of the attaching member (see Figure 14A), except re-inspection is not required if the previously inspected weld was previously contoured in accordance with Section 14 and MT inspected in accordance with 6.5.

5/ Final inspection shall be performed after forming or straightening operations.

6/ Surface areas of butt welds which are to be subsequently covered by faying pads, shall be final MT inspected prior to being covered (after being ground as necessary for fitting of the faying pads).

7/ For inspection categories noted, ET inspection may be substituted for MT inspection of welds in or to material other than HY-100/130 and HSLA-100.

8/ Detailed records of the MT inspections covered by this item are not required. A record of accomplishment shall be maintained. Surveillance of accomplishment is required and shall be conducted in accordance with a written procedure. A formal procedure for accomplishing these inspections shall be established and available for review.

9/ Detailed records, or records of accomplishment are not required. A formal procedure for accomplishing these inspections must be established and available for review.

10/ For arc strikes, nicks, gouges and fabrication scars which do not require weld repair, PT or 5X VT inspection may be substituted for MT; acceptance criterion is no linear or crack like indications.

11/ Surface preparation is considered to be the removal of material in excess of 1/32 inch. Examples which typically do not exceed 1/32 inch and would not require MT inspection include base materials ground to prepare for painting, grit finish for UT inspection, fitup or layoff of attaching structure, removal of weld spatter, or removal of punch marks.

12/ MT inspection is not required for welds in or to HSS of any thickness which are 100 percent RT or UT inspected.

TABLE 6-3. MT INSPECTION REQUIREMENTS APPLICABLE TO HY AND HSLA BASE MATERIAL, MILL DEFECTS AND FORMING.

Inspection category	Time of inspection	Notes
(1) Repairs of base material defects.	If repair welding is required, the area to be repaired shall be MT inspected prior to welding. Final inspection shall be made no sooner than 24 hours after the weld is completed and has cooled to ambient temperature. If repair welding is not required, final inspection shall be made after the defect is removed.	1/ 2/ 3/ 4/
(2) Tension surface of HY-130 and HSLA-80/100 base material that is cold formed in excess of 12 percent total elongation. (see 6.11.1.1)	After forming.	1/ 2/ 3/ 5/
(3) Tension surface of base material that is hot formed in excess of 15 percent total elongation.	After forming and the material has reached ambient temperature.	1/ 2/ 3/ 5/

Notes:

1/ Inspection shall include the entire surface of the repair or area involved.

2/ Lamellar indications in the base materials shall be evaluated in accordance with Section 7. Repairs shall be in accordance with Section 13.

3/ Detailed records of the MT inspection covered by this table are not required. A record of accomplishment shall be maintained. Surveillance of accomplishment is required and shall be conducted in accordance with a written procedure. A formal procedure for accomplishing these inspections shall be established and available for review.

4/ For arc strikes, nicks, gouges and fabrication scars which do not require weld repair, PT or 5X VT inspection may be substituted for MT; acceptance criterion is no linear or crack like indications.

5/ If repairs are necessary, the inspection requirements of category (1) apply.

6.5.2 Exemptions (to Tables 6-1, 6-2 and 6-3).

a. Inspection is not required for the installation of permanent automatically timed arc stud welds, capacitor discharge stud welds, and resistance spot welds. In addition, inspection is not required for areas where automatically timed arc stud welding, 3/8 inch and less in diameter, capacitor discharge stud welds, and resistance spot welds have been removed.

b. Weld surface areas which are to be subsequently covered by other partial or full penetration welds do not require final MT inspection, for example, surface areas of longitudinal butt welds under frame webs and their associated welds, surface areas of frame and stiffener

connections covered by intercostal welds. This exemption does not apply to clad welds, or hard-surfacing/wear-surfacing.

c. Inspection is not required for arc strike removal sites, fabrication scars, nicks and gouges prior to repair welding.

d. Inspection is not required for base material prepared surfaces and tension surfaces of formed materials that will be covered by weld metal. This exemption does not apply to clad welds, or hard-surfacing/wear-surfacing.

e. Inspection is not required for base material surfaces that are prepared for bolts and studs regardless of diameter) or for pipe, mechanical, or electrical penetration holes, including holes for vent and drain, less than 4 inches in diameter.

f. Re-inspection of previously accepted welds is not required for weld surfaces that are prepared (i.e., spot faced; drilled) for bolts and studs (regardless of diameter) or pipe, mechanical, or electrical penetration holes, including holes for vent and drain, less than 4 inches in diameter, except that weld surfaces in pressure hull structure (other than inside holes less than 4 inches in diameter) shall require 5X VT inspection. The MT acceptance criterion in 7.5.1 shall be used for the 5X VT inspection.

g. Inspection is not required for attachment welds to pressure hull and containment structure made with type MIL-7018-M or MIL-70S filler materials (see 3.39.1).

h. Inspection is not required of the backgouged surfaces of root passes or repair weld excavation sites if the weld will subsequently be either RT or UT inspected.

i. Inspection is not required for attachment welds to non-pressure hull structure (see 3.39.1).

j. For foundations, low pressure tanks, or non-support structure, inspection is not required for welds attaching non-compensating coamings and non-compensating penetrations and label plates (signs) to these structures. This exemption does not apply to coamings and penetrations which penetrate the low pressure tank boundary.

k. For foundations, inspection is not required for web to flanges and longitudinal seams of manufactured shapes and longitudinal welds of foundation stiffeners to the foundation structure where:

   (1) the thickness of both members are one inch or less, and

   (2) welds are made with filler materials other than MIL-120 or MIL-140 series electrodes.

   This exemption does not apply to specific welds in critical applications as determined by the Design Yard or NAVSEA.

l. Inspection is not required when approved by NAVSEA on a case basis.

m. For Table 6-2 applications only, inspection is not required for fillet welds 3/8 inch and smaller of partial penetration joint design group PT2S.1 or PT1S.1.

n. For Table 6-2 applications only, inspection is not required for butt joints in material 3/8 inch or less in thickness, except those in tank boundaries.

o. When approved by the Design Yard or NAVSEA, low pressure (soft) tank inspection is not required for web to flange welds where all the following conditions exist:

(1) the weld is not in or to the tank boundary,

(2) the weld is not in or to pressure hull structure,

(3) the thickness of all joint members are one inch or less, and

(4) welds are made with filler materials other than MIL-120 or MIL-140 series electrodes.

6.5.3 Inspection for loss of interpass or heat soak temperature. When HY and HSLA base materials are being welded with ferritic filler materials (other than MIL-120 or MIL-140 series), MT inspection is required for the partially completed weld(s) when the minimum preheat/interpass temperature required by Table 13-1 is 150 °F or higher and the interpass temperature drops below the temperature specified in 13.6.3.4. This inspection shall be performed prior to resumption of welding and shall meet the acceptance criteria of Section 7. Detailed records or a record of accomplishment are not required, however, a formal procedure for accomplishing this inspection must be established and available for review. Requirements for loss of interpass or heat soak temperature of welds made with MIL-120 or MIL-140 series filler material and HY-130 base material welded with ferritic filler materials shall be in accordance with 16.6.2.

6.5.4 Hard tanks. The inspection sequence for hard tanks is specified in 6.5.5. New hard tank welds and conditions which exceed the limits stated in 6.5.4.1 (d) and (e) in a hard tank that has successfully passed hydrostatic and final MT tests as specified in Table 6-1, require that the new welds be contoured, as required by 14.4, and the tank retested hydrostatically and inspected. (MT inspection after hydrostatic testing may be limited to the additional welding; plus, in the event that the new weld is a full penetration weld through the tank boundary, the previously inspected full penetration welding in or to the tank boundary within 6 inches of the toe of the new weld). This re-inspection shall also include 6 inches (measured from the tank boundary) of any butt weld in an attached member that terminates on the tank boundary. Backup structure, as identified on Figure 4 shall be inspected as specified in Table 6-1. ET may be used as an alternate to MT for the final post-hydro NDT inspection of welds provided the welds have passed initial MT inspection prior to hydrostatic testing.

6.5.4.1 Re-hydrostatic testing of hard tanks is not required for the following:

a. Re-contour grinding or other grinding of previously finished welds.

b. Weld cladding.

c. Weld buildup of plate surfaces for dimensional purposes or correction of mis-machining.

d. Repair of plate surface defects such as nicks, gouges and scars, which were not detected by MT inspection and which will require weld repair consistent with the depth limitations of 14.6.2. Such repairs shall not exceed 10 percent of the area of any one panel or more than 100 square inches for any individual area. The distance between the edges of any two adjacent weld repaired areas shall not be less than 12 inches. For small isolated repairs less than 2 inches in diameter, this edge-to-edge distance may not be less than two times the diameter of the larger repair. In addition, all weld repaired areas are to be ground smooth and MT inspected. This inspection shall extend to include 1/2 inch of the adjacent surface.

e. Additional weld deposit on finished welds (this does not include repair of rejected linear indications greater than 1/8 inch in length), provided the additional weld deposit does not exceed two layers.

6.5.5 Sequence of MT inspection for hard tanks. After all hard tank welds are contoured (as required by 14.4), MT inspection of hard tanks shall be in the following sequence:

a. Hydrostatic test.

b. MT inspect 100 percent of all hard tank welds:

(1) If no rejectable indications are found, the tank is acceptable.

(2) If relevant linear indications greater than 1/8 inch are found, repair in accordance with Sections 13 and 14.

c. Repeat hydrostatic test when condition 6.5.5.b(2) applies. (See 6.5.4.1 for conditions when re-hydrostatic testing is not required.)

d. MT inspect all weld repairs in accordance with the requirements of Note 2 to Table 6-1:

(1) If no rejectable indications are found, the tank is acceptable.

(2) If relevant linear indications greater than 1/8 inch are found, repair in accordance with Sections 13 and 14; repeat steps 6.5.5.c and 6.5.5.d until the weld repairs and associated expansion areas are free of rejectable indications.

6.5.5.1 Welds under Category I.A.(3)(a) of Table 6-1, which have passed final inspection, are exempt from the MT inspection of 6.5.5.b. See 6.5.4 for re-inspection requirements for an accepted hard tank. For hull surveillance inspection, the inspection sequence for the required welds shall be in accordance with 6.5.5.b through d. The MT inspection of 6.5.5.b is limited to the required welds only. Final MT inspection shall be performed after all machining or grinding is completed.

6.6 PT inspection.

6.6.1 Non-ferrous or austenitic welding. Non-ferrous or austenitic stainless steel welds in the pressure hull envelope shall have the final weld surface(s) and backgouged surface (if backgouging is required) PT inspected. If the final weld requires RT or UT inspection, PT of the backgouged surface is not required. Applications include:

a. Weld clad O-ring or gasket seating surfaces to the pressure hull envelope require inspection.

b. Welds that seal openings in the pressure hull envelope require inspection. This includes the welds of sleeves, liners, or inserts which pass through the pressure hull envelope.

c. Welds in interface support structure and welds between interface support structure and other pressure hull structure require inspection.

d. Clad welds used in wear-resistant applications do not require inspection unless they also are a seating surface in the pressure hull envelope.

6.6.1.1 Excavations where repair by welding is required.

6.6.1.1.1 Excavations of non-ferrous or austenitic welds to remove a PT indication do not require PT inspection but require a 5X VT prior to welding to ensure removal of the indication.

6.6.1.1.2 Excavations to remove fabrication scars, arc strikes and areas where attachments are removed do not require either PT or 5X VT of the final excavation surface prior to welding.

6.6.1.1.3 Weld repair excavations of clad welds or attachment/seal welds of non-ferrous or austenitic liners in hull penetrations and inserts, other than the removal of a detected PT indication do not require 5X VT of the excavation prior to repair welding.

6.7 RT inspection.

6.7.1 General. RT inspection requirements are specified in Table 6-4.

TABLE 6-4. RT OR UT INSPECTION REQUIREMENTS. 1/ 2/ 3/

Inspection category	Sequence of inspection	Notes
I. Pressure hull structure		
A. Pressure hull envelope.		
(1) Full penetration welds in the pressure hull envelope. Penetrations 4 inches in outside diameter or less do not require RT/UT inspection.	See Note 4.	5/ 6/ 7/ 8/ 9/
(2) Weld repair of holes or gouges in the pressure hull envelope which exceed 1/3 of the base material in depth.	See Note 4.	5/ 6/ 10/
(3) Full penetration butt welds in the pressure hull envelope which have been hot formed as specified in 6.11.2.2.	Final inspection shall be made after heat treatment.	5/ 6/
(4) Full penetration tee joints welded from both sides to the pressure hull envelope simultaneously (twin arc) or which are not root cleaned and inspected as required by Table 6-1 (unless exempted by 6.5.2).	See Note 4.	5/ 6/ 11/

TABLE 6-4. RT OR UT INSPECTION REQUIREMENTS – CONT'D.

Inspection category	Sequence of inspection	Notes
I. Pressure hull structure – Cont'd		
B. Support structure.		
(1) Butt welds in the boundary plating of holding bulkheads.	See Note 4.	5/ 6/ 7/
(2) Butt welds in flanges of pressure hull frames.	See Note 4.	5/ 6/ 7/
(3) Butt welds in unflanged pressure hull frames to the extent shown on Figure 15.	See Note 4.	5/ 6/ 7/
(4) Full penetration butt welds in support structure which have been hot formed as specified in 6.11.2.2.	Final inspection shall be made after heat treatment.	5/ 6/
II. Containment structure and containment bulkheads		
(1) Butt welds in the boundary plating of containment structure and containment bulkheads.	See Note 4.	5/ 6/ 7/
III. Non-pressure hull structure		
A. Intermediate pressure tanks.		
(1) Butt welds in tank boundary plating.	See Note 4.	5/ 6/ 7/
IV. Weld repair of HY and HSLA wrought base material and mill defects		
A. Weld repair of HY and HSLA plate.		
(1) Weld repair of defects, holes and gouges in plate which exceed 1/3 of the base material in depth.	Final inspection shall be made no sooner than 8 hours after the weld is completed and the preheat (or post weld soak) source has been de-energized.	10/ 12/
B. Weld repair of HY and HSLA bar and forgings.		
(1) Weld repair of defects, holes and gouges in plate which exceed 1/3 of the base material in depth.	Final inspection shall be made no sooner than 8 hours after the weld is completed and the preheat (or post weld soak) source has been de-energized.	10/ 12/ 13/

Notes:

1/ Unless specifically noted, either RT or UT may be used, and when necessary, RT and UT may be combined to obtain the required coverage without prior NAVSEA approval. When either RT or UT may be used, UT should be used.

2/ The degree of inspection shall be 100 percent unless otherwise specified.

3/ Grinding or machining, within the limits of Section 14, of welds previously accepted by RT or UT shall not require re-inspection by RT or UT.

TABLE 6-4. RT OR UT INSPECTION REQUIREMENTS – CONT'D.

Notes: (Cont'd)

4/ For HY and HSLA materials, final inspection shall be made no sooner than 8 hours after the weld is completed and the preheat (or post weld soak) source has been de-energized. For materials other than HY and HSLA, final inspection shall be made after the weld is completed and has cooled to ambient temperature.

5/ (a) When repair welding is required as a result of RT or UT inspection, the defective area shall be re-inspected using the same inspection method used to detect the defect. The repair area plus 3 inches on each end of the repair shall be inspected by RT/UT. However, re-inspection using an alternate inspection method (i.e., UT for RT or vice versa) from the original inspection is permitted, provided a baseline inspection is performed using the alternate method prior to the repair. The alternate re-inspection method must be able to find the original defect. After repair, the final inspection shall meet the applicable acceptance criteria for weld metal of Section 7 for the alternate method. When an intersecting 100 percent efficient weld, that is 1/4 the member thickness or greater, falls within the 3-inch expansion requirement, the RT or UT inspection of the repair of a butt weld need only extend to the intersecting weld.

(b) Re-RT or re-UT of welds previously accepted by RT or UT is not required when the depth of repair of a defect which is MT or VT detected does not exceed two layers (or 1/4 inch) or half the thickness of the thinnest member joined, whichever is less.

(c) Re-RT or re-UT of welds previously accepted by RT or UT is not required when the depth of repair due to over grinding does not exceed two layers (or 1/4 inch) or half the thickness of the thinnest member joined, whichever is less.

6/ When additional weld is deposited on the surface of RT or UT accepted welds, re-RT or re-UT is not required provided the additional weld deposit does not exceed two layers (or 1/4 inch). Subsequent weld overlay or buildup for corrosion or dimensional control which covers previously accepted welding is not subject to the two layer limitation, and re-RT or re-UT of the previously accepted welding is not required.

7/ UT inspection shall be substituted for those portions of butt welds which are obscured from previous RT inspection by frame webs, attaching webs, or structural bulkheads. (see Figure 15)

8/ See Figure 11.

9/ For penetrations 4 inches or less in outside diameter which require weld buildup to correct oversized root openings, RT/UT shall be performed when the sum of the buildups on opposite sides of the penetration is 1 inch or greater. RT/UT may be performed prior to welding the penetration in, or as part of the final weld inspection.

10/ Bolt holes which are weld repaired and will be re-drilled within 1/2D, where D is the bolt hole diameter, of the initial location (centerline to centerline) of the bolt hole do not require RT or UT.

11/ Weld shall be UT inspected for complete root penetration in accordance with 7.9.1.

TABLE 6-4. RT OR UT INSPECTION REQUIREMENTS – CONT'D.

Notes: (Cont'd)

12/ RT or UT inspection of weld repairs shall be interpreted to the acceptance criteria for weld metal.

13/ If the applicable RT or UT inspection cannot be interpreted to the acceptance criteria for weld metal, then longitudinal wave UT may be performed in accordance with NAVSEA T9074-AS-GIB-010/271 for wrought material. Any indication greater than the reference reflector shall be cause for rejection.

6.8 UT inspection.

6.8.1 General. UT inspection requirements are specified in Table 6-4. Applications of UT as a substitute for MT or PT shall be subject to approval. Applications of UT as a substitute for RT other than as specified in Table 6-4 (e.g., when specifically required by drawing requirement or base material specification) shall be subject to NAVSEA approval.

6.9 Stud welding test and inspection requirements. Weld studs shall be tested and inspected as noted below. Preproduction testing of temporary weld studs is not required. Removal of temporary studs shall be accomplished in accordance with 14.6.3 and the area inspected in accordance with this section.

6.9.1 Acceptance criteria. Studs shall be inspected in the as-welded condition. Visible gouging of the stud or base material or visible separation between the stud and base material shall be cause for rejection. Studs which show signs of failure shall be removed, the surface of the metal ground smooth, the condition causing failure rectified (by testing as necessary), and new studs welded and inspected.

6.9.2 Studs used in pressure containing openings. In addition to the preproduction testing requirements of 6.9.3, permanent studs used in connection with openings in water tight and pressure containing compartments shall be tension tested in accordance with 6.9.3.2. When required to tension test permanent high strength, low alloy steel studs (HY and HSLA), or studs welded to these materials, use of molybdenum disulfide lubricant is prohibited.

6.9.3 Preproduction testing of permanent studs. Automatic timed arc or capacitor discharge welded studs for all permanent applications shall be tested at the beginning of each set-up (change of stud material, base material, stud weld end diameter, or stud weld equipment which affects the stud weld parameters) or shift duration by successfully bending (in accordance with 6.9.3.1) or tension testing (in accordance with 6.9.3.2) five consecutively welded studs. When testing is performed, the studs to be tested shall be welded to a piece of scrap of the same material used in production. The plate shall be held in the vertical position, unless production welding is to be limited to flat position work in which the material shall be held in the flat position. Preproduction weld studs shall be inspected to the requirements of 6.9.1. Weld studs shall not exhibit any visual evidence of tears or cracks when tested by bending or tensile loading. Failure of the base material or stud shank outside the weld zone shall not be cause for rejection.

6.9.3.1 Bend testing. Bend testing of production studs is prohibited. Preproduction test studs shall be bent to an angle of 15 degrees (except for 5000 series aluminum which shall be bent to 10 degrees) and returned using a device similar to that shown on Figure 16. As an alternate, hammer each stud over until at least one-fourth of its length touches the test plate, or until the stud is bent more than 90 degrees and the entire inner surface of the stud is within one diameter of the test plate.

6.9.3.2 Tension testing. Studs may be tested by axial tensile loading. The axial tensile load may be applied directly or by torquing using any convenient means, such as the application of a sleeve over the stud using a washer and nut with force being applied by a torque wrench. The studs shall be subjected to an axial tensile load 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. The axial load and torque test used shall be calculated as follows:

$$AXIAL\ LOAD(pounds) = \frac{(D^2 \times \pi \times YS)}{4} \times 0.8$$

$$TORQUE(inch\text{-}pounds) = AXIAL\ LOAD \times D \times K$$

where

D is the stud minor diameter (inches) (see Table 6-5) or the actual stud base diameter (whichever is less).

YS is the stud minimum yield strength (pounds per square inch) as specified in the applicable stud specification or acquisition document.

K is the lubrication factor. To ensure the weld is loaded primarily in tension, the threads of the stud shall be lubricated with molybdenum disulfide, graphite base or comparable lubricant in which case K is 0.15. If stud lubrication is prohibited, the stud shall be tested with no lubricant in which case K is 0.20.

TABLE 6-5. STUD MINOR DIAMETERS.

Stud size	Minor diameters 1/	
	UNC, NC Class 2A	UNF, NF Class 2A
10	.1379	.1508
1/4	.1876	.2052
5/16	.2431	.2603
3/8	.2970	.3228
7/16	.3485	.3749
1/2	.4041	.4374
5/8	.5119	.5554
3/4	.6255	.6718
7/8	.7368	.7858
1	.8446	.8960
1⅛	.94751	1.0210
1¼	1.0725	1.1460

Note:
1/ For use of studs having minor diameters other than those listed, calculation of appropriate torque and axial load will be required. Such calculation shall be included in the procedure qualification.

6.9.3.2.1 Internally threaded studs. Internally threaded studs shall be tested to the torque values of the internal major thread diameter of the stud, not the diameter of the stud base.

6.10 Electrode moisture determinations. Electrode moisture inspection requirements shall be in accordance with Section 10.

6.11 Formed materials and welds. Requirements for forming base materials and welds are contained in Section 9. Inspection requirements for formed base materials, welds and base material repair welds shall be as follows. Figure 17 may be used as an aid in determining the percent elongation.

6.11.1 Materials.

6.11.1.1 Surface inspection requirements for cold formed material. MT inspection shall be performed on finished tension surfaces of any HY-130 and HSLA-80/100 material as required by Table 6-3. When these tension surfaces are machined, final MT inspection shall be performed after finish machining. MT inspection is not required on the finished tension surface of HY-80/100 material when cold formed to an inside radius of 2T or greater, see 9.3.2.

6.11.1.2 Surface inspection requirements for hot formed material. After heat treatment and cleaning, the surfaces of the hot formed HY and HSLA material shall be MT inspected as required by Table 6-3.

6.11.2 Welds and base material repair welds.

6.11.2.1 Inspection requirements for cold formed welds and base material butt and repair welds. MT inspection shall be performed on all welds in HY and HSLA material that are cold formed (including straightening) during fabrication when required by Table 6-1. Repair welds to plate edges which will be subsequently covered with weld metal and base metal repair welds, accomplished, inspected and accepted prior to forming, do not require this inspection. PT inspection shall be performed on all finished tension surfaces of any austenitic or non-ferrous welds that are cold formed after welding, except when located in OSS and HSS materials.

6.11.2.2 Inspection requirements of hot formed welds and base metal repair welds. After heat treatment of HY and HSLA, all weld joints, temporary weld sites, or areas of welded surface repair, welded prior to heat treatment, shall be subjected to a MT inspection as required by Table 6-1. In addition, all full penetration butt welds in hot formed HY and HSLA material shall be RT or UT inspected as required by Table 6-4. Hot formed welds and base metal repair welds inspected and accepted after forming and heat treating in accordance with the requirements herein, shall be considered as base metal for the purpose of any further inspection requirements stated in this section.

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7. INSPECTION ACCEPTANCE STANDARDS

7.1 Scope. This section contains the inspection acceptance standards for base materials and welds used in submarine structure. Acceptance criteria for stud welding shall be in accordance with Section 6; workmanship inspections in accordance with Section 14, and castings in accordance with Section 15. Conditions that do not meet the required acceptance criteria shall be corrected in accordance with the requirements of this document.

7.2 General. Acceptance standards are contained for the following NDT/inspection methods, when inspected as required by this document:

a. Visual inspection of completed welds (VT).

b. Magnetic particle inspection (MT).

c. Liquid penetrant inspection (PT).

d. Eddy current inspection (ET).

e. Radiographic inspection (RT).

f. Ultrasonic inspection (UT).

g. Hardness measurement.

Submarine structure fabricated in accordance with this document shall comply with all applicable drawings, specifications, and standards.

7.3 Inspection of base materials. Inspection of base materials shall be in accordance with Section 8.

7.4 VT inspection of completed welds. Completed welds shall be inspected in accordance with Class 2 requirements of MIL-STD-2035, except as noted below.

7.4.1 Weld inspection zone. The area to be inspected shall include the weld face and 1/2 inch of adjacent base material on each side of the weld. Areas beyond this weld zone shall be controlled by the workmanship requirements of Section 14.

7.4.2 Cleanliness. Welds inspected for final acceptance shall meet the surface condition as noted below.

7.4.2.1 Paint. Surfaces which have been cleaned and painted with one coat of primer are considered suitable for VT. VT inspection of surfaces with high solids paint systems applied are not allowed.

7.4.2.2 Spatter.

a. Weld spatter which can be removed with a hand wire brush is rejectable.

b. When MT and VT is required, the surface shall be free of tightly adhering spatter greater than 1/8 inch in diameter or length.

c. When PT, ET, UT or RT is required, the surface shall be free of spatter.

7.4.3 Shape of fillet weld face. Unless otherwise approved, fillet and fillet reinforced welds should be essentially flat (-1/16 inch +3/16 inch

of a line drawn toe-to-toe) except that 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 1).

7.4.4 Arc strikes. Except for arc strikes on heat treated materials (see Section 14), acceptance criteria for arc strikes on welds and base material shall be in accordance with Class 2 requirements of MIL-STD-2035 for gouges, grind marks and surface roughness.

7.4.5 Undercut, end-melt and corner-melt. Depth of undercut and grinding shall be measured from the un-ground plate surface adjacent to the weld area (see Figure 18 for gages). End-melt and corner-melt shown in Figure 19 and undercut shall meet the requirements of Table 7-1. When materials of different thicknesses are welded to each other, the acceptance criteria shall be determined by the material thickness at the location of the undercut.

TABLE 7-1. UNDERCUT, END-MELT AND CORNER-MELT.

Condition	Base metal thickness (inches)	Maximum depth as-welded condition (inches)	Maximum depth/length after grinding	
			Depth (inches)	Length restriction
Undercut	Less than 1/2	1/32	1/32	None
	1/2 and larger	1/32	1/32	None
			1/16	1/
End-melt 2/	1/4 and less only	1/32	1/16	Only at ends of a member, Figure 19.
Corner-melt	Any thickness	1/32	1/16	Only at the corners of a member, Figure 19.

Notes:
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 material greater than 1/4 inch, undercut requirements apply.

7.4.6 Weld size.

7.4.6.1 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 for seal-off/wrap-around and contour grinding). However, fillet welds 1/4 inch and greater and fillet reinforcement of partial penetration groove welds may be undersized by no more than 1/16 inch from the drawing size provided the undersized length does not exceed 6 inches in any single location or have an accumulated length of more than 15 percent of the joint length, whichever is less. When fillet size must be increased due to excessive gap between members at the time of fit-up, the required weld size shall be increased as required by 14.2.4.

7.4.6.2 Butt, corner and groove tee welds. 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 7.4.5. Butt welds ground for hydrodynamic purposes shall not extend more than 1/16 inch above the adjacent plate surfaces. In the case of butt welds joining plates of unequal thickness, the weld shall taper gradually, approximately four to one unless otherwise specified, 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 weld reinforcement shall not require a maximum height limitation provided all other requirements of this section are met.

7.4.6.3 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 out between the continuous end welds. The size and spacing of intermittent fillets shall be as specified in 11.4.6.1.1. The start and stop ends outside the effective length are not subject to rejection for surface irregularities such as weld size, re-entrant angle, etc.

7.4.7 Seal-off and wrap-around welding. Fillet and fillet reinforced partial penetration welds shall be sealed off with weld at the end(s) of members (flatbars, 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) at the end(s) is not obtainable, the maximum size obtainable shall be considered acceptable provided the above seal-off requirement in wetted areas is maintained.

7.4.8 Weld contouring. When required by 14.4, contouring of welds shall comply with the requirements of Figure 20. When contouring of fillet or partial penetration welds is performed, as required by the ships specifications or drawings, or 14.4, the fillet size requirements shall be maintained after contouring except as permitted by 7.4.6.

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

a. Single pass fillet welds. One indication greater than 1/32 inch but not to exceed 3/32 inch in diameter or length in any 6-inch length of weld, exclusive of weld crater porosity which shall be evaluated in accordance with MIL-STD-2035.

b. Multipass fillet welds. MIL-STD-2035, Class I, Figure 33 medium, shall apply for gouged surfaces. If VT inspection of the first pass deposited is performed in lieu of gouging, the acceptance criteria for the first pass shall be as defined in item a above.

7.5 MT inspection.

7.5.1 Welds. All welds, and 1/2 inch of adjacent base material shall be inspected, when specified. Relevant linear indications greater than 1/8 inch in length shall be rejected. Indications which are removed by grinding without the need for weld repair shall be considered nonrelevant and not recorded provided all other requirements of this section are met.

7.5.1.1 Adjacent base material. While inspecting welds, 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 MT, any indication greater than 1/8 inch shall be removed and the area examined for conformance to the workmanship requirements of Section 14. Visual examination at 5X magnification or MT shall be used to ensure that there are no linear or crack-like indications.

7.5.2 Flame-cut, arc-cut or machined plate edges and tapers. Indications in excess of the following shall be cause for rejection.

a. Any single linear indication lying approximately parallel to the surface whose length exceeds 2 inches.
b. Linear indications lying approximately parallel to the surface whose accumulated length exceeds 4 inches in the least favorable 6-inch length.
c. Any linear indication normal to the major surfaces of the material.

7.5.3 Formed material. Inspected surfaces of hot or cold formed material shall be free of linear indications greater than 1/8 inch.

7.5.4 Forgings and Bars. Inspected surfaces of forgings and bars shall be free of linear indications greater than 1/8 inch.

7.6 ET inspection.

7.6.1 Welds and base material. The weld inspection zone shall be in accordance with 7.5.1. All discontinuities detected by ET shall be re-inspected by MT (or PT for non- ferromagnetic materials), and evaluated using the acceptance criteria for that method.

7.7 PT inspection.

7.7.1 Welded joints. Weld joints shall be evaluated in accordance with Class 2 criteria of MIL-STD-2035, except that, when PT is substituted for the required MT of welds, the acceptance criteria shall meet the requirements of 7.5.1.

7.7.2 Weld cladding. Weld cladding of O-ring or gasket seating surfaces shall be evaluated in accordance with the applicable class of MIL-STD-2035 as shown in Figure 5. Weld cladding for other applications, (e.g., corrosion protection) shall be evaluated in accordance with Class 2 of MIL-STD-2035.

7.7.3 Base materials. Where PT is specified, the acceptance criteria shall be in accordance with base material specification. If the base

material specification does not contain PT acceptance criteria, the MT acceptance criteria of 7.5 herein applies. Where PT is substituted for MT (when permitted by this document), the acceptance criteria shall be as specified for MT inspection.

7.8 RT inspection.

7.8.1 Welds. Radiographs of welds shall be interpreted to the Class 2 standards of MIL-STD-2035. Rejectable RT indications shall be evaluated as inadvertent defects if it can be determined that the indications are contained within the base material. Rejectable RT indications observed to occur within the base material shall be evaluated in accordance with the inadvertent radiography criteria of MIL-STD-2035.

7.9 UT inspection.

7.9.1 Welds. Acceptance standards for full penetration butt and corner welds inspected by the UT method, shall be in accordance with the Class 1 requirements of MIL-STD-2035. Acceptance standards for full penetration tee welds inspected by the UT method for complete root penetration, shall be in accordance with the requirements of MIL-STD-2035. In cases where volumetric UT inspection of tee welds is required, acceptance standards shall be in accordance with the Class 3 requirements of MIL-STD-2035 for full penetration butt and corner welds.

7.9.2 Base materials. Base materials shall meet the UT inspection acceptance standards of the applicable base material specification.

7.10 Hardness measurements.

7.10.1 Hardness range. When hardness measurements are required for HY-80/100/130 base materials or castings by Section 8 or 15 (respectively), the measurements shall fall within the following ranges:

a. For HY-80; 200-260 BHN.

b. For HY-100; 230-290 BHN.

c. For HY-130; 290-360 BHN.

7.10.2 Measurement location. Location of hardness measurements shall be as follows:

a. For bar and rolled or extruded shapes; at each end.

b. For forgings and castings; at areas of minimum and maximum thickness.

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8. INSPECTION OF MATERIALS

8.1 Scope. This section contains requirements for the inspection of materials intended for use in submarine structures. Inspection requirements of castings shall be in accordance with Section 15. Additional requirements for inspection of MIL-120 and MIL-140 series filler materials shall be in accordance with Section 16. Other required NDT shall be as required by the acquisition specification. Section 6 also contains inspection requirements for materials. In general, the difference is that Section 8 inspections typically apply to procurement and Section 6 inspections typically apply to fabrication. However, the applicable requirements of both sections shall be met.

8.2 General.

8.2.1 Inspections and tests. The inspections and tests required by this section may be performed by any activity (e.g., producer, shipyard, etc.), provided all the requirements of this document are met. As a minimum, the receiving activity shall:

a. Review chemical and mechanical properties test results for compliance with the applicable material specification. Identification marking of material shall be verified against certified test results.

b. For material specifications that require first article testing, ensure that each manufacturer has successfully completed and has received the required approval letter for first article testing for the specific type and class or grade of material.

c. Except for material supplied by the Government or directly from the manufacturer, perform periodic independent testing to establish reasonable confidence in the reliability of contractor test data. Details of periodic independent testing shall be in accordance with a written procedure.

d. Where a required inspection or test has not been performed prior to receipt, or when records are not obtained for a required inspection or test, perform the inspection or test.

8.2.2 Documentation. The receiving activity shall ensure that documentation shows compliance with all applicable inspection and test requirements and acceptance criteria, and that the documentation complies with Section 5.

8.2.3 Alternate program. Use of alternate programs for inspection of materials shall require NAVSEA approval and must demonstrate compliance with the specification requirements.

8.3 Surface cleaning and preservation of wrought materials. Plates, bars, shapes, and forgings shall be free of mill scale and extraneous matter in accordance with the applicable material specifications. Prior to inspection, the materials shall have been cleaned by an approved pickling procedure or by blasting, however, pickling shall not be used for HY-130 material. When pickling is used, heavy scale shall be broken by flame descaling or other suitable means. The pickling time shall be limited as necessary to prevent surface pitting. Excessive quantities of nickel smut produced in pickling solution shall be removed from finished items. After

cleaning and required inspections, materials shall be preserved in accordance with the applicable material specification.

8.4 Wrought HY and HSLA base materials. Inspections shall be in accordance with the applicable material specification and shall contain the following items.

8.4.1 Surface defects. All surfaces, including all formed surfaces, shall be inspected for surface defects. Base materials which are flame or arc cut, shall have the cut surfaces inspected. If defects over 1/4 inch long are found, MT inspection shall be performed on all cut surfaces of the involved material. These cut surfaces shall meet the MT acceptance criteria of Section 7.

8.4.2 Dimensions. Dimensions shall comply with the applicable material specification and acquisition document, as applicable.

8.4.3 Soundness. Base materials shall be inspected for soundness in accordance with the applicable material specification. Forgings shall be MT and, when specified, UT inspected as required by the applicable specifications.

8.4.4 Identification. Base materials shall be identified in accordance with the applicable material specification.

8.4.5 Hardness. All HY-80/100/130 bar, shapes and forgings shall be tested for Brinell hardness in accordance with the acceptance criteria of Section 7.

8.5 Hot formed HY and HSLA materials. Records of contractor repairs, together with certified mechanical/impact test, and RT results shall be maintained for all HY and HSLA hot formed materials. In addition to the inspection requirements for base materials, inspection shall include the following.

8.5.1 Surface and soundness. Hot formed materials (including welds and base metal repair welds) shall have been inspected as required by the applicable material specification and Section 6 for thickness, soundness, and surface defects.

8.6 Non-conforming base material. Material which does not meet the requirements of the applicable material specification or this document, shall be isolated and not used for production, unless the non-conforming condition(s) is corrected. Repair of defects shall be in accordance with 13.8.

8.7 Welding filler materials. Welding filler materials shall comply with the applicable material specification.

8.7.1 Ferritic filler material verification. The chemistry of ferritic welding wire and electrodes (bare and coated) and submerged arc flux shall be verified by the receiving activity in the following manner.

8.7.1.1 Manual shielded metal arc electrodes. Chemical analysis shall be made from coated electrode weld deposits as specified in the applicable

filler material specification. The sampling plan for selection of samples for deposition of chemical analysis pad shall be in accordance with Table 8-1.

TABLE 8-1. ELECTRODE SAMPLING PLAN.

Level I	Each lot of material submitted by a single contractor shall be sampled. Upon obtaining five consecutive acceptable sample lots, sampling shall be made at level II.
Level II 1/	One lot selected at random from each five lots submitted by a contractor shall be sampled. Upon obtaining ten consecutive acceptable sample lots, sampling shall be made at level III.
Level III 1/	One lot selected at random from each ten lots submitted by a contractor shall be sampled. Upon obtaining 15 consecutive acceptable sample lots, sampling shall be made at level IV.
Level IV 1/	One lot selected at random from each 20 lots submitted by a contractor shall be sampled.
Note: 1/ If an unacceptable sample lot is obtained at level II, III or IV, sampling level shall revert to the next lower (more restrictive) level until satisfactory performance is demonstrated by conformance with the requirements at that level.	

8.7.1.2 Gas metal arc spooled bare wire. Chemical analysis shall be made from gas metal arc spooled wire samples taken from each lot to determine specification compliance. One sample per lot shall be taken for analysis.

8.7.1.3 Submerged arc wire and flux testing.

8.7.1.3.1 Filler wire chemical analysis.
The chemical composition of each heat/lot of wire intended for submerged arc welding shall be determined to verify specification compliance. One sample per heat/lot shall be taken for analysis.

8.7.1.3.2 Weld testing of flux.
Each unique lot of submerged arc welding flux shall be tested to ensure weldability characteristics and provide objective test data on weld metal mechanical properties. Welding shall be conducted using MIL-100S-1 electrode meeting applicable specification requirements. Testing shall be in accordance with the low cooling rate conformance test specified in NAVSEA T9074-BC-GIB-010/0200, including Section 3.15 of the Main Body, with the following modifications:

a. Nondestructive testing is not required.

b. Testing is limited to mechanical testing (all weld metal tensile, Charpy V-notch) per T9074-BC-GIB-010/0200.

   (1) Mechanical properties produced are evaluated for acceptance in accordance with T9074-BC-GIB-010/0200.

   (2) Tensile specimens with reduction in area measurements below 55 percent should be examined for signs of hydrogen damage. If present, an evaluation should be conducted to determine if the flux is suitable for production use, and if any material should be rejected.

c. During the course of welding, bead shape, de-slagging characteristics, etc. should be evaluated. Material that does not meet normal shipyard expectations may be rejected.

8.7.2 Nonconforming filler materials.

Lots of filler materials which do not comply with the applicable specification requirements shall be isolated and not used for production welding. If the activity desires to use the filler material, additional inspections including redetermination of chemistry, mechanical properties, moisture or hydrogen (as applicable) determinations should be performed to establish conformance or nonconformance to applicable material specifications.

9. FORMED MATERIALS AND WELDS

9.1 Scope. This section covers requirements for additional forming of plate, forgings, and rolled, extruded or fabricated shapes (for castings, see Section 15), beyond that permitted by the applicable material specifications.

9.2 General. Cold and hot forming temperatures for materials and welds shall be in accordance with Tables 9-1 and 9-2, respectively. Cold forming may be done on fully heat treated material and welds in such material. For HSLA-100 materials and welds, forming requirements shall be subject to NAVSEA approval. For materials not specified in Tables 9-1 and 9-2 (other than HSLA-100), forming shall be as recommended by the manufacturer and procedures thereof shall be subject to NAVSEA approval prior to the start of production forming. Inspection requirements for formed materials, welds and base material repair welds shall be in accordance with Section 6.

TABLE 9-1. COLD-FORMING TEMPERATURE REQUIREMENTS.

Material	Temperature (°F maximum)
OS steel	1/ 1,175
HS steel	1/ 1,175
High-yield strength steel (HY-80)	2/ 500
High-yield strength steel (HY-100)	2/ 500
High-yield strength steel (HY-130)	2/ 500
HSLA-80	3/ 500
Austenitic stainless steel (CRES)	900
Nickel-copper (Monel)	1,050
5000 series aluminum alloys	175
Copper nickel	900
NiCrFe (Inconel 600)	4/ 125
NiCrMoCb (Inconel 625)	4/ 125

Notes:
1/ Cold forming is not permitted between 400 and 700 °F.
2/ See 9.3.2.
3/ See 9.3.3.
4/ NiCrFe and NiCrMoCb shall not be heated above ambient temperature (125 °F).

TABLE 9-2. HOT-FORMING TEMPERATURE REQUIREMENTS.

Material	Temperature range (°F)
OS steel	1/ 2/ 1550-1675
HS steel	1/ 2/ 1550-1675
High-yield strength steel (HY-80)	3/ 1600-2150
High-yield strength steel (HY-100)	3/ 1600-2150
High-yield strength steel (HY-130)	3/ 1700-2150
Austenitic stainless steel (CRES)	4/ 1750-2100
Nickel-copper (Monel)	1700-2100

Notes:

1/ For normalized material, the material shall be air cooled from the forming temperature.

2/ OS steel (1 inch and less in thickness) and HS 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 HS 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/ See 9.4.3.

4/ 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.

9.3 Forming restrictions.

9.3.1 Material other than HY and HSLA-80. Structural materials formed to an inside radius less than 2T shall be hot formed in accordance with 9.4 unless otherwise approved.

9.3.1.1 NiCrFe (Inconel 600) and NiCrMoCb (Inconel 625) material. The following additional requirements and restrictions apply to the forming of NiCrFe and NiCrMoCb base materials:

a. During cold forming operations, NiCrFE and NiCrMoCb shall not be heated above ambient temperature (125 °F).

b. NiCrFe and NiCrMoCb shall not be formed to an inside bend radius of less than 2T, where T is the thickness of the base material being formed.

c. Hot forming of NiCrFe and NiCrMoCb is prohibited.

d. Prior to forming, a visual inspection (VT) of the base material surface and plate edges in way of the formed area shall be performed. Surface irregularities such as nicks, gouges, fabrication scars, and plate edge roughness shall be faired out and blended by grinding to the maximum extent practicable. Weld repair of surface defects in the formed area is not permitted, unless approved by the Shipyard Welding Engineer.

e. NiCrFe and NiCRMoCb are subject to rapid strain hardening during cold forming. Care shall be taken not to over bend NiCrFe and NiCrMoCb base

materials from the design requirements. Therefore, every effort shall be taken to minimize or eliminate reverse bending operations to the maximum extent practicable. When reverse bending cannot be avoided it shall not exceed 15 degrees total (i.e., a maximum over-bend of 7.5 degrees or an over reverse bend of 7.5 degrees from the design bend) and the maximum corrective reverse bend shall not exceed 10 degrees.

f. Tool access bends are temporary bends, often required to facilitate tool access to create the final production part. Tool access bends will be flattened or straightened after the required production bends are completed. Tool access bending of NiCrFe and NiCrMoCb shall be avoided to the maximum extent practicable. When tool access bending cannot be avoided, they shall be performed using an 8T minimum inside bend radius.

g. When reverse bending is used to correct overbending, or to straighten out tool access bends, visual inspection (VT) of both the inside and outside surfaces in way of this formed area shall be accomplished after all forming operations have been completed.

9.3.2 HY materials. HY alloys embrittle in the temperature range of 500 to 1,100 °F; hence, losing some of their toughness. Therefore, forming in the temperature range between the hot and cold forming temperatures of any HY material is prohibited. Welds in HY-130 material shall not be cold formed in excess of six percent total elongation unless otherwise approved. Cold forming of HY base materials to an inside radius less than 2T is prohibited. HY base materials formed to an inside radius less than 2T shall be hot formed in accordance with 9.4.

9.3.3 HSLA-80 material. Cold forming of HSLA-80 shall not exceed 5½ percent total elongation unless otherwise approved by NAVSEA. Hot forming is not permitted unless otherwise approved by NAVSEA.

9.4 Hot forming requirements.

9.4.1 Contaminants. Prior to hot forming operations, the surfaces of 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, and substances which contain these materials or elements, or other low melting point alloys.

9.4.2 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.

9.4.3 Base material testing for HY materials. After forming, HY materials shall be reheat treated and retested for mechanical and impact properties in accordance with the 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.

9.4.3.1 Thickness and soundness tests. After heat treatment, each hot formed piece of HY material shall be subjected to thickness and ultrasonic soundness tests to the extent required in Section 8.

9.4.4 Welding procedure qualification for hot formed and heat treated welds. A level I procedure qualification test, as described in NAVSEA S9074-AQ-GIB-010/248, shall be performed to qualify any electrode employed for weld joints, temporary welds, or welded surface repairs in material which is to be subjected to hot forming and heat treatment after such welding. The qualification test plate shall undergo cycling representative in magnitude and time at temperature of that employed in hot forming and subsequent heat treating operations.

9.4.4.1 Production weld testing. For welds made from filler metal group number A-5 per NAVSEA S9074-AQ-GIB-010/248, weld metal impact and tensile tests shall be performed for each piece of hot formed and heat treated material which contains a weld deposit prior to hot forming or heat treating. Test results shall meet the requirements of the applicable filler material specification for minimum yield strength, elongation, and impact strength. These tests may be taken from runoff tabs of the same material.

10. WELDING MATERIALS

10.1 Scope. This section covers welding materials to be employed for fabrication of submarine structure. Special requirements for the control of MIL-120 and MIL-140 series filler materials and flux are contained in Section 16.

10.2 Welding filler materials for base metal combinations. Unless otherwise approved, base metal combinations, the filler material type, specifications, and the associated welding processes shall be restricted to the applications listed in Tables 10-1, 10-2, 10-3, and 10-4. Ferritic filler materials shall not be deposited over austenitic or non-ferrous base materials or filler materials, however, austenitic or non-ferrous filler materials may be deposited over ferritic base materials or filler materials. Use of commercial specifications in lieu of those specified shall require NAVSEA approval.

10.2.1 HY and HSLA materials to HSS or OSS. MIL-7018-M and MIL-8018-C3 covered electrodes may be used for welding HSS or OSS (0.30 percent C maximum) materials to HY and HSLA when permitted by Table 10-1, provided the covered electrode exposure and coating moisture content are controlled within the limitations for covered electrodes specified in 10.6. In addition, MIL-7018-M and MIL-8018-C3 electrode moisture content and moisture resistance shall meet the requirements of MIL-DTL-22200/1H or later revision and use of MIL-8018-C3 shall be specifically approved by NAVSEA (see Note 10 of Table 10-1). Equivalent bare wires may also be used.

TABLE 10-1. FILLER MATERIALS FOR FERRITIC STEELS. 1/

Process	Filler material		Application
	Type	Specification number	
SMAW	MIL-14018-M1	MIL-E-22200/9	N/A 2/
	MIL-12018-M2 3/	NAVSEA T9074-BC-GIB-010/0200	HY-100 to HY-100/130 and HSLA-100 HSLA-100 to HY-100/130 and HSLA-100 HY-130 to HY-130 4/
	MIL-10018-M1	NAVSEA T9074-BC-GIB-010/0200	HY-80 to All 7/ 19/ HSLA-80 to All OSS/HSS to HY-80/100/130 7/ OSS/HSS to HSLA-100
	MIL-10718-M 5/ 6/	NAVSEA T9074-BC-GIB-010/0200	OSS/HSS to HY-80/100/130 7/ OSS/HSS to HSLA-100 HY-80 to All 7/ HSLA-80 to All HY-100/HSLA-100 to HY-100/HSLA-100 9/
	MIL-11018-M 5/ 8/ 18/	MIL-DTL-22200/1	OSS/HSS to HY-80/100/130 7/ OSS/HSS to HSLA-100 HY-80 to All 7/ HSLA-80 to All
	MIL-7018-M 8/ MIL-8018-C3 10/	MIL-DTL-22200/1	OSS to All 11/ HSS to All 11/
GMAW, SAW, GTAW	MIL-140S-1 3/ 12/	MIL-E-24355	HY-130 to HY-130 13/
	MIL-120S-1 3/ 14/	NAVSEA T9074-BC-GIB-010/0200	HY-100 to HY-100/130 and HSLA-100 HSLA-100 to HY-100/130 and HSLA-100 HY-130 to HY-130 4/
	MIL-100S-1 5/ 15/	NAVSEA T9074-BC-GIB-010/0200	OSS/HSS to HY-80/100/130 7/ HY-80 to All 7/ HSLA-80 to All HY-100/HSLA-100 to HY-100/HSLA-100 9/
	MIL-70S 16/	MIL-E-23765/1	OSS to All 11/ HSS to All 11/
FCAW	MIL-101TC MIL-101TM	NAVSEA T9074-BC-GIB-010/0200	HY-80 to All 17/ HSLA-80 to All 17/
	MIL-7XT-1-HY MIL-7XT-X-HY MIL-7XTX-X-HY MIL-8XTX-X-HY	MIL-E-24403/1	OSS to All 17/ HSS to All 17/

TABLE 10-1. FILLER MATERIALS FOR FERRITIC STEELS – CONT'D.

Notes:

1/ Alternate filler materials may be used when approved by NAVSEA.

2/ For the SMAW process, use of MIL-140 series filler material is not permitted unless specifically approved by NAVSEA.

3/ See Section 16.

4/ MIL-120 series filler materials may be used to weld HY-130 to HY-130 when specifically approved by NAVSEA.

5/ Use of MIL-100S-1, MIL-10718-M, and MIL-11018-M for repair of fillet or groove tee welds originally made with MIL-120 series filler materials shall require approval.

6/ MIL-10718-M electrodes are classified as Group A-5A per NAVSEA S9074-AQ-GIB-010/248.

7/ MIL-100S-1, MIL-10718-M, MIL-10018-M1, or MIL-11018-M is required for welds of OSS and HSS (other than attachment welds, see 3.39.1) to HY-80/100/130 pressure hull envelope and support structure or when a high strength joint is required by 11.3.1. For support structure, this requirement applies only to support structure identified as being SUBSAFE.

8/ MIL-11018-M and MIL-7018-M type electrodes shall be in accordance with MIL-DTL-22200/1H or later revision.

9/ MIL-100S-1 and MIL-10718-M filler materials may be used to weld HY-100/HSLA-100 to HY-100/HSLA-100, including repair of HY-100/HSLA-100 base materials, when specifically approved by NAVSEA or allowed by 11.5.7., but shall not be used for HY-100 foundations and non-support structure designed to HY-100 allowable stresses, HY-100 structure designed by plastic design methods, and HY-100 structure designed using transient analysis or criteria unless specifically approved by NAVSEA. The applicable drawing(s) shall clearly state the allowance to use MIL-100S-1 and MIL-10718-M filler material. Additionally, these filler materials may be used for tack welds and root passes (not to exceed the root pass conditions of 13.7.1.2) when final weld surfaces will be deposited with an approved filler material.

10/ MIL-8018-C3 type electrodes shall be in accordance with MIL-DTL-22200/1H or later revision and its use shall be specifically approved by NAVSEA.

11/ Use of MIL-70S, MIL-7018-M or MIL-8018-C3 is not permitted for welds of OSS and HSS material (other than attachment welds, see 3.39.1) to HY-80/100/130 pressure hull structure, envelope and support structure or when a high strength joint is required by 11.3.1. For support structure, this requirement applies only to support structure identified as being SUBSAFE.

12/ MIL-140S-1 is not approved for submerged arc (SAW) use.

13/ Restricted to thickness over 3/4 inch. May be used for thinner material, when approved by NAVSEA, where the reduced weld metal yield strengths satisfy the design requirements.

14/ For the SAW process, use qualified neutral granular flux MIL-120S-1F with reduced moisture requirements and use wire with reduced hydrogen requirements as specified in NAVSEA T9074-BC-GIB-010/0200. Flux shall be procured from the manufacturer in hermetically sealed containers which are capable of maintaining the moisture content (by weight) to the maximum as specified by NAVSEA T9074-BC-GIB-010/0200.

TABLE 10-1. FILLER MATERIALS FOR FERRITIC STEELS – CONT'D.

Notes: (Cont'd)

15/ For the SAW process, use qualified neutral granular flux MIL-100S-1F or MIL-100S-2F.

16/ For the SAW process, use qualified neutral granular flux MIL-70S-F.

17/ The FCAW process is limited to non-pressure hull structure applications unless approved by NAVSEA on a case basis.

18/ Use of MIL-11018-M filler material is prohibited for HY-100 pressure hull envelope butt welds (excluding hard tank plating) except that MIL-11018-M may be used for tack welds and root passes when the final weld surface will be deposited using MIL-10718-M or MIL-100S-1.

19/ Use of MIL-10018-M1 filler material is prohibited for HY-80 to HY-100 pressure hull envelope butt welds (excluding hard tank plating).

TABLE 10-2. FILLER MATERIALS FOR WELDING FERROUS MATERIALS TO NON-FERROUS METALS AND AUSTENITIC STAINLESS STEELS AND FOR WELDING NICKEL BASE AND COPPER-NICKEL ALLOYS. 1/ 2/

Process	Filler material		Application
	Type	Specification number	
SMAW	MIL-309-15/16 MIL-309Cb-15/16 MIL-310-15/16 MIL-310Cb-15/16	MIL-E-22200/2	Welded joints between ferrous materials and austenitic stainless steel and for clad welding these alloys.
SMAW	MIL-4N11 MIL-9N10 MIL-8N12/H MIL-1N12	MIL-E-22200/3	Welded joints between ferrous materials and nickel/nickel-copper/copper-nickel/nickel-chromium iron/nickel-chromium-molybdenum-columbium alloys and for clad welding these alloys. Also, welded joints of nickel base alloys.
SMAW	E NiCrMo-4 (UNS-W80276) 3/ 4/	AWS A5.11	Cladding on ferrous or non-ferrous materials.
SMAW	MIL-CuNi 70/30	MIL-E-22200/4	Welded joints for copper-nickel alloys
GMAW, GTAW	ER NiCrMo-4 (UNS-N10276) 3/ 5/	AWS A5.14	Cladding on ferrous or non-ferrous materials.
GMAW, GTAW, SAW	MIL-309 MIL-309Cb MIL-310	MIL-E-19933	Welded joints between ferrous materials and austenitic stainless steel and for clad welding these alloys.

TABLE 10-2. FILLER MATERIALS FOR WELDING FERROUS MATERIALS TO NON-FERROUS METALS AND AUSTENITIC STAINLESS STEELS AND FOR WELDING NICKEL BASE AND COPPER-NICKEL ALLOYS – CONT'D.

Process	Filler material		Application
	Type	Specification number	
GMAW, GTAW, SAW	MIL-EN/RN60 MIL-EN/RN61 MIL-EN/RN62 MIL-EN/RN82/H MIL-EN/RN625	MIL-E-21562	Welded joints between ferrous materials and nickel/nickel-copper/copper-nickel/nickel-chromium-iron/nickel-chromium-molybdenum-columbium alloys and for clad welding these alloys. Also, welded joints of nickel base alloys.
GMAW, GTAW, SAW	MIL-EN/RN67	MIL-E-21562	Welded joints for copper-nickel alloys.

Notes:

1/ Applications involving welding to HY-130 shall require NAVSEA approval on a case basis.

2/ For applications involving the welding of or to duplex stainless steel, the applicable filler material type shall be as approved.

3/ The use of Nickel-Chromium-Molybdenum for applications covered by this document requires specific approval from NAVSEA.

4/ The covered electrodes shall conform to all the quality conformance requirements of MIL-1N12 specified in MIL-E-22000/3 but with tensile properties and chemical composition of E NiCrMo-4 specified in AWS A5.11.

5/ The filler metal shall conform to all the quality conformance requirements for EN/RN625 specified in MIL-E-21562 but have a minimum tensile strength of 100 ksi, an elongation of 25 percent and a chemical composition of ER NiCrMo-4 specified in AWS A5.14.

TABLE 10-3. FILLER MATERIALS FOR AUSTENITIC STAINLESS-STEEL ALLOYS. 1/ 2/ 3/

Base Metal	Base Metal				
	304	**310**	**316**	**321**	**347**
304	308	308 (309) (310)	308 (316)	308 (347)	308 (347)
310	308 (310) (309)	310 (309)	310 (316)	310 (347)	310 (347)
316	308 (316)	310 (316)	316	316 (347)	316 (347)
321	308 (347)	310 (347)	316 (347)	347	347
347	308 (347)	310 (347)	316 (347)	347	347

Notes:

1/ The preferred filler 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.

3/ Filler materials for the SMAW process shall be in accordance with MIL-DTL-22200/2. Filler materials for the GMAW and GTAW process shall be in accordance with MIL-E-19933.

TABLE 10-4. FILLER MATERIALS FOR WROUGHT ALUMINUM ALLOYS. 1/

Base metal type 2/	Base metal type 2/						
	5083	5456	5454	5086	5052	3003	1100
1100	3/ 5356	3/ 5356	4/ 4043	3/ 5356	4/ 4043	3/ 1100	3/ 1100
3003	3/ 5356	3/ 5356	4/ 4043	3/ 5356	4/ 4043	3/ 1100	
5052	4/5/ 5356	4/5/ 5356	3/5/6/ 5356	3/5/6/ 5356	4/5/ 5356		
5086	4/ 5356	4/ 5356	6/ 5356	4/ 5356			
5454	4/5/ 5356	5/ 5356	3/4/ 5554				
5456	4/ 5183	4/ 5556					
5083	4/ 5183						

Notes:

1/ Filler materials shall be in accordance with AWS A5.10.

2/ 6061 alloy can be used in minor structural applications (see 3.33.3.1) only. Use of 6061 alloy in other applications requires NAVSEA approval on a case basis.

3/ 4043 may be used.

4/ 5356, 5183, or 5556 may be used.

5/ Shall not be used where service temperature is above 150 °F.

6/ 5154, 5254, 5183, or 5556 may be used.

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 excessive moisture content, 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.

10.4 Inspection. Welding materials shall be inspected as required by Section 8.

10.5 Conditioning and maintenance of, MIL-7018-M, MIL-8018-C3, MIL-10018-M1, MIL-10718-M, MIL-11018-M, and MIL-12018-M2 electrodes. These electrodes may be used directly from manufacturer's hermetically sealed containers without baking prior to initial issue. (See Note 8 or 10 of Table 10-1 for moisture and moisture resistance restrictions on MIL-7018-M, MIL-8018-C3 and MIL-11018-M electrodes.) Subsequent issue shall meet the requirements of 10.6. Where the moisture requirements of 10.6 are exceeded or where deemed necessary by the activity concerned, baking followed by storage in holding ovens shall be accomplished in accordance with the following.

10.5.1 Baking. These electrodes shall be conditioned by baking at a temperature of 800±25 °F using a total time at temperature of 30 minutes to 1 hour. Variation to this time and temperature may be used provided the procedure is approved.

10.5.1.1 Loading temperature. Electrodes shall not be placed in the oven for baking while the temperature of the oven exceeds 300 °F.

10.5.1.2 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.

10.5.1.3 Time above 500 °F. The total elapsed time at oven temperatures above 500 °F shall be kept to a minimum.

10.5.1.4 Charging the oven. In charging the oven, the electrodes shall be spread on suitable trays. Electrodes can also be placed into open aluminum cans held in the vertical position. Trays or cans shall not be fabricated using any material which melts at less than 1000 °F.

10.5.1.5 Baking oven type. Automatically controlled, forced convection or circulation ovens capable of baking electrodes in accordance with 10.5.1 shall be used.

10.5.1.6 Baking controls. Oven controls and recording instruments shall be checked at periodic intervals in accordance with an established calibration program.

10.5.2 Storage in holding ovens. Electrodes which have been baked should be transferred to holding ovens while still hot without being allowed to cool below 150 °F. Transfer shall be protected from inclement weather.

10.5.2.1 Holding oven temperature. Holding oven temperature shall be 225 to 300 °F. Holding ovens shall be used for storage of electrodes removed from the baking ovens.

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

10.6 Exposure of ferritic covered electrodes. Exposure of MIL-10018-M1, MIL-10718-M, MIL-11018-M, MIL-12018-M2 (and MIL-7018-M, MIL-8018-C3, when used as permitted under 10.2.1) electrodes shall be controlled. Upon removal from the manufacturer's hermetically sealed containers or holding ovens, electrodes shall not be used after being exposed to the atmosphere for a total period of more than 9 hours. During exposure, suitable means shall be provided to protect electrodes from inclement weather.

10.6.1 Returned electrodes. Electrodes turned in before 9 hours exposure shall be returned to the holding ovens for 8 hours prior to re-issue. Electrodes turned in after 9 hours exposure shall be rebaked subject to the restriction of 10.5.3.

10.6.2 Moisture sampling and surveillance. Electrode coating moisture test samples shall be taken from welders at their job sites. The moisture determination shall be made in accordance with procedure outlined in MIL-DTL-22200. Records shall be kept as required by Section 5.

Random sampling shall be performed in accordance with the periodicity Levels listed below. The number of samples per period shall be four, except, where the average number of welders per period is six or less, the number of samples may be reduced to one-half of the number of production welders.

Level I Periodicity shall be weekly. If all samples are satisfactory for three consecutive months, sampling frequency may be made at Level II.

Level II Periodicity shall be every two weeks. If all samples are satisfactory for three consecutive months, sampling frequency may be made at Level III.

Level III Periodicity shall be monthly. If all samples are satisfactory for three consecutive months, sampling frequency may be made at Level IV.

Level IV Periodicity shall be quarterly.

For Level I, if two or more samples in the same week, or one sample in each of two consecutive weeks, exceed the coating moisture limitations of the applicable electrode specification, corrective and preventative action shall be taken and the number of samples shall be doubled by increasing the sampling frequency to twice per week until four consecutive weeks have elapsed without recurrence. The sampling program shall then return to Level I.

For Levels II, III and IV, if one or more samples exceed the coating moisture limitations of the applicable electrode specification, corrective and preventative action shall be taken and the sampling frequency shall be increased to twice per week until four consecutive weeks have elapsed without recurrence. The sampling program shall then revert to the next lower numbered Level. For example, if a problem occurs while at Level III, sampling would resume at Level II after control is re-established.

10.6.3 Alternate methods. Alternate methods or frequency of moisture testing shall require NAVSEA approval and must demonstrate that conformance with specification requirements is in control.

10.7 Austenitic and non-ferrous covered electrodes. Low hydrogen type stainless steel and non-ferrous covered electrodes shall be used within 9 hours after issue or if otherwise exposed to the atmosphere, shall be held for at least 8 hours in a vented holding oven maintained at 150 to 300 °F prior to re-issue.

10.8 Bare filler metal and flux core wire storage. Bare filler metal and flux core wire shall be stored in a dry area.

10.9 Neutral granular flux (other than MIL-100S-1F or MIL-120S-1F). Neutral granular flux shall be stored in a dry area.

10.9.1 Preparation for. Prior to the start of any welding operation, neutral 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.

10.9.2 Re-use. Unfused neutral granular flux may be re-used 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 reheated to 250 °F minimum.

10.9.3 Neutral granular flux for MIL-100S-1F.

10.9.3.1 Conditioning and maintenance of MIL-100S-1F flux. MIL-100S-1F flux may be used directly from manufacturer's hermetically sealed containers without baking prior to initial issue. Subsequent issue shall meet the requirements of 10.9.3.2. Where the moisture requirements of NAVSEA T9074-BC-GIB-010/0200 are exceeded or where deemed necessary by the activity concerned, baking followed by storage in holding ovens shall be accomplished in accordance with the following.

10.9.3.1.1 Baking. MIL-100S-1F flux shall be conditioned according to specific manufacturer's instructions incorporated in contractor's procedures to restore the moisture content to the requirements of NAVSEA T9074-BC-GIB-010/0200.

10.9.3.1.2 Storage in holding ovens. Upon removal from the manufacturer's hermetically sealed container or after baking in accordance with 10.9.3.1.1, MIL-100S-1F flux shall be stored in holding ovens at a minimum temperature of 250 °F. MIL-100S-1F flux which has been baked should be transferred to holding ovens while still hot without being allowed to cool below 250 °F. Transfer shall be protected from inclement weather. As flux can absorb moisture at elevated temperature over prolonged periods, indefinite storage in holding ovens should be avoided. The storage period should be established by the using activity.

10.9.3.1.3 Re-use. Unfused MIL-100S-1F flux may be reused subject to the following conditions:

a. Flux shall be collected from clean, dry work pieces which have been maintained at the 200 °F degree Fahrenheit minimum preheat/interpass temperature and must be at least warm to the touch at the time of reuse.

b. If flux is not collected as required above, it shall be discarded or reconditioned as described in 10.9.3.1.1 and stored at a minimum temperature of 250 °F.

10.9.3.2 Exposure of MIL-100S-1F flux. Exposure of MIL-100S-1F flux shall be limited to ensure that the reduced moisture requirements of NAVSEA T9074-BC-GIB-010/0200 are not exceeded. An appropriate exposure period should be established by the using activity, however, exposure shall not exceed 9 hours. Upon removal from the manufacturer's hermetically sealed containers or holding ovens, MIL-100S-1F flux shall not be used after being exposed to the atmosphere for a total period of more than 9 hours. During exposure, suitable means shall be provided to protect flux from inclement weather.

10.9.3.2.1 Returned MIL-100S-1F flux. All MIL-100S-1F flux shall be reconditioned in accordance with 10.9.3.1.1 prior to re-issue.

10.9.3.3 Responsibility. The activity shall establish and maintain written flux control procedures which will ensure that flux moisture levels in the production welding process do not exceed filler material procurement specification requirements.

10.9.4 Neutral granular flux for MIL-100S-2F. The activity shall develop a written flux control procedure which will ensure that flux moisture levels and diffusible hydrogen levels in production welding do not exceed any requirements of approved special welding procedures using this flux and the filler material procurement specification requirements. This procedure must be submitted to NAVSEA for approval. Upon NAVSEA approval this approved procedure must be maintained.

10.10 Identification. All welding filler materials and the flux shall be identified up to the point of usage.

10.10.1 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 suitable identification is restored.

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

10.10.3 Neutral granular flux. Each container of neutral granular flux shall be labeled by type.

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11. WELDING DESIGN

11.1 Scope. This section provides the requirements for the design of welds and structural details used in submarine structure. In addition to specific requirements such as allowable joint designs, minimum joint efficiencies and design requirements for items such as penetrations and inserts, this section encourages designing for fabrication.

11.2 Design for pressure hull structure welding. All welds in or to the pressure hull structure should be designed to permit fabrication by the GMAW process. Manufacturing plans for detailing fabrication or erection sequences, welding processes and procedures, and NDT shall be developed concurrently with the detailed design plans. The manufacturing plan shall be approved by the shipyard welding engineering group. The shipyard welding engineering group shall determine: (1) if the GMAW or SAW process can be used based on the accessibility for welding equipment, etc., (2) if an alternate welding process should be used, (3) if structure redesign is necessary for welding.

11.3 Functional joint requirements. The required joint efficiencies of Table 11-1, column 2, are the minimum efficiencies which will develop the intended functional strength of the itemized connections and shall be used. The group of joint configurations permitted for use in fulfilling the required joint efficiencies shall be as specified in Table 11-1, column 3. The notes in column 4 are applicable to the specific item. Subject to approval on a case basis, reduced efficiencies of those specified in column 2 may be utilized based on engineering analysis which demonstrates that the reduced efficiency of the designed joint is sufficient to carry the working loads in the connection. Reduced efficiencies of HY-100 and HSLA-100 joints as outlined in 11.5.7 fall within this exception. For aluminum alloys, efficiencies of full penetration welds shall be based on the proportional strength of filler material and annealed base material, unless otherwise approved as a result of testing.

11.3.1 Special requirements for welds of HY or HSLA material to OSS/HSS. When HY and HSLA material is joined to OSS/HSS and a high strength joint is required by design analysis, the applicable drawing(s) shall specify the joint be welded with the appropriate higher strength welding filler materials specified in Table 10-1. The size of the connection of the high strength joint to the continuous member should satisfy the following equation:

$$(\text{Sum of bevel and fillet dimensions}) \times R_5 \geq e \times T_I \times R_1$$

where terms are as defined in MIL-STD-1628.

In addition, for applications involving the welding of OSS/HSS material (other than attachment welds, see 3.39.1) to HY-80/100/130 pressure hull envelope and support structure, high strength welding filler materials shall be used as specified in Table 10-1.

TABLE 11-1. WELD JOINT DESIGN REQUIREMENTS.

Column 1 Structural category and connection or type of weld 1/	Column 2 Minimum required efficiency (percent) 2/	Column 3 Weld joint design group 3/	Column 4 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	4/ 5/
(c) Noncompensating penetrations.	100	T, PT, C	5/
2. Welds to pressure hull envelope.			
(a) Frames and floors to hull.			
(1) External.	100	T	
(2) Internal floors and frame webs.	100	T, PT	6/
(3) Internal frame flanges.	100	T	
(b) Hard tank stiffener to hard tank plating.			
(1) Stiffener on pressure side.	100	T, PT	6/
(2) Stiffeners not on pressure side.	75	T, PT	
(3) End connection of stiffeners.	100	T, PT	6/
(c) Stiffeners of trunks, tunnels, missile tubes, and seachests to boundary plating.			
(1) External.	100	T	
(2) Internal.	75	T, PT	
(d) Connections of foundations, tanks, bulkheads to pressure hull envelope.			
(1) Bulkhead stiffener end connections.	100	T, PT	6/
(2) Other connections.	100	B, T, PT, C	7/
(e) Connection of non-support structure to pressure hull envelope (unless otherwise stated below).	100	B, C, T, PT	8/
(f) Attachment of fairwater and superstructure.	100	T, PT	9/
(g) Attachment welds (see 3.39.1).	100	B, C, T, PT	
(h) Interface support structure to pressure hull envelope.	100	B, T, C	
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	7/

TABLE 11-1. WELD JOINT DESIGN REQUIREMENTS – CONT'D.

Column 1 Structural category and connection or type of weld 1/	Column 2 Minimum required efficiency (percent) 2/	Column 3 Weld joint design group 3/	Column 4 Notes
(c) Bulkhead stiffener.			
(1) End connections.	100	T, PT	7/
(2) Web to flange and tank or bulkhead.	75	T, PT, C	
(d) Penetrations. (1) Compensating.	100	T, PT, C	5/
(2) Penetrations through special sandwich bulkheads with solid filler.	100	PT	5/ 10/
(3) Water or oil tight.	75	T, PT, C	5/
(4) Other penetrations not listed above.	50	T, PT, C	5/
2. Welds to support structure.			
(a) Connections of foundations, tanks to support structure.	100	B, T, PT, C	9/ 11/
(b) Connections of non-support structure to support structure (unless otherwise stated below).	100	B, T, PT, C	8/ 9/
(c) Attachment welds.	100	B, T, PT, C	12/
(d) Tilting brackets.	50	T, PT, C	
II. Containment structure - joint design requirements for containment structure shall be obtained by referring to the applicable support structure in Category I.B.1 above.			
III. Non-pressure 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	5/ 13/
(2) Other.	50	T, PT, C	5/ 13/
2. Welds to intermediate pressure tanks.			
(a) Intermediate pressure tank stiffener to plating.			
(1) Stiffener on pressure side.	100	T, PT	7/
(2) Stiffener not on pressure side.	75	T, PT	
(3) End connections of stiffeners.	100	T, PT	7/
(b) Stiffener web to flange.	75	T, PT, C	
(c) Connection of foundations and tanks to intermediate pressure tanks.	100	T, PT, C	9/

TABLE 11-1. WELD JOINT DESIGN REQUIREMENTS – CONT'D.

Column 1 Structural category and connection or type of weld 1/	Column 2 Minimum required efficiency (percent) 2/	Column 3 Weld joint design group 3/	Column 4 Notes
(d) Connection of non-support structure to intermediate pressure tanks (unless otherwise stated below),	100	T, PT, C	8/ 9/
(e) Attachment welds.	100	T, PT, C	12/
(f) Tilting brackets.	50	T, PT, C	
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	9/ 13/
(b) Penetrations.			
(1) Water or oil tight.	75	T, PT, C	5/ 13/
(2) Other.	50	T, PT, C	5/ 13/
2. Welds to low pressure tanks.			
(a) Low pressure tank stiffener to plating.			
(1) Stiffener web to tank plating.	75	T, PT, C	
(2) End connections of stiffeners.	100	T, PT	9/
(b) Stiffener web to flange.	75	T, PT, C	
(c) Connection of foundations to low pressure tanks.	100	T, PT, C	9/
(d) Connection of non-support structure to low pressure tanks (unless otherwise stated below).	100	B, T, PT, C	8/ 9/
(e) Attachment welds.	100	T, PT, C	9/ 12/
(f) Tilting brackets.	50	T, PT, C	
C. Foundations.			
1. Welds in foundations.			
(a) Welds joining foundation material (unless otherwise stated below).	100	B, T, PT, C	9/
(b) Penetrations.			
(1) Water or oil tight.	75	T, PT, C	5/
(2) Other.	50	T, PT, C	5/
2. Welds to foundations.			
(a) Connection of non-support structure to foundations (unless otherwise stated below).	100	B, T, PT, C	8/ 9/
(b) Attachment welds.	100	T, PT, C	9/ 12/
(c) Tilting brackets.	50	T, PT, C	

TABLE 11-1. WELD JOINT DESIGN REQUIREMENTS – CONT'D.

Column 1 Structural category and connection or type of weld 1/	Column 2 Minimum required efficiency (percent) 2/	Column 3 Weld joint design group 3/	Column 4 Notes
D. Non-support structure.			
1. Welds in non-support structure.			
(a) Welds joining non-support structure material (unless otherwise stated below).	100	B, T, PT, C	9/ 14/
(b) Not used.	--	--	--
(c) Penetrations.			
(1) Water or oil tight.	75	T, PT, C	5/
(2) Other.	50	T, PT, C	5/
(d) Welds in masts.	100	B, T, PT	
2. Welds to non-support structure.			
(a) Stanchion butt weld and head and heel connection.	100	B, T, PT, C	9/
(b) Non-support structure stiffener to plating.			
(1) Deck and platform stiffener web to deck or flange.	75	T, PT, C	14/
(2) Web to plating or flange connection in superstructure and fairwater.	75	T, PT, C	14/
(c) Welds to the masts.	100	T, PT	
(d) Attachment welds.	100	T, PT, C	9/ 12/
(e) Tilting brackets.	50	T, PT, C	

Notes:

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 that required for similar connections in the same structural category.

2/ For weld joints of HY-100 or HSLA-100 to HY-100 or HSLA-100, the maximum attainable joint efficiencies of partial penetration welds PT2V.3, PT2V.4 and PT2V.5 and all full penetration weld joints shall be as specified in 11.5.7 and Table 11-2.

3/ Section 11.4 defines weld joint design groups. Additional allowances and approval requirements for changes in weld joint designs are contained in 11.4.7.

4/ Only joint PT2V.2 and PT2J.2 of design group PT may be used.

5/ Weld buildup is required on penetrations when required by 13.9.1.

6/ Only joint PT2V.5 of design group PT may be used with a NAVSEA specifically approved automatic, machine or semi-automatic welding procedure. Such welds shall be identified on the drawing and shall reference use of a specifically approved procedure. (Modification of PT2V.5 joint design for welding procedures using automatic SAW for all weld passes will be considered by NAVSEA). No group PT joints shall apply to welds in reactor plant tanks, or to the periphery joints of holding bulkheads. Fillet weld reinforcement for PT2V.5 welds for internal pressure hull frame webs to the pressure hull envelope and to the pressure hull frame flange may be sized in accordance with the requirements for a T2V.2 weld when using the NAVSEA specifically approved automatic, machine or semi-automatic weld procedure. No additional reduction in fillet reinforcement size is permitted for the PT2V.5 welds which are contour ground.

TABLE 11-1. WELD JOINT DESIGN REQUIREMENTS – CONT'D.

Notes: Cont'd

7/ No group PT joints shall apply to welds in reactor plant tanks, or to the periphery joints of holding and containment bulkheads. Elsewhere, only joint PT2V.5 of design group PT shall be used, except that foundation to pressure hull envelope applications of solid bar or tubing may be designed in accordance with Figure 21. Where specified by NAVSEA, faying pad and tapping pad connections may also be designed in accordance with Figure 21.

8/ The minimum required efficiency may be reduced to 75 percent for the attachment of minor structure (see 3.33.3.1) to other submarine structure, or when approved on a case basis.

9/ 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. For backing bar welds involving HY-100 or HSLA-100 materials, the maximum obtainable efficiencies are listed in Table 11-2.

10/ See Figure 22.

11/ No backgouging is required for pressure hull frame web and flange to tank top.

12/ C2S.1 joint design is also allowed for attachment welds (see 3.39.1) to Category I.B, II, and III structures.

13/ All fillet welded (PT1S.1 and PT2S.1) joints in tank boundaries shall have a minimum of two weld layers per side, unless otherwise approved by NAVSEA.

14/ Joint configurations listed in 11.4.6 may also be used.

11.4 Design group classification.

11.4.1 General. Weld joint symbols shall be in accordance with AWS A2.4. Permissible weld joints referenced in 11.4.2 through 11.4.5 shall be in accordance with MIL-STD-22 except:

a. Permanent backing bar joints shall not be used in joints subject to cyclic loading where the weld root will be subject to a tensile bending stress greater than or equal to 1/2 the lower of the weld metal or base material yield strength.

b. The material thickness limitation of MIL-STD-22 is not applicable.

Full penetration butt, corner and tee groove joints when welded from both sides with electrodes listed in Section 10 or combinations thereof, have a maximum efficiency of 100 percent, except as specified in 11.5.7. When backing bars are used and not removed, the maximum efficiency shall be 90 percent. If the backing bar is removed and the weld exposed by removal of the backing bar passes the required NDT, the joint shall be considered 100 percent. Butt, corner and tee groove joints welded from one side without backing (e.g., B1S.1, C1V.2, T1V.3) shall have a maximum efficiency of 80 percent, unless otherwise approved by NAVSEA. The limitations of 11.4.2 through 11.4.5 apply only to joint designs used in the pressure hull envelope, containment and support structure. Single or double bevel groove joints within the same design group may be interchanged without drawing change provided joint efficiencies are not reduced. For partial penetration type joint designs, square, single or double bevel joints may be interchanged provided that joint efficiencies are not reduced and the joint design is allowed per Table 11-1. Full penetration joint designs may be used where partial penetration joint designs are specified except as specified in 11.5.7. Where a full penetration joint design is substituted for a partial penetration joint design, the inspection requirements for the partial

penetration joint design apply. This allowance does not apply to PT2V.5 welds which reference Note 6 of Table 11-1. When PT2V.5 welds which require a NAVSEA specifically approved automatic, machine or semi-automatic welding procedure are changed to a full penetration weld, the root area after backgouging shall be MT inspected as required Table 6-1, Category I.A(12).

11.4.2 Group B joints. Group B joints are butt welds (B1V.1, B1V.2, B1V.3, B2V.1, B2V.3, B2U.1, B2U.2, B2U.3, B2U.4, and B2U.5).

11.4.2.1 Taper requirements. Butt welding of members of unequal thickness in pressure hull structure and intermediate pressure tanks, shall require chamfering of the thicker member as specified in MIL-STD-22, detailed drawings, or the ships detailed specifications. Welding of abutting member of unequal thickness in other structure (e.g., foundations, soft tanks, etc.) may be designated as corner or tee joint welds.

11.4.3 Group T joints. Group T joints are groove tee welds (T2V.1, T2V.2, T2J.1, T1V.1, T1V.2, and T2J.2).

11.4.3.1 Canted T joints. Where full penetration group T joints are formed by structural elements at an angle other than 90 degrees to one another, 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. For double beveled or double J-grooved group T joints (T2V.2 and T2J.2) the angle formed between the tee member and the through plate should not be greater than 105 degrees on the open or obtuse angle side of the joint. Where the angle between members exceeds 105 degrees, a bevel shall be provided on the obtuse angle 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 a T2V.1.

11.4.4 Group PT joints. Group PT joints are partial penetration groove tee or double fillet tee joints (PT2S.1, PT2V.1, PT2J.1, PT2J.2, PT2V.2, PT2V.3, PT2V.4 and PT2V.5). In the case of round bar or tubing, they are single fillet joints (PT1S.1). The strength of group PT welded joints (PT2S.1 and PT2V.1) shall be in accordance with MIL-STD-1628. For members (such as round, square or rectangular tubing) which can be welded on one side only (PT1S.1), the weld sizing requirement shall be based on doubling the nominal wall thickness of the tube member and determining the fillet weld size in accordance with MIL-STD-1628. For example, the fillet size for a 3/8 inch thick square tube shall be based on a 3/4 inch thick intercostal member. When welded with filler materials specified in Section 10, joints PT2V.3, PT2V.4 and PT2V.5 are 100 percent efficient and are exempt from the sizing requirements of MIL-STD-1628. For efficiencies of weld joints PT2V.3, PT2V.4 and PT2V.5 of HY-100 or HSLA-100 to HY-100 or HSLA-100, see 11.5.7.

11.4.4.1 Canted PT joint. Where partial penetration groove T joints are formed by structural elements at an angle other than 90 degrees to one another, 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. For partial penetration fillet welds, the end of the tee member shall be corrected to meet the fitup requirements of MIL-STD-22. 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 PT2V.4.

11.4.5 Group C joints. Group C joints are corner joints (C2V.1, C2V.2, C2V.4, C2V.5, C2V.6, C2U.1, C2J.2, C2J.3, C2J.4, C2J.5 and C2J.6).

11.4.6 Other joints. The joint configurations listed below are limited to use in non-support structure only, unless specifically approved by NAVSEA for use in other applications. Such joints shall meet the efficiency requirements contained in Table 11-1 (for efficiencies of weld joints involving HY-100 or HSLA-100 material see 11.5.7) and any approved limitations.

11.4.6.1 Intermittent fillet welded joints. Intermittent fillet weld joints are partial penetration group tee welds (PT2S.2 and PT2S.3). These joint designs shall not be used in areas exposed to water or weather and 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.

11.4.6.1.1 Intermittent fillet weld size. Intermittent fillet weld sizes shall be determined by increasing the continuous double fillet size required by this document in proportion to the unwelded length of the joint. That is, if the unwelded length of the joint is half the total length, 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.

11.4.6.2 Group L joints. Group L joints are lap welds (L2S.1, L1V.1, L1V.2, L1S.1 and L1S.2) including plug, slot and fillet welded lap joints. The strength and efficiency of fillet welded lap joints shall be determined using the requirements of MIL-STD-1628 for a PT2S.1.

11.4.6.3 Group E joints. Group E joints are edge joints (E1S.1, E1V.1, E1U.1, and E1U.2). Edge joints shall only be used in minor structure (see 3.33.3.1), and for purposes of joint sealing.

11.4.7 Special joints. Special joints are those joint configurations not in accordance with the requirements of MIL-STD-22, or are joint designs used in applications not permitted by this section. The joint shall be detailed on the drawing and approved for the specific application involved, or the special joint shall be specifically approved as an acceptable alternate and contained in a class specific non-standard weld joint drawing. Such joints shall meet the efficiency and design requirements contained herein or any limitations imposed via approval. The use of partial penetration weld joint designs for applications in Table 11-1 categories that only allow full penetration weld joint designs requires specific NAVSEA approval.

11.5 Design requirements.

11.5.1 Penetrations. The toes of welds connecting penetrations in the pressure hull envelope should be separated from the toe of any full penetration or partial penetration weld in or to the pressure hull envelope by a minimum of 3/4 inch. If either is a fillet weld, the minimum separation should be 1/2 inch.

11.5.1.1 Intersecting welds. Penetrations in the pressure hull envelope shall not intersect full penetration welds except where absolutely necessary. In those instances where it is necessary for a penetration to intersect a butt weld, the penetration should preferably be centered on the butt weld or shall intersect the butt weld with the penetration weld overlapping the butt weld by at least 3/4 inch as shown on Figure 23.

11.5.1.2 Spacing from structure. The distance between the centerline of a penetration in the pressure hull envelope and an adjacent frame, floor, or bulkhead shall be a minimum of 20 percent of the frame space, subject to non-interference with flanges for welding accessibility.

11.5.2 Projection of penetrations or liners. Penetrations greater than 4 inches in diameter or liners through the pressure hull envelope shall be designed to permit volumetric inspection by either RT or UT. Where this is not practical due to location or orientation, the weld must be MT inspected in accordance with Table 6-1, Category 1.A.

11.5.3 Inserts, patches, and small access plates. The minimum dimension of an insert, patch, or small access plate in the pressure hull envelope shall be 4T (four times the thickness (T) of the member penetrated) or 6 inches, whichever is greater. The minimum dimension of an insert, patch, or small access plate in plating and structure other than the pressure hull envelope shall be 4T or 3 inches, whichever is greater. Corners of inserts, patches, or small access plates in the pressure hull envelope shall have a minimum radius as shown on Figure 24, except where those inserts, patches, or small access plates land on full penetration butt welds. Corners of inserts, patches, or small access plates in plating and structure other than pressure hull envelope shall have a minimum radius as shown on Figure 25 unless otherwise approved by NAVSEA.

11.5.3.1 Intersection of inserts, patches and 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 an angle of 90 plus or minus 15 degrees as shown on Figure 26. When this requirement is not met, the condition shall be dispositioned in accordance with 13.9. If the condition is known at time of design, the extent of buttering, filler metal type and applicable NDT shall be detailed on the drawing. 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 not be 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 insert, patch or small access plate welds shall be a minimum of 3 inches from the toes 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 outlined in 11.5.3.2.

The above items a through d should have weld toe-to-toe distance as specified in 11.5.1.

11.5.3.2 Termination on full penetration butt joints. When inserts, patches or small access plates in the pressure hull envelope terminate on other full penetration butt welds, one of the existing longitudinal or circumferential butt welds shall be cut back a minimum of 3 inches as shown in Figure 26, 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 surface or tank top.

11.5.4 Access and closure plates. 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 weld. In the latter instance, the corners shall intersect the butt weld at 90 plus or minus 15 degrees.

11.5.4.1 Boundaries. Boundaries of access and closure plates in the pressure hull envelope shall either land on existing hull (circumferential or longitudinal) butt welds, or the weld toe-to-toe spacing from any adjacent hull butt weld shall be a minimum of 3 inches, except for the items listed in 11.5.3.1.a, b, c, and d. These items should have weld toe-to-toe distances as specified in 11.5.1. When a transverse boundary of an access or closure plate does not land on an existing butt weld, it shall be located so that the center of the weld is between 15 and 25 percent of the frame spacing from the face of the adjacent frame or bulkhead.

11.5.4.2 Termination on full penetration butt joints. When access or closure plate welds in the pressure hull envelope terminate on other full penetration butt welds, the existing longitudinal or circumferential butt welds shall be cut back a minimum distance of 3 inches as shown in Figure 26, 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 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.

11.5.5 Permanent snipes. Where water or oil tightness or strength is not a consideration, use of permanent corner or scallop snipes in members joining to plating shall be permitted to provide accessibility for welding and for vents and drains. The radiused type snipe shown in Figure 27 shall be used for vents, drains, or permanent snipes wherever practical. Drain holes may be used as an alternate to permanent snipes. When drain holes are used, they may be made at any time during the fabrication by drilling or burning provided the edges of the hole meet the requirements of Section 14. The maximum allowable size for holes shall be determined by design consideration and should be a minimum of 1 inch from adjacent structure.

11.5.6 Pressure hull envelope attachment. Every effort should be made to minimize welded structure and miscellaneous attachment to the pressure hull envelope. 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 may be applied anywhere on the pressure hull.

11.5.7 Reduced efficiency for HY-100 and HSLA-100 weld joints. Welding of thin HY-100 or HSLA-100 (less than 3/4 inch) using allowable filler materials of Section 10, will result in reduced joint efficiency. HY-100 or HSLA-100 to HY-100 or HSLA-100 partial penetration joints PT2V.3, PT2V.4, and PT2V.5, and all full penetration weld joints, when welded with the filler materials listed in Table 11-2, shall have the maximum efficiencies specified in Table 11-2, unless otherwise approved by NAVSEA. For those HY-100 or HSLA-100 weld joints where at least one member is less than 3/4 inches thick, full penetration joint designs can be substituted for partial penetration joint designs only if the minimum required joint efficiencies of Table 11-1 are met by the requirements noted herein. Efficiencies for welding HY-130 to HY-130 with MIL-120 series filler material shall be approved by NAVSEA.

TABLE 11-2. MAXIMUM JOINT EFFICIENCIES FOR HY-100 OR HSLA-100 TO HY-100 OR HSLA-100 WELD JOINTS. 1/

Electrode	Thickness, t (in), of thinnest plate forming the weld joint.	Maximum efficiency (percent)	
		Backing bar weld joint where backing bar is not removed.	(a) Full penetration weld joints welded both sides. (b) Backing bar weld, where the weld is exposed by removal of the backing bar and the exposed weld passes NDT. (c) Weld joints PT2V.3, PT2V.4 or PT2V.5.
MIL-12018-M2 MIL-120S-1	t ≥ 0.75	90	100
	0.375 ≤ t < 0.75	81	90
	t < 0.375	72	80
MIL-100S-1 MIL-10718-M	All	74	82
MIL-11018-M 2/	t ≥ 0.75	90	100
	0.375 ≤ t < 0.75	81	90
	t < 0.375	72	80

Notes:

1/ Assumes the use of weld procedures qualified in accordance with Sections 4 and 16 (as applicable) for the specific application HY-100 or HSLA-100 to HY-100 or HSLA-100 welding.

2/ For pressure hull structure, use of MIL-11018-M electrode for HY-100 or HSLA-100 to HY-100 or HSLA-100 welds is limited to base material thicknesses less than or equal to 1.0 inch, unless otherwise approved by NAVSEA.

11.5.8 Stress corrosion cracking (SCC) criteria. All HY-130 base material and welds shall be evaluated to determine if they are a stress corrosion cracking critical application as defined in the ship's detailed specifications. Every effort should be made to avoid SCC through design. Where this cannot be accomplished, NAVSEA approval is required. All SCC weld joints shall be identified on the drawing as such.

11.5.9 Low melting material precautions. Special precautions are required when welding in-way-of structures (e.g., containment bulkhead, lead-bins, control surfaces, etc.) utilizing low melting materials such as polyethylene or foam (see Table 13-1, Part 1 Note 1 and Part II Note 1). Elevated welding preheat and heat soak temperature requirements (e.g., MIL-120 and MIL-140 series filler material) may result in damage to the underlying low melting material. Those structures which cannot tolerate elevated temperatures should be designed for use of other base materials (e.g., HSLA materials) and/or welding filler materials and procedures allowing lower temperatures. Welds as such shall be identified on the drawing and shall reference appropriate notes to control heat during welding in order to preclude significant melting or loss of these materials.

12. ERECTION REQUIREMENTS

12.1 Scope. This section contains the requirements necessary for fabrication and erection of submarine structure. Where other design structural erection tolerances are specified in the ships specification, they shall apply.

12.2 General requirements. During fabrication and erection of submarine structure, welded temporary attachments, such as erection clips, fairing bolts, staging braces, brackets for alignment and fitup, and lifting pads/padeyes, should be kept to an absolute minimum and should be used only when attachments which do not require welding cannot be used. Every attempt should be made to use mechanically fastened alignment or lifting devices such as frame alignment or staging braces, and slings, clamps or belly bands.

12.2.1 Location of attachments. When welded temporary attachments are used, the attachment should be kept a minimum of one inch away from existing submarine welds, whenever practical. Removal of temporary attachments shall be performed in accordance with Section 14 and the area inspected in accordance with Section 6. When permanent studs are attached to submarine structure, they may be located on or near existing welds. The toe-to-toe distance between the stud weld and any existing full penetration weld should be 1/4 inch or more when it does not land on the existing weld.

12.3 Structural requirements.

12.3.1 Circularity, sphericity and hull fairness.

12.3.1.1 Circularity requirements and hull fairness. Circularity and hull fairness measurements shall be made in those portions of the pressure hull (including the bridge access trunk and the sonar sphere access tunnel, when required by the ships detailed specifications) that are designed to be circular and fair between frame lines. These measurements shall be made in accordance with written full or partial circularity and hull fairness procedures which have been approved by NAVSEA. Full circularity procedures are defined as those where the entire hull contour is established at the same time; partial circularity procedures are defined as those where the hull contour is measured at different times. The pressure hull circularity and hull fairness shall meet the following requirements:

a. For circularity: The trace of the actual contour shall not deviate from the mean circle by more than 1/2 the thickness of the pressure hull plating or 1/2 inch, whichever is less, or as specified in the ship's detailed specification.

b. For circularity: The radius of the mean circle shall not depart from the design radius by more than 1/2 the thickness of the pressure hull plating or 1/2 inch, whichever is less, or as specified in the ship's detailed specifications.

c. For hull fairness: The measurement of the hull fairness shall be 3/16 inch or less or as specified in the ship's detailed specification. Direction of the hull fairness measurements shall be recorded. The positive direction shall be considered to be radially outward.

12.3.1.1.1 Location of final acceptance circularity and hull fairness measurements. Final acceptance circularity and hull fairness measurements of

pressure hull envelope shall be recorded at the following stations as noted below. (For circularity, the fore and aft tolerance of each station shall be plus or minus 6 inches and the actual reading location shall be recorded. In no case shall circularity be taken on a hull butt weld.):

a. For circularity: One set on at least every third frame.

b. For circularity: One set on the frame (exclusive of structural bulkheads) nearest each circumferential butt, and at the two frames adjacent to each bay containing over tolerance fairness.

c. For circularity: One set on each frame that has been cut and reinstalled as part of a hull closure plate.

d. For hull fairness: One set in each pressure hull frame bay containing a circumferential butt weld or as defined in the ship's detailed specification. In the case of over tolerance fairness in these frame bays, fairness shall be measured in adjacent frame bays. If these frame bays are also over tolerance, further adjacent bays shall be measured until frame bays are found with no over tolerance fairness forward and aft of the frame bay containing the circumferential butt weld. No fairness measurements are required in way of toriconical transitions.

At each station, circularity and hull fairness measurements of the actual hull contour shall be made at points not more than 5 degrees apart except as approved by NAVSEA. Circularity measurements are required in way of tank floors or bulkheads that form part of the hull structure when the mean circle is calculated using the circularity measurements. Individual circularity measurements which fall on penetrations or inserts that deviate from the molded line shall be omitted; the circularity of the section shall be calculated from the remaining locations. Hull fairness measurements which fall on penetrations, inserts, or hull butt weld reinforcements that deviate from the molded line shall be taken as close to the required location as practical. A notation shall be made on the data sheet (Figure 9) noting the penetration or insert and the location of the actual measurement. Frame bays with conical frustums shall be measured in the same way as a typical frame bay in the cylindrical portion of the pressure hull. The design out-of-fairness due to the frustums shall be factored out using a NAVSEA approved procedure. When fairness measurements of a frustum are taken, both corrected and uncorrected numbers shall be recorded.

For the bridge access trunk and sonar sphere access tunnel, location of final acceptance circularity and hull fairness measurements shall be as specified on approved drawings.

12.3.1.1.2 Sequence of final acceptance circularity and hull fairness measurements. Circularity and hull fairness measurements shall be taken after all major welding has been completed, after all spiders, bracing and temporary support structure have been removed or released, and after the structure has cooled to ambient temperature.

a. For circularity measurements, major welding is considered to be the accomplishment of full penetration (or 100 percent efficient partial penetration) welds in either the measured frame, the pressure hull plating in an adjacent frame bay, or an adjacent frame and frame welds to the pressure hull. The installation of hull penetrations or inserts

which are 24 inches or less in diameter and do not cross the frame being measured are not considered major welding.

b. For hull fairness, major welding is considered to be the accomplishment of full penetration (or 100 percent efficient partial penetration) welds in the frame bay being measured or either adjacent frame within 120 inches circumferentially from the measurement. Penetrations and inserts which are 24 inches or less in diameter, do not cross adjacent frames, and are over 60 inches from the fairness measurement are not considered major welding.

c. Weld repairs, to welds defined above, that do not exceed a depth of 1/3T (T equals the thickness of the thinnest member involved in the joint) into the base material of the thinnest member involved in the joint and 24 inches in continuous length are not considered major welding.

12.3.1.1.3 Circularity measurements in way of hull penetrations, inserts, and closure patches. For construction, these measurements shall be full circularity measurements. During a ship's life, acceptable hull circularity may be verified by either full circularity measurements or by the procedure stated in 12.3.1.4, which uses the following. Partial circularities shall not be used during construction without prior NAVSEA approval.

12.3.1.1.3.1 Complementary circularity measurements. Complementary circularity measurements are measurements of that portion of the hull contour not covered by partial circularity. The complementary circularity measurements shall be made by the activity prior to making the hull cut, unless the circularity procedure used does not require hull closure to establish the hull contour over the measured arc and has been approved by NAVSEA for such measurements. In addition, the radial location of the end points shall be established relative to bench marks on undisturbed frames forward and aft of the proposed cut. These end points shall be coincident with those of the partial circularity that completes the hull contour.

12.3.1.1.3.2 Partial circularity measurements. Partial circularity measurements are measurements over a transverse arc length between twice and three times the transverse arc length of the proposed cut, but need not exceed 30 degrees beyond each end of the cut. The transverse arc shall be centered on the proposed cut except where tank tops or stiff or rigid (strong-back type) permanent coamings intersect the pressure hull, in which case the partial circularity end points may terminate at the tank top or permanent coaming. In all cases, the radial location of the end points for the partial circularity check shall be established relative to bench marks on adjacent undisturbed frames forward and aft of the proposed cut.

12.3.1.1.4 Fairness measurements in way of hull penetrations and inserts. When penetrations and inserts that intersect a frame do not allow for the end readings of the frame bay to be zeroed and a realistic representation of the as-built condition cannot be achieved, fairness readings adjacent to penetrations and inserts are not required.

12.3.1.2 Documentation requirements for circularity and hull fairness procedures. NAVSEA approval shall be obtained for any circularity procedure used to develop final acceptance circularity or hull fairness measurements, including both full and partial circularities. The documentation required

for NAVSEA approval shall be written for each circularity and hull fairness procedure and shall include the following:

a. Qualification requirements for personnel responsible for taking circularity measurements and hull fairness. (Records shall be kept as required by Section 5.) The qualification requirements shall include:

   (1) Training and written examination of the personnel in the structural significance of hull circularity and hull fairness measurements.

   (2) Training and written examination of the personnel in the specific operations they will be responsible for in establishing hull circularity and hull fairness measurements.

   (3) Written certification by supervisory level personnel that their personnel have a thorough understanding of their function in establishing hull circularity and hull fairness measurements and have demonstrated satisfactory performance in both the operations for which they are being certified and the results of the above written exams.

   (4) Continued certification of previously certified personnel shall be required every three years and shall consist of item (3) above.

b. A requirement that compliance to circularity and hull fairness procedures shall be monitored in accordance with the activity's quality program. Monitoring shall be on an annual basis, except that if circularity or hull fairness procedures are performed at longer intervals, the monitoring shall be accomplished whenever the measurements are taken.

c. Documentation of the activity's calibration standards for the equipment and a requirement that all measurements be made with calibrated equipment.

d. Process instruction delineating all steps followed in establishing the hull circularity and hull fairness deviations. If more than one approach will be used for any step, procedure documentation shall be included for each approach. Examples of steps to be included, as appropriate, are:

   (1) Laying out measurement points on the hull.

   (2) Establishing control frame of reference to uncut frames (for partial circularities).

   (3) Taking the hull circularity and hull fairness measurements.

   (4) Developing the mean circle radius (for full and complementary circularities).

   (5) Determining the hull contour eccentricity.

e. Identification of all limitations associated with implementing the steps outlined by the process instruction of d. above.

f. Qualification data for the procedure that demonstrates acceptable accuracy and repeatability of circularity and hull fairness measurements obtained with that procedure. This data shall reflect the limitations stated in e. and shall demonstrate the applicability of the procedures as a function of hull form, diameter, stepped hull plate, and areas of hull inserts. This data shall be taken by the personnel responsible for the production use of the procedure and shall be taken with the cylinder in the worst orientation (axis horizontal or vertical) in which it will be used by the activity. For full circularity and hull fairness procedures, the qualification data shall consist of the following:

(1) Demonstration of the procedure accuracy by comparing measurements made with the procedure to a set of baseline measurements (NAVSEA approval shall be obtained on a case basis as to what constitutes a baseline; an approved photogrammetry procedure is one approach that is considered appropriate for obtaining a baseline). Acceptable accuracy for circularity shall require that (a) the mean circle radius determined by the procedure vary from the baseline mean circle radius by no more than 0.07 inch and (b) the hull eccentricity determined by the procedure at each measurement location, relative to the procedure mean circle radius, vary by no more than 0.07 inch from the baseline hull eccentricity, relative to the baseline mean circle radius, at the same measurement location. Hull fairness measurement procedures shall be demonstrated to be accurate to 1/64 inch by a methodology approved by NAVSEA.

(2) Demonstration of the procedure repeatability by measuring a single hull contour five times using different personnel (if the activity does not have five different personnel or teams to conduct the procedure, rotation of personnel is allowed) and equipment setups. Acceptable repeatability shall require that (a) the five mean circle radii do not vary by more than 0.05 inch and (b) at any measurement location, the difference between the five eccentricity measurements, relative to their individual mean circle radii, varies by no more than 0.05 inch. For hull fairness the repeatability shall be addressed in the fairness procedure submitted by the shipyard.

g. The qualification data for partial circularity procedures shall consist of the following:

(1) Demonstration of the procedure accuracy by comparing measurements made with the procedure to a set of baseline measurements (NAVSEA approval shall be obtained on a case basis as to what constitutes a baseline). Acceptable accuracy shall require that, at any measurement location, the hull contour determined by the procedure, relative to a control frame of reference, vary no more than 0.07 inch from the baseline hull contour, relative to the same control frame of reference.

(2) Demonstration of the procedure repeatability by measuring a single hull contour five times using different qualified personnel (if the activity does not have five different personnel or teams to conduct the procedure, rotation of personnel is allowed) and equipment setups. Acceptable repeatability shall require that, relative to a control frame of reference, the five hull contours do not vary by more than 0.05 inch at any measurement location.

h. Continuance of procedure qualification shall require redoing steps f. and g. on a five year basis, including submittal of results to NAVSEA for approval.

12.3.1.3 Establishing hull circularity using full circularity measurements. Circularity measurements shall be taken so that the actual hull contour at any station may be analyzed for eccentricity. A circle, defined as the mean circle, shall be developed to characterize the hull radius at the station where the circularity measurements are taken. The mean circle shall be positioned over the actual measured contour and may be positioned such that the maximum deviation between the mean circle and hull contour is minimized. The deviations between the mean circle and the measured hull contour shall be calculated at each circularity measurement point, if discrete points on the hull are measured, or at every 5 degrees, if

a continuous measurement is made of the hull contour. These deviations are not required to be calculated or evaluated for those areas in way of tank floors or bulkheads that form part of the hull structure.

12.3.1.4 Establishing acceptable hull circularity using partial circularity measurements. As required by 12.3.1.1.2, the verification of acceptable circularity shall be accomplished after completion of all major welding. If this verification is done using full circularity measurements, the procedure of 12.3.1.3 applies. If this verification is to be accomplished by taking partial circularity measurements, as specified in 12.3.1.1.3.1 and 12.3.1.1.3.2, the radial location of the end points taken prior to installation must be checked against the radial location of the end points taken after the installation. After adjusting the end points to account for any change in the bench marks from pre-installation to post-installation, if either end point at a station has changed by more than 1/16 inch, a full circularity shall be taken at that station. If the radial end point locations are satisfactory, accomplish one of the following:

a. Superimpose the partial circularity contour (12.3.1.1.3.2) after installation on the pre-installation complementary circularity contour (12.3.1.1.3.1). Develop a total hull contour, adjusting the post-installation partial contour for any radial movement of the end points, and a mean circle corresponding to this hull contour and calculate the deviations between the measured hull contour and the mean circle at the locations specified in 12.3.1.1.1. If the mean circle radius, or the deviations from the mean circle, exceed the limits of 12.3.1.1.a. or 12.3.1.1.b., a full circularity measurement shall be made.

b. Compare the partial circularity contour after installation to the pre-installation partial hull contour. A full circularity measurement shall be made if any of the following occur:

   (1) The geometry relative to zero end points (lines B and either D or E of Figure 8.E) shows a difference at any location along the arc that exceeds the limit of 12.3.1.1.a.

   (2) The difference between the contour measurements before installation (line B of Figure 8.E) differs by more than 1/8 inch from the contour measurements after installation (either line D or E of Figure 8.E) at any point on the contour.

12.3.1.5 Sphericity.

12.3.1.5.1 Sphericity requirements. A procedure shall be developed for taking sphericity measurements, including the method, location of measurements and documentation requirements for final acceptance measurements. This procedure shall be submitted for NAVSEA approval. The final acceptance measurements shall meet the following requirements:

a. Spherical segment closure bulkheads: The radius of the bulkhead shall not deviate more than plus or minus 1¼ inches from the design radius at any point or as specified in the ship's detailed specification. The maximum out-of-sphericity defined by the ship specification over a critical arc length shall not be more than 1/2 inch after completion of major welding. For spherical closure bulkheads (heads), major welding is considered to include the welding of the head segments to themselves, the closure head to the conical hull sections, the pressure hull frames to the heads, the trim tanks (fwd or aft as applicable) to

the heads, the sonar access tunnel to the heads, the longitudinal centerline bulkhead and all horizontal flats to the heads, and all penetrations and inserts in the heads.

b. Sonar sphere: The radius of the sphere shall not deviate more than plus or minus 3/8 inch from the design radius at any point or as specified in the ship's detailed specification. The maximum out-of-sphericity defined by the ship specification over a critical arc length shall not be more than 3/4 inch.

12.3.1.6 Records of circularity, sphericity and hull fairness checks. Records of all final acceptance measurements for circularity, sphericity and hull fairness and the methods of taking these measurements shall be in accordance with Section 5 and shall be forwarded to NAVSEA at time of delivery.

12.3.1.7 Resolution of circularity, sphericity and hull fairness deviations. When final circularity, sphericity and hull fairness measurements show deviations that exceed the specified tolerances, they shall be approved by NAVSEA.

12.3.2 Pressure hull frames.

12.3.2.1 Frame dimensional tolerances. After welding of the flange to web is finished (including all required NDT), the flange width and flange unbalance of fabricated frames shall be within the tolerances of Table 12-1. In-process inspection of the flange to web tilt should be made. After finish welding of the frames to the hull plating, including completion of all required NDT (except expansion requirements of Section 6), the tilt of the web from its designed position, the tilt of the flange to the web and the depth of all frames shall be within the tolerance specified in Table 12-1. Such measurements shall be made at intervals of 45 degrees. If interferences exist at the required intervals, rotate the station locations, or take measurements at additional locations so that a minimum of 8 sets of measurements are made at intervals of not more than 50 degrees. When a frame station is located in an area where by design, the depth of the frame is non-uniform, then select another uniform depth location close to the non-uniform depth station to take the measurement. If an alternate uniform depth position is not feasible, then take frame measurements except the frame depth at the non-uniform frame depth station. For the bridge access trunk and sonar sphere access tunnel, location of final acceptance frame dimension measurements shall be as specified on approved drawings. Repairs to frame welds do not require re-measuring of the frame dimensions when the depth of repair of a frame weld does not exceed 1/3T (T equals the thickness of the thinnest member involved in the joint) below the base material surface. When a frame is reworked to correct dimensional errors, or when the depth of repair of a frame weld exceeds 1/3T below the base material surface, the frame dimensions at the area of repair shall be re-measured. Re-measure only the dimensions that are determined to be affected by the repair (e.g., re-measure web tilt and frame depth when repairs are made to the weld joining the web to pressure hull).

TABLE 12-1. PRESSURE HULL FRAME TOLERANCES. 1/ 2/

Depth of frame (inches)	Frame depth H (inches)	Web tilt maximum	Flange tilt maximum	Flange width W (inches)	Flange unbalance G1-G
Up to and including 12	+3/16 -1/8	±2 degrees	±2 degrees	±1/8	±3/16
Greater than 12 to and including 15	+1/4 -1/8	±2 degrees but 7/16 inches maximum	±2 degrees	±1/8	±3/16
Greater than 15 to and including 24	+5/16 -1/8	7/16 inches maximum	±2 degrees but 17/32 inches maximum	±1/8	±3/16
Greater than 24	+3/8 -1/8	7/16 inches maximum	17/32 inches maximum	±1/8	±3/16

Notes:

1/ Overdepth (H) and overwidth (W) tolerances may be exceeded provided the resulting overweight does not exceed 3 percent of the weight of the cross-section specified on the drawing. The nominal thickness of the cross-section as shown on the drawing shall be used in determining this overweight.

2/ See Figure 28.

12.3.2.2 Frame flange curvature. For fabricated frames, flange curvature (transverse bow) shall not deviate from a reference line tangent to the top of the flange on flanges less than 12 inches wide by more than 1/8 inch and on flanges 12 inches wide and over by more than 3/16 inch.

12.3.2.3 Frame spacing. The distance between adjacent frame webs shall be measured and shall be as stated in Table 12-2 or the ship's detailed specification. This dimension shall be measured perpendicular to the frame within 1 inch of one web toe of the hull attachment weld and may be adjusted for web tilt. Care should be taken to ensure that the accumulation of these tolerance allowances permits proper alignment of attached or installed foundations or other components. Where feasible, frame spacing measurement locations shall be taken at the same locations as frame dimension measurements in Section 12.3.2.1. Weld repairs, to completed frame welds and frame to pressure hull welds that do not exceed 2/3T (T equals the thickness of the thinnest member involved in the joint) in depth, do not require frame spacing measurements to be retaken.

TABLE 12-2. TOLERANCES FOR FRAME SPACING.

Tolerances for other than reactor compartment		Tolerances for reactor compartments
In way of hull butt	Other than hull butt	
±3/8 inch	±1/4 inch	See NAVSEA approved drawings

12.3.2.4 Frame butt alignment. The transverse and vertical offset of abutting surfaces at weld joints in webs and flanges of pressure hull frames shall not exceed 1/8 inch, unless so designated. If any point across the flange face exceeds 1/8 inch, but does not exceed 1/4 inch, it shall be faired by grinding to a four to one taper. These limits are applicable after completion of welding and cool down.

12.3.2.5 Records of pressure hull frames. Records of frame dimensions and frame spacing shall be in accordance with Section 5.

12.3.2.6 Resolution of frame deviations. When frame measurements show deviations that exceed the specified tolerances, they shall be submitted for approval as follows:

a. To NAVSEA for deviations that result in stress levels in excess of 95 percent of, or collapse pressures less than 102 percent of the allowables in the ship's detailed specifications. To NAVSEA for deviations in end bay frame measurements that result in exceeding DDS 110-2 sections 3.2.5 a through 3.2.5.e requirements.

b. To NAVSEA's authorized representative for all other deviations not included above.

12.3.3 Fairness and alignment. When the requirements noted below are not met, the condition shall be dispositioned in accordance with 13.9.4.

12.3.3.1 Pressure hull structure alignment. When pressure hull plating and support structure are tacked and are ready for welding, the misalignment of surfaces projected to the centerline of joints shall not exceed the limits of Table 12-3.

TABLE 12-3. ALIGNMENT TOLERANCE.

Thickness (inches)	Maximum misalignment (inches)
Pressure hull structure	
5/8 and less	1/16
Over 5/8	1/8
Non-pressure hull structure	
Less than 3/8	1/16
3/8 to 3/4	1/8
Over 3/4 to 1½	3/16
Over 1½	1/4

12.3.3.2 Non-pressure hull structure alignment. When non-pressure hull structure is tacked and is ready for welding, and special requirements for fairness, flatness or alignment are not otherwise specified, the misalignment of structure projected to the centerline of joints shall not exceed the limits of Table 12-3.

12.3.3.3 Intercostal structure alignment. Unless otherwise detailed on the drawing, the centerline of discontinuous members on opposite sides of a through member shall line up back-to-back, when measured perpendicular to the axes of the discontinuous members, within one-half the thickness of the through member but not more than 3/4 inch. Where the discontinuous member is a structural shape, both webs and flanges shall be aligned within this limit.

12.3.3.4 Flat plate panel unfairness. Unfairness of welded flat plate panels in free flooding areas, and structural bulkheads shall be in accordance with tolerances on Figure 29.

13. WELDING REQUIREMENTS

13.1 Scope. This section contains the requirements for welds in submarine structure. Special requirements for welding with MIL-120 and MIL-140 series filler materials, including preheat and interpass temperatures, heat input, hydrogen removal and weld process control requirements are contained in Section 16.

13.2 Qualification. Except as permitted by 4.3 and 4.4, welding procedures, welders, and welding operators shall be qualified in accordance with Section 4 prior to their employment in production work.

13.2.1 Stud welding. Stud welding is permitted using procedures and equipment qualified in accordance with Section 4. Either automatically timed arc or capacitor discharge stud welding may be used with approved stud configurations for the respective processes. Capacitor discharge stud welding shall be limited to 1/4-inch maximum diameter, unless otherwise approved. Acceptance criteria and inspection requirements shall be in accordance with Section 6.

13.2.2 Welding prohibitions. Unless specifically approved by NAVSEA, the procedures noted below are prohibited for welds in submarine structure:

a. Gas metal arc welding - short circuiting transfer (GMAW-short arc).
b. Oxyfuel gas welding and gas gouging on quenched and tempered steels.
c. Welding in the vertical position, down progression.
d. Welding over galvanized coated surfaces.
e. Welding over primer coated surfaces, except as allowed by 13.2.6.
f. Welding of precipitation hardenable alloys, except HSLA-80/100.
g. Welding on material when water, oil, or similar materials are in contact with the surface opposite the side to be welded and less than 1/4 inch of base material is between the weld area and the surface in contact with the liquid.

13.2.3 Welding of aluminum. When welding aluminum using the gas metal arc welding (GMAW) process, protection of the weld site shall be provided as necessary to prevent disturbance of the shielding gases.

13.2.4 Welding in way of austenitic or non-ferrous base and filler materials. Ferritic filler materials shall not be deposited over austenitic or non-ferrous base and filler materials, however austenitic or non-ferrous filler materials may be deposited over ferritic base and filler materials.

13.2.5 Welding equipment grounding. Welding equipment grounding for waterborne submarines and submarines in graving docks shall be in accordance with NAVSEA S9086-CH-STM-010/CH-074V1. Welding equipment grounding for other applications shall be in accordance with the equipment manufacturer's requirements.

13.2.6 Welding over primer coated surfaces. Welding over primer coated surfaces is allowed on S-1 base materials when all of the following conditions are met:

a. The weld is a fillet weld.

b. The primer meets general or ship's detailed specifications.

c. The welding procedure is qualified in accordance with NAVSEA S9074-AQ-GIB-010/248 for welding over primer.

d. Inspection and acceptance criteria are performed in accordance with 6.4.1.1 and 7.4.9, respectively.

e. The welding filler material shall be limited to those allowed by Table 10-1 for the shielded metal arc welding process, unless otherwise approved by NAVSEA.

13.3 Joint preparation. Plate edges shall be prepared for welding in accordance with Section 14. Temporary backing (compatible ferrous or non-ferrous material or approved non-metallic materials) may be used in the joint root to assist in welding provided it is subsequently removed prior to completing the weld.

13.3.1 Joint configuration. Weld joint configurations prior to welding shall be in accordance with Section 11. Use of joint configurations other than those detailed on drawings, may be used when permitted by 11.4 or 14.2.4.

13.3.2 Joint fit-up. Joint fit-up in submarine structure shall be in conformance with this document prior to release of the weld joint or partial weld joint for welding.

13.3.3 Material identification. The materials to be welded shall be positively identified.

13.4 Erection requirements. Fabrication and erection requirements including sequence of welding and manufacturing plans shall comply with the requirements of 11.2 and Section 12.

13.5 Welding filler materials. Welding filler materials shall be positively identified prior to production use and shall comply with Section 10.

13.5.1 Tack welds. Tack welds shall be made using approved filler materials and shall be deposited in accordance with the requirements herein. Cracked tack welds and those of poor quality shall be removed. 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. Sufficient restraint must be provided by the remaining unbroken tack welds.

13.5.2 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.

13.6 Preheat and interpass temperature.

13.6.1 Welding. Preheat and interpass temperatures required for welding base materials and filler materials used in submarine structure are listed in Table 13-1 and shall also apply to tack welds, overlay cladding and repair welding. The temperature limits shall be based on the thickness and type of base materials being welded or the welding filler material used (when using HY and HSLA consumables), whichever is more restrictive. When temperatures are governed by the filler material, the limit shall apply to all members involved in the joint and shall be based on the joint member with the most restrictive preheat and interpass requirements. When temperatures are governed by the base material, the limits shall be based on the actual thickness and type of the specific member. Welding procedures using preheat and interpass temperatures other than those listed in this section shall require NAVSEA approval, unless otherwise specified herein.

13.6.1.1 Examples of Table 13-1 usage. Provided below are examples of Table 13-1 usage.

Example a) Governed by filler material; 1-inch HY-80 (Member 1) to 2-inch HY-100 (Member 2) using MIL-11018 filler material.

From Table 13-1, preheat and interpass temperature limits for:

Member 1 - 125 to 300 °F
Member 2 - 150 to 300 °F
MIL-11018 - 200 to 300 °F (most restrictive)

Therefore, preheat and interpass temperature for Members 1 and 2 shall be 200 to 300 °F.

Example b) Governed by base material; 1-inch HSS (Member 1) to 1½-inch HY-100 (Member 2) using MIL-7018-M filler material.

From Table 13-1, preheat and interpass temperature limits for:

Member 1 - 60 °F minimum
Member 2 – 150 to 300 °F
MIL-7018-M - not listed

Therefore, preheat and interpass temperature for Member 1 shall be 60 °F minimum and for Member 2, 150 to 300 °F.

TABLE 13-1. PREHEAT AND INTERPASS TEMPERATURE LIMITS.

PART I. LIMITS FOR S-1 AND S-2 STEELS. 1/

A. Material Preheat and Interpass Temperature Limits Based on Thickness and Group						
Material Group Number	Material Identification	Thickness (in)	Minimum Preheat Temperature, °F, 7/		Maximum Interpass Temperature, °F	Supplementary Provisions for Preheat and Interpass Temperature
			Groups A, B, C (CEN ≤ 0.43)	Groups D, E (CEN > 0.43)		
S-1 2/	Carbon Steel	t ≤ 1.25	-- 8/	125	-	For GTAW 3/, GMAW, SAW, SMAW 4/, and FCAW 5/ Process
		1.25 < t ≤ 1.75	60	175		
		T > 1.75	150	200		
		t ≤ 1.25	60	150		For SMAW and FCAW Process 6/
		1.25 < t ≤ 1.75	150	200		
		T > 1.75	200	200		
S-2 2/	Quenched and Tempered Carbon Steel	Same as above	Same as above		300	

TABLE 13-1. PREHEAT AND INTERPASS TEMPERATURE LIMITS - CONT'D.

PART I. LIMITS FOR S-1 AND S-2 STEELS – CONT'D. 1/

B. Grouping of S-1 and S-2 Base Materials			
Letter No.	**Group No. 10/ 11/**	**Applicable Document**	**Class or Type**
S-1 9/	A (CEN ≤ 0.32)	ASTM A178	Grade A
		MIL-S-15083	Class CW
		MIL-S-15083	Class 70-36 12/
		MIL-T-16286	Class a
		MIL-T-17188	Class A
		MIL-S-22698	Grade B
		MIL-S-22698	Grade E
		MIL-S-24412	
		ASTM A945	HSLA-65
	B (CEN > 0.32, ≤ 0.38)	ASTM A515	Grade 55
		ASTM A515	Grade 60 12/
		ASTM A515	Grade 65 12/
		ASTM A178	Grade C 12/
		MIL-T-16286	Class g
		MIL-T-17188	Class B 12/
		MIL-T-20157	Type E
		MIL-S-22698	Grade A
		MIL-S-22698	Grade D
		MIL-S-23284	Class 4
		MIL-S-24093	Type V
	C (CEN > 0.38, ≤ 0.43)	ASTM A515	Grade 70 12/
		ASTM A516	Grade 70 12/
		MIL-S-15083	Class B
		MIL-F-20236	
		MIL-S-22698	Grade AH36
		MIL-S-22698	Grade DH36
		MIL-S-22698	Grade EH36
		MIL-S-23284	Class 3 12/
		MIL-C-24707/1	Grade WCA
		WW-P-404	Grade A
	D (CEN > 0.43, ≤ 0.49)	MIL-S-15083	Class 65-35
		MIL-F-20670	
		MIL-S-24093	Type IV
		MIL-S-24238	Grade C
		MIL-P-24338	
		MIL-C-24707/1	Grade A2Q
		MIL-C-24707/1	Grade WCC
	E (CEN > 0.49, ≤ 0.54)	ASTM A216	Grade WCB
		ASTM A234	Grade WPB
		MIL-S-23194	Grade C
		MIL-F-24339	
		MIL-P-24691/1	Grade B
		MIL-C-24707/1	Grade A1Q
		MIL-C-24707/1	Grade WCB
		WW-P-404	Grade B
S-2	D	ASTM A537	Class 2

TABLE 13-1. PREHEAT AND INTERPASS TEMPERATURE LIMITS - CONT'D.

PART I. LIMITS FOR S-1 AND S-2 STEELS – CONT'D.

Notes to Part I:

1/ When welding in way of low melting material a preheat procedure shall be developed when changes from the temperature limits of this table are found necessary. This procedure shall be approved.

2/ The minimum preheat is specified to limit the possibility of hydrogen assisted cracking. The contractor is cautioned that it is the contractor's responsibility to produce crack-free welds regardless of the actual preheat temperature used. The group referenced in this section is selected based upon the Carbon equivalent (CEN) of the base material as shown in Note 10 below to Part I of Table 13-1. When materials of 2 different groups/thicknesses are welded, the higher preheat shall be specified.

3/ For the GTAW process, a minimum preheat of 60 °F may be used for any S-1 base material up to 1.25 inch thick. Thicker members shall comply with the preheat requirements of this section.

4/ The SMAW process listed in this section refers to use of MIL-7018-M electrodes.

5/ The FCAW process listed in this section refers to use of an allowed MIL-7XT-X-HY FCAW electrode meeting the H5 electrode destination.

6/ The SMAW and FCAW processes listed in this section refer to processes that do not meet the requirements of Note 4 or Note 5.

7/ Considering the intent of Note 2, the shipyard materials/welding engineering group may approve specific welding procedures that allow different preheat requirements based on its analysis that acceptable appropriate supporting data and service experience is available to support different preheat requirements (but not less than 60 °F) for specific S-1 and S-2 materials. These procedures and supporting information shall be submitted to the NAVSEA authorized representative for information. Shipyards may similarly approve vendors special welding procedures that allow different preheat requirements with acceptable appropriate supporting data and service experience.

8/ 60 °F preheat required for Group C Steels greater than 1 inch in thickness.

9/ Some specifications listed in the S-1 grouping allow the quenched and tempered condition. This note serves to state that materials in the quenched and tempered condition are not considered S-1 group materials.

10/ The group number referenced in this section is selected based upon the Carbon equivalent (CEN) of the base material. $CEN = C + \{0.75 + 0.25 \tanh [20 (C - 0.12)]\} \times [Si/24 + Mn/6 + Cu/15 + Ni/20 + (Cr + Mo + Nb + V)/5 + 5B]$, where the value for each element = 75 percent of the specified range for that element. For instance, if the specified silicon range is 0.10 – 0.50, then the silicon value that plugs into the CEN formula is 0.40. All Contractors must submit a request to the Shipyard Welding/Materials Engineering group or the NAVSEA authorized representative for a group number for any S-1 type material that is not listed in Table 13-1 Part I.

11/ Use of controlled chemistry for any specification allows the user to have the material reevaluated by the Shipyard Welding/Materials Engineering group or the NAVSEA authorized representative for a revised group number.

12/ If actual chemistry of the listed material identifies that Carbon content exceeds 0.30 percent, then that heat of material shall be considered a group D for the purpose of preheat temperature.

TABLE 13-1. PREHEAT AND INTERPASS TEMPERATURE LIMITS - CONT'D.

PART II. LIMITS FOR OTHER MATERIALS AS INDICATED. 1/

A. Base Material (Base material group number per NAVSEA S9074-AQ-GIB-010/248)			
Material	**Thickness (t) (inches)**	**Minimum preheat and interpass (°F)**	**Maximum preheat and interpass (°F)**
Austenitic Stainless Steels (cres) (S-8)	All	60	350
HY-80 4/ 8/ (S-11A)	t > 2¾	200	300
	1⅛ ≤ t ≤ 2¾	150	
	t < 1⅛	125 3/	
HY-100 4/ 5/ (S-11A)	t > 2¾	200	300
	1⅛ ≤ t ≤ 2¾	150	
	t < 1⅛	125	
HY-130 (S-11B)	t > 2¾	200	300
	t ≤ 2¾	150	
HSLA-80 (S-11C)	All	60	300
HSLA-100 (S-11D)	All	60	300

TABLE 13-1. PREHEAT AND INTERPASS TEMPERATURE LIMITS - CONT'D.

PART II. LIMITS FOR OTHER MATERIALS AS INDICATED - CONT'D.

A. Base Material – Cont'd			
Material	**Thickness (t) (inches)**	**Minimum preheat and interpass (°F)**	**Maximum preheat and interpass (°F)**
Aluminum Alloys (S-21, S-22, S-25 and S-26)	All	2/ 6/	2/ 6/
Bronze Alloys, except Ni Al Bronze (S-33, S-35, S-37A, S-37 B,S-38 and S-39)	All	2/	2/
Copper-Nickel (S-34)	All	60	350
Nickel Aluminum Bronze (S-36A, S-36B)	All	2/	600
Nickel-Copper (S-42)	All	60	350
Nickel-Chromium-Iron/Nickel-Chromium-Molybdenum-Columbium (S-43)	All	60	350
B. Welding Filler Material			
MIL-140S MIL-110T MIL-101T MIL-100T	All	2/	2/
MIL-12018 MIL-120S	All	225	300
MIL-11018 5/ MIL-10718 MIL-10018 MIL-100T MIL-100S (GTAW)	t > 2¾	200	300
	1⅛ ≤ t ≤ 2¾	200 7/	
	t < 1⅛	125 3/	
MIL-100S (GMAW, SAW)	t > 2¾	200	300
	1⅛ ≤ t ≤ 2¾	150	
	t < 1⅛	125 3/	

TABLE 13-1. PREHEAT AND INTERPASS TEMPERATURE LIMITS - CONT'D.

PART II. LIMITS FOR OTHER MATERIALS AS INDICATED - CONT'D.

Notes to Part II:

1/ When welding in way of low melting material, as identified in 11.5.9, a preheat procedure shall be developed when changes from the temperature limits of this table are found necessary. This procedure shall be approved.

2/ Temperature limits for joint welding, tacking and overlaying shall be as established in welding procedure qualification tests.

3/ When welding HY-80 and HSLA-80/100 using ferritic electrodes other than MIL-120 and MIL-140 series, the 125 °F minimum preheat and interpass limits may be reduced to 60 °F when welding member thicknesses 1/2 inch and less for joint designs other than butts, corners, and base metal repairs.

4/ When welding HY-80/100 with austenitic or non-ferrous type filler materials listed in Table 10-2, the minimum preheat and interpass temperatures specified may be reduced to 125 °F when welding in or to the pressure hull envelope or 60 °F when welding to structure other than the pressure hull envelope. The 125 °F minimum preheat and interpass temperature for pressure hull envelope applications may be further reduced to 60 °F either when welding member thicknesses 1/2 inch and less for joint designs other than butts and corners or after the HY-80/100 member has had 3/16 inch or two layers deposited.

5/ Where MIL-11018 electrode is permitted for welding HY-100, the minimum preheat temperature shall be 225 °F for joints where at least one member is 3/4 inch or greater in thickness and a minimum yield strength of 80 or 90 ksi is required. Where all members of the joint including the HY-100 member are less than or equal to 3/4-inch thick and a minimum yield strength of 80 or 90 ksi is required, the minimum preheat requirements specified for HY-80 base material in this table shall be used.

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

7/ After either one or both members of an HY-80 or HSLA-80 weld joint is built up 3/16 inch minimum or two layers (using these filler materials) 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 the final weld.

8/ On OSS or HSS attachment welds to HY-80 using MIL-7018-M or MIL-70S welding electrodes, the minimum preheat and interpass temperature specified may be reduced to a 60 °F minimum preheat and interpass temperature.

13.6.2 Arc stud welding. Preheat for temporary and permanent arc stud welding shall be 60 °F minimum, except that HY and HSLA material shall be preheated to a minimum of 150 °F when welding temporary and permanent studs 5/8-inch diameter and greater. In addition, the 60 °F minimum preheat temperature does not apply when welding temporary studs (such as preheat pins) 3/16-inch diameter or less. Preheat shall also be used to dry the surface of the material when moisture or moisture producing conditions (vapor or condensation) are present. When this is done, the preheat shall be applied until the area is warm to the touch and dry.

13.6.3 Application of preheat.

13.6.3.1 Methods. Preheat may be applied by any of the following methods used either singly or in combinations:

a. Resistance heaters.

b. Radiant and infra-red heaters.

c. Electrical induction.

d. Soft gas torch (gas-air).

e. Oxy-fuel torch.

f. Other approved methods.

13.6.3.2 Heating. The heating shall be of the uniform soaking type, applied preferably by means of electric heaters (resistance or induction) uniformly distributed on or around the area being welded. The spacing and wattage of heaters shall be such as to ensure that the entire welding area is maintained within the required temperature range.

13.6.3.3 Control of heating (general). Shielding for protection from wind and inclement weather shall be employed during welding and maintained until the structure has cooled to within approximately 50 °F of ambient temperature. Control of the required temperature range during welding may be accomplished by distribution of welders or by the use of welding sequence. Cyclic heating and the occurrence of temperature differentials greater than 100 °F along the joint during welding should be avoided to maintain thermal expansion and contraction stresses at a uniform level.

13.6.3.4 Control of minimum temperature. The minimum required temperature shall be established prior to welding. Loss of the minimum required temperature shall require reheating, as necessary, prior to resumption of welding. Except when permitted by Table 13-1, if the interpass temperature for HY-80/100 or HSLA material (welded with ferritic filler materials other than MIL-120 or MIL-140 series) drops below 100 °F, the partially completed weld(s) shall be inspected in accordance with 6.5.3, provided the minimum specified temperature (required by Table 13-1) for the weld is 150 °F or higher. Reheating to within the specified temperature range prior to the resumption of welding may be done before or after this inspection. For welds made with MIL-120 or MIL-140 series filler materials and HY-130 base material welded with any ferritic filler material the welds shall be dispositioned and inspected in accordance with 16.6.2.

13.6.3.5 Control of maximum temperature. The maximum required temperature shall be checked as specified in 13.6.4. If at any time during welding (except during deposition of a weld pass) the base metal temperature

is found to be above the maximum preheat and interpass temperatures noted in Table 13-1, the weld area shall be allowed to cool to within the required temperature prior to any subsequent welding.

13.6.3.6 Torch heating. Hand-held torch heating for HY and HSLA material shall be confined to tack or temporary welding operations or to those applications involving welding within a localized area. When torch heating is used for welding operations other than for tack welding, base material shall be brought up to preheat temperature with sufficient time allowed for the heat to soak through the thickness of the parts being welded. Heat shall be applied over an area approximately 6 inches beyond the weld site in all directions. Exceptions to the above are:

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, and 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 occur in the weld joint. This moisture should be removed by maintaining metal temperature above ambient temperature until the surface is warm and dry to the touch.

13.6.4 Temperature checks. Preheat temperature shall be checked prior to welding and interpass temperature shall be checked during welding between weld passes. Surveillance of preheat and interpass temperatures shall be in accordance with 6.3.1. Temperatures of 125 °F and above shall be checked using temperature indicating crayons or other temperature measuring devices. When the ambient temperature is below the required 60 °F or 32 °F (as applicable) or there is evidence of moisture on the material surface, preheat shall be applied until the area is dry and warm to the touch. Otherwise, no check of material temperature is required. Temperature indicating crayons shall not be applied to the weld metal or weld groove.

13.6.4.1 Preheat temperature measurement. 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.

13.6.4.2 Interpass temperature measurement. Interpass temperature shall be measured on the surface of the base material on the side from which welding will be performed, within 1 inch of the weld joint edge and along the joint within 3 inches of the start of the next weld pass, unless otherwise specified on an approved procedure.

13.7 Heat input.

13.7.1 Requirement. Welding heat input limitations for HY and HSLA material (welded with other than MIL-120 or MIL-140 series filler material) shall conform to the values listed in Table 13-2, unless otherwise approved

by NAVSEA or as specified herein. When welding HY and HSLA materials to other materials, the maximum heat input shall be based on the HY or HSLA thickness. Heat input shall be checked during welding. In-process monitoring of heat input shall be in accordance with 6.3.1.

TABLE 13-2. HY AND HSLA (WELDED WITH OTHER THAN MIL-120 OR MIL-140 SERIES FILLER MATERIAL) HEAT INPUT LIMITATIONS.

Thickness (inches) 1/	Maximum (joules/inch) 2/
Less than 1/2	45,000
1/2 and greater	55,000 3/

Notes:

1/ Based on thickness of thinner member.

2/ Maximums are the averages for each weld pass.

3/ For HY-100 base material repair or buildup exceeding 1/4 inch in depth and greater than 16 square inches in area and performed using MIL-10718-M or MIL-100S, the maximum heat input shall be limited to 45,000 joules/inch. This requirement does not apply to repair or buildup in HY-100 base material where the minimum yield strength is not required to exceed 82 ksi.

13.7.1.1 Alternative heat inputs. For the GMAW and SAW processes when welding HY-80 and HSLA-80, the alternative heat input limitations of Table 13-3 may be used.

TABLE 13-3. ALTERNATE HEAT INPUT LIMITATIONS.

Welding process 1/ 2/	Electrode filler wire	Shielding gas/flux 3/	Material thickness 4/	Alternate heat input (maximum joules/inch)
SAW	NAVSEA T9074-BC-GIB-010/0200 Type 100S-1	NAVSEA T9074-BC-GIB-010/0200 Type 100S-1F or equal qualified product	1 inch and greater	100,000
GMAW (spray and pulsed arc mode)	NAVSEA T9074-BC-GIB-010/0200 Type 100S-1	M-2 ($98Ar-2O_2$) or C-5 ($95Ar-5CO_2$)	1 inch and greater	100,000

Notes:

1/ Separate procedure qualification is required when using these alternate heat inputs. Qualifications shall be performed on HY-80 and HSLA-80 using a thickness that represents the thinnest material intended to be used in production. The qualification will only be applicable to the specific brand of welding electrode wire or wire/flux utilized for procedure qualification with the exception that qualification of an alternative brand of wire may be based on presently existing acceptable data. The minimum heat input used during qualification shall be 110,000 joules per inch. Preheat and interpass temperature shall be 300 to 325 °F throughout welding. NDT and destructive tests shall be as specified in NAVSEA S9074-AQ-GIB-010/248, except that regardless of test plate thickness, weld metal Charpy V-notch or 5/8 inch dynamic tear specimens as well as two all weld metal tensile tests are required. Minimum acceptable mechanical test results are as follows:

(a)	Yield strength	:	82,000 pounds per square inch minimum
(b)	Elongation (in 2 inches)	:	16 percent
(c)	Charpy V-notch	:	20 ft-lbs at minus 60 °F (average of 3 specimens with no specimen less than 15 ft-lbs and no more than one specimen less than 20 ft-lbs), and 60 ft-lbs at 0 °F (average of 3 specimens with no specimen less than 55 ft-lbs and no more than one specimen less than 60 ft-lbs)
(d)	5/8-inch dynamic tear test: (may be used in lieu of Charpy V-notch)	:	250 ft-lbs at minus 20 °F (average of 3 specimens with no specimen less than 200 ft-lbs and no more than one specimen less than 250 ft-lbs), and 425 ft-lbs at 30 °F (average of 3 specimens with no specimen less than 400 ft-lbs and no more than one specimen less than 425 ft-lbs)

In the event of a dispute between Charpy V-notch and dynamic tear test results, the dynamic tear values shall govern.

TABLE 13-3. ALTERNATE HEAT INPUT LIMITATIONS – CONT'D.

Notes: Cont'd

2/ Production testing and recording for each activity shall be as follows:

(a) Production testing of weldment run-off tabs. Weldment run-off tabs shall be provided on each of the first three production run high heat input welded joints for the purpose of establishing the mechanical properties of the weld metal for each high heat input welding process. High heat input welding is defined as welding in the range of 55,000 to 100,000 joules per inch. The runoff tab shall represent the highest heat input of the range used in the production weld joint for each welding process. Insofar as is practicable, the run-off tabs shall be produced as early as possible in the initial welding of a joint because of the consequences of failure of the weld metal to meet the mechanical property requirements. NDT and destructive tests shall be performed on the runoff tabs in accordance with NAVSEA S9074-AQ-GIB-010/248, except that the destructive tests shall consist of two all weld metal tensile tests, six Charpy V-notch tests and six 5/8-inch dynamic tear tests.

(b) All destructive tests shall meet the minimum requirements of Note 1 above. Failure of any test to meet these requirements shall be cause for the activity to cease all high heat input welding for the welding process involved. The failure test results shall be examined for validity in accordance with AWS B4.0. If failure results are found valid, all the welding represented by the welding process involved shall be rejected. The activity shall be permitted to salvage the base material by removing completely all of the non-conforming welds and rewelding using a qualified process. Six months after the initial production testing, the activity shall select a suitable production joint, and provide one weldment runoff tab for each high heat input welding process used. The runoff tab weldment shall be welded and subjected to the same testing requirements and failure provisions as for the initial production runoff tabs. Thereafter, one weldment runoff tab from a production joint for each welding process shall be selected and tested on a yearly basis for the next three years. If there are no failures at the end of the three-year period, the certification of high heat input welding for the specific welding process shall be considered satisfactorily completed.

3/ The qualification for SAW at the alternative heat input is based on the formulation of flux used in procedure qualification and any change in formulation shall require re-qualification of the welding procedures. The shipbuilder shall be responsible for insuring that they are advised of any change in formulation and the subsequent notification of NAVSEA of such changes.

4/ For the welding of tee and corner type joints, a lower limit thickness of 3/4 inch for one member may be used provided the thickness of the other member is at least 1½ inches and special weld procedures are approved by NAVSEA for each welding process and position used in the welding of these tee and corner joints.

13.7.1.2 Root passes. Root passes which will be removed during backgouging may be exempted from the requirements of 13.7.1. Root passes (including twin arc) not removed during backgouging may be exempted from the maximum heat input requirements of 13.7.1 when the following conditions are met:

a. the total cross-sectional root deposited weld thickness does not exceed 3/8 inch, and

b. the joint design is such that the surface of the root beads will not be less than 3/8 inch from the finished weld surface.

13.7.1.3 Computation of heat input. For computing the heat input (joules/inch), the following formula applies:

$$HEAT\ INPUT(joules/inch) = \frac{\text{ARC}VOLTAGE\ X\ WELDING\ AMPERAGE\ X\ 60}{RATE\ OF\ TRAVEL(inches\ per\ minute)}$$

Activities may use this formula to calculate, and incorporate in their welding procedures, acceptable burn off lengths for SMAW electrodes.

13.7.1.4 Alternate heat inputs. Except as allowed in 13.7.1.2, special procedure qualification approval by NAVSEA shall be required for alternate heat inputs exceeding the 45,000 and 55,000 joules per inch limitations.

13.8 Repairs. Repair to base materials and welds which fail to meet the requirements of the applicable material specification or this document (as applicable) shall be repaired as noted below. Welding requirements for repair of base materials and welds shall be in accordance with this section. Surface defects and damaged base material may be repair welded provided the repair weld and adjacent base material is inspected by the same methods as required for the intended use of the base material. Workmanship requirements, inspection and acceptance criteria for these repairs shall be in accordance with the requirements of Sections 14, 6 and 7, respectively. Requirements for repair of castings including repair limitations, acceptance criteria, inspection and record requirements shall be in accordance Section 15.

13.8.1 Repair of base material defects at the mill. Defects in excess of that permitted by the applicable base material specification or this document shall be repaired by grinding (to the maximum extent possible), provided the thickness is not reduced below that allowed by the base material specification or acquisition document. Defects which cannot be removed by grinding shall be repaired by welding, except that weld repair of defects in HY-80/100/130 forgings (other than fabrication scars and weld buildup to correct machining or dimensional errors) are prohibited, unless specifically approved by NAVSEA. Notation shall be made on the inspection records when required by Section 5 of areas repair welded or requiring weld repair. In addition, the areas which have been repair welded shall be marked such that marking will not be removed prior to performing all inspections as required by this document. On completion and acceptance, base material repair welds shall be considered as base metal for subsequent cold forming and straightening.

13.8.2 Repair of base material fabrication scars and other fabrication damage at shipyard. Repair welding should be limited to those locations which cannot be corrected by grinding to the extent specified in Section 14. Repairs may be accomplished prior to or after forming.

13.8.2.1 Weld repair of holes.

13.8.2.1.1 General. Holes cut into or through a member may be welded provided the original hole diameter does not exceed 2½ inches. Holes less than 1/2 inch in diameter shall be opened to 1/2-inch minimum diameter, except that holes in members 1/4 inch thick or less need only be opened to a diameter (d) equal to the thickness (t) of the member (e.g., d=t). The hole shall be shaped to 20 degrees minimum included angle as shown in Figure 30,

and shall ensure removal of all internal threads when present. Holes greater than 2½ inches in original diameter shall be repaired by expanding the hole size as required by 11.5.3 and welding a patch into the plating.

13.8.2.1.2 Partial penetration holes. Partial penetration holes shall have 3/16 minimum material remaining prior to welding, or shall be drilled through and prepared as a full penetration repair. Partial penetration holes greater than 2½ inches diameter may be welded closed to the above requirements provided the depth of the hole does not exceed 20 percent of the member thickness.

13.8.2.1.3 Full penetration holes. Full penetration holes shall be repaired using a 3/16-inch minimum backing plate of compatible ferrous or non-ferrous material or approved non-metallic material as shown on Figure 30. Permanent backing may be used to repair holes when 90 percent efficient welds are permitted per Table 11-1.

13.8.3 Repairs to welds. Removal of defects shall be considered repair.

13.8.3.1 Repairs by grinding. Every effort should be made to avoid the necessity for repair welding of minor defects that can be corrected by grinding. Defects may be repaired by grinding provided the limits of Section 14 are not exceeded. For welds in structure other than the pressure hull envelope, when the requirements of Section 14 cannot be met, defects may be repaired by grinding provided the weld is not reduced below minimum design thickness.

13.8.3.2 Repairs by welding. Repair welding of welds shall be performed subject to all of the requirements which apply to the original weld.

13.9 Weld buildup. When weld buildup is required for the conditions listed below, the buildup shall be deposited with filler materials as specified in Section 10, using methods and procedures in accordance with this section. The buildup shall be considered part of the involved weld and shall be inspected in accordance with Section 6. However, when weld buildup is required by 13.9.2:

a. re-RT or re-UT of adjacent pressure hull envelope welds (if originally required) is not required, and

b. MT inspection shall be in accordance with Table 6-1 Category 1.A(2), when the buildup is performed after completion of adjacent pressure hull envelope welds.

13.9.1 Penetrations containing 0.30 percent carbon. Weld buildup is required on all penetrations containing 0.30 percent carbon and higher, prior to welding into structure.

13.9.2 Intersection of full penetration butt welds in the pressure hull envelope. When full penetration butt welds in the pressure hull envelope intersect at an angle of less than 75 degrees, the metal bounded by the acute angle on both sides of the plate shall be built up by welding (see 11.5.3.1). The weld buildup shall consist of two layers of weld metal and shall extend from the point of butt weld intersection to a point where the

length of the chord formed between the intersecting welds is 1.5T minimum (where T is the thickness of the plating at the point of intersection). When exterior grinding is required for hydrodynamic or other considerations, application of exterior weld layers is not required provided the molded line of the hull is maintained and minimum thickness is achieved within the area bounded by the acute angle.

13.9.3 Correction of joint fit-up and surface or edge preparation. Where buildup by welding on the joint surface to correct oversize root opening or errors in joint or plate edge preparation is accomplished, it should be done prior to fitting. In all cases involving welding to correct excessive root openings, the joint edges shall not be joined until the root opening is corrected. Unless specifically approved, the sum of the buildup on the two joint edges shall not exceed 2 inches. When root openings or plate edges cannot be corrected within this limitation, repair should be made using patches, make-up plates, or other means in accordance with Section 11. The entire weld buildup to correct oversized root openings may be applied to one joint edge. In cases where only one member is involved, such as a mis-machined plate surface or plate edges which have been cut short, the 2-inch weld buildup limitation shall apply. Temporary backing (compatible ferrous or non-ferrous material or approved non-metallic materials) may be used to assist in this buildup.

13.9.4 Correction of misalignment and unfairness. Except as noted, misalignment and unfairness exceeding the tolerances of 12.3.3 shall be corrected by releasing the joints in way of the condition, aligning and fairing by strong backing only, and then rewelding the released joints. When releasing the joint is not practical, weld buildup to 3/8 inch may be used. For weld buildup over 3/8 inch in thickness, the following additional requirements apply:

a. An engineering evaluation is required.

b. Approval is required for pressure hull structure applications. For non-pressure hull structure applications, approval is required if the weld buildup thickness will exceed the following:

   (1) 3/8 inch, when the thinner plate thickness is 3/8 inch or less.

   (2) the thinner plate thickness, when the thinner plate thickness is greater than 3/8 inch, but less than or equal to 3/4 inch.

   (3) 3/4 inch, when the thinner plate thickness is greater than 3/4 inch.

c. If the weld requires MT in accordance with Section 6, MT shall be performed after deposition of each 3/8-inch thickness.

When weld buildup is used, the weld buildup shall be a minimum four to one slope and applied to one or both surfaces, as required by the application. When fairness tolerances are exceeded after welding, straightening shall be employed in accordance with Section 9 to the minimum extent necessary to bring the plating within the tolerances specified, except that HY and HSLA material shall not be faired or straightened by use of heat. Flame straightening of aluminum alloys shall not be performed without a NAVSEA approved procedure. After fairing or straightening operations, welds in affected areas shall be inspected in accordance with Section 6.

13.9.5 Insert, patch, access and closure plate requirements. Except as outlined in 13.9.2, when the design requirements of 11.5.3 and 11.5.4

cannot be met because of cutback and proximity limitations changes shall require approval.

13.10 Stress relief. When specified, material or welded assemblies shall be stress relieved for the purpose of reducing residual stresses, or maintaining dimensional stability of the weld or base metal. Stress relief shall be in accordance with Table 13-4. Post weld heat treatment other than that specified in this section shall be subject to approval. Heat soaks as detailed in Section 16 are not considered a post weld heat treatment.

13.10.1 Stress relief restrictions. HY and HSLA material or weldments shall not be stressed relieved or post weld heat treated, except as required for hot formed and heat treated welds in accordance with 9.4. Stress relief shall be performed in accordance with Table 13-4. Unless approved by NAVSEA, stress relief is 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 stress relief without NAVSEA approval for each application.

13.10.2 Temperatures. The specific temperatures and soak times for stress relief shall be in accordance with Table 13-5. References to the base material or weldment thickness in accordance with Table 13-5 apply to the thickness of the base material immediately adjacent to the weld deposit.

TABLE 13-4. STRESS RELIEF PROCEDURE.

I. Furnace	
A. General	When specified, a welded structure shall be subject to stress relief for the purpose of relieving stresses, or maintaining dimensional stability 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.
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. Stress relief 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.

TABLE 13-4. STRESS RELIEF PROCEDURE - CONT'D.

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.
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.
II. Local	
A. Heating Method	Stress relief 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.
D. Width of heating	Stress relief 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.

TABLE 13-5. STRESS RELIEVING PARAMETERS. 1/

Material	Temperature	Remarks
OSS and HSS steel	1150±50 °F 2/	
Austenitic stainless steel		Weldments shall not be stress relieved without approval.
Nickel-copper	1150±50 °F	Weldments shall not be stress relieved without approval.
Copper-nickel	575±25 °F	Heat treatment for dimensional stability only.
Aluminum		Weldments shall not be stress relieved without approval.
Bronze		Only heat treatable bronze alloys approved for the specific application may be stress relieved. The stress relief shall be as established in procedure qualification testing.

Notes:

1/ Holding times for weldments 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

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14. WORKMANSHIP REQUIREMENTS

14.1 Scope. This section contains the requirements for workmanship practices and methods associated with fabrication and welding of submarine structure.

14.2 Surface preparation.

14.2.1 Processes. Surfaces shall be prepared by any one or any combination of the following methods. Manual oxy-fuel gouging shall not be used.

a. Machining (such as planing and shearing).
b. Oxy-fuel cutting.
c. Air carbon arc gouging.
d. Chipping.
e. Grinding or burring.
f. Automatic oxy-fuel gouging.
g. Plasma arc cutting.
h. Water/abrasive cutting.

14.2.2 Weld joint surface preparation. Surfaces to be welded upon and adjacent surfaces for a distance of a minimum of 1/2 inch from the expected weld area shall be clean, dry and free of surface matter and defects such as:

a. Paint, except for primer as allowed by the welding procedure (see 13.2.6).
b. Oil, grease.
c. Moisture.
d. Objectionable scale.
e. Objectionable oxide or rust.
f. Objectionable nicks, gouges and irregularities.
g. Zinc, galvanizing, or thermal spray aluminum.
h. Excess slag.

14.2.2.1 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 the surface to be welded, as well as adjacent surfaces within 1/2 inch of the weld joint, by means of a clean stainless steel wire brush or by approved chemical or mechanical means. Welding shall take place within 16 hours after oxide film removal or the joint shall be recleaned.

14.2.2.2 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 (oxy-fuel gas) shall be used. The localized heating technique shall not be used for removing zinc coatings from HY or HSLA materials.

14.2.3 Surface finish. Flame or arc-cut surface finish shall be in accordance with the requirements of AWS C4.1. Unless otherwise specified, surface finish shall meet the acceptance of sample 2 or better.

14.2.4 Joint fit-up inspection. Joint preparation shall be in accordance with Section 11 or other approved configurations including those in approved welding procedures. When fit-up tolerances exceed the limitation of approved joint designs, correctional buildup by welding may be employed within the limitations of Section 13. For fillet welded joints, when the fit-up gap exceeds 1/16 inch as a nominal condition along the joint, fillet weld size shall be increased by an amount equal to the excess of opening above 1/16 inch. Where the gap between members exceeds 3/16 inch as a nominal condition along the joint, the condition shall be corrected by weld buildup in accordance with 13.9 or the joint shall be prepared as a full penetration weld in accordance with the requirements of 11.4.1.

14.2.5 Temporary snipes. Temporary 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 except temporary snipes are not required in way of intersecting full penetration welds for applications involving welds in foundations, non-support structure, or minor structure provided the joint design used is a single bevel type configuration (i.e., bevel J, U, or V) where the open side of the bevel is opposite of the crossing member. The location of temporary snipes shall be governed by the details of welding sequence, and snipe dimensions shall be the minimum required to allow satisfactory completion of welding in the through joint. Figures 31, 32, 33, and 34 specify dimensions of temporary snipes for the geometries shown. Bevels shall be provided on temporary snipes to allow proper closure welding and such welding shall be done in accordance with Section 13.

14.2.6 Structure. Completed structure shall meet the requirements of Sections 7, 12, and 14.

14.3 Welds, repair excavations and backgouged roots.

14.3.1 Backgouged weld roots. The roots of full penetration joints, welded from both sides, shall be backgouged after sufficient welding has been done on one side and before any welding is started on the opposite side. The weld root area shall be cleaned to sound metal in accordance with 14.2.2, and shall be contoured in accordance with 14.3.2. Exception to this requirement is permitted only by NAVSEA special weld procedure approval.

14.3.2 Backgouged weld root and weld repair excavation preparation. Backgouged roots and weld repair areas shall be contoured to produce an excavation which is fully visible to the welder and allows access of the electrode to all weld surfaces. The gouged area configuration shall have side walls sloping without sharp breaks or keyholing from the surface to the bottom, a bottom radius of approximately 1/8 inch minimum, and width sufficient to allow proper electrode accessibility and manipulation (see

Figure 35). Prior to resumption of welding, inspection of the root or repair area shall be performed as required by Section 6. Double-bevel weld joint designs may be prepared by beveling one side prior to any welding, and the second side beveled (by backgouging) after sufficient welding on the first side.

14.3.3 Slag removal. In multiple pass welds, slag shall be removed from all weld beads before starting to deposit subsequent beads. Slag shall be removed by chipping, grinding, or other suitable mechanical means. Silicates formed during GTAW or GMAW need only be removed to the extent necessary that they do not interfere with welding or required NDT.

14.3.4 Completed welds. Completed welds and 1/2 inch of adjacent base material shall comply with the requirements of Section 7. Where possible, mechanical means such as grinding or burring should be used in lieu of welding to reduce surface irregularity to an acceptable contour.

14.4 Weld contouring. Weld contouring by grinding, burring, or peening and grinding (see 14.5) may be done on any groove butt weld, groove tee weld, or groove corner weld, but shall be done to the welds listed below. For the applications noted below, recontouring is also required after weld repairs. Weld contouring shall meet the requirements of Section 7, as modified by Figure 20. When as deposited undercut is not present and the weld edges blend smoothly into the base material, grinding is not required.

a. Groove tee or corner joint connection of the pressure hull envelope to penetrations.

b. Bulkhead and bulkhead stiffener connections to the pressure hull envelope.

c. Hard tank groove tee or corner welds (see Figure 4).

d. All full penetration welds to the pressure hull envelope in the reactor compartment. In addition, when the primary shield tank is attached to the pressure hull envelope, all primary shield tank groove tee welds in or to HY or HSLA material subjected to submergence loads.

e. All full penetration welds of the shielded passageway to bulkheads in the reactor compartment.

f. Reactor compartment frame to pressure hull envelope welds.

g. All groove tee and corner boundary welds in sea chests and trunks which are attached to the pressure hull envelope.

h. Flange connections of pressure hull frames to tank tops (except web side of flange).

i. For HY-130 only, all weld repair areas in groove tee and corner welds in pressure hull structure.

14.5 Mechanical peening of welds. When required by specification or procedure, the method described herein shall be used for mechanical peening of welds.

14.5.1 General. Welds shall be free of surface matter such as slag, scale, rust and defects prior to peening to prevent entrapment of foreign materials or unfused areas in the weld. If weld bead overlap, excessive roughness or re-entrant bead contour is present, it should be corrected by grinding prior to peening. Movement of metal by the peening tool shall

remove any sharp discontinuities between the toe of the weld and the base material surface, and the peened area shall taper gradually into the base material. Peening may be used to correct distortion or minimize residual stresses and may be used for contour grinding purposes as permitted by 14.4. Peening of the last layer is permitted provided the finished contour is ground or burred prior to subsequent NDT to remove any evidence of peened surface. Peening shall not be performed on the first layer of a multiple layer weld unless approved by NAVSEA.

14.5.2 Peening tools. Peening tools shall be ground as required to obtain specified weld toe contours. Suggested peening tool tips are shown in Figure 36.

14.6 Base material.

14.6.1 Edge laminations. Laminations not acceptable to the requirements of Section 7, including laminations visually disclosed on exposed plate edges which are not included in a weld joint, shall be closed by excavating to a depth of approximately 3/4 inch, or less if the indication is removed prior to reaching 3/4 inch from the plate edge and filling the excavation with weld metal.

14.6.2 Arc strikes, nicks, gouges, and other fabrication scars. Arc strikes, nicks, gouges, and other fabrication scars up to and including 1/32-inch depth are 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. When weld repairs are required, the final repaired surface shall be essentially flush (within 1/8 inch above) with the adjacent surface, except that weld repairs shall be ground smooth and flush (within 1/16 inch above) when required for hydrodynamic purposes. All arc strikes on materials identified in 14.6.2.1 shall be dispositioned in accordance with 14.6.2.1.

Base material thickness	Maximum allowable depth (inches)
Less than 1/2 inch	1/32
1/2 inch and greater	1/16

14.6.2.1 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 2¾ percent maximum (S-4), alloy steel with total alloy content 10 percent maximum (S-5), martensitic stainless high alloy steels (S-6) and specialty martensitic stainless high alloy steels (S-6A), 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.

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

14.6.3 Removal of welds and welded attachments. When welds and welded attachments are removed from an HY or HSLA member, the accepted removal methods are:

a. Chipping.

b. Air carbon arc gouging.

c. Oxy fuel cutting.

d. Grinding.

Methods a, b, and c shall be followed by grinding. Removal of the attachments by methods a, b, or c should be accomplished at least 1/16 inch away from the member prior to grinding. The final surface shall be ground smooth and flush (within 1/16 inch above) with the adjacent surface. For removal of attachments from materials other than HY or HSLA, the 1/16-inch recommendation does not apply. Removal of attachments such as arc welded studs and spot welds shall not be accomplished by bending or hammering. All gouges, undercuts, or nicks produced during removal shall be faired out by grinding, or repair welded in accordance with the requirements of 14.6.2.

14.6.3.1 Austenitic or nonferrous weld attachment sites. Where attachments welded with austenitic or nonferrous filler materials are removed from pressure hull structure, complete removal of the austenitic or nonferrous weld metal shall be verified with an etchant that has been demonstrated to distinguish the materials. Etchants shall be prepared and used in accordance with good metallurgical practice. If a nonferrous or austenitic attachment on pressure hull structure requires temporary removal and is re-installed in approximately the same location (within 1/2 inch for stud welds, or within half of the original footprint but no more than 1½ inch from the original site for other structural members), then complete removal of the nonferrous or austenitic filler material and verification with an etchant is not required. Where these attachments are removed from non-pressure hull structure, complete removal of the austenitic or non-ferrous weld metal shall be verified with an etchant only when it is necessary to make ferritic welds over these areas.

14.6.3.2 Inspection of removed welds and welded attachment sites. Upon removal of welds and attachments, the areas which are ground or repair welded shall be inspected as required by Section 6.

14.7 Marking and other mechanical surface indentations. Mechanical surface indentations such as prick punch lay-out marks on submarine structure shall be kept to a minimum. Material identification or layout indentations shall be made with low stress die stamps or other approved techniques. Use of high stress die stamps on pressure hull structure is prohibited.

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15. CASTINGS

15.1 Scope. This section contains the requirements for castings such as NDT, acceptance criteria and repair. Castings which have passed the inspection requirements of 15.2 and 15.3 shall be treated in accordance with 15.5 for further fabrication and repair requirements.

15.2 General requirements. Castings shall comply with the requirements of the applicable material specification and this section. If no material specification or standards are invoked, drawings for castings which are specified in Table 15-1 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.

All casting material test samples shall be heat treated and processed in a manner representative of that which is used on the casting(s) they represent.

Records, as required by Section 5, shall be maintained for all castings. These records shall include location of all nominal and special repairs as specified in 15.4.5.

15.2.1 Surface cleaning and preservation. Prior to inspection, castings shall be cleaned by abrasive blastings or mechanical processes in accordance with the applicable material specification. After final inspection, castings shall be preserved in accordance with the applicable material specification.

15.2.2 Stress relief. Stress relief requirements shall be in accordance with 13.10.

15.2.3 Hardness. HY-80/100/130 castings shall be tested for Brinell hardness in accordance with the acceptance criteria of Section 7.

15.2.4 Design requirements. The casting designer shall be responsible for implementing the requirements as specified in 15.3 by selecting and identifying those areas requiring NDT on the engineering drawings using symbols in accordance with AWS A2.4.

When RT inspection is required, the foundry or activity performing the RT shall be responsible for preparing the radiographic shooting sketch (RSS) in accordance with NAVSEA T9074-AS-GIB-010/271 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.

15.3 Casting NDT requirements. NDT inspection shall be performed using personnel and procedures qualified in accordance with Section 4. In addition, 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 of these shall be subject to NAVSEA approval. Castings shall be inspected by the NDT methods, and to the extent as specified in Table 15-1. All NDT results, including radiographs, together with records of nominal and special weld repairs performed, shall be obtained by the receiving activity and reviewed for compliance with the acceptance criteria noted herein, and the applicable material specification. Areas exhibiting unacceptable soundness or surface defects shall be repaired in accordance with 15.4.

15.3.1 Inspection. Inspection of castings shall include the following:

a. Inspection for surface defects in accordance with the applicable material specification.

b. Dimensional inspection for compliance with drawing or acquisition requirements.

c. Verification that identification markings have been maintained.

15.3.2 MT/PT inspection. Accessible surfaces of castings shall be inspected to the extent specified in Table 15-1. MT shall be performed on ferrous materials and PT performed on non-ferrous materials, except that 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.

15.3.2.1 MT/PT inspection acceptance criteria. Final inspection shall be performed after all required machining or grinding has been completed. Relevant linear indications greater than 1/4 inch in length shall be rejected. Where PT is used for the inspection of weld clad surfaces, any defects found in adjacent base material shall be evaluated as noted herein.

15.3.3 RT inspection. Castings shall be RT inspected to the extent specified in Table 15-1.

15.3.3.1 RT inspection acceptance criteria. When RT is required by Table 15-1, casting radiographs shall meet the acceptance criteria specified in Tables 15-2 through 15-5 as applicable and 15.3.3.2.

TABLE 15-1. NDT REQUIREMENTS FOR CASTINGS.

INSPECTION CATEGORY (design application)	NDT REQUIRED	
	RT 1/ extent of coverage minimum (percent) 2/ 3/	MT/PT 4/ extent of coverage minimum (percent)
1) Castings in the Pressure Hull Envelope.	100	100 (of all accessible casting surface)
2) Castings in Support and Containment Structure.	75	100 (of all accessible casting surface)
3) Castings designed for Grade A Shock.	75	100 (of all accessible casting surface)
4) Castings not covered above but falling into one of the following categories: a) Castings which by failure would prevent normal propulsion, steering, or diving. b) Castings designed to be stressed in excess of 2/3 of yield strength, when yield is the basis for design. c) Castings designed to be stressed in excess of 1/2 of ultimate strength, when ultimate is the basis for design. d) Towing and rigging fitting castings.	50	100 (of all accessible surface areas within 3 inches of the contiguous surface to which welds will be applied)
5) Castings not covered above but welded into submarine structure (i.e., foundations, soft tanks, etc.).	RT Not Required	100 (of all accessible surface areas within 3 inches of the contiguous surface to which welds will be applied)

Notes:

1/ UT inspection may be used in lieu of RT where the geometry would not yield satisfactory RT results or where casting thickness is beyond practical RT limits. (see 15.3)

2/ 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.

3/ 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. (see 15.2.4)

4/ See 15.3.2.

TABLE 15-2. RT ACCEPTANCE CRITERIA FOR FERROUS CASTINGS OF CARBON STEEL, CORROSION-RESISTANT STEEL, COBALT-CHROMIUM-TUNGSTEN, AND ALLOY STEELS (INCLUDING HY-80/100/130).

Thickness (inches)	ASTM standard	Minimum percent RT coverage required (see Table 15-1)	Shrinkage	Porosity	Inclusion	Hot tears or cracks	Inserts or chaplets
			Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph
Less than 1	E446 1/	100	CA 2	A2	B2	NONE	NONE
			CB 2				
			CC 2				
			CD 2				
		75	CA 3	A3	B3	NONE	NONE
			CB 3				
			CC 3				
			CD 3				
		50	CA 4	A4	B4	NONE	NONE
			CB 4				
			CC 4				
			CD 4				
		Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	CA 5	A5	B5	NONE	CATEGORY F
			CB 5				
			CC 5				
			CD 5				

TABLE 15-2. RT ACCEPTANCE CRITERIA FOR FERROUS CASTINGS OF CARBON STEEL, CORROSION-RESISTANT STEEL, COBALT-CHROMIUM-TUNGSTEN, AND ALLOY STEELS (INCLUDING HY-80/100/130) - CONT'D.

Thickness (inches)	ASTM standard	Minimum percent RT coverage required (see Table 15-1)	Shrinkage	Porosity	Inclusion	Hot tears or cracks	Inserts or chaplets
			Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph
1 to Less than 2	E446 1/	100	CA 3	A3	B3	NONE	NONE
			CB 3				
			CC 3				
			CD 3				
		75	CA 4	A4	B4	NONE	NONE
			CB 4				
			CC 4				
			CD 4				
		50	CA 5	A5	B5	NONE	CATEGORY F
			CB 5				
			CC 5				
			CD 5				
		Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	ENGINEERING JUDGEMENT (CASTING REVIEW)				

TABLE 15-2. RT ACCEPTANCE CRITERIA FOR FERROUS CASTINGS OF CARBON STEEL, CORROSION-RESISTANT STEEL, COBALT-CHROMIUM-TUNGSTEN, AND ALLOY STEELS (INCLUDING HY-80/100/130) - CONT'D.

Thickness (inches)	ASTM standard	Minimum percent RT coverage required (see Table 15-1)	Shrinkage	Porosity	Inclusion	Hot tears or cracks	Inserts or chaplets
			Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph
2 to Less than 4½	E186 2/	100	CA 3	A3	B3	NONE	NONE
			CB 3				
			CC 3				
		75	CA 4	A4	B4	NONE	EA 3
			CB 4				
			CC 4				
		50	CA 5	A5	B5	NONE	EA 4
			CB 5				
			CC 5				
		Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	ENGINEERING JUDGEMENT (CASTING REVIEW)				

TABLE 15-2. RT ACCEPTANCE CRITERIA FOR FERROUS CASTINGS OF CARBON STEEL, CORROSION-RESISTANT STEEL, COBALT-CHROMIUM-TUNGSTEN, AND ALLOY STEELS (INCLUDING HY-80/100/130) - CONT'D.

Thickness (inches)	ASTM standard	Minimum percent RT coverage required (see Table 15-1)	Shrinkage	Porosity	Inclusion	Hot tears or cracks	Inserts or chaplets
			Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph
4½ and over	E280 3/	100	CA 2	A3	B3	NONE	NONE
			CB 2				
			CC 2				
		75	CA 3	A4	B4	NONE	EA 3 PER ASTM E186
			CB 3				
			CC 3				
		50	CA 4	A5	B5	NONE	EA 4 PER ASTM E186
			CB 4				
			CC 4				
		Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	ENGINEERING JUDGEMENT (CASTING REVIEW)				

TABLE 15-2. RT ACCEPTANCE CRITERIA FOR FERROUS CASTINGS OF CARBON STEEL, CORROSION-RESISTANT STEEL, COBALT-CHROMIUM-TUNGSTEN, AND ALLOY STEELS (INCLUDING HY-80/100/130) - CONT'D.

Notes:

1/ Where ASTM E446 is specified, use the following:

(a) Medium voltage (nominal 250 kVp X-rays) reference films for all X-ray sources up to, but not including, 320 kVp.

(b) 1 MV X-rays and Iridium 192 reference films for all X-ray sources from 320 kVp up to, but not including, 2 MV and for Iridium 192 sources.

(c) 2 MV to 4 MV X-rays and Cobalt 60 reference films for all X-ray sources from 2 MV to 10 MV and for Cobalt 60 sources.

2/ Where ASTM E186 is specified, use the following:

(a) 1 MV X-rays and Iridium 192 (called "1 to 2 MeV X-rays" in previous ASTM editions) reference films for all X-ray sources up to, but not including, 2 MV and for Iridium 192 sources.

(b) 2 MV X-rays and Cobalt 60 (called "gamma rays" in previous ASTM editions) reference films for all X-ray sources from 2 MV up to, but not including, 4 MV and for Cobalt 60 sources.

(c) 4 MV to 30 MV x-rays (called "10 to 24 MeV X-rays" in previous ASTM editions) reference films for all X-ray sources from 4 MV to 30 MV.

3/ Where ASTM E280 is specified, use the following:

(a) 2 MV X-rays and Cobalt 60 (called "gamma rays" in previous ASTM editions) reference films for all X-ray sources from 2 MV up to, but not including 4 MV, and for Cobalt 60 sources.

(b) 4 MV to 30 MV (called "10 to 24 MeV X-rays" in previous ASTM editions) reference films for all X-ray sources from 4 MV to 30 MV.

TABLE 15-3. RT ACCEPTANCE CRITERIA FOR COPPER BASED CASTINGS OF NICKEL BRONZE, COPPER-NICKEL, ALUMINUM BRONZE, NICKEL-ALUMINUM-BRONZE, MANGANESE BRONZE, AND NICKEL-COPPER.

Thickness (inches)	Minimum percent RT coverage required (see Table 15-1)	1/ ASTM E272									1/ ASTM E186
		Shrinkage			Dross		Porosity		Inclusions		Inserts or chaplets
		Type	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph
1 and less	75 or greater	Feathery	CD 3	X-ray 2/	BB 2	X-ray 2/	A 4	X-ray 2/	BA 3	Gamma 3/	EA 4
		Spongy	CD 3	Gamma 3/							
		Linear	CA 3	Gamma 3/							
	50	Feathery	CD 4	X-ray 2/	BB 3	X-ray 2/	A 5	X-ray 2/	BA 4	Gamma 3/	EA 5
		Spongy	CD 4	Gamma 3/							
		Linear	CA 4	Gamma 3/							
	Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	Feathery	CD 5	X-ray 2/	BB 4	X-ray 2/	ENGINEERING JUDGEMENT (CASTING REVIEW)				
		Spongy	CD 5	Gamma 3/							
		Linear	CA 5	Gamma 3/							
Over 1	75 or greater	Feathery	CD 4	X-ray 2/	BB 4	X-ray 2/	A 4	Gamma 3/	BA 4	Gamma 3/	EA 4
		Spongy	CD 4	Gamma 3/							
		Linear	CD 4	Gamma 3/							
	50	Feathery	CD 5	X-ray 2/	BB 5	X-ray 2/	A 5	Gamma 3/	BA 5	Gamma 3/	EA 5
		Spongy	CD 5	Gamma 3/							
		Linear	CA 5	Gamma 3/							
	Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	ENGINEERING JUDGEMENT (CASTING REVIEW)									

TABLE 15-3. RT ACCEPTANCE CRITERIA FOR COPPER BASED CASTINGS OF NICKEL BRONZE, COPPER-NICKEL, ALUMINUM BRONZE, NICKEL-ALUMINUM-BRONZE, MANGANESE BRONZE, AND NICKEL-COPPER – CONT'D.

Notes:

1/ ASTM E272 and ASTM E186 reference radiographs (films) shall be applied as indicated. Reference films specified in ASTM E272 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 15-4. RT ACCEPTANCE CRITERIA FOR TIN-BRONZE CASTINGS.

Thickness (inches)	Minimum percent RT coverage required (see Table 15-1)	1/ ASTM E310				1/ ASTM E186
		Shrinkage		Porosity	Inclusions	Inserts or chaplets
		Type	Reference radiograph	Reference radiograph	Reference radiograph	Reference radiograph
1/2 and less	75 or greater	Linear, feathery or spongy	CA 3 CD 2	A 3	2/ B 3	EA 2
	50	Linear, feathery or spongy	CA 4 CD 3	A 4	2/ B 2, B 4	EA 3
	Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	Linear, feathery or spongy	CA 5 CD 4	A 5	B 5	EA 4
Over 1/2	75 or greater	Linear, feathery or spongy	CA 4 CD 3	A 4	2/ B 2, B 4	EA 3
	50	Linear, feathery or spongy	CA 5 CD 4	A 5	B 5	EA 4
	Castings not requiring RT but inadvertently radiographed or radiographed for information purposes	Linear, feathery or spongy	ENGINEERING JUDGEMENT (CASTING REVIEW)			

Notes:

1/ ASTM E310 and ASTM E186 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 15-5. RT ACCEPTANCE CRITERIA FOR ALUMINUM CASTINGS.

Thickness (Dimension for finished part) (inches)	1/ ASTM E155													
	Type of discontinuity													
	Hot cracks, cold cracks, cold shuts, mis-runs	Gas holes		Gas porosity				Shrinkage				Foreign material			
				Round		Elongated		Cavity		Sponge		Less dense		More dense	
		Plate (inches)	Severity Grade	Plate (inches)	Severity Grade	Plate (inches)	Severity Grade	Plate (inches)	Severity Grade	Plate (inches)	Severity Grade	Plate (inches)	Severity Grade	Plate (inches)	Severity Grade
1/2 and less	None	1/4	3	1/4	4	1/4	4	1/4	3	1/4	4	1/4	3	1/4	3
Over 1/2 through 1¼	None	3/4	5	3/4	5	3/4	5	1/4	4	3/4	4	3/4	4	3/4	4
Over 1¼ through 2	None	3/4	6	3/4	6	3/4	6	1/4	5	3/4	5	3/4	5	3/4	5
Over 2 through 3	None	3/4	7	3/4	7	3/4	7	1/4	7	3/4	6	3/4	6	3/4	6
Over 3	None	3/4	8	3/4	8	3/4	8	1/4	8	3/4	8	3/4	7	3/4	7

Note:
1/ ASTM E155 reference radiographs (films) are to be applied as indicated. The films indicated are to be used for all production radiography sources.

15.3.3.2 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 15-2 through 15-5.

15.3.3.2.1 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.

15.3.3.2.2 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.

15.3.3.2.3 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.

15.3.3.2.4 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.

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

15.3.3.2.6 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 in the reference radiograph shall be the limiting number for a production radiograph.

15.3.3.2.7 Elongated or worm hole type gas discontinuities. The reference radiographs do not illustrate elongated or worm 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.

a. Source placed perpendicular to the length of gas hole, evaluate with reference shrinkage film.

b. Source placed diametrically or into the diameter of the gas hole, evaluate with reference gas film.

15.3.3.2.8 Mottling. Radiographs of certain cast materials may exhibit a characteristic mottled appearance with distinct radiographic 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 E310 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.

15.3.3.2.9 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.

15.3.3.2.10 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.

15.3.3.2.11 Inadvertent radiography. Inadvertent radiography shall be dispositioned in accordance with MIL-STD-2035.

15.3.4 UT inspection. UT inspection may be performed in lieu of RT when permitted by Table 15-1.

15.3.4.1 UT inspection acceptance criteria. When UT inspection is used in lieu of RT, final inspection shall be performed with the surface of the material in the condition specified in an 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 approved inspection procedure. Castings with UT indications in excess of the acceptance standards contained in the qualified procedures shall require the casting to be rejected and repaired. Alternately the UT rejected casting may be re-inspected by RT and, if shown to meet the applicable RT acceptance standards, may be accepted.

15.4 Casting repair requirements. Castings which fail to meet the applicable acceptance standards when inspected to the requirements of 15.3 shall be repaired by grinding or welding, as appropriate. Repair of rejectable indications in castings shall insure the removal of the defect to the extent necessary to bring the area within the acceptance criteria for the casting or 15.4.2.2, as applicable. RT may be employed after excavation, as detailed in 15.4.3.3, to determine the soundness of the remaining material.

15.4.1 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 by the originally required surface inspection techniques to the acceptance standards of 15.3. Re-RT/UT inspection required if grinding was performed to remove unacceptable RT/UT.

15.4.2 Repair by welding. Defects that cannot be repaired by grinding in accordance with 15.4.1 or where a minimum design thickness cannot be maintained shall be repaired by welding. Welding requirements for repair of castings shall be in accordance with Section 13, using procedures and welders qualified in accordance with Section 4. Unless otherwise approved by NAVSEA or as noted below, repairs shall be made using filler materials permitted by Section 10. Limits of repair welding, inspection requirements and acceptance criteria are contained in this section.

15.4.2.1 Weld repair of HY-80/100/130 castings. Weld repair of HY-80/100/130 castings shall be performed after completion of all heat treatments and mechanical testing. MIL-10718-M and MIL-100S-1 filler materials may be used to perform minor repairs in HY-100 castings. Use of MIL-10718-M and MIL-100S-1 filler materials to repair nominal and special repairs in HY-100 castings shall require approval. No post weld stress relief or heat treatment shall be performed after such weld repairs.

15.4.2.2 General limitations. Excavated areas to be weld repaired should meet the contour requirements of Figure 37. As a minimum, the excavated area shall provide a 20 degree included side wall angle to permit proper electrode accessibility and manipulation. In addition, the following requirements apply:

a. On casting surfaces which do not require subsequent machining defects requiring repair shall be excavated until free of linear indications greater than 1/4 inch (as determined by MT/PT inspection) or until a depth of 3/8 inch is reached. Beyond a depth of 3/8 inch, the excavation shall be free of linear indications over 1/2 inch long as determined by MT/PT inspection prior to repair welding.

b. On casting surfaces which require subsequent machining to produce the final configuration, defects requiring repair shall be excavated until removed (as determined by MT/PT inspection) or until a depth of 3/8 inch below the final machined dimension is reached. Beyond a depth of 3/8 inch below the final machined dimension, the excavation shall be free of linear indications over 1/2 inch long as determined by MT/PT inspection prior to repair welding.

15.4.2.3 Minor repairs. Minor repairs are repairs of surface defects for which the excavations do not exceed the following limits:

a. The maximum depth does not exceed 1/2 inch or 20 percent of the casting thickness, whichever is less.

b. Individual repair areas do not involve more than 2 percent of the casting surface.

c. The total repair area does not exceed 10 percent of the casting surface.

15.4.2.3.1 Weld buildup. Weld buildup for correction of casting dimensions or machining errors not exceeding 10 percent of the total area of

the casting shall be considered to be a minor repair when the weld buildup is within the following limitations:

a. 3/16-inch maximum buildup for wall thickness 1 inch and under.

b. 20 percent of wall thickness maximum buildup for wall thickness over 1 inch but not to exceed 1/2 inch.

These thickness limitations apply to the finished condition. Weld buildup exceeding these thickness and area limitations shall be performed only with approval on a case basis by the shipyard welding engineering group or the NAVSEA authorized representative. Areas which are built up by welding in excess of these requirements shall be recorded by sketch, or other means to identify the buildup areas, dimensions, and inspection accomplishment.

15.4.2.4 Nominal repairs. Nominal repairs are those which exceed the limitations stated in 15.4.2.3 for minor repairs but which do not exceed 2 inches or half the casting thickness in depth, whichever is less. The total accumulated volume of weld metal involved for nominal repairs shall not exceed 4 percent of the volume of metal in the casting. Adjacent nominal repairs shall be separated by a distance equivalent to the maximum dimension of the smaller repair or 3/4 inch, whichever is less. If this condition is not met, the repairs shall be joined.

15.4.2.5 Special repairs. Special repairs are those which exceed the limitations of 15.4.2.4 for nominal repairs. Special repairs are permitted only with approval on a case basis by the shipyard welding engineering group or the NAVSEA authorized representative. These repairs may include excavations completely through the wall of the casting which may be repaired by employing a suitable contoured insert. The insert shall be of identical material to the casting, and fully documented to this document. It shall have radius corners (3/4-inch minimum). If adjacent special repairs are closer to each other than 3/4 inch, they shall be joined to make a single repair. Requests for approval of any repairs in this category shall be accompanied by a suitable sketch or photograph showing complete dimensional details, proposed welding and inspection procedures criteria, any post weld heat treatments (as applicable), and in addition, shall include a record of all previous repairs except minor repairs.

15.4.3 NDT requirements of weld repairs. All castings which have been repaired or built-up shall be inspected in accordance with 15.3.1. Weld repairs shall be inspected as detailed below.

15.4.3.1 VT inspection. VT inspection of weld repairs is required. Acceptance criteria shall be in accordance with Section 7, and marking in accordance with 15.4.4.

15.4.3.2 MT/PT inspection. MT/PT inspection and acceptance criteria of weld repairs shall be in accordance with Section 7. MT/PT inspection shall be performed on all weld repair and buildup areas in the final repair surface condition. For HY-80/100/130 castings, final inspection shall be made no sooner than 7 days (160 hours) after the weld is completed and has cooled to ambient temperature. At the contractor's or foundry's risk, this minimum 7-day (160-hour) inspection need not delay further processing of the casting, provided the accomplishment of all required inspection is documented. For castings other than HY-80/100/130, final inspection of the

weld repair shall be made after any required post weld heat treatment (i.e., stress relief).

15.4.3.3 RT inspection. RT is not required for minor repairs as defined in 15.4.2.3 nor for weld buildup to the extent permitted in 15.4.2.3.1. 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 except that bolt holes which are weld repaired and will be re-drilled within 1/2D, where D is the bolt hole diameter, of the initial location (centerline to centerline) of the bolt hole do not require re-RT. Repair of casting RT indications is required only to the extent of bringing such indications within the applicable RT acceptance standards. When radiographs are made after repair excavation and prior to weld repair to determine the extent of any remaining discontinuities, the acceptance standards for the designed thickness of the casting in the excavated area shall apply. UT inspection, employed in accordance with an approved procedure, may be used for such determinations. For post weld repair radiography, discontinuities occurring in the weld metal shall be judged for acceptance to the applicable reference radiograph for casting defects. If the combination of weld defects and casting defects does not exceed the discontinuities allowed in the applicable reference radiograph for castings, the area shall be accepted. Lack of fusion and incomplete penetration shall be evaluated in accordance with the Class 3 acceptance criteria of MIL-STD-2035 for welds. Slag and porosity shall be judged as sand inclusions and gas, respectively.

15.4.3.4 UT inspection. Weld repairs in castings that would require RT but cannot be RT inspected due to configuration or obstructions may be UT inspected for acceptance. The weld surface shall be ground flush and inspected in accordance with the original base material specification. In addition, a volume extending 1/2 inch from the weld toes and equal to the depth of excavation shall be inspected in accordance with MIL-STD-2035, Class 2 requirements. The design material thickness (DMT) shall be based on the depth of excavation. If the UT shear wave inspection cannot be performed, longitudinal wave UT may be performed provided a proposed procedure and acceptance criteria are submitted and approved by NAVSEA.

15.4.4 Repair weld marking. 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.

15.4.5 Records of weld repairs. Records of all nominal and special weld repairs shall be maintained as required in Section 5 and shall include the following:

a. The location, size, and depth of each weld repair (or thickness of buildup) shall be marked on a suitable sketch of the casting. Photographs, with weld repair dimensions shown, may be made of the casting after preparation and prior to repair welding. A scale should be placed on the casting, visible on each photograph, for use in approximating dimensions to assist in subsequent inspection.
b. Reference to welding procedure/electrode qualification document.
c. Weld repair inspection results.
d. Approval authority.

e. Welder identification.

f. For HY-100 castings, filler metal identification (electrode type, heat, lot, control number, or batch number, as applicable) if repaired with MIL-10718-M or MIL-100S-1 filler materials.

g. Post weld heat treatment (when required).

15.5 Castings released for fabrication. Castings which have satisfactorily passed the inspection requirements of 15.2 and 15.3, or have been repaired as necessary to pass the requirements (i.e., the casting has met the base material specification requirements including repair of base material defects), shall be considered as wrought material for further fabrication purposes with the exceptions related to the repair of casting defects as specified in 15.5.1, 15.5.2 and 15.5.3.

15.5.1 Minor repair or weld buildup. All repair or weld buildup operations of castings, such as casting defects, temporary attachment sites, arc strikes, fabrication damage and weld buildup for correction of misalignment, unfairness or machining errors, which do not exceed the minor repair limitations of 15.4.2.3 or the weld buildup limitations of 15.4.2.3.1 shall be dispositioned as wrought material. Inspection requirements, including extent and type of inspection to be performed for weld repair, shall be based upon the intended use of the casting (e.g., pressure hull envelope, support structure). For those castings which fulfill multiple functions (e.g., portions of the casting act as pressure hull envelope and other portions act as support structure), the inspection requirements for the applicable usage location applies.

15.5.2 Other repair or weld buildup operations. All repair or weld buildup operations of castings other than those allowed in 15.5.1, shall be repaired as specified in 15.4.

15.5.3 Defect removal allowances for casting defects. For all casting defects after castings have been released for further fabrication, the inspection requirements of Section 6 and acceptance standards of Section 7 apply with the following exceptions:

a. Rejectable MT indications found after machining or fabrication/installation welding need only be removed to the following extent:

   (1) Until the indication length is reduced to 1/4 inch or less for depths of excavation up to and including 3/8 inch.

   (2) Until the indication length is reduced to 1/2 inch or less for depths of excavation greater than 3/8 inch and up to and including one inch. Discontinuities in excavations over 1 inch below the as-cast or final machined surface may be sealed and the excavation repaired provided the root layers are MT inspected and comply with the requirements of 7.5.1.

b. Rejectable linear PT indications shown to be associated with the casting need not be removed if VT inspection verifies the indication to be less than or equal to 1/4 inch in length. Linear indications at the toe of the weld shall be evaluated to the respective weld class for the weld involved. Where the linear indication exceeds 1/4 inch in length, removal shall be as established in a. above. Rounded indications, up to and including 5/16 inch diameter, shall not be cause for rejection.

c. Rejectable RT or UT indications associated with fabrication or installation welds need not be removed if it is established that the indications are contained within the casting. Comparison to the radiographs of the casting of the area involved is an acceptable method for assessment of the indications.

15.5.4 Cold forming. Cold forming of castings (such as straightening to avoid weld buildup in way of misalignment between the casting and adjacent structure), which have passed the inspection requirements of 15.2 and 15.3, shall require approval by the shipyard welding engineer or the NAVSEA authorized representative.

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16. REQUIREMENTS FOR MIL-120 AND MIL-140 SERIES FILLER MATERIALS.

16.1 Scope. This section contains additional and modified welding requirements, including welding procedure and performance qualification, and inspection for MIL-120 and MIL-140 series filler materials.

16.2 Qualification requirements. Section 4 requirements shall apply, except as modified herein.

16.2.1 Welding procedure qualification. Procedures for welding using MIL-120 or MIL-140 series filler materials shall be qualified in accordance with a test program specifically approved by NAVSEA. The test program shall demonstrate that welds made in accordance with the procedure being qualified will have acceptable quality, satisfy mechanical property requirements, and show adequate control of weld metal hydrogen. Satisfactory performance over the full range of cooling rates allowed by the procedure must be proven. Welding procedures and qualification records require NAVSEA approval.

As a prerequisite for welding using these filler materials, the following requirements for welding procedure qualification shall apply, unless otherwise approved by NAVSEA:

16.2.1.1 Filler material. The welding filler material shall be the same MIL-type and electrode diameter (SMA only) to be used in production fabrication.

16.2.1.2 Test parameters. Two test weldments representing the maximum and minimum cooling rates to be used in production shall be produced for each combination of electrode size (SMA only), welding process, and welding position. Tests must be done in each position unless otherwise approved by NAVSEA. The fast cooling rate test weldment shall be produced using the lowest heat input and the lowest preheat/interpass temperature on the thickest section (not to exceed 2 inches) to be used in production. The slow cooling rate test weldment shall be produced using the highest heat input and highest preheat/interpass temperature on the thinnest section to be used in production. Qualification for applications less than 3/4 inch thick shall require NAVSEA approval of the test plan and evaluation criteria. Preheat/interpass temperature and specific welding parameters, including arc voltage, welding current, wire feed speed (for all GMAW and SAW), and travel speed, shall be recorded for each pass deposited.

16.2.1.3 Test assembly. Minimum test assembly length shall be 30 inches. Minimum test assembly width shall be 18 inches. Joint designs shall be limited to a MIL-STD-22 B2V.3 with a 3/16±1/16 inch root gap or a B1V.1 with 1/2±1/16-inch root gap and a 1/4- to 1/2-inch thick backing strap of the same material as the test plates. The included angles shall be 45 to 50 degrees. All 2-inch thick test assemblies shall utilize the B2V.3 joint design with a bevel depth balanced to ±1/8 inch. An accurate record of the actual joint fitup shall be included in the record. Weldments shall be fully restrained by clamps or other means during heating, welding and cooling. The table or other supporting device shall be stiff enough to prevent weldment distortion.

16.2.1.4 Heat input. In all cases, production minimum and maximum heat input limits shall be based on welding procedure qualification. The heat input limitations of 16.6.3 may be used as guidance. Weld beads shall be located within the joint such that the target heat input may be used while

maintaining acceptable weld quality. The direction of welding shall be the same for all beads in a weldment. In addition, bead placement in a layer should be from one sidewall to the other, with the "start" sidewall being the same for all layers in a weldment, as far as practical. For each test plate, a record of the actual weld bead placement and sequence shall be recorded for information. Heat inputs should be maintained within ±2 kJ/in of the target heat input for each weld pass for GMAW or SAW processes and ±4 kJ/in for each SMAW electrode deposited with a ±2 kJ/in average for each weld pass. If a weld pass or bead falls outside the acceptable heat input tolerance, it should be removed by grinding and recorded as such. Heat input shall be determined using the welding current and voltage measured using calibrated instruments. Current measurements shall be performed using meters which read average current, not RMS (such as tong type meters). For GMAW and SAW processes, voltage measurements shall be made at the wire feeder. For the SMAW process, the voltage shall be measured between the electrode holder and test plate. Heat input shall be calculated using the heat input formulas given in Section 13.

16.2.1.5 Preheat. The preheat and interpass temperatures shall be controlled and measured as specified in 16.6.2 including the procedure for planned interruptions. The minimum temperature that will be allowed by the welding procedure +0 -25 °F shall be used for the low heat input/low preheat/fast cooling rate test weldment and the maximum temperature that will be allowed by the welding procedure +25 -0 °F shall be used for the high heat input/high preheat/slow cooling rate test weldment.

16.2.1.6 Root passes. If required for ease of welding, the root layer may be deposited with a heat input other than that targeted or specified by 16.6.3. For single-V joints, this layer must not exceed one bead in thickness and must use the same wire type, lot or heat, process, and welding position as used for the fill passes. For double-V joints, alternate welding parameters may be used for root passes on both sides welded, but only one such pass may be deposited on each side welded. In addition, for double-V MIL-120S-1 joints, the root passes may be deposited using the shielded metal arc process with MIL-12018 filler material. In this case, two passes may be deposited on the first side welded using a welding position other than the qualification position to be welded.

16.2.1.7 Heat soak. Intra weld or post weld soaks shall be performed during procedure qualification to the minimum time and temperature allowed for production welds in accordance with 16.6.4.

16.2.1.8 Repairs. Repairs shall only be allowed to correct surface defects and defects not exceeding 1/8 inch below the weld surface. The location of such repairs shall be documented so that weld metal mechanical test specimens can be located to avoid the repair area.

16.2.1.9 Nondestructive testing. Prior to destructive testing, each test weldment shall be nondestructively tested to the requirements of NAVSEA S9074-AQ-GIB-010/248. The backing bar shall be removed and the weld ground flush on both sides prior to any nondestructive testing. Final nondestructive test inspections shall be performed no sooner than 24 hours after the weld has cooled to ambient temperature. Weld metal within one inch from each end of the qualification test assembly need not be evaluated. All transverse indications and test failures shall be reported.

16.2.1.10 Destructive testing. Each test weldment shall be destructively tested as follows:

a. For each side welded for B2V.3 assemblies, the type and quantity of test specimens to be removed shall be:

   (1) Two all-weld metal 0.505-inch diameter tensile tests.

   (2) For MIL-120 series filler material, ten Charpy V-notch specimens, five tested at 0 °F and five tested at -60 °F. For MIL-140 series filler material, three dynamic tear specimens shall be tested at +30 °F.

   Results from each side of B2V.3 assemblies shall be evaluated and reported separately. Failure of either side shall constitute failure of the entire assembly.

b. For B1V.1 assemblies, the type and quantity of test specimens to be removed shall be:

   (1) Two all-weld metal 0.505-inch diameter tensile tests, except if joint design and material thickness precludes obtaining this diameter, then all weld-metal specimens having the largest diameter that can be machined from the weld shall be obtained.

   (2) For MIL-120 series filler material, ten Charpy V-notch specimens, five tested at 0 °F and five tested at -60 °F. For MIL-140 series filler material, three dynamic tear specimens shall be tested at +30 °F.

The grip ends of all-weld metal tensile specimens shall be located 0 to 0.063 inch below the plate surface. The mechanical properties measured and reported in the all-weld metal tensile test shall be the ultimate tensile strength, yield strength, elongation, and reduction in area. Allowable tensile yield strengths for MIL-120 series filler materials shall be 100 to 130 ksi for thicknesses 3/4 inch and greater. Allowable tensile yield strengths for MIL-140 series filler materials shall be 125 to 150 ksi for thicknesses 3/4 inch and greater to less than 1 inch, and 130 to 150 ksi for thicknesses 1 inch and greater. If reduced size tensile specimens are used (see 16.2.1.10.b.1), alternate minimum tensile yield strengths, if needed, shall be approved by NAVSEA. The surface of all dynamic tear and Charpy V-notch specimens shall be located 0.063±0.032 inch below the plate surface. Machining and testing of weld metal tensile, dynamic tear and Charpy V-notch specimens shall be in accordance with AWS B4.0. Flame cutting shall not be used for the removal of test coupons. Only sawing or machining shall be used. The fracture surface of each all-weld metal tensile specimen shall be photographed at 5X magnification and shall be included in the test records. Each tested all-weld metal tensile specimen shall be properly identified and forwarded to NAVSEA along with test records. Care shall be taken so as to avoid damage to the fracture surfaces during shipment. Weld metal within one inch from each end of the qualification test assemblies need not be evaluated. All test assembly remnants containing weld shall be properly identified and saved to allow for possible follow-on testing. Similarly, all tested mechanical test specimens shall be saved for possible additional analysis. Remnants and specimens saved need only be held until the procedure is approved unless other criteria warrants their retention.

16.2.1.11 Test report. Qualification records shall include all test data, including individual test values, and data on test assemblies considered test failures.

16.2.1.12 Material thickness qualification limits. For test assemblies having a thickness of less than 2 inches, the minimum and maximum thickness of the assemblies tested qualifies the minimum and maximum thicknesses of the procedure range. Test assemblies having a thickness of two inches qualifies the procedure for all thicknesses two inches and greater. In all cases, including repair welds, welding procedures shall be selected according to the thickness of the base material. For welds between members of different thicknesses, the welding procedure used shall be acceptable to weld both thicknesses. Procedure applicability for repair welding and weld buildup shall be based on the thickness of the base material to be built-up or repaired, not the depth of repair or thickness of build-up as specified in NAVSEA S9074-AQ-GIB-010/248.

16.2.1.13 Welding procedure qualification retesting and reporting of retests. If a procedure qualification test fails to meet the nondestructive or destructive test requirements, the procedure may still be qualified under the following conditions:

a. If the test assembly did not meet the acceptance standards for nondestructive tests and it is determined to be unsatisfactory as a result of welding process, equipment or operator related defects (i.e., lack of fusion, porosity, slag, etc.), then that determination shall be substantiated and documented. A retest involving one test assembly for each failed assembly shall then be performed.

b. If the test assembly did not meet the acceptance standards for destructive tests and it is determined to be unsatisfactory for reasons other than those stated in a above, one retest involving twice the number of mechanical test specimens originally required shall be performed. All failed test results shall be reported with an assessment for reasons of the failure.

16.2.2 Welder and welding operator performance qualification. For procedures using MIL-120 or MIL-140 series filler materials, the following additional welder and welding operator performance qualification requirements apply:

a. Except as permitted by 16.2.2.1, initial performance qualification is required using the same filler material type to be used in production (e.g., MIL-120S, MIL-12018 or MIL-140S, as applicable), regardless of welder qualification status with other A5 filler materials. Welder performance qualification using MIL-120S (for GMAW) shall qualify MIL-140S and vice versa.

b. Welders and welding operators shall undergo a formal training program and demonstrate by examination their understanding of all aspects of the welding procedure and technique sheets including preheat/interpass temperature control, heat input and hydrogen removal methods prior to performing production welding.

16.2.2.1 Supplemental welder qualification. Performance qualification using MIL-120S or MIL-12018 is not required for welders previous qualified using MIL-100S or MIL-11018 (respectively) provided additional supplemental weld qualification testing is performed prior to production welding, as noted below. This supplemental qualification testing shall not extend the welder's previous qualification limitations, such as weld position, process or thickness.

16.2.2.2 Welding. Welding shall be performed and verified in accordance with qualified procedures of 16.2.1.

16.2.2.3 Test assembly. For welding with MIL-120 series filler material, one test assembly per NAVSEA S9074-AQ-GIB-010/248 using HY-100 plate with MIL-120S or MIL-12018 filler materials is required for each weld process. The test assembly thickness shall be 3/4 inch except that 3/8-inch minimum thickness plate may be substituted when using the SMAW or GTAW process.

16.2.2.4 Position. Test assemblies shall be welded in either the flat or vertical position provided that the welder has previously qualified for the respective position. Test assemblies welded in the flat position will qualify for production welding in the flat and horizontal positions. Test assemblies welded in the vertical position will qualify for production welding in all positions.

16.2.2.5 Test and evaluation. Test and evaluation of qualification test assemblies shall include: Visual Test (VT) and 2 guided side bend tests for 3/4-inch thick plates, or VT and 1 root and 1 face guided bend test for 3/8-inch thick plates. VT acceptance criteria shall be in accordance with Section 7. Guided bend test acceptance criteria shall be in accordance with NAVSEA S9074-AQ-GIB-010/248.

16.3 Inspection. Section 6 requirements shall apply, except as modified herein.

16.3.1 Surface condition for MT inspection. For one side of all Category I.A.1 butt welds (see Table 6-4) made with MIL-120 or MIL-140 series filler material, final MT inspection shall be performed in the ground flush surface condition. If rejectable transverse indications exist which are potentially cracks, the cause and extent of the potential cracking problem shall be determined and reported, with recommended corrective action, for approval by NAVSEA, prior to defect removal.

16.4 Inspection of filler materials. Section 8 requirements shall apply, except as modified herein.

16.4.1 Additional requirements for MIL-120S and MIL-140S filler materials. In addition to conformance testing requirements performed by the filler metal manufacturer, MIL-120S filler materials shall be tested by the receiving activity to assure that mechanical properties are satisfactory when used with the receiving activity's welding procedures. For MIL-140S filler material, conformance testing requirements, including testing requirements by the receiving activity shall be as approved by NAVSEA. For each heat of MIL-120S filler material, this testing shall include the following as a minimum:

a. For each welding process, one slow cooling rate test and one fast cooling rate test in accordance with 16.2.1 that tests the limits of the shipyard's welding procedures (e.g., shielding gas; minimum heat input, minimum preheat, maximum thickness or 2 inches whichever is less; and maximum heat input, maximum preheat and minimum thickness). In many cases, the welding parameters specified for conformance testing will be appropriate. Lean electrodes shall be used for the slow

cooling rate tests; rich electrodes shall be used for fast cooling rate tests.

b. For approximately every 150 sequential pounds of finished wire, the carbon content shall be determined from a sample. If any sample falls outside the NAVSEA approved range, all spools between acceptable samples produced before and after the failed sample shall be isolated and checked for acceptable carbon content prior to use. If successive samples are acceptable, all spools in sequence between those spools are considered acceptable. Samples may be taken by the manufacturer as the wire is spooled and sent to the receiving activity for analysis.

c. A full chemical analysis in accordance with the applicable welding filler material specification.

16.4.1.1 Auditing of conformance testing. The conformance testing of the consumable shall be audited to insure that all the requirements of the applicable specification are being met and the welding parameters specified by the purchaser are being correctly utilized in the conformance testing.

16.4.2 Material ordering requirements. The following additional requirements apply when ordering MIL-120 and MIL-140 series filler materials:

a. Spools of wire shall be numbered sequentially by the manufacturer as they are wound.

b. Conformance test welding parameters shall be modified as necessary for consistency with the activity's welding procedures and applications. The intent is for conformance testing to simulate the limits of the activity's approved welding procedures.

16.5 Welding materials. Section 10 requirements shall apply except as modified herein.

16.5.1 MIL-140S bare filler metal. MIL-140S bare filler metal shall be stored in a clean, dry environment. When not intended to be used for a period of more than 24 hours, spools shall be replaced in the receiving container with a desiccant and sealed. Desiccant material shall be dried or recharged as required to maintain its effectiveness and shall not be placed in direct contact with the bare filler metal.

16.5.2 Neutral granular flux MIL-120S-1F.

16.5.2.1 Conditioning and maintenance of MIL-120S-1F flux. MIL-120S-1F flux may be used directly from manufacturer's hermetically sealed containers without baking prior to initial issue. Subsequent issue shall meet the requirements of 16.5.2.1.1. Where the moisture requirements of NAVSEA T9074-BC-GIB-010/0200 are exceeded or where deemed necessary by the activity concerned, baking followed by storage in holding ovens shall be accomplished in accordance with the following.

16.5.2.1.1 Baking. MIL-120S-1F flux shall be conditioned according to specific manufacturer's instructions incorporated in contractor's procedures to restore the moisture content to the requirements of NAVSEA T9074-BC-GIB-010/0200.

16.5.2.1.2 Storage in holding ovens. Upon removal from the manufacturer's hermetically sealed container or after baking in accordance with 16.5.2.1.1, MIL-120S-1F flux shall be stored in holding ovens at a minimum temperature of 250 °F. MIL-120S-1F flux which has been baked should be transferred to holding ovens while still hot without being allowed to cool below 250 °F. Transfer shall be protected from inclement weather. As flux can absorb moisture at elevated temperature over prolonged periods, indefinite storage in holding ovens should be avoided. The storage period should be established by the using activity.

16.5.2.1.3 Re-use. Unfused MIL-120S-1F flux may be reused subject to the following conditions:

a. Flux shall be collected from clean, dry work pieces which have been maintained at the 225 °F minimum preheat/interpass temperature and must be at least warm to the touch at the time of reuse.

b. If flux is not collected as required above, it shall be discarded or reconditioned as described in 16.5.2.1.1 and stored at a minimum temperature of 250 °F.

16.5.2.2 Exposure of MIL-120S-1F flux. Exposure of MIL-120S-1F flux shall be limited to ensure that the reduced moisture requirements of NAVSEA T9074-BC-GIB-010/0200 are not exceeded. An appropriate exposure period should be established by the using activity, however, exposure shall not exceed 9 hours. Upon removal from the manufacturer's hermetically sealed containers or holding ovens, MIL-120S-1F flux shall not be used after being exposed to the atmosphere for a total period of more than 9 hours. During exposure, suitable means shall be provided to protect flux from inclement weather.

16.5.2.2.1 Returned MIL-120S-1F flux. All MIL-120S-1F flux shall be reconditioned in accordance with 16.5.2.1.1 prior to re-issue.

16.5.2.2.2 Moisture tests. At least four MIL-120S-1F flux moisture test samples shall be taken per week from welders at their job sites. Samples may be taken from flux holding ovens, flux hoppers on the welding machines, or loading buckets used to transport flux from ovens to hoppers. The moisture determination shall be made in accordance with procedures outlined in NAVSEA T9074-BC-GIB-010/0200. Where the average number of welders per week is six or less, the moisture samples may be reduced to sampling one-half of the welders. If two or more samples in the same week or one sample in each of two consecutive weeks exceed the flux moisture limitations of NAVSEA T9074-BC-GIB-010/0200, corrective and preventative action shall be taken and the number of samples shall be doubled by increasing the sampling frequency to twice per week until the condition is corrected. Records shall be kept as required by Section 5.

16.5.2.3 Alternate methods. Alternate methods for moisture testing shall require NAVSEA approval and must demonstrate that conformance with specification requirements is in control.

16.5.2.4 Responsibility. The activity shall establish and maintain written flux control procedures which will ensure that flux moisture levels in the production welding process do not exceed filler material procurement specification requirements.

16.6 Welding requirements. Section 13 requirements shall apply except as noted herein.

16.6.1 Joint preparation. Use of approved non-metallic temporary backing materials, as permitted by 13.3, to assist in the welding of MIL-120 and MIL-140 series filler materials shall be restricted as noted below.

16.6.1.1 Restrictions for using adhesive tape with ceramic backing materials. Unless specifically approved by NAVSEA, the use of adhesive coated tape to hold ceramic backing material in place is restricted for the following applications:

a. When welding with MIL-120 series filler materials, the adhesive coated tape shall not be applied closer than 1/2 inch from the bevel edge or weld zone, at the time of welding.

b. When welding with MIL-140 series filler materials, use of a adhesive coated tape is prohibited.

16.6.2 Preheat/interpass temperature measurement and control requirements. Section 13.6 requirements shall apply except as modified herein.

16.6.2.1 Control of minimum preheat/interpass temperature. Heating shall be of the uniform soaking type and shall be maintained continuously until the completion of the intra weld soaking or post weld soaking cycle (see 16.6.4). Cyclic heating and the occurrence of large temperature differentials (greater than 100 °F) should be avoided.

16.6.2.2 Loss of minimum interpass temperature. Loss of minimum interpass temperatures shall be treated as follows:

a. Unplanned losses. If, after welding begins the interpass temperature inadvertently drops below the minimum specified in the welding procedure, the temperature of the weld metal shall be determined and recorded. If the temperature inadvertently drops below 150 °F for MIL-120 series or 175 °F for MIL-140 series, all affected weld metal deposited since the previous intra weld or post weld soak shall be removed, along with the associated heat affected zone. The excavated area shall be MT inspected in accordance with 6.5 and accepted to the requirements of Section 7 prior to the resumption of welding.

b. Planned losses. When planned interruptions are known for partially completed welds (e.g., turning a cylinder, dropping preheat for a weekend), which could result in the interpass temperature dropping below the minimum required by Table 13-1, the weld shall be heat soaked in accordance with 16.6.4 prior to the temperature dropping below the specified minimum. Partially completed welds which have received a planned loss heat soak and which have been reduced in temperature to below 100 °F and are 1⅛ inch and over in thickness shall be MT inspected in accordance with 6.5 and accepted to the requirements of Section 7 prior to the resumption of welding.

16.6.2.3 Measurement. Preheat and interpass temperatures shall be measured on the surface of the base material on the side from which welding is to be performed. Both the minimum and maximum temperatures shall be checked along the entire length of the intended weld pass one to three inches

away from the weld joint edges or weld area. However, when performing long continuous welds, such as hull butts and frames, the interpass temperature limits need only comply within an area of two feet ahead of the moving welding arc. Where only a portion of a weld is being welded, for example, a block tack weld, the temperature need only be checked for that area.

16.6.3 Heat input requirements. Heat input limitations shall be those supported by 16.2.1 welding procedure qualification data and approved. Table 16-1 identifies approximate heat input limits as guidance when qualifying MIL-120 series filler materials. Heat input limits for welding with MIL-140 series filler materials shall be as developed in the weld procedure qualification and shall be approved by NAVSEA.

16.6.3.1 Root passes. For multiple pass welds, root passes which will be removed during backgouging may be exempted from the maximum heat input limits established by the qualified welding procedure. Root passes not removed during backgouging may be exempted from the maximum heat inputs limits when the following conditions are met:

a. the total cross-sectional root deposited weld thickness does not exceed 3/8 inch, and
b. the joint design is such that the surface of the root beads will not be less than 3/8 inch from the finished weld surface.

In addition, the maximum heat input limits may be exceeded by 5,000 joules per inch for the root layer of one-sided welds and for the root layer of two-sided welds whose surfaces are less than 3/8 inch from the finished weld surface.

TABLE 16-1. HEAT INPUT GUIDELINES WHEN USING MIL-120 SERIES FILLER MATERIAL.

Welding process	Wire Dia. (in)	Thickness (t) (inches) 2/ 3/	Position	Heat input (joules/inch) 1/	
				Min	Max
SMAW	1/8	t < 1.0	4/	4/	4/
		t ≥ 1.0	Flat Horizontal	30,000	50,000
			Vertical	40,000	55,000
			Overhead	30,000	55,000
	5/32	t < 0.75	4/	4/	4/
		0.75 ≤ t < 1.0	Flat Horizontal	30,000	45,000
		t ≥ 1.0	Flat Horizontal	30,000	55,000
GMAW spray	0.045 0.062	t < 0.75	4/	4/	4/
		0.75 ≤ t < 0.875	Flat Horizontal	30,000	46,000
		t ≥ 0.875	Flat Horizontal	30,000	55,000
GMAW pulsed	0.045	t < 0.75	4/	4/	4/
		0.75 ≤ t < 0.875	Vertical Flat Overhead	28,000	45,000
		0.875 ≤ t ≤ 1.0	Vertical Flat Overhead	28,000	55,000
		t > 1.0	Vertical	34,000	55,000
			Flat Overhead	28,000	55,000
SAW	0.062 0.093	t < 0.75	4/	4/	4/
		0.75 ≤ t < 0.875	Flat	40,000	50,000
		t ≥ 0.875	Flat	40,000	55,000

Notes:

1/ Minimum and maximum heat input refers to the averages for each weld pass.

2/ For welds between members of different thicknesses, the welding procedure used shall be acceptable to weld both thicknesses.

3/ Exceptions to these thickness requirements for hull frame webs may be modified based on acceptable design and test data when approved by NAVSEA. This includes butt welds in the webs, tee welds between the webs and the flanges and between the webs and the shell.

4/ Heat input limitations not available for this thickness range. The minimum and maximum heat inputs shall be as established by welding procedure qualification.

16.6.4 Weld metal hydrogen removal requirements. Unless otherwise approved, all welds, except tack welds (not block tacks) and temporary attachments, other than lifting pads, made partially or completely with MIL-120 or MIL-140 series filler material shall be heat soaked. Heat soaks should be controlled in order to minimize exposure to temperatures above 600 °F.

16.6.4.1 Weld thickness determination for intra weld and post weld soaking purposes. The weld thickness is defined as the design weld metal thickness. For example:

a. For fillet welds, the weld throat thickness. Double fillet welds may be considered as two separate single fillet welds. The same thickness shall apply to corner and tee weld reinforcing fillets if the reinforcing fillets are added after the rest of the weld has been either intra weld or post weld soaked.

b. For butt and corner welds, the sum of the depths of the weld groove(s). For fillet reinforced corner welds, 1/2 the fillet leg size shall be added to the thickness determination.

c. For full penetration tee welds, the thickness of the intersecting (beveled) member plus 1/2 the fillet leg size of any reinforcing fillets (includes partial penetration joints PT2V.3, PT2V.4 and PT2V.5).

d. For partial penetration tee welds other than double fillets, the depth of bevel of the beveled member plus 1/2 the fillet leg size of any reinforcing fillets.

e. For weld buildup or repair of base metal gouges, etc., the depth of the weld deposit.

16.6.4.2 Intra weld soaking requirements - welds over 2 inches. All welds, as defined in 16.6.4, over 2 inches in thickness, shall be intra weld soaked at 250 °F minimum for 10 hours minimum. The intra weld soak shall be accomplished after each 1/2 inch or less of deposited weld metal. The final 1/2 inch or less weld increment shall also be soaked at 250 °F minimum for 10 hours minimum. When welding is performed simultaneously on two sides of a weld joint (e.g., double bevel groove weld), the intra weld soak may be performed after each 1/2 inch or less of weld metal has been deposited on both sides. As an alternate to some or all the intra weld soaks, each 2 inches or less of deposited weld metal may be intra weld soaked using the post weld soaking requirements of 16.6.4.3. Loss of heat soak shall be treated the same as loss of preheat in accordance with 16.6.2.2.

16.6.4.3 Post weld soaking requirements - welds 2 inches or less. All welds, as defined in 16.6.4, 2 inches or less, shall be post weld soaked at 350 °F minimum for 12 hours minimum. As an alternate to post weld soaking, the weld may be intra weld soaked in accordance with 16.6.4.2. Loss of heat soak shall be treated the same as loss of preheat in accordance with 16.6.2.2.

16.6.4.4 Weld repairs of cracks. For weld repairs of cracks only, excavation heat soaking shall be performed after excavation and prior to repair welding. Soaking shall be 350 °F minimum for 12 hours minimum.

16.6.5 Production weld process control verification. Unless otherwise approved by NAVSEA, the shipbuilder (including vendors and subcontractors)

shall verify initial production welding using MIL-120 series filler material is being performed properly and reflects the mechanical properties developed in their approved welding procedures. A similar program, as noted herein, shall be developed by the shipbuilder for initial production welding using MIL-140 series filler materials and approved by NAVSEA. At the time each welding procedure is released for production use, production weld joints shall be selected for the addition of test plates (prolongations) for the purpose of weld metal testing to verify the welding process is in control. Butt or seam welds located in way of hull valves, inserts, etc. may be welded complete and cut out for testing in lieu of or in addition to the prolongation. The welding process, position and material thickness to be tested shall be in accordance with Table 16-2.

TABLE 16-2. PRODUCTION WELD PROCESS CONTROL VERIFICATION TEST MATRIX.

Thickness (inches)	Welding process	Position
0.70 - 1.25	SMAW	Flat
		Vertical
	GMAW (spray)	Flat
		Horizontal
	GMAW (pulsed)	Vertical
	SAW	Flat
1.80 - 2.25	SMAW	Flat
		Vertical
	GMAW (spray)	Flat
		Horizontal
	GMAW (pulsed)	Vertical
	SAW	Flat
Greater than 3	SMAW	Flat
		Vertical
	GMAW (spray)	Flat
		Horizontal
	GMAW (pulsed)	Vertical
	SAW	Flat

16.6.5.1 Production prolongs. For thicknesses of 0.70 to 1.25 inches and 1.80 to 2.25 inches (for processes in continuous use), the tests shall be welded during first use of the production procedures, and six months after first chronological use and one year after first chronological use. For thicknesses greater than three inches the tests shall be welded during the first production use of the procedure and after six months. Length of prolongs shall be sufficient enough to obtain the required test specimens. The results of these tests shall be reported to the NAVSEA authorized representative as soon as possible after completion of the test weld. The tests shall be welded for each of the welding processes employed using the applicable production welding procedure. The thicknesses selected for the test plates shall be representative of the production weld joint thicknesses being welded. The results of this test shall be reported to the government representative as soon as possible after completion of the test weld.

16.6.5.2 Prolong nondestructive testing. The nondestructive testing accomplished on the test weld shall be the same as that required by Section 6 for the production weld and the requirements of 16.2.1.9.

16.6.5.3 Prolong destructive testing. Destructive tests and evaluations which shall be performed on the prolongations are as follows:

a. Two all weld-metal tensile tests from each side welded. Charpy V-notch specimens - five tested at 0 °F and five tested at -60 °F. The fracture surfaces of the tensile specimens shall be examined for hydrogen damage and described in test report. Destructive test results must meet the minimum requirements of the applicable filler metal specification.

b. Test results which that do not conform to the mechanical property requirements of the applicable filler metal specification shall be evaluated as follows:

   (1) If the yield strength from a test plate welded with MIL-120 series filler material (average of two specimens) is greater than 130 ksi or less than 100 ksi, the activity shall stop use of the process for any new applications of the material thickness and position represented by the test plate and immediately notify the NAVSEA authorized representative.

   (2) For each individual tensile specimen that exhibits an elongation value less than 15 percent for the SMAW process, or 14 percent for other processes using MIL-120S filler materials the activity should test two additional retest specimens. These retest specimens should be removed from the same side of the test weld that displayed the low elongation values. If any of the retest specimens display an elongation value less than 15 percent for the SMAW or 14 percent for other processes, the activity shall stop use of the process for any new application of the material thickness and position represented by the test plate and notify the NAVSEA approval representative.

   (3) CVN tests (average values from 5 tests at 0 °F and 5 tests at -60 °F from each side of a test plate shall meet 60 ft-lbs average at 0 °F and 37 ft-lbs average at -60 °F with no two individual values at either temperature more than 10 ft-lbs below the minimum average. If CVN results fail to meet the above criteria, the activity should perform a retest consisting of 5 CVN specimens at each failed test temperature(s) and side(s) to confirm or refute the validity of the failed test result(s). In the event that the retest specimens also fail to meet the criteria listed above, the activity should stop use of the process for any new application of the material thickness and position represented by the test and notify the NAVSEA authorized representative.

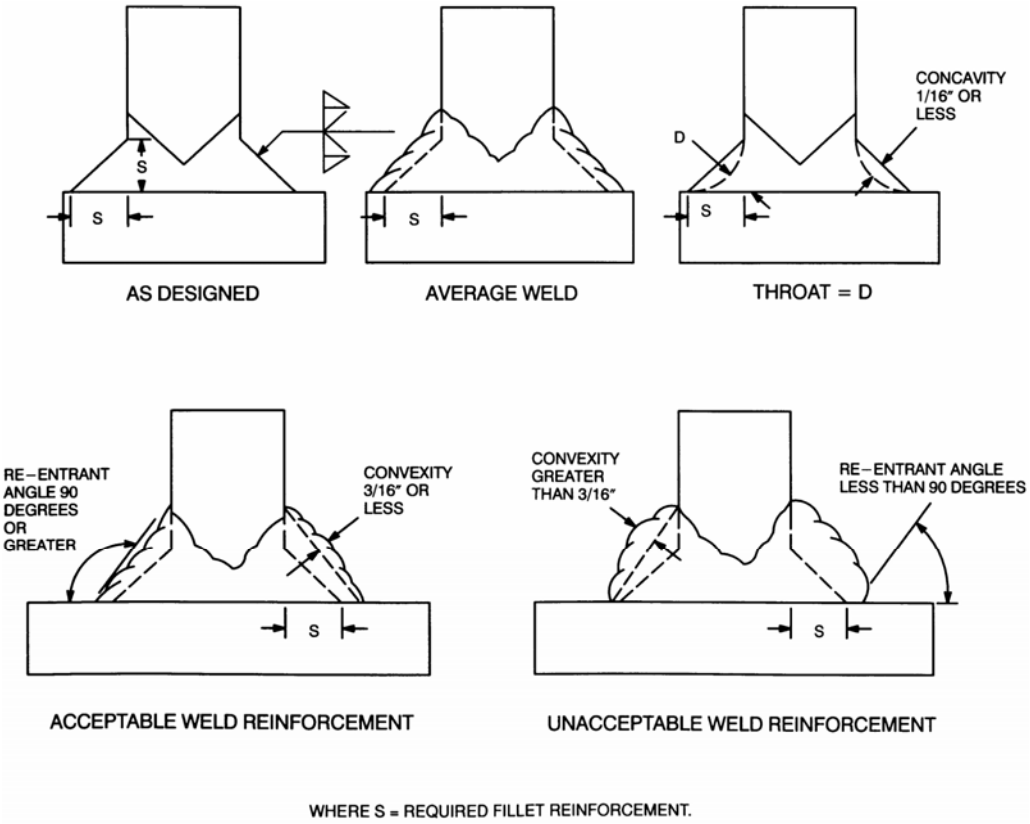
16.6.5.4 Prolong test data report. Test data shall be reported to NAVSEA for each test prolongation. The report shall include the following:

a. Welding parameters used for the test welds (preheat/interpass temperature, heat input, amperage, volts, travel speed).

b. Mechanical results. Tensile strength, yield strength, elongation, percent reduction in area and Charpy V-notch results.

c. Filler metal identification and chemistry for each heat or lot of filler metal used. For bare wire, the chemistries shall be from the bare wire and from deposited weld metal. For covered electrode the chemistry shall be from deposited weld metal.

d. Whether hydrogen damage was found.



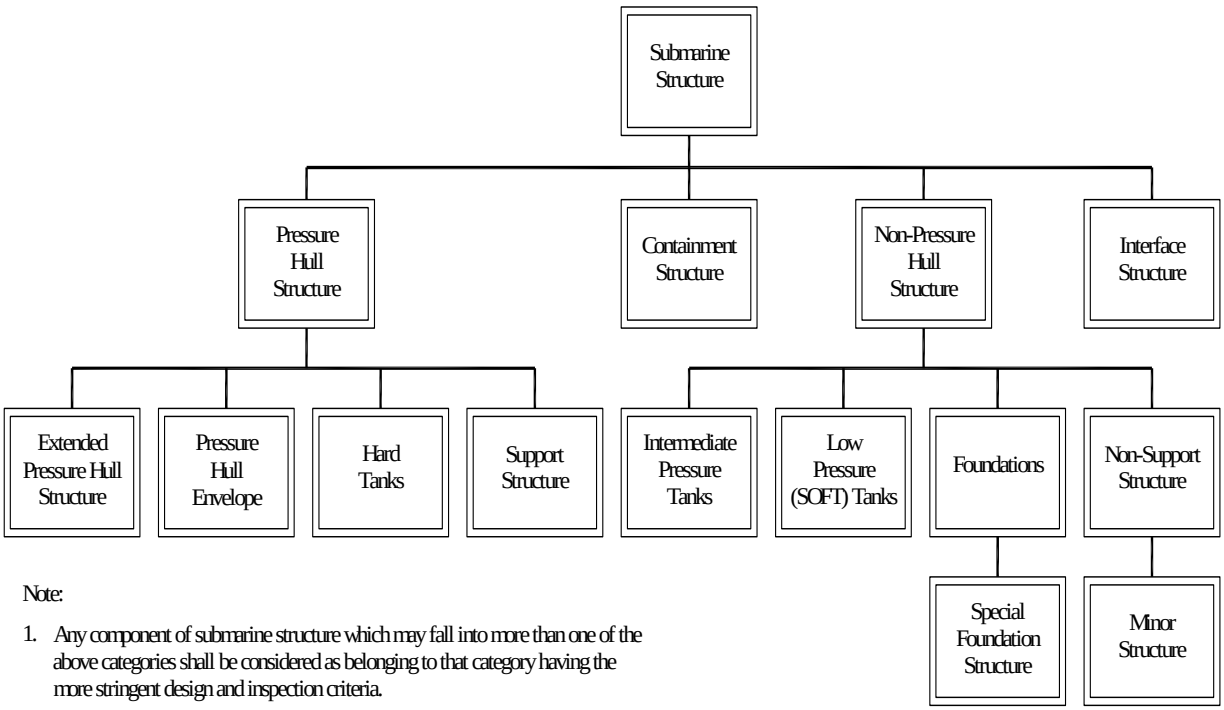
Figures not to scale

Notes:

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, except that concavity is acceptable provided the minimum throat thickness is at least equal to 70 percent of the required fillet reinforcement size (D > 0.7 x S).

FIGURE 1. TYPICAL CONTOUR FOR FILLET GROOVE TEE WELDS AND FILLET WELDS.

(see 3.28 and 7.4.3)



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 2. FUNCTIONAL DIAGRAM OF SUBMARINE STRUCTURE.

(see 3.33)

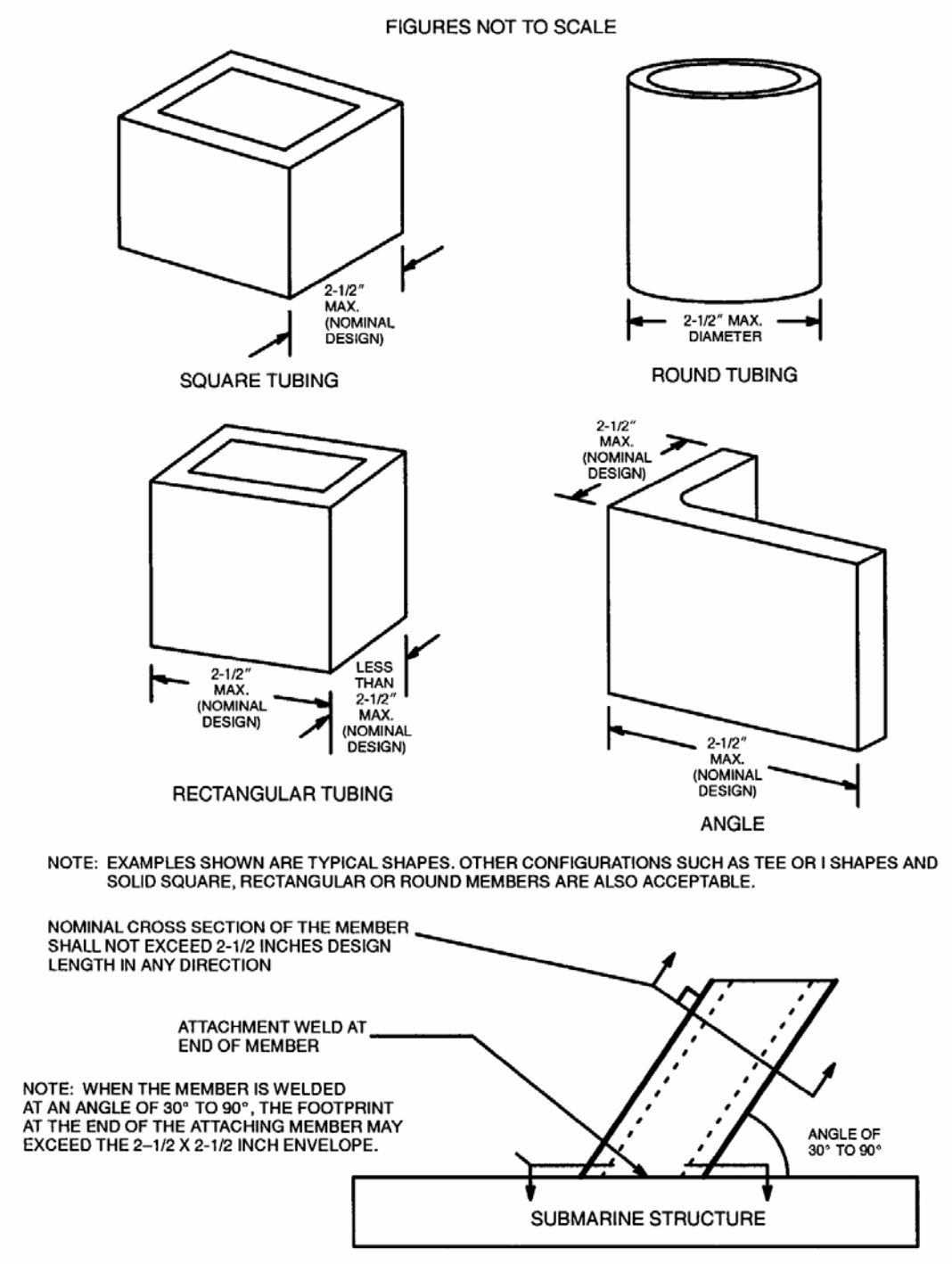
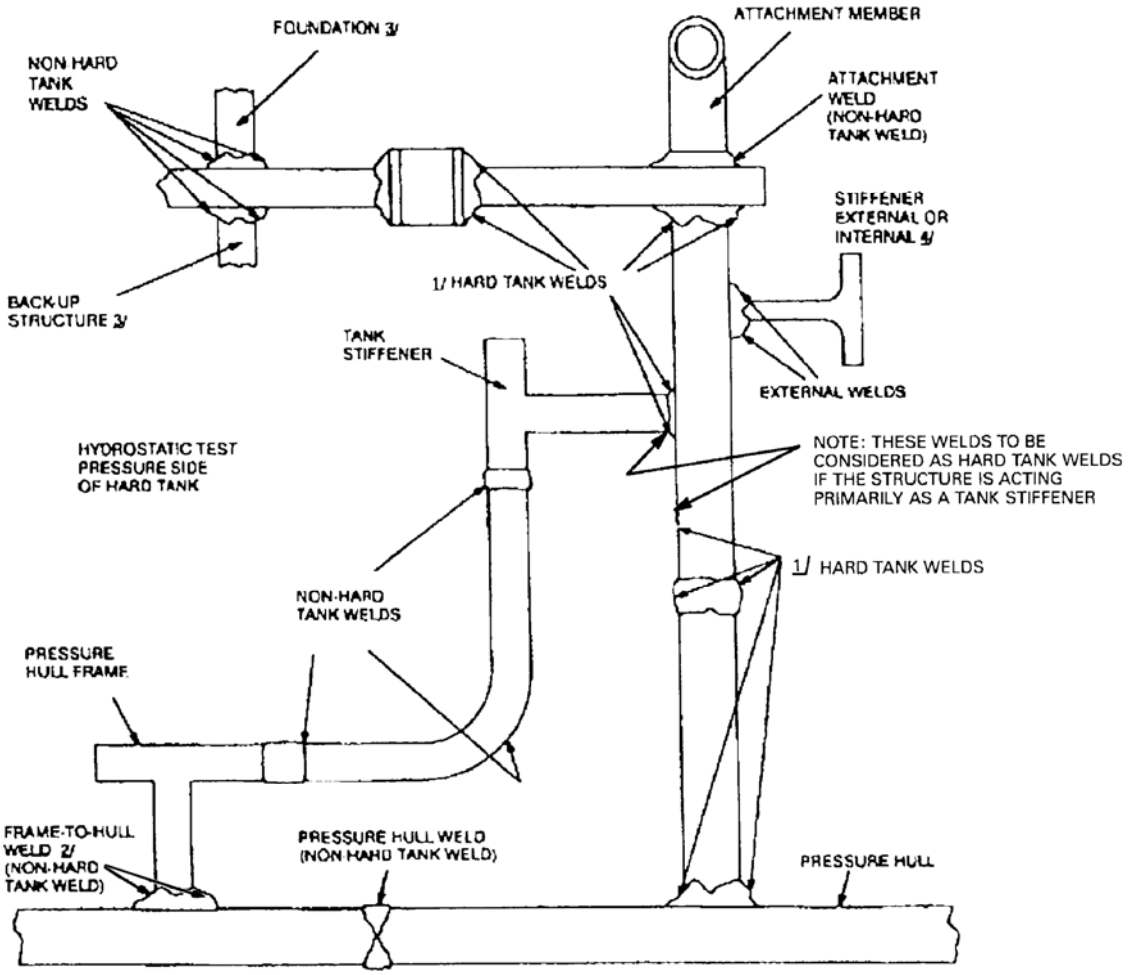


FIGURE 3. EXAMPLES OF MEMBERS FOR ATTACHMENT WELDS.

(see 3.39.1)



Notes:

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 boundary 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 hard tank weld.

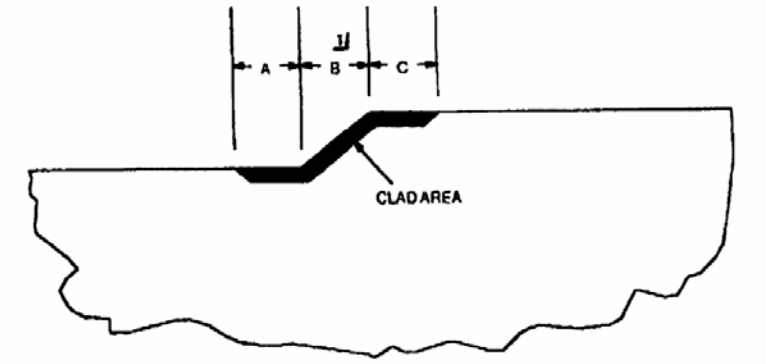
3/ Back-up structure for foundations is structure welded to the hard tank boundary plating for the design purpose of supporting foundations and not primarily as a tank stiffener.

4/ Where the stiffener, external or internal, is not active as a primary tank panel stiffener, inspect the stiffener attachment weld as non-hard tank welds.

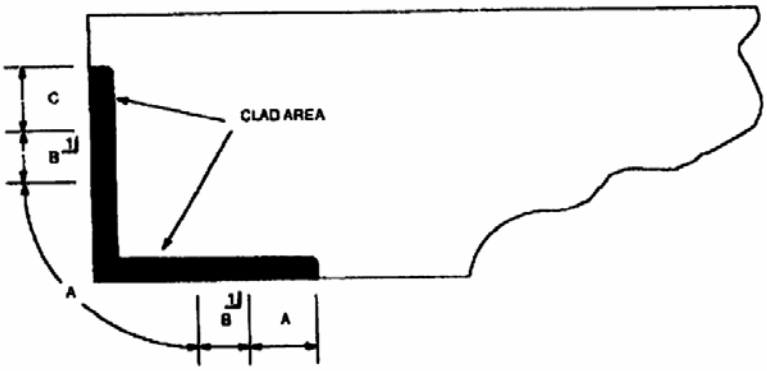
5/ Welds not specifically identified in this figure as tank welds are to be inspected as non-hard tank welds.

FIGURE 4. HARD TANK WELDS. 5/

(see 6.5.4)



TYPICAL CLAD AREA WITH SINGLE SEATING SURFACE



TYPICAL CLAD AREA WITH DOUBLE SEATING SURFACE

A = INBOARD SURFACES	CLASS 3	PER MIL-STD-2035
B = SEATING OR SEAL AREA	CLASS 1	PER MIL-STD-2035
C = OUTBOARD SURFACES	CLASS 2	PER MIL-STD-2035

Note:

1. The width of zone B shall be the width of the gasket retaining groove in the matching part plus 1/8 inch.

FIGURE 5. CLAD AREAS FOR O-RING OR GASKET SEATING SURFACES.

(see 7.7.2)

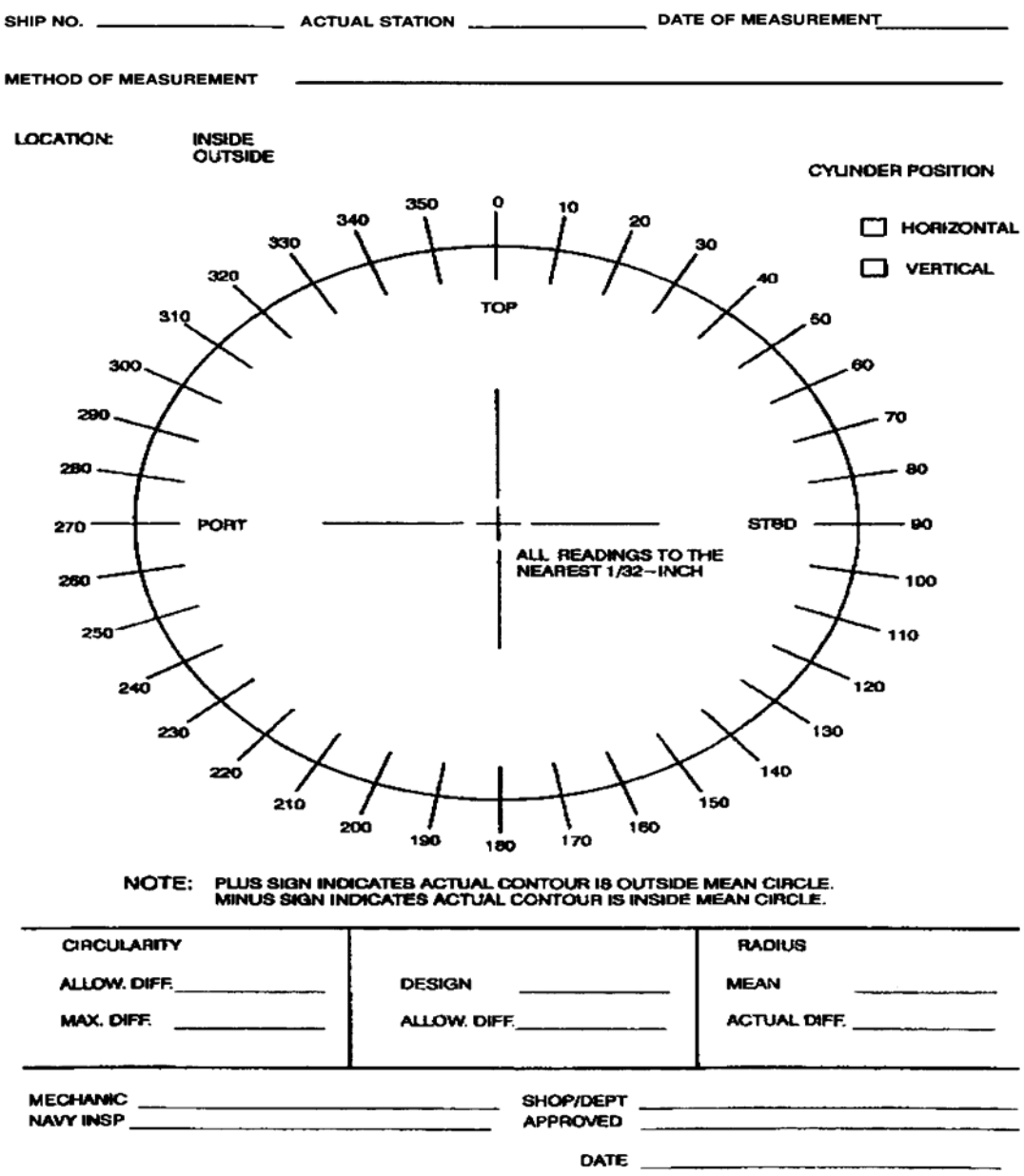
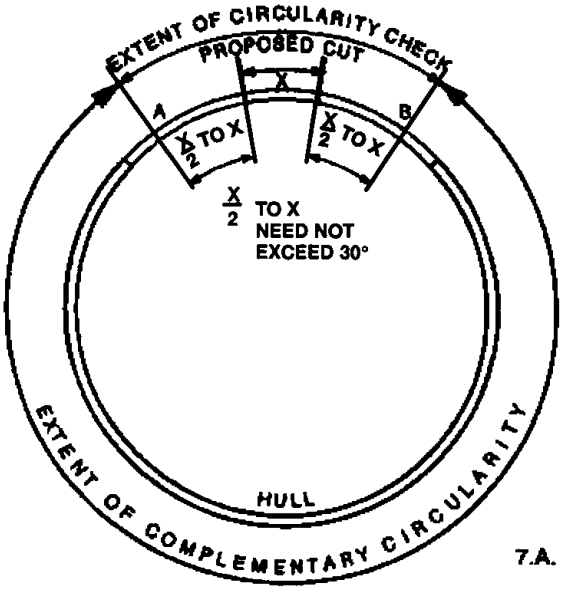


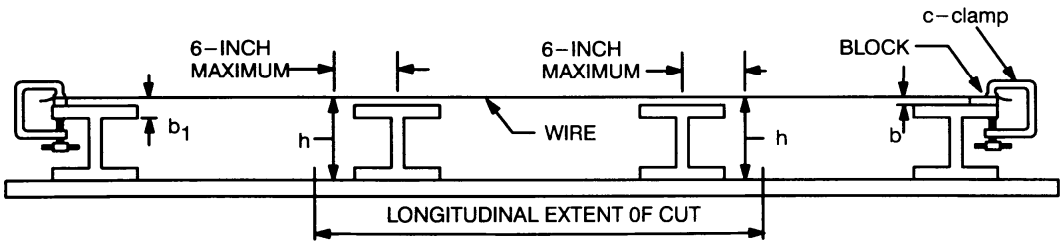
FIGURE 6. QUALITY CONTROL HULL CIRCULARITY MEASUREMENT RECORD.
(see 5.5.1.a)

1. Total hull circularity based on complementary plus partial circularity measurements shall be made in accordance with 12.3.1.1.3.1. Figure 7.A shows the extent of complementary and partial circularity measurements.



7.A.

2. The elevation of points "A" and "B" in Figure 7.A shall be established relative to reference lines from bench marks established on undisturbed frames forward and aft of the proposed cut. This can be done by use of optics, or other methods such as the range wire shown in Figure 7.B. The end point elevations, "b" dimensions, shall be recorded for future reference at each frame to be cut. The reference line elevations, "h" dimensions, shall also be recorded.



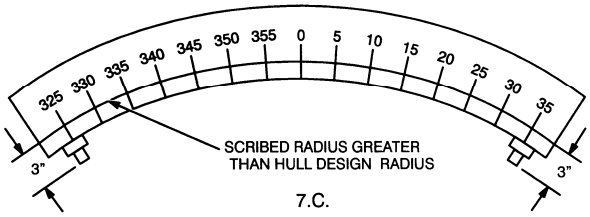
7.B.

3. After the hull has been restored and all major welding completed, the reference lines shall be re-established and the reference line and end point elevations, dimensions "b" and "h", respectively, of Figure 7.B shall be again measured and recorded.

FIGURE 7. COMPLEMENTARY CIRCULARITY MEASUREMENTS.

(see 5.5.1.a)

4. Using an appropriate measurement method, the existing hull radial geometry shall be measured at five degree intervals over the arc from, and including, points "A" and "B". (For illustration purposes only, Figure 7.C shows a template approach for taking these measurements). These measurements shall be recorded for future reference.



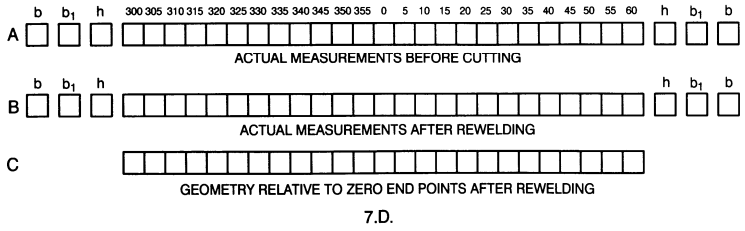
7.C.

5. Figure 7.D illustrates an acceptable method of recording all measurements.

(a) The actual measurements of the bench mark and end point elevations taken before cutting shall be recorded on line "A".

(b) The actual measurements of the reference line elevations, end point elevations and the contour taken after installation shall be recorded on line "B".

(c) If the pre-cut reference lines could not be re-established, the end point elevations recorded on line "B" shall be adjusted to account for any change in the reference line elevations between lines "A" and "B". These adjusted end point elevations shall be recorded on line "C" and shall be considered the post-installation zero points. The contour relative to these zero points shall then be recorded on line "C".



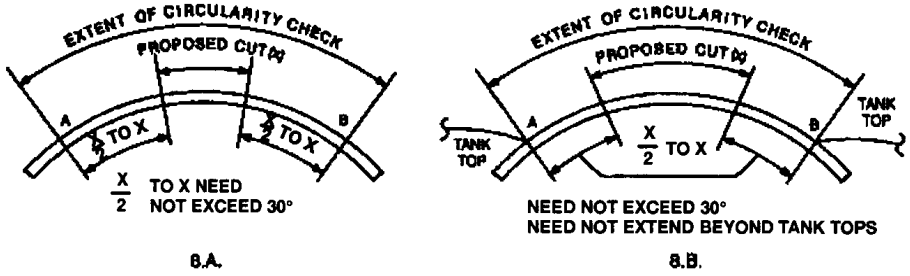
7.D.

6. Using the partial circularity contour from either line "B" or "C" above, the total hull contour shall be developed and evaluated in accordance with 12.3.1.4.a.

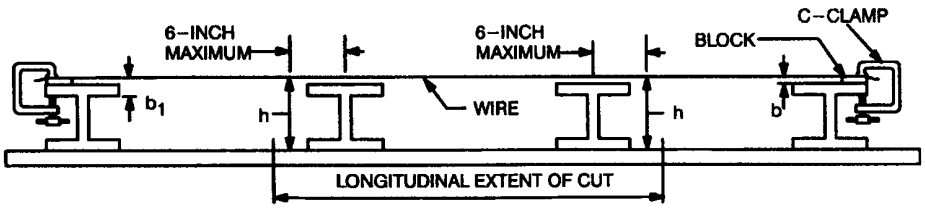
FIGURE 7. COMPLEMENTARY CIRCULARITY MEASUREMENTS – CONT'D.

(see 5.5.1.a)

1. Partial circularity measurements shall be made in accordance with 12.3.1.1.3.2. Figures 8.A and 8.B show the extent of partial circularities in cases with and without tank structure intersecting the hull.



2. The elevation points "A" and "B" in Figures 8.A and 8.B shall be established relative to reference lines from bench marks established on undisturbed frames forward and aft of the proposed cut. This can be done by the use of optics or other methods such as the range wire shown in Figure 8.C. The end point elevations, "b" dimensions, shall be recorded for future reference at each frame to be cut. The reference line elevations, "h" dimensions, shall also be recorded.



3. Using an appropriate measurement method, the existing hull radial geometry shall be measured at five degree intervals over the arc from, and including, points "A" and "B". (For illustration purposes only, Figure 8.D shows a template approach for taking these measurements.) These measurements shall be recorded for future reference.

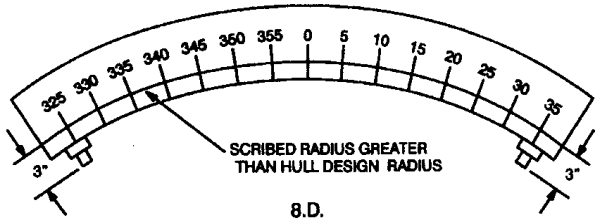


FIGURE 8. PARTIAL CIRCULARITY MEASUREMENTS.

(see 5.5.1.a)

4. After the hull has been restored and all major welding completed, the reference lines shall be re-established and the reference line and end point elevations, dimensions "b" and "h", respectively, of Figure 8.D shall again be measured.

5. The post-installation hull radial geometry shall again be measured at the same points and using the same method as in step 3 above. These measurements shall be recorded.

6. Figure 8.E illustrates an acceptable method of recording all measurements.

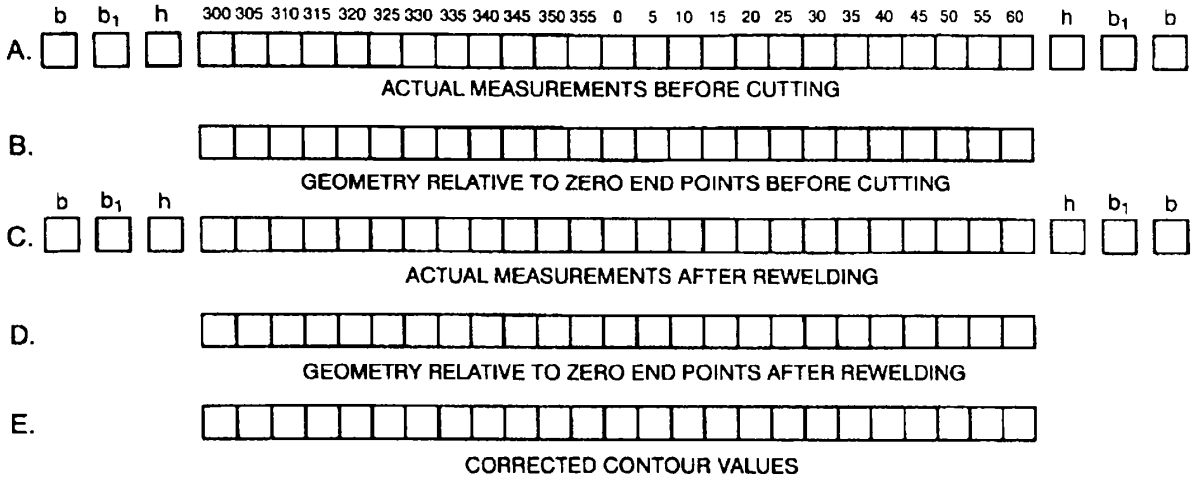
(a) The actual measurements of the reference line elevations, end point elevations and the contour taken before cutting shall be recorded on line "A".

(b) The end point elevations shall be considered zero points. Therefore all reading greater than the zero point distance reveal a dip in the hull and shall be considered negative readings; all readings less than the zero point distance reveal a hump in the hull and shall be considered positive readings. The contour measurements relative to the zero end points before cutting shall be recorded on line "B".

(c) The actual measurements of the reference line elevations, end point elevations and the contour taken after installation shall be recorded on line "C".

(d) If the pre-cut reference lines could not be re-established, the end point elevations recorded on line "C" shall be adjusted to account for any change in the reference line elevations between lines "A" and "C". These adjusted end point elevations shall be recorded on line "D" and shall be considered the post-installation zero points. The contour relative to these zero points shall then be recorded on line "D".

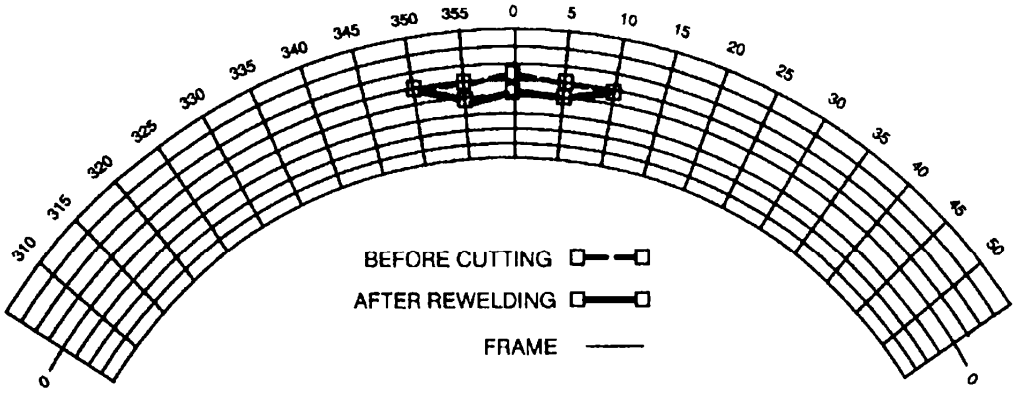
(e) If the end point elevations, "h" dimensions, on line "D" deviate from the "h" dimensions on line "A", corrections shall be made to the contour measurements recorded on line "D". The corrected contour measurements shall be recorded on line "E".



8.E.

FIGURE 8. PARTIAL CIRCULARITY MEASUREMENTS – CONT'D.

7. Record the pre-cut hull contour, line "B", with the post-installation hull contour, line "D" or "E", as applicable, on Figure 8.F.



8.F.

FIGURE 8. PARTIAL CIRCULARITY MEASUREMENTS – CONT'D.

DATA SHEET FOR PRESSURE HULL FAIRNESS

DEGREE STATION / LOCATION	FWD FRAME	QUARTERBAY MEASUREMENT	MIDBAY MEASUREMENT	QUARTERBAY MEASUREMENT	AFT FRAME	REMARKS

Notes:

1. Ensure that both station and degree location are recorded on form (for example station 13 is equal to 60 degrees).
2. Measurements that exceed +3/16 inch (0.19 inch) or as specified in the ship's detailed specification shall be annotated in remarks column as REJECTED.

FIGURE 9. PRESSURE HULL FAIRNESS DATA SHEET.

(see 5.5.1.b)

RECORD OF FRAME DIMENSIONS

STA. DET. "A"	FRAME DEPTH AS DESIGNED	FRAME DEPTH $\frac{H+J}{2}$ DET "C" TOLERANCE	WEB TILT ANGULAR VALUE $\frac{B-C}{M} \times 57.3$ LINEAR VALUE $\frac{B-C}{M} \times \left[\frac{H+J}{2} - T\right]$ TOLERANCE	FLANGE TILT ANGULAR VALUE $\frac{E-F}{N} \times 57.3$ LINEAR VALUE $\frac{E-F}{N} \times W$ TOLERANCE	FLANGE WIDTH W(DET "C") TOLERANCE = 1/8"		FLANGE UNBALANCE G_1-G DET."E" TOLERANCE = 3/16"
					PLAN	ACTUAL	
1							
2							
3							
4							
5							
6							
7							
8							

TOLERANCE
UP TO 12.00" +3/16" – 1/8"
12.01 TO 15" +1/4" – 1/8"
15.01 TO 24" +5/16" – 1/8"
24.01" & UP +3/8" – 1/8"

WEB TILT TOLERANCE
UP TO 12.00" ± 2°
12.01 TO 15" ± 2° BUT 7/16" MAX
15.01 TO 24" 7/16" MAX
24.01" & UP 7/16" MAX

FLANGE TILT TOLERANCE
UP TO 12.00" ± 2°
12.01 TO 15" ± 2°
15.01 TO 24" ± 2° 17/32" MAX
24.01" & UP 17/32" MAX

INSPECTOR

DATE

FIRST READINGS ☐
SECOND READINGS ☐
THIRD READINGS ☐

THIS RECORD SHEET SUPERSEDES SHEET NO. _____

DATA AND CALCULATIONS EXCEEDING TOLERANCES OF MIL-STD-XXX(SH) TO BE MARKED THUS *

CALCULATED BY:

BADGE NO. | DEPT.

DATE

FOREMAN INSP. REC.

REMARKS:

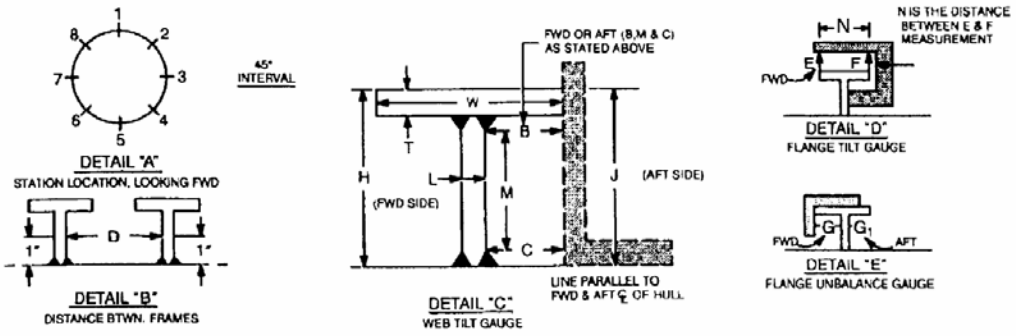


FIGURE 10. RECORD OF FRAME DIMENSIONS.

(see 5.5.2)

NO.

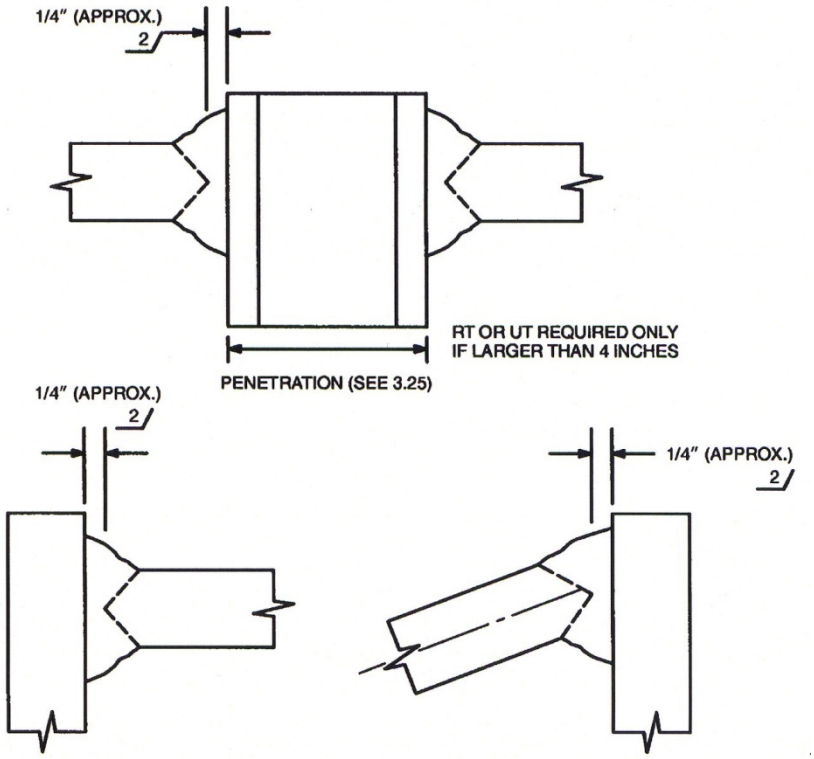
RECORD OF FRAME DIMENSIONS

BOAT	PLAN	REV.	FRAME NO.	INTERNAL ☐ EXTERNAL ☐	FABRICATED ☐ EXTRUDED ☐	SHIP ☐	BLOCKS ☐ VENDOR ☐

STA DET "A"	ACTUAL DISTANCE BTWN. FRAMES DET "B"	GAGE LOCATION: AFT SIDE OF FRAME ☐ FWD SIDE OF FRAME ☐											
		SEE DETAIL "C" BELOW							SEE DETAIL "D" BELOW			SEE DETAIL "E" BELOW	
	D	L	H	J	B	C	M	T	E	F	N	G	G_1
1													
2													
3													
4													
5													
6													
7													
8													

REMARKS:

FIGURE 10. RECORD OF FRAME DIMENSIONS – CONT'D.



Notes:

1/ Any combination of UT and RT inspection may be used to inspect the weld.

2/ If performed, RT inspection shall be in accordance with NAVSEA T9074-AS-GIB-010/271 with the following modification: for RT inspection of the 1/4 inch adjacent to the through member of tee and corner welds, the film density of the shim image shall not be greater than 75 percent more than the film density of the area of interest.

3/ If 100 percent of the weld length cannot be inspected by UT/RT in accordance with NAVSEA T9074-AS-GIB-010/271 and Notes 1 and 2, as determined by the fabrication activity at the time of joint fit-up (prior to production welding), then the following applies:

a. If a minimum of 90 percent of the weld length can be volumetrically inspected by UT/RT (or a combination of UT and RT), then UT/RT shall be performed to the maximum extent practicable. MT/PT inspection of each layer or 3/8 inch (whichever is greater) of the remaining portion of weld is not required.

b. If a minimum of 90 percent of the weld length cannot be volumetrically inspected by UT/RT (or a combination of UT and RT), then in addition to performing UT/RT to the maximum extent practicable, MT/PT of each layer or 3/8 inch (whichever is greater) shall be performed on the entire weld length. Approval to use this alternate inspection is not required.

FIGURE 11. APPLICATION EXAMPLES OF TABLE 6-4, CATEGORY I.A.1. 1/ 3/ 4/

Notes:

3/ Continued.

c. If after considering the requirements in items a and b above, it is determined that a minimum of 90 percent of the weld length cannot be volumetrically inspected by UT/RT (or a combination of UT and RT), and the amount of UT/RT coverage is minimal and not considered to be meaningful or practical, then MT/PT of each layer or 3/8 inch (whichever is greater) may be considered to be the only meaningful inspection. When approved, MT/PT of each layer or 3/8 inch (whichever is greater) shall be performed over the entire weld length.

For welds which cannot be UT/RT inspected for a minimum of 90 percent of the weld length (i.e., subparagraph b and c above), a list of these welds shall be forwarded to NAVSEA for information. The list shall include the boat number, drawing number, joint number and percent (or length) of UT/RT inspection achieved, as applicable.

4/ Whenever the design activity determines that inspection per Note 3.c is required, the details of the alternate inspection shall be included on the drawing with a note that acknowledges inspection per Note 3.c is required and approved for the specific weld joint. If this has not been included on the drawing, the fabrication activity shall develop the alternate inspection requirements and document the application as noted in Note 3 above. It is important that the fabrication activity evaluate each weld joint prior to production welding so that the intermediate weld layer MT/PT inspection of Note 3.b or 3.c is accomplished where necessary.

FIGURE 11. APPLICATION EXAMPLES OF TABLE 6-4, CATEGORY I.A.1 – CONT'D.

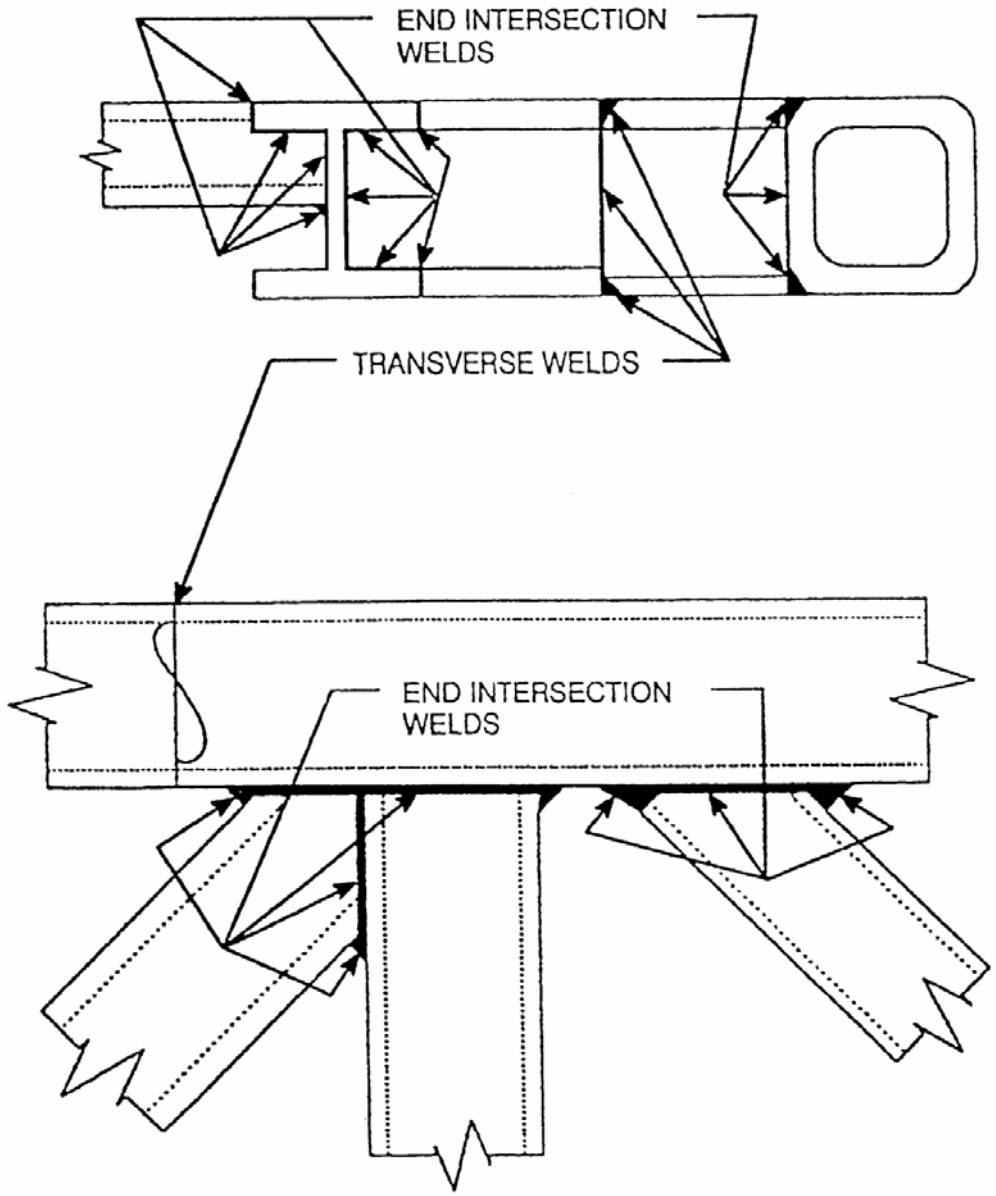


FIGURE 12. EXAMPLES OF END INTERSECTION WELDS OF, OR TRANSVERSE WELDS IN, BEAM-TYPE OR BUILT-UP MEMBERS.

(see Table 6-2, Cat III.C(2))

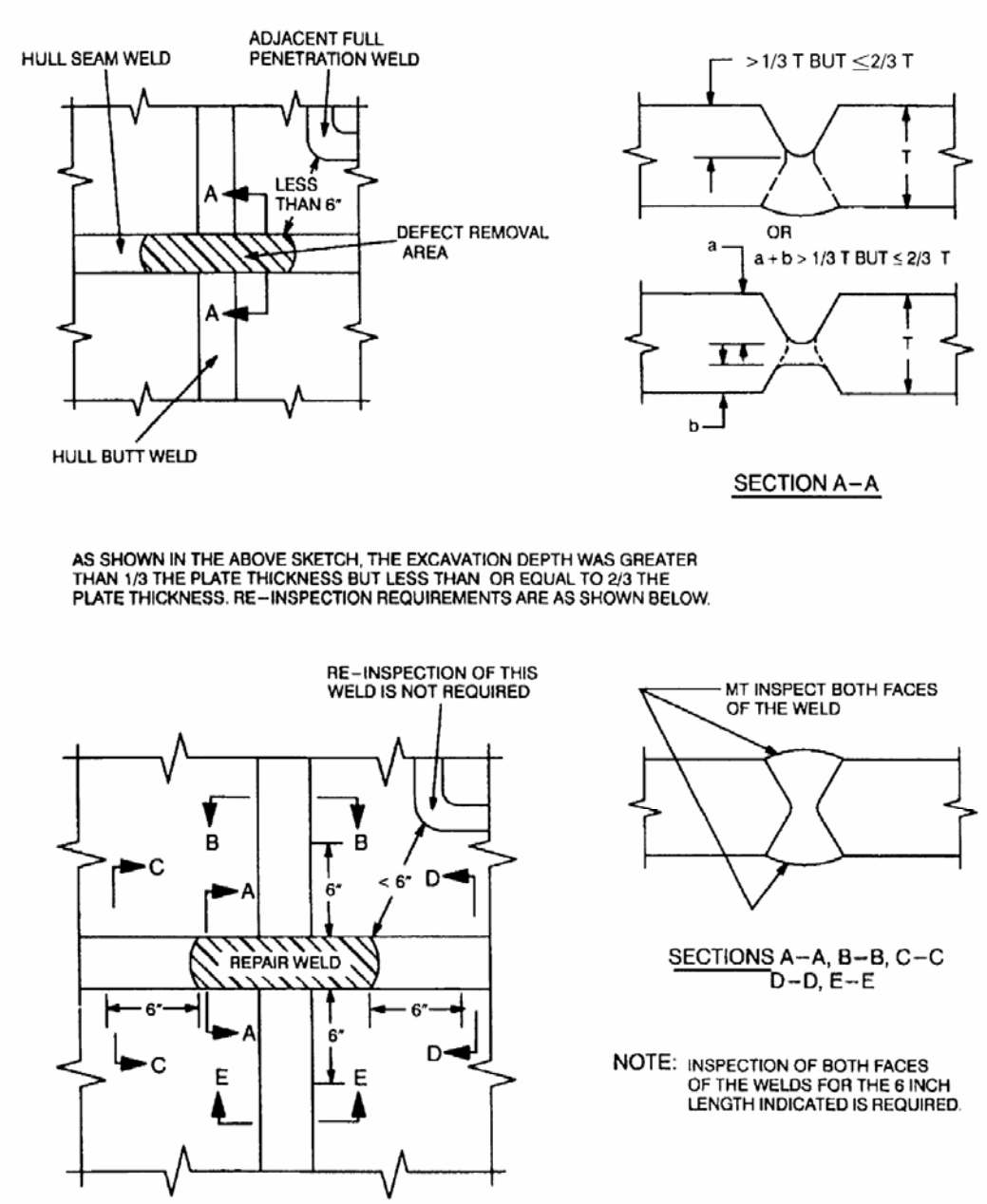


FIGURE 13. MT INSPECTION REQUIREMENTS FOR REPAIR OF FULL PENETRATION WELDS IN THE PRESSURE HULL ENVELOPE WHERE THE TOTAL REPAIR DEPTH IS GREATER THAN 1/3 T BUT LESS THAN OR EQUAL TO 2/3 T.

(see Table 6-1, Note 2)

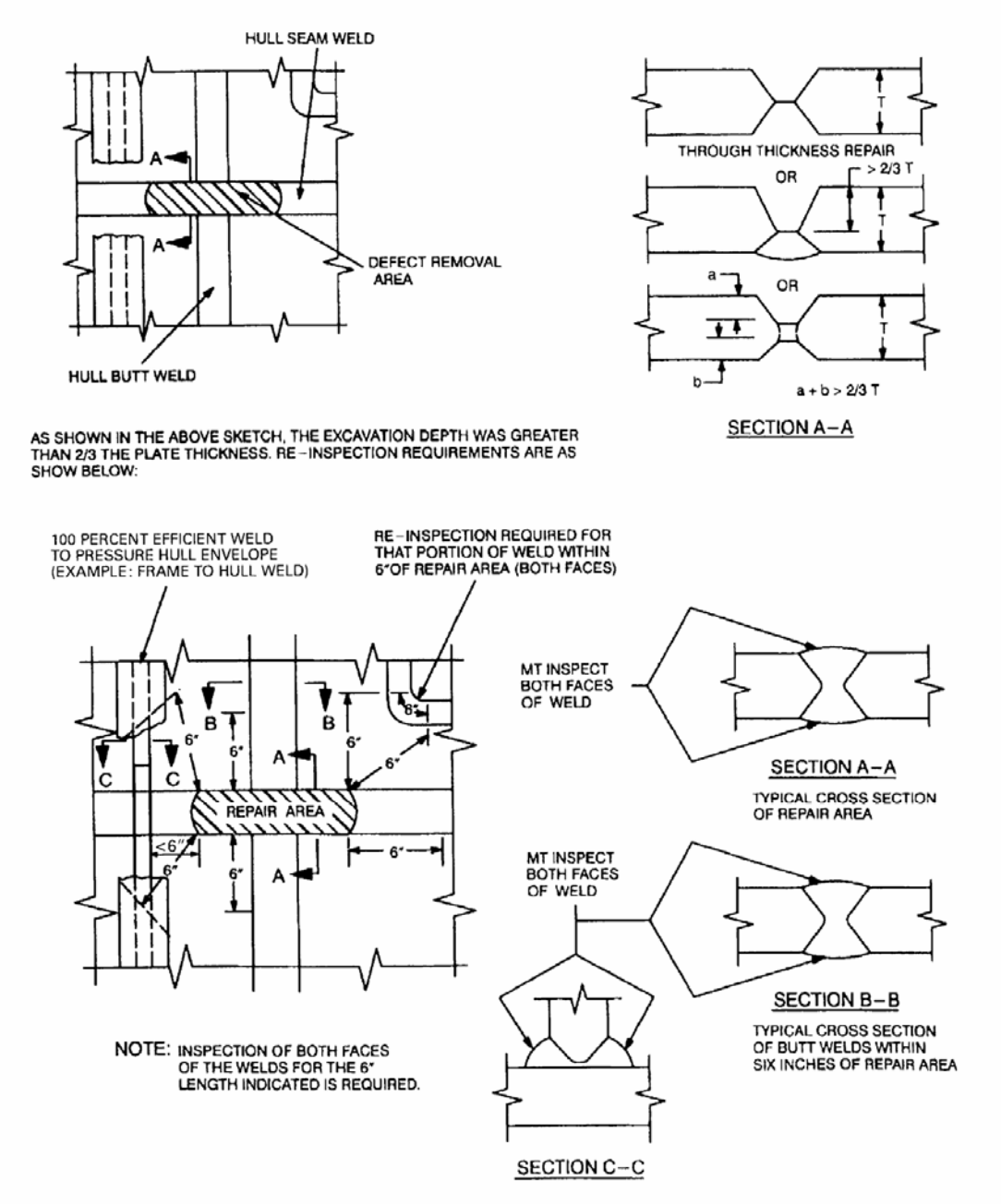


FIGURE 14. MT INSPECTION REQUIREMENTS FOR REPAIR OF FULL PENETRATION WELDS IN THE PRESSURE HULL ENVELOPE WHERE THE TOTAL REPAIR DEPTH IS GREATER THAN 2/3 T.

(see Table 6-1, Note 2)

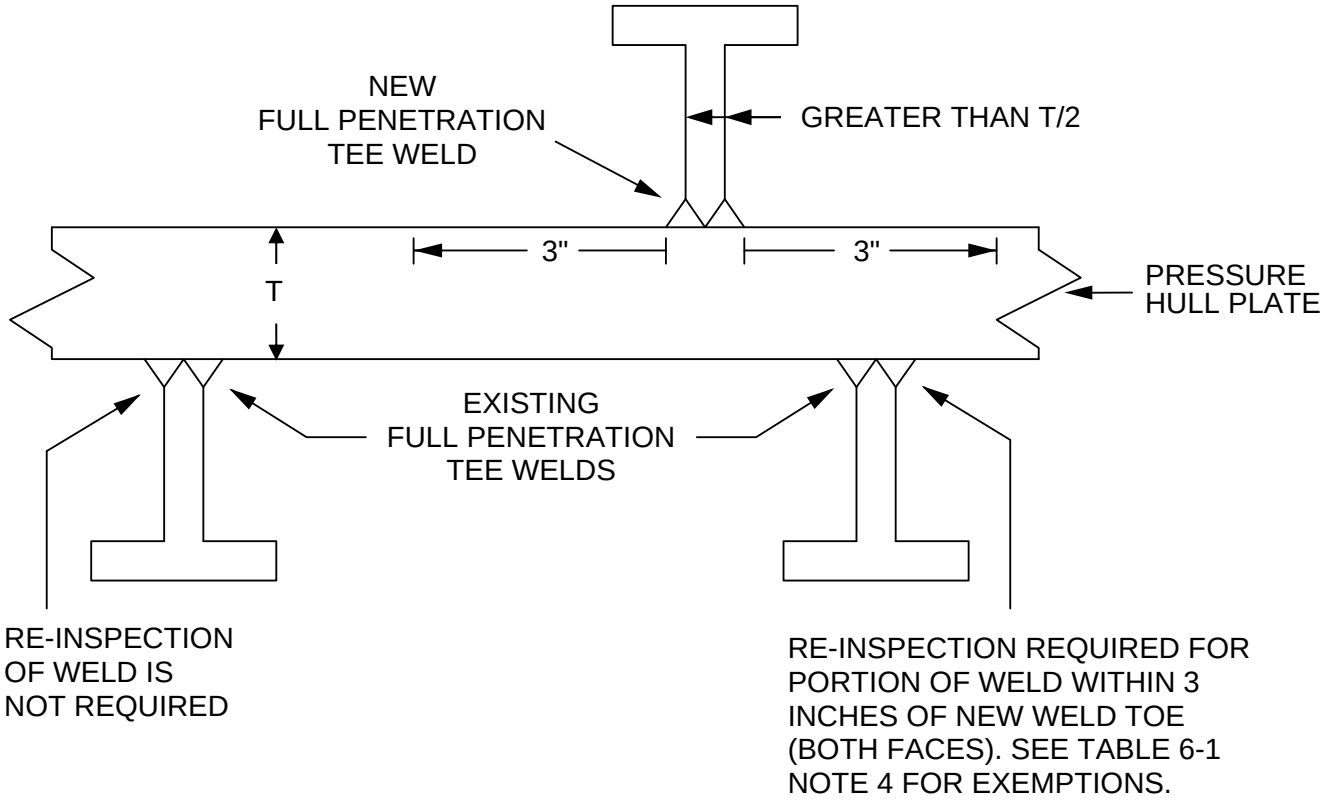
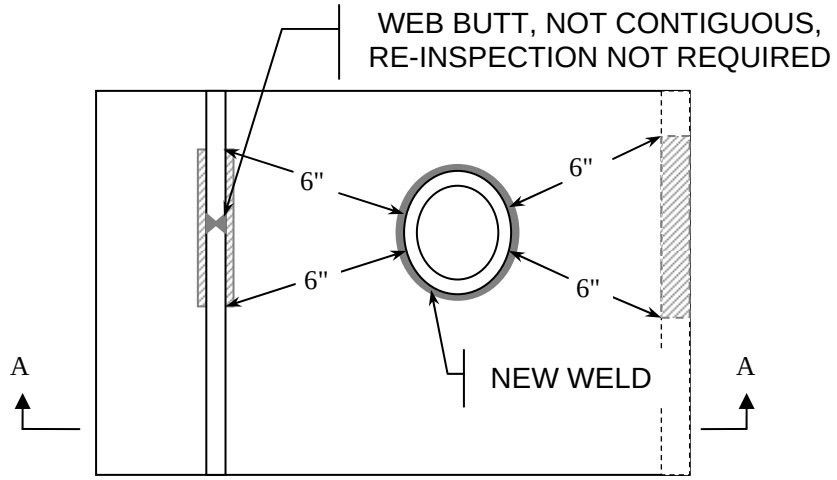
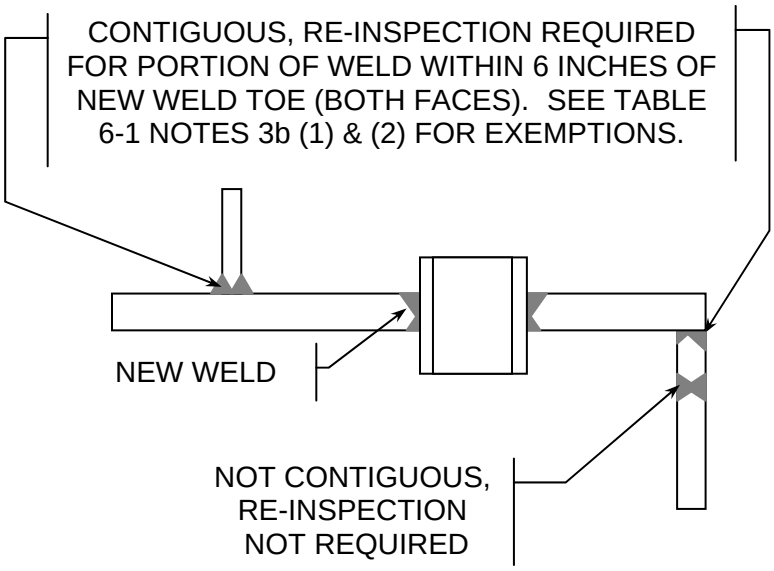


FIGURE 14A. MT INSPECTION REQUIREMENTS FOR EXISTING FULL PENETRATION WELDS IN THE VICINITY OF NEW FULL PENETRATION TEE WELD IN PRESSURE HULL ENVELOPE.

(see Table 6-1, Note 4)



Plan View



Section A-A

FIGURE 14B. EXAMPLES OF CONTIGUOUS MEMBER WELD RE-INSPECTION.
(see Table 6-1, Note 3)

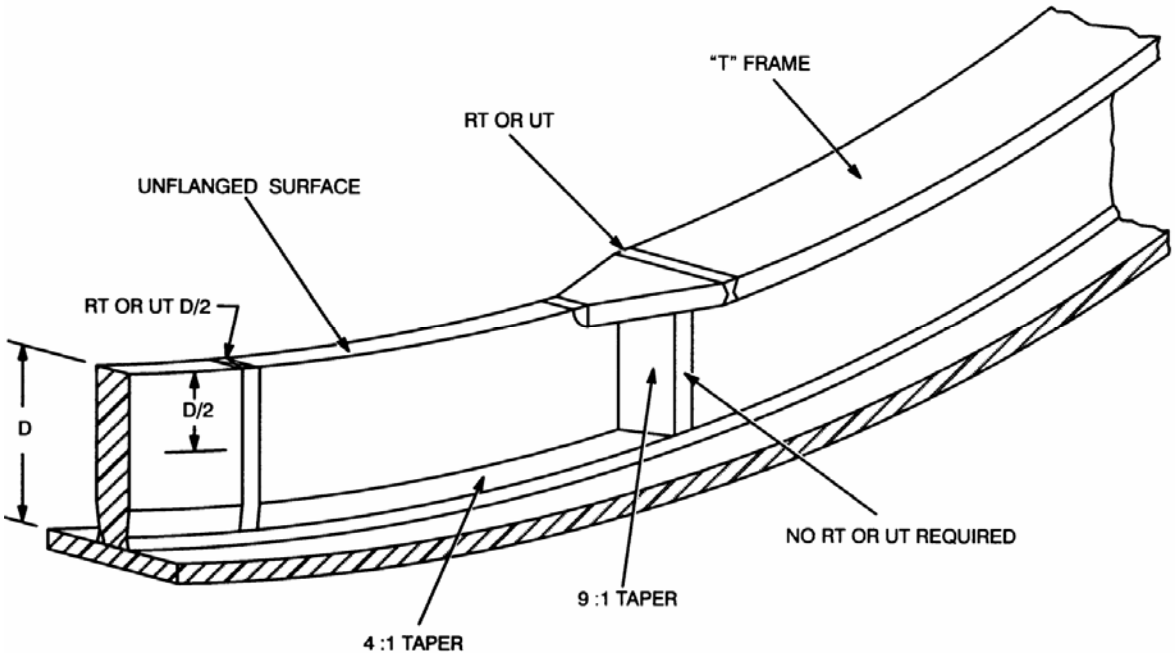


FIGURE 15. RT/UT REQUIREMENT FOR FLANGED TO UNFLANGED FRAME TRANSITIONS. (see Table 6-4, Cat 1.B(3))

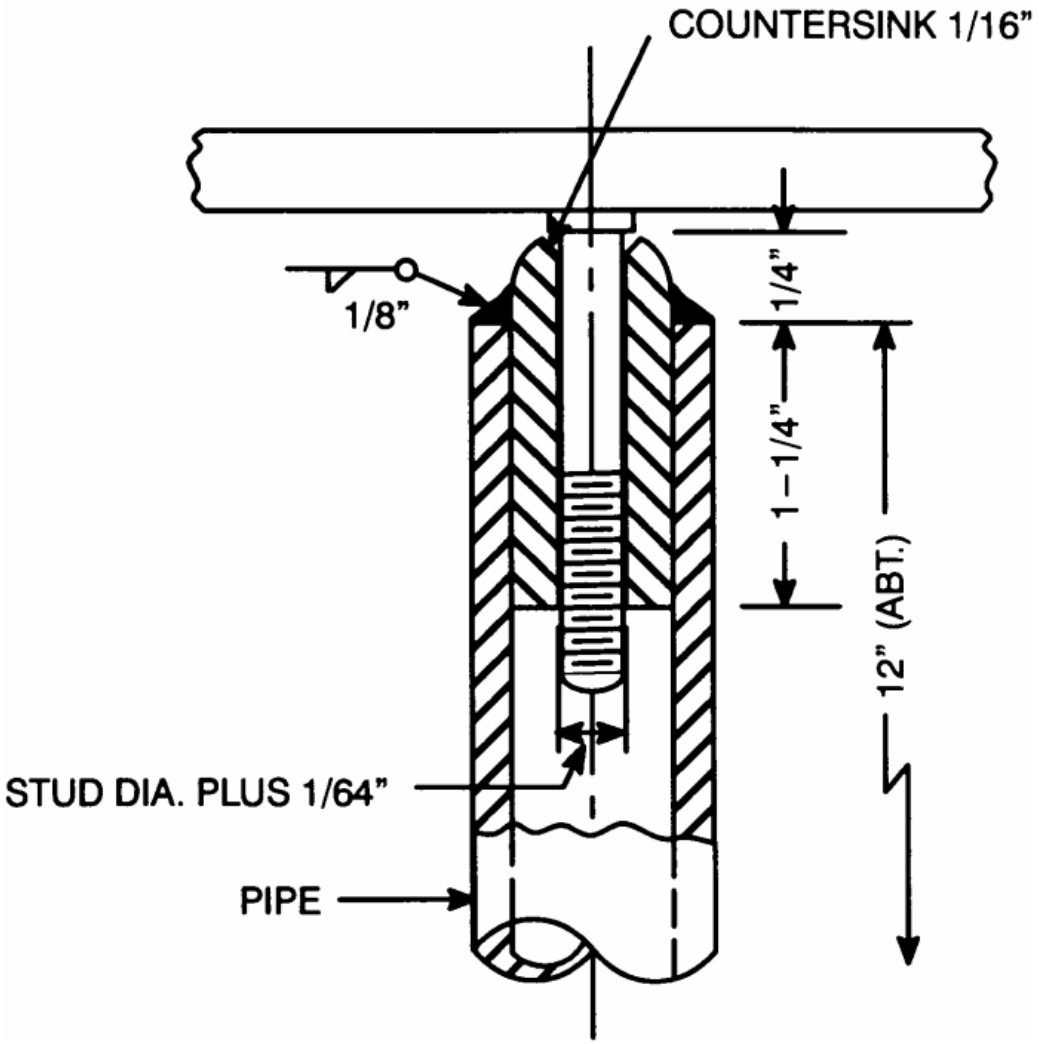


FIGURE 16. DEVICE FOR BEND TESTING WELDED STUDS.
(see 6.9.3)

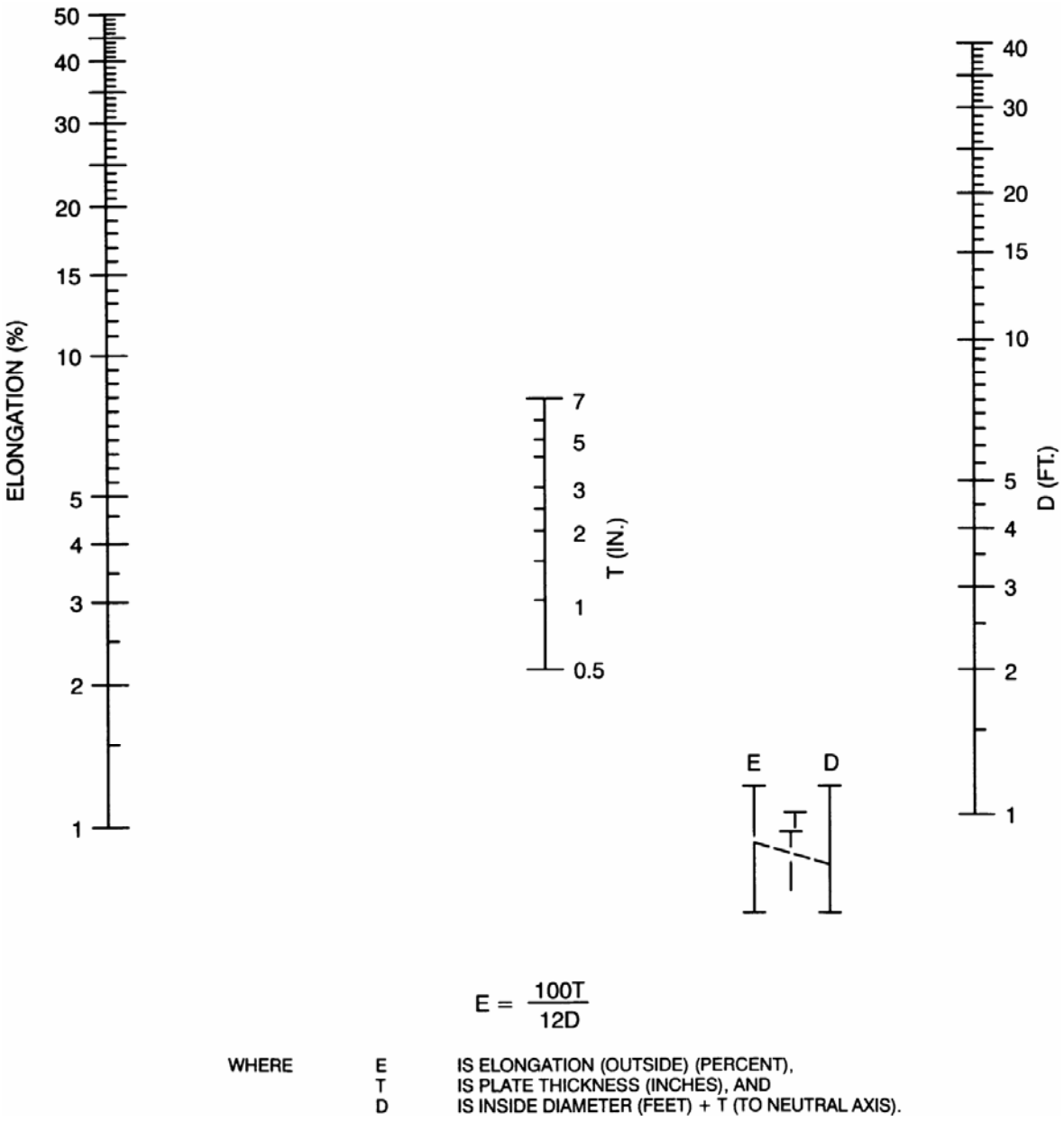


FIGURE 17. NOMOGRAPH OF OUTSIDE SURFACE ELONGATION AFTER BENDING OR ROLLING. (see 6.11)

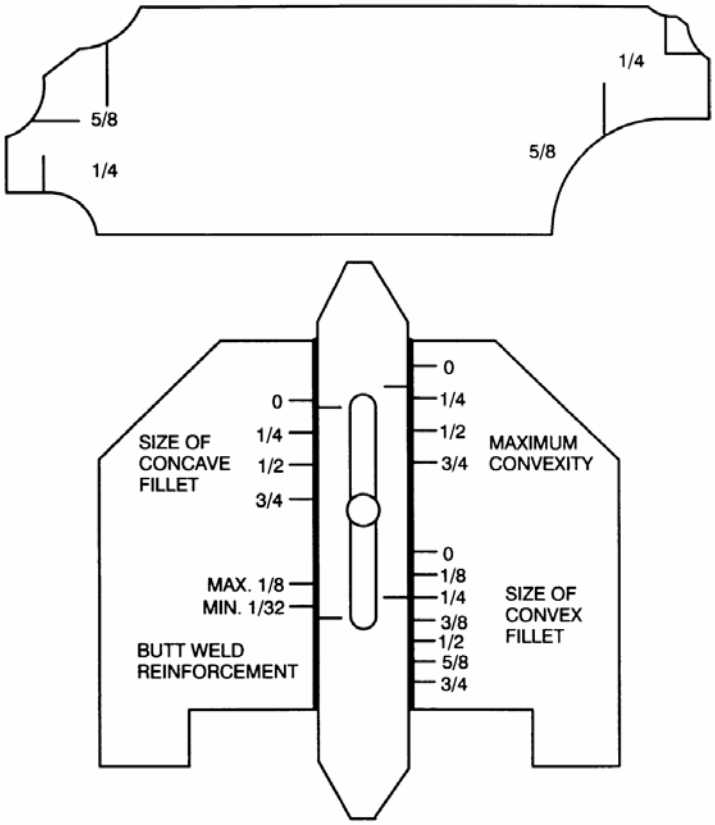


FIGURE 18. TYPICAL GAGES.

(see 7.4.5)

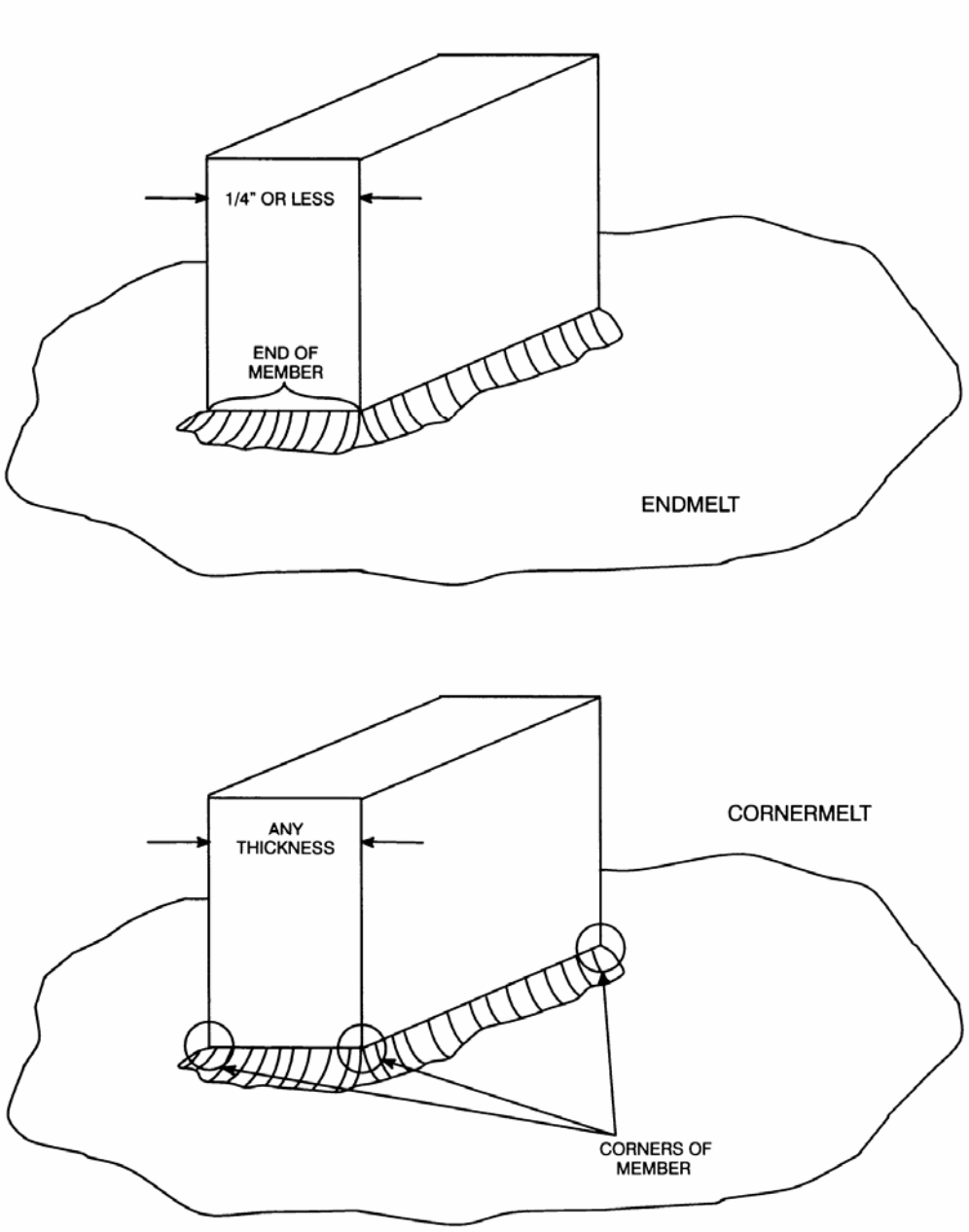
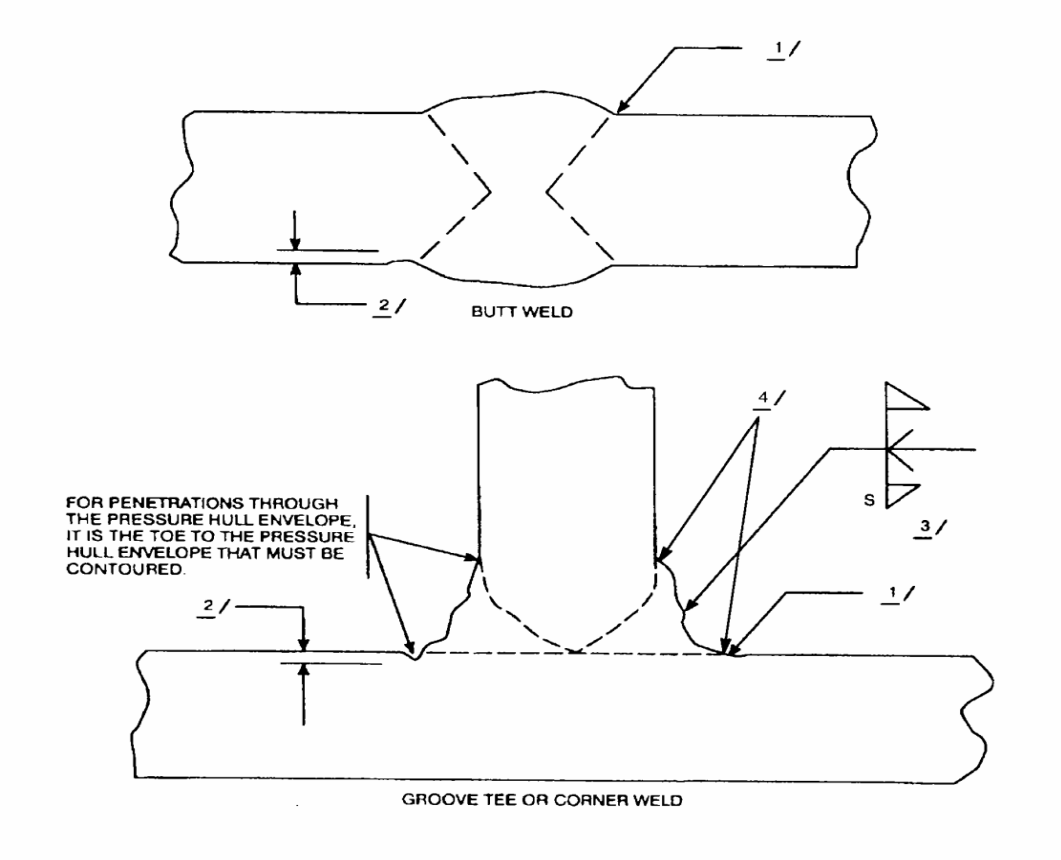


FIGURE 19. END-MELT AND CORNER-MELT.
(see 7.4.5)



Notes:

1/ The weld edges shall blend smoothly into the base material with no sharp notches.

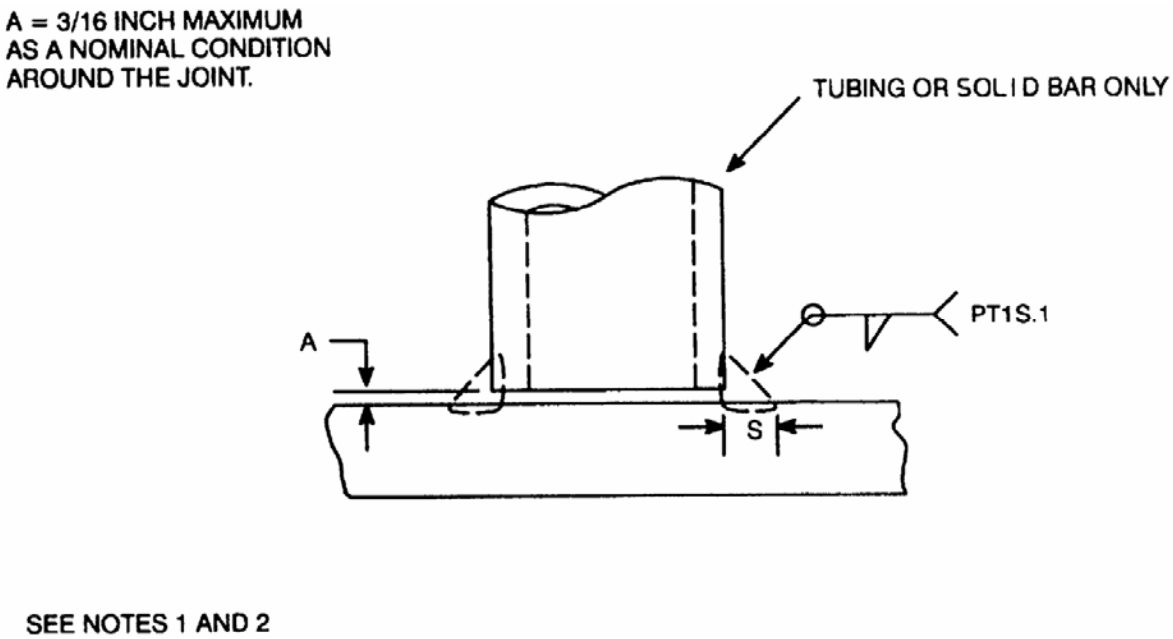
2/ Finished depth of contour below plate surface shall not exceed 3/64 inch, or 5/64 inch provided the length does not exceed 12 inches in any 36 inch length of ground length.

3/ S is the required fillet reinforcement. For full penetration groove tee and corner welds, maintain 1/3 "S" minimum after contouring. In this case the minimum throat thickness of 7.4.3 need not be maintained. For partial penetration groove and fillet welds, the required fillet reinforcement shall be maintained after contouring.

4/ For hard tank boundary groove tee and corner welds, all toes shall be contoured.

FIGURE 20. CONTOURED WELD REQUIREMENTS.

(see 7.4.8)

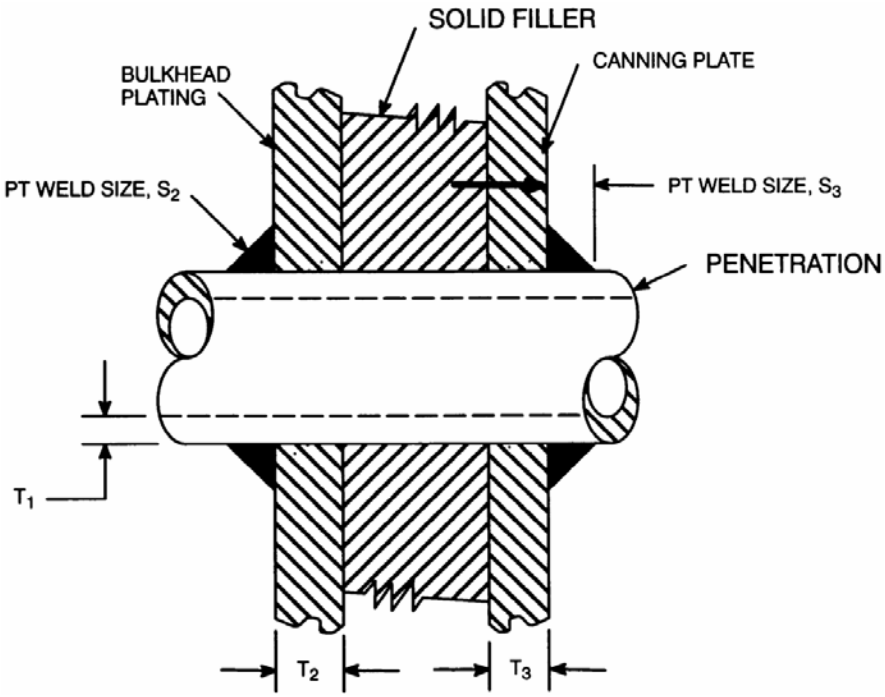


Notes:

1. Welds shall be sized in accordance with 11.4.4.
2. Where A is greater than 1/16 inch, S equals required fillet size plus (A minus 1/16 inch).

FIGURE 21. SINGLE FILLET TEE JOINT.

(see Table 11-1, Note 7)



Notes:

1. Welds (S2 and S3) shall be 100 percent efficient per MIL-STD-1628 (size doubled as appropriate for one-sided weld) based on the thickness of the weaker member (T1 or T2 for S2 and T1 or T3 for S3) when bulkhead and canning plate are both structural. Weld S3 may be 50 percent efficient when canning plate is non-structural.
2. A minimum efficiency of 50 percent is permitted where NAVSEA approved analyses/testing show that a less efficiency is adequate for a specific application.
3. The penetration sleeve is considered the continuous member for designing the welds.

FIGURE 22. PENETRATION THROUGH SPECIAL SANDWICH BULKHEAD WITH SOLID FILLER.

(see Table 11-1, Note 10)

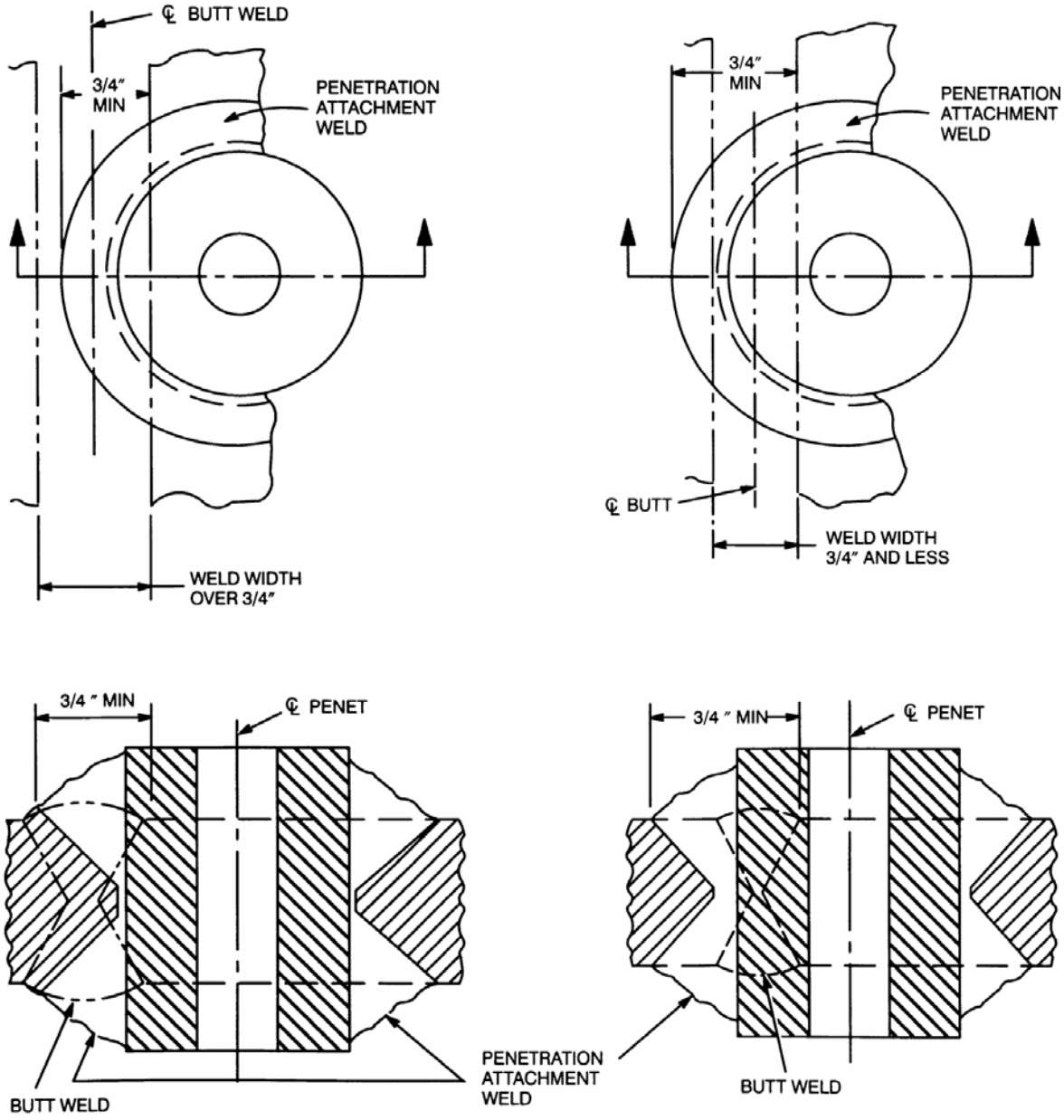
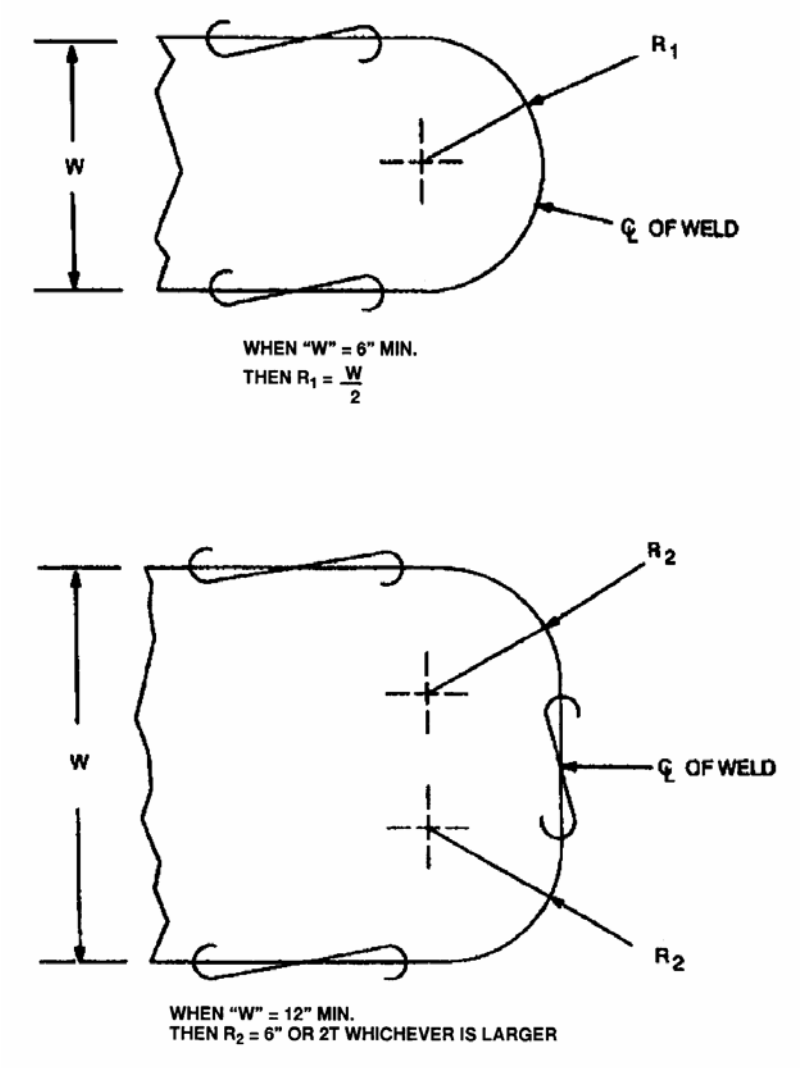


FIGURE 23. LOCATIONS OF PENETRATION ATTACHMENT WELDS IN RELATION TO BUTTS AND SEAMS.

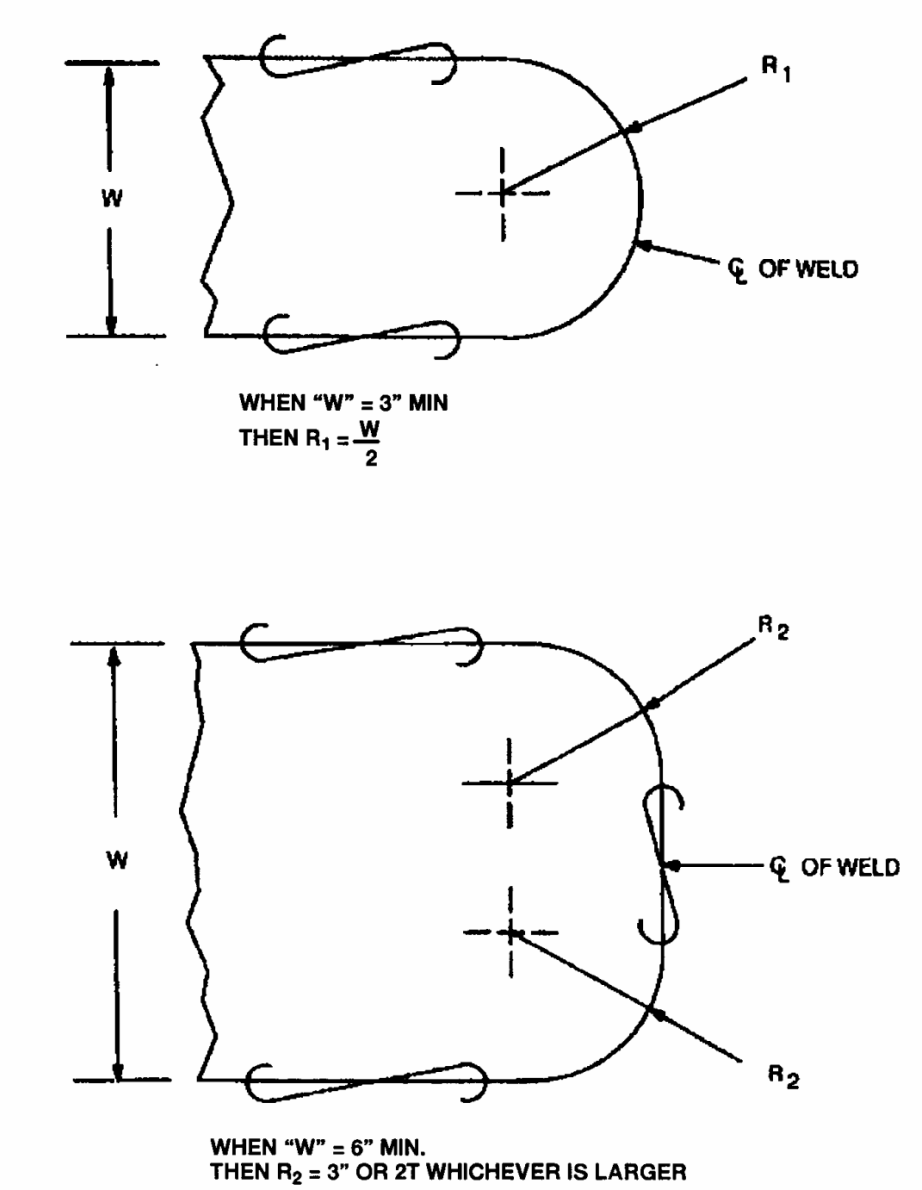
(see 11.5.1.1)



Where T is the thickness of the member penetrated.

FIGURE 24. INSERTS, PATCHES AND SMALL ACCESS PLATES IN PRESSURE HULL ENVELOPE.

(see 11.5.3)



Where T is the thickness of the member penetrated.

FIGURE 25. INSERTS, PATCHES AND SMALL ACCESS PLATES IN PLATING AND STRUCTURE OTHER THAN THE PRESSURE HULL ENVELOPE.

(see 11.5.3)

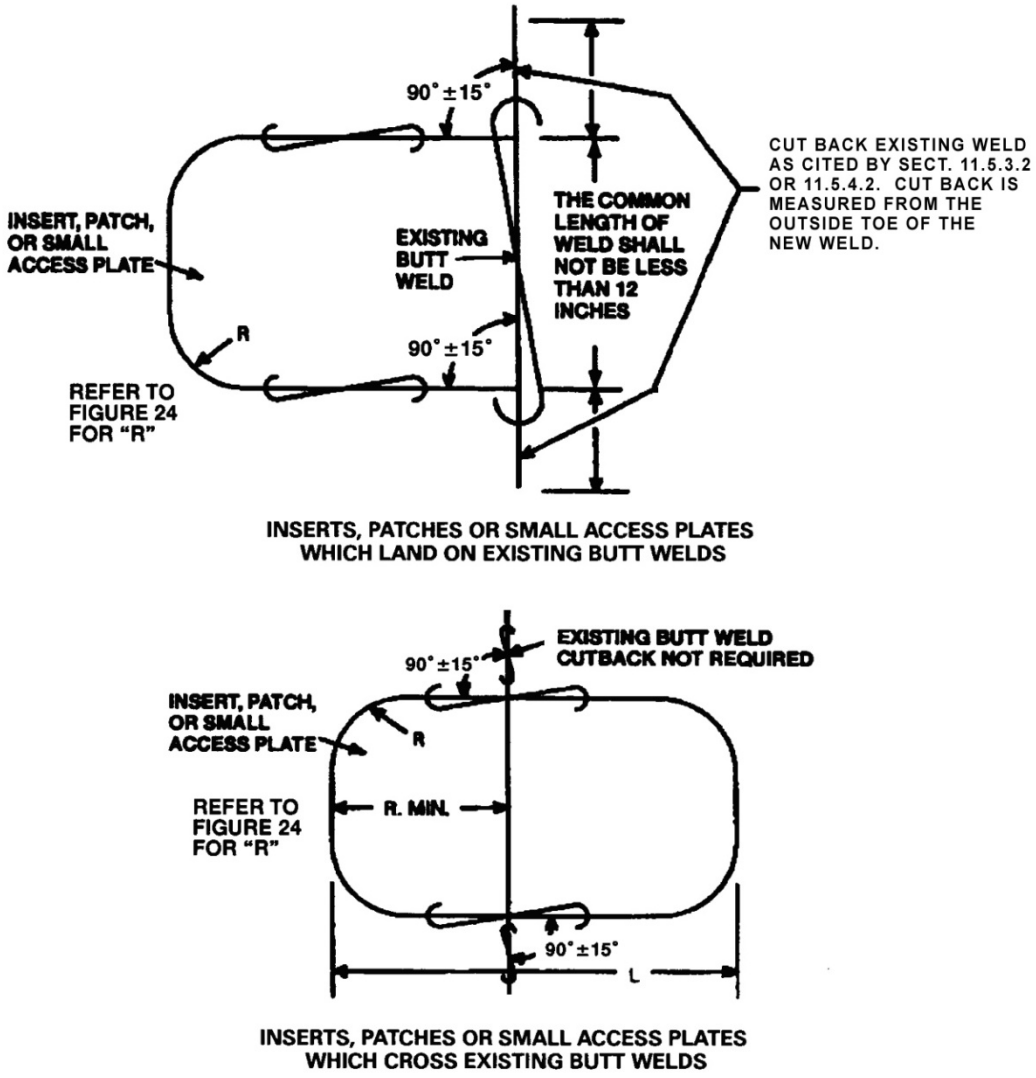
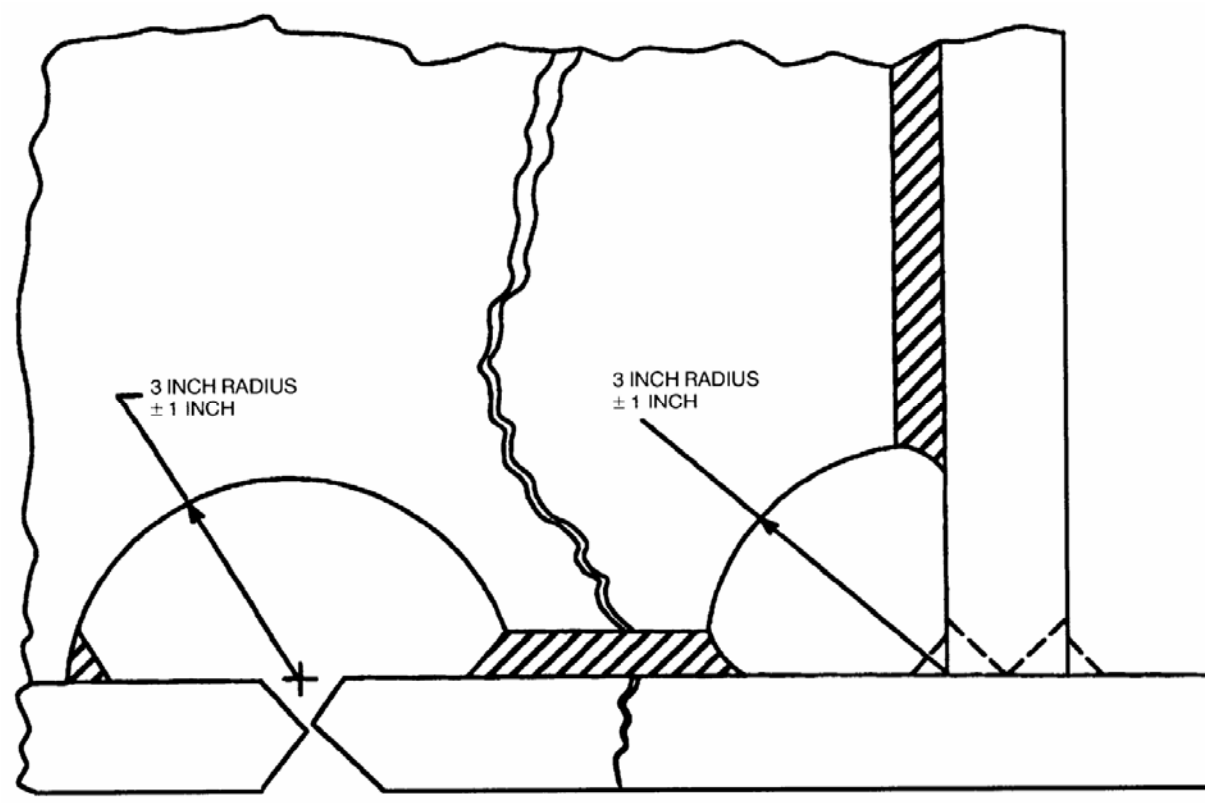


FIGURE 26. INSERTS, PATCHES, ACCESS PLATES OR CLOSURE PLATES IN PRESSURE HULL ENVELOPE WHICH LAND ON OR CROSS EXISTING BUTT WELDS.

(see 11.5.3.1, 11.5.3.2 and 11.5.4.2)



Note:
1. Seal-off or wrap around all snipes with weld in accordance with 7.4.7.

FIGURE 27. DRAIN, VENT OR PERMANENT SNIPE OPENING.
(see 11.5.5)

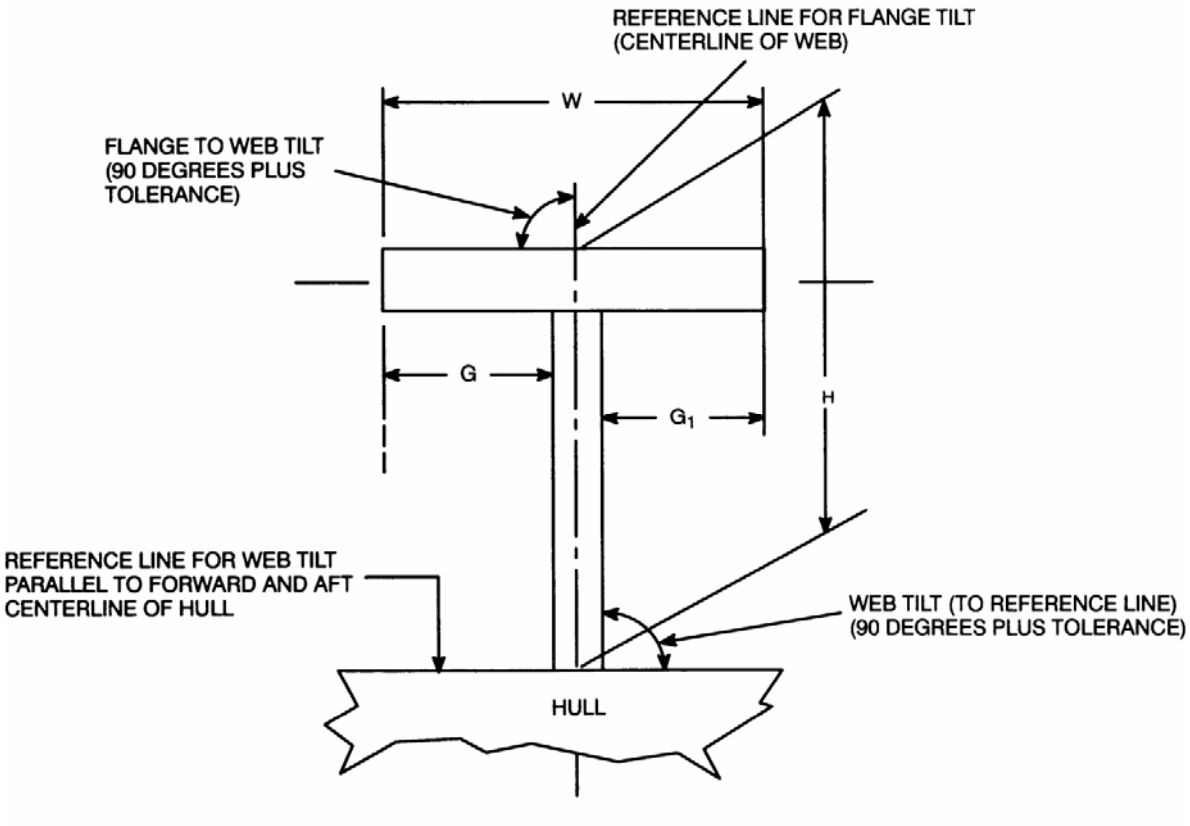
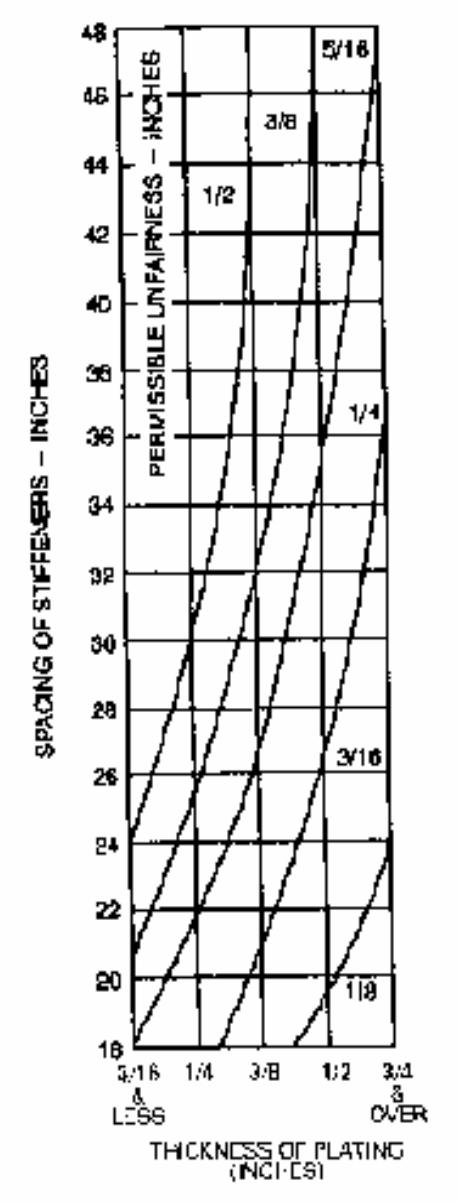


FIGURE 28. PRESSURE HULL FRAME TOLERANCES.

(see Table 12-1, Note 2)

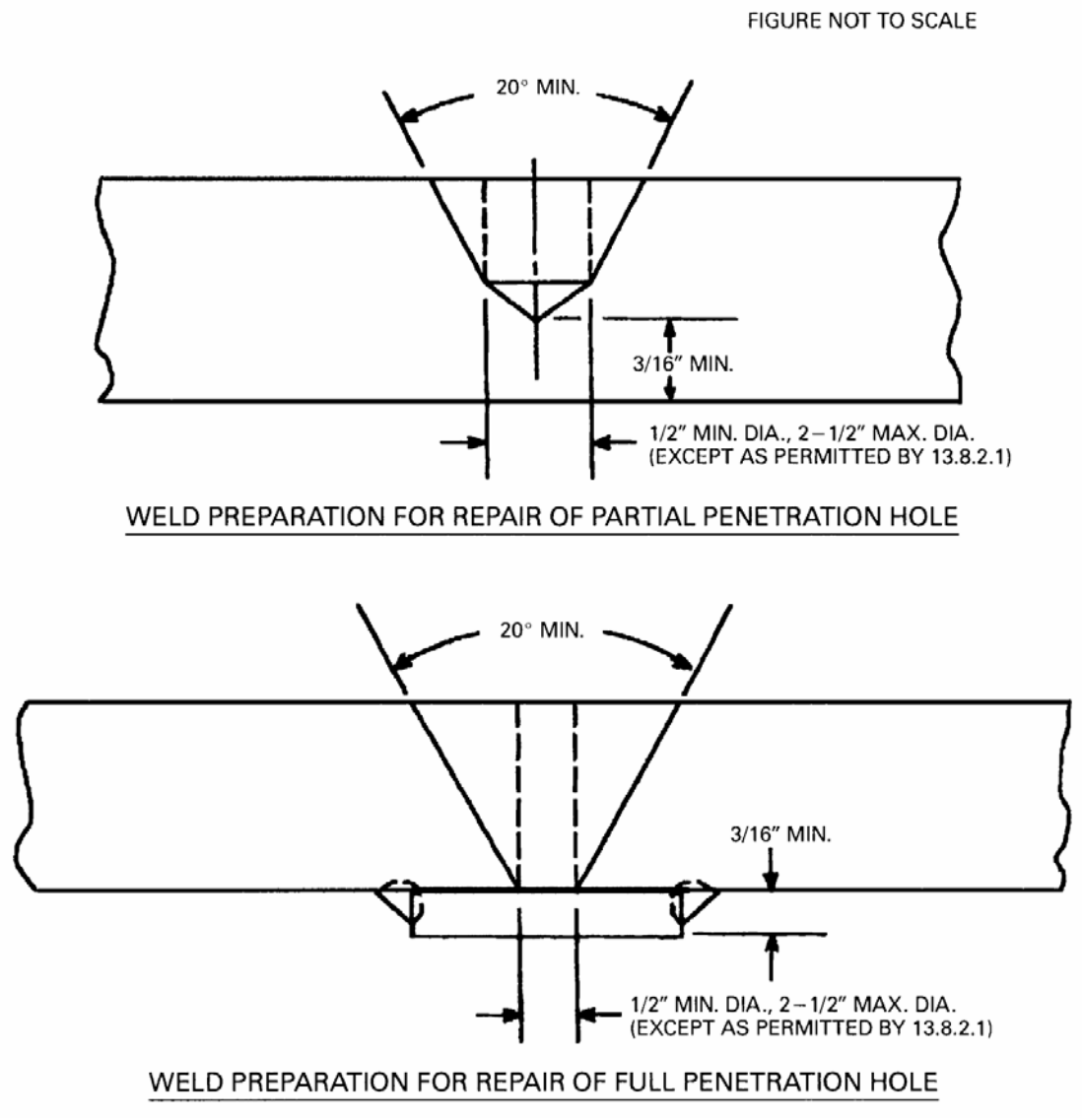


Note:

1. In applying the above tolerances, the unfairness of the plating shall be measured across the minor dimension of the panel.

FIGURE 29. TOLERANCE FOR UNFAIRNESS OF WELDED PLATE PANELS.

(see 12.3.3.4)

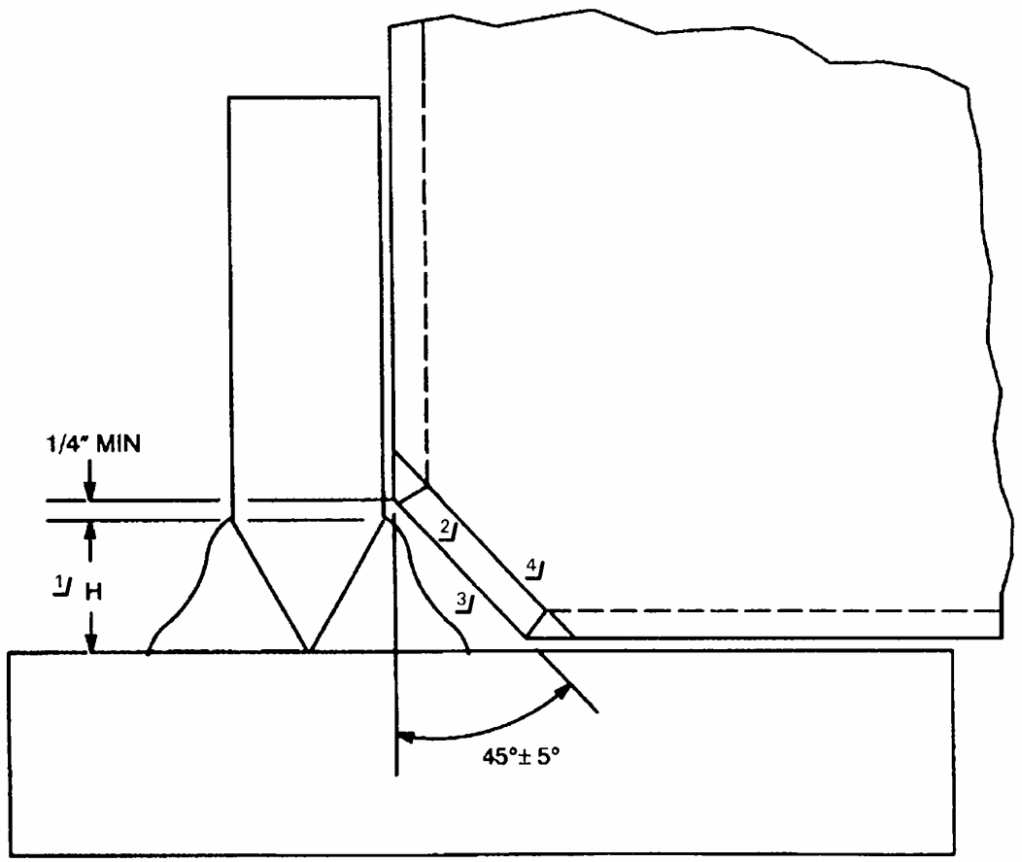


Note:

1. Repair of original holes with diameters over 2½ inches shall be in accordance with 13.8.2.1.

FIGURE 30. WELD REPAIR OF HOLES.

(see 13.8.2.1)



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.

4/ When the size of the snipe opening exceeds the maximum weld buildup limitations of 13.9.3, a patch plate shall be used in accordance with Figure 33.

FIGURE 31. TEMPORARY SNIPE IN CORNER OF CONNECTING STRUCTURAL MEMBER WHICH INTERSECTS TWO OR MORE OTHER MEMBERS.

(see 14.2.5)

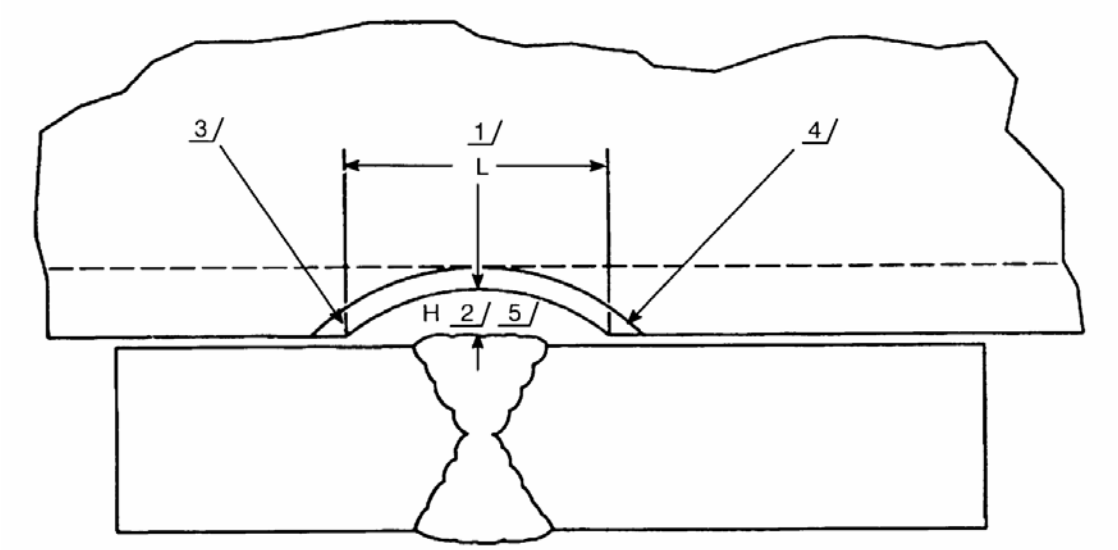


Figure not to scale.

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. The snipe shall be shaped and 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.
5. When the size of the snipe opening exceeds the maximum weld buildup limitations of 13.9.3, a patch plate shall be used in accordance with Figure 34.

FIGURE 32. TEMPORARY SNIPE IN STRUCTURAL MEMBER CONNECTION CROSSING A BUTT WELD.

(see 14.2.5)

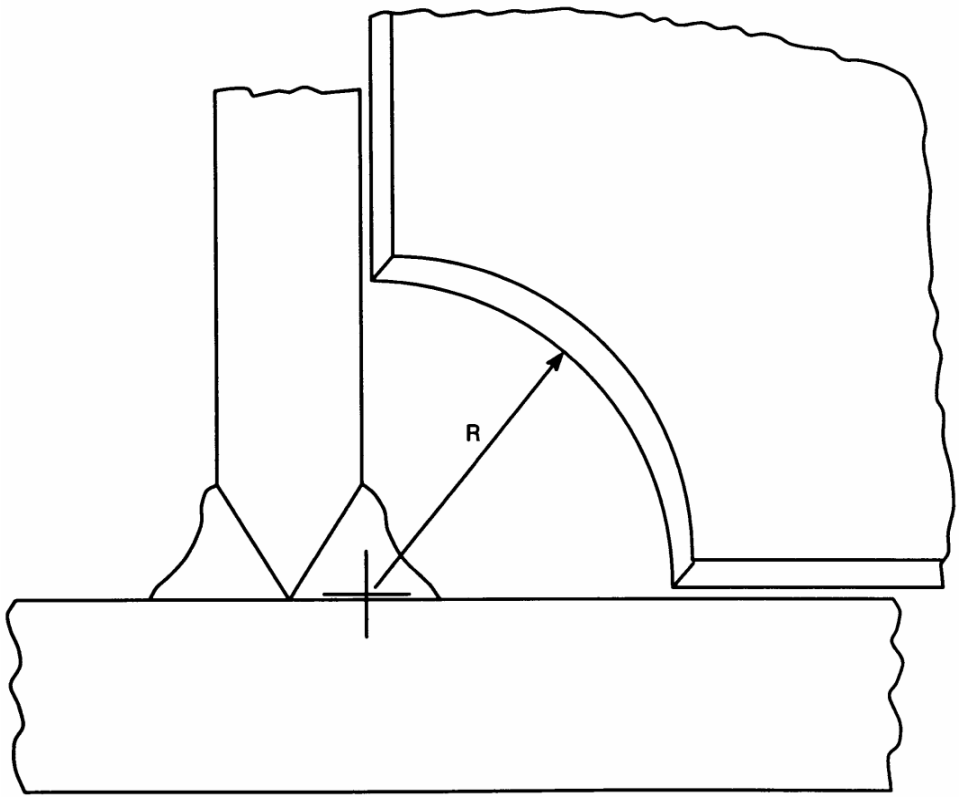


Figure not to scale.

Notes:

1. The radius of the temporary snipe shall be 2-inch minimum in non-pressure hull structure and 3-inch minimum in pressure hull structure.
2. Regardless of whether design of the sniped member specifies beveled or square edge preparation, the snipe shall be beveled as shown to insure maximum accessibility for welding.
3. Temporary snipes shall be closed by installation of a patch plate. Full penetration welds shall be employed and all welding shall be in accordance with the requirements of Section 13.
4. NDT for the temporary snipe weld shall be as specified in Section 6 as applicable for the member involved.

FIGURE 33. PATCH PLATE DETAIL FOR CLOSING TEMPORARY SNIPES IN CORNER OF CONNECTING STRUCTURAL MEMBER WHICH INTERSECTS TWO OR MORE OTHER MEMBERS.

(see 14.2.5)

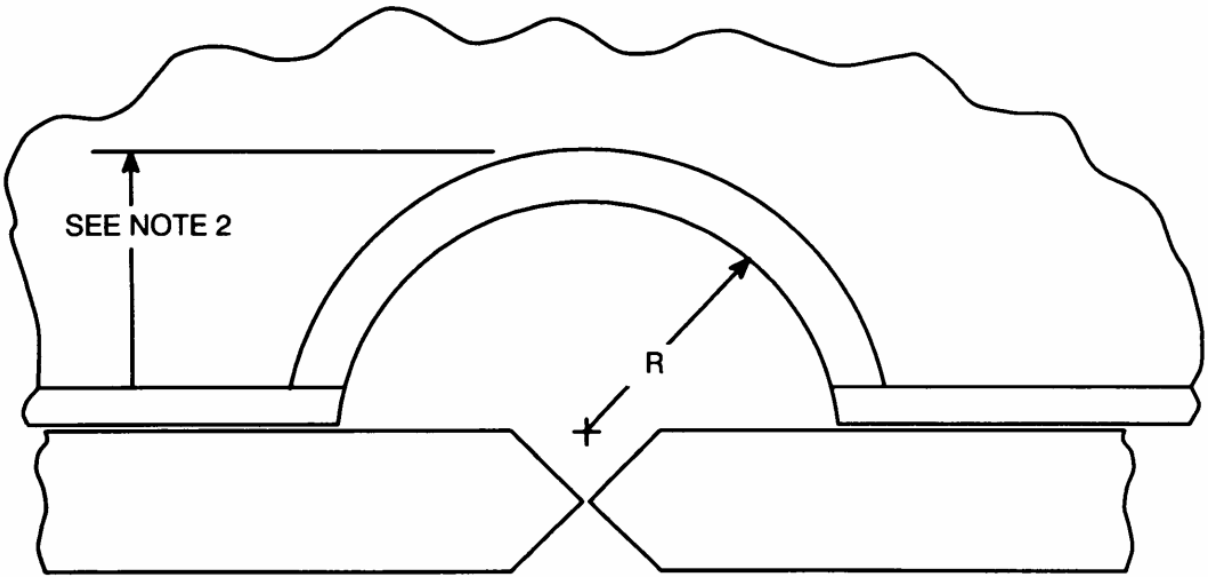


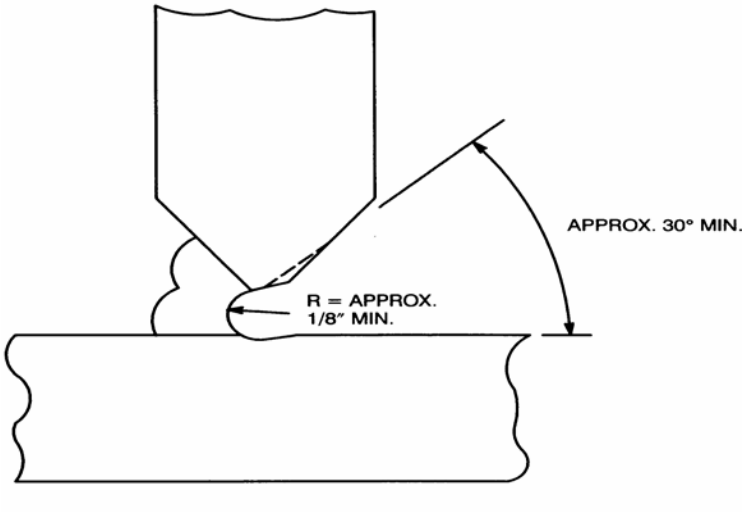
Figure not to scale.

Notes:

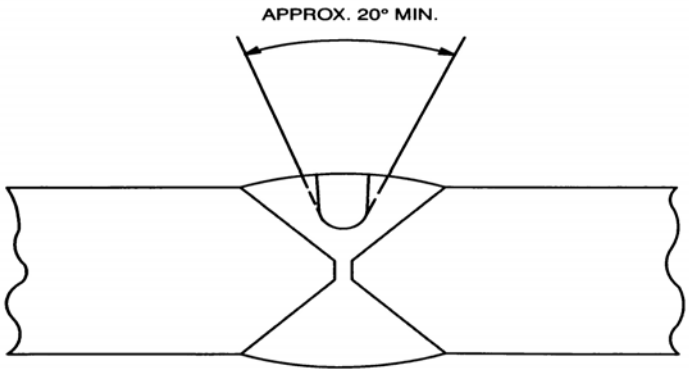
1. The radius of the temporary snipe shall be 2-inch minimum in non-pressure hull structure and 3-inch minimum in pressure hull structure.
2. Regardless of whether design of the sniped member specifies beveled or square edge preparation, the snipe shall be beveled as shown to insure maximum accessibility for welding. Where added height is required to provide access for the welding process being employed, the temporary snipe may be elongated by maintaining the specified minimum width and the 3-inch minimum radius at the upper end of the hole.
3. Temporary snipes shall be closed by installation of a patch plate. Full penetration welds shall be employed and all welding shall be in accordance with the requirements of Section 13.
4. NDT for the temporary snipe weld shall be as specified in Section 6 as applicable for the member involved.

FIGURE 34. PATCH PLATE DETAIL FOR CLOSING TEMPORARY SNIPES IN STRUCTURAL MEMBER CONNECTION CROSSING A BUTT WELD.

(see 14.2.5)



Keyholing resulting from grinding or gouging. Additional metal shall be removed as shown by dotted line to permit proper electrode accessibility and manipulation.



Excavation of weld metal for repair. Side walls of groove shall be opened as shown by dotted lines before rewelding. Radius at bottom contour = approximately 1/8 inch minimum.

FIGURE 35. BACKGOUGED WELD ROOT AND WELD REPAIR EXCAVATION CONTOURS.
(see 14.3.2)

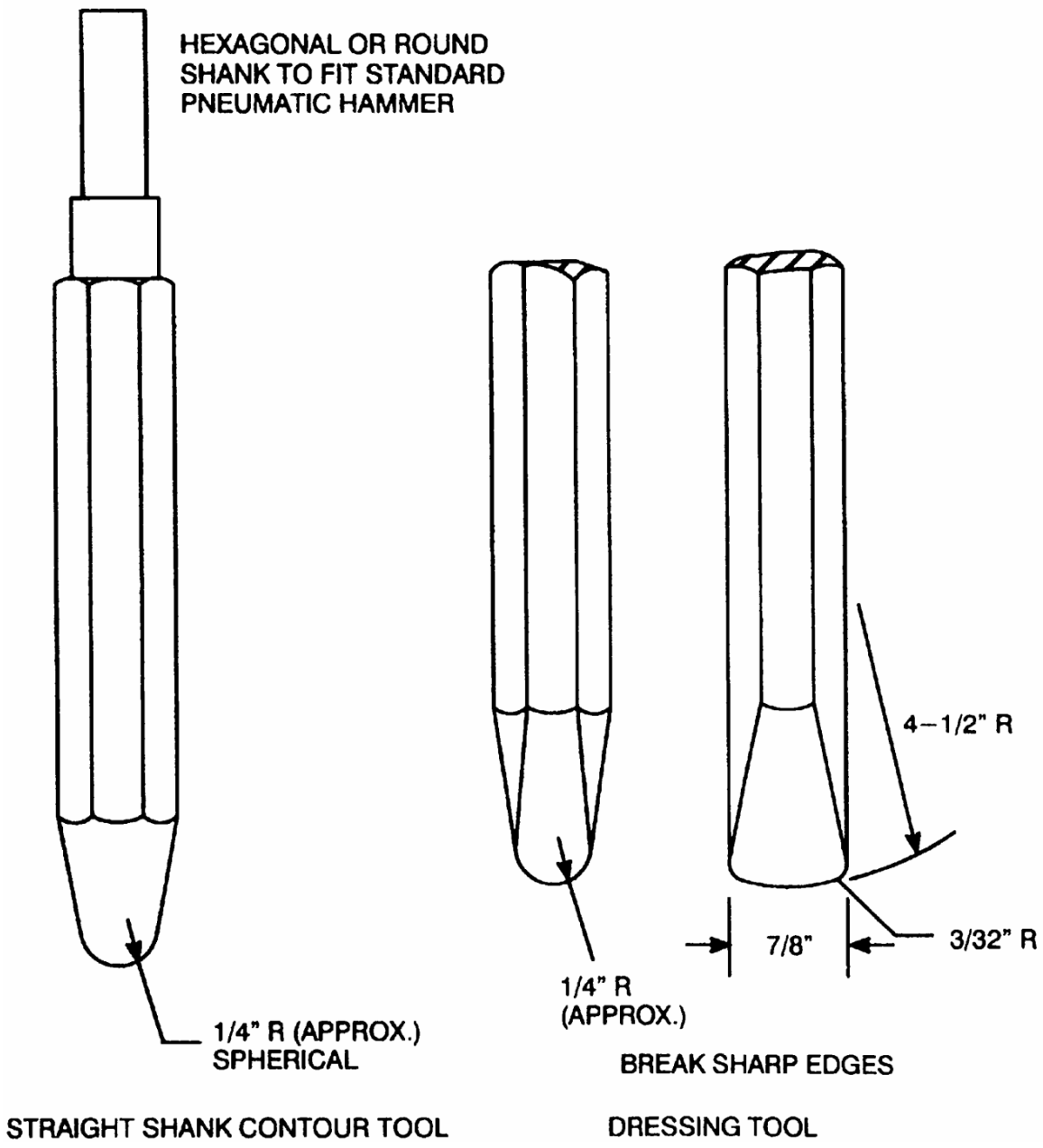


FIGURE 36. SUGGESTED MECHANICAL PEENING TOOLS.

(see 14.5.2)

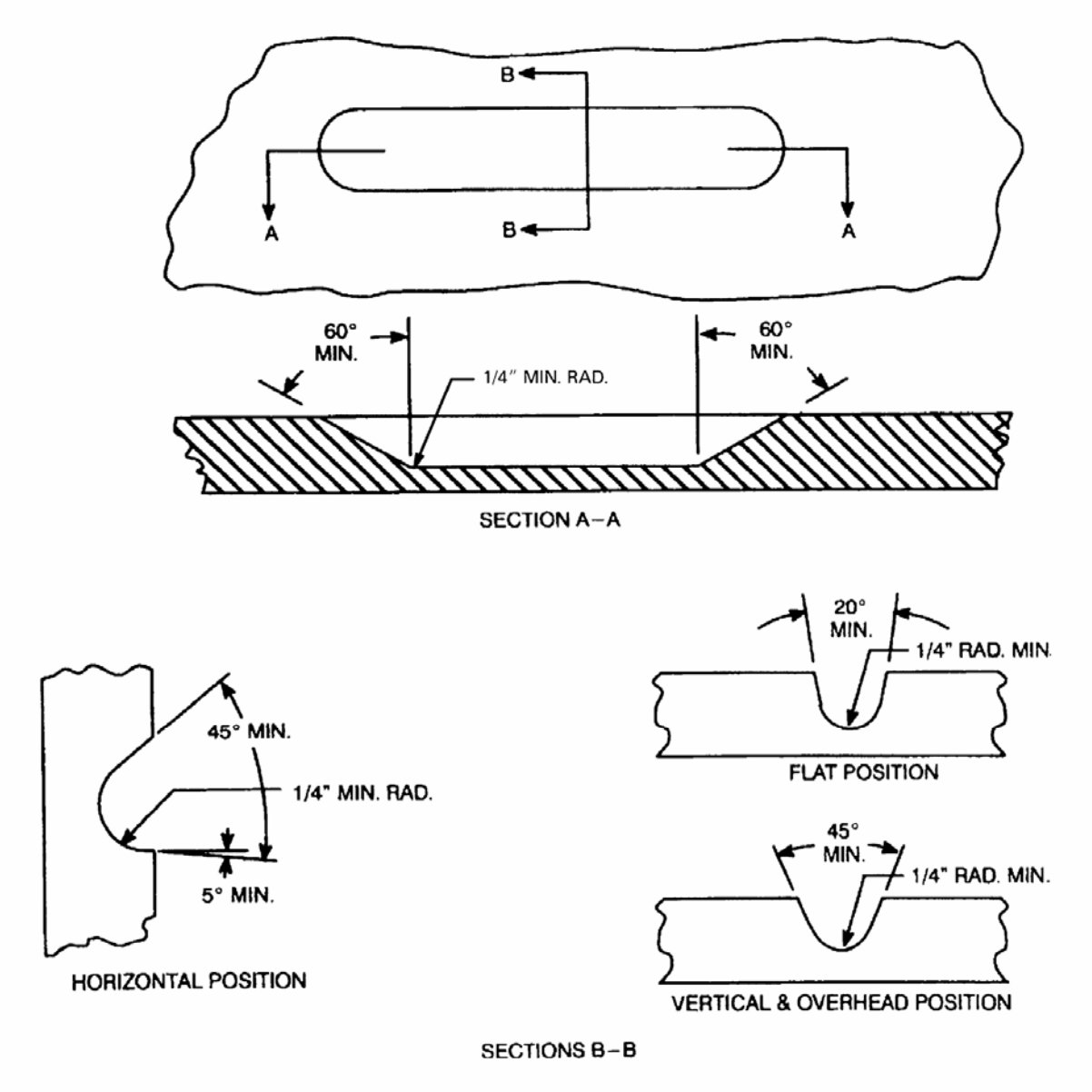
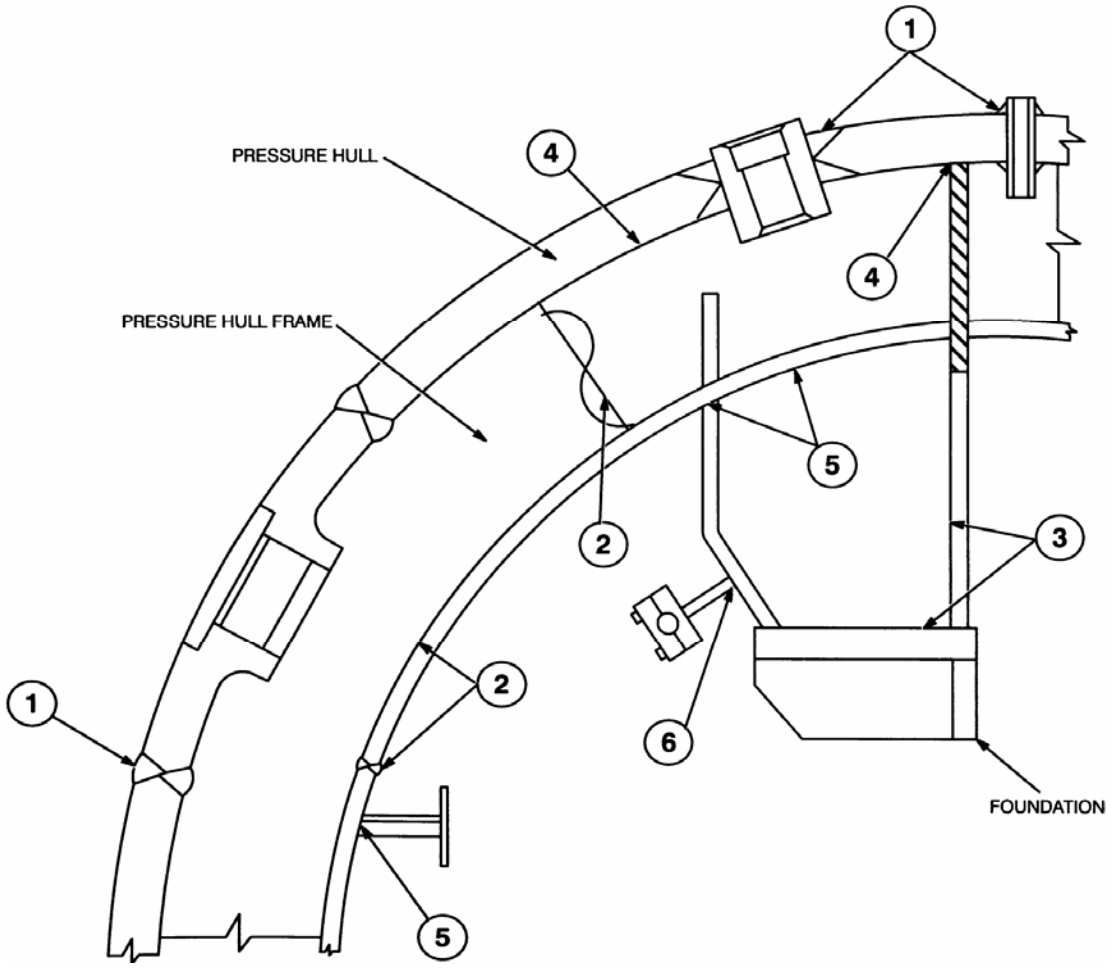


FIGURE 37. TYPICAL WELD REPAIR CONFIGURATIONS FOR CASTINGS.
(see 15.4.2.2)



Notes:

1. Weld location examples, numbers correspond to ones shown in figure:
   (1) WELDS IN Pressure Hull Envelope.
   (2) WELDS IN Support Structure.
   (3) WELDS IN Foundation.
   (4) WELDS TO Pressure Hull Envelope.
   (5) WELDS TO Support Structure.
   (6) WELDS TO Foundation.
2. Welds such as cladding, buttering, buildup, and repairs are independently categorized.
3. Any weld which may fall into more than one weld location category shall be considered as belonging to that category having the more stringent design and inspection criteria.

FIGURE 38. WELD LOCATION EXAMPLES.

(see 3.42)

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