S9074-AQ-GIB-010/248

REVISION 1

NAVSEA TECHNICAL PUBLICATION

REQUIREMENTS FOR WELDING AND BRAZING PROCEDURE AND PERFORMANCE QUALIFICATION

Supersedure Notice: This revision supersedes S9074-AQ-GIB-010/248 dated 1 August 1995.

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND

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12 NOVEMBER 2019

RECORD OF REVISIONS

REVISION NO.	DATE	TITLE OR BRIEF DESCRIPTION/PREPARING ACTIVITY
0	01 AUG 1995	Initial issue.
1	12 NOV 2019	This revision incorporates numerous changes to update the document for reduced lifecycle costs due to lessons learned, increased alignment to industry qualification requirements, problem resolutions, new materials (including more environmentally friendly brazing alloys), and advancements in technology. Of the hundreds of changes made, the more significant ones include: (1) Addition of: a. Pre-qualified NAVSEA Standard Welding Procedure Specifications b. Robotic welding c. Aluminum friction stir welding and processing d. Expanded cross qualification of HY/HSLA steels e. Navy high strength titanium alloy f. Expanded thickness ranges and increased dilution control for cladding and hardfacing qualification g. Cadmium-free brazing alloys; h. 6000 series aluminum alloys i. Requirements for computer-controlled power supplies j. Numerous S-1/P-101 and S-8/P-102 similar materials k. Bi-metal transition area qualification l. Limits for manual and semi-automatic process bead weaving (2) Increased periodicity for maintenance of welding and brazing performance qualification from 3 months to 6 months; (3) Eliminated approval of Level II qualification data; (4) Reduced qualification testing for automatic/mechanized pipe welding; (5) Addition of an annual meeting of authorized representatives; (6) Updating of nonferrous welding performance cross qualification allowances.

FOREWORD

This document contains the requirements for the qualification of welding and brazing procedures, welders, welding operators, brazers, and brazing operators that must be met prior to any production fabrication. It includes manual, semiautomatic, automatic, mechanized, and robotic welding and brazing of ferrous, nonferrous, and dissimilar metals. The qualification tests required by this document are devised to demonstrate the adequacy of the welding or brazing procedures and to demonstrate the ability of welders, brazers, welding operators, and brazing operators to produce sound welds or brazes.

NAVY DISTANCE SUPPORT (DS) CUSTOMER ASSISTANCE CONTACT INFORMATION

Fleet users of this technical manual (TM) may request NAVY 311 assistance. NAVY 311 is the Fleet's single point of entry for technical and logistics support whenever routine sources of support are unavailable or are not readily identifiable. NAVY 311 is operated via the Global Distance Support Community (GDSC) of geographically dispersed, centrally coordinated, Tier 1/2 call centers that function on a 24/7 basis. Point of entry options:

Phone: 1-855-NAVY311 (1-855-628-9311)/DSN 510-NAVY311 (510-628-9311)

Navy Distance Support/Navy 311 Web: http://www.navy311.navy.mil/ (unclassified) or https://www.navy311.navy.smil.mil/ (classified). (Provides program information and links to an online Support Request Form and Support Request Status, Live CHAT with a Call Center Rep, Knowledge Base Searching, etc.)

Email: Navy311@navy.mil or Navy311@navy.smil.mil

TMDER INSTRUCTIONS

Ships, training activities, supply points, depots, Naval Shipyards, and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA and NAVWAR TMs. All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA and NAVWAR TMs shall be submitted as a Technical Manual Deficiency/Evaluation Report (TMDER). All feedback comments shall be thoroughly investigated and originators will be advised of action resulting there from.

The NAVSEA/NAVWAR TMDER form, NAVSEA 4160/1, is included at the back of the TM.

The following methods are available for generation and submission of TMDERs against unclassified TMs:

For those with a Technical Data Management Information System (TDMIS) account, the most expedient and preferred method of TMDER generation and submission is via the TDMIS website at https://mercury.tdmis.navy.mil/.

For those without a TDMIS account, generate and submit a TMDER via the Naval Systems Data Support Activity (NSDSA) website at https://mercury.tdmis.navy.mil/def_external/pubsearch.cfm. (TDMIS accounts may be requested at the NSDSA website at https://nsdsa.dc3n.navy.mil/ by submitting a Customer Service Request [CSR].)

When internet access is not available, submit TMDER via hardcopy to:

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COMMANDER NAVAL SURFACE WARFARE CENTER
NAVAL SYSTEMS DATA SUPPORT ACTIVITY
4363 MISSILE WAY
ATTN:  CODE 310 BLDG 1389 TMDERS
PORT HUENEME, CA 93043-4307
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Additional copies of the TMDER form may also be downloaded from the NSDSA website at https://nsdsa.dc3n.navy.mil/ by clicking on the blue tab labeled "Reference Docs/Forms".

TMDERs against classified/restricted TMs (includes all NOFORN) must be submitted using the hardcopy method cited above.

Urgent priority TM deficiencies shall be reported by naval message with transmission to Port Hueneme Division, Naval Surface Warfare Center (Code 310), Port Hueneme, CA. Local message handling procedures shall be used. The message shall identify each TM deficiency by Technical Manual Identification Number (TMIN) and title. This method shall be used in those instances where a TM deficiency constitutes an urgent problem (i.e., involves a condition, which if not corrected, could result in injury to personnel, damage to the equipment, or jeopardy to the safety or success of the mission).

Complete instructions for TMDER generation and submission are detailed on the NSDSA website at https://nsdsa.dc3n.navy.mil/ by clicking on the blue tab labeled “TMDER/ACN” and then clicking on the gray button labeled “TMDERs”.

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CHAPTER 1
SCOPE

1-1 SCOPE.

This document contains the requirements for the qualification of welding and brazing procedures, welders, welding operators, brazers, and brazing operators that must be met prior to any production fabrication. It includes manual, semiautomatic, automatic, mechanized, and robotic welding and brazing of ferrous, nonferrous, and dissimilar metals. The qualification tests required by this document are devised to demonstrate the adequacy of the welding or brazing procedures and to demonstrate the ability of welders, brazers, welding operators, and brazing operators to produce sound welds or brazes.

1-1.1 SAFETY. Safety and health issues and concerns are beyond the scope of this document and are therefore not addressed herein. Safety and health information is available from the following sources:

a. Department of the Navy – Office of The Chief of Naval Operations:
   (1) OPNAVINST 5100.23 (series)
   (2) OPNAVINST 5100.19 (series)
b. American Welding Society:
   (1) ANSI Z49.1
   (2) AWS Safety and Health Fact Sheets
   (3) Other safety and health information on the AWS website
c. Material or Equipment Manufacturers:
   (1) Safety Data Sheets supplied by materials manufacturers
   (2) Operating Manuals supplied by equipment manufacturers
d. Applicable Regulatory Agencies.

Work performed in accordance with this document may involve the use of materials that have been deemed hazardous and may involve operations or equipment that may cause injury or death. This document does not purport to address safety and health risks that may be encountered. Users of this document shall comply with appropriate safety programs to address such risks as well as to meet applicable regulatory requirements.

1-2 PREVIOUSLY QUALIFIED PROCEDURES AND PERSONNEL.

Except as required by 1-2.1 and 1-2.2, procedures and personnel previously qualified to earlier revisions of this document, for which records are available and qualifications have been maintained, are acceptable for use to this revision. However, the authorized representative may require requalification to this revision on a case-by-case basis where both of the following apply:

a. There are specific concerns about the adequacy of procedures or ability of personnel to produce welds of intended integrity or which meet requirements of the applicable fabrication document, and
b. The existing qualification requires requalification by this document.

These requirements also apply to the visual inspection training of personnel required by this document. It is not the purpose of this document to require extensive requalification of previously qualified procedures or personnel. Changes to existing procedures and procedure and personnel qualifications, and qualification of new procedures and personnel performance, shall be accomplished in accordance with the requirements of this document. New procedures developed from existing qualifications shall conform to this revision.

1-2.1 MIL-120XX PROCEDURES. Procedures involving the use of MIL-12018-M2 or MIL-120S-1 electrodes previously qualified to other revisions of this document are not approved for use when this revision is invoked, unless specifically approved by NAVSEA.

1-2.2 HIGH-HEAT INPUT PROCEDURES FOR MIL-S-22698. Unless accompanied by heat affected zone (HAZ) toughness testing or specifically approved by NAVSEA, procedures previously qualified to other revisions of this document involving MIL-S-22698, grades D, E, AH36, DH36, and EH-36 with heat inputs of 110 kilojoules/inch or higher are not approved for use when this revision is invoked (see table 7-7, footnote 5).

1-3 REQUIREMENTS AND GUIDANCE.

This document contains both mandatory requirements (indicated by the word "shall"), designed to serve as standards applicable to methods, materials, and inspection, and guidance information (indicated by either the word "should" or "may"). Guidance information is recommended but is not mandatory.

1-4 OTHER NAVSEA WELDING QUALIFICATION STANDARDS.

Existing welding procedures and personnel qualifications in accordance with NAVSEA 250-1500-1 may be used as discussed below in lieu of the qualification requirements of this document, provided the prior qualification is for base and filler materials and welding processes normally allowed by NAVSEA 250-1500-1:

a. Welding procedure qualification evidence that supports an approved welding procedure in accordance with NAVSEA 250-1500-1 may be considered approved in lieu of welding procedure qualification evidence required by this document, even though the nondestructive and destructive tests conducted on the qualification test assembly may have differed from those required by this document. In addition to the base and filler materials which this qualification evidence allows to be welded in accordance with this document, base and filler materials allowed by the NAVSEA 250-1500-1 approved welding procedure may also be considered qualified. The welding procedure shall be rewritten, as necessary, to conform to the requirements of this document (e.g., to reflect differences in requalification requirements).

b. Welding personnel qualifications in accordance with NAVSEA 250-1500-1 may be used in lieu of qualifications in accordance with this document, provided personnel are trained on the applicable differences. The extent of qualification shall be as allowed in either document.

1-5 AUTHORIZED REPRESENTATIVE ANNUAL MEETING.

Authorized representatives (see 3-1.6) shall meet annually to discuss any issues or deficiencies encountered with qualifications in accordance with this document. NAVSEA will arrange the time and place of this meeting.

CHAPTER 2
REFERENCED DOCUMENTS

2-1 GOVERNMENT DOCUMENTS.

2-1.1 SPECIFICATIONS AND STANDARDS. 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.

FEDERAL SPECIFICATIONS

O-F-499	-	Flux Brazing, (Silver Brazing Filler Metal, Low Melting Point)
QQ-B-639	-	Brass, Naval: Flat Products
QQ-B-654	-	Brazing Alloys, Silver
QQ-C-450	-	Copper-Aluminum Alloy (Aluminum Bronze) Plate, Sheet, Strip, and Bar (Copper Alloy Numbers 606, 610, 613, 614, and 630)
QQ-N-281	-	Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-T-1368	-	Tube and Pipe, Nickel-Copper Alloy, Seamless and Welded
MIL-T-15005	-	Tubes, Condenser and Heat Exchanger, Copper-Nickel Alloys (UNS C70600 & C71500)
MIL-B-15382	-	Bolt, Firebrick Anchor
MIL-C-15726	-	Copper-Nickel Alloy, Sheet, Plate, Strip, Bar, Rod, and Wire
MIL-T-16286	-	Tube, Steel, Seamless, Marine Boiler Application
MIL-T-16420	-	Tube, Copper-Nickel Alloy, Seamless and Welded (Copper Alloy Numbers 715 and 706)
MIL-R-17131	-	Rods and Powders, Welding, Surfacing
MIL-E-19933	-	Electrodes and Rods – Welding, Bare, Chromium and Chromium-Nickel Steels
MIL-T-20219	-	Tube, Brass, Voice and Pneumatic (Copper Alloy No. 260)
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-22200/8	-	Electrodes, Welding, Covered, Low-Hydrogen, and Iron-Powder Low-Hydrogen, Chromium-Molybdenum Alloy Steel and Corrosion Resisting Steel
MIL-S-22698	-	Steel Plate, Shapes and Bars, Weldable Ordinary Strength and Higher Strength: Structural
MIL-S-23193	-	Steel, Corrosion Resistant; Castings
MIL-DTL-23194	-	Steel, Forgings, Carbon and Low Alloy (UNS K13502, K12766, and K42365)
MIL-DTL-23195	-	Steel Bars and Forgings, Corrosion Resistant, Austenitic (UNS S30400, S30403, S31600, S31603, S34700, and S34800)
MIL-DTL-23196	-	Steel Plate, Corrosion Resistant (UNS S30400/S30403, S31600/S31603, S31703, S34700, and S34800)
MIL-DTL-23226	-	Tube and Pipe, Corrosion-Resistant Steel, Seamless (UNS S30400, S30403, S34700, and S34800)
MIL-DTL-23227	-	Tube and Pipe, Nickel-Chromium-Iron Alloy (UNS N06600)
MIL-N-23228	-	Nickel Chromium Iron Alloy Plate, Sheet and Strip
MIL-DTL-23229	-	Nickel-Chromium-Iron Alloy Bars and Forgings (UNS N06600)
MIL-S-23284	-	Steel Forgings, Carbon and Alloy, for Shafts, Sleeves, Propeller Nuts, Couplings, and Stocks (Rudders and Diving Planes)
MIL-I-23413	-	Inserts, Welding, Filler Material, Coiled and Solid Rings
MIL-DTL-23467	-	Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding, Austenitic Corrosion-Resistant Steel
MIL-DTL-23508	-	Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding, Nickel Chromium Iron Alloy (UNS N06600)
MIL-DTL-23509	-	Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding, Nickel-Copper Alloy (UNS N04400)
MIL-DTL-23520	-	Tube and Pipe, Nickel-Copper Alloy, Seamless, Air Melted
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-23765/2	-	Electrodes and Rods – Welding, Bare, Solid, or Alloyed Cored, and Fluxes, Low Alloy Steel
MIL-E-23765/3	-	Electrodes and Rods – Welding, Bare, Solid Copper Alloy
MIL-E-23765/4	-	Electrodes-Welding, Bare, Solid; and Fluxes, Submerged Arc Welding, Carbon and Low Alloy Steels
MIL-S-24093	-	Steel Forgings, Carbon and Alloy Heat Treated
MIL-N-24106	-	Nickel-Copper Alloy Bars, Rods, and Forgings
MIL-T-24107	-	Tube, Copper (Seamless) (Copper Alloy Numbers C10100, C10200, C10300, C10800, C12000, C12200, and C14200)

MIL-DTL-24114 - Nickel-Chromium-Iron Age-Hardenable Alloy Bars, Rods, and Forgings

MIL-L-24128 - Low Carbon Chromium Steel Bars and Forgings

MIL-S-24149 - Studs, Welding, and Arc Shields (Ferrules), General Specification for

MIL-S-24149/1 - Stud, Welding, and Arc Shields (Ferrules); Type I, Class 1, 2, 3, and Type II, Class 1, 4, 5, 5 A, 6, Carbon Steel, for Direct Energy Arc Welding

MIL-S-24149/2 - Studs, Welding, and Arc Shields (Ferrules); Type III, Class 1, 2, 3, and Type IV, Class 1, 2, 3, 4, 5, 6, Aluminum Alloy, for Direct Energy Arc Welding

MIL-S-24149/3 - Studs, Welding, and Arc Shields (Ferrules); Type V, Class 1, 4, 5, 5A, Corrosion-Resistant Steel, for Direct Energy Arc Welding

MIL-S-24149/4 - Studs, Welding, Type VI, Class 1, 2, 3, Carbon Steel, for Stored Energy (Capacitor Discharge) Arc Welding

MIL-S-24149/5 - Studs, Welding; Type VII, Class 1, 2, 3, Aluminum Alloy, for Stored Energy (Capacitor Discharge) Arc Welding

MIL-S-24149/6 - Studs, Welding; Type VIII, Class 1, 2, 3, Corrosion-Resistant Steel for Stored Energy (Capacitor Discharge) Arc Welding

MIL-S-24238 - Steel Plate, Carbon and Low Alloy

MIL-N-24271 - Nickel-Chromium-Iron Alloy Castings

MIL-P-24338 - Pipe, Carbon Steel, Seamless

MIL-DTL-24339 - Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding Carbon Steel

MIL-DTL-24342 - Fitting and Flanges, Wrought Seamless, Butt and Socket Welding 70-30 Copper-Nickel Alloy (UNS C71500)

MIL-E-24403 - Electrodes – Welding, Flux Cored, General Specification for

MIL-DTL-24403/1 - Electrodes – Welding, Flux Cored, Ordinary Strength and Low Alloy Steel

MIL-E-24403/2 - Electrodes – Welding, Flux Cored, Low-Alloy Steel

MIL-B-24480 - Bronze, Nickel Aluminum (UNS No. C95800) Castings for Seawater Service

DOD-F-24669 - Forgings and Forging Stock, Steel Bars, Billets and Blooms, General Specification for (Metric)

DOD-F-24669/1 - Forgings and Forging Stock, Steel (Carbon and Alloy) Blooms, Bars, Billets and Slabs (Metric)

DOD-F-24669/2 - Forgings and Forging Stock, Steel Bars and Billets – Chromium-Molybdenum Alloy (Metric)

DOD-F-24669/6 - Forgings and Forging Stock, Steel Bars and Billets, Corrosion Resisting; for Reforging (Metric)

DOD-F-24669/7 - Forgings and Forging Stock, Steel Bars and Billets, Corrosion Resisting; Naval Steam Turbine Parts Use (Metric)

MIL-P-24691 - Pipe and Tube, Carbon, Alloy and Stainless Steel, Seamless and Welded, General Specification for

MIL-P-24691/1 - Pipe and Tube, Carbon Steel, Stainless

MIL-P-24691/2	-	Pipe and Tube, Chromium-Molybdenum Steel, Seamless
MIL-P-24691/3	-	Pipe and Tube, Corrosion-Resistant, Stainless Steel, Seamless or Welded
MIL-DTL-24707/1	-	Castings, Ferrous, for Machinery and Structural Applications
MIL-C-24707/2	-	Castings, for Pressure Containing Parts Suitable for High Temperature Service
MIL-C-24707/3	-	Castings, Ferrous, Corrosion-Resistant, Austenitic, Chromium-Nickel
MIL-C-24707/6	-	Castings, Ferrous, Chromium Steel, for Pressure-Containing Parts Suitable for High-Temperature Service
MIL-C-24723	-	Castings, Nickel-Copper Alloy
MIL-DTL-32528	-	Rod, Bar, and Billet, Titanium Alloy TI-5111 for Use in Critical Seawater Application

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-22	-	Welded Joint Design
MIL-STD-1689	-	Fabrication, Welding, and Inspection of Ships Structure
MIL-STD-2035	-	Nondestructive Testing Acceptance Criteria
MIL-STD-2191	-	Repair Welding, Weld Cladding, Straightening, and Cold Rolling of Main Propulsion Shafting

(Copies of these documents are available online at https://quicksearch.dla.mil.)

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 of these documents are those cited in the solicitation or contract.

OFFICE OF THE CHIEF OF NAVAL OPERATIONS (OPNAV) ISSUANCES

OPNAVINST 5100.19	-	Navy Safety and Occupational Health Program Manual for Forces Afloat
OPNAVINST 5100.23	-	Navy Safety and Occupational Health Program Manual

(Copies of these documents are available online at https://www.secnav.navy.mil/doni/Directives.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

0900-LP-001-7000	-	Requirements for Fabrication and Inspection of Brazed Piping Systems
250-1500-1	-	Welding Standard
S9074-A1-GIB-010/1628	-	Fillet Weld and Partial Penetration Weld Size, Strength, and Efficiency Determination.
S9074-AR-GIB-010/278	-	Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels
S9221-C1-GTP-010	-	Main Propulsion Boilers; Repair and Overhaul, Vol. 1
S9221-C1-GTP-020	-	Main Propulsion Boilers; Repair and Overhaul, Vol. 2
T9074-AD-GIB-010/1688	-	Requirements for Fabrication, Welding, and Inspection of Submarine Structure
T9074-AS-GIB-010/271	-	Requirements for Nondestructive Testing Methods

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
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

(Copies of these documents are available online via Technical Data Management Information System (TDMIS) at https://mercury.tdmis.navy.mil/ by searching for the document number without the suffix. Refer questions, inquiries, or problems to: DSN 296-0669, Commercial (805) 228-0669. These documents are available for ordering (hard copy) via the Naval Logistics Library (NLL) at https://nll.navsup.navy.mil. For questions regarding the NLL, contact the NLL Customer Service at nllhelpdesk@navy.mil, (866) 817-3130, or (215) 697-2626/DSN 442-2626.)

2-2 NON-GOVERNMENT PUBLICATIONS.

The following documents 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.

AMERICAN BUREAU OF SHIPPING (ABS)

Steel Vessel Rules Part 2, Rules for Materials and Welding

(Copies of this document are available online at ww2.eagle.org.)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

Boiler and Pressure Vessel Code (BPVC), Section IX-Welding, Brazing, and Fusing Qualifications

(Copies of this document are available online at www.asme.org.)

AMERICAN WELDING SOCIETY (AWS)

ANSI Z49.1	-	Safety in Welding, Cutting, and Allied Processes
AWS A3.0M/A3.0	-	Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying
AWS A5.1/A5.1M	-	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
AWS A5.2/A5.2M	-	Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding
AWS A5.4/A5.4M	-	Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding
AWS A5.5/A5.5M	-	Specification for Low Alloy Steel Electrodes for Shielded Metal Arc Welding
AWS A5.6/A5.6M	-	Specification for Copper and Copper-Alloy Electrodes for Shielded Metal Arc Welding
AWS A5.7/A5.7M	-	Specification for Copper and Copper-Alloy Bare Welding and Electrodes
AWS A5.8M/A5.8	-	Specification for Filler Metals for Brazing and Braze Welding
AWS A5.9/A5.9M (ISO 14343 MOD)	-	Welding Consumables - Wire Electrodes, Strip Electrodes, Wires, and Rods for Arc Welding of Stainless and Heat Resisting Steels - Classification
AWS A5.10/A5.10M (ISO 18273 MOD)	-	Welding Consumables – Wire Electrodes, Wires, and Rods for Welding of Aluminum and Aluminum Alloys – Classification
AWS A5.11/A5.11M	-	Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding

AWS A5.13/A5.13M - Specification for Surfacing Electrodes for Shielded Metal Arc Welding

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

AWS A5.16/A5.16M (ISO 24034 MOD) - Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods

AWS A5.21/A5.21M - Specification for Bare Electrodes and Rods for Surfacing

AWS A5.22/A5.22M - Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods

AWS A5.23/A5.23M - Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

AWS A5.28/A5.28M - Specification for Low Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding

AWS B4.0 - Standard Methods for Mechanical Testing of Welds

AWS C3.4M/C3.4 - Specification for Torch Brazing

AWS C3.5M/C3.5 - Specification for Induction Brazing

AWS C3.6M/C3.6 - Specification for Furnace Brazing

AWS D17.2/D17.2M - Specification for Resistance Welding for Aerospace Applications

(Copies of these documents are available online at www.aws.org.)

ASTM INTERNATIONAL

ASTM A27/A27M - Standard Specification for Steel Castings, Carbon, for General Application

ASTM A36/A36M - Standard Specification for Carbon Structural Steel

ASTM A105/A105M - Standard Specification for Carbon Steel Forgings for Piping Applications

ASTM A106/A106M - Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service

ASTM A131/A131M - Standard Specification for Structural Steel for Ships

ASTM A134/A134M - Standard Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)

ASTM A178/A178M - Standard Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler Tubes

ASTM A179/A179M - Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes

ASTM A182/A182M - Standard Specification for Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service

ASTM A192/A192M - Standard Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service

ASTM A210/A210M - Standard Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes

ASTM A213/A213M	-	Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat-Exchanger Tubes
ASTM A214/A214M	-	Standard Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes
ASTM A216/A216M	-	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High Temperature Service
ASTM A217/A217M	-	Martensitic Stainless Steel and Alloy Steel Castings for Pressure-Containing Parts Suitable for High-Temperature Service
ASTM A234/A234M	-	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A240/A240M	-	Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
ASTM A269/A269M	-	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A276/A276M	-	Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes
ASTM A283/A283M	-	Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
ASTM A285/A285M	-	Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
ASTM A302/A302M	-	Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum Nickel
ASTM A312/A312M	-	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
ASTM A333/A333M	-	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness
ASTM A334/A334M	-	Standard Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service
ASTM A350/A350M	-	Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components
ASTM A351/A351M	-	Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
ASTM A352/A352M	-	Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure Containing Parts, Suitable for Low-Temperature Service
ASTM A369/A369M	-	Standard Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
ASTM A372/A372M	-	Standard Specification for Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels
ASTM A403/A403M	-	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM A414/A414M	-	Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy for Pressure Vessels

ASTM A420/A420M - Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service

ASTM A473 - Standard Specification for Stainless and Heat-Resisting Steel Forgings

ASTM A479/A479M - Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

ASTM A487/A487M - Standard Specification for Steel Castings Suitable for Pressure Service

ASTM A494/A494M - Standard Specification for Castings, Nickel and Nickel Alloy

ASTM A500/A500M - Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes

ASTM A501/A501M - Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

ASTM A511/A511M - Standard Specification for Seamless Stainless Steel Mechanical Tubing and Hollow Bar

ASTM A512 - Standard Specification for Cold-Drawn Buttweld Carbon Steel Mechanical Tubing

ASTM A513/A513M - Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing

ASTM A515/A515M - Standard Specification for Pressure Vessel Plates, Carbon Steel for Intermediate- and Higher-Temperature Service

ASTM A516/A516M - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

ASTM A519/A519M - Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing

ASTM A524 - Standard Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures

ASTM A537/A537M - Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel

ASTM A554 - Standard Specification for Welded Stainless Steel Mechanical Tubing

ASTM A556/A556M - Standard Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes

ASTM A562/A562M - Standard Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings

ASTM A572/A572M - Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

ASTM A575 - Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades

ASTM A576 - Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality

ASTM A587 - Standard Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry

ASTM A606/A606M - Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance

ASTM A659/A659M	-	Standard Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled
ASTM A660/A660M	-	Standard Specification for Centrifugally Cast Carbon Steel Pipe for High-Temperature Service
ASTM A662/A662M	-	Standard Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service
ASTM A666	-	Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
ASTM A671/A671M	-	Standard Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
ASTM A672/A672M	-	Standard Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures
ASTM A709/A709M	-	Standard Specification for Structural Steel for Bridges
ASTM A727/A727M	-	Standard Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness
ASTM A743/A743M	-	Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
ASTM A744/A744M	-	Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
ASTM A757/A757M	-	Ferritic and Martensitic Steel Castings for Pressure-Containing and Other Applications for Low-Temperature Service
ASTM A765/A765M	-	Standard Specification for Carbon Steel and Low-Alloy Steel Pressure-Vessel-Component Forgings with Mandatory Toughness Requirements
ASTM A793	-	Standard Specification for Rolled Floor Plate, Stainless Steel
ASTM A794/A794M	-	Standard Specification for Commercial Steel (CS), Sheet, Carbon (0.16% Maximum to 0.25% Maximum), Cold-Rolled
ASTM A813/A813M	-	Standard Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe
ASTM A830/A830M	-	Standard Specification for Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements
ASTM A945/A945M	-	Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness
ASTM A1008/A1008M	-	Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable
ASTM A1011/A1011M	-	Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
ASTM B16/B16M	-	Standard Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines

ASTM B21/B21M	-	Standard Specification for Naval Brass Rod, Bar, and Shapes
ASTM B26/B26M	-	Standard Specification for Aluminum-Alloy Sand Castings
ASTM B36/B36M	-	Standard Specification for Brass Plate, Sheet, Strip, and Rolled Bar
ASTM B43	-	Standard Specification for Seamless Red Brass Pipe, Standard Sizes
ASTM B88	-	Standard Specification for Seamless Copper Water Tube
ASTM B98/B98M	-	Standard Specification for Copper-Silicon Alloy Rod, Bar, and Shapes
ASTM B121/B121M	-	Standard Specification for Leaded Brass Plate, Sheet, Strip, and Rolled Bar
ASTM B124/B124M	-	Standard Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes
ASTM B138/B138M	-	Standard Specification for Manganese Bronze Rod, Bar, and Shapes
ASTM B139/B139M	-	Standard Specification for Phosphor Bronze Rod, Bar, and Shapes
ASTM B150/B150M	-	Standard Specification for Aluminum Bronze Rod, Bar, and Shapes
ASTM B152/B152M	-	Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar
ASTM B166	-	Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600 and N06690) Rod, Bar, and Wire
ASTM B169/B169M	-	Standard Specification for Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar
ASTM B209	-	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B210/B210M	-	Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
ASTM B211/B211M	-	Standard Specification for Aluminum and Aluminum-Alloy Rolled or Cold Finished Bar, Rod, and Wire
ASTM B221	-	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B241/B241M	-	Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
ASTM B265	-	Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate
ASTM B271/B271M	-	Standard Specification for Copper-Base Alloy Centrifugal Castings
ASTM B283/B283M	-	Standard Specification for Copper and Copper-Alloy Die Forging (Hot-Pressed)
ASTM B338	-	Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
ASTM B348	-	Standard Specification for Titanium and Titanium Alloy Bars and Billets
ASTM B361	-	Standard Specification for Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
ASTM B363	-	Standard Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings
ASTM B367	-	Standard Specification for Titanium and Titanium Alloy Castings

ASTM B369	-	Standard Specification for Copper-Nickel Alloy Castings
ASTM B381	-	Standard Specification for Titanium and Titanium Alloy Forgings
ASTM B443	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip
ASTM B444	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) Pipe and Tube
ASTM B446	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Rod and Bar
ASTM B483/B483M	-	Standard Specification for Aluminum and Aluminum-Alloy Drawn Tubes for General Purpose Applications
ASTM B505/B505M	-	Standard Specification for Copper Alloy Continuous Castings
ASTM B564	-	Standard Specification for Nickel Alloy Forgings
ASTM B574	-	Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium Alloy Rod
ASTM B575	-	Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium Alloy Plate, Sheet, and Strip
ASTM B622	-	Standard Specification for Seamless Nickel and Nickel Cobalt Alloy Pipe and Tube
ASTM B763/B763M	-	Standard Specification for Copper Alloy Sand Castings for Valve Applications
ASTM B861	-	Standard Specification for Titanium and Titanium Alloy Seamless Pipe
ASTM B862	-	Standard Specification for Titanium and Titanium Alloy Welded Pipe
ASTM B928/B928M	-	Standard Specification for High Magnesium Aluminum-Alloy Products for Marine Service and Similar Environments
ASTM E604	-	Standard Test Method for Dynamic Tear Testing of Metallic Materials
ASTM E1316	-	Standard Terminology for Nondestructive Examinations

(Copies of these documents are available online at www.astm.org.)

SAE INTERNATIONAL

SAE AMS6345	-	Steel Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130) Normalized or Otherwise Heat Treated
SAE AMS6350	-	Steel Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130)
SAE AMS6351	-	Steel Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130) Spheroidized
SAE AMS-A-21180	-	Aluminum-Alloy Castings, High Strength
SAE AMS-T-9046	-	Titanium and Titanium Alloy, Sheet, Strip, and Plate
SAE AMS-T-9047	-	Titanium and Titanium Alloy Bars (Rolled or Forged) and Reforging Stock, Aircraft Quality
SAE AMS-W-6858	-	Welding, Resistance: Spot and Seam

SAE AMS-QQ-A-200	-	Aluminum Alloy, Bar, Rod, Shapes, Structural Shapes, Tube, and Wire, Extruded: General Specification for
SAE AMS-QQ-A-200/1	-	Aluminum Alloy 3003, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-200/4	-	Aluminum Alloy 5083, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-200/5	-	Aluminum Alloy 5086, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-200/6	-	Aluminum Alloy 5454, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-200/7	-	Aluminum Alloy 5456, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-225	-	Aluminum and Aluminum Alloy, Bar, Rod, Wire, or Special Shapes; Rolled, Drawn, or Cold Finished; General Specification for
SAE AMS-QQ-A-225/1	-	Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished, 1100
SAE AMS-QQ-A-225/2	-	Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished, 3003
SAE AMS-QQ-A-225/7	-	Aluminum Alloy 5052, Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished
SAE AMS-QQ-A-250	-	Aluminum and Aluminum Alloy, Plate, and Sheet
SAE AMS-QQ-A-250/1	-	Aluminum 1100, Plate and Sheet
SAE AMS-QQ-A-250/2	-	Aluminum Alloy 3003, Plate and Sheet
SAE AMS-QQ-A-250/6	-	Aluminum Alloy 5083, Plate and Sheet
SAE AMS-QQ-A-250/8	-	Aluminum Alloy 5052, Plate and Sheet
SAE AMS-QQ-A-250/10	-	Aluminum Alloy 5454, Plate and Sheet
SAE AMS-QQ-S-763	-	Steel Bars, Wire, Shapes, and Forgings; Corrosion Resistant
SAE AMS-WW-T-700	-	Tube, Aluminum and Aluminum Alloy, Drawn, Seamless, General Specification for
SAE AMS-WW-T-700/1	-	Tube, Aluminum, Drawn, Seamless, 1100
SAE AMS-WW-T-700/2	-	Tube, Aluminum Alloy, Drawn, Seamless, 3003
SAE AMS-WW-T-700/5	-	Tube, Aluminum Alloy, Drawn, Seamless, 5086

(Copies of these documents are available online at www.sae.org.)

2-3 ORDER OF PRECEDENCE.

Except for fabrication documents, in the event of a conflict between the text of this document and the references cited herein, the text of this document shall take precedence.

CHAPTER 3
DEFINITIONS

3-1 TERMS RELATED TO BOTH WELDING AND BRAZING.

3-1.1 GENERAL.

a. Except as noted herein, welding and brazing nomenclature and definitions shall conform to AWS A3.0M/A3.0.

b. Except as noted herein, nondestructive testing nomenclature and definitions shall conform to NAVSEA T9074-AS-GIB-010/271, including the nomenclature and definitions of ASTM E1316 as specified therein, and MIL-STD-2035.

3-1.2 ACCEPTABLE. An item is acceptable when it complies with or conforms to the applicable standard or specification.

3-1.3 ACTIVITY. Activity refers to all sites of an organization, under the same quality assurance management and using the same quality assurance plan, performing work to which this document is applicable.

3-1.4 APPLICABLE FABRICATION DOCUMENT. Applicable fabrication document is the document invoked by the contract, purchase order, or circular of requirements governing the work being accomplished.

3-1.5 APPROVAL (APPROVED). Approval means the item under consideration requires acceptance by NAVSEA or its authorized representative. "Approval" or "approved", as used herein, is granted by the NAVSEA-authorized representative unless NAVSEA approval is specified.

3-1.6 AUTHORIZED REPRESENTATIVE. An authorized representative is any Government representative specifically authorized to approve equipment, material, or procedures within the scope of this document for NAVSEA. They are as follows:

a. For Government shipyards: The delegated representative of the shipyard commander. This includes all applicable areas in the shipyard, and items and work contracted by the shipyard.

b. For commercial shipyards: The delegated representative of the Supervisor of Shipbuilding, Conversion, and Repair (SUPSHIP) or the Regional Maintenance Center (RMC), as applicable. This includes all applicable areas in the shipyard and applicable items furnished to the shipyard by subcontractors.

c. For Government purchase items (other than Government shipyards): The delegated representative of the Commanding Officer, Naval Surface Warfare Center Carderock Division (NSWCCD), the Commanding Officer, Naval Surface Warfare Center Philadelphia Division (NSWCPD), or the Commanding Officer, Naval Sea Logistics Center (NAVSEALOGCEN), Mechanicsburg.

d. When delegated by 3-1.6.a, b, or c above, the representative of the Defense Contract Management Agency (DCMA).

e. Technical representative specifically authorized by NAVSEA.

3-1.7 ESSENTIAL ELEMENTS. Essential elements are those elements, either materials or processes that are important in establishing a welding or brazing procedure. These elements shall be defined as part of a welding or brazing procedure. Changes in these elements after a procedure has been qualified shall require a change in the written procedure and may require level I or level II requalification, depending on the element being changed and the magnitude of the change.

3-1.8 FIRST ARTICLE TEST. A first article test is the fabrication and evaluation of a production part or simulated configuration of a production part using an automatic robotic welding procedure to validate weld bead placement and soundness. In this context, "part" can encompass weldments such as structural panels or foundations and sub-assemblies (piping or structural).

3-1.9 INSIDE DIAMETER (ID). ID refers to the inner surface or inside of a weld joint, usually in piping; ID can also mean an inside diameter of nominal dimension in a cylindrical, hollow product if the context is such.

3-1.10 INSPECTOR. An inspector is any contractor, Naval shipyard and other Government agency employee, or ABS Surveyor qualified as required by this document to accept or reject materials or workmanship on the basis of specified test results.

3-1.11 OUTSIDE DIAMETER (OD). OD refers to the outside diameter of a cylindrical product and usually relates to an outer diameter nominal dimension; OD can also mean the outer surface of a joint in a cylindrical product if the context is such.

3-1.12 PERFORMANCE QUALIFICATION. Performance qualification is the action by which welders and welding operators (and brazers and brazing operators) are evaluated by nondestructive and destructive methods for their demonstrated ability to produce welds (and brazed joints) that meet the requirements of this specification. Also included are requirements for qualification record keeping.

3-1.13 POST WELD HEAT TREATMENT (PWHT). PWHT refers to any heat treatment subsequent to welding, except for post-weld soaking treatments for hydrogen evolution that are specified by the fabrication document.

3-1.14 PROCEDURE. A procedure is a written fabrication instruction that contains all the applicable essential elements listed in this document.

3-1.15 PROCEDURE QUALIFICATION. Procedure qualification is the action by which test assemblies are prepared in accordance with a proposed procedure and evaluated by destructive or nondestructive tests, or both. Also included are requirements for qualification record keeping.

3-1.16 QUALIFIED. Qualified means that the item under consideration has been approved as required by this document.

3-1.17 STRAW (COLOR). Straw is a color occurring on titanium welds from slight contamination whose hue ranges from light gold through brass.

3-2 TERMS RELATED TO WELDING.

3-2.1 BUILD-UP. Build-up is a surfacing variation in which weld metal, usually of similar or matching composition, is deposited to restore base material or weld surface dimensions.

3-2.2 BUTTERING. Buttering is a surfacing variation that deposits weld metal on one or more surfaces to provide metallurgically compatible weld metal for the subsequent completion of the weld.

3-2.3 CLADDING. Cladding is a surfacing variation that deposits or applies surfacing materials, usually to improve corrosion or heat resistance.

3-2.4 DISSIMILAR METAL WELDS. Dissimilar metal welds are welds involving two metals that differ sufficiently in metallurgical and physical properties to require special consideration in procedure qualification and inspection (see Chapter 4 for exceptions).

3-2.5 GOVERNMENT INSPECTOR. A Government inspector is a Government official charged with the responsibility for ensuring that the materials, processes, fabrication techniques, inspections, tests, and testing personnel meet specification and contractual requirements. In this regard, he or she shall be the authorized representative, or the following:

a. When delegated by the authorized representative, the DCMA inspector.

b. For forces afloat: The Squadron Commander or their delegated representative.

c For Naval repair facilities: The commanding officer or their delegated representative.

3-2.6 HARDFACING. Hardfacing refers to a surfacing variation in which surfacing metal is deposited to reduce wear.

3-2.7 INSTANTANEOUS POWER OR ENERGY. As used for waveform controlled welding, instantaneous power or energy is the determination of power or energy using the product of current and voltage measurements made at rapid intervals (see 4-4.1.13.2.b), which capture brief changes in the welding waveform.

3-2.8 KEYHOLE WELDING. Keyhole welding is a technique in which a concentrated heat source penetrates completely through a workpiece, forming a hole at the leading edge of the weld pool. As the heat source progresses, the molten metal fills in behind the hole to form the weld bead.

3-2.9 LOCK WELD. Lock welds are generally in the form of small fillet welds intended to provide extra assurance that anchors, bolts, nuts, and pins remain threaded, fastened, or secured to a mating part. Welds that carry or transmit loads of mating parts, or that are seal welds, are not lock welds.

3-2.10 ORIFICE GAS (PLASMA ARC WELDING AND CUTTING). Orifice gas is the gas that is directed into the torch to surround the electrode. It becomes ionized in the arc to form the plasma, and issues from the orifice in the torch nozzle as the plasma jet.

3-2.11 OSCILLATION. Defining characteristics of oscillation include:

a. Amplitude. Amplitude is the distance normal to the direction of welding between the outermost positions that the electrode tip reaches while oscillating.

b. Dwell. Dwell is the time during which the electrode rests at any point in each oscillating swing or traverse.

c. Frequency. Frequency is the number of complete cycles made by the oscillating head in 1 minute, or other specified time increment.

3-2.12 ROBOTIC WELDING. Robotic welding is a welding process performed with a controlled, reprogrammable, multipurpose manipulator of three or more axes linked through a kinematic chain requiring occasional or no observation or operator parameter adjustment during welding. Robotic welding may be subcategorized as automatic robotic, requiring no operator intervention, or mechanized robotic, requiring occasional operator intervention, during an arc-on/arc-off welding cycle.

3-2.13 SEAL WELD. A seal weld is a weld provided for a fluid containment function only, as in a closure where strength is provided by a separate device. This definition does not apply to boiler, economizer, and superheater tube-to-header seal welds.

3-2.14 SOCKET WELD. Socket welds include, but are not limited to, MIL-STD-22, P-13, -14, -15, -16, -17, -42, and -80 joint design welds in pressure-containing piping.

3-2.15 SPECIAL WELDS. Special welds are welds involving:

a. Base materials not covered in table 7-1 of this document.

b. Filler materials not covered in table 7-2 of this document.

c. Processes not specified in 4-4.3, 4-4.4, or table 7-3.

d. For friction stir, also see A-2.1.24.

3-2.16 SURFACING. Surfacing is the application by welding, brazing, or thermal spraying of material layers to a surface to obtain desired properties or dimensions, as opposed to making a joint. (Also see definitions for build-up, buttering, cladding, and hardfacing.)

3-2.17 STANDARD WELDING PROCEDURE SPECIFICATION FOR NAVAL APPLICATIONS (SWPS-N). SWPS-Ns are an outgrowth of the coordinated work of the Welding Procedures Committee of the Welding Research Council, the American Welding Society (AWS) B2 Committee on Procedure and Performance Qualification, and a Task Group of this committee that included NAVSEA. SWPS-Ns are adaptations of existing AWS Standard Welding Procedure Specifications (SWPS) with modifications for specifying requirements of NAVSEA welding related documents.

SWPSs were developed by AWS and the Welding Research Council by reviewing multiple welding procedure qualification records for a particular process, material, filler material, etc. A specific standard welding procedure was then prepared based on those qualification records with sufficiently narrow values and ranges of essential elements such that the procedure would not require qualification testing if used by a sufficiently skilled and knowledgeable activity.

Upon joint agreement of AWS and NAVSEA, each SWPS-N is published by AWS (e.g., AWS-NAVSEA B2.1-1-1301:2018, Standard Welding Procedure Specification for Naval Applications (SWPS-N) for Gas Tungsten Arc Welding of Carbon Steel (S-1), 1/8 inch (3mm) through 1-1/2 inch (38mm) Thick, MIL-70S-2, in the As-Welded or PWHT Condition, Primarily Plate and Structured Naval Applications). SWPS-Ns are permitted to be used by an activity upon successfully completing and reporting a verification test weld (see Appendix C). Qualification of SWPS-Ns is not required provided toughness is not required for the intended application (see C-1.1).

3-2.18 TEMPERATURE CONTROLLED AREA (TCA). TCAs are areas close to production weld joints where temperature rise must be limited during welding to avoid degradation of properties or other features. These areas include bi/tri-metallic transition joints (e.g., explosive or roll bonded material for transitioning between aluminum and steel plating, and similar products of other alloys/applications, excluding tube welds to roll/explosive bonded-type tubesheets), and other areas specifically required by NAVSEA to be qualified as a TCA in accordance with this document.

3-2.19 TUBE-TO-HEADER SEAL WELD. Tube-to-header seal welds are a particular type of weld between various types of boiler tubes and their respective headers (or drums), such as economizer headers or superheater headers. These welds are located on the interior of the header (or drum) where integrity is usually provided by a combination of welding and rolling the tube.

3-2.20 TUBE-TO-TUBESHEET WELD. Tube-to-tubesheet welds are welds between tubing (usually heat transfer tubing) and the respective tubesheet usually occurring in some type of heat exchanger (see also 3-2.19).

3-2.21 WAVEFORM CONTROLLED WELDING. Waveform controlled welding is a welding process modification of the voltage wave shape, current wave shape, or both, to control characteristics such as droplet shape, penetration, wetting, bead shape, or transfer mode(s).

3-2.22 WELD DEPOSITED PAD. A weld deposited pad is a weld which is built up by a sequence that is essentially normal to a pressure boundary or non-pressure boundary surface; it is a type of surfacing (i.e., build-up).

3-2.23 WELDING SPEED (TRAVEL SPEED). Welding speed is the rate of progression of the welding arc along the weld axis.

3-2.24 WIRE FEED ANGLE. Wire feed angle is the angle between the filler metal and the tangent to the pipe or plate surface at the arc.

3-3 TERMS RELATED TO BRAZING.

3-3.1 BRAZEMENT. A brazement is an assembly whose component parts are joined by brazing.

3-3.2 CLEARANCE. Clearance is the actual gap, at room temperature, prior to brazing for capillary flow of filler metal.

3-3.3 MANUAL TORCH BRAZING. Manual torch brazing is torch brazing with the brazer controlling the torch by hand.

3-3.4 MECHANIZED TORCH BRAZING. Mechanized torch brazing is torch brazing with an automatic or mechanical method of controlling the torch while brazing.

3-3.5 PEEL TEST. A peel test is a destructive method of inspection where a lap joint is mechanically separated by peeling (see figure 7-20).

3-3.6 PREPLACED BRAZING ALLOY. A preplaced brazing alloy is any form (shims, wire, rings, and so forth) of brazing alloy that is placed in a joint prior to brazing.

CHAPTER 4
WELDING PROCEDURE QUALIFICATION

4-1 SCOPE.

This section provides general requirements for welding procedures, including Standard Welding Procedure Specifications for Naval Applications (SWPS-Ns), and their qualification. Specific qualification requirements for the categories listed below shall be as specified in 4-4. For friction stir, including repair of friction stirred material, specific qualification requirements shall be in accordance with Appendix A in addition to the general requirements of 4-2.

a. Groove welds and fillet welds (manual, semi-automatic, automatic, mechanized, and robotic welding).
b. Fillet welds – welding over primer coated surfaces.
c. Weld surfacing (build-up, buttering, hardfacing, and cladding).
d. Dissimilar metal welds.
e. Resistance welding.
f. Stud welding.
g. Welds made without adding filler material (autogenous welds).
h. Seal, pipe socket, and tube-to-tubesheet welds.
i. Tube-to-header seal welds.
j. Special welds.
k. Lock welds.

4-2 GENERAL REQUIREMENTS.

4-2.1 RESPONSIBILITY. When this document is specified by the applicable fabrication document or other governing specification, each activity shall prepare written welding procedures, and shall perform the required tests to qualify these procedures except (1) for SWPS-Ns conforming to Appendix C and (2) as specified by 4-2.6. The activity shall notify the authorized representative a minimum of 72 hours prior to the conduct of procedure qualification testing and, where applicable, first article testing and afford him or her the opportunity to observe the welding of the test assemblies and the performance of the required nondestructive and destructive testing. The 72-hour time limit may be modified upon agreement between the authorized representative and the activity. Such observation shall be at the discretion of the authorized representative.

4-2.1.1 SWPS-Ns. SWPS-Ns are acceptable for use subject to the requirements of Appendix C, including completion of a verification weld; approval of qualification test data is not required for SWPS-Ns.

4-2.1.2 Qualification Welding. Personnel welding qualification test assemblies (including SWPS-N verification welds) shall be regular employees of the activity (i.e., not subcontractors or temporary specialists) and under the full supervision and control of the activity. Welding of qualification test assemblies should be accomplished at one of the activity's sites with the activity's welding equipment or equipment similar to that being acquired by the activity; if welding is performed at a site other than the activity's site, the activity's employee(s) responsible for developing the procedure being qualified and ensuring that it is correctly implemented shall also be present and directing the activity's welder/operator during all welding.

4-2.2 CERTIFICATION OF QUALIFICATION TESTING AND OTHER AGENCY QUALIFICATIONS. After testing, the responsible official of the activity shall certify that the tests and the test results meet all requirements of this document (including revision number) and that the welding procedure meets all requirements of this document (revision numbers not mandatory) and the applicable fabrication document. Qualification tests and data containing minor deviations from requirements of this document may be submitted for approval if such deviations are specifically identified as deviations, and the technical justification for each deviation is provided; in each case where deviations are accepted, the authorized representative shall provide a copy of the affected welding procedure and test report to NAVSEA for information.

4-2.2.1 Other Agency Qualifications. Procedure qualifications previously prepared for other Government agencies, the American Bureau of Shipping (ABS), the American Society of Mechanical Engineers (ASME), or other established regulatory codes may be submitted for approval to the authorized representative, provided qualification testing and approval (to the other Government agencies' or regulatory bodies' requirements) occurred prior to an activity's invitation for bid or request for proposal. Nondestructive examination requirements, as specified in this document but not required by other agencies, shall be accomplished on an additional test sample or, if approved by an authorized representative, on a production application. Such data shall be submitted for approval as required in 4-2.3.

4-2.2.2 Other Agency Qualification Limitations. The qualification limitations for welding procedure qualifications performed for other agencies shall be as specified in this document. As an example, a flat position ASME procedure qualification may only qualify flat position welding in accordance with this document.

4-2.3 SUBMITTAL OF WELDING PROCEDURES AND QUALIFICATION TEST REPORTS. Procedures shall be the activity's responsibility. Prior to production application of the welding procedure, the activity shall obtain approval of the procedure qualification data (unless exempted by 4-2.7.3.2). This entails submittal of the welding procedure qualification test report to the authorized representative for approval and submittal of the corresponding welding procedure to the authorized representative for review; where permitted by 4-2.7.3, level II data does not require approval. Welding procedures shall also be submitted to the authorized representative per 4-7 and 4-8 at the time of requalification or revision of the procedure. The submittal shall be made to NAVSEA if required per 4-2.5. For robotic welding, first article test reports shall also be submitted per 4-4.1.10.3.

4-2.3.1 Requirements. The following requirements shall apply for welding procedure qualification test reports and welding procedures.

4-2.3.1.1 Welding Procedure Qualification Test Report. The welding procedure qualification test report shall be in accordance with 4-6.1. Supporting information shall be maintained per 4-6.2.

4-2.3.1.2 Welding Procedure. The welding procedure shall be in accordance with 4-3.

4-2.3.2 Lot Testing Information for Unclassed Filler Materials. Lot conformance testing for tensile properties, toughness, weldability, cleanliness, and so forth, for any filler material not classified in table 7-2 (for example, submerged arc welding fluxes covered by table 7-2, footnote 5) shall also be described in the submittal for approval.

4-2.4 VENDOR QUALIFICATION. It shall be the responsibility of each activity to ensure that its subcontractors have qualified procedures. Activities shall ensure that subcontractor procedures and qualification test data are in compliance with this document before submittal for approval per 4-2.3.

4-2.4.1 Approval Letters of Subcontractors. Where the prime contractor deems it appropriate, subcontractors should be provided a copy of the approval letter from the authorized representative for their qualification test report; where this is not appropriate, the subcontractor shall receive the serial number, date, and command title of the authorized representative's approval letter.

4-2.5 APPROVAL OF PROCEDURE QUALIFICATION FOR SPECIAL WELDS. In addition to the procedure qualification test data and procedure, submittals shall include a description of the welding process, evaluation method, and the proposed welding performance qualification tests (see 5-2.7). NAVSEA approval of procedure qualification data shall be obtained for special welds, as defined in 3-2.15, for the following areas:

a. Surface ship primary structure and superstructure.
b. Submarine pressure hull structure.
c. Submarine intermediate pressure tanks.
d. P-1 and P-LT piping.
e. A-1, A-2, A-F, and A-LT pressure vessels.
f. M-1, Category A and B, and M-2 Category A machinery.
g. T-1 and T-2 turbines.
h. Exothermic welding.

For other special welds, approval of procedure qualification data shall be obtained from the authorized representative per 4-2.3, or NAVSEA. The authorized representative shall provide a copy of submittals and their approvals to NAVSEA for information.

4-2.6 WAIVER OF QUALIFICATION. Qualification tests for welding on assemblies, the possible failure of which is remote and would not result in danger to the ship, personnel, or components, such as identification plates, galley equipment, furniture, fixtures, and miscellaneous outfitting, may be omitted provided this omission is permitted by the applicable fabrication document or is approved prior to the commencement of such work.

4-2.7 QUALIFICATION LEVELS.

4-2.7.1 General. Except as permitted by 4-2.6, when this document is specified in the applicable fabrication document or other governing specification, procedure qualification is required for base materials listed in table 7-1; filler materials listed in table 7-2; welding processes listed in table 7-3, 4-4.3, and 4-4.4; and special welds per 3-2.15 (for friction stir, see Appendix A). Table 7-3 may be used to extend procedure qualifications to base material/filler metal combinations other than those specifically welded and tested. The essential elements for welding each base material/filler metal combination shall be incorporated into the welding procedure and be in accordance with the requirements of this document and the applicable fabrication document.

4-2.7.2 Level I. This qualification level covers (1) the initial qualification of any welding procedure for the fabrication welding of wrought or cast material or the repair welding of wrought or cast material by any activity and (2) requalification of welding procedures due to variations specified by 4-7. Approval of the required level I welding procedure qualification shall be obtained from the authorized representative, except as noted in 4-2.5. This qualification level covers any welding procedure to be qualified by performing the destructive and nondestructive tests required by this document. Qualification for fabrication welding of cast or wrought material shall also qualify for repair welding of cast or wrought material within the limits of the qualified procedure.

4-2.7.3 Level II. This qualification level (1) governs requalification of procedures already level I qualified where changes specified by 4-8 are made, (2) involves reduced testing in most instances (see 4-2.7.3.1) as compared to level I qualification, and (3) does not require approval of qualification test data in most instances (see 4-2.7.3.2).

4-2.7.3.1 Level II Qualification Testing. The required level II test assembly shall be based on (1) qualification limits of the procedure (see 4-4 and 4-7), (2) the change involved (see 4-8) and (3) other applicable requirements (see 4-2 and 4-4). In general, the level II test assembly and its welding shall incorporate needed changes (e.g., 4-8.c, 4-8.g) and otherwise repeat the welding used for level I qualification, except as required or allowed by the following:.

a. Welding shall be performed on the form of base material needed. For example, if a shielded metal arc welding butt weld procedure originally level I qualified on pipe requires a 1/16-inch increase in electrode size for all position welding (i.e., 4-8.b), then plate or pipe may be used per 4-4.1 and table 7-6 (and test position would be 3G or 5G/6G); or, if a change per 4-8.e is involved, the same, original level I test assembly per 4-4.6.3 is required; or, if an amplitude change per 4-8.j is required for an automatic pipe procedure, pipe (of a qualified OD) shall be used (see 4-4.1.10.1).

b. Base material and weld material thickness shall be as required for the change where applicable (e.g., 4-8.t, 4-8.z). Additionally, for butt welds:

   (1) If originally qualified on thicknesses of ½ inch or greater, ½ inch (or greater) shall be used.

   (2) For pipe welds per 4-4.1.10.1, a single representative qualified thickness may be used, provided that, if the procedure allows more than three layers, at least three layers shall be used for qualification welding.

c. If pipe is used for butt weld qualification, the largest (qualified) OD to be used in production shall be employed, but need not be greater than 3 inches OD (unless OD increases are being qualified [e.g., 4-8.s]).

d. When a plate assembly is used, at least 15 inches of weld shall be inspected.

e. For all position GMAW, only a 3G or 5G/6G assembly is required and the 2G position of table 7-4, footnote 3 is not required.

f. Also, where a change to an all position procedure is desired to qualify only one position, the test assembly may be welded in that position.

g. Joint design shall be as required by the change where applicable (e.g., 4-8.c, 4-8.e, 4-8.z).

h. Other qualified variations from the original level I qualification test are permissible for level II qualification, where warranted and prior approval of the authorized representative is obtained.

i. The test assembly shall be subject to nondestructive testing as required by table 7-7 and 4-5.

j. Destructive testing is not required, except that level I destructive testing is required for the following welds:

   (1) Fillet welds.

   (2) Tube-to-tubesheet welds.

   (3) Tube-to-header seal welds.

   (4) Socket welds.

   (5) Cladding and hardfacing, except that composition (or dilution) testing is not required.

(k) For butt welds, when suitable, as an alternative to welding of a separate level II test assembly, 15 inches of production weld or the largest size pipe used in production (see 4-2.7.3.1.c) may be nondestructively inspected per 4-2.7.3.1.i if all other requirements of 4-2.7.3.1 are met and prior approval is obtained.

4-2.7.3.2 Submittals and Qualification Test Report Approval Exemptions. Prior to production welding, the certified level II qualification test report and revised welding procedure, with all changes identified, shall be submitted to the authorized representative per 4-2.3. Approval of level II welding procedure qualification data is not required unless (1) deviations (see 4-2.2) are involved, (2) changes per 4-8.aa or 4-8.bb are made, or (3) nuclear propulsion condenser tube-to-tubesheet welds are involved, where in all cases approval shall be obtained (see 4-2.3); also, approval is required for friction stir per Appendix A. When approval is not required, a response from the authorized representative for the level II submittal is also not required and production welding may proceed (after submittal).

4-2.7.3.2.1 Noncompliance and Reinstatement of Required Approval. Where technical errors, omissions, and other such discrepancies are found in the submittals of level II welding procedures or qualification test reports, the authorized representative may, at their sole discretion, reinstate the requirement to obtain prior approval per 4-2.3 of all level II qualification test reports until the cause of the discrepant submittals is corrected and a reliably compliant submittal process is demonstrated by the activity.

4-2.8 WELDING POSITION QUALIFICATION LIMITS. The orientation of positions for welding procedure qualification test assemblies shall be classified by reference to the positions shown in figure 7-1. Procedure qualification test assemblies welded in a given position shall qualify the procedure as shown in table 7-4, or per 4-4.4, 4-4.6.3, or D-1.1, as applicable.

4-2.9 REPAIR OF TEST ASSEMBLY. Assemblies may be repair welded only under the following conditions:

a. The weld defects repaired are not indicative of an inadequate weld procedure or improper execution of the requirements of a SWPS-N and are representative of defects that would be rejected by nondestructive tests required for production work.

b. The repair welding is representative of repair that would be performed on production work.

c. Cracks (other than crater cracks) and rejectable titanium weld color per 4-5.1.1.1 may not be repair welded.

d. Only one cycle of repair welding is permitted.

e. Test results, including a description of the nondestructive test results which failed to meet the requirements and repair work performed to correct the condition, shall be submitted with the procedure qualification test report.

f. The welding procedure being qualified shall be used except that, for automatic, mechanized and robotic procedures, a qualified, equivalent manual or semi-automatic procedure may be used for repair where the following conditions are met:

   (1) The total accumulated repair length shall not exceed 10 percent of the joint length.

   (2) The procedure is qualified for the same base material, position, heat input, and post weld heat treatment (PWHT), and shall use an equivalent filler metal alloy.

   (3) The repair location shall be marked and shall not form part of destructive test specimen test areas (e.g., tensile specimen gauge area, bend specimen convex surface, etc.).

4-2.10 TRANSFER OF WELDING PROCEDURE QUALIFICATION. Requalification of previously qualified procedures shall be required for procedures transferred from one activity to another.

4-2.10.1 Procedure Transfer Within an Activity. Transfer of qualified procedures between sites of an activity shall be governed by requirements stated in the activity's quality assurance manual and shall require approval by the authorized representative.

4-2.10.2 Naval Shipyard Procedure Transfer. Transfer of qualified procedures from one Navy shipyard to another Navy shipyard shall require NAVSEA approval.

4-2.10.3 Technical Manual Welding Procedure Usage. Procedures contained in NAVSEA technical manuals for specific applications may be used without qualification, provided the following conditions are met:

a. The NAVSEA procedure permits use without qualification, or authorization for waiver of qualification is obtained from NAVSEA.

b. Welders or welding operators are qualified in accordance with this document for the applicable welding.

c. The NAVSEA procedure is incorporated by the activity into a separate written procedure that meets the requirements of this document and is certified by the activity's responsible official per 4-2.2.

d. The activity demonstrates its ability to produce welds to the satisfaction of the authorized representative using the final procedure.

4-3 WRITTEN WELDING PROCEDURE.

4-3.1 ESSENTIAL ELEMENTS OF A WELDING PROCEDURE. Welding procedures shall be written such that instructions, parameters, and equipment shall ensure conformance with this document and all fabrication documents for which they will be used. Unless otherwise specified in the applicable fabrication document, the welding procedure shall include, at a minimum, the applicable essential elements listed in table 7-5 for each base material/filler metal combination per 4-2.7.1. For stud welding, see 4-4.4.2. Each welding procedure shall also include the following information:

a. Activity name
b. Welding procedure number, revision, and date
c. Supporting procedure qualification test report number, revision, and date
d. Certification statement per 4-2.2

4-3.1.1 Identification of S-23 Welding Procedure Applicability. For S-23 materials, the welding procedure shall list each specific application for which the welding procedure will be used (see table 7-1, footnote 8), including a reference to the governing required NAVSEA approvals if applicable. For applications of S-23 alloys not specifically permitted by a fabrication document, the following shall also be listed:

a. Component/system
b. Weld location for welds not identified by drawing
c. A statement prohibiting repair welding of other than existing weld locations, unless specific approval is obtained for each repair or type of repair

4-3.2 WELDING PROCEDURE INTENT. Welding procedures shall ensure sound welds when executed by welding personnel qualified to this document.

4-4 SPECIFIC QUALIFICATION REQUIREMENTS.

These paragraphs provide the requirements for qualification test assembly design, size, orientation, and methods of evaluation for qualification of welding procedures for both general applications and special applications.

4-4.1 GROOVE WELDS AND FILLET WELDS (FOR TEMPERATURE CONTROL AREAS, ALSO SEE 4.4.10).

4-4.1.1 Base Material. Qualification test assemblies shall be made using either base materials procured to the applicable specifications referenced in the procedure or using base materials of the same alloy type or grade procured to alternate Government or commercial specifications. Base material forms may consist of either plate or pipe, or other material as specified in table 7-6.

4-4.1.2 Test Assembly Size. Typical test assemblies are shown in figures 7-2 and 7-3. The size of each test assembly shall be sufficient to permit removal of the required test specimens, or additional test assemblies shall be welded as required, to furnish the remaining test specimens (see 4-5). For S-10H materials, see 4-7.5.f and 4-7.10.

4-4.1.3 Test Assembly Joint Design. The test assembly shall employ a butt joint in accordance with MIL-STD-22 or other applicable fabrication document. Joint design requirements for heat affected zone (HAZ) toughness testing shall be as shown in figure 7-24. A test assembly for preplaced filler metal insert joints shall include a consumable insert of the material and shape to be qualified. For S-10H materials, see 4-7.5.f and 4-7.10.

4-4.1.3.1 Dissimilar Metal Welds. Except for backing joints per 4-4.1.3.1.1, the test assembly shall be the joint design shown in figure 7-7 or a standard butt joint design as specified in the applicable fabrication document or MIL-STD-22. For the purposes of tables 7-7 and 7-8, the following combinations of S-groups are not considered to be dissimilar metal welds within each grouping:

a. S-1, S-2, S-3, S-3A, S-4, S-5, S-11A, S-11B, S-11C, S-11D, S-11E, and S-11F
b. S-21, S-22, S-23, S-25, and S-26

c. S-35, S-36A, and S-36B

d. S-37A and S-37B

The range of base material thicknesses qualified by the test assemblies shall be as specified in table 7-6. If plate is used, either longitudinal or transverse bend testing shall be employed. If pipe is used, radiographic inspection in lieu of bend testing shall be employed.

4-4.1.3.1.1 Dissimilar Metal Joints Involving Metallic Backing (Permanent or Temporary). Qualification of these joints shall employ a backing strap/ring of the same S-group that will be used in production except for production joints involving temporary metallic backing where the root pass is removed by back-gouging.

4-4.1.4 Test Assembly for Qualification of Root Deposition. If qualification is being performed for deposition of the root layer or for depositing previously qualified fill procedures over the root layer, only the root layer and one layer of fill material need be deposited over the root using the procedure to be followed in production welding (see table 7-7, footnote 13 for testing requirements).

4-4.1.5 Material Thickness Qualification Limits. Table 7-6 indicates the material thickness range qualified by a specific qualification test material thickness. Qualifications performed in accordance with 4-4.1.4 are not subject to table 7-6 (i.e., the root deposition method is qualified thereby, and the qualification limits of the fill pass procedure govern the composite thickness qualification limits).

4-4.1.6 PWHT. Prior to nondestructive testing, test assemblies shall be subjected to the same PWHT as that required for production weld joints, except as allowed by 4-7.8.

4-4.1.7 Joint Design Qualification Limits. Qualification using a standard butt joint design qualifies casting repair welding and all standard joint designs of the applicable fabrication document or MIL-STD-22, including fillet welds of any size and edge seal welds, subject to the restrictions specified in 4-4.1.10.3.b (robotics), 4-4.1.12, 4-4, 4-7.3, and 4-8.

4-4.1.7.1 Single Pass Welding. Single pass welding shall be qualified by welding a single pass butt test assembly, except that a multipass butt weld assembly qualifies single pass welding for any size fillet, build-up, or repair, and specific joint designs listed in MIL-STD-22 where base material thickness is less than 1/4 inch.

4-4.1.8 Evaluation of Procedure Qualification Test Results. Evaluation of procedure qualification weldments shall be in accordance with 4-4.1.4, 4-4.1.10, 4-4.1.11, or 4-4.1.12, as applicable, and 4-5 and table 7-7.

4-4.1.9 Use of Qualified Groove Butt Weld Procedures for Repair, Buttering, and Build-Up. Groove weld procedure qualification shall constitute approval for repair, buttering, and build-up with deposited metal depth limited to the maximum thickness limitations of the procedure.

4-4.1.10 Qualification Requirements for Automatic, Mechanized, and Robotic Welding. Welding procedure qualification tests shall meet the requirements of 4-4.1.10.1 through 4-4.1.10.4.

4-4.1.10.1 Pipe. One weld in each qualifying position (see table 7-4) shall be made on the smallest and largest sizes (combination of diameter and nominal thickness) to be welded in production using the procedure being qualified, except that:

a. Qualification testing employing a 5-inch outside diameter (OD), 3/8-inch wall pipe or larger, shall qualify for all larger pipe (both diameter and thickness) within the limits of table 7-6, and

b. For certain flat position welds, see 4-4.1.10.1.1.

For butt welds, both the small and the large pipe shall be nondestructively tested and the larger pipe shall be destructively tested in accordance with table 7-7; the small pipe shall also be destructively tested per table 7-7, footnote 15 if wall thickness is less than 0.058 inch. For socket welds, qualification shall also meet the requirements of 4-4.6 and inspection/testing shall be as specified therein for both pipes.

4-4.1.10.1.1 Flat Position Longitudinal Welds in Pipe 2-7/8 Inches OD and Greater, and Flat Position Girth Welds in Pipe Over 24 Inches OD. These welds are qualified by any pipe weld test within the normal thickness limits of table 7-6 (see table 7-6, footnote 13(d)). These welds may also be qualified using plate per 4-4.1.10.2. If plate is used for qualifying flat position girth welds in pipe over 24 inches OD, torch offset remains an essential element per table 7-5.

4-4.1.10.2 Plate. A qualification test assembly weld of sufficient length to provide the required test specimens shall be made in each qualifying position.

4-4.1.10.3 Robotic Welding. Qualification test welds shall be prepared in accordance with 4-4.1.10.1 or 4-4.1.10.2, as applicable, with the same equipment to be used in production, except as otherwise permitted by 4-7 and 4-8. In addition to the requirements of 4-4.1.10.1 and 4-4.1.10.2, the following shall apply:

a. For each cross-qualified welding position (see table 7-4) listed in the welding procedure, an additional level I qualification test assembly shall be welded and subjected to level II testing. For pipe, only the larger diameter test assembly is required in each additional position.

b. Groove joints shall not qualify fillet joints.

4-4.1.10.3.1 Automatic Robotic Welding. The following requirements shall also be met for automatic robotic welding:

a. Except for single pass fillet welds per 4-4.1.10.3.1.a(5) and similarities per 4-4.1.10.3.1.b, a first article test shall be performed for each production part involving the weld types listed in 4-5.4 that are not 100-percent volumetrically inspected. First article testing shall conform to the following requirements:

   (1) Pipe shall be treated separately from plate.

   (2) Test assemblies shall be evaluated in accordance with 4-5.4.

   (3) A first article test report shall be prepared per 4-6.1.2 and submitted to the authorized representative for review prior to production welding. Approval is not required and production welding may commence upon submittal.

   (4) First article test data shall be maintained along with the applicable welding procedure.

   (5) Parts limited to single pass fillet welds are excluded from first article testing.

   (6) In addition to the requirements of 4-2.1.2, welding of the first article test item shall be performed at the activity's production facility using the same equipment to be used in production, except as otherwise permitted by 4-7 and 4-8.

b. The first article test assembly shall be either a production part or a simulated configuration of the production part (see 3-1.8). A simulated configuration would usually apply for large items such as structural panels, egg crate configurations, foundation assemblies, etc., each of which can differ greatly in size, spacing/arrangement of framing, etc., and for piping assemblies that can have many different shapes, sizes, etc. Use of production parts would usually apply for repetitive smaller components having essentially the same geometry.

   (1) The simulated configuration of a production part shall, as a minimum, replicate each of the following attributes if the attribute is present in the part: joint type(s) (see 4-5.4); welding position(s); welding position transitions (e.g., horizontal fillet to vertical fillet and vice versa); and generic welding path type(s) (i.e., straight, curved, or end wrap around); for piping, branch-to-run, canted branch-to-run, straight (i.e., run) piping, weld-o-let (i.e., MIL-STD-22 P-68) and ID versus OD welds shall be treated as different attributes, as well as welds in the following different NPS size groups, excluding 1G/1F welds: ≤ 1-inch; > 1-inch ≤ 3-inch; > 3-inch ≤ 8-inch; > 8-inch.

   (2) A production part or simulated configuration that replicates each attribute (see 4-4.1.10.3.1.b(1)) of another part or simulated configuration that was previously subjected to first article testing, and which contains no additional attributes, shall not require additional first article testing (i.e., differences in parts or simulated configurations based solely on size [except as specified for pipe], qualified thicknesses, number of repeated members, etc., do not require additional first article testing).

(3) First article testing shall be re-performed when a procedure is re-qualified per 4-7 for any of the following changes, if applicable to welding of the part involved:

(a) Welding process

(b) Base material alloy/S-group

(c) Filler material A-group

(d) Welding position.

4-4.1.10.4 Special Automatic, Mechanized, and Robotic Welds. Qualification requirements shall be as specified in 4-4.7.

4-4.1.11 Fillet Welds – Welding on Bare Surfaces. When this document is specified in the applicable fabrication document, procedures for depositing fillet welds on bare surfaces (except for piping system applications; see 4-4.6) may be qualified in accordance with figure 7-8. The test assembly shall be welded with the type and largest diameter electrode to be used and shall be visually inspected and either dye penetrant or magnetic particle inspected, as appropriate, per 4-5. The fractured weld surface shall be visually examined and free of incomplete root fusion or any other indication exceeding 3/32 inch in length; the sum of the greatest dimensions of all indications over 1/32 inch shall not exceed 3/8 inch in any 4-inch length of weld. Fillet weld qualifications in accordance with figure 7-8 are limited to those base metal/filler metal combinations acknowledged in Appendix B. Butt weld qualification may also qualify for fillet weld joints. For S-10H materials, testing shall also be performed per 4-7.5.f, 4-7.10, and table 7-7, footnote 22.

4-4.1.12 Fillet Welds – Welding Over Primer-Coated Surfaces. When this document is specified in the applicable fabrication document, procedures for welding over primer-coated surfaces of S-1 materials with any process using a previously qualified procedure shall require additional qualification in accordance with figure 7-9. The test assembly shall be welded with the type and the largest diameter electrode to be used and shall be visually inspected and magnetic particle inspected per 4-5. Both pieces of each test assembly shall be coated with the maximum allowable thickness of the paint system to be used in production prior to test welding. Separate test assemblies are required for each manufacturer and for each manufacturer's specific paint system. Separate test assemblies are also required for each manufacturer and manufacturer's designation of the electrode used. These details are essential elements and must be added to the weld procedures. Weld quality shall be considered acceptable provided visual examination of the fractured weld surface conforms to the criteria of 4-4.1.11.

4-4.1.13 Heat Input. For materials where toughness testing is required by table 7-7, footnote 2 (including thicknesses less than 1/2 inch), S-10H per 4-7.5.f, and for cladding and hardfacing, the requirements of this section shall apply.

4-4.1.13.1 Test Assembly Welding. Test assemblies shall be welded such that:

a. At least 80 percent of all weld beads are 90 percent of the maximum heat input to be qualified or greater (applies only to the first two layers for cladding and hardfacing), and

b. The heat input, when averaged for all beads in the completed test assembly, shall not be less than the maximum heat input to be qualified; beads removed by back-gouging, etc., shall be excluded, and

c. The same welding process shall be used for repair welding per the conditions in 4-4.1.13.1.a and 4-4.1.13.1.b above, unless the repair area is marked and toughness test specimens are removed away from the repair weld. See 4-2.9.f for repair welding with alternate qualified processes.

The requirements of 4-4.1.13.1.a and 4-4.1.13.1.b above are optional for qualification of HY/HSLA-80/100 when the welding procedure restricts maximum heat input to that specified by the fabrication document or 55 kilojoules/inch, whichever is less; instead, the test assembly should be welded such that most weld passes are close to the maximum heat input to be qualified.

4-4.1.13.2 Heat Input Calculation. Heat input shall be determined by a., b., or c. below for non-waveform controlled welding, or by b. below for waveform controlled welding. Appendix H of Section IX of the ASME Boiler and Pressure Vessel Code can be consulted for detailed guidance if needed.

a. $$\text{heat input [joules per inch]} = \frac{\text{voltage} * \text{amperage} * 60}{\text{travel speed [inches per minute]}}$$

b. Heat input determined using instantaneous energy or power by:

(1) For instantaneous energy measurements in joules:

$$\text{heat input [joules per inch]} = \frac{\text{energy [joules]}}{\text{weld bead length [inches]}}$$

(2) For instantaneous power measurements in joules per second or watts:

$$\text{heat input [joules per inch]} = \frac{\text{power} \left[\frac{\text{joules}}{\text{second}} \text{ or watts}\right] * \text{arc time [seconds]}}{\text{weld bead length [inches]}}$$

c. For shielded metal arc welding only, the volume of weld metal, as measured by length of weld bead deposited per unit length of electrode, may be used when correlated to heat input values determined by 4-4.1.13.2.a or 4-4.1.13.2.b above. The length of the weld bead per unit length of the electrode shall be recorded along with other heat input variables on the qualification test report.

4-4.1.14 Bead Width for Manual and Semi-Automatic Welding Where Toughness is Required. Where toughness testing is required by table 7-7, footnote 2 and weaving is permitted for bead widths over 3/4 inch, at least 80 percent of the test assembly beads shall be approximately equal to, or greater than, the maximum bead width to be permitted by the procedure; however, this shall not mean that beads such as side wall and root pass beads must meet this criteria where proper fusion and soundness would be degraded. The percentage of beads meeting this maximum width criteria shall be included in the report of 4-6.

4-4.1.15 Multiple Processes. Multiple processes may be qualified in a single butt joint, provided all of the following are met:

a. If more than one process is used in a single joint, the processes shall be used in welding the qualification test assembly, unless the processes have been previously qualified and no changes specified in 4-7 and 4-8 have been made.

b. The thickness of each process to be qualified in a single joint shall be based on the thickness welded with that process (per table 7-6), except for root layers per 4-4.1.4 and 4-4.1.5; the qualified thickness for all processes combined in a single joint shall be based on the test assembly thickness per table 7-6.

c. For joints to be welded with multiple, separately qualified processes, the qualified thickness of each process shall not be additive in determining the maximum thickness of the production joint to be welded; instead, maximum (and minimum) thickness shall be based on the process with the highest qualified thickness, and the maximum thickness welded with each process in a single joint shall not exceed the thickness qualified for the respective process.

d. Each process shall be included in all destructive test specimens. Where specimens are too small to include representative weld metal from all processes (e.g., Charpy V-notch specimens), all required test specimens shall be taken from weld metal from each process, except for specimens and processes subject to the following limitations:

(1) The weld process involves no more than two layers in qualification and production welds (e.g., the root plus one layer), and

(2) The test specimens involved cannot be removed so as to include representative weld metal from each process (e.g., 0.505 all-weld metal tensiles).

e. One or more processes may be deleted from a production joint qualified by a combination of processes, provided each remaining process has been qualified within the limits specified by 4-4, 4-7, and 4-8 for each of the processes to be used in the production joint. Similarly, more than one process may be used in a single production joint, provided each process has been qualified either separately or in combination with other processes. However, root layers up to a thickness of 3/16 inch shall be deposited with the same process used in the qualification of the root layers. A change in sequence of the processes used does not require requalification.

4-4.2 QUALIFICATION REQUIREMENTS FOR WELD SURFACING. Build-up or buttering is qualified by qualification of a groove-weld procedure with thickness limits per table 7-6. Weld cladding shall be qualified as specified in 4-4.2.1. Hardfacing shall be qualified as specified in 4-4.2.2. Cladding and hardfacing thickness and weld layer limits shall be per figures 7-4 and 7-6, respectively, and also table 7-6; for cylindrical products, OD limits per table 7-6 and figure 7-5 shall also apply. Buttering in the form of an intermediate layer of different material before cladding or hardfacing shall be qualified with the respective surfacing per 4-4.2.1 or 4-4.2.2, employing the minimum number of buttering layers allowed for production.

4-4.2.1 Weld Cladding for Corrosion Resistance. The test assemblies shall duplicate the production cladding with respect to the base material, and filler material type, except that base and filler material groupings of tables 7-1 and 7-2 and the cross-qualification rules of table 7-3 shall apply. Position limitations for qualifications shall be as outlined in 4-2.8. The clad area, thickness, and other details shall be as shown in figure 7-4. Testing shall be as specified in table 7-7 and figure 7-4.

4-4.2.2 Hardfacing for Wear Resistance. The test assemblies shall duplicate the production hardfacing with respect to the base material, and filler material type, except that the base and filler material grouping of tables 7-1 and 7-2 and the cross-qualification rules of table 7-3 shall apply. Position limitations for qualifications shall be as outlined in 4-2.8. The hardfaced area, thickness, and other details shall be as shown in figure 7-6. Testing shall be as specified in table 7-7 and figure 7-6.

4-4.3 RESISTANCE WELDING. Procedure qualification for resistance welding shall be in accordance with the requirements of AWS D17.2/D17.2M. Procedures and qualification test data shall be submitted per 4-2.3.

4-4.4 STUD WELDING. The stud welding procedure qualification record and qualification limits shall be as follows:

The Stud Welding Procedure Qualification Record Shall Include the Following Essential Elements:	**Requalification of Welding Procedure is Required for the Following Changes Corresponding to Essential Elements Listed to the Left:**
a. Intended application, activity name, date.	N/A
b. Equipment used, including manufacturer and manufacturer's model number of the power source and stud gun.	See 4-7.4.t.
c. Stud material (specification and alloy) and size. Also, flux type or load (e.g., ball load, ring load, fluxless stud).	For material change, see 4-7.2.a; for grouping of stud material, see table 7-3, footnotes 22 and 24. For stud size, see 4-7.2.l. For flux type or load, see 4-7.4.u. For stud shape other than solid cylindrical, see 4-7.2.g.
d. Base material and thickness (specification and alloy).	For material change, see 4-7.1.a. For thickness, see table 7-6.

The Stud Welding Procedure Qualification Record Shall Include the Following Essential Elements:	Requalification of Welding Procedure is Required for the Following Changes Corresponding to Essential Elements Listed to the Left:
e. Gas shield and flow.	A change in shielding as a result of ferrule or flux type. Any change listed in 4-7.7.
f. Timer range setting.	See 4-7.5.g.
g. Maximum cable length and cable size.	See 4-7.5.j.
h. Amperage range or machine settings.	For drawn arc stud welding, see 4-7.5.h for amperage; for other stud welding, an increase or decrease in amperage. Change in machine settings other than specifically allowable by this table.
i. Current and polarity.	See 4-7.5.a.
j. Results of bending, flattening, or torque testing, visual examination, and, if required, backside examination.	N/A
k. Lift and plunge settings for drawn arc welding.	See 4-7.4.s.
l. Machine capacitance for capacitor discharge welding.	See 4-7.5.i.
m. Charging voltage for capacitor discharge welding.	See 4-7.5.i.
n. Preheat.	See 4-7.8.a.
o. A certification statement in accordance with 4-2.2.	N/A
p. Post weld heat treatment.	See 4-7.8.
q. Material cleaning.	N/A

4-4.4.1 Method of Qualification. Studs, as specified in MIL-S-24149/1 through MIL-S-24149/6 or other approved specification, shall be welded for each material combination and each nominal stud base diameter to be used in production, except as permitted by table 7-3. Qualified base material thickness shall be per table 7-6. Welding in the overhead and horizontal positions shall qualify all positions. Alternatively, each welding position shall be qualified. A minimum of five studs shall be welded in each position and shall be tested as specified in 4-4.4.1.a or 4-4.4.1.b, and 4-4.4.1.d and 4-4.4.1.e below. For stud diameters greater than 3/8 inch, another five studs shall be welded in each position and tested per 4-4.4.1.c below.

a. Studs shall be tested by axial tensile loading until failure. 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 a nut with force being applied by a torque wrench. To ensure that the weld is loaded primarily in tension, the threads of the stud should be lubricated with molybdenum disulfide, graphite base, or comparable lubricant. The required axial load or torque shall be not less than the value listed in table 7-16 for the stud material and size tested except that, when failure occurs outside the weld (in the stud or plate), the test shall be considered satisfactory if the axial load or torque was not less than 90 percent of the table value.

b. As an alternate to the tensile tests, studs may be tested by bending as follows:

(1) For other than aluminum alloy and titanium alloy studs, 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, or until the stud itself fails. The bending of difficult studs may be assisted with a device similar to that shown in figure 7-10. The welds shall exhibit no cracks. In the case of collared studs, remove a portion of the collar to permit hammering of the stud.

(2) For aluminum alloy (5000 series) studs, each stud shall be bent to an angle of 15 degrees. For titanium alloy studs, bend testing is applicable only to the ¼-inch stud, which shall be bent to an angle of 10 degrees. There shall be no visible evidence of cracking in the weld zone or shank. The device used for bending may be similar to that shown in figure 7-10.

c. Section each stud-weld junction through the diameter along the long axis of the stud; for horizontal position studs, the cut shall be vertical (i.e., 12 to 6 o'clock). Polish, etch, and examine the weld and HAZ under 5× to 10× magnification. Linear indications 1/16 inch and greater in length shall be cause for rejection.

d. All stud welds shall be subjected to visual examination. Visible gouging of the stud or base material or visible separation between the stud and base material shall be cause for rejection. For titanium, the weld and the backside of the qualification plate opposite where the studs are welded shall meet the criteria of 4-5.1.1.1.

e. For stud welding to base material thicknesses less than d/2 for aluminum or less than d/3 for all other materials, the backside of the qualification plate opposite where the studs are shot shall be free of burn-through, and rejectable melt-through and oxidation as specified in MIL-STD-2035.

4-4.4.2 Procedure Requirements. The stud welding procedure shall contain, at a minimum, the requirements listed in 4-4.4, excluding 4-4.4.j. For S-51, S-52, S-53, and S-53A materials, procedures shall also include:

a. Details of the stud and base material contact area preparation and cleaning.

b. Statement of workmanship standards, including welding environment, material storage, and handling.

4-4.4.3 Internally Threaded Studs. Internally threaded studs shall be qualified in accordance with 4-4.4.1, provided the stud is long enough to be subjected to bending. If the stud is too short to facilitate bending, the internally threaded stud shall be qualified by subjecting either an unthreaded stud of sufficient length or externally threaded stud that is of the same stud base diameter, end configuration, and material to the requirements of 4-4.4.1. The qualified diameter of the internally threaded stud is the actual stud base diameter, not the internal thread size.

4-4.5 WELDS MADE WITHOUT ADDING FILLER METAL. The test assembly shall consist of a duplicate of the production welds. Each test assembly shall be fully tested in accordance with 4-5. Where test assembly size or shape does not permit the above, testing two macro sections may be substituted for the destructive tests. Unless otherwise approved, the thickness qualified shall be limited to the test assembly thickness ±10 percent.

4-4.6 SEAL WELDS, PIPE SOCKET WELDS AND TUBE-TO-TUBESHEET WELDS (EXCEPT FOR TUBE-TO-HEADER SEAL WELDS; SEE 4-4.8).

4-4.6.1 Socket Joints. For all socket welds, the following shall apply:

a. If the base material/filler material combination involved is not covered by Appendix B, a butt weld qualification in accordance with Chapter 4 is required. This butt weld qualification shall be in addition to the tests required for 4-4.6.1.

b. For automatic, mechanized, and robotic welding of socket joints, two pipes shall be prepared in accordance with 4-4.1.10 and inspected in accordance with 4-4.6.1.1.1 for each position to be qualified.

c. In vertical pipe axis position socket welds, the fitting shall be on top of the pipe (i.e., 4F).

d. Qualified thickness shall be per table 7-6.

e. Base and filler material groupings of tables 7-1 and 7-2 and the cross-qualification rules of table 7-3 shall apply, except for non-ferrous welds in pipe wall thicknesses less than 3/16 inch, where table 7-3 shall not apply, except for S-34 and S-42 materials welded to themselves or each other.

4-4.6.1.1 Test Assembly. For pipe with nominal wall thickness less than 3/16 inch, socket welds shall be qualified by welding a test assembly employing a MIL-STD-22, P-14 or other socket joint design with the base and filler materials to be qualified, in the position to be qualified per table 7-4. For pipe 3/16 inch and greater in thickness, socket welds shall be qualified the same way, or by completion of a butt weld in accordance with Chapter 4.

4-4.6.1.1.1 Inspection and Testing. Completed socket welds shall be visual and dye penetrant inspected in accordance with 4-5. Each weld shall then be sectioned into quadrants to provide four macro-etch specimens approximately 90 degrees apart; pipe less than 0.840 inch nominal OD may be sectioned in half to provide one macro-etch specimen. At least one specimen in each weld shall be taken through a start/stop location. All specimens shall be evaluated in accordance with 4-5.2.6.

4-4.6.2 Seal Welds. Seal weld qualification shall not be limited to a maximum base material thickness.

4-4.6.2.1 Seal Welds Other Than Fillet and Edge Seal Welds. These welds shall be qualified by welding a test assembly that incorporates the base and filler materials and weld joint design of the production weldment for the positions to be qualified per table 7-4. Materials shall be per 4-4.6.1.e. Inspection shall be per 4-4.6.1.1.1, except that, for macro testing, two macro-etch specimens equally spaced on the length of the joint shall be inspected; if the joint is less than 2 inches in length, one macro-etch specimen shall be inspected. The minimum qualified thickness shall be the same as that shown in table 7-6 for butt joints. Qualification by a butt joint for the materials, joint design, and position involved per Chapter 4 shall also be acceptable.

4-4.6.2.2 Fillet Seal Welds in Pipe. These shall be qualified per 4-4.6.1, except that joint design may simulate the production joint design in lieu of using a socket design if desired, and base material/filler material combinations other than those of Appendix B do not require additional butt weld tests.

4-4.6.2.3 Fillet Seal Welds in Other Than Pipe, and Edge Seal Welds. These shall be qualified by completion of a socket weld test per 4-6.1, a mock-up weld test per 4-6.2, or a butt weld test per Chapter 4, for the materials and positions involved.

4-4.6.3 Tube-to-Tubesheet Welds. For tube-to-tubesheet welds, as a minimum, the tube-to-tubesheet mock-up shall consist of ten consecutively welded joints in each position to be qualified. The mock-up shall simulate the production application in all aspects (i.e., same tube hole pattern, nominal tube OD and wall thickness, tubesheet thickness [except 2 inches need not be exceeded], tube hole ligaments, joint variables, number of passes, filler material diameter, base/filler material types, and any other variable that contributes to the integrity of the joint). All mock-up variables and any variation desired for production welding shall be identified in the submittal. Completed mock-ups shall be visual and dye penetrant inspected in accordance with 4-5. Each weld shall then be sectioned into quadrants to provide four macro-etch specimens approximately 90 degrees apart; pipe less than 0.840 inch nominal OD may be sectioned in half to provide one macro-etch specimen. At least one specimen in each weld shall be taken through a start/stop location. All specimens shall be evaluated in accordance with 4-5.2.6. Welding procedure and qualification test data for tube-to-tubesheet welding shall be submitted for approval to NAVSEA.

4-4.7 SPECIAL WELDS. Special welds, as defined in 3-2.15, shall be qualified, inspected, evaluated, and recorded to all applicable requirements of this document. In addition, for base metals, filler metals, and welding processes not covered by this document, all variables and special techniques considered essential in producing a weld that will meet minimum material mechanical properties and the inspection requirements of this document shall be recorded and submitted with the procedure for approval per 4-2.5.

4-4.8 TUBE-TO-HEADER SEAL WELDS IN BOILER COMPONENTS. Welding procedures shall conform to NAVSEA S9221-C1-GTP-010 and NAVSEA S9221-C1-GTP-020, unless otherwise approved by NAVSEA. The requirements of this paragraph are applicable only to manual welding. For other than manual welding, qualification shall be in accordance with 4-4.7.

4-4.8.1 Requirements. Qualification shall consist of welding and testing a mock-up in accordance with the following:

a. The mock-up shall consist of six joints welded in this sequence: complete six root welds, then inspect, complete all welds, and then perform final inspection.

b. Each joint shall simulate the production weld joint, except:

(1) Groove depth shall be 3/16 inch, minimum.

(2) Flat plate of the required alloy may be used. Plate thickness shall be at least 1 inch.

c. The number of weld passes for each joint shall equal the minimum number of passes allowed for production welding.

d. Position of welding shall be in accordance with 4-2.8.

e. Root pass welds shall be inspected visually and with dye penetrant or magnetic particle for porosity, cracks, slag, and fusion in accordance with 4-5. Also, the reentrant angle between the weld and sidewall shall be 90 degrees minimum and surface condition shall be in accordance with NAVSEA S9221-C1-GTP-010 and NAVSEA S9221-C1-GTP-020.

f. Completed welds shall be inspected visually and with dye penetrant in accordance with 4-5. Final welds shall also be inspected to the requirements of NAVSEA S9221-C1-GTP-010 and NAVSEA S9221-C1-GTP-020 for size, surface condition, and other controlled attributes.

g. After completion of the required nondestructive testing, three of the six welds shall be sectioned into quadrants to provide four macro-etch specimens 90 degrees apart. At least one section of each weld shall be taken through a root weld pass start. All macro-etch specimens shall be evaluated in accordance with 4-5.2.6.b and 4-5.2.6.c.

h. The remaining three welds (and tubes) shall be machined down to 1/32 inch +1/32, -0 below the base material surface, examined, then machined to 1/32 inch +0, -1/64 above the original groove bottom and examined again. Examination and preparation of machined surfaces shall be in accordance with 4-5.2.6.b.

i. Acceptance criteria for nondestructive testing and macro section examination shall be based on tube wall thickness, except that reinforcement shall be 1/8 inch maximum.

j. Failure of either the root pass or final weld by nondestructive testing on more than one joint or by other testing on any joint shall constitute failure of the qualification test. For compliance with 4-2.9.d, repair of a root pass defect shall preclude further repair.

k. Test failure shall require retesting of another complete (i.e., six tube joints) mock-up.

4-4.9 LOCK WELDS. Lock welds shall be qualified by one of the following methods:

a. Welding a butt or fillet weld test per 4-4.1 for the process, materials, positions, and thicknesses to be qualified.

(1) If the production weld involves a pressurized component less than 3/16 inch thick at the weld, qualification shall be performed by a socket or fillet seal weld test per 4-4.6 for the thickness involved, or a mock-up per 4-4.9.b below.

b. Welding a mock-up test simulating the process, materials, components, and joint design to be welded in production. Components that are complex or large can be qualified by simplified mock-ups and do not actually have to be welded themselves. Multiple components (e.g., different size nuts) can be qualified by one representative test weld but the test assembly is subject to approval and any desired variances from the test assembly shall be described in the welding procedure. The following requirements shall apply:

(1) Qualified positions shall be per table 7-4, footnote 7(a).

(2) Table 7-3 shall apply.

(3) Qualified thicknesses shall be per table 7-6; where condition 4-4.9.a(1) above applies and a mock-up test is used, the base material thickness representing the pressurized component shall conform to table 7-6, footnote 6 for socket welds.

(4) The completed weld shall be visual and dye penetrant inspected per 4-5. Where weld ends involve open crevices, the 1 inch of weld at each end shall be visually inspected per 4-5 at 5× magnification in lieu of dye penetrant inspection.

(5) After nondestructive testing, macro-etch specimens per 4-5.2.6 shall be tested. Remove one specimen for every 2 inches of weld, except that no less than one and no more than four specimens are required. If the welding procedure will allow overlapping starts and stops, one macro-etch specimen shall be removed from a start/stop.

4-4.10 TEMPERATURE CONTROLLED AREAS (TCA). Where production welding on a member containing a TCA (see 3-2.18) can be closer to a TCA than the minimum distance, additional qualification testing shall be performed per Appendix D to verify that excessive temperatures at the TCA will not occur. Minimum distance shall be at least 8 inches of uninsulated metal between the TCA and production welding, unless a different distance is specified by the fabrication document or governing specification, or is approved; insulation shall require approval of a proportionately larger minimum distance, or qualification per Appendix D with representative insulation. This minimum distance or that qualified per Appendix D, as applicable, shall be specified by each welding procedure used for TCA members. Production welding at distances greater than this minimum distance does not require additional qualification per this paragraph or Appendix D.

4-5 EVALUATION OF PROCEDURE QUALIFICATION WELDMENTS.

This section provides methods for evaluation of the tests required for the qualification of welding procedures. The type and number of nondestructive and destructive tests required for each assembly are shown in table 7-7 or are as specified in the applicable sections of 4-4.1.11, 4-4.1.12 (fillet welds), 4-4.3 (resistance welding), 4-4.4 (stud welding), 4-4.5 (autogenous welding), 4-4.6 (seal welds, pipe socket welds, tube-to-tubesheet welds), 4-4.8 (tube-to-header seal welds in boiler components), 4-4.9 (lock welds), and 4-4.1.10 (TCAs). Weldments shall have undergone all applicable post weld heat treatments prior to evaluation, as stated in 4-4.1.6.

4-5.1 NON-DESTRUCTIVE TESTS. Prior to performing any destructive tests, all procedure qualification test assemblies shall be nondestructively tested as required in table 7-7. A maximum of 1 inch on each end of fillet and butt plate assemblies is exempt from inspection, except for titanium weld appearance per 4-5.1.1.1.

4-5.1.1 Visual Inspection (VT). VT shall also ensure suitability of the weld surface for performance and evaluation of other required nondestructive testing and shall conform to NAVSEA T9074-AS-GIB-010/271. Grinding of the weld surface is permitted to meet the acceptance criteria of MIL-STD-2035.

4-5.1.1.1 VT and Titanium Weld Appearance. Prior to altering the as-welded surface (e.g., brushing), VT of S-51, S-52, S-53, and S-53A welds shall ensure that the following criteria are met:

a. All weld surfaces and surrounding 1/32 inch of material shall exhibit a bright, shiny, silvery luster. Other conditions are unacceptable and shall be dispositioned as follows:

(1) A first occurrence of straw color shall be left as-is and recorded on the qualification test report.

(2) Other conditions, such as loss of luster, or other colors like blue or gray, shall be cause for rejection of the qualification weldment and repair welding shall not be permitted. In all cases, the welding and shielding deficiencies shall be corrected prior to further welding.

(3) A second occurrence of straw on the initial weldment or any straw occurrence on replacement weldments (i.e., qualification welds made after failure of an initial qualification weld) shall be cause for rejection of that qualification weldment and repair welding shall not be permitted.

b. Areas beyond 1/32 inch from the weld toes should not exhibit any discoloration. Gray color shall be cause for rejection of the qualification weldment. Other colors such as blue or straw are acceptable, but shall be removed if they occur on surfaces to be welded over.

c. Personnel performing color inspection of welds shall be qualified in accordance with the requirements of NAVSEA S9074-AR-GIB-010/278.

4-5.1.2 Radiographic (RT), Magnetic-Particle (MT), Liquid-Penetrant (PT), and Ultrasonic (UT) Inspection. RT, MT, PT, and UT shall be performed in accordance with NAVSEA T9074-AS-GIB-010/271. For PT of hardfacing, see figure 7-6, note 4. Backing bars, if employed, may be removed and weld reinforcement ground smooth prior to RT and UT inspection.

4-5.1.3 Acceptance Standards. Acceptance standards for RT, UT, MT, PT, and VT shall be based on the requirements of MIL-STD-2035, class I; for titanium welds, also see 4-5.1.1.1.

4-5.2 DESTRUCTIVE TESTS. Required specimen preparation, dimensions, mechanical testing, and test reports shall be in accordance with AWS B4.0. Test results shall be evaluated as outlined in 4-5.2.1 through 4-5.2.6.

4-5.2.1 Transverse Weld Tension Tests. For acceptance, transverse weld tension test specimens shall be as follows:

a. Shall have a tensile strength not less than the minimum specified in the applicable base material specification. If materials of different minimum tensile strengths are used, the strength of the weaker material shall govern.
b. Shall have a tensile strength not less than the specified minimum tensile strength of the weld metal in those cases where the fabrication documents allow the use of weld metal of lower room temperature strength than the base materials. For aluminum, where the governing specification does not require minimum tensile strength, filler metal minimum tensile strength shall be the value listed by S9074-A1-GIB-010/1628, except that 40,000 psi shall be used for alloy 5183 and strengths for A-24B shall be as approved by NAVSEA.
c. In applying the criteria of 4-5.2.1.a and 4-5.2.1.b above for A5-A, A5-B, A5-C, and A5-D filler materials and HSLA-65, HY/HSLA-80, HY/HSLA-100, and HY-130 base materials, where the governing specification does not list a minimum tensile strength, the minimum tensile strength shall be that specified by S9074-A1-GIB-010/1628 .
d. 6061-T6 and 6082-T6 aluminum shall have tensile strengths not less than 24 ksi and 28 ksi, respectively.

Except for the case in 4-5.2.1.d, if the specimen breaks in the base material outside of the weld or fusion line, the test shall be accepted as meeting the requirements, provided the strength is not more than 5 percent below the requirements specified herein. For the case in 4-5.2.1.d, no reduction in the minimum specified strength is permitted. For castings, see table 7-7, footnote 1.

4-5.2.2 All-Weld Metal Tension Tests. For acceptance, all-weld metal tension test specimens shall meet the minimum specified mechanical properties of the applicable filler material specification.

4-5.2.2.1 Titanium Specimens. Where properties are not specified in the filler material specifications, titanium weld specimens shall meet the minimum tensile and yield strength of the base material, and elongation and reduction in area shall be reported for information.

4-5.2.3 Guided Bend Tests. When guided bend tests are specified in table 7-7, joints of similar materials shall be tested by transverse bends, and joints of dissimilar materials shall be tested by longitudinal or transverse bends. For materials with 20 percent or less minimum elongation requirements, elongation for determining bend radius shall be selected based on the base metal or filler metal specification minimum elongation requirement, whichever is lower; where base material elongations are different, the lower minimum elongation shall govern. For welds and materials with elongation requirements exceeding 20 percent elongation, bend testing at 20 percent elongation is required.

4-5.2.3.1 Criteria for Acceptance. For acceptance, the guided bend specimen after bending shall have no cracks or other open defects greater than 1/8 inch (except weld cladding). The maximum open defect dimension in the cladding of corrosion-resistant weld clad bend tests shall be 1/16 inch. Cracks occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that they result from slag inclusions or other internal defects. Openings in the base metal outside the weld deposit and HAZ shall not be cause for rejection.

4-5.2.4 Impact Test. When specified in the footnotes to table 7-7, specimens shall be prepared and tested. Test full specimen sets (at each temperature required for heat/lot conformance testing by the governing material specification, unless all test values at the lowest temperature also meet the minimum energy criteria for all other temperatures). Weld metal Charpy V-notch specimens shall be taken transverse to the axis of the weld groove with one surface of each specimen located a minimum of 1/16 inch below the finished surface of the weld after removal of weld reinforcement. The length of the notch shall be perpendicular to the surface of the weld. Base metal and HAZ specimens shall be removed in accordance with figure 7-2 and figure 7-24. Weld tests shall be evaluated to the requirements of the filler metal specification. Base metal and HAZ impact tests shall be evaluated to the requirements of the applicable base metal specification or per 4-5.2.4.2, as applicable. Dynamic tear testing shall be in accordance with ASTM E604 and may be substituted for Charpy V-notch testing as allowed in table 7-7, footnote 14.

4-5.2.4.1 Titanium Weld Metal Toughness Tests. If the design requires base material toughness properties, the weld metal shall also have the same toughness properties.

4-5.2.4.2 HAZ Toughness Criteria Where Base Material Criteria are Absent. Where toughness testing is required by the fabrication document or other governing specification and the base material(s) involved has no specified toughness requirements, base material and HAZ Charpy V-notch specimens shall be tested at the minimum design temperature. The average tested base metal toughness shall not exceed the average HAZ toughness by more than 10 percent or 5 ft-lbs, whichever is greater, unless approved by NAVSEA.

4-5.2.4.3 HSLA-65 HAZ Toughness. HSLA-65 HAZ tests shall meet a toughness of 30 ft-lbs minimum at -20 °F.

4-5.2.5 Hardness Test. Specimens shall be prepared and evaluated in accordance with figure 7-6.

4-5.2.6 Macro-Etch Specimens. Specimens shall be removed transverse to the weld, suitably prepared and etched to show weld cross-section, and examined at 5× to 10× magnification to the following requirements:

a. Weld cladding or hardfacing. Discontinuities in the weld area up to and including 1/32 inch in length are acceptable. Incomplete fusion at weld/base metal interface is unacceptable. Certain wear-resistant alloys are subject to fine cracking that does not defeat the intended purpose. Accordingly, this fine cracking shall not be cause for rejection if confined to the weld deposit.

b. All other welds. Discontinuities in the weld area greater than 1/32 inch or 10 percent of the thickness of the weld, whichever is less, are unacceptable. Each cross-section shall exhibit no cracks, except that linear or rounded conditions at the root of partial penetration welds (including welds with backing rings or straps that are not removed) are acceptable, provided they do not reduce weld thickness below the minimum allowance and provided they do not exceed 1/32 inch in length and adjacent linear defects are not closer than 1/8 inch. For partial penetration welds, root conditions outside the original joint configuration shall not be evaluated. The pipe or tube inner diameter surface of socket and seal welds shall reveal no melt-through, burn-through, or oxidation beyond the visual inspection acceptance criteria of MIL-STD-2035.

c. Tube-to-tubesheet and tube-to-header seal welds. In addition to 4-5.2.6.b above:

   (1) Unless otherwise specified by the governing drawing, fabrication document, and so forth, weld throats (minimum leakage path) of all macro-etch specimens shall be no less than two-thirds of the specified wall thickness, and

   (2) Allowable linear root indications shall not exceed 0.015 inch, even if occurrence is below the original joint preparation.

4-5.3 SPECIAL TESTS. When tests, such as explosion-bulge, dynamic tear, hardness traverses, and other tests not detailed in this document are required, these tests will be specified by NAVSEA and information as to methods and guidance for performance of the required test and acceptance criteria will be provided at that time.

4-5.4 FIRST ARTICLE TEST EVALUATION FOR AUTOMATIC ROBOTIC WELDING. Each weld pass in a first article test assembly shall be visually examined to ensure intended bead placement, profile, and fusion, and that intended fit-up tolerances are maintained throughout welding of the part; for multipass fillet welds, only the first three passes must be inspected this way. First article test assembly welds shall also be evaluated as follows:

a. Butt welds shall be inspected by VT and by RT or UT per 4-5.1.1 and 4-5.1.2 upon completion.
b. Other full penetration welds shall be inspected by VT per 4-5.1.1 and by RT (if suitable or, if not, UT) per 5-4.1.2 upon completion. If the weld is not amenable to RT or UT, MT/PT per 4-5.4.d below shall be applied on the root layer, back-gouged surface (if applicable), and each subsequent 1/4-inch thickness of the deposited weld and completed weld surface.
c. Plug/slot welds shall be examined per 4-5.4.a above.
d. Multipass fillet welds shall require MT/PT of the root layer per 4-5.1.2 to ensure absence of linear and non-linear indications in excess of MIL-STD-2035, class I. VT and MT/PT of the completed weld shall be per 4-5.1.1 and 4-5.1.2.
e. Partial penetration groove welds shall be inspected per 4-5.4.d above.
f. Socket welds shall be inspected per 4-5.4.d above and also receive macro inspection per 4-5.2.6.

Repair of defects shall be per 4-2.9. The same welding procedure to be used for production repairs shall be used for repair of the first article test weld and shall also be recorded on the report of 4-6.1.2. If the first cycle of repair fails, then two additional first article test specimens shall be welded and tested in accordance with the requirements of this document, and any further defects shall require three additional such tests for each defect.

4-6 DATA ACCUMULATION AND REPORTING FOR PROCEDURE QUALIFICATION.

This section specifies the requirements for procedure qualification data reporting to obtain approval of a welding procedure qualification test report.

4-6.1 TEST REPORT. The welding procedure qualification test report shall include the following items in sufficient detail to ensure compliance with the requirements of this document:

a. Welder/welding operator (name and badge number).
b. Bend radius.
c. Essential elements of the welding procedure, as specified in table 7-5, or for stud welding, as specified in 4-4.4. For each essential element, the actual value(s) used for qualification welding shall be recorded. Where heat input is a required essential element, it shall be reported for each pass. Where bead width applies, see 4-4.1.14.
d. Destructive test results.
e. Nondestructive test results and acceptance criteria.
f. The repair data required in 4-2.9, if applicable.
g. The test report number, revision, and date.
h. The qualifying activity's name.
i. For filler materials not listed in table 7-2 that are intended for production welding, lot conformance testing requirements per 4-2.3.2.

When HAZ Charpy V-notch (CVN) testing is performed, photomacrographs of CVN-HAZ specimens per figure 7-24 shall be submitted with the test report. A sample welding procedure qualification test report with a form for data accumulation is provided for guidance in figure 7-11. The report shall contain a certification statement in accordance with 4-2.2. See 4-4.10 for additional reporting of distance and temperatures.

4-6.1.1 Cladding, Hardfacing, and A-45 Filler Materials. In addition to the requirements of 4-6.1, the following shall be included:

a. For A-45 filler materials, the information required by table 7-2, footnote 9 shall be submitted along with procedure qualification data.

b. For all cladding procedures, the following shall also be included:

(1) Clad weld chemical composition or dilution test results.

(2) For A-45 filler materials, Fe, Mo, and Cr composition of the filler material lot used.

(3) For filler materials other than A-45, composition of the filler material lot used for each element analyzed in the finish machined cladding surface.

(4) Number of weld layers and clad weld thickness at which composition testing was performed.

(5) Macro-etch specimens or photomacrographs (see figure 7-4, notes 4 and 6(b) or figure 7-6, note 5).

(6) Clad weld thickness at which bend testing was performed.

c. For hardfacing procedures, also include the number of weld layers and minimum weld thickness at which hardness testing was performed and, where applicable, the second weld thickness tested (figure 7-6, note 3) and macro-etch specimen information (figure 7-6, note 5).

4-6.1.2 Automatic Robotic Welding First Article Test Report. This report shall include:

a. A sketch of the production part or simulated configuration

b. Production part identification; or, if using a simulated configuration, a listing of attributes (see 4-4.1.10.3.1.b.(1))

c. Number of weld passes per joint

d. Welding procedure and qualification test report identification

e. Test date

f. Test results inclusive of acceptance criteria (see 4-5.4)

g. A certification statement per 4-2.2

4-6.1.3 Accompanying Documentation. The qualification test report shall be accompanied by the destructive and nondestructive test reports for all tests/inspections performed.

4-6.1.4 Level II Qualification Submittals Where Approval is Not Required. When approval of level II qualification test data is not required (see 4-2.7.3), the submittal of 4-2.7.3.2 shall also include the following information:

a. The supporting/original approved level I qualification test report number and date. A copy of the supporting, approved level I qualification report (and prior level II qualification reports supporting the procedure, if applicable) shall be provided upon request.

b. A description (e.g., Agency, serial number and date) or copy of the Government correspondence approving the original level I qualification test report. If the qualifying activity was never provided with the foregoing, then a description or copy of the correspondence (e.g., from a prime contractor) accepting the level I procedure qualification test report shall be provided.

c. A copy of the qualifying activity's letter originally submitting each level II qualification test report to an authorized representative (or, for subcontracting activities, to the prime contractor) shall be maintained along with the test report; the identification of changes required by 4-2.7.3.2, if not in the procedure (i.e., via a Change History), shall be maintained with the original submittal letter. This letter shall be provided upon request (i.e., by authorized representatives after the original submittal).

4-6.2 MAINTENANCE OF RECORDS. The approved procedure qualification reports, and all level II qualification reports, shall be retained by the activity as long as the procedure is applicable. Each qualifying activity shall retain the pertinent qualification test data, destructive test specimens and reports, and nondestructive test result reports, including radiographs, until written approval of the qualification data is obtained; for level II qualification reports where approval is not required (see 4-2.7.3.2), all of these items shall be retained for at least 12 months following submission of the report, and shall be provided upon request.

4-7 CHANGES REQUIRING LEVEL I REQUALIFICATION OF PROCEDURE.

New welding procedure qualification test data shall be submitted to the authorized representative for approval when any of the changes listed herein are made in the welding procedure. Changes other than those listed in this paragraph and those listed in 4-8 for level II qualification may be made in a welding procedure without the necessity for requalification; however, if such changes affect the essential elements of table 7-5, the revised welding procedure with all changes identified shall be submitted for information to the authorized representative. The changes specified in 4-7.1 through 4-7.11 require requalification of the welding procedure for qualification level I.

4-7.1 BASE MATERIAL.

a. Unless permitted by table 7-3, a change from a base material listed under one S-number in table 7-1 to a material listed under another S-number, or to any other material not listed (unless considered a part of a group in accordance with table 7-1, footnote 1), except as follows:
   (1) 4-4.6For tube-to-tubesheet welds and nonferrous socket and seal welds in pipe less than 3/16 inch thick, see 4-4.6.
   (2) For base materials having toughness requirements, see table 7-7, footnote 2.
   (3) For groups S-4 and S-5, qualification for all materials within these groups applies only when these materials are welded in the annealed or normalized and tempered conditions. When any one of these base materials is welded in a quenched and tempered condition, separate qualification is required. However, qualification using any one of these materials in the quenched and tempered condition shall also qualify for welding all of the materials in the S-group in the annealed or normalized and tempered condition.
   (4) A change to a UNS N06625 base material (i.e., any Inconel 625 type alloy) from any other base material (including other S-43 group materials).
   (5) A change from one alloy to another alloy within group S-11F, unless permitted by MIL-STD-2191.
b. A change in the base material thickness to a thickness outside the limits for which the procedure was qualified (see table 7-6). For automatic, mechanized, and robotic welding of pipe that is 5 inches OD or greater with a thickness of 3/8 inch or greater, where the increase is more than 1.1T but not more than 2T, only level II qualification per 4-8.t is required. For cladding and hardfacing base material thickness, also see 4-7.9.1.e, and for weld thickness and layers, see 4-7.2.c.
c. In plasma arc welding, when welds are made between two base materials that have different S-numbers, requalification is required even if the two base materials have been independently qualified using the same procedure.
d. An increase in base material paint/primer thickness or type per 4-4.1.12.
e. For mechanized, automatic, and robotic welding of pipe groove and socket joints, a change in OD shall be governed by 4-8.s, 4-4.1.10.1, and table 7-6. For all cladding and hardfacing of cylindrical products, see 4-7.9.1.e and 4-7.9.1.i.

4-7.2 FILLER MATERIAL.

a. Unless permitted by table 7-3, a change from a filler material listed under one A-number in table 7-2 to a material listed under another A-number or to any other material not listed (unless considered a part of a group in accordance with table 7-2, footnote 1). Table 7-3 allowances for one A-group to qualify another A-group filler material shall not apply where toughness testing would be required by table 7-7, footnote 2 for the latter A-group filler material (e.g., an HY-80 procedure qualified with MIL-10718-M does not cross qualify welding of HSLA-65 with MIL-7018-M).

b. For A-2C materials, the following apply:

(1) A change in flux/wire classification of lower specified tensile strength to a flux/wire classification with higher specified tensile strength (e.g., MIL-F-6XX-XXXXX to MIL-F-7XX-XXXXX or MIL-70S-X).

(2) When joining base metals 1/2 inch and thicker having toughness requirements, a change in flux/wire classification with no toughness requirements to a flux/wire classification with toughness requirements. Also a change in flux/wire classification with toughness specified at a higher temperature to a flux/wire classification with toughness specified at a lower temperature.

(3) A change from neutral to active flux and vice versa for multilayered weld deposits.

c. For cladding and hardfacing, see 4-7.9.1.c and 4-7.9.1.d.

d. For MIL-120 and MIL-140 series filler materials, see table 7-2, footnote 13.

e. For tube-to-tubesheet welds, see 4-4.6.3.

f. See table 7-2 citations of footnote 2.

g. In the submerged arc process, a change in the type of flux used, except as permitted in table 7-2.

h. In the plasma arc process, the addition or deletion of supplementary powdered filler metal.

i. In the plasma arc process, a change in the form of filler metal from solid to fabricated wire, flux-cored wire, powdered metal, or vice versa.

j. In plasma arc weld cladding or hardfacing, a change from a homogeneous powdered metal to a mechanical mixed powdered metal or vice versa.

k. For tube-to-header seal welds in boiler components:

(1) A change in electrode coating classification (e.g., MIL-XX15 to MIL-XX16 or MIL-XX18) and vice versa, or

(2) An increase in electrode diameter of 1/32 inch or more from that qualified for any weld pass.

l. In stud welding, a change in the nominal stud base diameter or shape of the stud at the section to be fused. Where stud shape at this section is not solid cylindrical, table 7-3 shall not apply (i.e., each different shape, size, and alloy shall require qualification, unless otherwise approved by NAVSEA, and the test method and application shall be as approved by NAVSEA).

m. For weld cladding and hardfacing applications, when using the automatic, mechanized, or robotic gas tungsten arc or plasma arc processes, a reduction of 10 percent or greater in the filler wire (or powder) feed rate from that recorded in the procedure qualification record.

n. For submerged arc processes, a change in the flux trade name when the flux is not classified in table 7-2. Also a change in the flux type (e.g., neutral to active and vice versa) for multilayer welds in S-1 or S-2 materials.

o. For A-45 filler materials, see table 7-2, footnote 11.

p. In plasma arc weld cladding or hardfacing, a change in the powdered metal particle size range recorded in the procedure qualification record.

q. A change in manufacturer or manufacturer's designation of electrodes for welding over primer per 4-4.1.12.

4-7.3 JOINT DESIGN.

4-7.3.1 Full Penetration Joints Welded from One Side Only. For these joints, the following shall apply:

a. The omission of a backing ring or backing strip. For dissimilar metal weld joints, the addition of metallic backing or a change in metallic backing S-group (permanent or temporary), except as permitted by 4-4.1.3.1.1.

b. The addition or omission of a consumable insert, except that welding a full penetration joint with or without a consumable insert also qualifies for welding joints with a backing ring or backing strip.

c. A change in the shape of a consumable insert.

d. A change from a metal backing strip to a ceramic or other non-metallic backing strip. Full penetration joints welded from one side only with or without a backing ring, backing strip, or consumable insert also qualify for welding full penetration joints welded from both sides and partial penetration joints.

e. A change from multipass welding to single-pass welding, except as allowed by 4-4.1.7.1.

4-7.3.2 Tube-to-Header Seal Weld Joints for Boiler Components. For these joints, the following shall apply:

a. A 1/32-inch or greater decrease in root opening from that qualified. (Root opening is one-half the difference between nominal tube OD and nominal counterbore size.)

b. A decrease in included angle of 5 degrees or more from that qualified (any beveling of the header side of the counterbore shall also be considered as part of the weld joint included angle). However, requalification is not required for joints with angular decreases of up to 10 degrees, provided the root opening is at least 1/16 inch greater than that qualified.

c. For tube end lands 1/16 inch and smaller, a decrease in tube end land below that qualified.

d. An increase in counterbore depth of 1/32 inch or greater beyond that qualified, except that qualification performed on 3/16-inch deep counterbores shall qualify up to and including 1/4-inch deep counterbores.

4-7.3.3 Butt and Fillet Joints in Robotic Welding. For robotic welding, a change from a butt (or other groove) joint to a fillet joint.

4-7.4 PROCESS.

a. A change from one welding process to another process (shielded metal arc, gas metal arc, oxyacetylene, gas tungsten arc, flux-cored arc, etc.).

b. For gas tungsten arc processes and plasma arc processes, the addition or omission of filler material or a change from electrically hot to cold-wire or vice versa. The addition of filler material at the end of the pass to fill craters is not cause for requalification.

c. A change within a process of arc-metal transfer characteristics. For instance, in gas metal arc welding, a change from one mode to any other mode (e.g., spray transfer to globular transfer or vice versa, globular transfer to short-circuiting arc transfer or vice versa). A change to or from the pulsed arc mode in gas tungsten arc welding.

d. A change from mechanized, automatic, or robotic to semi-automatic (also see 4-8.aa).

e. A change from robotic, automatic, mechanized, or semi-automatic to manual and vice versa.

f. A change from single-arc to multiple-arc, or vice versa, or a change to another type of multiple-arc (e.g., from series- to parallel-arc).

g. In the plasma arc process, a change in the arc from transferred to non-transferred or vice versa.

h. In the robotic, automatic, or mechanized plasma arc process, the addition or elimination of an oscillating motion of the torch or filler wire.

i. In robotic, automatic, or mechanized weld cladding or hardfacing with oscillation, the addition or deletion of a dwell period in the oscillation.

j. In robotic, automatic, or mechanized weld cladding or hardfacing, a change from a simple harmonic to a constant-velocity oscillating motion or vice versa.

k. In the plasma arc process, a change in the type or model of welding equipment.

l. In plasma arc weld cladding or hardfacing, a change of 10 percent or more in the diameter of the constricting orifice in the torch.

m. In robotic, automatic, or mechanized plasma arc weld cladding or hardfacing, a change greater than ±15 percent in the travel speed range recorded in the procedure qualification record.

n. In robotic, automatic, or mechanized weld cladding or hardfacing, a change greater than ±20 percent in oscillation displacement recorded in the procedure qualification record. A procedure qualified using a minimum oscillation displacement and a procedure qualified using a maximum oscillation displacement, with all other essential variables remaining the same, shall qualify for all weld bead oscillations in between.

o. In robotic, automatic, or mechanized weld cladding or hardfacing with oscillation, a change in dwell time from that used for qualification greater than the following:

(1) ±20 percent for cladding.

(2) Any change for hardfacing.

p. In robotic, automatic, or mechanized weld cladding or hardfacing with oscillation, a change in the frequency of oscillation greater than ±20 percent beyond the frequency used for qualification.

q. In robotic, automatic, or mechanized weld cladding or hardfacing, the omission of self-regulating arc length or voltage control if the procedure was qualified with such control. In this regard, a constant potential power supply is considered to be a self-regulating voltage control.

r. Where toughness testing is required by table 7-7, footnote 2, an increase in bead width or oscillation as follows (also see 4-8.j):

(1) For manual or semi-automatic welding with weaving, an increase in bead width to more than 3/4 inch, or for qualified widths of more than 3/4 inch, a bead width increase greater than 3/8 inch.

(2) For mechanized, automatic, and robotic welding with oscillation, an increase in amplitude (see 3-2.11.a) to more than 1/2 inch, or for qualified amplitudes of more than 1/2 inch, an amplitude increase greater than 1/4 inch or 20 percent, whichever is greater.

s. For stud welding, a change in the lift greater than ±1/32 inch; also, a change in plunge exceeding ±1/16 inch.

t. For stud welding, a change in the model of the power supply or stud gun.

u. For stud welding, a change in flux type or load (e.g., a ball load to a ring load and vice versa, or a ball or ring load to a fluxless stud and vice versa).

v. A change in shielding from ferrule or flux (see 4-4.4.e).

w. For machine settings other than those specifically listed in 4-4.4, see 4-4.4.h.

4-7.5 ELECTRICAL CHARACTERISTICS.

a. Except for a shielded metal arc process, a change in the welding current from AC to DC or vice versa, or a change in polarity.

b. For base metals having toughness requirements, an increase in the heat input over that qualified (also see 4-4.1.13, 4-7.5.f, and 4-7.9.1.g). Fabrication document requirements for heat input shall not be exceeded in any case for production welding.

c. For socket and fillet seal weld procedures in pipe with nominal wall thickness less than 3/16 inch, a change in welding current greater than 15 percent from that used for qualification.

d. In plasma arc weld cladding or hardfacing, a change greater than 10 percent in the welding current or voltage recorded in the procedure qualification record.

e. In plasma arc weld surfacing, a change greater than 10 percent in the filler wire wattage recorded in the procedure qualification record. Wattage refers to resistance-heated filler wire and is a function of current voltage and wire stickout dimension.

f. For S-10H base materials, an increase or decrease in weld metal cooling rate over that originally used during qualification.

NOTE

In order to accommodate this requirement, the welding procedure shall be qualified with two test plates, one with the maximum plate thickness, the minimum heat input, and the minimum preheat/interpass temperature and the other with the minimum thickness, the maximum heat input, and the maximum preheat/interpass temperature to be used during production welding. For the minimum heat input plate, the requirements of 4-4.1.13 shall also apply (i.e., at least 80 percent of beads shall be no more than 20 percent above the minimum heat input to be qualified and the average of all beads shall not exceed the minimum). Specific cooling rate values are not required to be determined. Plate thickness need not exceed 1.5 inches for this test; where production welding exceeds the normal 3-inch thickness limit of table 7-6 for a 1.5-inch test plate, either a plate exceeding 1.5 inches can be welded as above, or a 1.5-inch thick plate can be welded as above and a third plate of necessary thickness can be welded within the qualified parameters selected by the activity (e.g., heat input need not be the minimum). This testing may be reduced where solution annealed heat treatment is involved, if approved by NAVSEA.

For S-10H base materials welded to other than S-10H base materials with other than A-9A or A-9B weld metal, the welding procedure need not be qualified at the lowest cooling rate (minimum plate thickness, maximum heat input, and maximum preheat/interpass temperature) if cooled at a rate higher than the lowest rate at which an S-10H to S-10H weld was qualified.

g. For stud welding, a change in the arc timing greater than ±10 percent.

h. For drawn arc stud welding, a change in amperage greater than ±10 percent; for other stud welding, see 4-4.4.h.

i. For capacitor discharge stud welding, a change in charging voltage or machine capacitance above or below that used during qualification.

j. For stud welding, an increase in maximum cable length or decrease in cable size from that originally qualified.

4-7.6 POSITION AND VERTICAL PROGRESSION.

a. A change to a position other than one already qualified as specified in 4-2.8.

b. For any base material where toughness testing is required by table 7-7, footnote 2, a change in weld progression from vertical-up to vertical-down, or vice versa, except root pass welds that are completely removed by back-gouging; also see 4-8.j for cladding and hardfacing, and for level II qualification, see 4-8.h.

4-7.7 SHIELDING GAS (TORCH, PURGE GAS, AND POWDER FEED GAS).

a. A change from a mixture of gases to another mixture of gases or to a single gas.

b. A change from a single gas to another gas or mixture of gases.

c. For the plasma arc process,

(1) A change in the orifice gas composition,

(2) A change greater than 5 percent in the flow rate of orifice gas, or

(3) A change greater than 5 percent in flow rate of powder metal feed gas.

d. A change in the nominal percentage of any non-inert gas in a gas mixture.

e. When using a mixed inert gas, a change of ±25 percent or 5 cubic feet per hour (whichever is larger) in the flow rate of the minor constituents of the gas mixture.

f. A decrease greater than 10 percent or 5 cubic feet per hour (whichever is larger) in the rate of gas flow below that used during qualification for torch shielding gases only.

g. The addition or deletion of a shielding gas.

h. Elimination of purge gas, except that purge gas may be deleted as follows (for S-51, S-52, S-53, and S-53A materials, see 4-7.7.l below):

(1) Welds re-welded from the reverse side.

(2) Partial penetration and fillet welds and groove welds made with backing strips or rings.

(3) Socket welds, unless qualification was performed with socket weld joints and purging was employed.

i. For plasma arc keyhole welding, a change in the nominal composition of the backing (i.e., purge) gas or gas mixture.

j. See footnote 8 of table 7-2.

k. For S-51, S-52, S-53, and S-53A materials, a change from welding in a chamber to welding outside of a chamber.

l. For S-51, S-52, S-53, and S-53A materials welded outside of a chamber, the omission of a trailing shield or backing (purge) gas.

m. For S-51, S-52, S-53, and S-53A materials, the requirements of a., b., d., e., and f. also apply to trailing shield gas. Also, addition of a trailing shield gas other than a gas of the same composition as the torch shielding gas.

4-7.8 HEAT TREATMENT.

a. A decrease in preheat or interpass temperature below the minimum temperature specified by the applicable fabrication document. For stud welding, also a decrease in minimum preheat temperature greater than 100 °F.

b. An increase in preheat or interpass temperature above either:

(1) The maximum interpass temperature specified by the applicable fabrication document, except for S-1 materials without toughness requirements, or

(2) Where no maximum interpass temperature is specified by the fabrication document, the maximum interpass temperature used for qualification.

c. The addition or omission of post-weld heat treatment; for S-1 materials, addition or omission of stress relief heat treatment does not require requalification, unless required by 4-7.8.e below.

d. A change in PWHT outside the temperature range specified in the applicable fabrication document for the materials involved.

e. For base metals and weld metals having impact requirements, a change in the PWHT temperature and time range from that recorded in the procedure qualification record. The procedure qualification test weldment shall be subjected to heat treatment essentially equivalent to that encountered during fabrication of the weldments, including at least 80 percent of the aggregate times at temperature. A change in temperature that is within the range specified by the fabrication document does not require requalification.

f. For S-44 materials, the addition or omission of a post-weld solution anneal. Also, an increase greater than 25 percent in the total stress relief holding time beyond that used for qualification.

g. For S-1 through S-6A, S-8, S-10H, S-11, S-51, S-52, S-53, and S-53A base materials, a change from one of the following types of PWHT to any other type of PWHT shall also apply:

NOTE

PWHT of S-10H materials by other than a full solution anneal is prohibited unless approved by NAVSEA.

(1) PWHT below the lower transformation temperature.

(2) PWHT above the upper transformation temperature (e.g., normalizing, annealing).

(3) PWHT above the upper transformation temperature followed by heat treatment below the lower transformation temperature (e.g., normalizing or quenching followed by tempering; or annealing or solution annealing followed by aging).

(4) PWHT between the upper and lower transformation temperatures.

(5) For S-8, a change from a solution anneal to a stress relief and vice versa.

h. For hardfacing, an increase greater than 25 percent in total time at post weld heat treating temperature. For cladding for corrosion resistance with A-8 filler materials, when total time at post weld heat treatment in production exceeds 20 hours, the qualification weld post weld heat treatment holding time shall be at least 80 percent of the total holding time allowed for production.

4-7.9 ADDITIONAL PROCEDURE CHANGES REQUIRING LEVEL I REQUALIFICATION FOR CLADDING AND HARDFACING. In addition to other applicable changes of 4-7 (e.g., 4-7.1, 4-7.2.m, and 4-7.3), the following changes also require level I requalification of procedures for cladding or hardfacing.

4-7.9.1 Changes for All Processes. For all welding processes:

a. An increase in the maximum interpass temperature over that used for qualification.

b. An increase of 25 percent or more in total time at PWHT temperature.

c. A reduction in the number of cladding/hardfacing layers used for qualification (see figure 7-4, note 1, or figure 7-6, note 3 as applicable). Also, a reduction in the number of butter layers used for qualification, or the addition of a butter layer.

d. A decrease in weld thickness of cladding or hardfacing beyond that permitted by table 7-6, including figure 7-4, note 2, or figure 7-6, note 3, respectively; also see 4-8.z for weld thickness increases.

e. A **decrease** in base material thickness beyond that permitted by table 7-6 and figure 7-4, note 2.a for cladding or, for hardfacing, a **change** in base material thickness beyond that permitted by table 7-6 and figure 7-6, note 2.

f. For manual welding, a change from a stringer bead type of deposition to weaving in excess of three times the core diameter of the electrode, and vice versa. For semiautomatic welding, a change greater than 30 percent in bead width from that used for qualification.

g. An increase in heat input greater than 10 percent (or, for shielded metal arc welding only, a decrease in bead length deposited per unit length of weld greater than 10 percent) over that used for qualification (see 4-4.1.13).

NOTE

Fabrication document heat input requirements shall not be exceeded in any case.

h. For cladding or hardfacing of cylindrical products 5 inches OD and less, a decrease in diameter from that used for qualification welding except as allowed by table 7-6, footnote 14 and figure 7-5, note 4. Also, for circumferential cladding in positions other than 1G or 2G, an increase in OD to greater than 5 inches when qualification was performed on an OD of 5 inches or less for either of the following cases:

(1) For A-45 filler materials.

(2) For cladding, where composition testing is required by the fabrication document or other component or system specification.

i. Where qualification was performed on a plate-type product, a change to a cylindrical product (see table 7-4, footnote 7(a)(2)).

j. A change in weld progression from vertical-down to vertical-up; for vice versa, see 4-8.h.

4-7.9.2 Shielded Metal Arc Welding. For shielded metal arc welding:

a. A change in the nominal electrode diameter used for the first layer of weld.

b. An increase greater than 10 percent in the amperage used in application for the first layer.

4-7.9.3 For Processes Other Than Shielded Metal Arc Welding. For processes other than shielded metal arc welding, the following shall apply:

a. The addition or omission of supplementary filler metal to the welding arc.

b. For robotic, automatic, or mechanized welding, the addition or elimination of oscillation; a change greater than ±20 percent in the oscillation displacement used for qualification. However, a procedure qualified using a minimum oscillation displacement and a procedure qualified using a maximum oscillation displacement, with all other essential variables remaining the same, shall qualify for all weld bead oscillations in between.

c. A change in the nominal cross-section of the electrode or supplementary filler metal greater than 10 percent.

d. For gas tungsten arc welding, a change greater than 15 percent in the filler wire wattage used for qualification. Wattage refers to resistance-heated filler wire and is a function of current multiplied by voltage for a given wire stickout dimension.

4-7.10 REPAIR WELDS OF S-10H BASE MATERIALS.

a. For S-10H base materials, repair welds that do not completely remove the initial welds and the associated base metal HAZs shall require qualification to the maximum extent and for the maximum number of weld repair cycles to be used on the production application. This testing may be reduced where post-repair heat treatment is involved, if approved by NAVSEA.

NOTE

In order to accommodate this requirement, the repair welding technique shall be qualified in the manner of the thin plate described in 4-7.5.f except that after initial welding, the qualification assembly shall be cut and re-prepared with one bevel edge as close as practical to the original bevel and the other bevel edge with approximately 3/16 inch weld deposit remaining. The test plates shall be re-welded for the maximum number of cycles of repair to be allowed during construction.

4-7.11 WELDS REQUIRING TEMPERATURE CONTROL (SEE 4-4.10). For welding on TCA (see 3-2.18) members, the changes specified by D-1.4.4 shall require requalification per Appendix D.

4-8 PROCEDURE CHANGES REQUIRING LEVEL II REQUALIFICATION.

One additional qualification test assembly, as specified in 4-2.7.3, shall be welded whenever the following changes are made to a procedure qualified under level I:

a. An increase in wire or rod diameter greater than 0.015 inch (0.020 inch for flat position) for gas metal arc and flux-cored arc, or greater than 1/32 inch for gas tungsten arc and plasma arc, than that previously qualified.

b. An increase in covered electrode diameter greater than 1/32 inch for horizontal, vertical, and overhead welding and an increase in diameter greater than 1/16 inch for flat position welding or horizontal fillets.

c. In robotic, automatic, mechanized, or semi-automatic welding, a decrease greater than 20 percent in the included angle of the welding groove beyond that qualified.

d. A change in particle size of flux used in robotic, automatic, mechanized, or semi-automatic submerged arc welding.

e. In tube-to-tubesheet welds, a decrease in the number of weld passes.

f. In oxy-fuel gas welding, a change in the type of fuel gas employed.

g. A change greater than ±25 percent in the welding current or voltage from the range qualified for robotic, automatic, mechanized, or semi-automatic welding. Any change in amperage or voltage shall not result in a change in arc metal transfer characteristics unless the procedure is requalified per 4-7.4.c.

h. For cladding and hardfacing, a change from vertical-up to vertical-down (see 4-7.9.1.j for vice versa). For other welding, for materials not having toughness requirements, a change in weld progression from vertical-up to vertical-down or vice versa, except for root pass welds that are completely removed by back-gouging; see 4-7.6 for toughness applications.

i. In robotic, automatic, or mechanized plasma arc welding, a change of more than 15 percent in the travel speed range recorded in the procedure qualification record.

j. Where toughness testing is not required by table 7-7, footnote 2, for robotic, automatic, or mechanized welding with oscillation, a change in the amplitude (see 3-2.11.a), dwell, or frequency of oscillation greater than ±20 percent from that used for qualification (also see 4-7.4.r). Requalification is not required for oscillation parameter changes when oscillation amplitude remains smaller than the nominal electrode diameter. Qualification with minimum and maximum oscillation amplitude, with all other essential variables remaining the same, shall qualify for all amplitudes in between.

k. In robotic, automatic, or mechanized welding by circumferential deposition, a change in the torch offset greater than a distance that moves the torch ±5 degrees of the circumference beyond the offset used during qualification.

l. In robotic, automatic, or mechanized welding, the omission of self-regulating arc length or voltage control if the procedure was qualified with such control.

m. For the plasma arc welding process, termination of a weld made with the keyhole technique after overlapping a completed part of the weld, as occurs in circumferential welds or in repair welding.

n. For tube-to-header seal welding, a change greater than ±10 percent in the actual amperage recorded during qualification.

o. For the robotic, automatic, or mechanized gas tungsten arc or plasma arc process, a change in filler metal feed rate greater than ±10 percent for powder metal and electrically hot wire or ±20 percent for cold wire from the feed rate used for qualification, except that for changes requiring level I requalification for weld cladding and hardfacing, see 4-7.2.m.

p. For cladding and hardfacing, and all welding of S-44, the following changes shall also apply:

(1) In robotic, automatic, or mechanized welding employing pulsed current, a change in the pulse frequency greater than ±25 percent or 2 hertz, whichever is greater, or a change in pulse duty cycle (pulse duration as a percent of total cycle time) greater than ±10 percent.

(2) In robotic, automatic, or mechanized welding, a change in the tilt or lead angles greater than ±5 degrees beyond the angles used for qualification.

(3) For cladding and hardfacing, a decrease greater than 100 °F from the preheat temperature used for qualification.

q. For S-51, S-52, S-53, and S-53A materials, a change in the material used (other than austenitic stainless steels, copper alloys, or aluminum alloys) for the trailing shield.

r. For waveform controlled welding (i.e., pulsed gas metal arc welding), a change from one program to a different program on the same power supply, or a change in the manufacturer's power supply model number, or from one manufacturer's power supply to a different manufacturer's power supply.

s. For robotic, automatic, or mechanized pipe groove and fillet welding of diameters less than 5 inches OD, an increase or decrease in pipe diameter from that qualified (see 4-4.1.10.1 and table 7-6, footnote 13).

t. For robotic, automatic, and mechanized welding of pipe that is 5 inches OD or greater with a thickness of 3/8 inch or greater, an increase in pipe thickness exceeding 1.1T but not more than 2T; for greater thickness increases, see 4-7.1.b for level I qualification.

u. For robotic, automatic, or mechanized welding, the following changes shall also apply:

(1) An addition, deletion, or change of adaptive fill welding control algorithm that determines the bead planning or placement.

(2) An addition, deletion, or change in weld joint tracking method (e.g., through-arc, laser, camera), including changes in make or model.

(3) Except for manual methods, a change in joint locating method (e.g., wire touch, laser, camera), including changes in make or model. A change from manual joint location to any other method of joint location.

(4) Where sensing is employed, a change in joint measurement method (e.g., wire touch, laser, camera).

v. In robotic welding, a change in model of the robot controller or a change in manufacturer of the robot.

w. In robotic welding, a change from a later (i.e., more current) version to an earlier version of robotic controller software.

x. For robotic welding, the addition of cross-qualified positions (see 4-4.1.10.3.a).

y. In robotic or automatic welding using through-arc tracking, a change in length of ±25 feet of the welding ground cable or voltage measurement cable used for feedback control. Qualification at a minimum and a maximum cable length shall qualify cable lengths in between.

z. For cladding and hardfacing, an increase in weld thickness beyond that allowed by table 7-6; however, qualification testing shall not require composition or dilution testing.

aa. A change from semi-automatic to mechanized, automatic, or robotic welding (see 4-7.4.d for vice versa); however, level I qualification shall be required if the mechanized, automatic, or robotic oscillation amplitude (see 3-2.11.a) exceeds 1/2 inch for materials where toughness testing is required by table 7-7, footnote 2.

bb. A change from robotic to mechanized or automatic welding and vice versa.

cc. An increase in shielding gas flow rate greater than 50 percent.

CHAPTER 5
WELDING PERFORMANCE QUALIFICATION

5-1 SCOPE.

This chapter provides the requirements for qualification testing of welders and welding operators. For friction stir, including repair of friction stirred material, specific qualification requirements shall be per Appendix A in addition to the general requirements of this chapter. Also included are the requirements for qualification records with suggested record format and forms for data accumulation and reporting.

5-2 GENERAL REQUIREMENTS.

5-2.1 RESPONSIBILITY. When this document is specified by the applicable fabrication document, each activity shall establish that each welder and welding operator to be employed for welding has been qualified by demonstrating an ability to produce welds that meet the requirements of this chapter. Performance qualification is not required for resistance welding per 4-4.3 or stud welding; however, welding personnel shall be trained in the proper application of the welding procedure and all governing acceptance criteria.

5-2.1.1 Waiver of Qualification Tests. Qualification tests of welders working on assemblies, the possible failure of which is remote and would not result in danger to the ship, plant, or structure, such as identification plates, galley equipment, furniture, fixtures, and miscellaneous outfitting, may be omitted provided this omission is permitted by the applicable fabrication document or is approved.

5-2.2 PREREQUISITE. As a prerequisite to performance qualification, each activity shall have qualified procedures in accordance with Chapter 4 for all applications for which performance qualification is intended. Although it is essential that the welder be cognizant of the contents of the qualified procedures, this requirement shall not be interpreted to mean that the performance qualification must be accomplished in accordance with any qualified procedure. Performance qualification shall be accomplished as specified in this chapter. Where multiple performance qualifications are attained as specified in 5-2.5, the welder shall be familiar with the content of each involved procedure. If subsequent procedure qualification data approvals are obtained for procedures for which the multiple performance qualification of 5-2.5 would apply, the qualified welder shall be familiarized with the contents of each new procedure.

5-2.3 METHOD OF ESTABLISHING QUALIFICATION. Qualification of welding personnel requires satisfaction of all of the following conditions:

a. Each welder and welding operator shall know the workmanship requirements and visual inspection requirements of all fabrication documents to which the welder will be working. To ensure this knowledge, each welder and welding operator shall be trained and tested in accordance with a program meeting the requirements of 5-2.3.1. For robotic welding, the requirements of 5-2.3.2 shall also apply.
b. Assurance that each welder and welding operator has satisfactorily welded the applicable performance qualification test assemblies.
c. Inspection of each qualification test assembly in accordance with the requirements of this chapter.
d. Evaluation of the results of either the destructive or nondestructive tests, or both, in accordance with the applicable standards unless otherwise specified in this document.
e. Maintenance of current records of the extent of qualification for each welder and welding operator (see 5-5.1).

5-2.3.1 Welding Personnel Training in Workmanship and Visual Acceptance Criteria. Training shall be administered in accordance with a program approved by one of the activity's NAVSEA T9074-AS-GIB-010/271 certified level III nondestructive test examiners or other NAVSEA-approved individual. This program shall include:

a. A written procedure covering all aspects of this training program and associated responsibilities. A copy of the procedure shall be provided to the authorized representative for approval.

b. Training in workmanship and detailed visual inspection requirements of all fabrication documents to which welding is performed. For pipe welders performing socket joints or one-sided groove joints not subject to RT, training and examination shall specifically include all of the following:

(1) The need to visually check the pipe ID immediately after joint completion when any portion is accessible

(2) Pipe ID acceptance criteria for all joints involved (e.g., sockets, backing rings, consumable inserts, no backing)

(3) How to obtain final pipe ID VT before welding other joints that may render an ID inaccessible

(4) For socket joints over 2 inches NPS, requirements for pipe-to-fitting diametrical clearance and engagement and measurement methods and, when applicable, conditions for increasing fitting leg size

c. Examinations covering detail workmanship and visual inspection requirements to be passed by each person with a grade of no less than 75 percent.

d. Approval of items (a), (b), and (c) by the level III examiner or other NAVSEA-approved individual.

e. Maintenance of examination records for each welder or welding operator, which shall include: name, fabrication/acceptance standards covered, date of test, results of test (in percent), and certifying signature of test administrator.

f. Re-testing of each welder or welding operator every 3 years.

g. Auditing of the entire program specified in 5-2.3.1 by the level III examiner or other NAVSEA-approved individual to ensure adequacy. Audits shall be conducted at least once every 2 years and, where applicable, the audit shall be extended to specifically address titanium welders.

5-2.3.2 Robotic Welding Operator Requirements. These personnel shall also be trained and tested in accordance with a program established by the activity meeting the following requirements, as applicable, for each procedure:

a. Identification and use of robotic welding system equipment.

b. Routine operator maintenance of the robotic welding system equipment.

c. Operation of the robot teach pendant, control station, or both to execute, modify, or stop a production weld or program cycle.

d. Creation or modification of robot programs and routines.

e. Use of adaptive welding technologies.

f. Use of audio and vision aids (e.g., weld puddle cameras) for mechanized robotic welding.

5-2.4 ALTERNATIVE QUALIFICATION METHODS. As an alternative to 5-2.3.b, qualification requirements for welders or welding operators shall be satisfied as follows:

a. Welding a production weld that is RT or UT inspected and found satisfactory. Approval to use this method of establishing performance qualification must be obtained for each welder and welding operator from the authorized representative prior to start of the individual's production work. This method is not applicable to S-51, S-52, S-53, and S-53A materials.

b. Welding satisfactory procedure qualification test assemblies subject to the limitations of performance qualification in Chapter 5.

c. Qualifying in accordance with the requirements of other U.S. Government agencies, ABS, or ASME within the limits imposed by this document, provided evidence of qualification is verified and approved.

5-2.5 QUALIFICATION LIMITS BY BASE MATERIAL, FILLER MATERIAL, AND PROCESS. Multiple performance qualifications may be attained by qualifying as outlined in table 7-8. When radiography is used for evaluation, S-1 material may be used when using filler metal groups A-1 through A-8, and A-34, A-42, A-43, and A-45; other base material/filler material combinations shall be from a qualified similar or dissimilar metal groove welding procedure. When bend tests are used for evaluation, the base material shall be compatible to the filler material with regard to weldability and shall be of comparable strength. Utilization of commercially equivalent filler material (see 5-6.2.a) is permitted for performance qualification tests.

5-2.6 QUALIFICATION LIMITS BY POSITION AND JOINT TYPE. The positions and joint types for which a test assembly qualifies are as shown in table 7-9; for specific test assemblies, see 5-3 and table 7-10.

5-2.7 REQUIREMENTS FOR SPECIAL WELDS. For special welds, the proposed performance qualification program shall be included with the procedure qualification data submitted for approval (see 4-2.5).

5-2.8 REPAIR TO TEST ASSEMBLIES. Test assemblies, other than those for automatic, mechanized, and robotic welding, may be repair welded under the following conditions:

a. Cracks (other than crater cracks), root oxidation, burn-through, and backside defects per figure 7-14, note 3 and rejectable titanium weld color per 4-5.1.1.1 shall not be repair welded.

b. Only one cycle of repair welding is permitted and the repair shall be recorded on the permanent test records.

c. All test results, including a description of the nondestructive test results that failed to meet the requirements, shall be recorded on the permanent test record.

Qualification test assemblies for automatic, mechanized, and robotic welding shall not be repair welded.

5-2.9 RETESTS. If a performance qualification test assembly fails to meet the applicable requirements, retests may be allowed under the following conditions:

a. One retest may be made without further training for each test assembly that failed.

b. Subsequent retests may be made for each test assembly that failed to meet the requirements if the welder or welding operator has had at least 4 hours of training or practice designed to correct the reasons for previous failures.

5-2.10 TRANSFER OF QUALIFICATION. Transfer of performance qualification from one activity to another is not permitted without specific approval by the authorized representative.

5-2.11 MAINTENANCE OF QUALIFICATION. Each activity shall establish that an active qualification status is maintained for each qualified welder or welding operator. This requirement pertains only to process qualification without regard to the initial qualification limitations of 5-2.5 and 5-2.6. For each qualified process, evidence of maintenance of qualification, consisting of at least one verification of process use (i.e., activity certification of the use of shielded metal arc, gas metal arc, etc.) within 6 months after the month the person last used the process, shall be maintained. In addition, for titanium welders and welding operators, at least one verification of the process being used on titanium base metal within this 6-month period shall also be maintained. Process use shall be (1) production welding, (2) completion of one figure 7-16 weld tested per 5-4.1.1 and 5-4.2.2, or (3) completion of one previously performed butt qualification test weld, other than figure 7-16, that is visually inspected per 5-4.1.1. In cases (2) and (3), the test position and filler material may be any for which qualification is held with the process, except that the flat position shall not be used, unless only flat position qualification is held for the process. Alternative, equivalent verification welding can be used for process use if approved.

5-2.11.1 Renewal of Qualification. Renewal of qualification due to a 6-month lapse, as noted in 5-2.11, shall be made for the welding process (for which qualification has lapsed) by making only one test joint (plate or pipe) with all the essential elements used on any one of the welder's or welding operator's previous qualification test joints. The joints shall be inspected in accordance with table 7-11. For renewal of qualification for titanium, the welder or welding operator shall make the test joint on titanium base metal and shall also conform to the color criteria as defined in 4-5.1.1. These renewal requirements will re-establish the welder's or welding operator's qualification for all conditions for which he or she had previously qualified with the welding process employed. Renewal of qualifications due to a lapse of process use greater than 1 year, and under all other conditions, shall be in accordance with initial qualifications required by this document, except where less stringent requirements are approved by the authorized representative.

5-2.11.1.1 Welding Workmanship and Visual Inspection Criteria Re-Examination. Each welder and welding operator shall be re-tested every 3 years in accordance with 5-2.3.a.

5-2.12 VISION TEST REQUIREMENTS. Each welder and welding operator (except for tack, fillet, and stud welders) shall be required to pass an annual vision test. Vision tests shall be conducted using standard test methods for determining visual acuity. In addition, vision tests for welders and welding operators for S-51, S-52, S-53, and S-53A materials shall include a color perception test on workmanship samples displaying the colors and shades expected in titanium welds, which shall be passed with no errors. As a minimum, these colors and shades shall include silver, straw, light blue, dark blue, purple, and gray; the silver loss of luster condition should also be included in this test unless it cannot be replicated. The standard of acceptance for vision acuity testing shall be natural or corrected near distance acuity such that the individual can read J1 letters on the standard Jaeger-type chart for near vision. Other equivalent visual tests, such as the Snellen chart, may be substituted for the Jaeger chart. When corrective aids are used for the vision test, equivalent aids shall be employed in production work. Welders and welding operators who do not pass the color perception part of the vision test shall not be permitted to weld on S-51, S-52, S-53, and S-53A materials.

5-2.13 LOSS OF QUALIFICATION. Requalification is required when the authorized representative or Government inspector has specific reasons to question the ability of the welder or welding operator to make welds that meet the requirements of the applicable fabrication document.

5-3 PERFORMANCE QUALIFICATION TEST REQUIREMENTS.

5-3.1 MANUAL, SEMI-AUTOMATIC, AUTOMATIC, MECHANIZED, AND ROBOTIC WELDING.

5-3.1.1 Base Material Form, Size, and Thickness. Qualification tests performed on a given base material form and thickness shall qualify as shown in table 7-10 with limitations as indicated; for pipe, see the restricted access requirements of 5-6.6. Test assemblies employing butt joint designs specified in MIL-STD-22 may be used in lieu of those in figures 7-14, 7-15, and 7-22, provided the thickness requirements of table 7-10 are met. Test assemblies which simulate production assemblies may be used in lieu of those specified in table 7-10, in which case the qualification shall be limited to the base material form and joint design employed with qualified thickness as follows: for butt welds, T or 0.058 inch, whichever is less, to 2T (where T is equal to the nominal thickness of the test assembly); for fillet and socket type welds, see 5-3.3 and 5-3.5, respectively. Test assembly evaluation shall be as specified in 5-4.

5-3.1.2 Requirements for Repair Welding of Castings. The performance qualification test assemblies for repair welding of castings shall meet the requirements specified in 5-3.1.1. Either cast or wrought base material may be used.

5-3.1.3 Automatic, Mechanized, and Robotic Welding. Welding operators shall qualify using equipment possessing control features similar to those of the equipment that will be used to make the production welds and shall be required to set the equipment with regard to adjustments and settings that affect the welding characteristics and weld-bead placement. Welders qualified to a multiple position semi-automatic process shall be qualified to machine, automatic, or robotic weld multiple positions by performing a single position performance test using the mechanized, automatic, or robotic process equipment, respectively. Also, see 5-6.3.e, l, and m.

5-3.2 FUEL GAS WELDING.

5-3.2.1 Base Material Form, Size, and Thickness. Performance qualification tests performed on a given base material form and thickness shall qualify as shown in figures 7-12 and 7-13, as applicable. Qualification position limitations shall be as specified in table 7-9. Test assemblies shall be tested and evaluated as specified in 5-4.

5-3.3 TACK AND FILLET WELDING (EXCLUDING SOCKET JOINTS; SEE TABLE 7-10, FOOTNOTE 12).

5-3.3.1 Base Material Form and Size. Qualification tests shall conform to the requirements of table 7-10, test no. 8. The positions for which a test assembly welded in a given position qualifies are shown in table 7-9. The test assembly shall be tested and evaluated as specified in 5-4.

5-3.3.2 Extent of Qualification. Multiple material performance qualifications may be attained by qualifying as outlined in table 7-8. Fillet joints are also qualified by butt and socket joints per tables 7-9 and 7-10.

5-3.4 WELD SURFACING (BUILD-UP, BUTTERING, HARDFACING, AND CLADDING). Build-up shall be qualified by a butt weld test. Except as permitted by 5-3.4.1, qualification for hardfacing and cladding, including qualified thickness and minimum layers, where applicable, shall be per table 7-10, test no. 9. Qualified positions shall per table 7-9. The test no. 9 assembly shall be tested and evaluated as follows:

a. Perform visual, dye penetrant, and macro-etch examination as specified by table 7-11 and 5-4.
b. Perform hardness testing per figure 7-17 or figure 7-17A for hardfacing.
c. Perform composition testing per figure 7-17 or figure 7-17A for cladding where both figure 7-4, note 5a applies and production weld layers, thickness, or both meet the criteria of figure 7-17A, note 8(a)(ii).

5-3.4.1 Cladding for Applications Where Composition Testing is Not Required, and Buttering. In these instances, qualification shall be by either a butt weld test, or test no. 9, per table 7-10.

5-3.5 SEAL, SOCKET, AND TUBE-TO-TUBESHEET WELDS.

5-3.5.1 Thin Socket Welds, Tube-to-Tubesheet Welds, and Seal Welds Other Than Edge or Thicker Fillet Welds. Seal welds (including fillet seal welds in piping with nominal wall thickness less than 3/16 inch but not including other fillet seal welds or edge seal welds), socket welds in piping with nominal wall thicknesses less than 3/16 inch, and tube-to-tubesheet welds shall require welding, inspecting, and evaluating mock-ups of the production weld in accordance with 4-4.6, except as follows:

a. Qualified positions, materials, and thicknesses shall be in accordance with Chapter 5.
b. Tube-to-tubesheet test assemblies shall consist of a minimum of six joints.
c. The requirements of 4-4.6.1.a and b do not apply.
d. For the socket weld test, the smallest pipe size (OD and nominal wall thickness) to be welded in production shall be used, except that (1) the diameter allowances of table 7-10, footnote 15 shall apply and (2) 1/2 NPS schedule 10 (or equivalent tube size) shall qualify all diameters and thicknesses of 0.058 inch and greater. This test shall be designated as number 3S.

5-3.5.2 Thicker Socket Welds and Other Seal Welds. Qualification of the following welds shall require completion of a mock-up weld per 5-3.5.1 or the weld test indicated below in accordance with Chapter 5:

a. For all diameter socket welds with wall thickness 3/16 inch or greater – pipe butt weld test.
b. For all diameter fillet type seal welds in pipe with thickness 3/16 inch or greater – pipe butt or socket weld test.
c. For other fillet type seal welds (i.e., not in pipe) and edge seal welds – butt weld test on plate or pipe per table 7-9 or socket weld test.

5-3.6 TUBE-TO-HEADER SEAL WELDING OF BOILER COMPONENTS. Welders shall be qualified on a test assembly consisting of four joints that are welded in the sequence of 4-4.8. Joint design shall simulate the production joint except as specified by 4-4.8.1.b. S-1 material may be used. The requirements of this paragraph apply only to manual welding. Qualification shall otherwise be in accordance with 4-4.8. The requirements of this paragraph do not negate any additional requirements that may be imposed by specific component fabrication or repair documents.

5-3.6.1 Space Restrictions. Welding shall be performed under the space restrictions depicted by figure 7-25. The entire space restriction assembly shall be held at 400 °F minimum for the entire test, except as needed for root nondestructive testing. The welder shall perform all grinding and any repair weld preparation in the heated assembly. The inspection sequence shall be as follows: complete all root welds, then inspect; complete all welds, then inspect.

5-3.6.2 Nondestructive Testing. The root pass and finished welds of the test assembly shall be nondestructively tested in accordance with 4-4.8.1.e, f, and i. Undercut of 1/32 inch maximum is permissible along the plate weld toes.

5-3.6.3 Macro Testing. After successful nondestructive testing, all four welds shall be macrosectioned and examined in accordance with 4-4.8.1.g and i.

5-3.6.4 Positions. Qualification position shall be in accordance with table 7-9.

5-3.6.5 Repairs. Failure of either the root pass or final weld by nondestructive testing on more than one joint or by other testing on any joint shall constitute failure of the qualification test. Repair of the test assembly per 5-2.8.b as a result of a root pass defect shall preclude further repair.

5-3.7 LOCK WELDS. Lock welds shall be qualified by either (1) a mock-up test per 4-4.9, but with visual and dye penetrant inspection only or (2) a butt, fillet, or where applicable, socket weld test per 4-4.9. In both cases, qualified positions and filler materials shall be per Chapter 5.

5-4 TEST AND EVALUATION OF QUALIFICATION TEST ASSEMBLIES.

This section provides for evaluation of test assemblies required for qualification. The tests required for each assembly are as specified in table 7-11. For suggested removal of destructive test specimens (when used), see figures 7-12 through 7-17A.

5-4.1 NONDESTRUCTIVE INSPECTION.

5-4.1.1 Visual Examination. Visual examination shall be performed for weld surface geometry and weld surface soundness. Titanium and titanium alloy welds shall also be inspected per 4-5.1.1.1.

5-4.1.2 Nondestructive Test Performance. Visual and other nondestructive testing shall be performed in accordance with NAVSEA T9074-AS-GIB-010/271 and, for titanium, 4-5.1.1.1. Except as permitted by 5-4.1.3, test assembly welds shall be 100-percent inspected.

5-4.1.3 Acceptance Standards. Acceptance standards for nondestructive testing shall be per 4-5.1.3. For fillet and butt plate assemblies, 1 inch maximum of weld on each end of the test assembly is exempt from inspection, except for titanium and titanium alloy weld appearance per 4-5.1.1.1.

5-4.2 DESTRUCTIVE TESTS. Required specimen preparation, dimensions, and mechanical testing shall be in accordance with AWS B4.0.

5-4.2.1 Guided-Bend Tests. Acceptance standards shall be as specified in 4-5.2.3.1.

5-4.2.2 Break Test. The tack and fillet welder qualification test specimen shall be flattened in accordance with figure 7-16 such that the root of the weld is in tension. The load shall be steadily increased until the specimen fractures. The fractured surfaces shall be visually examined without magnification and shall conform to the criteria of 4-4.1.11.

5-4.2.3 Macro-Etch Specimen. Specimens shall be extracted transversely to the weld, prepared, and etched to show weld cross-section and examined at 5× to 10× magnification. Acceptance standards shall be as specified in 4-5.2.6.

5-5 DATA ACCUMULATION AND RECORDS.

This section provides requirements for performance qualification data accumulation and maintenance of records. A sample is provided for guidance (see figure 7-18).

5-5.1 RECORDS. Qualification records for each welder and welding operator shall be kept by the activity. The qualification test record shall include at least the following information:

a. Welder or welding operator identification (name and clock number or badge number).
b. Date of qualification test.
c. Qualification test number (or joint design, if different than test number), process, position, base material form/type and (if different than test number) thickness, and filler metal type and size; also, where applicable, pipe diameter, shielding gas, and other attributes of 5-6 that could require requalification.
d. Results of each qualification test; for nondestructive testing and titanium appearance, list the nondestructive testing standard and acceptance criteria. For bend tests, list bend radius.
e. For cladding and hardfacing where qualification of minimum thickness and number of layers is required by table 7-10, footnote 16, record the layer and weld thickness at which composition or hardness testing is performed. Where composition testing is performed, record the information required by figure 7-4, note 6.
f. Record of omission of space restriction when not used in pipe tests.
g. Certifying signature by activity.

The qualification test record shall be retained while the person is employed to weld and for 3 years after the expiration of the last contract under which the person welded.

5-5.1.1 Workmanship and Visual Inspection Criteria Examination. The current examination specified in 5-2.3.a shall also be maintained as part of the qualification test record.

5-5.2 DISPOSABLE DATA. Radiographs, test assemblies, and metallographic sections required for welding personnel qualifications need not be retained.

5-5.3 QUALIFICATION CURRENCY RECORD. Detailed records of maintenance of personnel qualification (see 5-2.11) need only be retained for the current and preceding 6-month period.

5-5.4 VISION TEST RECORDS. Current vision test records shall be retained.

5-6 CHANGES REQUIRING REQUALIFICATION OF WELDER OR WELDING OPERATOR.

Requalification of the welder or welding operator is required for the changes specified in 5-6.1 through 5-6.8; see 5-6.9 for re-training.

5-6.1 BASE MATERIAL.

a. A change from one base material thickness to a thickness outside the limits specified in table 7-10 and figures 7-12 and 7-13.
b. A change from plate to pipe, except as permitted by tables 7-9 and 7-10.
c. For pipe, see 5-6.6.
d. For socket joints, see 5-6.5.e and for pipe diameter, see table 7-10, footnote 15.

5-6.2 FILLER MATERIAL.

a. A change from a filler material listed under one A-number in table 7-2 to a filler material listed under another A-number, except as permitted by table 7-8. Also, a change to an alloy 625 filler material from any other filler material, including other A-43 filler materials, except as permitted by table 7-8. Filler materials conforming to AWS, ASTM, ASME, etc. classifications, for which there is a qualified procedure (see 5-2.5), may be grouped with the appropriate A-number of table 7-2, and the extent of welder performance cross-qualification by A-numbers shall be as permitted by table 7-8.

b. For tube-to-header seal weld joints, a change in electrode coating classification (i.e., MIL-XX15 to MIL-XX16 or MIL-XX18, etc.), and vice versa.

c. For tube-to-header seal weld joints, an increase in electrode diameter of 1/32 inch or more than that qualified for any weld pass.

d. A change in the form of filler metal from solid to fabricated wire, flux-cored wire, or powdered metal or vice versa.

e. For MIL-120 and MIL-140 series filler materials, see table 7-2, footnote 13.

f. For consumable insert joints, a change in the shape of consumable insert.

g. For cladding where composition testing is required, and hardfacing, the addition or deletion of a butter layer.

h. For cladding where composition testing is required, and hardfacing, a decrease in the number of layers or weld thickness exceeding the values in table 7-10, except as follows:

(1) For welding operators, where cladding qualification is initially performed with composition testing at the minimum thickness/layers intended for initial production per table 7-10, any further reductions in minimum thickness/layers shall not require requalification.

(2) For welding operators, hardfacing qualification shall be initially performed at the minimum thickness/layers intended for initial production per table 7-10; any further reductions in minimum thickness/layers shall not require requalification.

i. For hardfacing, an increase in thickness exceeding the values in table 7-10.

5-6.3 PROCESS.

a. For gas metal arc, a change from one mode to any other mode (e.g., spray, short circuiting, or pulsed spray), except that a pulse arc groove weld in any position qualifies flat groove welds and flat and horizontal fillet welds made with spray arc.

b. For gas tungsten arc, a change to or from the pulsed arc mode.

c. For plasma arc, a change from transferred arc mode to non-transferred arc mode and vice versa.

d. A change from one welding process to any other welding process (as defined in the master chart of welding and allied processes of AWS A3.0M/A3.0).

e. A change from automatic welding to mechanized welding. A change from manual to semi-automatic welding and vice versa. A change from manual or semi-automatic welding to automatic, mechanized, or robotic welding and vice versa, except as permitted for semi-automatic welding by 5-3.1.3.

f. For robotic, automatic, or mechanized welding, a change from direct visual control to remote visual control and vice versa.

g. The deletion of automatic arc voltage control for gas tungsten arc welding.

h. The deletion of automatic joint tracking.

i. For robotic welding, a change in manufacturer of the robot.

j. For robotic welding, the addition, deletion, or change in method of seam tracking (e.g., arc, laser).

k. For robotic welding, a change in method of adaptive bead planning or placement.

l. A change from automatic welding or mechanized welding to robotic welding and vice versa.

m. A change from automatic robotic welding to mechanized robotic welding.

5-6.4 POSITION AND PROGRESSION. A change to a welding position other than one already qualified (see table 7-9) or a change in progression from vertical-up to vertical-down or vice versa, except as permitted by table 7-9, footnote 9 for pipe welding. Also see 5-3.1.3 for automatic and mechanized welding.

5-6.5 JOINT DESIGN.

a. In full penetration butt joints welded from one side, the omission of a backing ring or backing strip.

b. In full penetration butt joints welded from one side, the omission or addition of a preplaced filler metal insert (for the welder or welding operator who makes the root pass or root pass plus an additional layer), except as permitted by table 7-10. Also, a change in the shape of the insert used.

c. In tube-to-header seal weld joints for boiler components:

(1) A 1/32-inch or greater decrease in root opening from that qualified. Root opening is one-half the difference between nominal tube OD and nominal counterbore size.

(2) A decrease in included angle of 5 degrees or more from that qualified (any beveling of the header side of the counterbore shall also be considered as part of the weld joint included angle). However, requalification is not required for joints with angular decreases of up to 10 degrees, provided the root opening is at least 1/16 inch greater than that qualified.

(3) For tube end lands 1/16 inch and less, a decrease in tube end land below that qualified.

(4) An increase in counterbore depth of 1/16 inch or greater beyond that qualified, except that qualification performed on 3/16-inch deep counterbores shall qualify up to and including 1/4-inch deep counterbores.

d. In full penetration butt joints, the use of a plasma arc keyhole technique for fusing the root pass.

e. A change from any joint to a socket or fillet seal weld joint in piping less than 3/16 inch thick.

f. A change from a fillet joint to a groove.

g. A change from any joint to those addressed by 5-3.4, 5-3.5, and 5-3.6, and vice versa, except as permitted therein. A change from a lock weld joint to any other joint.

5-6.6 ACCESSIBILITY. For pipe welders, when there is a change from a condition of no restriction on joint accessibility to a condition of restricted accessibility (i.e., 12 inches or less between anything and the weld on any radial line through the weld) and the existing qualification was made under no restriction (over 12 inches). Refer to figure 7-21 for layout and construction of restricted accessibility qualification test assembly positions.

5-6.7 SHIELDING GAS.

a. For gas-shielded arc welding, a change from argon, helium, or mixtures thereof to mixtures containing more than 5 percent oxygen, more than 5 percent hydrogen, or more than 25 percent carbon dioxide or to 100-percent carbon-dioxide (CO_2) and vice versa. Requalification for flux-cored arc welding is not required for a change from 100-percent CO_2 to an argon/CO_2 gas mixture.

b. For plasma arc welding, when using the keyhole technique, a change in orifice gas from argon to mixtures of argon and helium, or the addition of hydrogen to the orifice gas or gas mixture and vice versa.

c. For flux-cored arc welding, the deletion of a shielding gas.

d. For torch shielding gas for S-51, S-52, S-53, and S-53A materials, a change from a single gas to any other gas or a change from a single gas to a gas mixture and vice versa.

e. For S-51, S-52, S-53, and S-53A materials, a change from welding in a chamber to welding outside of a chamber.

f. For trailing or backing shielding gas used for S-51, S-52, S-53, and S-53A materials when welding outside of a chamber, a change from a single gas to any other gas or a change from a single gas to a gas mixture and vice versa, or the omission of the shielding gas.

g. For socket and fillet seal weld joints in piping wall thicknesses less than 3/16 inch, and consumable insert joints and one-sided full penetration joints without backing rings or consumable inserts, the deletion of backside shielding.

5-6.8 CLADDING WITH AND WITHOUT COMPOSITION TESTING. Where clad weld qualification was performed without composition testing and the production application has composition specified for the clad surface, requalification with composition testing per 5-3.4 is required where weld thickness, layers, or both meet figure 7-17A, note 8(a)(ii) criteria.

5-6.9 FABRICATION DOCUMENT REQUIREMENTS. Welding to the requirements of a fabrication document shall require training and testing on the requirements of that document in accordance with 5-2.3.a.

CHAPTER 6
BRAZING

6-1 SCOPE.

This chapter contains the requirements necessary to qualify brazing procedures, brazers, and brazing operators for applications other than piping and pressure vessels. The requirements for piping and pressure vessel applications are contained in NAVSEA 0900-LP-001-7000. The purpose of these qualification requirements is to ensure that qualified procedures are used with adequate equipment by properly trained personnel.

6-2 GENERAL REQUIREMENTS.

Each activity performing work within the scope of this document shall direct and supervise the necessary qualification tests (see 6-3.1.1). Upon completion of all qualification tests, each activity shall certify that the tests and test results meet all the requirements of this document and shall maintain records of the qualification tests, as specified in 6-3.4 and 6-4.10. Approval of the required qualification test data shall be obtained from NAVSEA or its authorized representative, as specified in this chapter. Brazing procedures, brazers, and brazing operators qualified to NAVSEA 0900-LP-001-7000 are considered qualified to this document within the process, material (base and filler), thickness, joint design, and position limitations of NAVSEA 0900-LP-001-7000; however, the brazing procedure must also meet the requirements of this document (e.g., identification of specific joint design, nondestructive testing) and be submitted to the authorized representative for review.

6-2.1 FABRICATION REQUIREMENTS. Where specific brazing fabrication requirements (e.g., nondestructive testing, joint designs, records) for a given application are contained within a component or system specification, those specification requirements shall apply in lieu of the corresponding requirements of a.(1) and a.(2) below. Where such added requirements are not specified, the following shall apply:

a. The requirements of AWS C3.4M/C3.4, C3.5M/C3.5, or C3.6M/C3.6, as applicable, should be used as guidance. All joints shall be visually inspected as required therein. Class A and B joints shall be UT inspected as required therein except that, where configuration does not permit UT, alternative inspections may be submitted for approval. Acceptance criteria shall be as specified in the respective AWS document. Personnel and procedure qualification, equipment calibration, and inspection records may conform to NAVSEA T9074-AS-GIB-010/271 as an alternative.

   (1) The classification of joints (A, B, or C) shall be established by the fabricating, design, or contracting activity where knowledge of service, design, or both exists. Otherwise, classification shall be as approved by the authorized representative. Joint classification shall be identified in the submittal of the brazing procedure.

   (2) The sample plan for UT inspection of class B joints and the inspection expansion in way of rejectable joints shall be proposed by the fabricating activity for approval.

   (3) The requirements specified herein (e.g., for materials, procedures, personnel, qualification records) shall be met in any case. Brazing procedures and personnel need not be qualified to the cited AWS specifications in addition to the qualification requirements specified herein.

6-3 BRAZING PROCEDURE QUALIFICATION.

6-3.1 RESPONSIBILITY. Before any brazing is performed, each activity shall accomplish the following:

a. Prepare a written brazing procedure, including essential elements as specified in 6-3.8.1, and submit the procedure for review per 6-3.3.

b. Qualify the proposed brazing procedure by brazing test assemblies and performing nondestructive and destructive tests in accordance with the requirements of this section and submit results per 6-3.3. Except as noted herein, procedure qualification tests are not required for oxy-fuel manual torch brazing with base materials, brazing alloys other than F-101A and F-102A, and flux combinations specified by table 7-12; F-101A and F-102A brazing alloys require qualification. Qualification tests shall be performed for manual torch brazing procedures that specify materials not classified in table 7-12 and for all other brazing processes, including the following:

(1) Mechanical-torch

(2) Furnace

(3) Induction

(4) Electrical resistance

(5) Dip brazing – salt and flux bath

6-3.1.1 Qualification Brazing. Personnel brazing qualification test assemblies shall be regular employees of the activity (i.e., not subcontractors or temporary specialists) and under the full supervision and control of the activity. Brazing of qualification test assemblies should be accomplished at one of the activity's sites, with the activity's brazing equipment or equipment similar to that being acquired by the activity; if brazing is performed at a site other than the activity's site, the activity's employee responsible for developing the procedure being qualified and assuring that it is correctly implemented shall also be present and directing the activity's brazer/operator during all brazing.

6-3.2 CERTIFICATION OF QUALIFICATION TESTING. After testing, the responsible official of the activity shall certify that the tests and the test results meet all requirements of this document. Inasmuch as the activity is responsible for the quality of its work as well as that of its subcontractors, the activity shall submit qualification tests and data of its subcontractors only after careful review and verification of their completeness. Qualification tests and data containing deviations from requirements may be submitted if such deviations are identified and the technical justification for each deviation is provided. When brazing to the requirements of the ASME code is specified or approved, the specific component or system specifications or approval letter shall be identified. Procedure qualification previously prepared for other Government agencies, ABS, ASME, or other established regulatory codes may be used, provided qualification testing and approval (by the other Government agencies or regulatory bodies) occurred prior to the activity's invitation for bid or request for proposal. It is the intent of this provision that certified qualification data acquired by these agencies be considered acceptable proof of qualification. Such data shall be submitted for approval as requested in 6-3.3.

6-3.3 APPROVAL OF QUALIFICATION TEST DATA AND PROCEDURE SUBMISSION. When qualification testing is required by 6-3.1, the activity shall submit the qualification test report of 6-3.4 to NAVSEA or its authorized representative for approval. Approval shall be obtained prior to production brazing. Procedures are the activity's responsibility but shall be submitted for review, including upon initial preparation, even where qualification testing is not required. Resubmission of procedures is only required for changes involving (1) requalification or (2) a reduction in joint classification (see 6-2.1.a(1)) or nondestructive testing. Brazing procedure submittal does not mitigate the performing activity's responsibility for conformance with the requirements of this document.

6-3.3.1 Requirements. The following requirements shall apply for the brazing procedure and the brazing procedure qualification test report.

a. Brazing procedure qualification test report. The brazing procedure qualification test report shall be in accordance with 6-3.4.

b. Brazing procedure. The brazing procedure shall be in accordance with 6-3.8.

6-3.4 TEST REPORT. The procedure qualification test report shall include the essential elements of the brazing procedure as specified in 6-3.8, with the values used for qualification, and the results of the destructive and nondestructive tests specified in 6-3.9.

6-3.5 MAINTENANCE OF RECORDS. The approved procedure qualification reports shall be retained by the activity for as long as the procedure is applicable. Each qualifying activity shall retain the pertinent qualification test data, destructive test specimens, and nondestructive test result reports until written approval of the qualification data is obtained.

6-3.6 VENDOR QUALIFICATION. It shall be the responsibility of each activity to ensure that its subcontractors comply with the qualification provisions of this document.

6-3.7 TRANSFER OF BRAZING PROCEDURE QUALIFICATION. Requalification of previously qualified procedures shall be required for procedures transferred from one activity to another.

6-3.7.1 Procedure Transfer Within an Activity. Transfer of qualified procedures between sites of an activity shall be the same as for welding procedures (see 4-2.10.1).

6-3.7.2 Naval Shipyard Procedure Transfer. Transfer of qualified procedures between Navy shipyards shall be the same as for welding procedures (see 4-2.10.2).

6-3.7.3 Technical Manual Welding Procedure Usage. Procedures contained in NAVSEA technical manuals shall be the same as for welding procedures (see 4-2.10.3).

6-3.8 WRITTEN BRAZING PROCEDURE CONTENT.

6-3.8.1 Essential Elements. The brazing procedure shall include the following essential elements, as applicable:

a. Base metal (plate, sheet, pipe, tubing, fitting, etc.)
   (1) Type
   (2) Specification
   (3) Thickness range qualified
b. Brazing process (see 6-3.1)
c. Brazing alloy – specification and classification (as specified in table 7-14)
d. Fluxes where required – specification and type, trade, or brand designation
e. Joint design
f. Torch brazing – type of fuel gas
g. Type of flame (i.e., neutral, oxidizing, or reducing)
h. Furnace (atmosphere), if used
i. Position of brazing
j. Induction brazing – frequency and source of high-frequency electric current
k. Pre-cleaning of base metal joint surfaces – method of cleaning joints (emery, polishing, chemical cleaning, etc.)
l. Fixturing
m. Placement of brazing alloy – method of applying the brazing alloy (face feeding, insert ring, shims, etc.)
n. Joint fit-up – maximum clearances
o. Nondestructive testing requirements (reference to inspection procedure of fabrication plan) specific to component and system involved
p. Applicable thicknesses
q. For procedures involving use of minimum flux technique, fluxing technique and internal purge requirements (if used)
r. Joint classification (see 6-2.1.a(1))
s. Post-brazing cleaning including flux removal and applicable removal inspections

6-3.9 PROCEDURE QUALIFICATION TEST REQUIREMENTS. The brazing procedure shall be qualified where required by 6-3.1.b as follows:

6-3.9.1 Qualification Test Assemblies. Base materials and brazing alloys shall be as specified in tables 7-13 and 7-14. The size of each test assembly shall be sufficient to permit removal of the required test specimens. The method used in brazing the qualification test assemblies shall be in accordance with proposed brazing procedure. No repair of test joints is permitted. Qualification shall be obtained for the position to be used in production, except qualification in either the flat-flow, vertical-up flow or horizontal-flow position shall also qualify the vertical-down flow position (see figure 7-23). Material thickness limits are shown in table 7-15. Butt or scarf joints shall qualify for lap joints and vice versa. The type and number of tests shall be as specified in table 7-15.

6-3.9.2 Qualification Assembly Destructive Test Evaluation.

6-3.9.2.1 Tension Test. Reduced specimens conforming to figure 7-19 shall be used for tension tests. The stress shall be computed by dividing the ultimate load by the nominal total cross-sectional area of the thinnest member comprising the joint. The tension specimen shall have, as a minimum, a tensile strength that is not less than:

a. The specified tensile strength of the base material in the annealed condition.
b. The specified tensile strength of the weaker of the two members, in the annealed condition, if materials of different specified minimum tensile strengths are used.
c. If the specimen breaks in the base metal outside of the braze, the test shall be accepted as meeting the requirements, provided the strength is not more than 5 percent below the specified tensile strength of the base material in the annealed condition.

6-3.9.2.2 Peel Test. The peel test specimen shall conform to figure 7-20. The peel specimen shall show evidence of brazing alloy along each edge. Specimens shall be separated or peeled either by clamping "section A" and striking the fulcrum point with a suitable tool or by clamping "section A" and "section B" in a machine suitable for separating the sections under tension. The separated faying surfaces of joints shall meet the following criteria:

a. The total area of defects, unbrazed areas, flux inclusions, and so forth, shall not exceed 30 percent of the total area of any faying surface.
b. The sum of the lengths of the defects measured on any one line in the direction of the lap shall not exceed 25 percent of the lap.

6-3.9.3 Qualification Assembly Nondestructive Test Inspection. Prior to destructive testing, brazements shall be visually (VT) inspected to the following acceptance standards:

a. Excess braze metal. Braze filler metal in excess of that required by (c) is acceptable, provided the excess alloy does not interfere with the function of the completed assembly.
b. Residual flux. Visual evidence of residual flux is not permitted on the surface of a completed joint.
c. Evidence of brazing alloy on completed joints. Brazed joints shall be considered acceptable when the total length of exposed brazing alloy along the length or perimeter of the joint is equal to or greater than three-fourths of the joint length.
d. Unmelted filler metal. There shall be no unmelted filler metal.
e. Cracks. There shall be no cracks.

6-3.10 CHANGES REQUIRING REQUALIFICATION OF BRAZING PROCEDURES. A revised brazing procedure shall be prepared and the procedure requalified when any of the changes specified in 6-3.10.1 through 6-3.10.8 are made (except where qualification is not required as specified in 6-3.1). Changes other than those specified in 6-3.10.1 through 6-3.10.8 may be made without requalifying the procedure but must be documented in the revised procedure.

6-3.10.1 Base Material.

a. A change from a base material classified under one P-number in table 7-13 to a material classified under another P-number in table 7-13, or to any other base material not classified in table 7-13. Requalification is not required when the base material P-numbers have been qualified for brazing in a dissimilar base material joint. (A similar base material joint is one in which both base materials are in the same P-number group.)

b. A change in base material thickness to a value outside the range qualified in accordance with table 7-15.

6-3.10.2 Brazing Alloy. A change from a brazing alloy classified under one F-number in table 7-14 to a brazing alloy classified under another F-number, or to a brazing alloy not classified in table 7-14, except that grade IV may be used in repairing by manual torch or induction brazing joints which were brazed with a brazing alloy of a different F-number, without requalification of the procedure.

6-3.10.3 Brazing Process. A change from one brazing process listed in 6-3.1 to another process listed in 6-3.1 or to a brazing process not listed, except as permitted in 6-3.1.b. For processes not listed in 6-3.1, any technical change in a process variable unless otherwise approved.

6-3.10.4 Flux. A change in type of flux except as permitted by table 7-12.

6-3.10.5 Furnace Atmosphere. A change in the furnace atmosphere from one basic type to another basic type.

6-3.10.6 Induction Brazing.

a. A change in the source of high-frequency electric current (motor generator, resonance spark gap, vacuum tube oscillator, transformer, and so forth).

b. A change in the frequency of greater than ±50 percent of the range qualified.

6-3.10.7 Joint. A change in joint type (a butt to/from a lap to/from a socket, etc.).

6-3.10.8 Position. A change in brazing position.

6-4 BRAZER AND BRAZING OPERATOR PERFORMANCE QUALIFICATION.

6-4.1 RESPONSIBILITY. When this document is specified by the applicable fabrication document, each activity shall establish that each brazer and brazing operator to be employed for brazing has been qualified by demonstrating his ability to produce sound and satisfactory joints in accordance with this section.

6-4.2 PREREQUISITE. As a prerequisite to performance qualification, each activity shall have procedures qualified in accordance with this section for all applications for which performance qualification is intended. Although it is essential that the brazer be cognizant of the contents of the procedure being used for qualification, this requirement shall not be interpreted to mean that the performance qualification must be accomplished in accordance with the qualified procedure. Performance qualification shall be accomplished as specified in this section.

6-4.3 METHOD OF ESTABLISHING QUALIFICATION. The method of establishing qualification is as follows:

a. Each brazer and brazing operator shall know the workmanship and visual inspection requirements of all fabrication documents to which the brazer will be working. To ensure this knowledge, each brazer and brazing operator shall be trained and tested in accordance with a program meeting the requirements of 6-4.3.1.

b. Ensure that each brazer and brazing operator has satisfactorily brazed the applicable performance qualification test assemblies.

c. Inspect each qualification test assembly in accordance with the requirements of this section.

d. Evaluate the results of either the destructive or nondestructive tests or both in accordance with the applicable standards, unless otherwise specified in this document.

e. Maintain current records of the extent of each brazer's and brazing operator's qualification (see 6-4.10).

6-4.3.1 Brazing Personnel Training in Workmanship and Visual Acceptance Criteria. Training shall be administered in accordance with a program approved by one of the activity's NAVSEA T9074-AS-GIB-010/271 certified level III nondestructive test examiners. This program shall include:

a. A written procedure covering all aspects of training and associated responsibility. A copy of the procedure shall be provided to the authorized representative for approval.

b. Training in workmanship and detailed visual inspection requirements of all fabrication documents to which brazing is performed.

c. Examinations covering all significant workmanship and visual inspection requirements to be passed by each person with a grade of no less than 75 percent.

d. Approval of items (a), (b), and (c) by the level III examiner.

e. Maintenance of examination records for each brazer or brazing operator, which shall include: name, fabrication/acceptance standards covered, date of test, and certifying signature of test administrator.

f. Re-testing of each brazer or brazing operator every 3 years.

g. Auditing of the entire program by the level III examiner to ensure adequacy. Audits shall be conducted at least once every 2 years.

6-4.4 ALTERNATE QUALIFICATION METHODS. As an alternative to 6-4.3.b, qualification requirements for brazers or brazing operators shall be satisfied as follows:

a. By brazing a production joint which is UT inspected by qualified personnel and found satisfactory. Permission to use this method of establishing performance qualification must be obtained for each brazer and brazing operator from the authorized representative prior to start of the individual's production work.

b. By brazing satisfactory procedure qualification test assemblies.

c. By having been qualified by other U.S. Government agencies, ABS, or ASME, within the limits covered by the qualification tests passed, provided evidence of qualification is verified and approved.

6-4.5 TRANSFER OF QUALIFICATION. Transfer of performance qualification from one activity to another is not permitted without specific approval of the authorized representative.

6-4.6 QUALIFICATION REQUIREMENTS. Brazer qualification shall consist of making a joint in the flat flow and vertical-up flow positions (see figure 7-23) with a minimum thickness of 1/8 inch. Each joint, when peeled or UT inspected, shall show bonding on at least 70 percent of the lapped area. Qualification with any one base material, any one flux and, except as required by 6-4.9.b, and any one brazing alloy qualifies for all combinations listed in table 7-12 for a given process.

6-4.6.1 Fabrication Document Requirements. Brazing to the requirements of a fabrication document shall require training and testing on the requirements of that document in accordance with 6-4.3.a. Documents addressed by 6-2.1 shall be considered a fabrication document where they apply.

6-4.7 RETESTS. If a performance qualification test assembly fails to meet the applicable requirements, a retest may be allowed under the following conditions:

a. One retest may be made without further training for each test assembly that failed.

b. Subsequent retests may be made for each test assembly that failed to meet the requirements, provided that the brazer or brazing operator has had at least 4 hours of training or practice designed to correct the reasons for the previous failures.

6-4.8 MAINTENANCE OF QUALIFICATION. Each activity shall ensure that an active qualification status is maintained for each qualified brazer and brazing operator by verifying at least one use of each qualified process (that is, activity certification of the use of manual torch brazing, or induction brazing, etc.) within 6 months after the month the person last used the process. Process use shall be production brazing or completion of one previously performed qualification test joint that is tested per 6-4.6. The test position and material can be any for which qualification is held with the process. Alternative, equivalent verification brazing can be used for process use if approved.

6-4.8.1 Renewal of Qualification. Renewal of performance qualification is required when (1) a brazer or brazing operator has not used the specific brazing process in the preceding 6-month period noted in 6-4.8, or (2) the authorized representative has specific reason to question the ability of a brazer or brazing operator to make brazed joints that meet the specification requirements. Renewal of qualification under (1) need be made on only a single test assembly in any position. Where the requirements of 6-4.6 are met, renewal will reestablish the brazer or brazing operator's qualification for the specific process for any thickness, position, brazing alloy, and base materials for which he or she was previously qualified, unless otherwise specified by the authorized representative. Renewal of qualification under (1) is not authorized if lapse of process use is greater than 1 year, unless approved.

6-4.8.1.1 Retest. Each brazer and brazing operator shall be retested every 3 years in accordance with 6-4.3.a.

6-4.9 REQUALIFICATION REQUIREMENTS. Requalification of brazers and brazing operators is required for any of the following changes or conditions.

a. Base material. A change to a base material not listed in table 7-13, except as permitted by footnote 1 thereto.
b. Brazing alloy.
   (1) A change to F-101A or to F-102A.
   (2) A change to a brazing alloy not listed in table 7-14, except as permitted by footnote 1 thereto.
c. Brazing process. A change in the brazing process.

6-4.10 TEST RECORDS. Qualification records for each brazer or brazing operator, together with identification data, shall be kept by the activity. The qualification test record shall include the following information:

a. Brazer or brazing operator identification (name and clock number or badge number).
b. Date of test.
c. Process, position, base material types (P-No.), material thickness, and brazing alloy type (F-No.).
d. Results of qualification tests.
e. Record of space restrictions, if applicable.
f. Certifying signature by activity designated representatives.

The qualification test record shall be retained while the person is employed to braze and for 3 years after the expiration of the last contract under which the brazer performed work.

6-4.10.1 Qualification Maintenance Record. Detailed records of the maintenance of personnel qualification (see 6-4.8) for the current and preceding 6-month period shall be retained.

6-4.10.2 Workmanship and Visual Inspection Criteria Examination. The current examination of 6-4.3.a shall also be maintained as part of the qualification test record.

6-4.10.3 Vision Test Records. Current vision test records shall be retained.

6-4.11 VISION TEST REQUIREMENTS. Each brazer or brazing operator shall be required to pass an annual vision test. Vision tests shall be conducted using standard test methods for determining visual acuity. The standard of acceptance for vision tests shall be natural or corrected near distance acuity so the individual can read J1 letters on the standard Jaeger-type chart for near vision. Other equivalent visual tests, such as a Snellen chart, may be substituted for the Jaeger chart. When corrective aids are used for the vision test, equivalent aids shall be employed in production work.

CHAPTER 7
TABLES AND FIGURES

Table 7-1. Grouping of Base Materials (Welding) 1/

Letter No.	Applicable Document	Class or Type
S-1	Carbon steel	
	ABS Steel Vessel Rules Part 2	Grade A (plate, wide flats, sections, and bars) Grade B (plate, wide flats, sections, and bars) Grade D (plate, wide flats, sections, and bars) Grade AH-36 (plate, wide flats, sections, and bars) Grade DH-36 (plate, wide flats, sections, and bars)
	ASTM A27/A27M	Grade 60-30 (castings) Grade 65-35 (castings) Grade 70-36 (castings)
	ASTM A36/A36M	Shapes, plates, and bars
	ASTM A53/A53M	Grade A, type E (resistance welded pipe) Grade A, type F (furnace welded pipe) Grade A, type S (seamless pipe) Grade B, type E (resistance welded pipe) Grade B, type S (seamless pipe)
	ASTM A105/A105M	Flanges, fittings, and valves
	ASTM A106/A106M	Grade A (seamless pipe) Grade B (seamless pipe)
	ASTM A131/A131M	Grade A (plates, shapes, and bars) Grade B (plates, shapes, and bars) Grade D (plates, shapes, and bars) Grade AH-36 (plates, shapes, and bars) Grade DH-36 (plates, shapes, and bars)
	ASTM A134/A134M	A283 (pipe) A285 (pipe)
	ASTM A178/A178M	Grade A (tube) Grade C (tube) Grade D (tube)
	ASTM A179/A179M	Tube
	ASTM A192/A192M	Seamless tube
	ASTM A210/A210M	Grade A-1 (seamless tube)
	ASTM A214/A214M	Tube
	ASTM A216/A216M	Grade WCA (castings) Grade WCB (castings)
	ASTM A234/A234M	WPB (fittings) WPC (fittings)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont'd)	ASTM A283/A283M	Grade B (plate) Grade C (plate)
	ASTM A285/A285M	Grade A (plate) Grade B (plate) Grade C (plate)
	ASTM A333/A333M	Grade 1 (seamless and welded pipe) Grade 6 (seamless and welded pipe)
	ASTM A334/A334M	Grade 1 (welded tube) Grade 6 (welded tube)
	ASTM A350/A350M	Grade LF1 (forging)
	ASTM A352/A352M	LCA (castings) LCB (castings)
	ASTM A369/A369M	FPA (forged pipe) FPB (forged pipe)
	ASTM A372/A372M	Type I/Grade A (forging)
	ASTM A414/A414M	Grade A (sheet) Grade B (sheet) Grade C (sheet) Grade D (sheet) Grade E (sheet) Grade F (sheet) Grade G (sheet)
	ASTM A420/A420M	Grade WPL6 (fittings)
	ASTM A500/A500M	Grade A (tube) Grade B (tube) Grade C (tube) Grade D (tube)
	ASTM A501/A501M	Grade A (tube) Grade B (tube)
	ASTM A512	1008 (mechanical tubing) 1010 (mechanical tubing) 1012 (mechanical tubing) 1015 (mechanical tubing) 1016 (mechanical tubing) 1018 (mechanical tubing) 1019 (mechanical tubing) 1020 (mechanical tubing) 1021 (mechanical tubing) 1025 (mechanical tubing)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont'd)	ASTM A513/A513M	1008 (mechanical tubing) 1010 (mechanical tubing) 1012 (mechanical tubing) 1015 (mechanical tubing) 1016 (mechanical tubing) 1018 (mechanical tubing) 1019 (mechanical tubing) 1020 (mechanical tubing) 1021 (mechanical tubing) 1025 (mechanical tubing)
	ASTM A515/A515M	Grade 55 (plate) Grade 60 (plate) Grade 65 (plate) Grade 70 (plate)
	ASTM A516/A516M	Grade 55 (plate) Grade 60 (plate) Grade 65 (plate) Grade 70 (plate)
	ASTM A519/A519M	1008 (mechanical tubing) 1010 (mechanical tubing) 1012 (mechanical tubing) 1015 (mechanical tubing) 1016 (mechanical tubing) 1018 (mechanical tubing) 1019 (mechanical tubing) 1020 (mechanical tubing) 1021 (mechanical tubing) 1025 (mechanical tubing)
	ASTM A524	Grade I (pipe) Grade II (pipe)
	ASTM A537/A537M	Class 1 (plate)
	ASTM A556/A556M	Grade A2 (tube) Grade B2 (tube)
	ASTM A557/A557M	Grade A2 (tube) Grade B2 (tube)
	ASTM A562/A562M	Plate
	ASTM A569/A569M	Type A (sheet and strip) Type B (sheet and strip) Type C (sheet and strip)
	ASTM A570/A570M	Grade 36 Type I (sheet and strip)
	ASTM A572/A572M	Grade 42 (plate, bar, and shapes) Grade 50 (plate, bar, and shapes)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) 1/ - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont'd)	ASTM A575	M 1008 (bar) M 1010 (bar) M 1012 (bar) M 1015 (bar) M 1017 (bar) M 1020 (bar) M 1023 (bar) M 1025 (bar)
	ASTM A576	1008 (bar) 1010 (bar) 1012 (bar) 1015 (bar) 1016 (bar) 1017 (bar) 1018 (bar) 1019 (bar) 1020 (bar) 1021 (bar) 1022 (bar) 1023 (bar) 1025 (bar)
	ASTM A587	Pipe
	ASTM A606/A606M	Type 2 (sheet and strip) Type 4 (sheet and strip)
	ASTM A659/A659M	1015 (sheet) 1016 (sheet) 1017 (sheet) 1018 (sheet) 1020 (sheet) 1021 (sheet) 1023 (sheet)
	ASTM A660/A660M	WCA (pipe)
	ASTM A662/A662M	Grade A (plate) Grade B (plate)
	ASTM A671/A671M	Grade CA55 (pipe) Grade CB60 (pipe) Grade CB65 (pipe) Grade CC60 (pipe) Grade CC65 (pipe) Grade CE55 (pipe) Grade CE60 (pipe)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont'd)	ASTM A672/A672M	Grade A45 (pipe) Grade A50 (pipe) Grade A55 (pipe) Grade B55 (pipe) Grade B60 (pipe) Grade B65 (pipe) Grade C55 (pipe) Grade C60 (pipe) Grade C65 (pipe) Grade E55 (pipe) Grade E60 (pipe)
	ASTM A709/A709M	Grade 50W (plate, bar, and shapes)
	ASTM A727/A727M	Forging
	ASTM A765/A765M	Grade I (forging)
	ASTM A794/A794M	1015 (sheet) 1016 (sheet) 1017 (sheet) 1018 (sheet) 1020 (sheet) 1021 (sheet) 1023 (sheet)
	ASTM A830/A830M	1006 (plate) 1008 (plate) 1009 (plate) 1010 (plate) 1012 (plate) 1015 (plate) 1016 (plate) 1017 (plate) 1018 (plate) 1019 (plate) 1020 (plate) 1021 (plate) 1022 (plate) 1023 (plate) 1025 (plate)
	ASTM A945/A945M [9/]	Grade 65 (also referred to as HSLA-65) (plate)
	ASTM A1008/A1008M	Grade CS Type A (sheet) Grade CS Type B (sheet)
	ASTM A1011/A1011M	Grade 36 Type 1 (sheet and strip) Grade 36 Type 2 (sheet and strip) Grade CS Type B (sheet and strip)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont'd)	WW-P-404	Grade A (pipe, seamless and welded) Grade B (pipe, seamless and welded) Type F (furnace welded pipe)
	MIL-S-15083	Grade 70-36 (cast) Grade 65-35 (cast) Grade CW (cast) Grade B (cast)
	MIL-T-16286	Class a (tube, seamless) Class g (tube, seamless)
	MIL-S-24093	Type V (forgings)
	MIL-T-20157	Type E (tube and pipe)
	MIL-S-24412	Grade HT (shape)
	MIL-F-20236	Flanges, pipe
	MIL-F-20670	Flanges, pipe
	MIL-S-22698	Plate, bar, and shapes
	MIL-DTL-23194	Composition C (forgings)
	MIL-S-23284	Class 3 Class 4
	MIL-S-24238	Composition C (plate)
	MIL-P-24338	Pipe
	MIL-DTL-24339	Fittings and flanges
	MIL-P-24691/1	Grade B (tube and pipe)
	MIL-DTL-24707/1	ASTM A757/A757M, grade A1Q (castings) grade A2Q ASTM A216/A216M, grade WCA (castings) grade WCB grade WCC
S-2	Quenched and tempered carbon steel	
	ASTM A537/A537M	Class 2
S-3	Carbon molybdenum steel	
	MIL-S-870	CMo (cast)
	DOD-F-24669/2	CMo, class a (forgings) CMo, class b (forgings)
	MIL-T-16286	CMo, class d (tube)
	DOD-F-24669/1	CrNi, type 8620 (bar and forgings)
	MIL-T-20155	CMo (tube and pipe)
	MIL-C-24707/2	ASTM A217/A217M, grade WC1 (castings)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-3A	Alloy steels (Cr content not to exceed 3/4 percent; total alloy not to exceed 2 percent)	
	ASTM A302/A302M	MnMo, grade B (plate)
	MIL-DTL-23194	NiCrMo, composition A (forgings)
	MIL-S-24238	NiMnMo, composition A (plate)
S-4	Alloy steels (Cr content 3/4 - 2 percent; total alloy not to exceed 2-3/4 percent)	
	SAE AMS6530	CrNiMo, type 8630 (tube)
	MIL-T-6736	CrMo, type 4130 (tube)
	MIL-S-8699	CrMoV, type 4330 (bar, forging)
	MIL-S-15464	CrMo class 1 (casting)
	ASTM A182/A182M	Grade F11
	ASTM A213/A213M	Grade T11 (tube)
	DOD-F-24669/1	CrMo, type 4130 (bar)
	MIL-P-24691/2	CrMo, grade P11 (tube and pipe)
	DOD-F-24669/2	CrMo, class a (forgings)
	MIL-C-24707/2	ASTM A217/A217M, grade WC6 (casting)
	MIL-S-18728, SAE AMS6345, SAE AMS6350, SAE AMS6351	CrNiMo, type 8630 (plate)
	MIL-S-18729, SAE AMS6345, SAE AMS6350, SAE AMS6351	CrMo, type 4130 (plate)
S-5	Alloy steels (total alloy content 10 percent max.)	
	ASTM A182/A182M	Grade F22
	ASTM A213/A213M	Grade T22
	MIL-S-860	CrMoV, grade F (forgings)
	MIL-S-15464	CrMo, class 2 (casting)
	MIL-T-16286	CrMo, class e (tube)
	MIL-P-24691/2	CrMo, grade P22 (tube and pipe)
	DOD-F-24669/2	CrMo, class b (forging)
	MIL-F-24669/8	CrMoV, grade F (forgings)
	DOD-F-24669	CrMo (bar and forgings)
	MIL-C-24707/2	ASTM A217/A217M, grade WC9 (casting)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) 1/ - Continued

Letter No.	Applicable Document	Class or Type
S-6	High alloy steels (martensitic)	
	MIL-L-24128	403 (bars, rods, forgings)
	QQ-S-763, SAE AMS-QQ-S-763	403 (bars, rods, forgings) 410 414 420
	QQ-S-766	410 (plate, sheet, strip) 420
	DOD-F-24669/7	403 (bars) 410
	DOD-F-24669/6	403 (bars) 410 414 420
	MIL-S-16993	12 percent Cr, class 1 (casting) 12 percent Cr, class 2 (casting)
	MIL-C-24707/6	ASTM A217/A217M, grade CA-15 (casting) ASTM A487/A487M, grade CA-15M, class A
S-6A	High alloy steels (martensitic)	
	ASTM A182/A182M	F6NM (forgings)
	ASTM A176	410S (plate, sheet, strip)
	ASTM A240/A240M	410S (plate, sheet, strip)
	ASTM A473	410S (forgings)
	ASTM A487/A487M	CA-6NM (castings)
S-7	High alloy steels (ferritic)	
	QQ-S-763, SAE AMS-QQ-S-763	405 (bar, shapes, forgings) 430
	QQ-S-766	430 (plate, sheet, strip)
S-8	High alloy steels (austenitic)	
	QQ-S-763, SAE AMS-QQ-S-763	304 (bar, shapes, forgings) 304L 309 310 316 316L 321 347

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-8 (Cont'd)	QQ-S-766	304 304L 309S 310S 316 316L 321 347 348
	MIL-S-867	Class I (castings) Class II Class III
	MIL-P-24691/3	304 (pipe and tube) 304L (pipe and tube) 316 (pipe and tube) 316L (pipe and tube) 321 (pipe and tube) 347 (pipe and tube)
	MIL-T-8504	304 (tubing)
	MIL-T-16286	Class c (tube, seamless)
	MIL-S-17509	Class I, II, III
	MIL-S-23193	Composition A (304) Composition B (348) Composition C (316)
	MIL-DTL-23195	304 (bar and forgings) 304L 347 348
	MIL-DTL-23196	304 (plate, sheet, strip) 304L 347 348
	MIL-DTL-23226	304 (tube and pipe) 304L 347 348
	MIL-DTL-23467	304 (fittings and flanges) 304L 347 348
	MIL-C-24707/3	ASTM A744/A744M, grade CF-8 (castings) ASTM A744/A744M, grade CF-8C (castings) ASTM A744/A744M, grade CF-8M (castings)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-8 (Cont'd)	ASTM A182/A182M	F304 (flanges, fittings, and valves) F304L (flanges, fittings, and valves) F316 (flanges, fittings, and valves) F316L (flanges, fittings, and valves)
	ASTM A213/A213M	TP 304 (seamless tube) TP 304L (seamless tube)
	ASTM A240/A240M	304 (plate, sheet, and strip) 304L (plate, sheet, and strip) 309S 310S 316 (plate, sheet, and strip) 316L (plate, sheet, and strip) 321 (plate, sheet, and strip) 347 (plate, sheet, and strip) 348 (plate, sheet, and strip)
	ASTM A269/A269M	TP 304 (seamless welded pipe) TP 304L (seamless welded pipe) TP 316 (seamless welded pipe) TP 316L (seamless welded pipe)
	ASTM A276/A276M	304 (bar) 304L (bar) 316 (bar) 316L (bar)
	ASTM A296	CF8 (casting)
	ASTM A312/A312M	TP 304 (seamless and welded pipe) TP 304L (seamless and welded pipe) TP 316 (seamless and welded pipe) TP 316L (seamless and welded pipe) TP 321 (seamless and welded pipe) TP 347 (seamless and welded pipe) TP 348 (seamless and welded pipe)
	ASTM A351/A351M	CF3 (castings) CF3M (castings) CF8 (castings) CF8M (castings)
	ASTM A403/A403M	304 (fittings) 304L (fittings) 316 (fittings) 316L (fittings)
	ASTM A473	316 (forging)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-8 (Cont'd)	ASTM A479/A479M	304 (bar and shapes) 304L (bar and shapes) 316 (bar and shapes) 316L (bar and shapes) 321 (bar and shapes) 347 (bar and shapes) 348 (bar and shapes)
	ASTM A511/A511M	304 (seamless tube) 304L (seamless tube) 316 (seamless tube) 316L (seamless tube)
	ASTM A554	MT-304 (mechanical tubing) MT-304L (mechanical tubing) MT-316 (mechanical tubing) MT-316L (mechanical tubing) MT-321 (mechanical tubing) MT-347 (mechanical tubing)
	ASTM A666	304 (sheet, strip, plate, flat bar) 304L (sheet, strip, plate, flat bar) 316 (sheet, strip, plate, flat bar) 316L (sheet, strip, plate, flat bar)
	ASTM A743/A743M	CF3 (casting) CF8 (casting) CF8M (casting) CN-7M (castings) CN-7MS
	ASTM A744/A744M	CN-7M (castings) CN-7MS
	ASTM A793	304 (floor plate) 304L (floor plate) 316 (floor plate) 316L (floor plate)
	ASTM A813/A813M	TP 304 (pipe)
S-10H	High alloy steel (duplex stainless)	
	ASTM A240/A240M	UNS 31803 (plate) [4/] Type 2205, UNS S32205 (plate) [4/]
	ASTM A276/A276M	UNS 31803 (plate) [4/] Type 2205, UNS S32205 (bar) [4/]

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-11A	Quenched and tempered alloy steels	
	MIL-S-16216, NAVSEA T9074-BD-GIB-010/0300	HY-80 (plate) HY-100
	MIL-S-23008, NAVSEA T9074-BD-GIB-010/0300	HY-80 (castings) HY-100
	MIL-S-21952, NAVSEA T9074-BD-GIB-010/0300	HY-80 (bars) HY-100
	MIL-S-23009, NAVSEA T9074-BD-GIB-010/0300	HY-80 (forgings) HY-100
	MIL-S-24451, NAVSEA T9074-BD-GIB-010/0300	HY-80 (heads) HY-100
	NAVSEA T9074-BD-GIB-010/0300	HY-80 (shapes) HY-100
S-11B	Quenched and tempered alloy steels	
	MIL-S-24371, NAVSEA T9074-BD-GIB-010/0300	HY-130 (plate, castings, bars, forgings, extrusions, and shapes)
S-11C	Age hardening alloy steel	
	MIL-S-24645, NAVSEA T9074-BD-GIB-010/0300	HSLA-80 (plate, sheet, or coil)
S-11D	Age hardening alloy steel	
	MIL-S-24645, NAVSEA T9074-BD-GIB-010/0300	HSLA-100 (plate, sheet, or coil)
S-11E [6/]	Age hardening alloy steel	
	Specification as approved by NAVSEA.	HSLA-115 (plate)
S-11F	Low alloy steels	
	MIL-S-23284 [5/]	Class 1 Class 2
S-21	Aluminum and aluminum base alloys	
	QQ-A-200/1, SAE AMS-QQ-A-200/1, ASTM B221	3003 (extruded bars, rods)
	ASTM B241/B241M	3003 (pipe, tube)
	QQ-A-225/1, SAE AMS-QQ-A-225/1, ASTM B211/B211M	1100 (bars, rods)
	QQ-A-225/2, SAE AMS-QQ-A-225/2, ASTM B211/B211M	3003 (bars, rods)
	QQ-A-250/1, SAE AMS-QQ-A-250/1, ASTM B209	1100 (plate)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-21 (Con't)	QQ-A-250/2, SAE AMS-QQ-A-250/2, ASTM B209	3003 (plate and sheet)
	WW-T-700/1, SAE AMS-WW-T-700/1 ASTM B210/B210M	1100
	WW-T-700/2, SAE AMS-WW-T-700/2 ASTM B210/B210M	3003
S-22	Aluminum and aluminum base alloys	
	QQ-A-200/6, SAE AMS-QQ-A-200/6, ASTM B221	5454 (extruded bar, rods)
	ASTM B241/B241M	5454 (pipe, tube)
	QQ-A-225/7, SAE AMS-QQ-A-225/7, ASTM B211/B211M	5052 (bar, rod)
	QQ-A-250/8, SAE AMS-QQ-A-250/8, ASTM B209	5052 (plate)
	QQ-A-250/10, SAE AMS-QQ-A-250/10, ASTM B209	5454
S-23 [8/]	Aluminum and aluminum base alloys	
	ASTM B209 ASTM B210/B210M ASTM B211/B211M ASTM B483/B483M	6061
	ASTM B221 ASTM B241/B241M ASTM B361	6061, 6082
S-25	Aluminum and aluminum base alloys	
	QQ-A-200/5, SAE AMS-QQ-A-200/5, ASTM B221	5086 (extruded bar, rod)
	ASTM B241/B241M	5086 (pipe, tube)
	QQ-A-200/4, SAE AMS-QQ-A-200/4, ASTM B221, ASTM B241/B241M	5083

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) 1/ - Continued

Letter No.	Applicable Document	Class or Type
S-25 (Cont'd)	QQ-A-200/7, SAE AMS-QQ-A-200/7, ASTM B221, ASTM B241/B241M	5456
	QQ-A-250/6, SAE AMS-QQ-A-250/6, ASTM B209	5083
	ASTM B209	5086 5456
	ASTM B928/B928M	5083 (plate, sheet, extrusions) 5086 5456
	WW-T-700/5, SAE AMS-WW-T-700/5	5086 (seamless tube)
S-26	Aluminum and aluminum base alloys	
	ASTM B26/B26M	Alloy A03550 (castings) Alloy A03560 Alloy A05140 Alloy A24430
	QQ-A-601	B443 (castings) 514 355 356
	MIL-A-21180, SAE AMS-A-21180	A356 (castings)
S-31	Copper and copper base alloys	
	ASTM B152/B152M	Alloy C10200 (plate, bar) Alloy C10400 Alloy C10500 Alloy C11000 Alloy C11300 Alloy C11400 Alloy C12200 Alloy C12300
	QQ-C-576	99.9 Cu (plate, bar)
S-32	Brass	
	ASTM B21/B21M	Alloy C46400 (rod/bar/shapes)
	ASTM B124/B124M	Alloy C46400 (forging rod/bar/shapes)
	ASTM B283/B283M	Alloy C46400 (die forgings)
	QQ-C-390	Alloy C85700 (castings)
	QQ-B-637	Naval brass (alloy 464) (rod, bar, and forgings)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-32 (Con't)	QQ-B-639	Naval brass alloy (rod, bar, and forgings) Alloy 462 Alloy 464
S-33	Silicon bronze	
	ASTM B98/B98M	Alloy C65500 (rod, bar, and shapes)
	ASTM B124/B124M	Alloy C65500 (forging rod, bar, and shapes)
	QQ-C-390	Alloy C87200 (castings)
	QQ-C-591	Alloy 655 (rod, shapes, flats)
S-34	Copper nickel	
	ASTM B369	Alloy C96200 (castings) Alloy C96400
	MIL-T-15005	70/30 (tube) 90/10
	MIL-C-15726	70/30 (plate, bar, rod) 90/10
	MIL-T-16420	70/30 (tube) 90/10
	MIL-C-20159	UNS No. C96200 (castings) C96400
	MIL-DTL-24342	70/30 (fittings and flanges)
S-35	Aluminum bronze	
	ASTM B124/B124M	Alloy C64200 (forging rod, bar, and shapes)
	ASTM B150/B150M	Alloy C60600 (rod, bar, and shapes) Alloy C61400 Alloy C64200
	ASTM B169/B169M	Alloy C61400 (plate, sheet, strip, and rolled bar)
	ASTM B283/B283M	Alloy C64200 (die forgings)
	QQ-C-390	Alloy C95200 (castings)
	QQ-C-450	Alloy 606 (plate, bar) Alloy 613 Alloy 614
	QQ-C-465	(rod, bar, plate, strip, flats, and forgings) Alloy 606 Alloy 614 Alloy 642
	QQ-C-390	Alloy C95400 (castings)
	MIL-C-15345	Alloy 13 (castings) Alloy 15

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) 1/ - Continued

Letter No.	Applicable Document	Class or Type
S-36A	Nickel-aluminum bronze	
	ASTM B124/B124M	Alloy C63000 (forging rod, bar, shapes) Alloy C63200
	ASTM B150/B150M	Alloy C63000 (rod, bar, shapes) Alloy C63200
	ASTM B283/B283M	Alloy C63000 (die forgings) Alloy C63200
	QQ-C-390	Alloy C95500 (castings)
	QQ-C-465	Alloy 630 (bar, rod, plate, strip, forging) Alloy 632M
	MIL-C-15345	Alloy 14 (castings) Alloy 15
	MIL-B-21230	Alloy 1 (castings)
	MIL-B-24059	Flat products, shapes, forgings
	MIL-B-24480	Castings
S-36B	Manganese-nickel-aluminum bronze	
	MIL-B-21230	Alloy 2 (castings)
S-37A	Manganese bronze	
	ASTM B138/B138M	Alloy C67000 (rod, bar, and shapes) Alloy C67500
	QQ-B-728	Class A Class B
	QQ-C-390	Alloy C86100 Alloy C86200 Alloy C86300 Alloy C86400 Alloy C86500
S-37B	Nickel-manganese bronze	
	QQ-C-390	Alloy C86800
S-38	Tin bronze	
	MIL-B-16541	Castings
	QQ-C-390	Alloy C94700
S-39	Phosphor bronze	
	ASTM B139/B139M	Alloy C51000 (rod, bar, and shapes) Alloy C52400
	QQ-B-750	Composition A Composition D
	MIL-T-3595	Composition D (tubing)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-42	Nickel and nickel base alloys	
	ASTM A494/A494M	Composition M-30C (casting)
	QQ-N-281	NiCu, class A (bar, plate, rod, forging) Class B
	MIL-N-24106	NiCu, class A (bar, rods, forgings)
	QQ-N-288	NiCuSiCb, composition E (casting)
	MIL-T-1368	NiCu (tubing)
	MIL-DTL-23520	NiCu (tube and pipe)
	MIL-C-15345	NiCuSiCb, Alloy 19 (casting)
	MIL-N-17163	NiCu (bar, rod, plate, forging)
	MIL-DTL-23509	Fittings and flanges
	MIL-C-24723	Composition M-30C (casting)
S-43	Nickel-chromium iron	
	MIL-DTL-23508	Fittings and flanges
	ASTM B166	Bar, rod, forging
	ASTM B564	Forgings
	MIL-B-15382	Bar and rod
	MIL-DTL-23227	Tube and pipe
	MIL-N-23228	Condition A (plate)
	MIL-DTL-23229	Condition A (bar, rod, forging)
	MIL-N-24271	Castings
	ASTM A494/A494M	GR CW-6MC [7/]
	ASTM A494/A494M	GR CW-6MC MOD [2/, 7/]
	ASTM B443	UNS N06625 (plate) [7/]
	ASTM B444	UNS N06625 (pipe and tube) [7/]
	ASTM B446	UNS N06625 (bar and rod) [7/]
S-44 [3/]	Nickel-molybdenum-chromium alloy	
	ASTM B574	UNS N10276 (rod)
	ASTM B575	UNS N10276 (plate, sheet, strip)
	ASTM B622	UNS N10276 (pipe, tube)
S-51	Titanium and titanium base alloys	
	MIL-T-9046	CP-3 (sheet, strip, plate) CP-4 (sheet, strip, plate)
	ASTM B265	Grade 7 (sheet, strip, plate)
	ASTM B337, ASTM B861, ASTM B862	Grade 1 (pipe) Grade 2 (pipe) Grade 7 (pipe)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) [1/] - Continued

Letter No.	Applicable Document	Class or Type
S-51 (Con't)	ASTM B338	Grade 1 (tubing) Grade 2 (tubing) Grade 7 (tubing)
	ASTM B348	Grade 1 (bars, billets) Grade 2 (bars, billets) Grade 7 (bars, billets)
	ASTM B363	WPT 1 (fittings) WPT 2 (fittings) WPT 7 (fittings)
	ASTM B381	Grade F-1 (forgings) Grade F-2 (forgings)
S-52	Titanium and titanium base alloys	
	MIL-T-9046	CP-1 (sheet, strip, plate) CP-2 (sheet, strip, plate)
	MIL-T-9047	CP-70 (bars, reforging stock)
	ASTM B337, ASTM B861, ASTM B862	Grade 3 (pipe)
	ASTM B338	Grade 3 (tubing)
	ASTM B363	WPT 3 (fittings)
	ASTM B367	Grade C-2 (castings) Grade C-3 (castings)
S-53	Titanium and titanium base alloys	
	MIL-T-9046	AB-1 (sheet, strip, plate) AB-2 (sheet, strip, plate)
	MIL-T-9047	6A1-4V (bars, forgings) 6A1-4V (ELI) (bars, forgings)
	ASTM B265	Grade 5 (sheet, strip, plate)
	ASTM B367	Grade C-5 (castings)
	ASTM B381	Grade F-5 (forgings)
S-53A	Titanium and titanium alloy, high toughness and high seawater stress corrosion cracking resistance	
	MIL-DTL-32528	Ti-5111 (UNS R5111)
	ASTM B348 [10/]	Grade F-32 (bars and billets)
	ASTM B381 [10/]	Grade F-32 (forgings)

See footnotes at end of table.

Table 7-1. Grouping of Base Materials (Welding) 1/ - Continued

NOTES:

1/ If material of similar chemistry and mechanical properties is not listed under an S-group, it may be considered as a part of a group upon approval. S-23 materials are as stated; other alloys shall be approved as special welds by NAVSEA. Also, for materials to be added to S-1 or S-2, the carbon equivalent shall be calculated for minimum preheat purposes as required by the applicable fabrication document (e.g., NAVSEA S9074-AR-GIB-010/278, table 6-2.1).

2/ Si = 0.40 maximum, Al = 0.15 maximum, and Cb + Ta = 3.15 - 4.50.

3/ Procedure qualifications for these materials shall be submitted to NAVSEA for approval.

4/ With additional requirements for toughness, composition, heat treatment, and testing for absence of intermetallic phases (e.g., ASTM A923, Test Method B) imposed by the component specification.

5/ Welding procedure and personnel qualification for S-11F propulsion shafting and rudder stocks shall be in accordance with MIL-STD-2191; otherwise, qualification shall be in accordance with the requirements of this document.

6/ Qualification requirements shall be as approved by NAVSEA.

7/ See 4-7.1.a(4).

8/ Welding procedures for S-23 materials shall identify each specific application for which the procedure will be used. Applications shall be limited to those specified by the fabrication document for S-23 materials or other applications specifically approved by NAVSEA (see 4-3.1.1).

9/ Welding of HSLA-65 is only permitted where the fabrication document lists specific electrode types for this specific steel; otherwise, welding requires NAVSEA approval.

10/ With additional toughness, composition, melting, processing and other controls as approved by NAVSEA. Toughness testing for welding procedure qualification is required as approved by NAVSEA.

Table 7-2. Grouping of Filler Materials (Welding) [1/]

Group	Applicable Document	Filler Material Type
A-1A	Low and medium carbon steel (covered electrodes)	
	AWS A5.1/A5.1M	E6010 E6011 E6012 [2/] E6013 [2/] E6020 E6027 E7024 [2/]
A-1B	Low and medium carbon steel (bare rod)	
	AWS A5.2/A5.2M	Class RG-60 Class RG-65
A-2A	Carbon and low alloy steel (covered electrode)	
	AWS A5.5/A5.5M	E7010-A1 E7011-A1 E7018-A1 E7020-A1
	MIL-DTL-22200/1	MIL-7018-M
A-2B	Carbon and low alloy steel (bare electrode, rod, and inserts)	
	MIL-E-23765/1	MIL-70S-1 MIL-70S-2 MIL-70S-3 MIL-70S-4 MIL-70S-5 MIL-70S-6
	MIL-I-23413 (inserts)	MIL-Ms-1 MIL-Ms-2
A-2C	Carbon and low alloy steel (bare electrode and flux)	
	MIL-E-23765/1	MIL-70S-1 (wire) [3/] MIL-70S-2 (wire) [3/] MIL-70S-3 (wire) [3/] MIL-70S-4 (wire) [3/] MIL-70S-5 (wire) [3/] MIL-70S-6 (wire) [3/] MIL-70S-7 (wire) [3/] MIL-70S-8 (wire) [3/] MIL-70S-9 (wire) [3/] MIL-70S-XF (flux) [3/]
	MIL-E-23765/4	MIL-F6A2-EL12 (wire and flux) [3/] MIL-F6A2-EM12K (wire and flux) [3/] MIL-F7AZ-EM12K (wire and flux) [3/] MIL-F7A2-EM12K (wire and flux) [3/]

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) [1/] - Continued

Group	Applicable Document	Filler Material Type
A-2D	Low alloy steel (flux-cored electrodes)	
	MIL-DTL-24403/1	MIL-70T-1 MIL-71T-1 MIL-70T-5 MIL-71T-1A MIL-70T-6 MIL-70T-8 MIL-71T-8 MIL-71T-8A MIL-71T8-K6 MIL-71T8-Ni1 MIL-71T-1-HYR MIL-71T-1-HYN MIL-71T-1-HYD MIL-7XT-X-HY MIL-7XTX-X-HY MIL-7XT-X-HZ MIL-7XTX-X-HZ
A-3A	Carbon and low alloy steel (low hydrogen covered electrodes)	
	MIL-DTL-22200/1	MIL-8018-C3
A-3B	Carbon and low alloy steel (bare electrode)	
	MIL-E-23765/2	MIL-80S-3
A-3C	Carbon and low alloy steel (bare electrode and flux)	
	MIL-E-23765/2	MIL-80S-1 (wire) MIL-80S-2 (wire) MIL-80S-1F (flux) MIL-80S-2F (flux)
A-3D	Carbon and low alloy steel (flux-cored electrode)	
	MIL-DTL-24403/1	MIL-80T1-Ni1 MIL-80T1-Ni2 MIL-81T1-Ni1 MIL-81T1-Ni2 MIL-8XTX-X-HY MIL-8XTX-X-HZ
A-4A	Low alloy, high yield steel (covered electrode)	
	MIL-E-22200/5	MIL-10018-N1 [4/]
A-5A	Low alloy, high yield steel (covered electrode)	
	MIL-DTL-22200/1	MIL-9018-M MIL-11018-M
	NAVSEA T9074-BC-GIB-010/0200	MIL-10018-M1 MIL-10718-M MIL-12018-M2 [13/]

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) [1/] - Continued

Group	Applicable Document	Filler Material Type
A-5A (Con't)	MIL-E-22200/9 (see NAVSEA T9074-AD-GIB-010/1688 sections 10 & 16 for direction)	MIL-14018-M1 [13/]
A-5B	Low alloy, high yield steel (bare electrode)	
	NAVSEA T9074-BC-GIB-010/0200	MIL-100S-1 MIL-100S-2 MIL-120S-1 [13/] MIL-120S-2 [13/]
	MIL-E-24355 (see NAVSEA T9074-AD-GIB-010/1688 sections 10 & 16 for direction)	MIL-140S-1 [13/]
A-5C	Low alloy, high yield steel (bare electrode and flux)	
	NAVSEA T9074-BC-GIB-010/0200	MIL-100S-1 (wire) MIL-100S-1F (flux) MIL-100S-2 (wire) MIL-100S-2F (flux) MIL-120S-1 (wire) [13/] MIL-120S-1F (flux) [13/] MIL-120S-2 (wire) [13/] MIL-120S-2F (flux) [13/]
A-5D	Low alloy, high yield steel (flux-cored electrode)	
	MIL-E-24403/2	MIL-100TC [7/, 8/, 2/] MIL-100TM [7/, 8/, 2/] MIL-100TS [7/, 2/] MIL-101TS [2/]
	NAVSEA T9074-BC-GIB-010/0200	MIL-101TC [2/, 8/] MIL-101TM [2/, 8/]
A-6A	CrMo steel (1.0 to 2.5 percent Cr, 0.4 to 1.2 percent Mo) (covered electrode)	
	MIL-E-22200/8	MIL-80XX-B2L or B2 (1.25Cr-0.5Mo) MIL-90XX-B3L or B3 (2.25Cr-1Mo)
	AWS A5.5/A5.5M	E70XX-B2L (1.25Cr-0.5Mo) E80XX-B2 (1.25Cr-0.5Mo) E80XX-B3L (2.25Cr-1Mo) E90XX-B3 (2.25Cr-1Mo)
A-6B	CrMo steel (1.0 to 3.0 percent Cr, 0.4 to 1.2 percent Mo) (bare electrode, rod, and insert)	
	MIL-I-23413	MIL-515 MIL-521
	AWS A5.23/A5.23M	EB2 EB3
	AWS A5.28/A5.28M	ER70S-B2L (1.25Cr-0.5Mo) ER80S-B2 (1.25Cr-0.5Mo) ER80S-B3L (2.25Cr-1Mo) ER90S-B3 (2.25Cr-1Mo)

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) [1/] - Continued

Group	Applicable Document	Filler Material Type
A-7A-1	CrMo steel (4.0 to 10.5 percent Cr, 0.4 to 1.5 percent Mo) (covered electrode)	
	MIL-E-22200/8	MIL-502-XX MIL-502-XX-L MIL-505-XX
A-7A-2	Cr and CrNiMo (martensitic) (11 to 13.5 percent Cr), (4 to 5 percent Ni, 0.75 percent max Mo) (covered electrode)	
	MIL-E-22200/8	MIL-410-XX
	AWS A5.4/A5.4M	E410NiMo-XX
A-7B-1	CrMo steel (4.0 to 10.5 percent Cr, 0.4 to 1.5 percent Mo) (bare electrode, rod, and insert)	
	MIL-I-23413	MIL-505
A-7B-2	Cr and CrNiMo (martensitic) (11 to 13.5 percent Cr), (4 to 5 percent Ni, 0.75 percent max Mo) (bare electrode and rod)	
	MIL-E-19933	MIL-410
	AWS A5.9/A5.9M	ER410NiMo [5/]
A-7C	High alloy steel (ferritic) (chromium 15 to 18 percent) (covered electrode)	
	AWS A5.4/A5.4M	E430
A-7D	High alloy steel (ferritic) (chromium 15 to 18 percent) (bare electrode and rod)	
	AWS A5.9/A5.9M	ER430
A-8A	High alloy steel (austenitic) (covered electrode)	
	MIL-E-22200/2	MIL-16.8.2-XX MIL-308-XX MIL-308L-XX MIL-308HC-X MIL-309-XX MIL-309L-XX MIL-309Cb-XX MIL-310-XX MIL-312-XX MIL-316-XX MIL-316L-XX MIL-317-XX MIL-318-XX MIL-330-XX MIL-347-XX MIL-347HC-XX
	AWS A5.4/A5.4M	MIL-349-XX E320

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) [1/] - Continued

Group	Applicable Document	Filler Material Type
A-8B	High alloy steel (austenitic) (bare electrode, rod, and insert)	
	MIL-E-19933	MIL-308 [5/] MIL-308L [5/] MIL-308HC [5/] MIL-309 [5/] MIL-310 [5/] MIL-312 [5/] MIL-316 [5/] MIL-316L [5/]
	MIL-E-19933	MIL-317 [5/] MIL-318 [5/] MIL-321 [5/] MIL-347 [5/]
	AWS A5.9/A5.9M	ER309L ER320
	MIL-I-23413 (inserts)	MIL-308 MIL-308L MIL-310 MIL-312 MIL-316 MIL-316L MIL-348
A-8D	High alloy steel (austenitic) (flux-cored electrode)	
	AWS A5.22/A5.22M	E308LT1-1 [15/] E308LT1-4 [15/] E309LT1-1 [15/] E309LT1-4 [15/] E309LNbT1-1 [15/] E309LNbT1-4 [15/] E310T1-1 [15/] E310T1-4 [15/] E316LT1-1 [15/] E316LT1-4 [15/] E347T1-1 [15/] E347T1-4 [15/]
A-9A	High alloy steel (duplex stainless) (covered electrode)	
	AWS A5.4/A5.4M	E2209-15 and -16 [14/]
A-9B	High alloy steel (duplex stainless) (bare electrode and rod)	
	AWS A5.9/A5.9M	ER 2209 [14/]
A-21B	Aluminum alloy (bare electrode, rod, and insert)	
	AWS A5.10/A5.10M	ER-1100, R1100
	MIL-I-23413 (insert)	MIL-1100

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) [1/] - Continued

Group	Applicable Document	Filler Material Type
A-22B	Aluminum alloy (bare electrode, rod, and insert)	
	AWS A5.10/A5.10M	ER5183, R5183 ER5356, R5356 ER5554, R5554 ER5556, R5556 ER5654, R5654
	MIL-I-23413 (inserts)	MIL-5356
A-23B	Aluminum alloy (bare electrode, rod, and insert)	
	AWS A5.10/A5.10M MIL-I-23413 (inserts)	4043 ER4043, R4043 MIL-4043
A-24B	Aluminum alloy (bare electrode and rod)	
	AWS A5.10/A5.10M	ER2319, R2319
A-31B	Copper alloy (bare electrode and rod)	
	AWS A5.7/A5.7M	ER Cu
A-32A	Copper alloy (silicon bronze covered electrode)	
	AWS A5.6/A5.6M	E CuSi
A-32B	Copper alloy (silicon bronze bare electrode and rod)	
	MIL-E-23765/3	MIL-CuSi
A-33A	Copper-tin alloy (covered electrode)	
	AWS A5.6/A5.6M	E CuSn-A E CuSn-C
A-33B	Copper-tin alloy (phosphor bronze) (bare electrode and rod)	
	MIL-E-23765/3	MIL-CuSn-C
	AWS A5.7/A5.7M	ERCuSn-A
A-34A	Copper nickel (covered electrode)	
	MIL-E-22200/4	MIL-CuNi (70:30)
A-34B	Copper nickel (bare electrode, rod, and insert)	
	MIL-E-21562	MIL-EN67 [5/] MIL-RN67
	MIL-I-23413 (insert)	MIL-67
A-35B	Copper-zinc alloy (bare rod)	
	AWS A5.27	RB CuZn-A RB CuZn-B RB CuZn-C RB CuZn-D
A-36B	Copper-aluminum alloy (aluminum bronze) (bare electrode and rod)	
	MIL-E-23765/3	Type CuAl-A2

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) [1/] - Continued

Group	Applicable Document	Filler Material Type
A-37A	Copper-aluminum alloy (aluminum bronze) (covered electrode)	
	AWS A5.6/A5.6M	ECuAl-A2 ECuAl-B
	AWS A5.13/A5.13M	ECuAl-C ECuAl-D
A-37B	Copper-aluminum-nickel alloys (NiAl and MnNiAl bronze) (bare electrode and rod)	
	MIL-E-23765/3	MIL-CuNiAl MIL-CuMnNiAl
A-38B	Surfacing alloys (bare rod) (metal powder)	
	MIL-R-17131	MIL-RNiCr-B-1 MIL-RNiCr-B-2 MIL-RNiCr-C-1 MIL-RNiCr-C-2 MIL-PNiCr-B-2 (powder) MIL-PNiCr-C-2 (powder)
A-39A	Surfacing alloys (covered electrode)	
	AWS A5.13/A5.13M	ECoCr-A [6/] ECoCr-B ECoCr-C
A-39B	Surfacing alloys (bare rod) (metal powder)	
	MIL-R-17131	MIL-RCoCr-A1 [6/] MIL-RCoCr-A2 [6/] MIL-RCoCr-A3 [6/] MIL-RCoCr-C-1 MIL-RCoCr-C-2 MIL-PCoCr-E-1 (powder) MIL-PCoCr-E-2 (powder)
	AWS A5.21/A5.21M	ER-CoCr-B
A-41A	Nickel (covered electrode)	
	MIL-E-22200/3	MIL-4N11
A-41B	Nickel (bare electrode, rod, and insert)	
	MIL-E-21562	MIL-EN61 [5/] MIL-RN61
	MIL-I-23413 (insert)	MIL-61
A-42A	Nickel base alloys (covered electrodes)	
	MIL-E-22200/3	MIL-9N10
A-42B	Nickel base alloys (bare electrode, rod, and insert)	
	MIL-E-21562	MIL-EN60 [5/] MIL-RN60
	MIL-I-23413 (insert)	MIL-60

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) [1/] - Continued

Group	Applicable Document	Filler Material Type
A-43A	Nickel base alloys (covered electrode)	
	MIL-E-22200/3	MIL-1N12 [18/] MIL-3N12 MIL-4N12 MIL-4N1A MIL-8N12 MIL-8N12H
A-43B	Nickel base alloys (bare electrode, rod, and inserts)	
	MIL-E-21562	MIL-EN62 [5/] MIL-RN62 MIL-EN82 [5/] MIL-EN82H MIL-RN82 MIL-RN82H MIL-EN6A MIL-RN6A MIL-EN625 [5/, 18/] MIL-RN625 [18/]
	MIL-I-23413 (inserts)	MIL-62 MIL-82 MIL-82H
A-44A	Nickel-cobalt alloys (covered electrodes)	
	MIL-E-22200/3	MIL-3N1B MIL-3N1C MIL-4N1W MIL-3N1N MIL-3N1L
A-45A	Nickel-molybdenum-chromium alloy (covered electrode)	
	AWS A5.11/A5.11M (UNS-W80276)	ENiCrMo-4 [10/, 11/, 16/]
A-45B	Nickel-molybdenum-chromium alloy (bare electrode)	
	AWS A5.14/A5.14M (UNS-N10276)	ER-NiCrMo-4 [9/, 10/, 11/, 12/]
A-51B	Titanium, unalloyed (bare electrode)	
	AWS A5.16/A5.16M	ER Ti-1 ER Ti-2 ER Ti-3 ER Ti-7
A-53B	Titanium base alloys (bare electrode)	
	AWS A5.16/A5.16M	ER Ti-5 ER Ti-23
A-53B-1	Titanium base alloys (bare electrode)	
	AWS A5.16/A5.16M	ER Ti-32 [17/]

See footnotes at end of table.

Table 7-2. Grouping of Filler Materials (Welding) 1/ - Continued

NOTES:

1/ If filler material of similar chemistry and mechanical properties not listed under an A-group is to be used, it may be considered as a part of a group upon approval.

2/ Separate procedure qualification required (see 4-2.5 and 4-7.2); E6012 and E6013 qualify each other.

3/ See 4-7.2.b.

4/ Procedure qualification limited to 1T of test plate thickness for production groove welds. Overlay production use limited to 1/2T of qualification test plate (see 4-4.1.9).

5/ To be used with neutral flux when used with the submerged arc process. A neutral flux is defined as being one that does not readily oxidize the alloying elements or add significant alloy to the weld.

6/ Deposition technique using CoCr-A must yield a surface hardness of Rc35 minimum, unless a higher minimum hardness is required by the governing component specification/drawing, in which case the higher hardness requirement shall be met.

7/ Use in any position other than that specified for qualification testing in MIL-E-24403/2 and NAVSEA T9074-BC-GIB-010/0200 for this electrode shall require separate qualification and NAVSEA approval.

8/ Use of any shielding gas other than that specified for qualification testing in MIL-E-24403/2 and NAVSEA T9074-BC-GIB-010/0200 for this electrode shall require separate qualification and NAVSEA approval.

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

10/ For other than clad welding applications involving these materials, procedure qualifications shall be submitted to NAVSEA for approval. Clad weld procedure qualifications shall be submitted for approval in accordance with 4-2.3.

11/ The interpass temperature for these materials shall not exceed 200 °F.

12/ These materials shall be used only with the gas tungsten arc, gas metal arc, and plasma arc welding processes, as applicable.

13/ The welding procedure and personal qualification requirements for MIL-120 and MIL-140 series filler materials shall be as approved by NAVSEA.

14/ With additional toughness and ferrite content requirements as imposed by the component specification.

15/ These electrodes are restricted in their use by the applicable fabrication document.

16/ The covered electrodes shall conform to all the quality conformance requirements of MIL-1N12 specified in MIL-E-22200/3 but with tensile properties and chemical composition of ENiCrMo-4 as specified in AWS A5.11/A5.11M.

17/ With additional melt control and composition, toughness, and other testing as approved by NAVSEA. Filler material specification requirements require NAVSEA approval prior to production welding.

18/ Alloy 625 type filler materials require separate welding performance qualification per table 7-8.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/]

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Ferritic materials/shielded metal arc process [13/, 16/]				
1	S-11B	S-11B	A-5A (MIL-14018 only)	1 through 6, 9, 10, 11, and 16
2	S-11B	S-11A (HY-100)	A-5A (MIL-14018 or 12018)	2 through 6, 9, 10, 11, and 16
3	S-11B	S-11D	A-5A (MIL-14018 or 12018)	3 through 6, 9, 10, 11, and 16
4	S-11B	S-11A (HY-80)	A-5A (MIL-14018, 12018, 10718, or 10018)	4 through 6, 9, 10, 11, and 16
5	S-11B	S-11C	A-5A (MIL-14018, 12018, 10718, or 10018)	5, 6, 9, 10, 11, and 16
6	S-11B	S-2 S-1	A-5A or the A-3A or A-2A electrodes specifically permitted by NAVSEA T9074-AD-GIB-010/1688	6, 9, 10, 11, and 16
7	S-11A (HY-100) S-11D	S-11A (HY-100) S-11D	[19/] A-5A (MIL-12018 only)	7 through 11, and 16
8	S-11A S-11C S-11D	S-11A S-11C S-11D	[18/] A-5A (MIL-10718 or 10018)	8 through 11, and 16
9	S-11A S-11C S-11D	S-2 S-1	[9/] A-5A (MIL-10718 or 10018); or A-3A or A-2A electrodes specifically permitted by NAVSEA T9074-AD-GIB-010/1688 or MIL-STD-1689	9, 10, 11, and 16
10	S-2	S-2	[9/] A-3A or A-2A (MIL-7018A1 or 7018)	10, 11, and 16
11	S-2	S-1	[9/] A-3A or A-2A (MIL-7018A1 or 7018)	11 and 16
12	S-3A	S-3A	[9/] A-3A or A-2A (MIL-7018A1)	12 through 16
13	S-3A	S-3 S-1	[9/] A-3A or A-2A (MIL-7018A1 or 7018)	13 through 16
14	S-3	S-3	[9/] A-3A or A-2A (MIL-7018A1 or 7018)	14 through 16
15	S-3	S-1	[9/] A-3A or A-2A (MIL-7018A1 or 7018)	15 and 16
16	S-1	S-1	A-2A	16
17	S-5	S-5	[9/] A-7A-1 or A-6A	17 through 21, and 16
18	S-5	S-4	[9/] A-7A-1 or A-6A	18 through 21, and 16
19	S-5	S-3 S-1	[9/] A-6A or A-3A or A-2A (MIL-7018A1 or 7018)	19, 21, and 16
20	S-4	S-4	A-6A	20, 21, and 16
21	S-4	S-3 S-1	[9/] A-6A or A-3A or A-2A (MIL-7018A1 or 7018)	21 and 16
22	S-6	S-6	A-7A-2 (MIL-410XX only)	22
23	S-6	S-6	A-7A-2 (E410NiMo-XX only)	23 through 25

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Ferritic materials/shielded metal arc process [13/, 16/] (continued)				
24	S-6	S-6A	A-7A-2 (E410NiMo-XX only)	24 and 25
25	S-6A	S-6A	A-7A-2 (E410NiMo-XX only)	25
Ferritic materials/gas tungsten arc, gas metal arc, and plasma arc processes [16/]				
1	S-11B	S-11B	A-5B (MIL-140S-1 only)	1 through 5, 8, 9, 10, and 15
2	S-11B	S-11A (HY-100)	A-5B (MIL-140S-1 or 120S-1)	2 through 5, 8, 9, 10, and 15
3	S-11B	S-11D	A-5B (MIL-140S-1 or 120S-1)	3 through 5, 8, 9, 10, and 15
4	S-11B	S-11A (HY-80) S-11C	A-5B (MIL-140S-1 or 120S-1 or 100S-1)	4, 5, 8, 9, 10, and 15
5	S-11B	S-2 S-1	[9/] A-5B; or A-3B or A-2B types specifically permitted by NAVSEA T9074-AD-GIB-010/1688	5, 8, 9, 10, and 15
6	S-11A (HY-100) S-11D	S-11A (HY-100) S-11D	[19/] A-5B (MIL-120S-1 only)	6 through 10, and 15
7	S-11A S-11C S-11D	S-11A S-11C S-11D	[20/] A-5B (MIL-100S only)	7 through 10, and 15
8	S-11A S-11C S-11D	S-2 S-1	[10/] A-5B (other than MIL-140S and MIL-120S types); or A-2B types specifically permitted by NAVSEA T9074-AD-GIB-010/1688 or MIL-STD-1689	8, 10, and 15
9	S-2	S-2	[9/] A-3B or A-2B	9, 10, and 15
10	S-2	S-1	[9/] A-3B or A-2B	10 and 15
11	S-3A	S-3A	[9/] A-3B or A-2B	11 through 15
12	S-3A	S-3 S-1	[9/] A-3B or A-2B	12 through 15
13	S-3	S-3	[9/] A-3B or A-2B	13 through 15
14	S-3	S-1	[9/] A-3B or A-2B	14 and 15
15	S-1	S-1	A-2B	15
16	S-5	S-5	[9/] A-7B-1 or A-6B	16 through 20, and 15
17	S-5	S-4	[9/] A-7B-1 or A-6B	17 through 20, and 15
18	S-5	S-3 S-1	[9/] A-7B-1 or A-6B or A-3B or A-2B	18, 20, and 15
19	S-4	S-4	A-6B	19, 20, and 15

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Ferritic materials/gas tungsten arc, gas metal arc, and plasma arc processes [16/] (continued)				
20	S-4	S-3 S-1	[9/] A-6B or A-3B or A-B	20 and 15
21	S-6	S-6	A-7B-2 (MIL-410 only)	21
22	S-6	S-6	A-7B-2 (ER410NiMo only)	22 through 24
23	S-6	S-6A	A-7B-2 (ER410NiMo only)	23 and 24
24	S-6A	S-6A	A-7B-2 (ER410NiMo only)	24
Ferritic materials/submerged arc process [16/]				
1	S-11A (HY-100) S-11D	S-11A (HY-100) S-11D	[19/] A-5C (MIL-120S-1 wire and 1F flux)	1 through 5, and 10
2	S-11A S-11C S-11D	S-11A S-11C S-11D	[20/] A-5C (MIL-100S wire and 1F or 2F flux only)	2 through 5, and 10
3	S-11A S-11C S-11D	S-2 S-1	[9/] A-5C (MIL-100S wire and 1F or 2F flux) or A-3C or A-2C wire and flux specifically permitted by NAVSEA T9074-AD-GIB-010/1688 or MIL-STD-1689	3, 4, 5, and 10
4	S-2	S-2	[11/] A-2C	4, 5, and 10
5	S-2	S-1	A-2C. Unless qualified by category 4 [11/]	5 and 10
6	S-3A	S-3A	A-3C	6 through 9
7	S-3A	S-3 S-1	A-3C	7 through 9 (qualification with A-2C qualifies categories 7 through 10 with A-2C)
8	S-3	S-3	A-3C	8 and 9 (qualification with A-2C qualifies categories 8 through 10 with A-2C)
9	S-3	S-1	A-3C	9 (qualification with A-2C qualifies categories 9 and 10 with A-2C)
[12/] 10	S-1	S-1	A-2C	10
11	S-6	S-6	A-7B-2 (ER410NiMo only)	11 through 13
12	S-6	S-6A	A-7B-2 (ER410NiMo only) [11/]	12 and 13
13	S-6A	S-6A	A-7B-2 (ER410NiMo only) [11/]	13
Ferritic materials/flux-cored arc process				
1	S-11A (HY-100)	S-11A (HY-100)	[21/] A-5D (MIL-101TC or MIL-101TM only)	1 through 6, and 11
2	S-11D	S-11D	[21/] A-5D (MIL-101TC or MIL-101TM only)	2 through 6, and 11

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Ferritic materials/flux-cored arc process (continued)				
3	S-11A S-11C S-11D	S-11A (HY-80) S-11C	[21/] A-5D (MIL-101TC or MIL-101TM only)	3 through 6, and 11
4	S-11A S-11C S-11D	S-2 S-1	[9/] A-5D; or A-2D or 3D electrodes specifically permitted by NAVSEA T9074-AD-GIB-010/1688 or MIL-STD-1689	4, 5, 6, and 11
5	S-2	S-2	[9/] A-2D or A-3D	5, 6, and 11
6	S-2	S-1	[9/] A-2D or A-3D	6 and 11
7	S-3A	S-3A	A-3D	7 through 11
8	S-3A	S-3 S-1	[9/] A-2D or A-3D	8 through 11
9	S-3	S-3	[9/] A-2D or A-3D	9 through 11
10	S-3	S-1	[9/] A-2D or A-3D	10 and 11
11	S-1	S-1	A-2D	11
Hardfacing and corrosion resistant cladding, all processes				
1	S-11A S-11B	--	Filler material type involved	For cladding, 1, 2, and 5. For hardfacing, 1 only. The same filler material type shall be used in all cases except the table 7-2 filler material A group allowances of 4-7 are permitted.
2	S-11C S-11D	--	Filler material type involved	For cladding, 1, 2, and 5. For hardfacing, 2 only. The same filler material type shall be used in all cases except the table 7-2 filler material A group allowances of 4-7 are permitted.
3	S-5 [12/] S-4	--	Filler material type involved	3 and 5. The same filler material type shall be used in all cases except the table 7-2 filler material A group allowances of 4-7 are permitted.

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Hardfacing and corrosion resistant cladding, all processes (continued)				
4	S-3/3A [12/]	--	Filler material type involved	4 and 5. The same filler material type shall be used in all cases except the table 7-2 filler material A group allowances of 4-7 are permitted.
5	S-1 S-2	--	Filler material type involved	For cladding, 5, 1, and 2. For hardfacing, 5 only. The same filler material type shall be used in all cases except the table 7-2 filler material A group allowances of 4-7 are permitted.
Austenitic stainless steel to ferritic materials/shielded metal arc				
1	S-8	S-11B S-11A S-11D S-11C	A-8A (MIL-309 or MIL-309L or MIL-309Cb or MIL-310 types only)	1 and 4
2	S-8	S-5 [12/] S-4	A-8A (MIL-309 or MIL-309L or MIL-309Cb or MIL-310 types only)	2 and 4
3	S-8	S-3/3A [12/]	A-8A (MIL-309 or MIL-309L or MIL-309Cb or MIL-310 types only)	3 and 4
4	S-8	S-2 S-1	A-8A (MIL-309 or MIL-309L or MIL-309Cb or MIL-310 types only)	4 and 1
5	S-8	S-11B S-11A S-11D S-11C	A-43A (MIL-1N12 or MIL-8N12/8N12H only)	5 and 8
6	S-8	S-5 [12/] S-4	A-43A (MIL-8N12/8N12H only)	6 and 8
7	S-8	S-3/3A [12/]	A-43A (MIL-8N12/8N12H only)	7 and 8
8	S-8	S-2 S-1	A-43A (MIL-8N12/8N12H only)	8 and 5
Austenitic stainless steel to ferritic materials/gas tungsten arc, gas metal arc, and plasma arc				
1	S-8	S-11B S-11A S-11D S-11C	A-8B (MIL-309 or ER-309L or MIL-310 types only)	1 and 4
2	S-8	S-5 [12/] S-4	A-8B (MIL-309 or ER-309L or MIL-310 types only)	2 and 4

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Austenitic stainless steel to ferritic materials/gas tungsten arc, gas metal arc, and plasma arc (continued)				
3	S-8	S-3/3A [12/]	A-8B (MIL-309 or ER-309L or MIL-310 types only)	3 and 4
4	S-8	S-2 S-1	A-8B (MIL-309 or ER-309L or MIL-310 types only)	4 and 1
5	S-8	S-11B S-11A S-11D S-11C	A-43B (MIL-EN625/RN625, MIL-EN82/EN82H or MIL-RN82/RN82H only)	5 and 8
6	S-8	S-5 [12/] S-4	A-43B (MIL-EN82/EN82H or MIL-RN82/RN82H only)	6 and 8
7	S-8	S-3/3A [12/]	A-43B (MIL-EN82/EN82H or MIL-RN82/RN82H only)	7 and 8
8	S-8	S-2 S-1	A-43B (MIL-EN82/EN82H or MIL-RN82/RN82H only)	8 and 5
Austenitic stainless steel to ferritic materials/submerged arc				
1	S-8	S-11B S-11A S-11D S-11C	A-8B (MIL-309 or ER-309L or MIL-310 types with neutral flux only)	1 and 4
2	S-8	S-5 [12/] S-4	A-8B (MIL-309 or ER-309L or MIL-310 types only)	2 and 4
3	S-8	S-3/3A [12/]	A-8B (MIL-309 or ER-309L or 310 types only) with neutral flux	3 and 4
4	S-8	S-2 S-1	A-8B (MIL-309 or ER-309L or MIL-310 only) with neutral flux	4 and 1
5	S-8	S-11B S-11A S-11D S-11C	A-43B (MIL-EN625, MIL-EN82, or MIL-EN82H with neutral flux only)	5 and 8
6	S-8	S-5 [12/] S-4	A-43B (MIL-EN82 or MIL-EN82H with neutral flux only)	6 and 8
7	S-8	S-3/3A [12/]	A-43B (MIL-EN82 or MIL-EN82H with neutral flux only)	7 and 8
8	S-8	S-2 S-1	A-43B (MIL-EN82 or MIL-EN82H with neutral flux only)	8 and 5

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Austenitic stainless steel to ferritic materials/flux-cored arc [17/]				
1	S-8	S-11B S-11A S-11D S-11C	A-8D (E309LT1-4 (or 1) or E309LNbT1-4 (or 1) or E310T1-4 (or 1) types only)	1 and 4
2	S-8	S-5 [12/] S-4	A-8D (E309LT1-4 (or 1) or E309LNbT1-4 (or 1) or E310T1-4 (or 1) types only)	2 and 4
3	S-8	S-3/3A [12/]	A-8D (E309LT1-4 (or 1) or E309LNbT1-4 (or 1) or E310T1-4 (or 1) types only)	3 and 4
4	S-8	S-2 S-1	A-8D (E309LT1-4 (or 1) or E309LNbT1-4 (or 1) or E310T1-4 (or 1) types only)	4 and 1
High alloy steel (duplex stainless) to ferritic materials/shielded metal arc processes				
1	S-10H	S-11A S-11C S-11D S-1 S-2	A-8A (MIL-309-XX or MIL-309L-XX types only)	1
High alloy steel (duplex stainless) to ferritic materials/gas tungsten arc, gas metal arc, and plasma arc processes				
1	S-10H	S-11A S-11C S-11D S-1 S-2	A-8B (MIL-309 or MIL-309L types only)	1
Copper-nickel and nickel base alloys/shielded metal arc				
1	S-34	S-34	A-34A	1 through 6
2	S-34	S-43 [14/]	A-43A or A-42A	2 through 6
3	S-34	S-42	A-42A or A-34A	2 through 6
4	S-42	S-42	A-42A	3 through 6
5	S-42	S-43 [14/]	A-43A or A-42A	5 and 6
6	S-43	S-43 [14/]	A-43A	6
Copper-nickel and nickel base alloys/gas metal arc, gas tungsten arc, and plasma arc				
1	S-34	S-34	A-34B	1 through 6
2	S-34	S-43 [14/]	A-43B or A-42B	2 through 6
3	S-34	S-42	A-42B or A-34B	2 through 6
4	S-42	S-42	A-42B	3 through 6
5	S-42	S-43 [14/]	A-43B or A-42B	5 and 6
6	S-43	S-43 [14/]	A-43B	6

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Copper-nickel and nickel base alloys to ferritic material/shielded metal arc				
1	S-34 S-42 S-43	S-11B S-11A S-11D S-11C	A-42A or A-43A [8/]	1 and 4
2	S-34 S-42 S-43	S-5 [12/] S-4	A-42A or A-43A [8/]	2 and 4
3	S-34 S-42 S-43	S-3 S-3A [12/]	A-42A or A-43A [8/]	3 and 4
4	S-34 S-42 S-43	S-2 S-1	A-42A or A-43A [8/]	4 and 1
Copper-nickel and nickel base alloys to ferritic materials/gas tungsten arc, gas metal arc, and plasma arc				
1	S-34 S-42 S-43	S-11B S-11A S-11D S-11C	A-42B or A-43B [8/]	1 and 4
2	S-34 S-42 S-43	S-5 [12/] S-4	A-42B or A-43B [8/]	2 and 4
3	S-34 S-42 S-43	S-3 S-3A [12/]	A-42B or A-43B [8/]	3 and 4
4	S-34 S-42 S-43	S-2 S-1	A-42B or A-43B [8/]	4 and 1
Copper-nickel and nickel base alloy to austenitic materials/shielded metal arc				
1	S-34	S-8	A-43A	1 through 3
2	S-42	S-8	A-43A	2 through 3
3	S-43	S-8	A-43A	3
Copper-nickel and nickel base alloy to austenitic materials/gas metal arc, gas tungsten arc, and plasma arc				
1	S-34	S-8	A-43B	1 through 3
2	S-42	S-8	A-43B	2 through 3
3	S-43	S-8	A-43B	3
Brass and bronze alloys/shielded metal arc				
1	S-32 S-37A	S-32 S-37A	A-37A	1

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Brass and bronze alloys/gas metal arc, gas tungsten arc, and plasma arc [7/]				
1	S-35 S-36A	S-35 S-36A	A-36B A-37B	1
2	S-36B	S-36B S-32 S-35 S-36A S-37A S-37B	A-37B	1 and 2
3	S-33	S-33 S-32 S-36A S-37A S-37B	A-32B	3
4	S-38	S-38 S-39 S-32 S-33 S-35 S-36A S-37A S-37B	A-32B A-33B	4
5	S-32 S-37A S-37B	S-32 S-37A S-37B	A-36B A-37B	5
Brass and bronze alloys/oxy-acet				
1	S-32 S-37A	S-32 S-37A	A-35B	1
Aluminum materials/gas metal arc, gas tungsten arc, and plasma arc				
1	S-22 S-25	S-22 S-25	A-22B or A-23B [15/]	1 through 3 [5/]
2	S-26	S-26 S-25 S-22 S-21	A-23B	2 through 3 [5/]
3	S-21	S-21 S-22 S-25 S-26	A-21B	3 [5/]
4	S-23	S-23	A-22B	4, 5, and 6

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification [1/, 2/, 6/] - Continued

Category	Base Material [3/]		Filler Material [10/]	Qualified for Categories [4/]
	A	B		
Aluminum materials/gas metal arc, gas tungsten arc, and plasma arc (continued)				
5	S-23	S-23	A-23B	5
6	S-23	S-22	A-22B	6
Titanium and titanium alloys/gas metal arc, gas tungsten arc and plasma arc				
1	S-53A	S-53A	A-53B-1	1 through 7
2	S-53A	S-53	A-53B-1 or A-53B [27/]	2 through 7
3	S-53	S-53	A-53B	3 through 7
4	S-53 S-53A	S-51 [26/] S-52 [26/]	A-51B	4 through 7
5	S-52	S-52	A-51B	5 through 7
6	S-52	S-51	A-51B	6 and 7
7	S-51	S-51	A-51B	7
Category	**Base Material [10/]**		**Stud Material [22/]**	**Qualified for Categories [4/]**
Stud welding				
1	S-11A [23/]		S-1	1 through 3
2	S-11C S-11D		S-1	2 and 3
3	S-1 S-2		S-1	3
4	S-11A [23/]		S-8 [24/]	4 through 6
5	S-11C S-11D		S-8 [24/]	5 and 6
6	S-1 S-2		S-8 [24/]	6
7	S-11A [23/]		S-11A [23/]	7 through 9
8	S-11C S-11D		S-11A [23/]	8 and 9
9	S-1 S-2		S-11A [23/]	9
10	S-11A [23/]		S-43 (UNS 06625 only) [25/]	10 and 12
11	S-11C S-11D		S-43 (UNS 06625 only) [25/]	11 and 12
12	S-1 S-2		S-43 (UNS 06625 only) [25/]	12

See footnotes at end of table.

Table 7-3. Grouping of Base/Filler Materials for Welding Procedure Cross-Qualification 1/, 2/, 6/ - Continued

NOTES:

1/ See 4-7 for limitations on applications for qualification coverage. Wherever PWHT is involved, the allowances of this table shall not apply, except for stress relief heat treatment of S-1, S-3, S-3A, S-4, or S-5 materials welded to themselves, and S-6 or S-6A materials welded to themselves or each other.

2/ Procedure qualification for any base metal/filler material combination within a material group or within the limits specified in this table shall constitute approval for repairing, build-up, and buttering. Requirements are also specified for corrosion-resistant cladding and hardfacing.

3/ Procedure qualification with any material listed in column A and with any material listed in column B qualifies all the material combinations in that category. For example, under category 6 for ferritic material/shielded metal arc, qualification of S-11B to S-1 or S-2 also qualifies S-11A to S-1 or S-2 (category 9) and categories 10, 11, and 16.

4/ Qualification of one material within an S-group qualifies for welding all materials in that S-group, except as restricted by 4-7.1.

5/ For groups S-21, S-22, and S-25, qualification covers only the qualified temper and tempers of lower strength.

6/ Base metal/filler metal combinations not listed in this table require separate procedure qualification; where material toughness is involved, see 4-7.2.a for additional restrictions on different A-groups.

7/ If S-36A material is to be post-weld temper-annealed, A-37B filler materials shall be used.

8/ Filler materials A-43A and A-43B apply only for S-43 base materials to materials in column B.

9/ The higher number A-group material qualifies the lower number A-group material, but not vice versa.

10/ In all instances where A-5A, B, or C filler materials are listed, the higher-strength materials are only qualified when the original qualification was performed using the same (or higher) strength filler material. For example, under shield metal arc, category 4, use of MIL-12018 would qualify MIL-12018 and MIL-10018 in category 5, but not MIL-14018. In this regard, MIL-10018-M1, MIL-11018-M, and MIL-10718-M filler materials are considered to have the same strength.

11/ Separate qualification of this category is required when the base material and filler material both have toughness requirements and thickness exceeds 1/2-inch.

12/ The higher number S-group material of this category qualifies the lower number S-group but not vice versa. For this purpose, S-3A is higher than S-3.

13/ MIL-11018 and MIL-10018 are equivalent for the purposes of this table.

14/ S-43, UNS number N06625 type material requires separate qualification.

15/ A-23B shall not be used for welding S-25 to S-25 or S-22 materials.

16/ For MIL-120 and MIL-140 series filler materials, see table 7-2, footnote 13.

17/ See table 7-2, footnote 15 for application limitations.

18/ For HY/HSLA-100 welded to themselves or each other, MIL-10018 shall not be permitted, and MIL-10718 is only permissible for production welding where specifically allowed by the governing fabrication document.

19/ This category also qualifies welding of these materials to HY-80, S-11C, S-2, and S-1 with MIL-12018 or MIL-120S, as applicable.

20/ For HY/HSLA-100 welded to themselves or each other, MIL-100S is only permissible for production welding where specifically allowed by the governing fabrication document.

21/ For HY/HSLA-100 welded to themselves or each other, MIL-101TC or MIL-101TM is only permissible for production welding where specifically allowed by the governing fabrication document.

22/ A stud material is within the indicated S-group when its specified chemical composition meets that of any other material in table 7-1 of the same group. Table 7-3 shall only apply to studs of a solid cylindrical shape at the section to be fused (see 4-7.2.l).

23/ HY-100 qualifies HY-80, but not vice versa.

24/ Alloy 310 and 310S stainless steel studs require separate qualification.

25/ The minimum tensile strength used for determining loading shall be 120,000 psi unless a different value is specified by the governing material specification from which the stud is made; in this case, that specification value shall apply.

26/ S-53 or S-53A materials shall not be welded to S-51 or S-52 materials without NAVSEA approval due to long-term hydride/cracking concerns.

27/ A-53B-1 qualifies A-53B, but not vice versa.

Table 7-4. Welding Procedure Qualification Position Limitation [2/, 5/, 6/, 7/]

Forms of Base Material Qualified	Welding Positions to be Qualified [1/] (Grooves and Fillets)	Test Positions Used During Qualification (See figure 7-1)			
		Using Plate [8/, 9/]		Using Pipe [8/, 9/]	
Plate, castings, and forgings	All positions	Vertical [3/]:	3G; 3F	Horizontal-fixed pipe (for socket test, vertical-fixed pipe also) [3/, 4/]:	5G; 5F and 4F
	Flat and vertical	Vertical:	3G; 3F	Horizontal-fixed pipe:	5G; 5F
	Flat and horizontal	Horizontal:	2G; 2F	Vertical-fixed pipe:	2G; 4F
	Flat and overhead	Overhead:	4G; 4F	Horizontal-fixed pipe (grooves), vertical-fixed pipe (fillets):	5G; 4F
	Horizontal (fillets only) and flat	Flat:	1G	Horizontal-rolled pipe:	1G
	Flat (fillets only)	Flat:	1F	45-degree inclined-rolled pipe:	1F
Pipe	All positions	Vertical [2/, 3/]:	3G	Horizontal-fixed pipe [3/, 4/]:	5G
	All positions, sockets/fillets only	--	--	Vertical and horizontal-fixed pipe:	4F and 5F
	Horizontal-fixed pipe, horizontal-rolled pipe, and 1F pipe (i.e., 45-degree inclined-rolled pipe, sockets/fillets)	Vertical [2/]:	3G	Horizontal-fixed pipe:	5G
	Horizontal-fixed pipe and 1F pipe, sockets/fillets only	--	--	Horizontal-fixed pipe:	5F
	Vertical-fixed pipe, horizontal-rolled pipe, and 1F pipe	Horizontal [2/]:	2G	Vertical-fixed pipe:	2G
	Vertical-fixed pipe, horizontal-rolled pipe, and 1F pipe, sockets/fillets only	--	--	Vertical-fixed pipe:	4F
	Horizontal-rolled pipe and 1F pipe	Flat [2/]:	1G	Horizontal-rolled pipe:	1G
	1F pipe, sockets/fillets only	--	--	45-degree inclined-rolled pipe:	1F

See footnotes at end of table.

Table 7-4. Welding Procedure Qualification Position Limitation [2/, 5/, 6/, 7/] - Continued

NOTES:

1/ For plate-type products, **welding positions** listed in this column are as defined by AWS A3.0M/A3.0. For pipe, illustrative pipe orientation positions are listed (e.g., "horizontal-fixed pipe" [which is qualified by a 5G/5F test position]); actual **welding positions** on pipe, as defined by AWS A3.0M/A3.0, qualified by the indicated pipe **test position** are as follows:

Pipe Test Position	**Qualified Welding Positions (subject to note 3 and, for sockets, 4-4.6.1.1)**
5G	All positions – grooves and sockets/fillets
4F & 5F	All positions – sockets/fillets
5F	Flat and vertical – sockets/fillets
2G	Flat and horizontal – grooves and sockets/fillets
4F	Flat, horizontal, and overhead – sockets/fillets
1G	Flat – grooves, and flat and horizontal – sockets/fillets
1F (45-degree inclined-rolled)	Flat – sockets/fillets

2/ For robotic, automatic, and mechanized pipe welding, qualification shall be performed on pipe or other cylindrically shaped material forms listed in table 7-4 except as specified in 4-4.1.10.1.

3/ For semi-automatic gas metal arc welding using the pulsed spray arc or short-circuiting arc mode, the horizontal position for plate (2G or 2F, as applicable) and the vertical-fixed position for pipe (2G or 4F, as applicable) must also be run to qualify for all positions. However, only nondestructive testing as specified for level no. II qualification shall be required for the horizontal plate and the vertical-fixed position pipe. For socket welds, see 4-4.6.1.c. For cladding and hardfacing, see footnote 7(a)(1)(ii).

4/ The 45-degree inclined position (6G) may be substituted for the horizontal fixed pipe position.

5/ When welding in the vertical plane, in either plate or horizontal fixed pipe, welding shall be in the up direction (except in robotic/automatic pipe welding, where the direction of rotation required by the procedure, shall be qualified).

6/ See table 7-2, footnote 7.

(Footnotes continued on next page.)

Table 7-4. Welding Procedure Qualification Position Limitation 2/, 5/, 6/, 7/ - Continued

NOTES (continued):

7/ (a) For cladding and hardfacing, groove weld test position designations (e.g., 3G, 5G) and positions qualified shall apply, except as follows:

(1) Qualification in the vertical position (3G), the inclined fixed position (6G), or the horizontal fixed position (5G) shall qualify for all positions provided:

(i) Vertical uphill weld progression is involved, and

(ii) For semi-automatic gas metal arc welding using the pulsed spray arc or short-circuiting arc mode, the 2G position for plate and pipe shall also be welded to qualify for all positions.

If vertical uphill welding is not used (e.g., for the 3G position, and at least the 3 or 9 o'clock location for the 5G or 6G position), then only the position welded and the flat position are qualified.

(2) Qualification on a cylindrical product is required for welding of shafting of all sizes (unless otherwise approved by NAVSEA) and for other cylindrical products 24 inches OD and less (see figure 7-5, note 4). Pipe of the correct alloy and of necessary thickness may be used to qualify solid cylindrical products. Welding of cylindrical products qualifies plate type products.

(b) For tube-to-tubesheet and tube-to-header seal welding, a change in the position of welding from that used for qualification (see figure 7-1) shall require requalification.

(c) An activity performing production welding in a particular orientation may make the tests in this particular orientation. Such qualifications are valid only for the position actually tested, except that an angular deviation of ±15 degrees is permitted in the inclination of the weld axis and the rotation of the weld face.

(d) For stud welding, qualification positions shall be per 4-4.4.1.

8/ For automatic robotic welding, see 4-4.1.10.3.a for additional positions to be welded and only NDT inspected.

9/ The indicated fillet or socket weld test positions (e.g., 3F, 5F) shall apply when qualifying fillet or socket welds only. Plate fillet tests do not qualify socket welds, and groove tests only qualify thicker socket welds (see 4-4.1.11 and 4-4.6.1.1). For fillet welding over primer, the 2F position shall be tested per figure 7-9, note 3 for all position qualification.

Table 7-5. Essential Elements of a Welding Procedure [12/]

	Arc Welding [1/]			Fuel Gas Welding
	Manual	Semi-Automatic	Robotic, Automatic, and Mechanized [3/]	
Base material [5/, 7/] Specification and type or class or chemical analysis, thickness, and condition; application per 4-3.1.1	X	X	X	X
Filler material Specification and type, diameter and form (wire, strip, powder, insert) For fillet welding over primer, the primer manufacturer, manufacturer's designation, and maximum thickness	X	X	X	X
Flux Specification, size, type	--	X	X	X
Base material cleaning	X	X	X	X
Applicable joint designs (reference or sketches)	X	X	X	X
Process [8/]	X	X	X	X
Arc-metal transfer mode [10/]	--	X	X	--
Machine, model or type for welding power supply and, as applicable, wire feeder and, for SAW, weld head	X (where [1/](b) or [11/] apply)	X	X	--
Electrical characteristics [6/, 11/] current, arc voltage range, polarity	X [2/]	X	X	--
Travel speed	-- [6/]	-- [6/]	X	--
Position (including progression vertical-up or -down)	X	X	X	X
Torch make and model	X [4/]	X	X	X (torch tip size only)
Torch shielding gases Type and flow rates	X [4/]	X	X	--
Purge gases Type and flow rates	X	X	X	--
Postheat treatments, holding times, and temperatures	X	X	X	X
Preheat and interpass temperature limits	X	X	X	X
Deposition method (weave vs stringer) and max. bead width	X [9/]	X [9/]	--	--
Oscillation (see 3-2.11) (amplitude, and frequency and dwell)	X [9/]	X [9/]	X	--

See footnotes at end of table.

Table 7-5. Essential Elements of a Welding Procedure [12/] - Continued

	Arc Welding [1/]			Fuel Gas Welding
	Manual	Semi-Automatic	Robotic, Automatic, and Mechanized [3/]	
Torch position (relative off-set from vertical center-line in horizontal-rolled position)	--	--	X	--
Electrode lead or trail angle (wire feed angle)	--	--	X	--
Gas cup size	X (GTAW only)	X	X	--

NOTES:

[1/] The following shall also be specified as essential elements:
- (a) Details of current slope, if used.
- (b) For the gas tungsten arc process:
  - (1) Detailed description of pulsed welding current, if used, including all pulsed current and voltage parameters that can be varied by adjustment of pulsed power supply controls; manufacturer and model number of pulsed power supply.
  - (2) Tungsten electrode diameter and type.

  Where applicable, see footnote 11.
- (c) For the gas metal arc process, a description of pulsed welding, if used, including current and average voltage and, if welding equipment permits monitoring and independent control, peak pulse voltage and pulse frequency. Where applicable, see footnote 11.
- (d) For semi-automatic welding, filler metal feed rate, except when feed rate is controlled by amperage and amperage is set by the welder.
- (e) Trade name (i.e., manufacturer and manufacturer's designation) and generic description of ceramic or non-metallic backing material, if used.
- (f) For hot wire feed, the hot wire amperage and voltage.
- (g) For robotic, automatic, and mechanized welding:
  - (1) Filler material feed rate;
  - (2) Type of arc length or voltage control;
  - (3) For gas metal arc and flux-cored arc, the gas cup to work distance and contact tube to work distance; and
  - (4) For submerged arc welding, the contact tube to work distance.
- (h) For welds in S-51, S-52, S-53, and S-53A materials:
  - (1) Trailing shield description (including materials);
  - (2) Shielding gas or mixture;
  - (3) Minimum purity and dew point(s) of shielding gas(es); and
  - (4) Flow rates in torch, trailing, and backing shields.
- (i) For S-51, S-52, S-53, and S-53A materials, a statement of workmanship standards including welding environment, material (filler wire, tools, etc.) storage and handling, and in-process quality control.
- (j) For weld cladding and hardfacing procedures, all parameters corresponding to each of the items of 4-7.9 and 4-8.p and weld bead overlap. For manual and semi-automatic welding, deposition technique (stringer or dimensioned weaving) shall also be specified. Any essential element that differs from one layer to another shall be specified on a per-layer basis; also see figure 7-4, note 5(c) if dilution testing is used for qualification.
- (k) For plasma arc welding, (1) plasma arc gas flow rate and composition; (2) powder metal feed gas flow rate and composition; (3) arc type (i.e., transferrable or nontransferable); (4) diameter of arc constricting orifice; (5) type and model of welding equipment; (6) type and size of electrode; (7) for robotic, automatic, and mechanized welding, electrode spacing; (8) powder metal size; and (9) description of keyhole technique when employed.
- (l) For procedures involving S-44 materials, all parameters corresponding to each item of 4-7.8.f and 4-8.p shall also be considered essential elements specified in the welding procedure when applicable.

[2/] Except for arc voltage.

(Footnotes continued on next page.)

Table 7-5. Essential Elements of a Welding Procedure [12/] - Continued

NOTES (continued):

[3/] For all automatic, mechanized, and robotic welding, any machine setting, when used alone to control the process parameters, shall be specified in the procedure and, for pipe welding, the settings for each pipe size to be welded in production shall be required. For robotic welding, the following shall also apply:
(a) A robotic welding equipment specification describing each part of the robotic welding cell and its function shall be included in the welding procedure. The robotic welding equipment specification shall include the robot, robotic controller (including software version), welding power source, wire feeder, torch type and neck angles, welding leads and cable bundle lengths, fixturing and tooling, positioners (including coordinated motion where applicable), filler wire form (e.g., spool or drum), and vision system, if applicable. Equipment manufacturer and model number shall also be included in the procedure.
(b) A description of the robotic welding program selection and execution protocol shall be included in the procedure.
(c) Any controls used to adjust or monitor the welding process in real-time (e.g., joint finding and adaptive controls), either automatically or through operator intervention, shall be specified in the procedure along with a description of its use in the welding process.
(d) For automatic robotic welding, a list of each joint type to be welded in production (see 4-5.4). The certified first article test record (see 4-6.1.2) for each joint type shall also be referenced in the welding procedure.

[4/] For plasma arc process and gas tungsten arc process.

[5/] See base material restriction in table 7-7, footnote 2. The welding procedure shall specify this restriction for each specific material affected. For fillet welding over primer, the primer manufacturer, manufacturer's designation, and maximum thickness.

[6/] Heat input requirements shall be specified for base materials with toughness requirements. Combination limits of amperage, voltage, and travel speed shall be specified for the ranges of each parameter (see 4-4.1.13.2). Equivalent means of limiting heat input (for example, nomographs or, for shielded metal arc, bead length methods) are permissible. Simple reference to a formula is unacceptable. Requirements for heat input shall comply with the applicable fabrication document in all cases.

[7/] For S-51, S-52, S-53, and S-53A materials, details of how joints, including weld repair excavations, are prepared; this includes permissible means of base metal cutting, machining, and grinding; description of machining and grinding tool bits; and interpass cleaning techniques and equipment.

[8/] Where qualification is by autogenous or single pass welding, these conditions shall be specified as applicable.

[9/] Weaving or stringer bead deposition shall be an essential element, and if weaving is permitted where toughness testing is required by table 7-7, footnote 2, maximum bead width shall also be an essential element.

[10/] It is the activity's responsibility to ensure the extent of the operating ranges do not alter the transfer mode that is qualified.

[11/] For waveform controlled welding, specify the welding power supply manufacturer, manufacturer's model number, and program identification (see 4-8.r).

[12/] For joints where temperature control away from the joint is required, heat input range, interpass temperature, electrode size, amperage, voltage (except SMAW), bead length (if used), and minimum distance of the weld from the temperature control point shall be specifically identified for each thickness and position of base material to be welded. Requirements for monitoring temperature at the area to be protected and the maximum temperature shall also be specified.

[13/] For welding on TCA (see 3-2.18) members, the essential elements specified by D-1.4.1 shall apply for all procedures.

Table 7-6. Welding Procedure Qualification Material Thickness and Diameter Limits [1/, 2/, 4/, 7/, 8/, 9/, 10/, 11/, 12/, 14/]

Test Material Thickness (T)		Thickness Qualified
Pipe [3/, 13/, 14/, 15/]		
Less than 0.058 inch		T to 2T
0.058 inch, up to and including 3/8 inch		0.058 inch to 2T [6/]
Greater than 3/8 inch		0.120 inch to 1.0 inch or 2T, whichever is greater [6/]
Other [3/, 5/, 15/]		
1/8 inch and less		T or 0.058 inch, whichever is less, to 2T
Greater than 1/8 inch but less than 3/4 inch		1/8 inch to 2T
3/4 inch and greater but less than 3 inches		3/16 inch to 2T
3 inches, up to and including 6 inches		3/16 inch to 8 inches
Greater than 6 inches		3/16 inch to 1.33T
Stud Welding Base Material (each stud diameter requires qualification; see 4-4.4**)**		
Aluminum:	T ≥ d/2 (d=stud base diameter)	d/2 to unlimited
	T< d/2	T to unlimited
Materials except aluminum:	T ≥ d/3	d/3 to unlimited
	T< d/3	T to unlimited

NOTES:

1/ When qualifying pipe using plate test assemblies, the test material thickness and qualified thickness limits specified for pipe shall govern. When qualifying plate using pipe test assemblies, the test material thickness and qualified thickness limits specified for plate shall govern.

2/ T is nominal thickness. For clarification, the thickness limits (T) are as follows:

(a) Butt joint: T is the nominal thickness of the pipe or plate. For materials of different thicknesses, T is the nominal thickness of the thinner member.

(b) Fillet and socket joint: For sockets, T is the thickness of the pipe wall; see footnote 6. For fillets, see footnote 10.

(c) Full penetration tee joint: T is the thickness of the web member.

(d) Pipe boss and partial penetration tee or butt joint: T is the depth of the groove. If the weld from the second side overlaps that of the first side, T is the thickness of the web member or the butt joint member.

(e) Hull penetration: T is the thickness of the hull plate.

(f) Weld deposited pads, and repairs/build-up: T is the depth of the weld deposit; however, there is no lower thickness limit.

(g) For weld cladding and hardfacing, separate qualification limits shall apply for base metal thickness and weld thickness; minimum and maximum qualified thicknesses for each shall be per figure 7-4 for cladding and figure 7-6 for hardfacing. Also, see footnote 14 for cylindrical product diameter.

(Footnotes continued on next page.)

Table 7-6. Welding Procedure Qualification Material Thickness and Diameter Limits 1/, 2/, 4/, 7/, 8/, 9/, 10/, 11/, 12/ - Continued

NOTES (continued):

(h) For buttering beneath cladding or hardfacing, there are no thickness limits, but see 4-4.2 for qualified number of layers. For other buttering, T shall be as follows:

(1) For buttered inlays (e.g., for tee joints, an inlay in the flange interfacing with the web), T shall be the thickness of the inlay.

(2) For all other cases, T is the thickness of the buttered joint member.

(i) For lock welds on pressurized thin material, see 4-4.9.

3/ Not applicable to root layer qualification (see 4-4.1.5) or to autogenous welds (see 4-4.5).

4/ The maximum thickness qualified shall be 1.10 times the thickness of the test assembly for any of the following conditions:

(a) When the weldment requires quenching and tempering.

(b) When single pass welding is used for full penetration groove welds.

(c) When weld pass thickness is greater than 1/2 inch.

(d) When the short circuiting mode of gas metal arc welding is used for groove welds; for fillet welds, the 1.1 upper limit shall apply to base metal thickness and weld throat thickness.

(e) When ferrous base metals (except S-7 and S-8) are subjected to PWHT exceeding the upper transformation temperature.

5/ "Other" includes all material other than pipe (such as structural plate, shapes, and castings) except for stud welding.

6/ For socket and fillet seal welds (other than robotic, automatic, or mechanized) on pipe with wall thicknesses in the range of 0.058 to 3/16 inch, the minimum wall thickness qualified shall be the greater of 0.058 inch or 20 percent below the pipe wall thickness welded and maximum thickness shall be 2T; for robotic, automatic, and mechanized welding, see footnote 13 below.

7/ See 4-4.1.15 for qualified thickness where multiple processes are used on one joint.

8/ When the production application is for thicknesses of 1/2 inch and greater and the material is one requiring impact testing (such as S-11 materials), the qualification test assembly shall be of a sufficient thickness and size to permit preparation of impact test specimens (see table 7-7, footnote 2).

9/ Where qualification is performed on a base material without toughness requirements and cross-qualification is permitted for materials having toughness requirements, welding of the materials with toughness requirements shall be limited to material thicknesses less than 1/2 inch when greater thicknesses are otherwise qualified.

10/ Qualified sizes and base metal thicknesses for fillet welds are as follows:

(a) Groove and socket welds and fillet welds per 4-4.1.11 and 4-4.1.12 qualify all sizes of fillet welds and fillet weld base metal thickness of 0.058 inch and greater.

(b) Fillet weld base metal thickness may be extended below 0.058 inch by completing a groove, socket, or fillet weld test of the production thickness (with maximum qualified fillet weld base metal thickness equal to twice the thickness welded).

11/ For S-10H materials, the maximum and minimum qualified thickness shall be the thickness used during qualification; maximum qualified thickness shall be the thickness used during qualification up to 1.5 inches, and for qualification plate thicknesses of 1.5 inches and greater, the thickness limits of this table for other materials shall apply. See also 4-7.5.f.

12/ For welds in S-51, S-52, S-53, and S-53A materials made outside of a chamber, the maximum thickness qualified below 2 inches is twice the thickness of test plate or depth of groove, whichever is smaller, welded during qualification. Qualified thicknesses 2 inches and above require that the test plate be at least 90.9 percent of the maximum thickness to be welded.

(Footnotes continued on next page.)

Table 7-6. Welding Procedure Qualification Material Thickness and Diameter Limits [1/, 2/, 4/, 7/, 8/, 9/, 10/, 11/, 12/] - Continued

NOTES (continued):

[13/] For robotic, automatic, or mechanized welding of pipe groove and socket joints, the following shall apply (see 4-4.1.10.1 and 4-7.1.b):

(a) Maximum thickness and OD qualified is T and the OD welded or, if OD is 5 inches or greater and wall thickness is 3/8 inch or greater, the following shall apply:

(1) 1.1T and all ODs 5 inches and greater, except as specified for (2).

(2) For 1G and 1F welds, 2T, and all ODs 5 inches and greater.

(b) Minimum thickness and OD qualified is T and the OD welded for ODs less than 5 inches or T less than 3/8 inch, and for a welded OD/T combination exceeding 5 inches and 3/8 inch, 5 inches OD and 3/8 inch thickness shall be the minimum qualified.

(c) Welding of a small pipe and a large pipe shall qualify thicknesses and ODs in between.

(d) For certain flat position welds per 4-4.1.10.1.1, the limits of (a) and (b) above do not apply and the rest of this table shall govern; for example, a 1.5-inch OD, 0.10-inch wall 2G test weld qualifies as follows:

(1) Thicknesses of 0.058 – 0.20 inch for flat position longitudinal pipe welds 2-7/8 inch OD and greater, and flat position pipe girth welds over 24 inches OD, and

(2) 0.10-inch thickness and 1.5 inch OD for 2G welds and flat longitudinal or girth welds.

[14/] Diameter limits for cladding and hardfacing of cylindrical products shall be per table 7-4, footnote 7(a)(2) and figure 7-5, note 4.

[15/] For base materials requiring toughness testing by table 7-7, footnote 2 (including thicknesses 0.058 to 1/2 inch), minimum base metal thickness qualified shall be T or 5/8 inch, whichever is less, except that, where T is less than ¼ inch, minimum qualified thickness shall be 1/2T or 0.058 inch, whichever is greater. These limits do not apply to S-11A, S-11C, and S-11D materials, or where PWHT is above the upper transformation temperature (or when an austenitic or S-10H material is solution annealed).

Table 7-7. Welding Procedure Qualification Assembly Test Requirements

Material Types	S-Number Group	Destructive Testing 1/, 2/, 3/, 4/, 5/, 14/, 15/			Nondestructive Testing 15/, 16/, 19/, 21/			
		Tensile 6/	Guided Bends 7/	Macro-Etch 8/, 13/	Radio-graphic	Liquid Penetrant	Magnetic Particle	Ultrasonic 20/
Carbon-steel	S-1	2	3	--	X	--	X	X
Quenched and tempered carbon-steel	S-2	2	3	--	X	--	X	X
Carbon molybdenum steel	S-3	2	3	--	X	--	X	X
Alloy steels	S-3A	2	3	--	X	--	X	X
	S-4	2	3	--	X	--	X	X
	S-5	2	3	--	X	--	X	X
High alloy steels	S-6	2	3	--	X	--	X	X
	S-6A	2	3	--	X	--	X	X
	S-7	2	3	--	X	--	X	X
	S-8	2	3	--	X	X	--	--
	S-10H 22/	2	3	--	X	X	--	--
Quenched and tempered alloy steel	S-11A	2	3	--	X	--	X	X
	S-11B	2	3 9/	--	X	--	X	X
Age hardening alloy steels	S-11C	2	3	--	X	--	X	X
Age hardening alloy steel HSLA-100	S-11D	2	3	--	X	--	X	X
Age hardening alloy steel HSLA-115	S-11E	23/	23/	--	23/	--	23/	23/
Low alloy steels	S-11F	2	3	--	X	--	X	X
Aluminum and aluminum base alloys	S-21	2	3	--	X	X	--	--
	S-22	2	3	--	X	X	--	--
	S-23	2	3 24/	--	X	X	--	--
	S-25	2	3	--	X	X	--	--
	S-26	2	--	2	X	X	--	--
Copper and copper base alloys	S-31	2	3	--	X	X	--	--
	S-32	2	--	2	X	X	--	--
	S-33	2	--	2	X	X	--	--
	S-34	2	3	--	X	X	--	--
	S-35	2	--	2	X	X	--	--
	S-36A	2	3	--	X	X	--	--
	S-36B	2	--	2	X	X	--	--
	S-37A	2	--	2	X	X	--	--
	S-37B	2	--	2	X	X	--	--
	S-38	2	--	2	X	X	--	--
	S-39	2	3	--	X	X	--	--
Nickel and nickel base alloys	S-42	2	3	--	X	X	--	--
	S-43	2	3	--	X	X	--	--
	S-44	2	3	--	X	X	--	--

See footnotes at end of table.

Table 7-7. Welding Procedure Qualification Assembly Test Requirements - Continued

Material Types	S-Number Group	Destructive Testing 1/, 2/, 3/, 4/, 5/, 14/, 15/			Nondestructive Testing 15/, 16/, 19/, 21/			
		Tensile 6/	Guided Bends 7/	Macro-Etch 8/, 13/	Radio-graphic	Liquid Penetrant	Magnetic Particle	Ultrasonic 20/
Titanium and titanium alloys	S-51	2	3 17/	2	X	X	--	--
	S-52	2	3 17/	2	X	X	--	--
	S-53	2	3 17/	2	X	X	--	--
	S-53A	2	3 17/	2	X	X	--	--
Dissimilar metals	--	2	1 10/	2	X	X	--	--
Weld cladding, corrosion-resisting 11/	--	--	2, 3 (for pipe/ shafting)	2, 3 (for pipe/ shafting)	--	X	--	--
Hardfacing, wear resisting 12/	--	--	--	3	--	X	--	--
Manual tube-to-header welds 18/	--	--	--	18/	--	X	X	--
For other than groove welds and those not listed above (fillet, socket, stud, tube-to-tubesheet, and lock welds, etc.)	See applicable portions of 4-4.							
For friction stir	See Appendix A.							

NOTES:

1/ The mechanical properties of test weldments for cast materials shall meet the minimum requirements of the applicable base material specification, except when the base material is shown, by actual testing, to have lower values. In this case, these lower values may be used to evaluate and accept the mechanical property test results of the weldment, provided:
(a) The actual tensile properties of the weldment are equal to at least 90 percent of the values in the applicable base material specification.
(b) The bend angle of the test weldment specimen is equal to or greater than that attained with the base metal test specimen.

2/ Charpy V-notch (CVN) impact tests shall be performed under any of the following conditions:
(a) For production welding of material 1/2 inch or greater in thickness when both the base metal specification and the filler metal specification have impact requirements (except when the production application is for weld cladding).
(b) For production welding of material 1/2 inch or greater in thickness in bimetallic joints where both base metals and the filler metal specifications have impact requirements.
Where qualification was performed on base material without specified toughness requirements and cross-qualification is permitted for materials having toughness requirements, welding of materials with toughness requirements shall be limited to 1/2 inch or less in thickness.
(c) When specified by the fabrication document or governing specification.
(d) For production welding of S-53A materials 1/2 inch or greater in thickness, unless otherwise approved by NAVSEA. Toughness test, test method, temperature, and acceptance criteria shall be as approved by NAVSEA.

3/ See 4-4.6 and 4-4.8.1.

4/ When required for the testing of specimens taken from thick test assemblies, the reduced section tensile specimens and the side bend specimens shall be cut into multiple specimens as permitted by AWS B4.0.

(Footnotes continued on next page.)

Table 7-7. Welding Procedure Qualification Assembly Test Requirements - Continued

NOTES (continued):

5/ When CVN impact tests are required by footnote 2 above, sets of five impact specimens shall be prepared from the weld metal, sets of three impact specimens shall be prepared from the HAZ of each base metal, and sets of three impact specimens shall be prepared from the unaffected area of each base metal. Base material and HAZ impact test data are not required for S-11 (HY-80/100 or HY-130 or HSLA-80/100 only) or S-1 MIL-S-22698 materials, except that such testing is required for MIL-S-22698, grades D, E, AH36, DH36, and EH36 for heat inputs greater than 109 kilojoules/inch; base metal and HAZ testing for S-53A are also not required when approved by NAVSEA. When more than one set of specimens for the weld metal is required, each set shall represent a different weld depth level with one set taken from the test assembly midthickness (1/4T for double bevel joints). When double beveled butt weld test assemblies are employed, weld metal impact specimens shall be removed from each side of the joint (i.e., at least two specimens from each side). Specimens shall be prepared as specified below:

Thickness	Minimum Sets of Specimens			Minimum No. of Specimens		
	Weld	HAZ	B.M.	Weld	HAZ	B.M.
½ to 2 inches, incl.	1	1	1	5	3	3
Over 2 to 4 inches, incl.	2	1	1	10	3	3
Over 4 inches	3	1	1	15	3	3

Base metal and HAZ specimens shall be prepared in accordance with figure 7-24.

6/ Tensile tests shall be transverse weld tensile specimens (round or reduced section). For S-11 materials welded to themselves or to each other and S-51, S-52, S-53, and S-53A base materials welded to themselves or to each other, and which are 3/4 inch and over in thickness, tensile tests shall include two transverse weld tensiles and two all-weld metal tensiles; when double bevel butt weld test assemblies are employed, one all-weld metal tensile specimen shall be removed from each side.

7/ When side bends are required for a given material and the test thickness is less than ¾ inch, two root bends and two face bends may be tested in lieu of side bends. If the procedure is for full penetration joints welded from one side without backing rings or preplaced inserts, root bends with the root surface in the as welded condition (i.e., no machining, grinding, etc.) are required when the root is welded without the addition of filler metal or without internal inert gas purge.

8/ Macro testing shall be per 4-5.2.6.

9/ Use a 3T bend for S-11B base material.

10/ See 4-4.1.3.1.

11/ Liquid penetrant (PT) inspection required (see 4-4.2.1) prior to destructive testing. Chemical testing for composition (or dilution evaluation when permissible) shall be performed per figure 7-4. Three macro-etch specimens and three bend specimens are required for pipe or other cylindrical product welds.

12/ Hardness testing is required for hardfacing and shall be as specified in figure 7-6. Chemical testing shall be performed only when specified in the applicable fabrication document or drawing.

13/ To perform qualification for root layer deposition and for depositing previously qualified fill procedures on root layers, in accordance with 4-4.1.4, four macro-etch specimens shall be examined and shall meet the requirements of 4-5.2.6 in lieu of RT, tensile, and bend tests; VT and MT/PT per this table also apply. If the procedure is for full penetration joints welded from one side without backing rings or preplaced inserts, root bends with the root surface in the as-welded condition (i.e., no machining, grinding, etc.) are required (in addition to the macro-etch specimens) when the root is welded without the addition of filler metal or without internal inert gas purge.

14/ Dynamic tear testing as specified in ASTM E604 may be substituted for CVN testing when the material specification (base or filler) or fabrication document provides for dynamic tear testing.

15/ Only VT and PT examination of the weld surface and two macro-etch specimens in accordance with 4-5.2.6 shall be required where test assembly thickness is 0.058 inch or less.

16/ VT inspection of all test assemblies shall be performed prior to other nondestructive testing. NDT shall be per 4-5.

17/ For S-51, S-52, and S-53A materials, bend radius shall be determined in accordance with AWS B4.0 using minimum base metal elongation. For S-53 materials, the bend radius shall be 8T.

18/ See 4-4.8.

19/ Inspect 100 percent of weld when RT or UT inspection is specified, except as permitted by 4-5.1.

20/ UT inspection shall be performed on material 1 inch thick and greater in accordance with 4-5.

(Footnotes continued on next page.)

Table 7-7. Welding Procedure Qualification Assembly Test Requirements - Continued

NOTES (continued):

21/ Use of the gas metal arc-short arc process for groove weld qualification of any material except S-8 shall require UT inspection of the test assembly in addition to all other tests and inspections. Where thickness is below that allowed by NAVSEA T9074-AS-GIB-010/271 for normal UT inspection and for S-8 materials, six transverse macro-etch specimens shall be substituted for UT inspection.

22/ In addition to the tests specified in this table, weld procedure qualification tests shall include a microsection of representative weld metal to be examined for ferrite content, which shall be in the range of 25-60%. This microsection shall be taken as close as practicable to the top centerline of the test weld. An additional transverse microsection shall also be examined for the presence of sigma phase in the weld metal and the base metal HAZ, the proportion of which is to be reported for information. These welds may be used for the qualification of magnetic or eddy current instruments which may then be used for the determination of production weld ferrite content.

23/ Qualification requirements shall be as approved by NAVSEA.

24/ For S-23 materials, root and face bends shall be employed. Four side bends may be substituted for root and face bends when base material thickness is greater than 3/8 inch. Wrap around guided bend testing shall be employed for all specimens and the mandrel radius shall be 6T maximum, where T is the thickness of the test specimen.

Table 7-8. Grouping of Filler Metals and Process Combinations for Welder or Welding Operator (Performance Qualification) [1/]

Category [2/]	Filler Metal Group [5/]	Category for Which Tests Qualify Welder [3/]
Shielded Metal Arc		
1	A-5A [7/, 8/]	1 through 3
2	A-2A, 3A, 4A, 6A, 7-A-1, 7-A-2 [8/]	2 and 3
3	A-1A [8/]	3
4	A-8A, A-9A	4
5	A-34A, 41A, 42A	5
6	A-43A (all except MIL-1N12)	6
7	A-43A (MIL-1N12 only), 45A	7, 6, 5 [9/], and 4 [9/]
Gas Metal Arc 6/		
1	A-5B [7/]	1 through 2
2	A-1B, 2B, 3B, 6B, 7-B-1	2
3	A-8B, A-7B-2, A-9B	3
4	A-34B, 41B, 42B	4
5	A-43B (all except MIL-EN625)	5
6	A-43B (MIL-EN625 only), 45B	6, 5, 4 [9/], and 3 [9/]
7	A-31B, 32B, 33B, 35B, 36B, 37B	7
8 [4/]	A-21B, 22B, 23B, 24B	8
9	A-51B, A-53B, A-53B-1	9
Gas Tungsten Arc, Plasma Arc [6/]		
1	A-5B [7/]	1 through 2
2	A-1B, 2B, 3B, 6B,7-B-1	2
3	A-8B, A-43B (all except MIL-EN/RN625), A-7B-2, A-9B	3
4	A-34B, 41B,42B	4
5	A-43B (MIL-EN/RN625 only), 45B	5, 4 and 3
6	A-31B, 32B,33B, 35B, 36B, 37B	6
7 [4/]	A-21B, 22B, 23B, 24B	7
8	A-51B, A-53B, A-53B-1	8
Submerged Arc [6/]		
1	A-5C [7/]	1 through 4
2	A-2C, A-3C	1 through 4
3	A-8B	1 through 4
4	A-34B, A-41B, A-42B, A-43B	1 through 4
5	A-7B-2	1 and 5
Flux-Cored Arc [6/]		
1	A-5D	1 and 2
2	A-2D, A-3D	1 and 2
3	A-8D	3

See footnotes at end of table.

Table 7-8. Grouping of Filler Metals and Process Combinations for Welder or Welding Operator (Performance Qualification) [1/] - Continued

NOTES:

1/ For hardfacing, a welder qualified on test number 9 with any hardfacing filler metal is qualified to hard surface using any filler metal within the limit of the welding process used for qualification.

2/ See 5-2.5.

3/ Welder and welding operator qualification within the filler metal categories shown in table 7-8 may be applied for welding similar, as well as dissimilar, base metal combinations with qualified welding procedures.

4/ On S-21 through S-26 base material.

5/ See table 7-2.

6/ For robotic, automatic, and mechanized welding, a welding operator qualified to weld with one filler material is also qualified to weld with all other filler materials in accordance with qualified procedures, using the same welding process and equipment.

7/ Welding personnel qualification requirements for MIL-120 and MIL-140 series filler materials shall be as approved by NAVSEA.

8/ The following groups of covered electrode types require separate qualification, except that (1) d qualifies a, b, c, and d; (2) c qualifies a and b; (3) b qualifies a. For welding of one-sided full penetration welds without backing, each group requires separate qualification, except that, where one qualification is obtained, additional groups can be qualified by performing the root pass plus one layer following table 7-10, footnote 3:

(a) XX20, XX24, XX27
(b) XX12, XX13, XX14, XX19
(c) XX10, XX11
(d) XX18

9/ For SMAW, category 7 qualifies categories 5 and 4 for buttering and cladding only and, for GMAW, category 6 qualifies categories 3 and 4 for buttering and cladding only. These allowances for cross-qualification of cladding and buttering shall not apply where composition testing is required by 5-3.4.c for the cross-qualified filler material.

Table 7-9. Performance Qualification – Position Limitations [1/, 5/, 8/, 9/]

Qualification Test		Position and Type Weld Qualified [1/, 4/, 6/, 7/, 8/]		
		Groove		Fillet
Weld	**Position**	**Plate and Pipe Over 24 Inches OD**	**Pipe**	**Plate and Pipe**
Plate – groove [3/]	1G	F	F [2/]	F, H [2/]
	2G	F, H	F [2/]	F, H [2/]
	3G	F, V	F [2/]	F, H, V [2/]
	4G	F, O	F [2/]	F, H, O [2/]
	3G and 4G	F, V, O	F [2/]	All [2/]
	2G, 3G, and 4G	All	F [2/]	All [2/]
Plate – fillet	1F	--	--	F [2/]
	2F	--	--	F, H [2/]
	3F	--	--	F, H, V [2/]
	4F	--	--	F, H, O [2/]
	3F and 4F	--	--	All [2/]
Pipe – groove [3/]	1G	F	F	F
	2G	F, H	F, H	F, H
	5G	F, V, O	F, V, O	All
	6G	All	All	All
	2G and 5G	All	All	All
Pipe – fillet/socket	1F	--	--	F
	2F	--	--	F, H
	2FR	--	--	F, H
	4F	--	--	F, H, O
	5F	--	--	F, V
	5F and 4F	--	--	All

NOTES:

1/ Test positions for qualification welding are as shown in figure 7-1. The following are the weld positions qualified and they are as defined in AWS A3.0M/A3.0.
F = Flat
H = Horizontal
V = Vertical
O = Overhead

2/ Pipe 2-7/8 inch OD and over. Plate fillet welds qualify fillet welds in structural pipe but not socket welds.

3/ Weld test positions for groove welds (e.g., 4G, 5G) shall also apply for surfacing.

4/ Including seal welds as allowed by 5-3.5.2.

5/ In special cases when production welding is to be done in a particular orientation intermediate to those shown in figure 7-1, the welder qualification may, if the organization desires, be made in an intermediate position with the limitation that the qualification shall be valid for the actual position tested with an angle tolerance of +15 degrees in incline to 0 degrees on the flat or horizontal axis.

6/ Tube-to-tubesheet welds shall be qualified in each position to be welded.

7/ Internal tube-to-header welds in boiler components shall be qualified in each position to be welded.

8/ The plasma arc process, using the keyhole technique, must be qualified for each position of welding to be used in production.

9/ When qualifying for welding in the vertical plane in either plate or horizontal fixed-pipe, welding shall be in the up direction. Welding vertical-down shall require separate qualification, except for root passes completely removed, and that for robotic, automatic, and mechanized welding, the 5G position pipe qualification employing 360-degree uninterrupted progression qualifies such progression for the passes involved.

Table 7-10. Performance Qualification Test Limitations [7/, 12/]

Form of Base Material Qualified	Thickness of Base Material to be Qualified	Required Qualification Test Assembly
Plate, castings, forgings, and shapes	0.058 inch and greater [1/]	Test no. 1 or 2 [9/] (figure 7-12 or 7-14)
Pipe [2/, 3/, 4/, 5/, 6/, 13/, 14/]	0.058 inch to 2T [1/]	Test no. 3 or 5 [9/] (figure 7-15 or 7-22)
	0.058 inch and greater	Test no. 4 or 6 [9/] (figure 7-15 or 7-22)
Pipe or plate (for tack and fillet welds only, not socket welds)	All thicknesses	Test no. 8 [8/, 12/] (figure 7-16)
Socket welds, seal welds, tube-to-tubesheet welds, and internal tube-to-header welds	[15/]	[15/]
Pipe or plate (for cladding, hardfacing, buttering)	T or 1 inch, whichever is less, to unlimited; for weld thickness, see footnote 16	Test no. 9 (figure 7-17 [plate] or 7-17A [pipe]) [17/]
Pipe or plate [10/]	[11/]	Test no. 10 (figure 7-26)
Friction stir (see Appendix A)	--	--

NOTES:

1/ Performance qualification for thicknesses under 0.058 inch may be accomplished by welding a thinner test piece similar to test number 1, 3, or 5, as applicable, using a qualified thickness range of T to 2T, where T is the test plate thickness. Also, performance qualification can be accomplished on thicknesses 0.058 inch or greater but less than the specified qualification test assembly thickness and the qualification range will be 0.058 inch to 2T.

2/ Welders qualified to either test number 3 or 4 or the fill portions of test number 5, 6, or 10 shall be considered qualified to weld (with the process employed) all types of pipe joints, except for:
(a) The root, or root plus one layer in preplaced filler metal insert root butt joints,
(b) Full penetration joints welded from one side with no backing ring or preplaced insert, and
(c) Joints requiring separate qualifications by 5-3.5 and 5-3.6.

3/ A welder or welding operator may perform only part of the preplaced filler metal insert or other root performance qualification test (i.e., just the root, root plus one layer or subsequent layers), but he or she shall be qualified only for that part of the insert joint actually made during qualification testing. Qualifications for welding the root only or root plus one layer are not subject to the thickness limitations of this table.

4/ Qualification test numbers 3 or 4 will qualify for root connections, fillets, bosses, and partial penetration welds, except for:
(a) The insert root or insert root plus one layer of preplaced filler metal insert root butt joints,
(b) All full penetration joints welded from one side with no backing ring or preplaced insert, and
(c) Joints requiring separate qualification by 5-3.5 and 5-3.6.

5/ Qualification test numbers 5 or 6 (i.e., insert root and fill portions) will qualify for use of the processes employed for all joint types, except for full penetration joints welded from one side with no backing ring or preplaced insert, and use of a different insert shape, and the welds addressed by 5-3.5 and 5-3.6.

6/ Qualification on a pipe test shall qualify the same thickness for plate welding.

7/ Qualified welders are also qualified as tack and fillet welders.

8/ Welders qualified on test number 8 are qualified as tack and fillet welders only (see table 7-9, footnote 2 for structural pipe size limit). For socket welds, see footnotes 12 and 15.

9/ For full penetration butt joints welded from one side with no backing or preplaced insert, the weld joint design used for performance qualification shall be that used for procedure qualification.

10/ Performance qualification test, no. 10 plasma arc welding, keyhole technique, will qualify other processes used for the remainder of the weld for all joint types, except for full penetration butt joints, welded from one side with a root gap and no backing ring or with a preplaced insert.

(Footnotes continued on next page.)

Table 7-10. Performance Qualification Test Limitations [7/, 12/] - Continued

NOTES:

11/ Qualification with joint-A, figure 7-26, qualifies plasma arc, keyhole technique welds on plate up to 1/4 inch thickness for square butt joints and up to 3/16 inch land for groove welds. Maximum plate thickness qualified with joint-B will depend on accessibility of plasma arc torch into weld groove. Weld groove can be modified to use a compound angle to permit plasma arc welding in plate thicknesses greater than 3/4 inch.

12/ Fillet welders are not qualified for socket welds. Tack welders and fillet welders are not qualified for tack welding socket welds on pipe with thickness less than 3/16-inch.

13/ For gas tungsten arc welding qualification using 1 inch NPS Sch 80, consumable insert assembly qualifies for all thicknesses 0.058 inch and greater.

14/ For robotic, automatic, and mechanized welding, qualification in either thickness range qualifies for thicknesses 0.058 inch and greater.

15/ (a) For required test assemblies, see 5-3.5 for tube-to-tubesheet welds, seal welds, and socket welds and 5-3.6 for tube-to-header seal welds for boiler components.

(b) For socket and fillet type seal welds performed with manual and semiautomatic processes on pipe with nominal wall thickness in the range of 0.058 to less than 3/16-inch, the following shall apply:

(1) The minimum thickness qualified shall be the greater of 20 percent below the nominal pipe wall thickness welded or 0.058 inch.

(2) For pipe sizes other than 1/2 inch NPS schedule 10 (see 5-3.5.1.d), weld test OD vs qualified OD (in inches) shall be as follows: <1 tested qualifies OD welded and greater; ≥1 but < 2-7/8 tested qualifies 1 and greater; ≥ 2-7/8 qualifies 2-7/8 and greater.

For mechanized, automatic, and robotic welding, any thickness less than 3/16 inch and any diameter shall be welded and shall qualify all thicknesses of 0.058 inch and greater, and all diameters. For all methods, where thickness is below 0.058-inch, the minimum qualified thickness is the nominal thickness welded. There is no maximum thickness limit for socket and fillet seal welds in pipe.

16/ T is the test base material thickness welded. For solid cylindrical products (shafting, etc.), pipe of the appropriate size can be used for qualification welding. Qualification limits for weld layers/thickness shall also apply as follows:

Production Weld Type	Minimum Qualified Weld Layers/Thickness (for Welding Operators see 5-6.2.h)	Maximum Qualified Weld Thickness
Hardfacing:		
For finish machined production welds at least 3/16 inch thick and 2 layers minimum	2 layers and 3/16 inch	2 times the weld thickness at which PT and macro testing are performed or 3/8 inch, whichever is greater.
For finish machined production welds not meeting the above criteria	The number of weld layers and thickness at which hardness testing is performed.	
Cladding, without composition testing (see 5-3.4.c), all:		
	N/A	N/A
Cladding with composition testing (see 5-3.4.c):		
For finish machined production welds at least 3/16 inch thick and 2 layers minimum	2 layers and 3/16 inch	N/A
For finish machined production welds not meeting the above criteria	The number of weld layers and thickness at which composition testing is performed.	N/A
Buttering, all:		
	N/A	N/A

17/ For cladding where composition is not required, and buttering, a butt weld test may be used.

Table 7-11. Performance Qualification Test Evaluation Requirements

Test Assembly	Evaluation Requirements 1/, 2/, 3/, 4/, 5/, 6/
Test no. 1 or 2A or 2B (figure 7-12 and 7-14)	Radiography or bend tests 9/, 10/
Test no. 3 or 3B (figure 7-15 or 7-13)	Radiography or bend tests 7/, 9/, 10/
Test no. 4 (figure 7-15)	Radiography or bend tests 7/, 9/, 10/
Test no. 5 (figure 7-22)	Radiography 7/, 9/
Test no. 6 (figure 7-22)	Radiography 7/, 9/
Test no. 8 (figure 7-16)	Break test
Test no. 10 (figure 7-26)	Radiography or bend tests 7/, 9/, 10/
Robotic, automatic, or mechanized pipe assembly	(a) Butt: radiography 7/, 9/ (b) Fillets: PT and two macro-etch specimens
Robotic, automatic, or mechanized plate assembly	Radiography 9/
Manual tube-to-header seal weld 8/ (figure 7-25)	Dye penetrant or magnetic particle and macro-etch examinations
Weld cladding, hardfacing, buttering test no. 9 (figure 7-17)	Macro-etch examination and dye penetrant; hardness per figure 7-17; composition per 11/ (see 5-3.4)
Special weld	As proposed in procedure qualification submittal 9/
Pipe socket welds, tube-to-tubesheet welds, seal welds	See 5-3.5
Lock welds	See 5-3.7

NOTES:

1/ VT inspection shall be made on each test assembly per 5-4.1. For titanium and titanium alloy welds, see 5-4.1.1. NDT shall be per 5-4.1.

2/ UT inspection in accordance with NAVSEA T9074-AS-GIB-010/271 may be substituted for RT inspection for plate welds. Acceptance criteria shall be per MIL-STD-2035, class I.

3/ See 5-2.5.

4/ RT of pipe shall be 360 degrees. RT of plates shall be performed along the entire length, except that 1 inch on each end of the weld will not be evaluated. Acceptance criteria shall be per MIL-STD-2035, class I.

5/ Use of the gas metal arc-short arc process for groove weld qualification of any material shall require UT inspection of the test assembly in addition to all other tests and inspections. Where thickness is below that allowed by NAVSEA T9074-AS-GIB-010/271 for normal UT inspection and for S-8 materials, six transverse macro-etch specimens shall be substituted for UT inspection.

6/ When the qualification test consists of root layer only or root plus one layer, four macro-etch specimens shall be evaluated to the requirements of 4-5.2.6 in lieu of RT or bend tests. When the joint is welded without addition of filler metal or without internal purge, root bends as described in footnote 7 are also required.

7/ When the qualification is for joints welded from one side without backing rings or preplaced inserts, root bends with the root surface in the as-welded condition (no machining, grinding, etc.) are required when the root is welded without the addition of filler metal or without internal inert gas purge.

8/ See 5-3.6.

9/ For welds in S-51, S-52, S-53, and S-53A materials:
(a) Bend tests shall be used in lieu of RT, except that both bend tests and RT are required for test no. 5 and 6 for joints welded from one side with no backing or consumable insert.
(b) Two macro-etch specimens separated by 90 degrees for pipe or 2 inches for plate are required for all joint types.

10/ For aluminum butt weld qualification, RT shall be employed, except for personnel exclusively welding non-critical sheet metal items (e.g., NAVSEA S9074-AR-GIB-010/278, class M-2C) where bend tests are acceptable.

11/ For cladding, where composition testing is required by 5-3.4, perform composition testing per figure 7-17, note 4.

Table 7-12. Material Combinations and Brazing Alloy Requirements [4/]

Material (P-no.)	Material (P-no.)					
	P-101 [2/]	**P-102** [3/]	**P-107** [2/]	**P-108** [1/]	**P-110** [2/]	**P-111** [3/]
P-101 [2/, 5/]	F-101	F-102	F-101	F-101	F-101	F-101
P-102 [3/, 5/]	F-102	F-102	F-102	F-102	F-102	F-102
P-107 [2/, 5/]	F-101	F-102	F-101 or F-103	F-101 or F-103	F-101	F-101
P-108 [1/, 5/]	F-101	F-102	F-101 or F-103	F-101 or F-103	F-101	F-101
P-110 [2/, 5/]	F-101	F-102	F-101	F-101	F-101	F-101
P-111 [3/, 5/]	F-101	F-102	F-101	F-101	F-101	F-101

NOTES:

1/ Aluminum bronze materials require special aluminum bronze brazing flux as specified in O-F-499, type A (Handy and Harman Special Flux Type A-1, or equal).

2/ Flux shall conform to type A or B or equivalent of O-F-499.

3/ Grade V alloy or another alloy containing 2 percent or more nickel shall be used for any brazed joint where one or both of the metals joined is stainless steel (see table 7-14, footnote 5).

4/ F-103 brazing alloys shall not be used on ferrous alloys, nickel base alloys, copper-nickel alloys containing more than 10% nickel, or stainless steel (see table 7-14, footnote 4).

5/ Where F-101 is listed, F-101A is included. Where F-102 is listed, F-102A is included.

Table 7-13. Grouping of Base Materials for Brazing Procedure and Performance Qualification [1/]

Group	Specifications	Type of Material
P-101	Ferrous alloys with chromium content less than 0.30 percent	
	ABS Steel Vessel Rules Part 2	Grade A Grade B Grade D Grade AH-36 Grade DH-36
	ASTM A27/A27M	Grade 60-30 Grade 65-35 Grade 70-36
	ASTM A36/A36M	Plates, shapes, and bars
	ASTM A131/A131M	Grade A Grade B Grade D Grade AH-36 Grade DH-36
	ASTM A216/A216M	Grade WCA Grade WCB
	ASTM A283/A283M	Grade B Grade C
	ASTM A285/A285M	Grade A Grade B Grade C
	ASTM A350/A350M	Grade LF1
	ASTM A352/A352M	LCA LCB
	ASTM A372/A372M	Type I/grade A
	ASTM A414/A414M	Grades A-G
	ASTM A515/A515M	Grade 55 Grade 60 Grade 65 Grade 70
	ASTM A516/A516M	Grade 55 Grade 60 Grade 65 Grade 70
	ASTM A537/A537M	Class 1 (plate)
	ASTM A562/A562M	Plate
	ASTM A569/A569M	Type A Type B Type C

See footnote at end of table.

Table 7-13. Grouping of Base Materials for Brazing Procedure and Performance Qualification [1/] - Continued

Group	Specifications	Type of Material
P-101 (Cont'd)	Ferrous alloys with chromium content less than 0.30 percent (continued)	
	ASTM A570/A570M	Grade 36
	ASTM A572/A572M	Grade 42 Grade 50
	ASTM A575	M 1008 M 1010 M 1012 M 1015 M 1017 M 1020 M 1023 M 1025
	ASTM A576	1008 1010 1012 1015-1023 1025
	ASTM A606/A606M	Type 2 Type 4
	ASTM A659/A659M	1015 1016 1017 1018 1020 1021 1023
	ASTM A662/A662M	Grade A (plate) Grade B (plate)
	ASTM A709/A709M	Grade 50W
	ASTM A727/A727M	Forging
	ASTM A765/A765M	Grade I
	ASTM A794/A794M	1015 1016 1017 1018 1020 1021 1023

See footnote at end of table.

Table 7-13. Grouping of Base Materials for Brazing Procedure and Performance Qualification [1/] - Continued

Group	Specifications	Type of Material
P-101 (Cont'd)	Ferrous alloys with chromium content less than 0.30 percent (continued)	
	ASTM A830/A830M	1006 1008 1009 1010 1012 1015-1023 1025
	ASTM A945/A945M [9/]	Grade 65 (also referred to as HSLA-65), (plate)
	ASTM A1008/A1008M	Grade CS, type A Grade CS, type B
	ASTM A1011/A1011M	Grade 36, type 1 Grade 36, type 2 Grade CS, type B
	MIL-S-15083	Grade 70-36 Grade 65-35 (cast) Grade CW Grade B
	MIL-S-22698	Carbon steel
	MIL-DTL-23194	Composition C
	MIL-S-23284	Class 3 Class 4
	MIL-S-24093	Carbon steel, types III-V
	MIL-S-24238	Composition C
	MIL-S-24412	Grade HT
	MIL-P-24691/1	Carbon steel
	MIL-DTL-24707/1	ASTM A757/A757M, grade A1Q, grade A2Q ASTM A216/A216M, grade WCA Grade WCB Grade WCC
	WW-P-404	Carbon steel
P-102	Ferrous alloys with chromium content 0.90 percent or greater	
	ASTM A240/A240M	Type 304, 316, 321, and 347
	MIL-P-24691/3	Type 304, 316, 321, and 347
	MIL-DTL-23195	Type 304 and 347
	MIL-DTL-23226	Type 304 and 347
	QQ-S-763, SAE AMS-QQ-S-763	Class 304, 316, 321, and 347
	QQ-S-766	Class 304, 316, 321, and 347

See footnote at end of table.

Table 7-13. Grouping of Base Materials for Brazing Procedure and Performance Qualification [1/] - Continued

Group	Specifications	Type of Material
P-107	Copper alloys with aluminum content less than 0.50 percent	
	ASTM B16/B16M	Brass, C36000
	ASTM B21/B21M	Naval brass, C46200, C46400, C48200, and C48500
	ASTM B36/B36M	Brass, C23000, C24000, C26000, C26800, C27200, and C28000
	ASTM B43	Red brass
	ASTM B88	Copper
	ASTM B121/B121M	Leaded brass, C35300
	ASTM B124/B124M	Naval brass, C46400, C48200, and C48500
	ASTM B138/B138M	Manganese bronze, C67500
	ASTM B139/B139M	Phosphor bronze, C51000, and C52400
	ASTM B271/B271M	Centrifugal casting alloys C90300, C90500, C92200
	ASTM B283/B283M	Naval brass, C46400, C48200, and C48500
	ASTM B505/B505M	Continuous casting alloys C90300, C90500, C90700, C91000, C91300, C92200, C94700, and C94800
	MIL-T-15005	Copper nickel
	MIL-C-15726	Copper nickel
	MIL-T-16420	Copper nickel
	MIL-T-20168	Brass
	MIL-T-20219	Brass
	MIL-T-24107	Copper
	QQ-B-626	Brass
	QQ-B-637	Naval brass
	QQ-B-639	Naval brass
	QQ-B-728 (class A)	Manganese bronze
	QQ-B-750 (compositions A and D)	Phosphor bronze
	MIL-T-24107	Copper
	WW-T-799	Copper
	QQ-C-390	Copper nickel alloys C92200, C92300
	QQ-C-390	Bronze alloys C90300, C90500, C90700, C91000, C91300, C91600, C92500, C96200, C96400, C94700, and C94800

Table 7-13. Grouping of Base Materials for Brazing Procedure and Performance Qualification [1/] - Continued

Group	Specifications	Type of Material
P-108	Copper alloys with aluminum content 0.50 percent or greater	
	ASTM B124/B124M	Copper aluminum alloys C61900, C62300, C63000, C63200, C64200, and C64210
	ASTM B138/B138M	Manganese bronze C67000
	ASTM B150/B150M	Copper aluminum alloys C60600, C61400, C63000, and C64200
	ASTM B169/B169M	Copper aluminum alloy C61400
	ASTM B271/B271M	Aluminum bronze alloys C95200, C95300, C95400, C95500, and C95800
	ASTM B283/B283M	Copper aluminum alloys C6300 and C64200
	ASTM B505/B505M	Aluminum bronze alloys C95200, C95300, C95400, C95500, and C95800
	ASTM B763/B763M	Aluminum bronze alloys C95200, C95300, C95400, C95500, and C95800
	MIL-B-24480	Nickel aluminum bronze
	MIL-B-21230	Nickel aluminum bronze
	MIL-C-15345	Aluminum bronze
	QQ-C-390	Aluminum bronze alloys C95200, C95300, C95400, C95500, C95700, and C95800
	QQ-C-450	Copper aluminum alloy
	QQ-B-728 (class B)	Manganese bronze
	QQ-C-465	Copper aluminum alloys 606, 614, 630, and 642
P-110	Nickel alloys with chromium content less than 1 percent	
	ASTM A494/A494M	Castings, nickel and nickel alloys N02100, N24025 N24130, N24030, N24135, and N24020
	MIL-T-1368	Nickel copper
	MIL-N-17163	Nickel copper
	MIL-DTL-23520	Nickel copper
	MIL-C-24723	Nickel copper, composition M-30C
	QQ-N-281	Nickel copper
	QQ-N-288 (compositions A and E)	Nickel copper
P-111	Nickel alloys with chromium content 1 percent or greater	
	MIL-B-15382	Nickel chromium iron
	MIL-DTL-23227	Nickel chromium iron
	MIL-N-23228	Nickel chromium iron
	MIL-DTL-23229	Nickel chromium iron
	MIL-DTL-24114	Nickel chromium iron

NOTE:

[1/] Alloys classified under identical P-numbers, listed in ASME BPVC Section IX, Part QB, Article XII or, when approved, alloys having similar chemical compositions, may be included in the categories listed above.

Table 7-14. Groupings of Brazing Alloys for Procedure and Performance Qualification [1/, 2/, 3/]

Group	Specification	Alloy Classification	AWS Classification
F-101	QQ-B-654	Grade IV [6/] Grade VII [6/]	BAg-1a [6/] BAg-1 [6/]
F-101A	QQ-B-654	BAg-8a	BAg-8a
	QQ-B-654	BAg-22	BAg-22
	AWS A5.8M/A5.8	--	BAg-8
F-102 [5/]	QQ-B-654	BAg-5 BAg-9 Grade V [6/] Grade VIII [6/]	BAg-5 BAg-9 BAg-3 [6/] BAg-2 [6/]
F-102A [5/]	QQ-B-654	BAg-7	BAg-7
	QQ-B-654	BAg-10	BAg-10
	AWS A5.8M/A5.8	--	BAg-24
	AWS A5.8M/A5.8	--	BAg-35
	AWS A5.8M/A5.8	--	BAg-36
F-103 [4/]	QQ-B-654	BCuP-5	BCuP-5
	AWS A5.8M/A5.8	FS B CuP-2 FS B CuP-3 FS B CuP-4	BCuP-2 BCuP-3 BCuP-4

NOTES:

1/ If brazing alloys of similar chemistry and mechanical properties not listed under an F-number group are to be used, they may be considered as a group upon approval.

2/ Brazing alloys that are not listed in this table but that are listed in NAVSEA 0900-LP-001-7000 are considered to be part of the same F-group in this table as they are in NAVSEA 0900-LP-001-7000, provided any additional requirements for such filler material types that may be specified by NAVSEA 0900-LP-001-7000 shall also apply here.

3/ See 8-2 for guidance on filler material characteristics.

4/ Category F-103 brazing alloys shall not be used on ferrous alloys (P-101), nickel base alloys (P-110 and P-111), copper-nickel alloys containing more than 10 percent nickel (P-107), or stainless steels (P-102).

5/ Category F-102/F-102A brazing alloy grades containing 2 percent or more nickel shall be used for any joint where one or both of the materials joined is stainless steel. Other Category F-102/F-102A grades may be used on nickel plated stainless steel, when approved.

6/ Grades IV, V, VII, and VIII as specified in QQ-B-654 and grades BAg-1, BAg-1a, BAg-2, and BAg-3 as specified in AWS A5.8 contain cadmium and are not intended for new design, unless approved by NAVSEA.

Table 7-15. Type and Number of Test Specimens Required and Range of Thickness Qualified (Brazing Procedure Qualification)

Thickness, t, of Test Sample as Brazed (in)	t to 3/8	over 3/8 to 3/4	over 3/4
Range of Thickness of Materials Qualified by Test (in)	1/2t to 2t	3/8 to 2t	3/4 to 2t
Type and Number of Tests Required			
Reduced Section Tension	2	2	2
Peel [1/]	2	2	2

NOTE:

[1/] UT may be used in lieu of peel testing.

Table 7-16. Axial Load and Torque Values for Procedure Qualification [1/, 2/, 3/]

Stud Size	Carbon Steel					
	UNC, NC Class 2A			UNF, NF Class 2A		
	Minor Dia., in	Axial Load, lbs	Torque, in-lbs	Minor Dia., in	Axial Load, lbs	Torque, in-lbs
10	0.1379	745	15	0.1508	895	20
1/4	0.1876	1380	39	0.2052	1655	51
5/16	0.2431	2320	85	0.2603	2660	104
3/8	0.2970	3465	154	0.3228	4090	190
7/16	0.3485	4770	249	0.3749	5520	310
1/2	0.4041	6410	389	0.4374	7515	493
5/8	0.5119	10298	790	0.5554	12115	1009
3/4	0.6255	15365	1442	0.6718	17725	1786
7/8	0.7368	21320	2356	0.7858	24250	2858
1	0.8446	28020	3550	0.8960	31525	4237
1-1/8	0.9475	35255	5011	1.0210	40935	6269
1-1/4	1.0725	45178	7268	1.1460	51570	8865
Stud Size	Corrosion-Resistant Steel					
	UNC, NC Class 2A			UNF, NF Class 2A		
	Minor Dia., in	Axial Load, lbs	Torque, in-lbs	Minor Dia., in	Axial Load, lbs	Torque, in-lbs
10	0.1379	1192	25	0.1508	1432	32
1/4	0.1876	2208	62	0.2052	2648	82
5/16	0.2431	3712	135	0.2603	4256	166
3/8	0.2970	5544	247	0.3228	6544	316
7/16	0.3485	7632	399	0.3749	8832	496
1/2	0.4041	10256	622	0.4374	12024	789
5/8	0.5119	16464	1264	0.5554	19384	1615
3/4	0.6255	24584	2307	0.6718	28360	2858
7/8	0.7368	34112	3770	0.7858	38800	4573
1	0.8446	44832	5680	0.8960	50440	6779
Stud Size	Aluminum (5000 Series)					
	UNC, NC Class 2A			UNF, NF Class 2A		
	Minor Dia., in	Axial Load, lbs	Torque, in-lbs	Minor Dia., in	Axial Load, lbs	Torque, in-lbs
10	0.1379	522	11	0.1508	627	14
1/4	0.1876	966	27	0.2052	1159	36
5/16	0.2431	1624	59	0.2603	1862	73
3/8	0.2970	2426	108	0.3228	2863	139
7/16	0.3485	3339	175	0.3749	3864	217
1/2	0.4041	4487	272	0.4374	5261	345
Stud Size	Titanium Alloy					
	UNC, NC Class 2A					
	Minor Dia., in	Axial Load, lbs	Torque, in-lbs			
1/4	0.1876	3317	93			
3/8	0.2970	8314	370			
1/2	0.4041	15390	933			

See footnotes at end of table.

Table 7-16. Axial Load and Torque Values for Procedure Qualification [1/, 2/, 3/] - Continued

NOTES:

1/ Torque is calculated using stud minor diameter (root of threads) and the following tensile strengths:

Carbon steel	50,000 lb/in^2
CRES	80,000 lb/in^2
Aluminum	35,000 lb/in^2
Titanium alloy	120,000 lb/in^2

The use of studs having minimum diameters other than those listed or of materials not in the table will require calculation of minimum required axial and torque loads based on the actual stud diameter and minimum required tensile strength for the stud and stud material involved in accordance with the equations below. Such calculations shall be submitted with the procedure qualification data.

$$\text{axial load (pounds)} = \frac{D^2 \times \pi \times TS}{4}$$

$$\text{torque (inch} - \text{pounds)} = \text{axial load} \times D \times k$$

where:

D = Stud minor diameter (inches)

TS = Tensile strength as specified in the applicable stud or material specification (pounds per square inch)

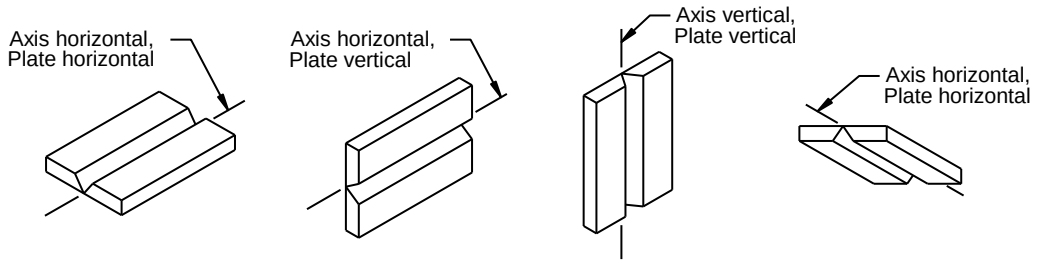
k = Lubrication factor. To ensure the weld is loaded primarily in tension, the threads of the stud shall be lubricated with molybdenum disulfide, graphite base, or comparable lubricant, in which case k = 0.15

For information, the following tensile strength values may be used:

HY-80	95,000 psi
HY-100	115,000 psi

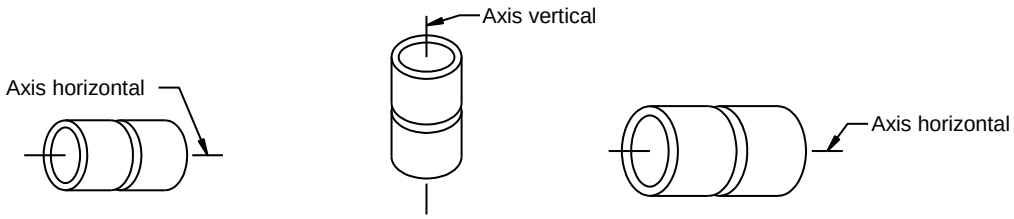
2/ If austenitic corrosion-resistant steel studs are welded to carbon steel plate, the torque values for carbon steel studs may be used.

3/ Not applicable to class 2B or internally-threaded studs (see 4-4.4).

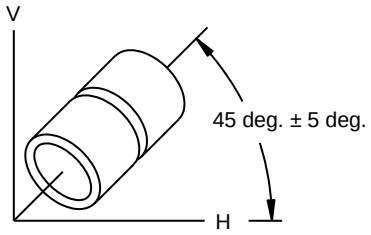


(a) 1G (b) 2G (c) 3G (d) 4G

GROOVE WELDS IN PLATE - TEST POSITIONS

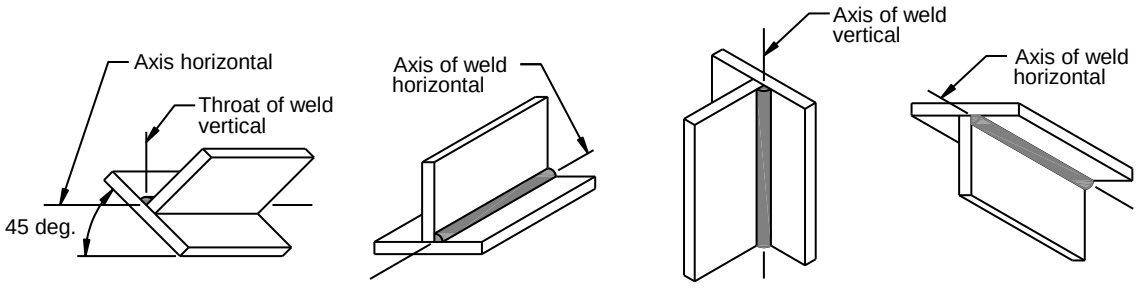


(a) 1G (Rotated) (b) 2G (Fixed) (c) 5G (Fixed)



(d) 6G (Fixed)

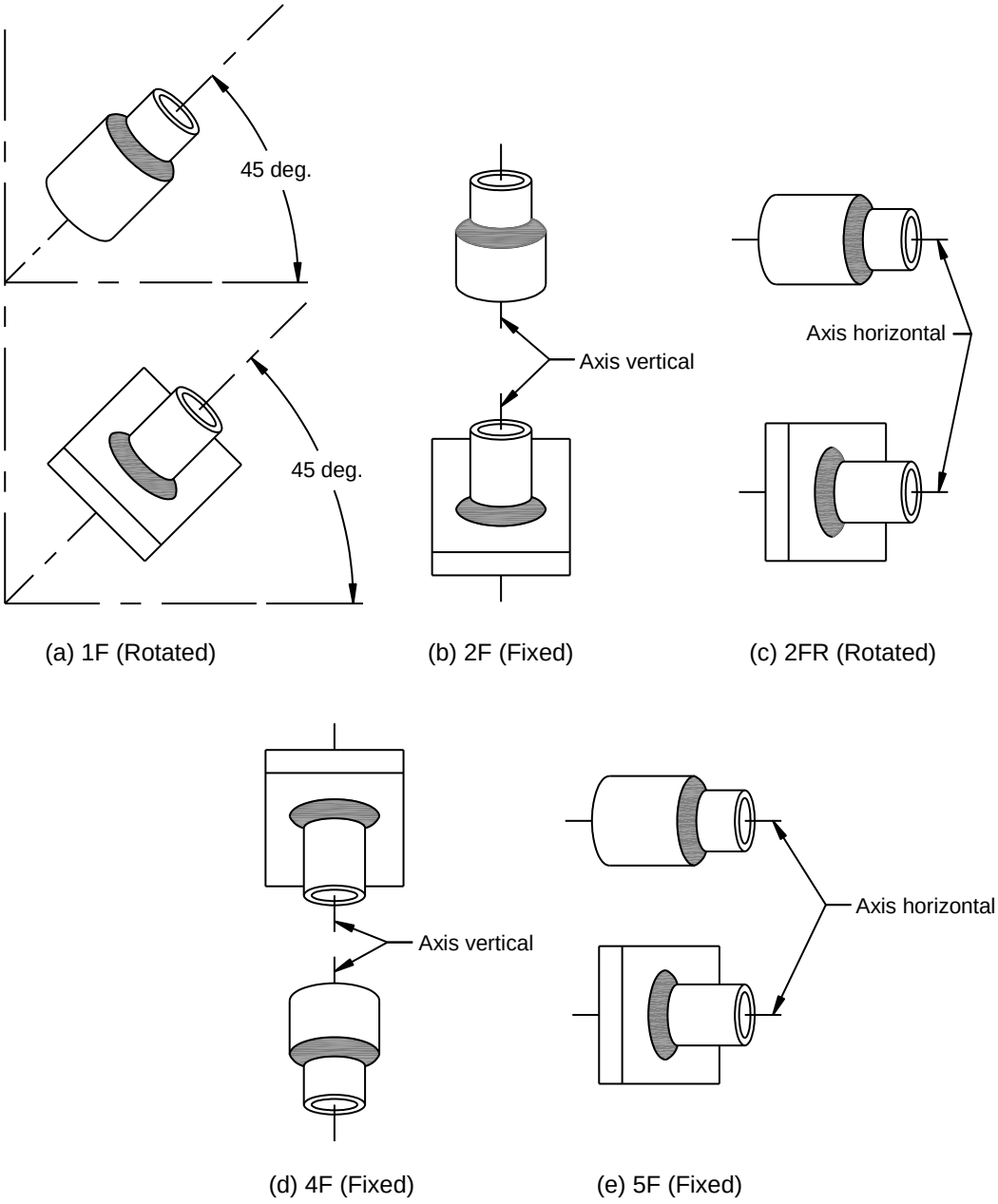
GROOVE WELDS IN PIPE - TEST POSITIONS



(a) 1F (b) 2F (c) 3F (d) 4F

FILLET WELDS IN PLATE - TEST POSITIONS

Figure 7-1. Positions of Welding

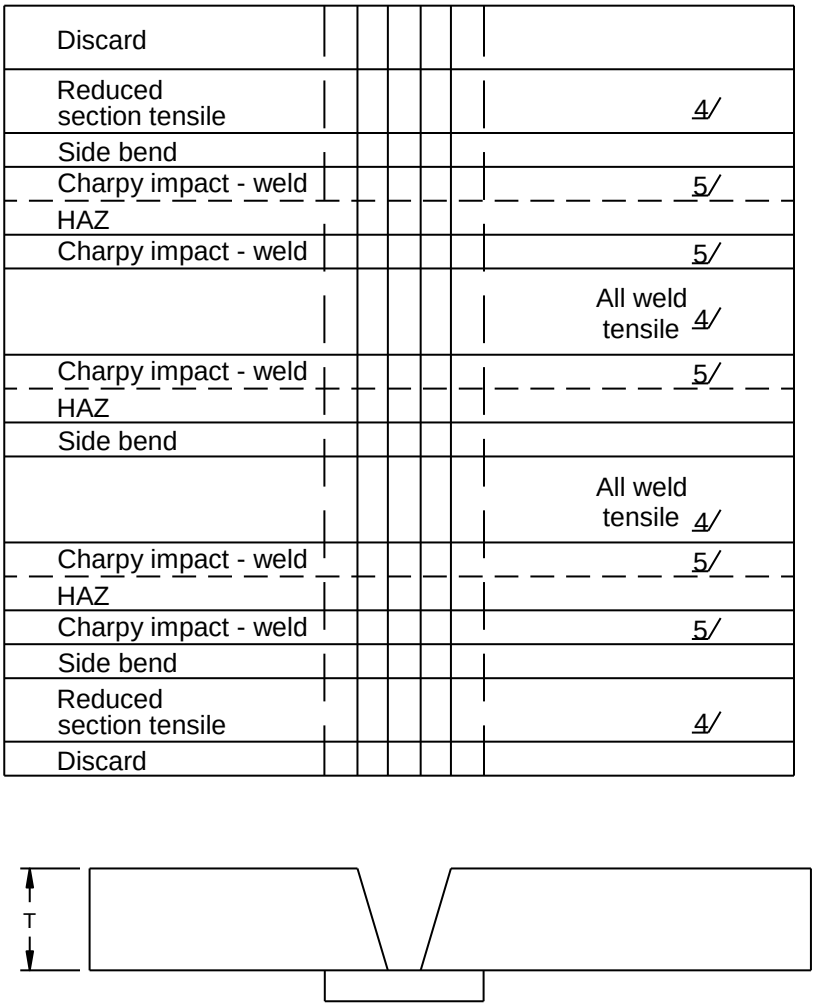


FILLET WELDS IN PIPE - TEST POSITIONS

NOTES:

1. Rotation of the weld face ±15 degrees about the axis of the weld from the orientation shown does not change the classification of the weld test position.
2. Weld test positions are as shown above. Welding positions – flat, vertical, overhead, and horizontal – are as defined by AWS A3.0M/A3.0.

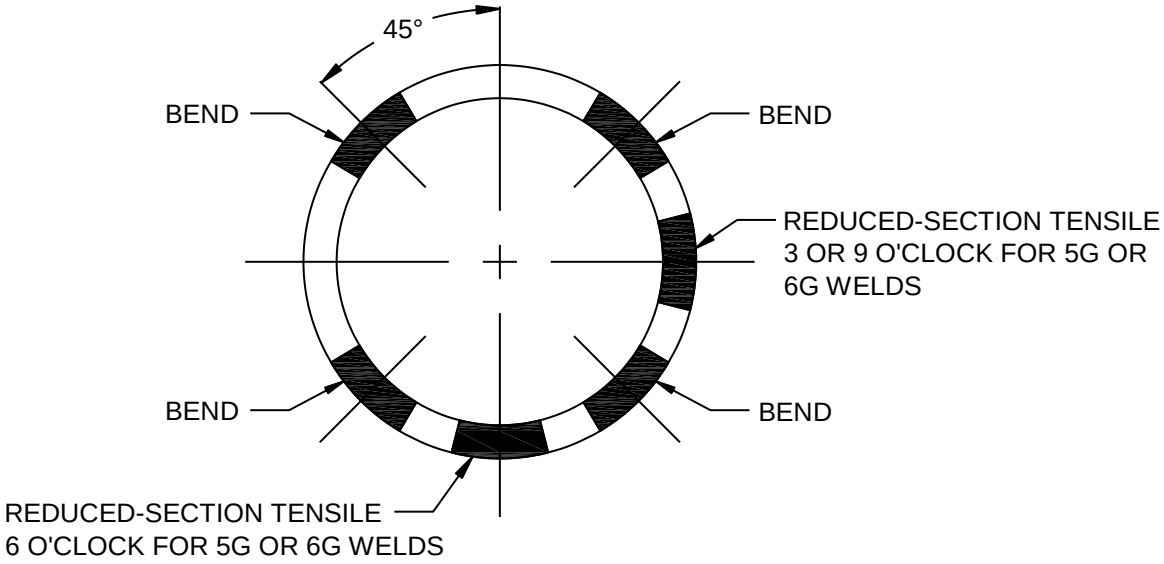
Figure 7-1. Positions of Welding - Continued



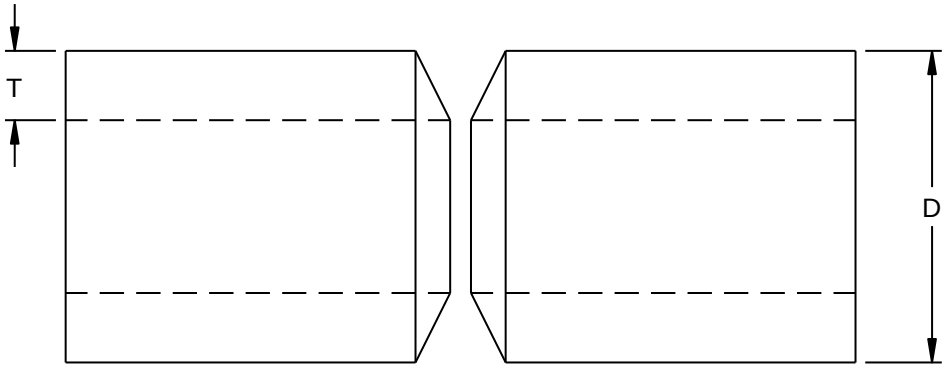
NOTES:

1. Joint design (see 4-4.1.3).
2. Test assembly material (see 4-4.1.1).
3. Test assembly size (see 4-4.1.2).
4. Tensile specimen requirements are specified in footnote 6 of table 7-7.
5. When HAZ toughness testing is required, a straight wall joint design is preferred. Material for specimens shall be removed as indicated. Base metal specimens shall be removed from the same side of the joint as the HAZ specimens and located along the same longitudinal axis as each HAZ specimen or immediately below or above its related HAZ specimen. See figure 7-24 for preparation of HAZ CVN impact specimens.

Figure 7-2. Typical Welding Procedure Qualification Test Plate and Recommended Locations for Removal of Test Specimens

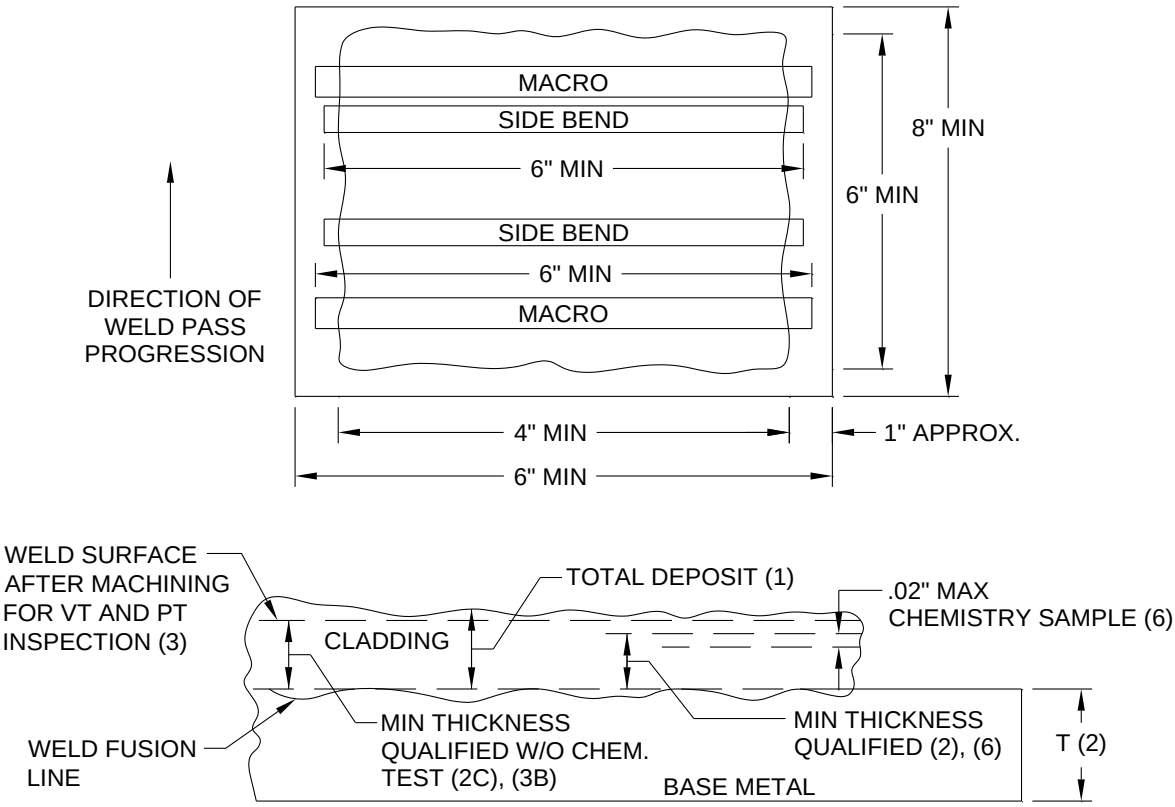


SUGGESTED ORDER OF REMOVAL OF
TRANSVERSE TEST SPECIMENS FROM WELDED PIPE



NOTES:
1. Diameter (D) (see 4-4.1.2 and 4-4.1.10.1).
2. Joint design (see 4-4.1.3).
3. Test assembly material (see 4-4.1.1 and 4-4.1.10.1).

Figure 7-3. Typical Welding Procedure Qualification Pipe Test Assembly



NOTES:

1. Total cladding thickness should be approximately equal to the unmachined thickness to be deposited in production, with adequate allowance to permit machining the entire weld surface while maintaining minimum required thickness (see notes 2, 3, 5(c), and 6). The number of weld layers at the minimum machined thickness used for qualification (see note 2) shall equal the minimum number of layers to be used in production. For cladding of cylindrical materials, also see figure 7-5.
2. Base Metal Thickness, Weld Thickness, and Minimum Number of Weld Layers.
   (a) T is the test assembly nominal base metal thickness.
      (1) For T = 1 inch or greater, qualified base metal thickness is 1 inch and greater.
      (2) For T less than 1 inch, qualified base metal thickness is T and all greater thicknesses.
   (b) Where composition testing is performed (see notes 5 and 6) the machined weld thickness and number of layers present at which composition testing is performed shall be the minimum qualified.
   (c) Where dilution testing is performed in lieu of composition testing (see notes 5(c) and 7), the minimum qualified weld thickness and layers shall be either of the following, as applicable:
      (1) Three layers and the machined weld thickness at which 3 layers are obtained, but no less than ¼ inch (see note 5(c)(1)); or
      (2) Two layers and the machined weld thickness at which 2 layers is obtained, but no less than 3/16 inch (see note 5(c)(2)).
   (d) Maximum weld thickness qualified shall be twice the machined weld thickness at which NDT and bend testing are performed.

(Notes continued on next page.)

Figure 7-4. Test Assembly for Procedure Qualification for Cladding for Corrosion-Resistance (Also, See Figure 7-5 for Cylindrical Materials)

NOTES (continued):

3. The surface of the weld cladding shall be machined. The weld cladding shall then be VT and PT inspected per 4-5 to the criteria of note 4 prior to removal of macro-etch specimens and side bends. All of the following shall apply:
   (a) 3/16-inch minimum cladding thickness is required for destructive tests, unless the welding procedure is restricted to welds less than 3/16 inch thick; in this case, face bends shall be tested at the maximum allowed weld thickness in place of side bends.
   (b) Where required by note 5, also perform composition testing per note 6 at the minimum machined weld thickness and layer to be qualified (see note 2(b)). Where composition testing is not performed, the minimum qualified weld thickness and layers shall be per note 2(c).
4. VT acceptance criteria shall be per MIL-STD-2035 class I. PT acceptance criteria shall be per MIL-STD-2035 for weld overlay class 1 (finished machined surface). Macro-etch examination and side bending shall be in accordance with table 7-7, note 5(c) and, as applicable, 4-5.2.6 or 4-5.2.3. Submit macro-etch specimens (or photo macrographs of these specimens clearly showing the fusion zone) along with other procedure qualification test data for approval.
5. Composition testing shall be performed per note 6 where any of the following conditions apply:
   (a) Where composition or related testing of the clad surface is specified by the governing system or component specification or fabrication document.
   (b) For A-45 filler material clad welds.
   (c) For all other filler material clad welds, unless one of the following criteria are met and dilution testing is performed per note 7:
      (1) A minimum of three weld layers shall exist at the minimum finish machined production weld thickness to be qualified, which shall be at least 1/4 inch (see note 2(c)(1)), and dilution shall be less than 20 percent.
      (2) A minimum of two weld layers shall exist at the minimum finish machined production weld thickness to be qualified, which shall be at least 3/16 inch (see note 2(c)(2)), and dilution shall be less than 8 percent.

      NOTE: The minimum final layer as required above shall be evident for at least 90 percent of the width of each macro test specimen, excluding rounding effects at specimen edges.

   Alternate criteria may be approved by NAVSEA if satisfactory justification is provided. Dilution testing is only permissible where minimum qualified weld thickness and layers are as above and where the same welding parameters are used until the minimum number of qualified layers have been deposited. Where these conditions are not met, composition testing per note 6 shall be performed.
6. When required by note 5, composition testing shall be performed as follows: from a suitable portion of the test assembly near the center of clad weld width and the upper bend specimen location, machine the weld clad material down to the minimum clad thickness/layer to be allowed for production, and test the resultant cladding surface for material chemistry per notes (c) or (d), and (e) below. Tooling and lubricants used for machining the final surface should replicate that to be used in production to preclude contamination effects. Any distortion in the test assembly shall not increase the machined clad thickness for this test. The thickness tested/shown is the minimum finish machined production weld thickness qualified.
   Report this thickness, the number of weld layers at this thickness, and chemistry results along with other qualification test data. If necessary, etching shall be employed to discern the weld layer from which chemistry is obtained. The following shall also apply:
   (a) The depth from which the sample is taken shall be limited to the top 0.020 inch of weld cladding.
   (b) For qualified clad welds less than 3/16 inch thick, submit a cross-section photo macrograph (or macro-etch specimen) clearly showing the machined thickness and number of weld layers present in the area where the composition test was taken.

(Notes continued on next page.)

Figure 7-4. Test Assembly for Procedure Qualification for Cladding for Corrosion-Resistance (Also, See Figure 7-5 for Cylindrical Materials) - Continued

NOTES (continued):

(c) A-45 filler material clad welds shall be as follows: quantitative chemical testing shall be required for the following elements to the specified acceptance values.

Weld Deposit Chemistry	
Element	**Percent**
C	0.02 max
*Fe	No more than 103% of filler chemistry. **
Si (A-45A)	0.20 max
Si (A-45B)	0.08 max
*Cr	At least 97% of actual filler chemistry. **
*Mo	At least 97% of actual filler chemistry. **
W	2.90 min
* Filler metal chemistry for these elements (e.g., lot test certificate values) shall be reported per 4-6. ** Weld procedures developed for clad welding nickel-molybdenum-chromium alloy to ferrous base materials (such as HY-100) that exceed the dilution requirements for Ni, Mo, or Cr may be approved on a case basis.	

(d) For clad filler materials other than A-45, elements requiring analysis and their acceptance criteria shall be as follows, unless otherwise specified by the governing component/system specification:

(1) At least the first three major alloying elements of the filler material shall be checked; the alloying element having the highest specification percentage shall be the first, the element having the next highest percentage shall be the second, and so forth (e.g., for a 316L overlay, this shall mean that Cr, Ni, and Mo are checked). Carbon, nitrogen, silicon, and manganese shall not count in this regard. If the overlay has less than three major alloying elements, then those present shall be tested. The overlay base element (e.g., Fe for 316L overlay) shall not count in this regard, except for NiCu and A-41 overlays, where Ni shall be checked (along with Ti). Results for each tested element shall be no less than 97% of the actual filler metal chemistry*** for the filler material lot used for welding.

(2) The basis element for the substrate (e.g., Fe for S-1 or S-8 plate) shall be checked. Results shall not exceed the lesser of the following:

(i) The actual amount of the base element present in the filler metal plus 3% of the nominal basis element amount present in the base material.

(ii) The maximum amount allowed by the specification for the clad filler material involved, if a value is listed.

Where an intermediate surfacing filler material (butter layer) is applied to the substrate prior to overlaying, these requirements shall also apply to the butter layer filler material into the overlay, unless the butter material basis element is an alloying element (or basis element) of the overlay filler material, in which case the value shall be within the specified range of the overlaying material specification.

(3) Where the criteria of (1) and (2) are not met, results can be submitted to NAVSEA for approval along with accompanying justification for why the associated dilution values are acceptable for the intended production application and service conditions.

*** For gas metal arc welding, where filler metal lot composition is determined from the bare wire, the composition to be used for comparison to the final machined overlay can be obtained from a weld deposited pad prepared in accordance with the specification for the equivalent alloy covered electrode regarding pad size, number of layers, and other applicable requirements.

(e) Chemical analysis shall be performed in accordance with the specifications required by the filler material specification for the cladding involved.

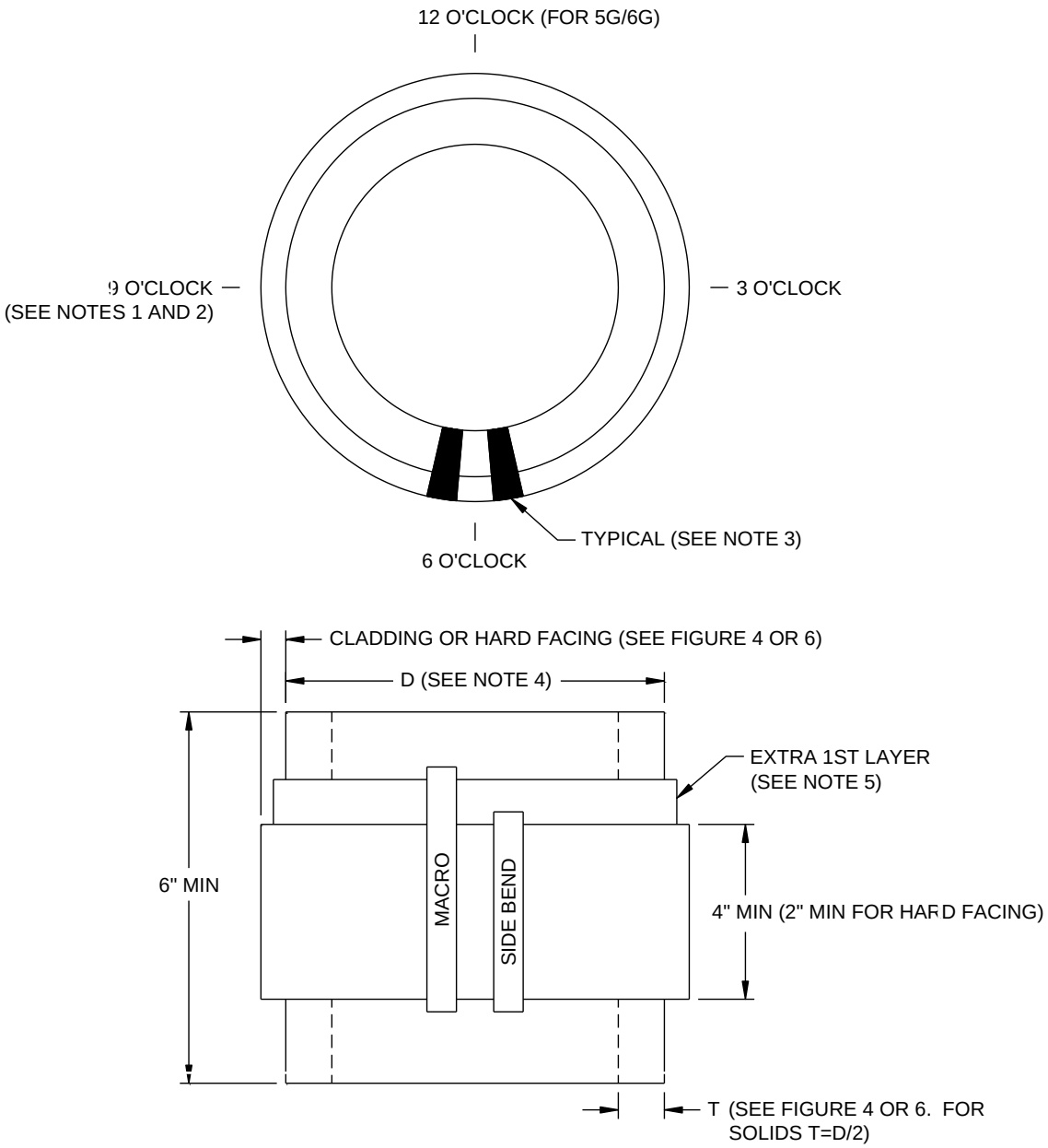
(Notes continued on next page.)

Figure 7-4. Test Assembly for Procedure Qualification for Cladding for Corrosion-Resistance (Also, See Figure 7-5 for Cylindrical Materials) - Continued

NOTES (continued):

7. Where specified by note 5(c), dilution shall be determined as follows:
   (a) The test assembly shall be extended an additional 2 inches minimum and the first layer only shall be continued for an additional 2 inches minimum.
   (b) One additional macro-etch specimen shall be taken across this first layer clad weld 1 inch from the end of the full thickness clad weld. There shall be no differences in welding parameters from the rest of the first layer at this sectioned area.
   (c) This macro-etch specimen shall be etched and examined per note 4. Additionally, the two deepest penetrating beads shall be measured at their deepest point below the original base metal surface for total height (H) and depth below the original base metal surface (h). Measurements shall be to the nearest 1/64 inch.
   (d) Dilution for each bead shall be estimated in percent as (h/H) x 100. The dilution of each bead shall be averaged together and this average shall be evaluated against the criteria of note 5(c). Alternatively, if the full bead profile of each of the two deepest beads is clearly discernable, the actual dilution can be calculated according to standard area calculation methods.
   (e) Where a butter layer is employed, it shall count as one of the layers cited in note 5(c). Furthermore, the dilution evaluation shall be separately evaluated for the butter and clad layers. A portion of the butter layer shall also be machined flat prior to the application of the clad layer to permit accurate measurement of the clad layer's penetration. Both layers shall meet the dilution values of note 5(c).
   (f) Dilution evaluation is not required where composition testing is performed.

Figure 7-4. Test Assembly for Procedure Qualification for Cladding for Corrosion-Resistance (Also, See Figure 7-5 for Cylindrical Materials) - Continued



NOTES:

1. For hardfacing, all requirements of figure 7-6 shall be met, except that the location of hardness testing and macro-etch specimens, and additional base metal diameter requirements, shall be per this figure. For 5G and 6G welds where uphill progression welding on the first layer occurs on at least one segment (i.e., 9 o'clock, 3 o'clock, or both), perform the hardness test on one of the uphill segments at 9 o'clock or 3 o'clock.
2. For clad welding, all requirements of figure 7-4 shall be met, except that the location of side bends, macro-etch specimens, and composition testing, and additional base metal diameter requirements, shall be per this figure. For 5G or 6G position welds where uphill progression welding on the first layer occurs on at least one segment (i.e., 9 o'clock and/or 3 o'clock), perform composition testing on one of the uphill segments at 9 o'clock or 3 o'clock (also see note 4(b)(i) for extra tests where OD exceeds 5 inches).

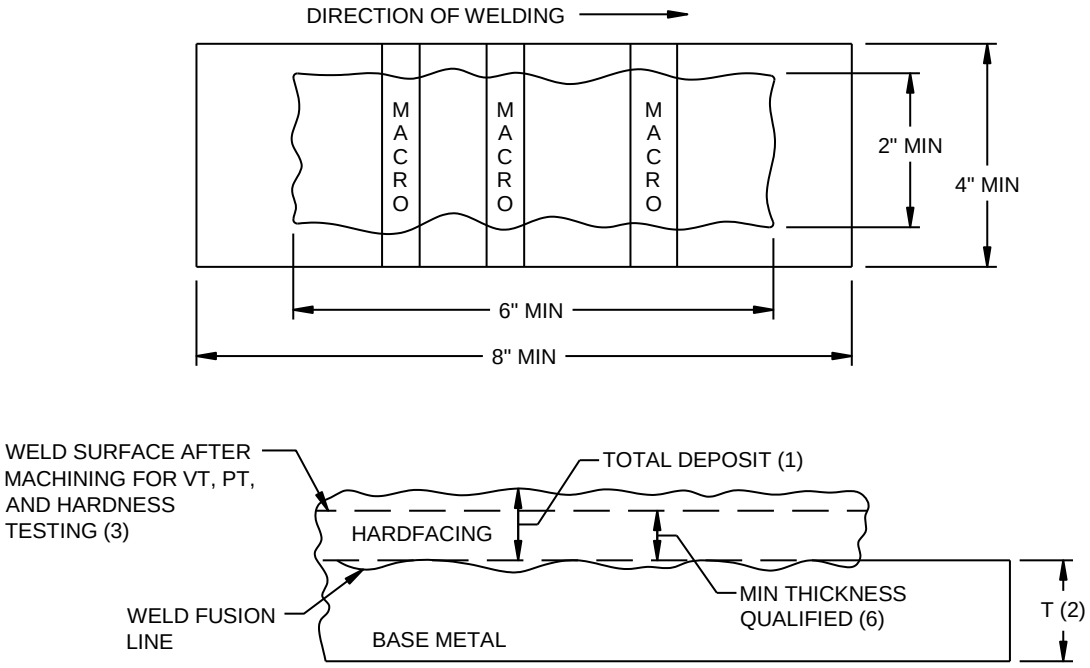
(Notes continued on next page.)

Figure 7-5. Test Assembly for Procedure Qualification of Hardfacing and Cladding for Circumferential Welding of Cylindrical Materials (for Propulsion Shafting, see MIL-STD-2191).

NOTES (continued):

3. A total of three macro-etch specimens for cladding and hardfacing, and three bend specimens for cladding, shall be tested. For 5G and 6G welds, specimens shall be taken from the approximate 3, 6, and 9 o'clock locations. For 1G and 2G welds, the center test location shall be separated by approximately 90 to 120 degrees from the surrounding locations.
4. Diameter (D) shall be as follows:
   (a) For production welding diameters 5 inches OD and less, D shall be the smallest to be welded in production except that diameters smaller than are practical for obtaining specified test specimens (including by multiple test assemblies) or for necessary qualified thickness are not required; diameters qualified shall be D and greater, except where note 4(b)(i) applies.
   (b) For welding minimum diameters greater than 5 inches OD, any diameter over 5 inches may be tested and qualified diameters shall be all greater than 5 inches OD.
      (i) In addition, for cladding in the 5G or 6G positions where products greater than 5 inches OD are to be welded in production, and where conditions of figure 7-4, note 5(a) or 5(b) apply, base material tested shall be greater than 5 inches OD; testing shall be per this figure and a second composition test at the minimum qualified clad thickness shall also be performed at the 6 o'clock position; qualification on a minimum OD (i.e., 5 inches or less) and on an OD greater than 5 inches shall qualify all ODs greater than the minimum OD tested.
5. For cladding only, where dilution evaluation is performed in lieu of composition testing (see figure 7-4, notes 5 and 7), depositing an additional 2-inch minimum extension of the first cladding layer is required. This cladding can be an extension of the first layer from the main overlay weld, or it can be deposited on a separate location beyond the main weld if welded along with the first layer of the main weld.

Figure 7-5. Test Assembly for Procedure Qualification of Hardfacing and Cladding for Circumferential Welding of Cylindrical Materials (for Propulsion Shafting, see MIL-STD-2191) - Continued



NOTES:

1. The total hardfacing thickness should be approximately equal to the unmachined thickness to be deposited in production, with adequate allowance to permit machining the entire weld surface while maintaining minimum required thickness (see notes 3 and 6). For cladding of cylindrical materials, also see figure 7-5.
2. Thickness (T) is the nominal base plate thickness. For production base metal thicknesses:
   (a) 1 inch and greater: T = 1 inch or greater.
   (b) Less than 1 inch: T = minimum thickness to be welded in production; qualifies up to 1 inch.
   (Qualified hardfacing weld thickness shall be per note 3).
3. The surface of the hardfacing shall be machined to the minimum thickness to be allowed for production (see note 6) and then visual (VT) and PT inspected per note 4; hardness testing shall then be performed per note 6 and macro-etch examination per note 5. This weld thickness and the number of layers at this thickness are the minimum qualified. Maximum qualified weld thickness shall be twice the machined weld thickness. Where greater qualified weld thicknesses are desired and other essential elements remain the same, a second test assembly shall be prepared and tested in this same fashion except that machined thickness for testing shall be as required.
4. VT and PT shall be per 4-5. VT acceptance criteria shall be per MIL-STD-2035, class I. PT acceptance criteria shall be per MIL-STD-2035 for the following:
   (a) Valve seating surface contact line; these criteria shall apply unless the welding procedure specifies that it is not applicable to valve seat hardfacing, in which case the criteria of note 4(b) shall apply.
   (b) Class 1 for the machined weld thickness, unless specific approval is obtained before qualification welding for a different MIL-STD-2035 hardfacing criteria and the following conditions are met:
      (i) The production application only involves the less stringent PT acceptance criteria.
      (ii) The welding procedure identifies, and is limited to, the specific application involved.
5. Macro-etch examination shall be per table 7-7 and 4-5.2.6. Where weld thickness less than 1/8 inch is to be qualified, submit macro-etch specimens (or photo macrographs of these specimens clearly showing the fusion area) along with other procedure qualification test data for approval.

(Notes continued on next page.)

Figure 7-6. Procedure Qualification Test Plate for Hardfacing (Also See Figure 7-5 for Cylindrical Materials)

NOTES (continued):

6. Machine the weld material down to the minimum machined weld thickness to be allowed for production and perform hardness testing near the end macro-etch specimen location as follows:
   (a) Hardness testing shall require a minimum of five random readings, which shall be averaged.
   (b) Hardness results shall be as specified in the applicable military specification (filler metal, component, etc.), commercial specification, manufacturer's data sheet, or footnote 6 to table 7-2, as applicable.
   (c) Testing shall conform to AWS B4.0 utilizing the test method corresponding to the hardness value specified by the applicable specification of note 6(b), or as otherwise approved.

   Any distortion in the test assembly shall not increase the machined weld thickness for this test. The thickness shown is the minimum machined production weld thickness qualified. Report this thickness, the number of weld layers at this thickness, and hardness results along with other qualification test data. If necessary, etching shall be employed to discern the weld layer from which hardness is obtained.

Figure 7-6. Procedure Qualification Test Plate for Hardfacing (Also, See Figure 7-5 for Cylindrical Materials) - Continued

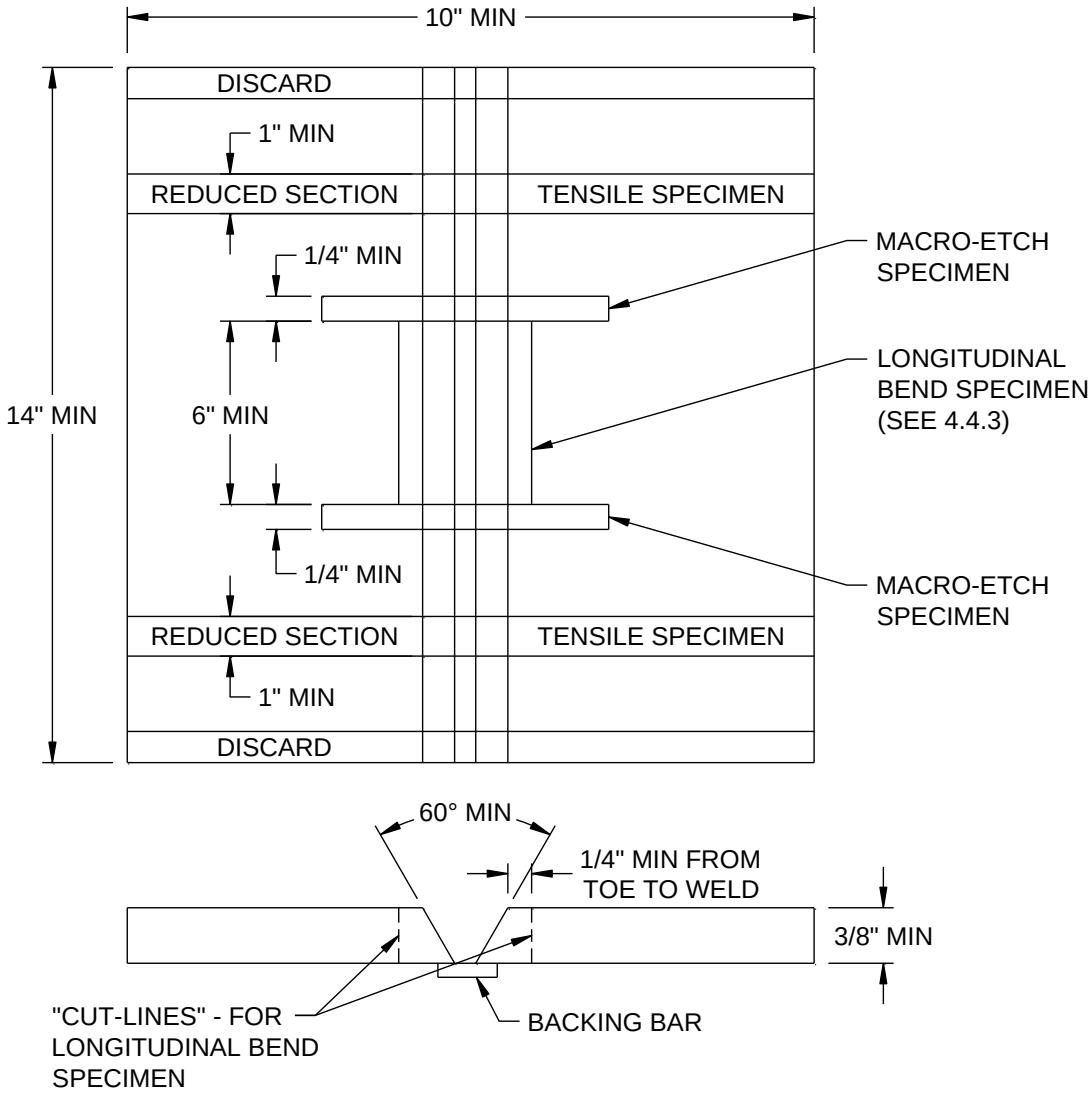
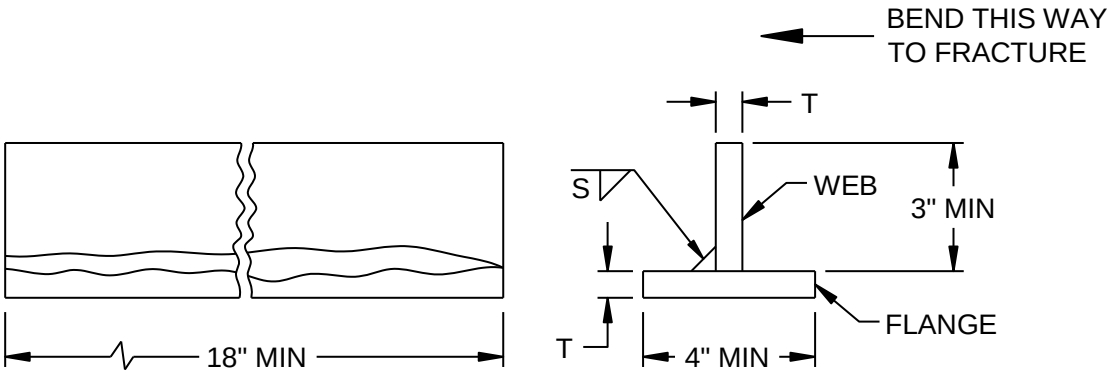


Figure 7-7. Typical Location of Test Specimens from Dissimilar Metal Welded Test Plate

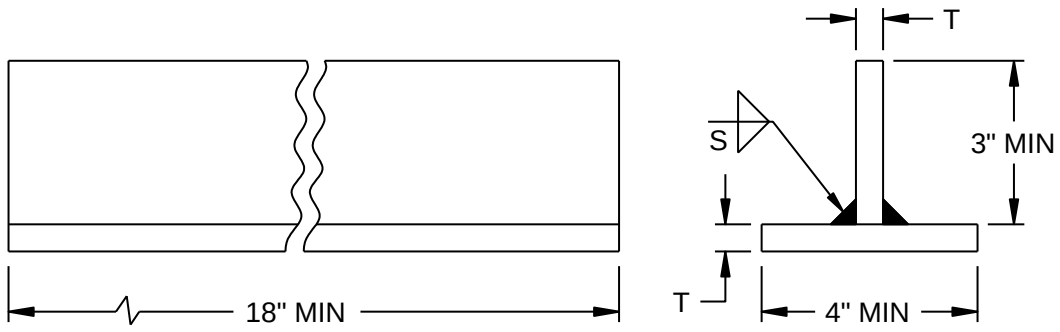


T = MAXIMUM THICKNESS TO BE USED IN PRODUCTION OR 3/8 INCH, WHICHEVER IS THE LESSER.

S = MAXIMUM SIZE SINGLE PASS FILLET TO BE USED IN PRODUCTION.

NOTES:
1. Positions qualified shall be in accordance with table 7-4.
2. Test assembly may be cut into shorter lengths after welding to facilitate testing.

Figure 7-8. Procedure Qualification Test Assembly for Fillet Welding Bare Surfaces



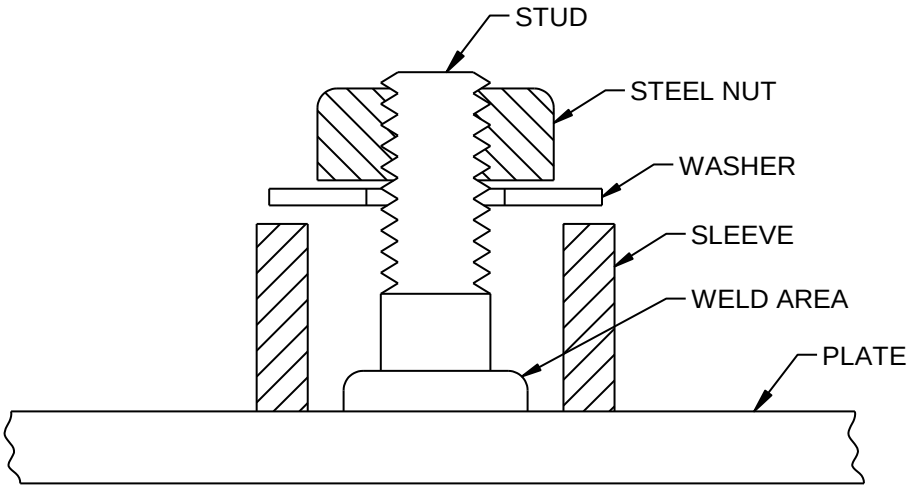
T = MAXIMUM THICKNESS TO BE USED IN PRODUCTION OR 3/8 INCH, WHICHEVER IS THE LESSER.

S = MAXIMUM SIZE SINGLE PASS FILLET TO BE USED IN PRODUCTION.

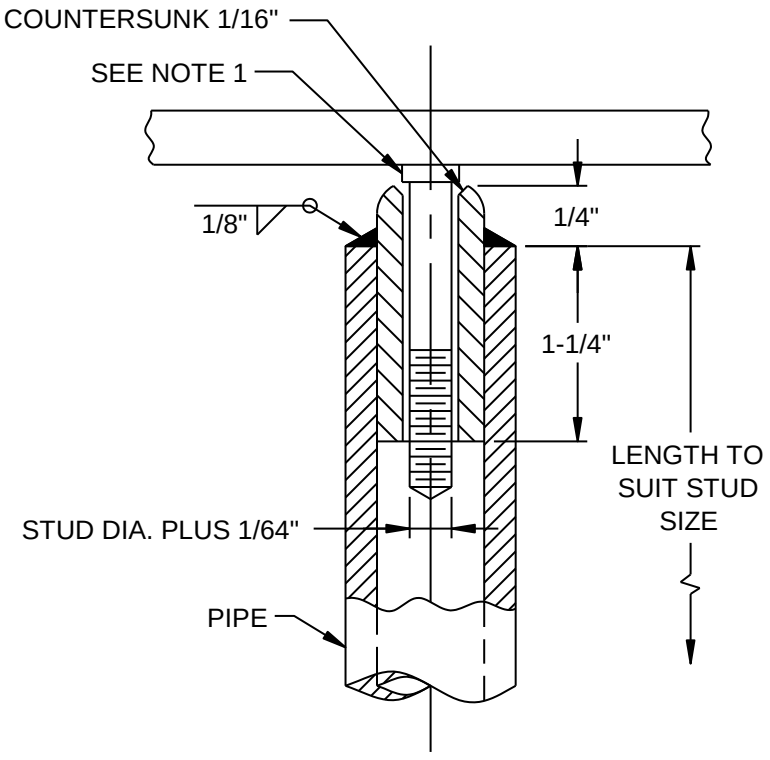
NOTES:

1. Plating shall be either ordinary or higher strength steel, as specified in MIL-S-22698, which qualifies the procedure for use on these materials.
2. Plating shall be primer-coated to maximize thickness that will be applied in production.
3. Plate shall be welded in the horizontal position and shall qualify for all positions.
4. Remove first side weld by gouging or mechanical means and fracture second side weld. Test assembly may be cut into shorter lengths after welding to facilitate fracturing for examination.

Figure 7-9. Procedure Qualification Test Assembly for Fillet Welding Over Primer-Coated Surfaces



A. STUD TORQUE TESTING APPARATUS



B. DEVICE FOR BENDING WELDED STUDS

NOTE: For hammer tests performed in accordance with 4-4.4.1.b, assisted bending with a pipe should feature an exposed length of stud 2X to 5X the stud diameter.

Figure 7-10. Stud Testing Apparatus

WELDING PROCEDURE QUALIFICATION TEST REPORT [1/] (see 4-6 and table 7-5)
Record actual values used for test assembly welding.

Performing Activity: _____ Test Report No. & Rev: _____

Welding Process: _____ Type (manual, etc.): _____ Transfer Mode: _____ Pulsing [2/] (Y/N): ____

Joint Design/Sketch: _____

Base Material	1	2	Backing
Spec:	_____	_____	_____
Grade/Type:	_____	_____	_____
Thickness:	_____	_____	_____
Diameter:	_____	_____	_____

Filler Metal	1	2	Flux Type
Spec:	_____	_____	Spec: _____
Type:	_____	_____	Classification: _____
Size:	_____	_____	Size: _____

Clad/HF Thickness/Layers [5/]: 1 _____ 2 _____

Welding Position: _____ Cleaning: _____
Progression (up/down): _____ Torch Type: _____
Cup Size: _____ Power Source: _____
Tungsten Dia./Type: _____ Other Equip.: _____
Arc Voltage Range [3/]: _____ Heat Input [4/] (max.): _____
Welding Current Range [3/]: _____ (min., e.g., S-10H): _____
Polarity: _____ Travel Speed: _____ Electrode Angle: _____
Stringer/Weave: _____ Bead Width [7/]: _____

Shielding Gas:	Purge Gas:	Trailing Gas:
Composition: _____	Composition: _____	Composition: _____
Flow Rate Range: _____	Flow Rate Range: _____	Flow Rate: _____

PWHT Type/Temp./Time: _____ Preheat Temp: _____
_____ Interpass Temp: _____

Other (torch offset, waveform/program number, wire feed speed, tube distance, flux trade name, etc.): _____
_____
_____
_____

Welded By (print): _____ ID No.: _____ Welding Date: _____

Page 1 of _____

Figure 7-11. Sample for Reporting Welding Procedure Qualification Data

Test Report No., Rev.: _____

Nondestructive Test Acceptance Criteria & Results:

RT: _____ UT: _____ MT: _____ PT: _____ VT [6/]: _____

Acceptance Criteria & Standard: _____

Other: _____

Tensile Test (* = optional)

Specimen No. & Type (Tr., AWM)	Thickness*	UTS	YS (AWM)	%EI (AWM)	Type of Failure & Location*

Bend Tests (R = Roof, F = Face, S = Side)

Specimen No. & Type (Long., Tr.)	Bend Type (R, F, S)	Bend Radius	Thickness, if not 3/8 in.	Results

Toughness Test Type/Units [8/]: _____: * - MLE, % Shear, Validity, if applicable

Specimen No. (Weld)	Results/ Temp. [9/]	Other*	Specimen No. (HAZ)	Results/ Temp. [9/]	Other*	Specimen No. (BM)	Results/ Temp. [9/]	Other*
Average:			Average:			Average:		

Macros: Criteria: _____ Specimen No./Results: _____

_____

Fillet Break: Criteria: _____ Fracture Surface: _____ Root Fusion: _____

Other: _____

[1/] Any of the form items not applicable should be so indicated by "N/A".

[2/] List required pulsing parameters on attached sheet.

[3/] In processes where amperage controls, arc voltages will be recorded for info only; where voltage controls, amperage will be recorded for info only.

[4/] Attach values for each pass.

[5/] List weld thickness and layers where composition or hardness test is performed.

[6/] For titanium, also list weld color (ID/OD); for thin socket/ seal welds, list ID criteria.

[7/] For mechanized, etc., list oscillation (amplitude, dwell, etc.) if used.

[8/] List test type (e.g., CVN, DT, J_{IC}, NDTT, etc.) and test result units (e.g., ft.-lbs.).

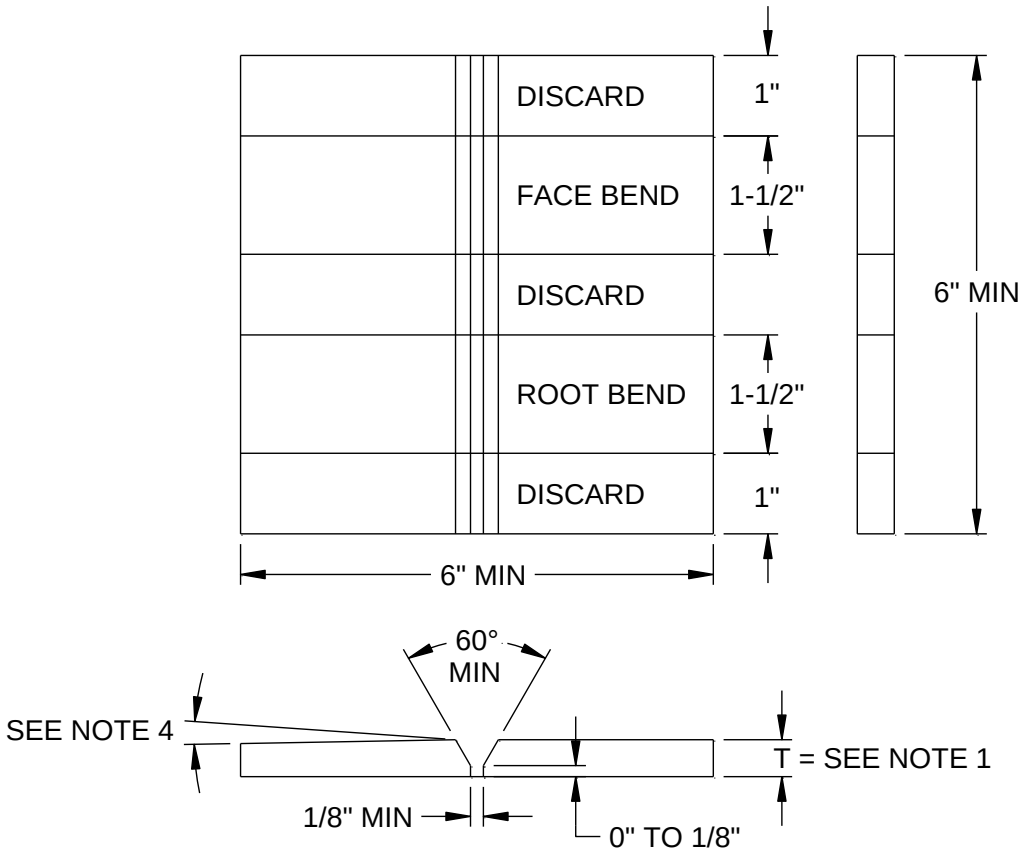
[9/] List test temp in °F and test value.

Performing Activity Certification Statement & Signature Performing Activity: _____

The statements in this record are correct and the test welds were prepared, welded, and tested in accordance with NAVSEA S9074-AQ-GIB-010/248 Rev. _____.

Name (Print): _____ Signature: _____ Date: _____

Figure 7-11. Sample for Reporting Welding Procedure Qualification Data - Continued



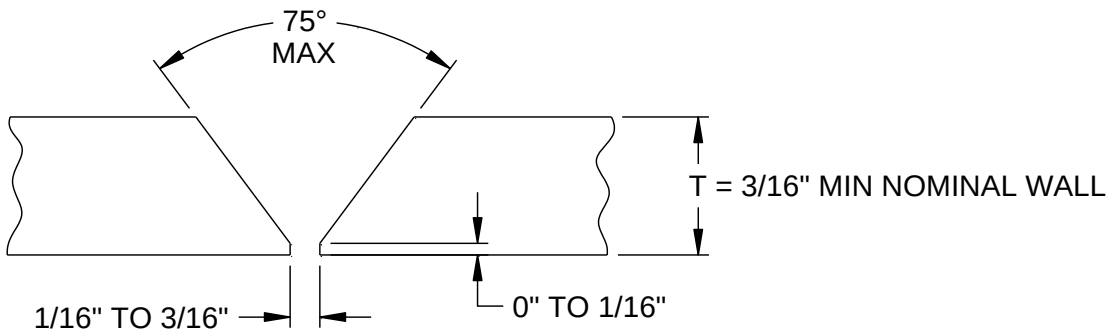
NOTES:

1. Performance qualification assembly thickness and thickness range qualified shall be as follows:

Test No.	Test Assembly Thickness (T)	Thickness Range Qualified to Weld
2A	Max thickness to be welded in production	1/16 inch to T
2B	3/8 inch	1/16 inch to unlimited

2. Weld should be made with the maximum size welding rod suitable for position of test plate.
3. Joint shall be welded from one side only and joints welded in the vertical position shall be welded upwards.
4. Plate shall not be more than 5 degrees out of parallel after welding.
5. If destructive testing is employed, after VT, weld face reinforcement may be removed as permitted by 5-4.2. Undercutting shall not be removed. No repair welding from the root side shall be permitted. Removal of root side reinforcement of one-sided welds with no backing is not permitted for root bends.
6. Two guided-bend test specimens shall be removed from the test plate if NDT is not employed.

Figure 7-12. Performance Qualification Test Nos. 2A and 2B for Fuel Gas Welding (Plate)

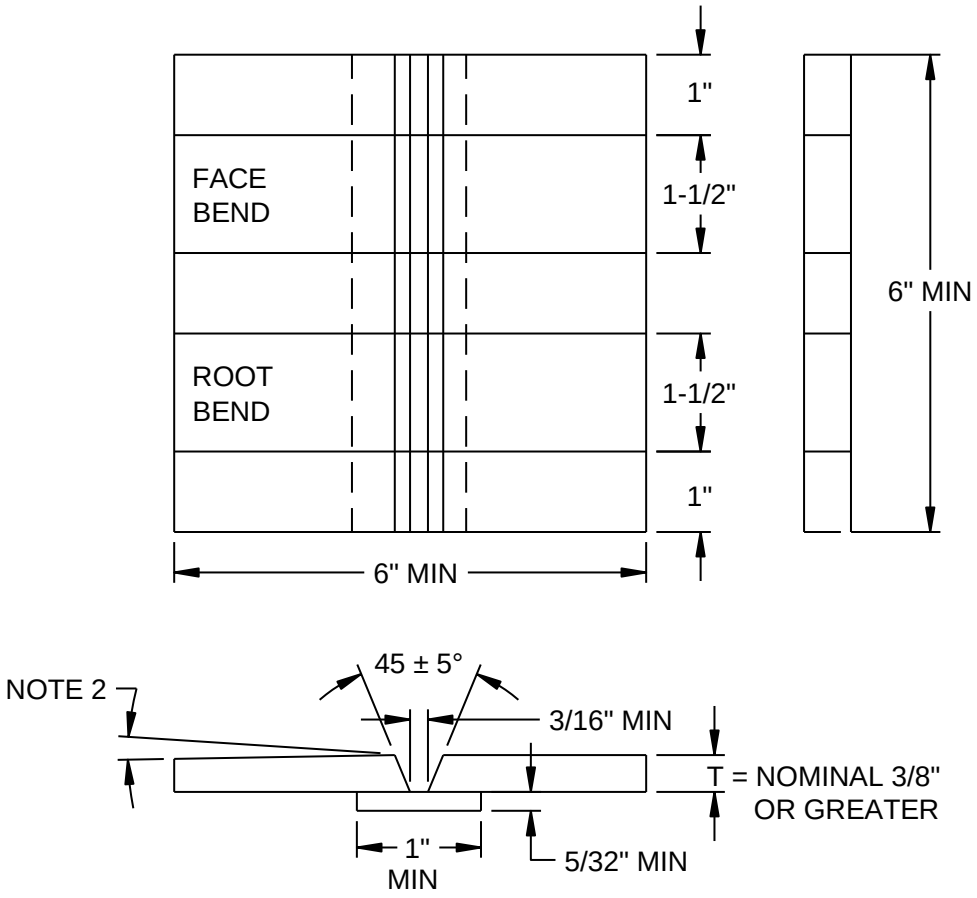


Qualification range limitation: 1/16-inch to 3/16-inch pipe wall

NOTES:

1. The joint design of an applicable, qualified welding procedure shall be employed.
2. Space restrictions may be omitted when welders are to weld piping without space restriction (see figure 7-21). This limitation shall be entered in the qualification records.
3. The weld should be made with the maximum size welding rod suitable for the position and thickness of the test assembly.
4. Mark pipe to ensure correct location of specimens or orientation for radiography.
5. If destructive testing is employed, after VT, weld face reinforcement may be removed and backing rings, when used, shall be removed prior to destructive testing per 5-4.2. Undercutting shall not be removed. Removal of root side reinforcement of one-sided welds with no backing is not permitted for root bends. When radiography is not employed for qualification evaluation, bend testing shall be conducted as follows:
   (a) Horizontal-fixed position pipe:
      (i) Face bends from the 45-degree and 225-degree positions (see figure 7-21).
      (ii) Root bends from the 135-degree and 315-degree positions (see figure 7-21).
   (b) Vertical-fixed position pipe:
      (i) Face bend from the 225-degree position (see figure 7-21).
      (ii) Root bend from the 135-degree position (see figure 7-21).
6. Minimum nominal wall thickness is used to indicate that the dimension is the minimum thickness based on the minimum pipe wall thickness allowed by the material specification. For example, 3/16 inch minimum nominal wall thickness would allow the use of any pipe wall considered 3/16 inch nominal even if the actual measured thickness was less than 0.187 inch.

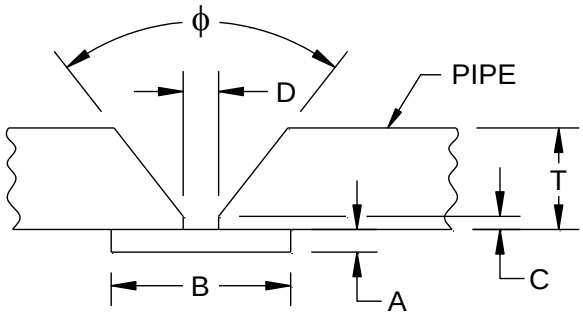
Figure 7-13. Performance Qualification Test No. 3B for Fuel Gas Welding (Pipe)



NOTES:

1. Weld should be made with a maximum size electrode or filler material rod suitable for position of test plate.
2. Plates shall not be more than 5 degrees out of parallel after welding.
3. If destructive testing is employed, after VT, weld face reinforcement may be removed and backing strips, when used, shall be removed prior to destructive testing per 5-4.2. Undercutting shall not be removed. No repair welding from the backing strip side shall be permitted. Removal of root side reinforcement of one-sided welds with no backing is not permitted for root bends
4. Two guided-bend test specimens shall be removed from the test plate if NDT is not employed.
5. In lieu of the joint design shown above, any applicable joint design from MIL-STD-22 or from an approved procedure may be employed. If this is done, the test shall be recorded as test no. 1. The welder shall be considered qualified to the extent specified for the standard test no. 1 joint.
6. Performance qualification for smaller thicknesses may be accomplished by using test plates less than 3/8 inch nominal thickness as permitted by table 7-10. The joint design of an applicable approved welding procedure shall be used and shall be noted on the welder qualification record. All testing shall be in accordance with this figure, 5-3, and 5-4. The welder shall be considered qualified to the extent specified for the standard test no. 1 joint except for the thickness limitations. The test may be designated as test no. 1A.
7. The bevel angle may be shifted from the vertical centerline of the joint ±22-1/2 degrees.
8. For test plate thickness 3/4 inch and greater, two 3/8-inch thick side bends may be used in lieu of face and root bends. Locations of the side bends shall be approximately 1-1/2 inches from each end of the test plate.

Figure 7-14. Performance Qualification Test No. 1 for Arc Welding

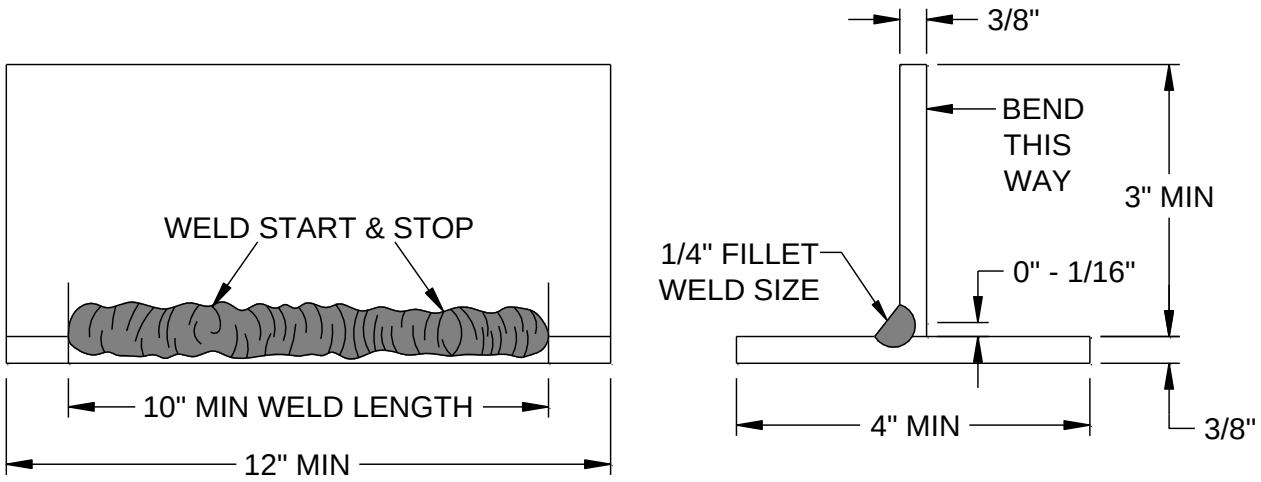


TEST	ϕ	A	B	C	D	T (MIN)
3	75±5°	Note 7	Note 7	0 to 1/16	5/16 max.	3/16 min. (nom. wall thickness)
4	75±5°	Note 7	Note 7	0 to 1/16	5/16 max.	3/8 min. (nom. wall thickness)

NOTES:

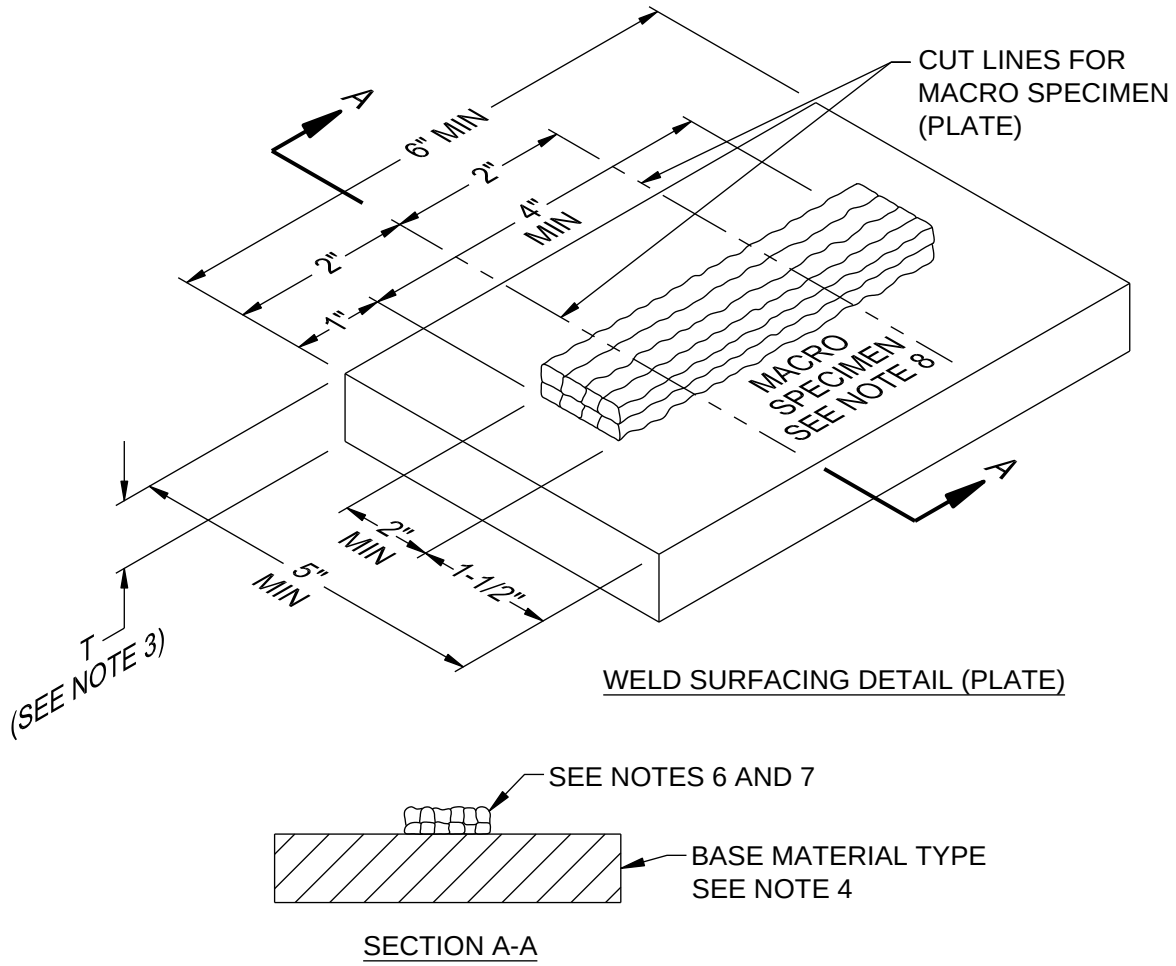
1. In lieu of the joint design shown above, any applicable joint design from MIL-STD-22 or from an approved welding procedure may be employed. If this is done, the test shall still be recorded as test nos. 3 and 4. The welder shall be considered qualified to the extent specified for the standard test nos. 3 and 4 joint.
2. Space restrictions may be omitted when welders are to weld piping without space restrictions (see figure 7-21). This limitation shall be entered in the qualification records.
3. The weld should be made with the maximum size electrode or welding rod suitable for the position and thickness of the test assembly.
4. Mark pipe to ensure correct location of specimens or orientation for radiography.
5. If destructive testing is employed, after VT, weld face reinforcement may be removed and backing rings, when used, shall be removed prior to destructive testing per 5-4.2. Undercutting shall not be removed. Removal of root side reinforcement of one-sided welds with no backing is not permitted for root bends. When radiography is not employed for qualification evaluation, bend testing shall be conducted as follows:
   (a) Horizontal-fixed position pipe.
      (i) Face bend from the 45-degree and 225-degree positions (see figure 7-21).
      (ii) Root bends from the 135-degree and 315-degree positions (see figure 7-21).
   (b) Vertical-fixed position pipe.
      (i) Face bend from the 225-degree position (see figure 7-21).
      (ii) Root bend from the 135-degree position (see figure 7-21).
6. Minimum (nominal wall thickness) is used to indicate that the dimension is a minimum thickness based on the minimum pipe wall thickness allowed by the material specification. For example, 3/16 inch minimum (nominal wall thickness) would allow the use of any pipe wall considered 3/16 inch nominal even if the actual measured thickness was less than 0.187 inch, but in considering the 2T maximum of the qualified thickness range, the welder would be qualified to 3/8 inch nominal pipe wall.
7. Backing ring dimensions shall be in accordance with MIL-STD-22.

Figure 7-15. Performance Qualification Tests Nos. 3 and 4 for Arc Welding (Pipe)



NOTES:
1. Weld should be made with a maximum size of filler wire suitable for the position of the test plate.
2. Weld size specified is for single pass weld only.
3. At least one start and stop shall be included within the weld length.
4. Any base metal may be used that is weldable with the electrode to be employed in the test.

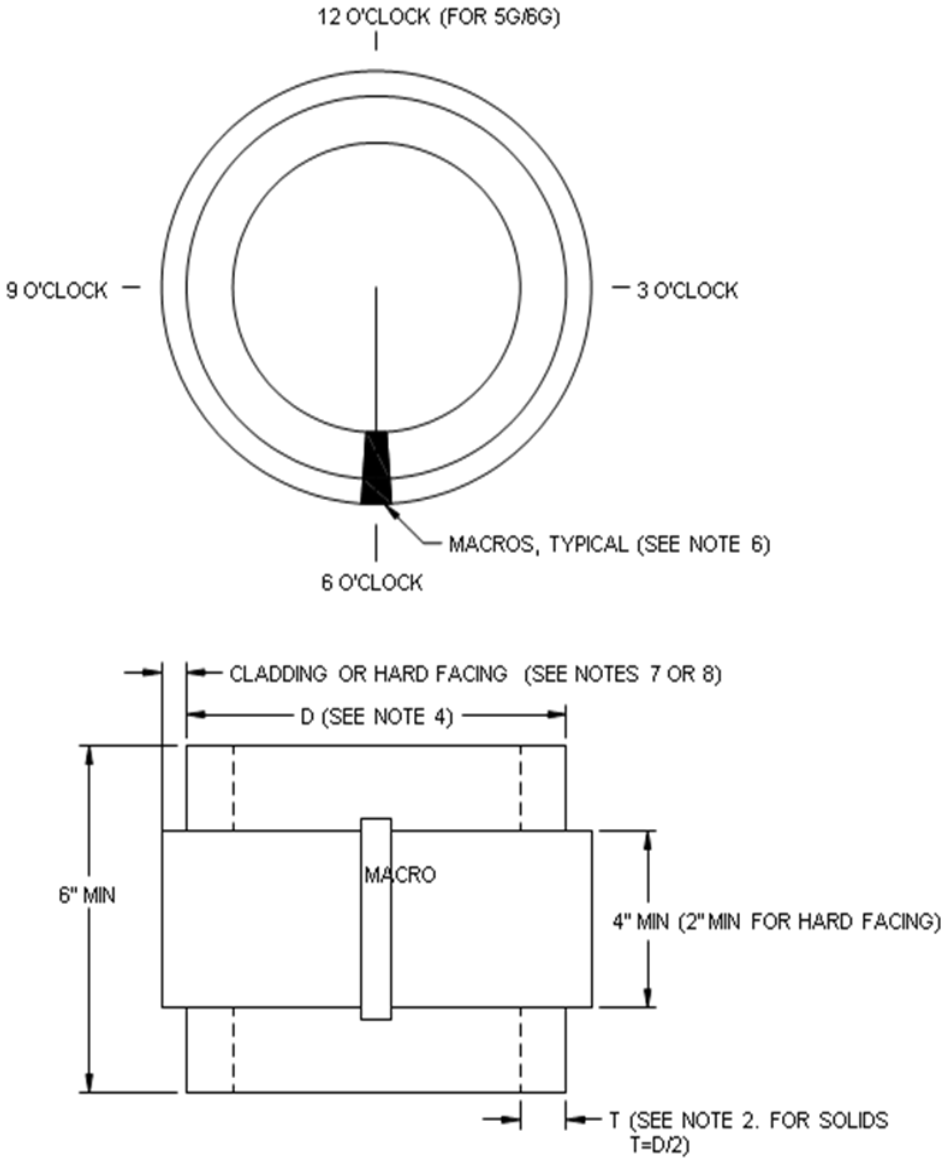
Figure 7-16. Performance Qualification Test No. 8 for Tack and Fillet Welders



NOTES:

1. Test assembly shown is for plate; for cylindrical products, see figure 7-17A.
2. Qualification positions shall be per table 7-9.
3. Base material thickness, T, shall be 1 inch or the minimum thickness to be qualified, whichever is less (see table 7-10).
4. Base material alloy shall match that of a qualified welding procedure for the filler material involved, except that S-1 base material may be used in lieu of S-2 through S-11 materials.
5. Welds should be made with the maximum size of filler metal suitable for the position of the test plate.
6. Test weld deposited thickness should be approximately equal to the un-machined weld thickness to be deposited in production; number of weld layers deposited shall be per figure 7-17A, note 7(a) (for hardfacing) or note 8(a) (for cladding).
7. Qualified weld thickness and minimum number of weld layers shall be per table 7-10, footnote 16 and figure 7-17A, note 7(a) (for hardfacing) or note 8(a) (for cladding).
8. The entire completed weld surface shall be machined and then VT and PT inspected per 5-4. Machining for hardfacing shall be per figure 7-17A, note 7(a) and, for cladding, figure 7-17A, note 8(a). Acceptance criteria for VT and PT shall be figure 7-6, note 4 for hardfacing or figure 7-4, note 4 for cladding. After NDT, cut, etch, and examine both faces of the macro-etch specimen per 5-4; for hardfacing, perform hardness testing per note 9 below and for cladding, perform composition testing per note 10 below when required.
9. For hardfacing, perform hardness testing by taking three evenly spaced hardness readings on the machined surface and following requirements of figure 7-17A for testing, acceptance criteria, and the allowance for retesting.
10. For cladding, where both criteria of figure 7-17A, note 8(a)(ii) are met, perform one composition test at a location near the end and center-width of the weld. The thickness and weld layer at which composition is obtained, and testing and acceptance criteria, shall be per figure 7-17A, notes 8(a)(ii) and 8(c).

Figure 7-17. Performance Qualification Test No. 9 for Weld Cladding and Hardfacing Plate



NOTES:

1. Qualification for cylindrical products shall be performed on pipe or other suitable cylindrical products per table 7-9. Notes 2 through 6 apply to all test welds. Additional requirements for hardfacing and cladding are specified by notes 7 and 8, respectively.
2. T, base material thickness, shall equal the minimum thickness to be qualified per table 7-10. Base material alloy shall match that of a qualified welding procedure for the filler material involved, except that S-1 base material may be used in lieu of S-2 through S-11 materials.
3. Welds should be made with the maximum size of filler metal suitable for the position of the test.
4. For manual and semiautomatic processes, weld test OD vs. production ODs to be welded (in inches) should be as follows:
   (a) Test an OD < 1 for production welding the OD tested and greater ODs.
   (b) Test an OD ≥ 1 but < 2-7/8 for production welding ODs 1 and greater.
   (c) Test an OD > 2-7/8 for production welding ODs 2-7/8 and greater.

For welding operators, the test diameter welded should be within the limits specified by a qualified welding procedure.

(Notes continued on next page.)

Figure 7-17A. Performance Qualification Test No. 9 for Hardfacing and Cladding for Circumferential Welding of Cylindrical Materials (for Propulsion Shafting, see MIL-STD-2191)

NOTES (continued):

5. Positions of welding shall be per table 7-9.
6. The entire completed weld surface shall be machined and then VT and PT inspected per 5-4 to the criteria of notes 7 or 8 as applicable. After NDT, a total of three macro-etch specimens shall be tested from each weld per 5-4. For 5G and 6G welds, macro-etch specimens shall be taken from the approximate 3, 6, and 9 o'clock locations; for 1G and 2G welds, the center test specimen location shall be separated by approximately 90 to 120 degrees from the surrounding locations. Hardness or composition testing shall also be performed where required by notes 7 or 8 at the thickness specified.
7. Hardfacing
   (a) Weld Thickness and Layers. Test weld deposited thickness should be approximately equal to the un-machined weld thickness to be deposited in production; weld layers and machined weld thickness shall be per notes 7(a)(i) or 7(a)(ii) below, as applicable. Qualified weld thickness and weld layers shall be per table 7-10, footnote 16 and as specified by notes 7(a)(i) or 7(a)(ii) below:
      (i) To qualify production welds of two layers minimum having a finished machined thickness of 3/16 inch minimum, at least two layers shall be deposited for the test weld. The test weld shall be machined to 3/16 inch before testing. A greater machined weld thickness may be used if required to support large qualified weld thicknesses per table 7-10.
      (ii) To qualify production welds having a minimum of one layer or a finished machined thickness of less than 3/16 inch, the number of layers deposited for the test weld should represent what is intended for production welding. The test weld shall be machined to the minimum number of layers and minimum machined thickness to be qualified for production. If necessary, etching shall be employed to discern the weld layer at which hardness testing is performed.
   (b) VT and PT Acceptance Criteria. The criteria of figure 7-6, note 4 shall apply.
   (c) Hardness Test. After NDT and machining to the thickness specified by 7(a) above, four evenly spaced hardness readings shall be taken on the surface; for 5G or 6G position test welds where uphill progression welding on the first layer occurs at the 9 o'clock and/or 3 o'clock location, take one reading at one of these uphill progression locations.

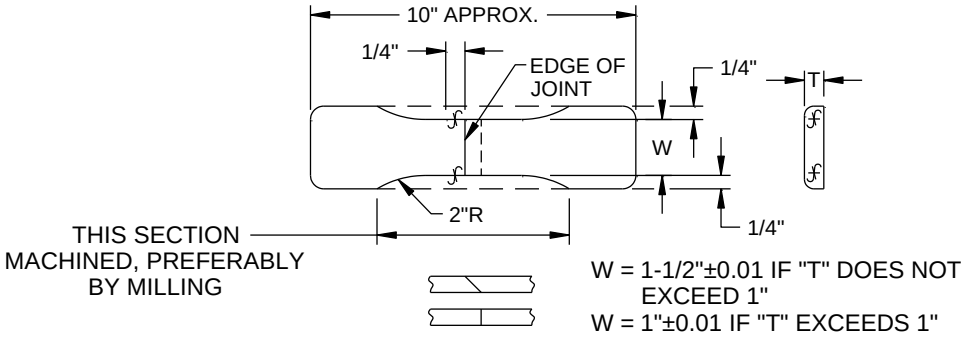
   Testing shall conform to AWS B4.0 utilizing the test method corresponding to the hardness value specified by the following applicable specification, or as otherwise approved: each reading shall meet the minimum hardness specified in the applicable Department of Defense specification, commercial specification, manufacturer's data sheet, or table 7-2, footnote 6, as applicable. Should one or more of these readings fail these criteria, five additional readings may be taken from each failure site and averaged; each average shall meet the hardness criteria of this note.
8. Cladding.
   (a) Weld Thickness and Layers. Test weld deposited thickness should be approximately equal to the un-machined weld thickness to be deposited in production; weld layers and machined weld thickness shall be per notes 8(a)(i) or 8(a)(ii) below, as applicable. Qualified weld thickness and weld layers shall be per table 7-10, footnote 16 and as specified by 8(a)(i) or 8(a)(ii) below:
      (i) For production welds (with or without composition being required per figure 7-4, note 5a) where two layers minimum and a finish machined thickness of 3/16 inch minimum is to be qualified, the test weld shall be two layers minimum and the weld shall be machined to 3/16 inch or greater thickness. Composition testing of the test weld is not required.
      (ii) For production welds where both (1) composition is required per figure 7-4, note 5a and (2) either one layer minimum or a finished machined weld thickness of less than 3/16 inch is to be qualified, the number of layers deposited for the test weld should represent what is intended for production welding. The test weld shall be machined to the minimum number of layers and minimum machined thickness to be qualified for production and then tested for composition per 8(c) below. If necessary, etching shall be employed to discern the weld layer at which composition testing is performed.
   (b) VT and PT Acceptance Criteria. Figure 7-4, note 4 criteria shall apply.
   (c) Composition Testing. Where required by note 8(a)(ii) above, after machining, perform one composition test. The location of the test shall be towards the center of the weld width, and the following:
      (i) For 5G or 6G position test welds where uphill progression welding on the first layer occurs at the 9 o'clock and/or 3 o'clock location, perform composition testing at one of the uphill progression locations.
      (ii) For other position test welds, circumferential location of the composition test site is discretionary.

   Machining, testing, and results shall conform to figure 7-4, note 6.

Figure 7-17A. Performance Qualification Test No. 9 for Hardfacing and Cladding for Circumferential Welding of Cylindrical Materials (for Propulsion Shafting, see MIL-STD-2191) - Continued

WELDING PERFORMANCE QUALIFICATION RECORD			
Welder/Welding Operator Name & ID No.			Date Welded
Welding Process	Type (manual, etc.)	Mode	Pulsing (Y/N)
Performance Qualification Test No. (or joint design)			
Base Material Form	Type	Thickness	Dia.
Filler Metal Type & Size/Shape (thickness [1/])			
Position – Plate	Position – Pipe		
Progression (up/dwn)	Restricted Access (fig. 7-24) (Y/N)		
Shielding Gas	Purge Gas		
NONDESTRUCTIVE TEST ACCEPTANCE CRITERIA & RESULTS			
RT	UT	MT	PT
VT [2/]			
NDT Acceptance Criteria & Standard			
Other		Repairs; attach info. _____	
DESTRUCTIVE TEST RESULTS			
Fillet Break: Fracture Surface -		Root Penetration -	
Bends (R, F) [3/]			Bend Radius
Macros			
Other			
[1/] For hardfacing and cladding, list weld thickness and layers where hardness or composition test is performed. [2/] For titanium, also list weld color (ID/OD); for thin socket/seal welds, list ID criteria. [3/] List bend type and result; R = Root, F = Face, etc.			
Workmanship/VT Criteria Exam; attach original exam certificate copy.			
Other (robotic seam tracking, etc.)			
Activity Certification Statement & Signature Activity Name: _____ The statements in this record are correct and the test welds were prepared, welded, and tested in accordance with NAVSEA S9074-AQ-GIB-010/248 Rev. _____ and _____. Name (print) Signature Date			

Figure 7-18. Sample Performance Qualification Record



REDUCED-SECTION TENSION SPECIMEN (PLATE) FOR BRAZED BUTT & SCARF JOINTS IN PLATE

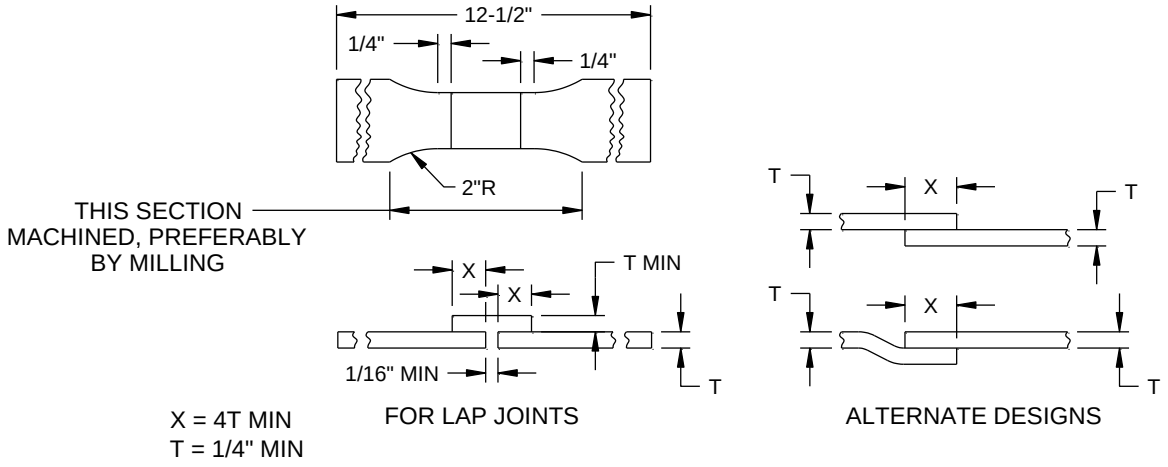
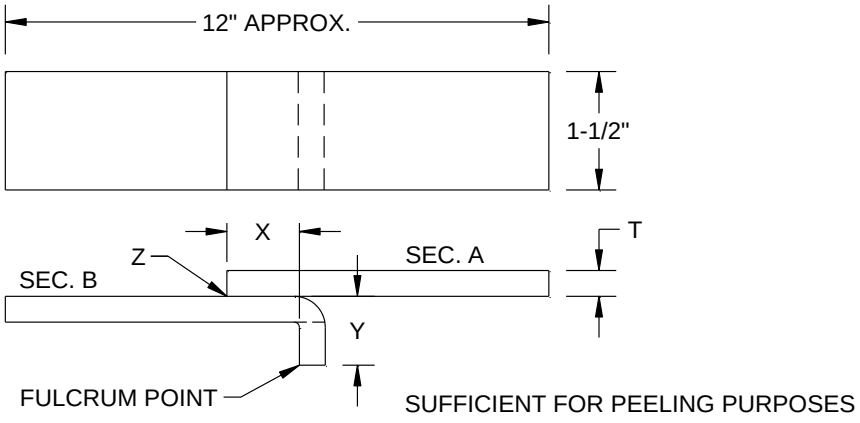


Figure 7-19. Reduced Section Tension Specimen (Plate) for Brazed Lap-Type Joints



LAP JOINT PEEL SPECIMEN

NOTES:
1. Flange Y may be omitted from section B when “peeling” is to be accomplished in a suitable tension machine.
2. Specimen shall be brazed from side marked Z.

X = 4T minimum or as required by design

Figure 7-20. Lap Joint Peel Specimen

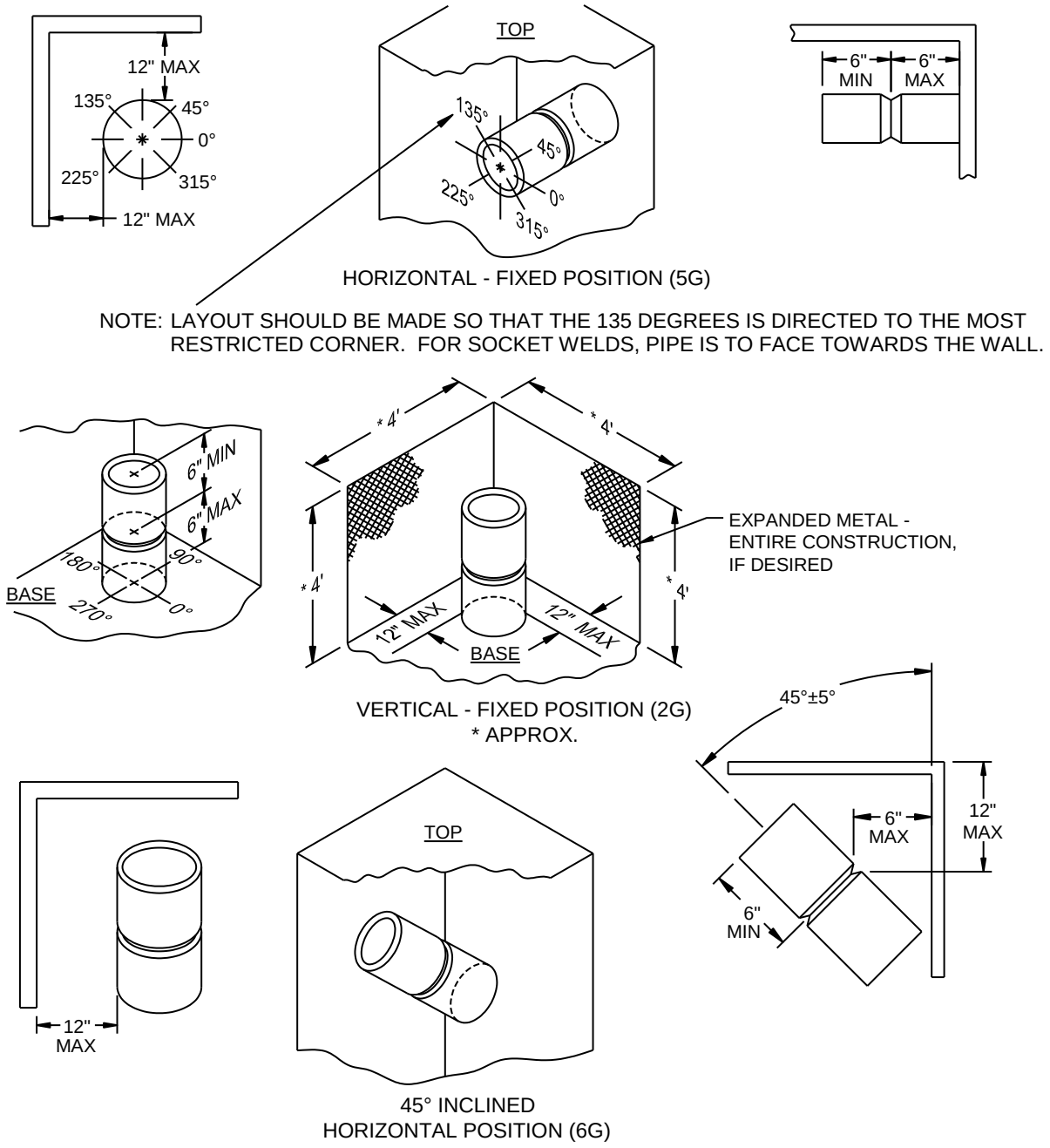
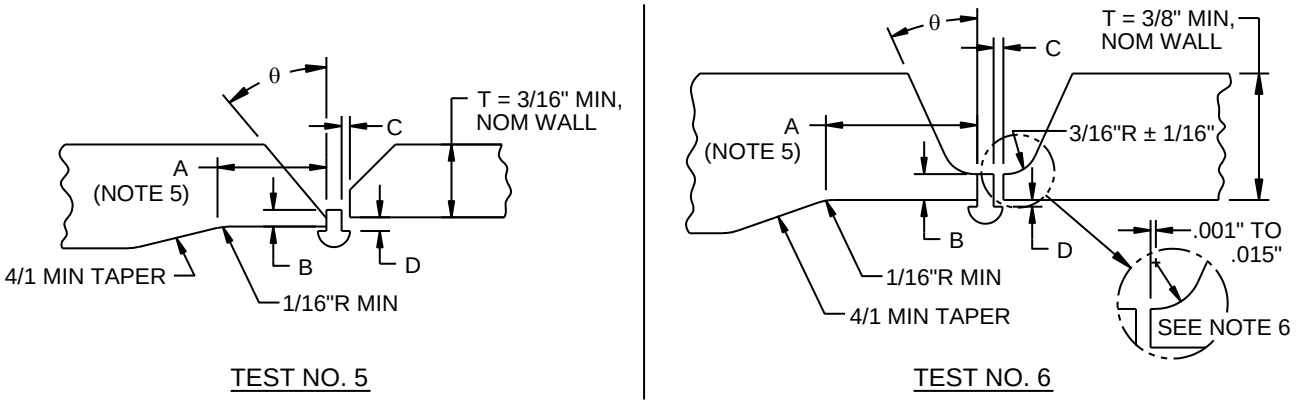


Figure 7-21. Typical Layout and Construction for Restricted Accessibility Qualification Test Assembly Positions



TEST NO.	DIM "B" 1 INCH NPS AND BELOW (SEE NOTE 9)	DIM "B" ABOVE 1 INCH NPS (SEE NOTE 9)	DIM "C" CLEARANCE	DIM "D" DIFF IN DIA	θ (SEE NOTES 8 AND 10)
5	0.010 ± 0.005	0.030 ± 0.005	0.031 MAX	0.031 MAX	40 ± 5°
6	0.010 ± 0.005	0.030 ± 0.005	0.031 MAX	0.031 MAX	25 ± 3°

NOTES:

1. The maximum difference in inside diameter of the pipes to be joined shall be 0.031 inch.
2. Welds should be made with the maximum size electrode or welding rod for the position and pipe wall thickness.
3. Radiographic inspection shall be performed for qualification evaluation. Pipe should be marked to ensure correct orientation for radiography.
4. If consumable inserts of different shapes than shown here are to be used in production, qualification is required for each shape of insert to be used. Joint geometry and fit-up tolerance shall be as developed during procedure qualification.
5. In lieu of the joint design shown above, any consumable insert joint design from MIL-STD-22 or from an approved procedure may be employed. If this is done, the test shall still be recorded as test nos. 5 and 6. The welder shall be considered qualified to the extent specified for the standard test nos. 5 and 6 joint.
6. Space restrictions may be omitted when welders are to weld piping without space restrictions (see figure 7-21). This limitation shall be entered in the qualification records.
7. Minimum (nominal wall thickness) is used to indicate that the dimension is the minimum thickness based on the minimum pipe wall thickness allowed by material specification. For example, 3/16 inch minimum (nominal wall thickness) would allow the use of any pipe wall considered 3/16 inch nominal even if the actual measured thickness was less than 0.187 inch, but in considering the 2T maximum of the qualified thickness range, the welder would be qualified to 3/8 inch nominal pipe wall.
8. For joints of nickel-copper materials, dimension "θ" may be changed to 47-1/2±2-1/2 degrees for test no. 5.
9. For joints of nickel-copper (S-42) and nickel-chromium-iron (S-43) materials, dimension "B" may be changed to 1/16±1/64 inch for test no. 6.
10. For pipe to be welded in the vertical axis position, θ on the low side of the joint may be as follows, provided the total included angle is two times the angle θ specified in the table:
    (a) 30±3 degrees for test no. 5.
    (b) 8±3 degrees for test no. 6.

Figure 7-22. Performance Qualification Tests Nos. 5 and 6 for Arc Welding (Pipe)

FLOW OF ALLOY THRU JOINT

C = JOINT CLEARANCE
L = LENGTH OF LAP OR THICKNESS

TYPICAL BRAZED JOINTS
SHOWING FLOW OF ALLOY

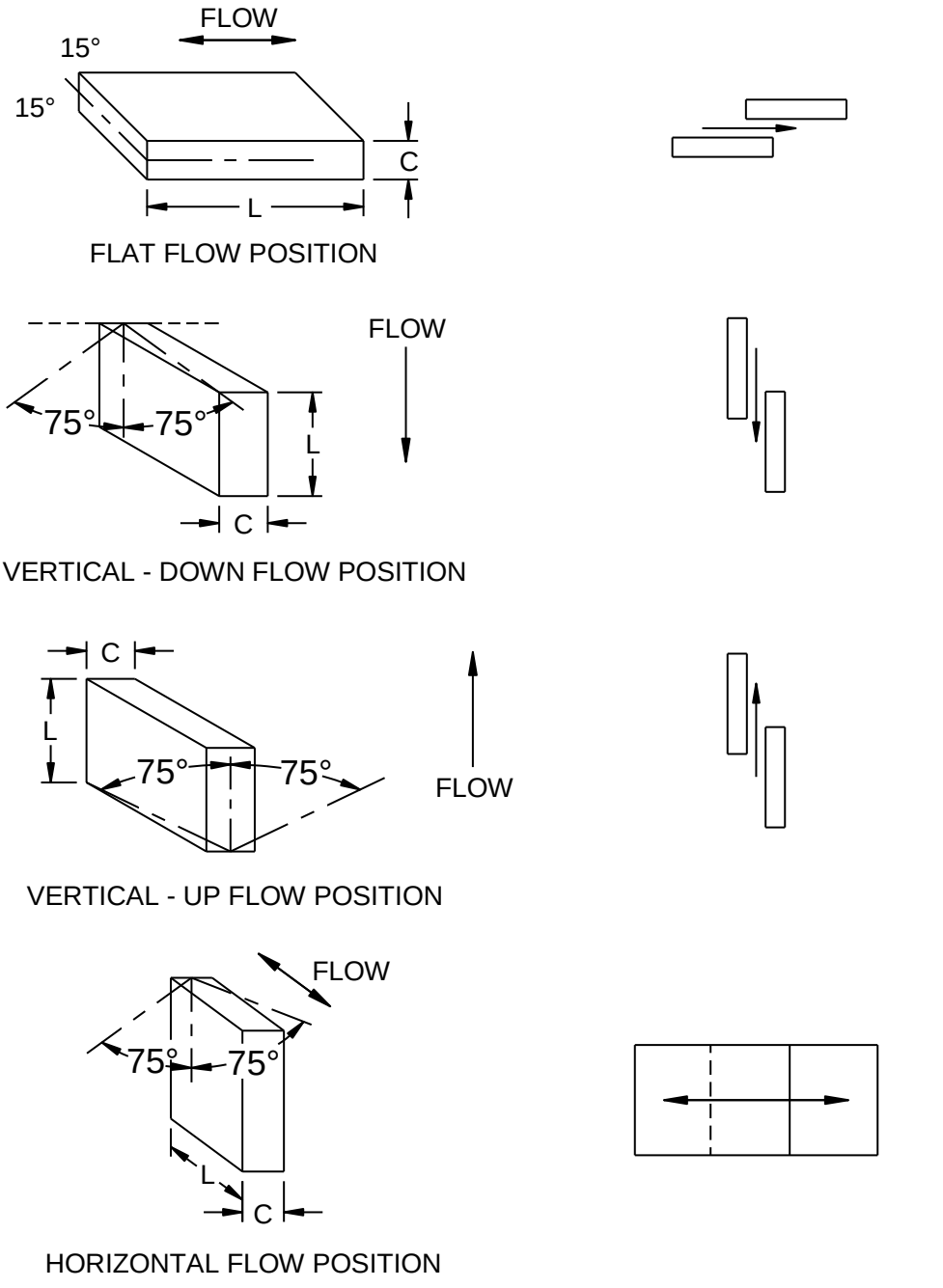
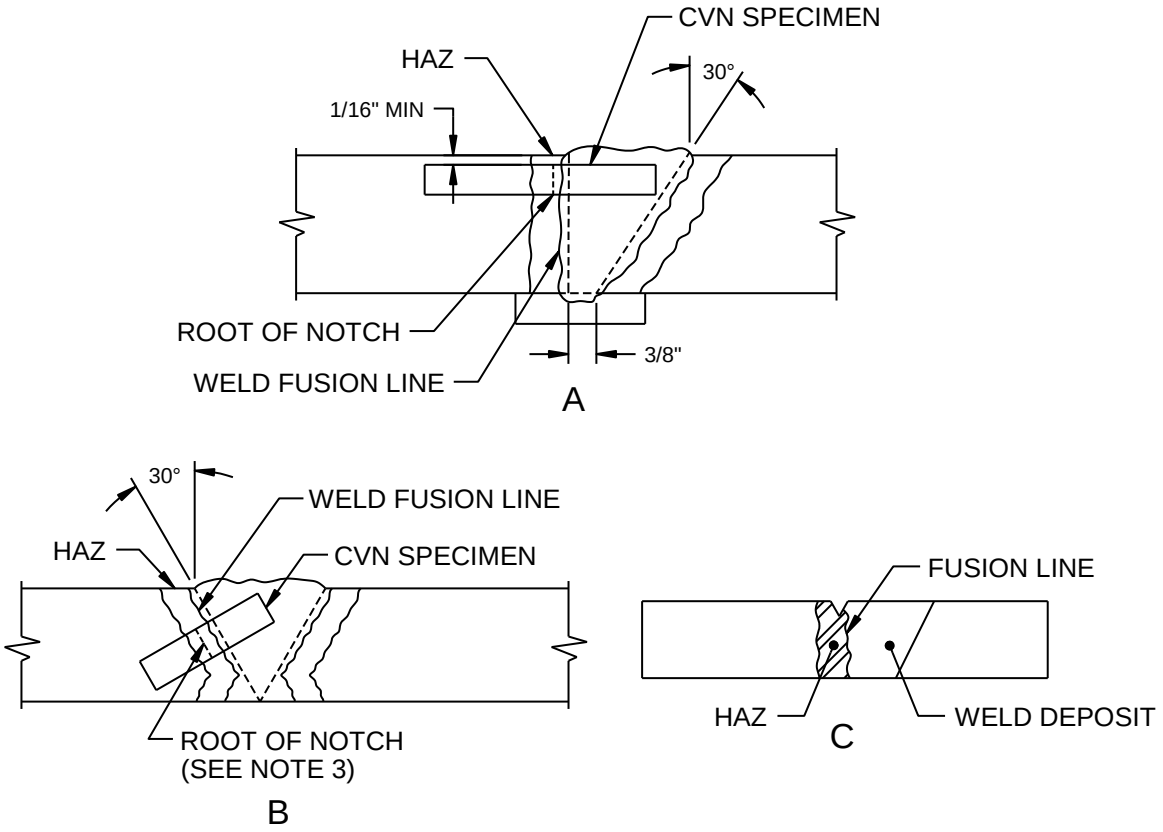


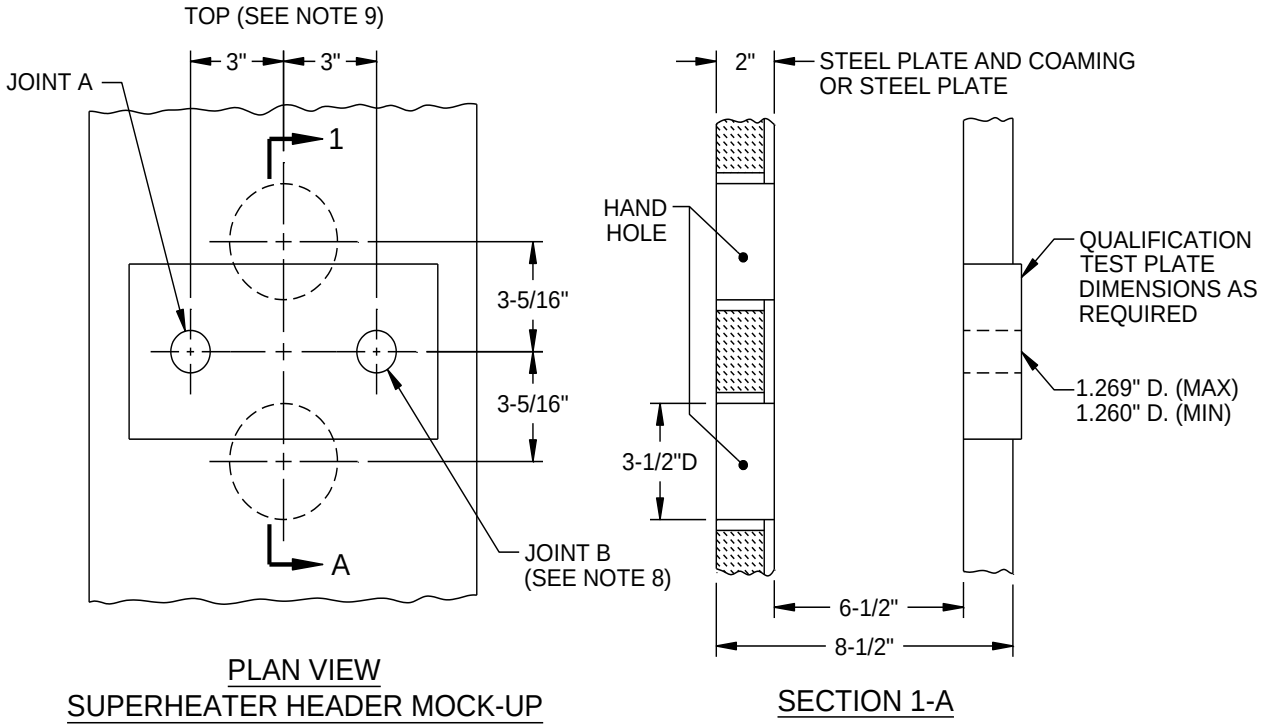
Figure 7-23. Brazing Positions



NOTES:

1. If the qualification test material is in the form of a plate or a forging, the axis of the weld shall be oriented in the direction parallel to the principal direction of rolling or forging. Unless inclined specimens are used as required below, a straight wall joint design similar to that shown in sketch A shall be used for obtaining HAZ CVN specimens. Where material thickness permits, the axis of each HAZ CVN specimen shall be inclined to allow the root of the notch to align parallel to the fusion line as shown in sketch B. The notch shall be entirely within the base metal HAZ. Material at least 1-1/2 inches thick is required for a single side, 30-degree bevel weld joint.
2. The CVN specimens shall be removed from a location as near as practicable to a depth midway between the surface and center thickness with the closest surface of the specimen being at least 1/16 inch from the surface of the base material (see sketch A). The coupons for HAZ CVN specimens shall be taken transverse to the axis of the weld and polished and etched to define the HAZ and fusion line prior to machining the notch. The notch of the CVN specimen shall then be cut approximately normal to the material surface, except for sketch B specimens, where the notch axis shall be approximately parallel to the fusion line.
3. Locate root of notch 0.5 to 1.5 millimeters from fusion line in the HAZ in a manner to include as much HAZ as possible in the fracture path.
4. For the comparison of HAZ values with base material values, CVN specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the HAZ specimens. The axis of the unaffected base material specimens and their notch axes shall be parallel to the axes of the HAZ specimens.
5. Testing and acceptance criteria shall be in accordance with 4.5.
6. Before testing, take color photomacrographs of at least one side view of all HAZ CVN specimens clearly showing the root of the notch and its location relative to the fusion line, and the entire etched HAZ/fusion line below the notch (see sketch C). Before testing, measure the distance of the root of the notch from the fusion line and record this distance using the location reference above, along with the energy required to break the specimen. Submit these along with other qualification test data for approval.

Figure 7-24. Heat Affected Zone (HAZ) and Base Material Charpy V-Notch (CVN) Specimens



NOTE: Orientation of the assembly shall be as required for the welding position specified in the welding procedure. Orientation shown is for welding in vertical headers (refer to note 9).

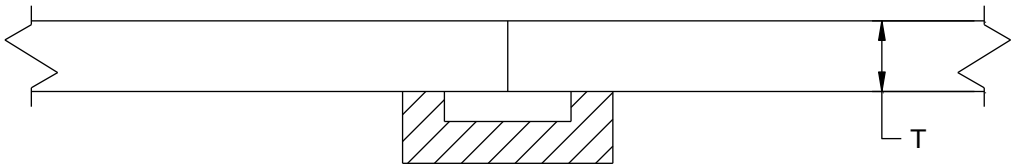
NOTES:

1. Header mock-up shall be fabricated from steel with top, bottom, and all sides closed, except as necessary for electrical lighting. Either pipe or plate may be used (plate shown) and thickness may be selected as necessary to achieve specified space restrictions, except material thickness shall be 3/16 inch nominal, minimum. Mock-up shall be at least 18 inches wide and 30 inches long with hand holes approximately centered.
2. Header mock-up should be constructed to permit easy removal of test plate for NDT inspection. Test plate shall be rigidly affixed in mock-up so that all welding and grinding is completed in place.
3. Insulation of hot surfaces shall simulate conditions the welder will experience in production. Inside surfaces of mock-up shall not be insulated.
4. Hand hole diameter and all other dimensions do not include insulation.
5. Babcock and Wilcox superheater headers provided by NAVSEA for welder qualification may be considered to meet these space restriction requirements for qualification of welding in the vertical position (that is, the tube in the horizontal-fixed position) only.
6. Except where minimum or maximum dimensions are shown, dimensional tolerances shall be ±1/16 inch.
7. More severe space restrictions than shown may be used if approved.
8. To meet the requirements of 5-3.6 for four joints, either of the following may be performed:
   (a) Under the conditions shown, the test assembly may be welded in two parts; that is, two joints followed by another two joints; or
   (b) An additional hand hole and enlarged/additional test plate meeting the same dimensional restrictions may be added as necessary to permit welding of all four joints at once.

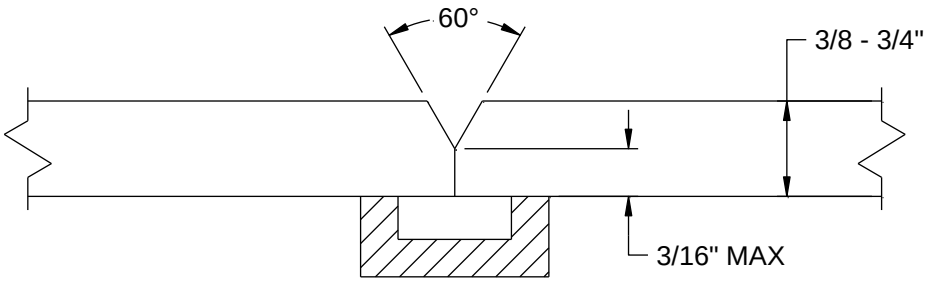
   In any event, the space restrictions and orientation shown shall be met for all joints and two "A" joints and two "B" joints shall be completed. Additionally, for the particular stage of welding (that is, root or final) inspection/testing shall be performed on all four joints at once (that is, welding and inspection of two joints followed by welding and inspecting another two is not permissible).
9. The orientation set by designation of "TOP" is for welding with the header mock-up positioned vertically; that is, the tube is in the horizontal fixed position.

Figure 7-25. Mockup and Orientation of Assembly for Performance Qualification for Manual Welding of Tube-to-Header Seal Weld Joints

	MANUAL	AUTOMATIC/ MECHANIZED
T	1/8" MAX	1/4" MAX



A. Weld joint for manual or automatic/mechanized weld



B. Weld joint for automatic/mechanized weld 1/

NOTES:

1/ Root pass made using keyhole technique, with no added filler metal. Remainder of weld made using melt-in technique with filler wire added or using another welding process.

Figure 7-26. Performance Qualification Test No. 10, Plasma Arc Welding – Keyhole Technique

CHAPTER 8
NOTES

8-1 CANCELLED SPECIFICATIONS.

The following are cancelled or superseded specifications for materials. They are listed in this document to identify applicable requirements for welding, nondestructive testing, etc., when the materials are encountered, such as on existing ships and components.

FEDERAL

QQ-A-200/1	-	Aluminum Alloy 3003, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-200/4	-	Aluminum Alloy 5083, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-200/5	-	Aluminum Alloy 5086, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-200/6	-	Aluminum Alloy 5454, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-200/7	-	Aluminum Alloy 5456, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-225/1	-	Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished, 1100
QQ-A-225/2	-	Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished, 3003
QQ-A-225/7	-	Aluminum Alloy 5052, Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished
QQ-A-250/1	-	Aluminum 1100, Plate and Sheet
QQ-A-250/2	-	Aluminum Alloy 3003, Plate and Sheet
QQ-A-250/6	-	Aluminum Alloy 5083, Plate and Sheet
QQ-A-250/8	-	Aluminum Alloy 5052, Plate and Sheet
QQ-A-250/10	-	Aluminum Alloy 5454, Plate and Sheet
QQ-A-601	-	Aluminum Alloy Sand Castings
QQ-B-626	-	Brass, Leaded and Nonleaded: Rod, Shapes, Forgings, and Flat Products with Finished Edges (Bar and Strip)
QQ-B-637	-	Brass, Naval: Rod, Wire, Shapes, Forgings, and Flat Products with Finished Edges (Bar, Flat Wire, and Strip)
QQ-B-728	-	Bronze Manganese; Rod, Shapes, Forgings, and Flat Products (Flat Wire, Strip, Sheet, Bar, and Plates)
QQ-B-750	-	Bronze, Phosphor; Bar, Plate, Rod, Sheet, Strip, Flat Wire, and Structural and Special Shaped Sections
QQ-C-390	-	Copper Alloy Castings (Including Cast Bar)
QQ-C-465	-	Copper-Aluminum Alloys (Aluminum Bronze) (Copper Alloy Numbers 606, 614, 630, 632M and 642); Rod, Flat Products with Finished Edges (Flat Wire, Strip, and Bar), Shapes, and Forgings)
QQ-C-576	-	Copper Flat Products with Slit, Slit and Edge-Rolled, Sheared, Sawed or Machined Edges, (Plate, Bar, Sheet, and Strip)
QQ-C-591	-	Copper-Silicon, Copper-Zinc-Silicon, and Copper-Nickel-Silicon Alloys: Rod, Wire, Shapes, Forgings, and Flat Products (Flat Wire, Strip, Sheet, Bar, and Plate)

QQ-N-288	-	Nickel-Copper Alloy and Nickel-Copper-Silicon Alloy Castings
QQ-S-763	-	Steel Bars, Wire, Shapes, and Forgings, Corrosion Resisting
QQ-S-766	-	Steel, Stainless and Heat Resisting, Alloys, Plate, Sheet and Strip
WW-P-404	-	Pipe, Steel, (Seamless and Welded, Black and Zinc-Coated (Galvanized))
WW-T-700/1	-	Tube, Aluminum, Drawn, Seamless, 1100
WW-T-700/2	-	Tube, Aluminum, Alloy, Drawn, Seamless, 3003
WW-T-700/5	-	Tube, Aluminum Alloy, Drawn, Seamless, 5086
WW-T-799	-	Tube, Copper, Seamless, Water (For Use with Solder-Flared or Compression Type Fittings)

MILITARY

MIL-S-860	-	Steel Forgings for Steam Turbine Rotors
MIL-S-867	-	Steel Castings, Corrosion Resisting, Austenitic
MIL-S-870	-	Steel Casting, Molybdenum Alloy
MIL-T-3595	-	Tubing, Phosphor Bronze: (Cda. No. 510) Round, Seamless
MIL-T-6736	-	Tubing, Chrome-Molybdenum, 4130 Steel, Seamless and Welded, Aircraft Quality
MIL-T-8504	-	Tubing Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded
MIL-S-8699	-	Steel Bars and Forging Stock (4330) Vanadium Modified, Aircraft Quality
MIL-T-9046	-	Titanium and Titanium Alloy, Sheet, Strip and Plate
MIL-T-9047	-	Titanium and Titanium Alloy Bars (Rolled or Forged) and Reforging Stock, Aircraft Quality
MIL-S-15083	-	Steel Castings
MIL-C-15345	-	Castings, Nonferrous, Centrifugal
MIL-S-15464	-	Steel Alloy, Chromium-Molybdenum; Castings
MIL-S-16216	-	Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)
MIL-B-16541	-	Bronze, Valve: Castings
MIL-S-16993	-	Steel Castings (12-Percent Chromium)
MIL-N-17163	-	Nickel-Copper Alloy, Wrought; (55-60 Percent Nickel) Low Permeability
MIL-S-17509	-	Steel Castings, Austenitic, Chromium-Nickel, Low Magnetic Permeability
MIL-S-18728	-	Steel Plate, Sheet and Strip, Alloy 8630, Aircraft Quality
MIL-S-18729	-	Steel Plate, Sheet, and Strip, Alloy 4130, Aircraft Quality
MIL-E-22200/9	-	Electrodes, Welding, Mineral Covered, Low-Hydrogen, Iron-Powder, Low-Hydrogen, Nickel-Manganese-Chromium-Molybdenum Alloy Steel for Producing HY-130 Weldments for As-Welded Applications
MIL-T-20155	-	Tubing, Steel, Alloy, Molybdenum, Seamless

MIL-T-20157 - Tube and Pipe, Carbon Steel, Seamless

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

MIL-T-20168 - Tubes, Brass, Seamless

MIL-F-20236 - Fittings, Tube and Pipe, Butt-Welding, 300 P.S.I and 775°F Maximum

MIL-F-20670 - Flanges, Pipe, Carbon Steel, 150 P.S.I, W.S.P (For Naval Shipboard Use)

MIL-A-21180 - Aluminum-Alloy Castings, High Strength

MIL-B-21230 - Bronze, Nickel Aluminum and Manganese-Nickel Aluminum, Castings, Ship Propeller Application

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

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

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

MIL-B-24059 - Bronze, Nickel Aluminum; Rod, Flat Products with Finished Edges, Shapes and Forgings

MIL-E-24355 - Electrodes, Welding, Bare, Solid, Nickel Manganese-Chromium-Molybdenum Alloy Steel for Producing HY-130 Weldments for As-Welded Applications

MIL-S-24371 - Steel Plate, Alloy, Structural, High Yield Strength (HY-130)

MIL-S-24412 - Steel, Special Structural Shape, Weldable, High Tensile (HT); for Submarine Hulls

MIL-S-24451 - Steel Heat Treated Heads, Alloy Structural, High Yield Strength (HY-80 and HY-100)

MIL-S-24645 - Steel Plate, Sheet or Coil, Age-Hardening Alloy, Structural, High Yield Strength (HSLA-80)

MIL-F-24669/8 - Forgings and Forging Stock, Steel for Integral Steam Turbine Rotors

AEROSPACE MATERIALS SPECIFICATION (AMS)

SAE AMS6530 - Steel Tubing, Seamless – 0.55 Ni-0.50 Cr-0.20 Mo (0.28-0.34C)

AMERICAN WELDING SOCIETY (AWS)

AWS A5.27 - Specification for Copper and Copper Alloy Rods for Oxyfuel Gas Welding

ASTM INTERNATIONAL

ASTM A53/A53M - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM A176 - Stainless Steel and Heat-Resisting Chromium Steel, Plate, Sheet and Strip

ASTM A296 - Specification for Corrosion-Resistant Iron-Chromium and Iron-Chromium Nickel and Nickel-B Alloy Castings

ASTM A557/A557M - Standard Specification for Electric-Resistance-Welded Carbon Steel Feedwater Heater Tubes

ASTM A569/A569M - Standard Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial

ASTM A570/A570M - Standard Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled

ASTM B337 - Standard Specification for Seamless and Welded Titanium and Titanium Alloy Pipe

8-2 BRAZING FILLER METAL INFORMATION.

The following line items provide information on intended uses and corresponding brazing temperatures for the filler metals listed in this manual. This information is advisory, not mandatory.

a. BAg-1 (grade VII) flows freely into tight capillary joints (small P-3a and P-3a special joints). It is not particularly susceptible to liquation. This metal contains cadmium, and the fumes it forms during brazing are toxic. Brazing temperature range 1,145 to 1,400 °F.

b. BAg-1a (grade IV) is similar to BAg-1. This metal contains cadmium, and the fumes it forms during brazing are toxic. Brazing temperature range 1,175 to 1,400 °F.

c. BAg-2 (grade VIII) is for general-purpose work. Care must be taken to prevent liquation. This metal contains cadmium, and the fumes it forms during brazing are toxic. Brazing temperature range 1,295 to 1,550 °F.

d. BAg-3 (grade V) is suitable for 300-series corrosion-resistant steel (CRES). This metal contains cadmium, and the fumes it forms during brazing are toxic. Brazing temperature range 1,270 to 1,500 °F.

e. BAg-5 (grade I) is suitable for brass. This alloy does not contain cadmium. It is better for filling wide joint clearances. Brazing temperature range 1,370 to 1,550 °F.

f. BAg-7 is a cadmium-free substitute for BAg-1. Brazing temperature range 1,205 to 1,400 °F.

g. BAg-8 is for copper and copper alloys, carbon steel, and nickel-based alloys. This alloy does not contain cadmium. It is very fluid. Brazing temperature range 1,435 to 1,650 °F.

h. BAg-8a is suitable for brazing precipitation hardening CRES and nickel alloys when they contain minor amounts of titanium or aluminum. This alloy does not contain cadmium. Brazing temperature range 1,410 to 1,600 °F.

i. BAg-9 (grade II) does not contain cadmium. Brazing temperature range 1,325 to 1,550 °F.

j. BAg-10 does not contain cadmium. Brazing temperature range 1,360 to 1,550 °F.

k. BAg-22 does not contain cadmium. Brazing temperature range 1,290 to 1,525 °F.

l. BAg-24 is low-melting and used for low-carbon 300-series stainless steels. This alloy does not contain cadmium. Brazing temperature range 1,305 to 1,550 °F.

m. BAg-35 is used to braze ferrous and nonferrous base metals. It is suitable for wider clearance joints. It is not suitable for stainless steel. This alloy does not contain cadmium. Brazing temperature of 1,390 to 1,545 °F.

n. BAg-36 is low-melting and used for ferrous and nonferrous base metals. It flows freely into tight capillary joints. It is not suitable for stainless steel. This alloy does not contain cadmium. Brazing temperature of 1,251 to 1,495 °F.

o. BCuP-2 is for copper and copper alloys. This alloy does not contain cadmium. Best with clearances of 0.001 to 0.003 inch. Brazing temperature range 1,350 to 1,550 °F.

p. BCuP-3 is for copper and copper alloys. This alloy does not contain cadmium. Best with clearances of 0.002 to 0.005 inch. Brazing temperature range 1,325 to 1,500 °F.

q. BCuP-4 is for copper and copper alloys. This alloy does not contain cadmium. Best with clearances of 0.001 to 0.003 inch. Brazing temperature range 1,275 to 1,450 °F.

r. BCuP-5 (grade III) is for copper and copper alloys. This alloy does not contain cadmium. Best with clearances of 0.002 to 0.005 inch. Brazing temperature range 1,300 to 1,500 °F.

APPENDIX A
PROCEDURE AND PERFORMANCE QUALIFICATIONS FOR FRICTION STIR WELDS, FRICTION STIR PROCESSING, AND REPAIR OF FRICTION STIR WELDS FOR ALUMINUM ALLOYS

A-1 SCOPE.

The following subsections contain the specific requirements for qualification of friction stir and are in addition to the applicable requirements of this document. The term friction stir (FS) is used to describe all friction stir variants, such as friction stir welding (FSW) and friction stir processing (FSP). If a requirement applies to a specific FS variant, the name of the FS variant will be used. The qualification tests required by this appendix are devised to demonstrate the adequacy of the FS procedures and the procedures for repair of friction stirred material, and the ability of FS operators to produce sound FS welds and FS processed material.

A-1.1 REFERENCED DOCUMENTS.

A-1.1.1 Non-Government Publications. The following document forms a part of this appendix to the extent specified herein.

AMERICAN WELDING SOCIETY (AWS)

AWS D17.3/D17.3M – Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications

(Copies of this document are available online at www.aws.org.)

A-1.2 ORDER OF PRECEDENCE. In the event of a conflict between the text of this appendix and the references cited herein, the text of this appendix shall take precedence.

A-2 DEFINITIONS.

Additional terms for FS shall be as follows:

A-2.1 GENERAL. Except as noted herein, FSW nomenclature and definitions shall conform to AWS D17.3. Additional terms related to FS are listed herein.

A-2.1.1 Dissimilar Metal Welding. The welding of two materials having different S-group numbers.

A-2.1.2 Double-Spindle. FS system equipped with two spindles to simultaneously weld or process material.

A-2.1.3 Effective Processing Size. For FS processed regions, the ratio of the plunge depth to the thickness of the material being processed (see figure A-1).

A-2.1.4 Force Control. A control method used to maintain the required force on the FS tool geometry during friction stir.

A-2.1.5 Friction Stir Processing (FSP). A removable, non-consumable component used to FS weld or FS process materials. The FS tool consists of a shoulder that may or may not have a protruding probe.

A-2.1.6 Friction Stir (FS) Tool. A removable, non-consumable component used to FS weld or FS process materials. The FS tool consists of a shoulder that may or may not have a protruding probe.

A-2.1.7 Friction Stir Tool (FS Tool) Class. A family of FS tools that share a common mechanical or geometrical feature, or that require unique control methodologies. For example, self-reacting, adjustable probe, fixed probe, or stationary shoulder.

A-2.1.8 Friction Stir (FS) Tool Design. Geometry of FS tool features that include, but are not limited to, shoulder diameter, shoulder shape, shoulder features, probe diameter, probe tip shape, probe length, probe shape (conical, cylindrical, etc.), threads, thread pitch, thread direction, number of threads, number of flats, and any other descriptive features of the shoulder, probe, or shank assembly.

A-2.1.9 Friction Stir Tool (FS Tool) Life. The maximum accumulated length of weld an FS tool can produce while maintaining weld soundness and performance requirements.

A-2.1.10 Friction Stir (FS) Variant. A technique employed that includes, but is not limited to, FSW, FSP, and FS spot welding.

A-2.1.11 Heel Plunge Depth. For tilted axis FS, the vertical dimension that the shoulder extends into the base material, measured perpendicularly from the base material surface to the bottom of the lowest point of the shoulder (see figure A-7).

A-2.1.12 Interpass Step-Over Distance and Direction. For FSP, the lateral distance the centerline of the FS tool moves between passes from the centerline of the preceding path and the direction the FS tool moves between passes relative to the centerline of the preceding path (i.e., to the advancing or retreating side of the preceding path's centerline).

A-2.1.13 Lateral Friction Stir Tool (FS Tool) Offset. The perpendicular distance measured from the centerline of the butt joint line to the FS tool axis (see figure A-5).

A-2.1.14 Multiple Pass (Multipass). Multiple FS passes performed in sequence that partially or entirely overlap a preceding FS pass.

A-2.1.15 Plunge Depth. The vertical dimension that the FS tool extends into the base material measured perpendicularly from the base material surface to the bottom of the probe tip (see figures A-7 and A-8).

A-2.1.16 Position Control. A control method whereby a programmed axial position profile is regulated and adapted by adjusting one or more process parameters via feedback in a closed loop control schema.

A-2.1.17 Probe-to-Anvil Gap. The vertical distance from the bottom surface of the base material to the bottom tip of the probe embedded within the base material (see figures A-7 and A-8).

A-2.1.18 Raster Pattern. A pattern defined by a shape (rectangular, circular, linear, etc.) and orientation (spiral in, spiral out, advancing side out, retreating side out, alternating retreating and advancing side out, etc.) that is formed as the FS tool traverses along a continuous programmed path and overlaps the preceding pass at a specified step-over distance between passes.

A-2.1.19 Remnant Oxide Trace (See Figure A-4). An oxide layer from the original joint area that is not fully mixed in the weld and can be seen upon viewing a weld cross-section under magnification. Remnant oxide traces are sometimes referred to as joint line remnants, kissing bonds, or Lazy S discontinuities.

A-2.1.20 Seam Tracking. The methodology (automatic, manual, or combination), equipment (cameras, gates, sensors, alarms, tooling, etc.) for maintaining the centerline of the FS tool axis at the desired distance from the centerline of the joint or programmed path.

A-2.1.21 Side Tilt Angle. Angle of the FS tool from the workpiece in the direction transverse to the direction of travel.

A-2.1.22 Single Pass. Welding or processing performed in a single continuous pass along the joint line or programmed path.

A-2.1.23 Single Spindle. FS equipment with a single spindle.

A-2.1.24 Special Welds. Welds as defined by 3-2.15 with the following additions for FS:

a. Base materials not covered in table A-1.
b. Dissimilar metals; also, welding of alloy 6061 to alloy 6082.
c. FS that involves the addition of filler materials.
d. Joint designs other than butt joints.
e. FSP of other than single or multiple passes following in a linear programmed path.

f. FS tool classes or variants not included in A-2.1.7 and A-2.1.10.

g. Use of portable FSW equipment.

h. Any application of FS other than for Littoral Combat Ship (LCS) 2 Ship Class hull structure fabrication/repair and other FS applications specified by a fabrication document.

A-2.1.25 Thermal Management. The method(s) employed for active or auxiliary heating or cooling of the FS tool, fixturing, base material(s), or machine component(s) (FS tool holder, spindle, etc.).

A-2.1.26 Thickness Mismatch. The height difference between the two parallel surfaces to be welded.

A-2.1.27 Tilt Angle (Travel Angle). The angle of the FS tool tilt from the workpiece in the direction of travel.

A-3 PROCEDURE QUALIFICATION FOR FSW, FSP, AND REPAIR OF FRICTION STIRRED MATERIAL.

A-3.1 SCOPE. This section provides general requirements for the qualification of FS procedures and procedures for repair of friction stirred materials, including repair by fusion welding. Specific qualification requirements for the categories listed below shall be as specified in A-3.4.

a. FSW

b. FSP

c. Repair of friction stirred material

d. Special welds

A-3.2 GENERAL REQUIREMENTS.

A-3.2.1 Submittal for Approval. Submittal for approval shall be as specified in 4-2.3, except that:

a. For FS processes, additional special weld requirements shall be per A-3.4.5, and

b. FS tool life procedures shall be approved per A-3.6.1.1.

A-3.2.2 Approval of Procedure Qualification for Special Welds. NAVSEA approval shall be obtained for special welds as defined in A-2.1.24.

A-3.2.3 Qualification Levels. Qualification levels for FSW, FSP, and repairs of friction stirred material shall be as specified herein.

A-3.2.3.1 General. Procedure qualification is required for base materials listed in table A-1, FSW, FSP, and associated repair of friction stirred materials as specified herein. The essential elements for each base material/filler metal combination shall be incorporated into the welding procedure and shall be in accordance with the requirements of this document and the applicable fabrication document.

A-3.2.3.2 Level I. This qualification level covers the initial qualification of any FS welding or processing procedure for the fabrication welding or processing of material by any activity. This qualification level also covers requalification of these procedures, after initial qualification, for variations outlined in A-3.7. The destructive and nondestructive test requirements and acceptance standards for the FSW and FSP qualification test assemblies shall be as specified by table A-2 and A-3.5. Qualification for fusion welding, FSW, and FSP does not qualify repair of friction stirred material. Repair of friction stirred material requires separate level II qualification in accordance with this document.

A-3.2.3.3 Level II. This qualification level covers requalification of level I qualified procedures for variations outlined in A-3.8, and for the initial qualification for repair of friction stirred material. The test assembly shall be welded with the modified essential element values and all other essential elements maintained within the level I qualification ranges unless otherwise stated herein. The destructive and nondestructive test requirements and acceptance standards for the FSW and FSP qualification test assemblies and qualification test assembly for repair of friction stirred material shall be as specified in table A-2 and A-3.5.

A-3.2.4 Position Qualification Limits for Position-Controlled FSW and FSP. For FSW and FSP employing the position-control method, the orientation of the spindle employed for procedure qualification test assemblies shall be classified by reference to the type of machine. The orientation of the spindle for FSW and FSP procedure qualification test assemblies shall be in the least stiff position of the machine.

A-3.2.5 Repair of Test Assembly. Assemblies shall not be repair welded. If a test assembly fails to meet the destructive or nondestructive requirements, the test assembly shall be rejected. In such cases, a duplicate test assembly may be welded using the same welding procedure and tested. If the second test assembly fails, that test assembly shall be rejected and an amended weld procedure that corrects the cause of defective welding shall be prepared and qualified as specified herein.

A-3.3 WRITTEN PROCEDURE CONTENT FOR FSW, FSP, AND REPAIR OF FRICTION STIRRED MATERIAL (SEE A-3.6.1.1 FOR FS TOOL LIFE PROCEDURE).

A-3.3.1 Essential Elements of a FSW Procedure, FSP Procedure, and Procedure for Repair of Friction Stirred Material. The FSW procedure, FSP procedure, and procedure for repair of friction stirred material shall include, at a minimum, the essential elements listed in table A-3. Essential elements for fusion welding repair of friction stirred material shall be per table 7-5 requirements and the applicable requirements from table A-3.

A-3.4 SPECIFIC QUALIFICATION REQUIREMENTS. This section provides the requirements for qualification test assembly size, test assembly fabrication, qualification limits, and methods of evaluation for qualification of an FSW procedure in A-3.4.1, an FSP procedure in A-3.4.2, and a procedure for repair of friction stirred material in A-3.4.3 for both general and special applications.

A-3.4.1 Qualification Requirements for FS Welded Butt Joints and Multi-Void Hollow Extrusion Joints.

A-3.4.1.1 Base Material. Qualification test assemblies shall conform to the base materials listed in table A-1 and shall be of the same alloy and form (plate, extrusion, etc.) to be welded in production.

A-3.4.1.2 Test Assembly Size. The typical test assembly size for an FSW qualification test assembly is shown in figure A-2 for level I qualification. The size of the test assembly shall be sufficient to permit removal of the required test specimens from the nominal start, middle and end of a single weld. The typical test assembly size for level II is shown in figure A-3. The size of the test assembly shall be sufficient to permit the removal of the level II required specimens from a single weld. FSW of additional test assemblies to furnish the required test specimens shall not be permitted.

A-3.4.1.3 Test Assembly Fabrication. The test assembly shall be prepared as specified in A-3.4.1.3.1. The test assembly shall be the same base material form and shall be fixtured and welded the same as intended for production welding to the extent possible. For example, the test assembly for a multi-void hollow extrusion should be fabricated on a multi-void hollow extrusion using the fixture and anvil arrangement, tack welding procedure, thermal management controls, and seam tracking, etc. employed during production to ensure that the procedure used is representative of a production weld.

A-3.4.1.3.1 Test Assembly Parameters. One test assembly each shall be prepared for the maximum and minimum nominal thickness to be welded in production employing (a) through (e) below such that the maximum anvil gap to be used in production is employed:

a. Minimum probe length.
b. Minimum heel plunge depth.
c. Minimum plunge depth.
d. Maximum allowable joint gap intended for production.
e. Maximum lateral FS tool offset intended for production.

A-3.4.1.3.1.1 Qualification of Thicknesses Between the Maximum and Minimum. Each nominal thickness in between the maximum and minimum nominal thickness to be welded in production requires level II qualification in accordance with A-3.2.3.3 employing the above conditions.

A-3.4.1.4 Test Assembly Joint Design. The test assembly shall employ the butt joint design to be used in production. Other joint designs shall be qualified in accordance with A-3.2.2.

A-3.4.1.5 FS Tool Life. Qualification welding shall be performed with a used FS tool. The FS tool shall be at 85 percent or greater of the proposed FS tool life. See A-3.6.1.1 for FS tool life procedure requirements.

A-3.4.1.6 Use of Qualified Procedures for Repair of Friction Stirred Material. A qualified FSW procedure is not qualified for repair of friction stirred material. Procedures for repair of friction stirred material shall be qualified as specified in A-3.4.3.

A-3.4.2 Qualification Requirements for FSP.

A-3.4.2.1 Base Material. Qualification test assemblies shall conform to the base materials specified in A-3.4.1.1.

A-3.4.2.2 Test Assembly Size. The typical test assembly size for an FSP qualification test assembly is shown in figure A-2 for level I qualification. The size of the test assembly shall be sufficient to permit removal of the required test specimens from the approximate start, middle, and end of a processed region. The typical test assembly size for level II is shown in figure A-3. The size of the test assembly shall be sufficient to permit removal of the required level II test specimens from a single test assembly. FSP of additional test assemblies to furnish the required test specimens shall not be permitted.

A-3.4.2.3 Test Assembly Fabrication. The test assembly shall be prepared as specified in A-3.4.2.3.1, and shall be fixtured and fabricated as intended for production, including the tooling and anvil arrangement, control methods, thermal management controls, etc. to the extent possible to ensure that the procedure used is representative of production FSP.

A-3.4.2.3.1 Test Assembly Parameters. One test assembly shall be prepared employing the following as intended for production:

a. Total number of passes to be used in production.
b. Travel direction and orientation of each pass relative to the preceding pass.
c. Maximum interpass step-over distance.
d. Effective processing size.

A-3.4.2.4 Qualification Limits for Interpass Step-Over Distance. The maximum interpass step-over distance shall not exceed the maximum interpass step-over distance recorded in the qualification test report.

A-3.4.2.5 FS Tool Life. Qualification welding shall be performed with a used FS tool. The FS tool shall be at 85 percent or greater of the proposed FS tool life. See A-3.6.1.1 for FS tool life procedure requirements.

A-3.4.2.6 Use of Qualified FSP Procedures for Repair of Friction Stirred Material. A qualified FSP procedure is not qualified for repair of friction stirred material. Repair of friction stirred material by FSP shall be qualified as specified in A-3.4.3.

A-3.4.3 Qualification Requirements for Repair of Friction Stirred Material.

A-3.4.3.1 Base Material. Qualification test assemblies shall conform to the base materials specified in A-3.4.1.1 and shall include the number of FS passes employed in the initial friction stirred region intended for production repair.

A-3.4.3.2 Test Assembly Size. The typical test assembly size for a repair qualification test assembly is shown in figure A-3. The size of the test assembly shall be sufficient to permit removal of the required test specimens as specified in table A-2 from the repair-welded area that contained the defect. Additional test assemblies to furnish the required test specimens shall not be permitted.

A-3.4.3.3 Test Assembly Fabrication. The test assembly shall be prepared employing the level I qualified FSW procedure or FSP procedure, as applicable. The use of an artificial or fabricated defect shall be approved by the authorized representative for in-service repairs. The test plate shall be made by FSW and the defect shall be similar in width and depth to those to be repaired in production. The test assembly shall be prepared as specified in table A-2.

A-3.4.3.3.1 FS Repair. For FS repair of friction stirred material, a qualified FS procedure shall be employed. The surfaces to be consumed by the FS repair pass may be ground to remove all irrelevant surface features. The defect shall be repair welded as intended in production.

A-3.4.3.3.2 Fusion Welding Repair of FS. For repair of friction stirred material by fusion welding, a qualified fusion welding procedure shall be employed. The defect shall be removed and repair welded as intended in production.

A-3.4.3.3.3 FS and Fusion Repair Combination. For FS repair of fusion-repaired friction stirred material, fusion repair shall be prepared as specified in A-3.4.3.3.2, ground flush with the base material surface, cleaned, and then FS repaired as intended in production within 4 hours from cleaning.

A-3.4.3.3.4 Exit Hole Repair. The exit hole shall be cleaned per the FSW procedure within 4 hours prior to repair and shall be repaired as intended during production.

A-3.4.3.4 Material Thickness Qualification Limits for Repair of Friction Stirred Material.

A-3.4.3.4.1 Surface Defects. For repairs of surface defects from a single side by FS, qualification of one nominal base material thickness qualifies unlimited base material thickness.

A-3.4.3.4.2 Other Defects. For repair of exit holes and defects other than surface defects, as specified in A.3.4.3.4.1, qualification at the maximum and minimum nominal base material thickness qualifies all base material thicknesses in between.

A-3.4.3.4.3 Fusion Welding. For repairs by fusion welding, material thickness qualification limits shall be based on the excavation depth and shall be in accordance with 4-4.1. Fusion weld repair of partial and full thickness excavations of FS welds shall be qualified separately.

A-3.4.3.5 Lateral FS Tool Offset Qualification Limits. For repairs of friction stirred welds with a remnant faying surface, the maximum lateral FS tool offset shall be no greater than the maximum offset used in repair qualification welding.

A-3.4.3.6 FS Tool Life. Qualification welding shall be performed with a used FS tool. The FS tool shall be at 85 percent or greater of the proposed FS tool life. See A-3.6.1.1 for FS tool life procedure requirements.

A-3.4.3.7 Changes to Qualified Repair Procedures. Changes that require level II requalification are listed in A-3.8.

A-3.4.4 Dissimilar Metal Welds. Dissimilar metal welds are special welds as specified in A-2.1.24. Refer to A-3.2.2 for approval of procedure qualification for special welds.

A-3.4.5 Special Welds. Special welds as defined in A-2.1.24 shall be qualified, inspected, evaluated, and recorded to all applicable requirements of this document. In addition, for base materials, filler metals, FS variants, and FS tool classes not covered by this document, the evaluation method and all variables and special techniques considered essential in producing a friction stirred region that will meet minimum material mechanical properties and the inspection requirements of this document shall be recorded and submitted with the procedure to NAVSEA for approval. Refer to A-3.2.2 for approval of procedure qualification for special welds.

A-3.5 EVALUATION OF PROCEDURE QUALIFICATION WELDMENTS. This section provides methods for evaluation of the tests required for the qualification of FSW procedures, FSP procedures, and procedures for repair of friction stirred materials. The type and number of destructive tests required for each assembly are shown in table A-2.

A-3.5.1 Nondestructive Tests. Prior to performing any destructive tests, all procedure qualification test assemblies shall be nondestructively tested as required in table A-2. Nondestructive testing and acceptance criteria shall be as specified in 4-5 and A-3.5.1.1 through A-3.5.1.3.

A-3.5.1.1 Visual Inspection. Prior to any cleaning or grinding, FS welded or FS processed regions shall be visually inspected.

A-3.5.1.1.1 Grinding Repair and Surface Preparation. Grinding of weld surfaces is not permitted to meet the acceptance criteria of MIL-STD-2035, but may be performed after acceptable visual inspection to prepare surfaces for other nondestructive tests in accordance with 4-5.1.2 and for removal of acceptable surface irregularities prior to destructive testing.

A-3.5.1.2 Liquid Penetrant Inspection. Prior to liquid penetrant inspection, the surface shall be prepared as specified in NAVSEA T9074-AS-GIB-010/271.

A-3.5.1.3 Acceptance Standards. Acceptance criteria for visual, radiography, liquid penetrant, and ultrasonic inspections shall be in accordance with class 1 of MIL-STD-2035 for FS.

A-3.5.2 Destructive Tests. Destructive testing shall be in accordance with 4-5 and the additional requirements of this section. Test results shall be evaluated as specified in A-3.5.2.1 through A-3.5.2.3.

A-3.5.2.1 Transverse Weld Tension Tests. For tensile tests, the recommended specimen dimensions of AWS B4.0 shall be followed. For acceptance, the transverse weld tension test specimens shall have a tensile strength not less than the minimum specified in table A-1, regardless of the failure location.

A-3.5.2.2 Guided Bend Tests. FS welds and FS processed regions shall be tested by wrap around bend tests. The elongation used to determine the radius of the mandrel shall be the greater of the minimum specified base material elongation or 10 percent.

A-3.5.2.2.1 Criteria for Acceptance. For acceptance, the bend test specimen after bending shall have no cracks or other open defects larger than ⅛ inch.

A-3.5.2.3 Macro-Etch Specimens. Specimens shall be removed transverse to the weld, prepared to 800-grit finish, etched to reveal remnant oxides, and examined at 10× magnification to the following requirements:

a. For FS welds or FS processed material, discontinuities in the weld or processed area greater in length than 1/32 inch or 10 percent of the material thickness, whichever is less, shall be cause for rejection. FS welds are subject to some amount of remnant oxides within the thermomechanically affected zone and shall not be cause for rejection if dispersed and discontinuous within the center of the thermomechanically affected zone. An aligned remnant oxide is rejectable if it has a linear accumulated length greater than 1/32 inch or 10 percent of the material thickness, whichever is less, within approximately 5 degrees of a line normal to the surface of the weld. An example of a remnant oxide trace is shown in figure A-4.

b. For partial penetration FS welds (such as multi-void extrusions), linear or rounded conditions at the root are acceptable provided they do not reduce the weld thickness below the minimum allowable thickness and provided they do not exceed 1/32 inch in length and adjacent linear defects are not closer than ⅛ inch. Root conditions outside the original joint configuration shall not be evaluated.

A-3.6 DATA AND REPORTING FOR PROCEDURE QUALIFICATION. This section specifies the requirements for procedure qualification data reporting to obtain approval of a procedure qualification test report for FSW, FSP, and repair of friction stirred material procedure qualification.

A-3.6.1 Test Report. The FSW, FSP, and repair of friction stirred material procedure qualification test report shall include the values employed for each of the essential elements of the welding procedure as specified in table A-3 and the destructive and nondestructive test results in sufficient detail to ensure compliance with the requirements of table A-2. Photomacrographs and any work instructions referenced in the procedure or test report that contain the required essential element information shall be submitted with the test report.

A-3.6.1.1 FS Tool Life Procedure Requirements. The test report shall include the activity's written procedure for establishing and tracking FS tool life. The procedure shall include:

a. A definition of maximum FS tool life measured in weld length and the testing (nondestructive and destructive) to validate the maximum life for each FS tool design. This shall account for the range of thicknesses to be welded in production with that FS tool.
b. The method used to track the FS tool life of each FS tool to ensure that the maximum FS tool life is not exceeded.
c. The method and frequency used to inspect, clean, and evaluate the conditions of FS tools.
d. Nominal dimensions of all geometrical features of the new FS tool and the used FS tool at the end of its life.

This procedure shall be provided for NAVSEA approval. An increase in FS tool life requires resubmission of the procedure to NAVSEA. Any decrease in FS tool inspection frequency or change in cleaning method shall be provided to the authorized representative for review. NAVSEA or the authorized representative may require requalification if there are specific technical concerns.

A-3.6.1.2 Control of Anvil Gap. The test report submittal shall include the activity's written procedure for establishing and maintaining the qualified FS tool plunge depth for the actual (not nominal) material thickness, probe length and, if used, heel plunge depth.

a. For each FS tool design qualified, define the maximum change in probe length for a given material thickness or the maximum change in material thickness for a given probe length. This change can be given in terms of a probe-to-anvil gap (see figure A-7) for a given FS tool design. This procedure shall account for the range of thicknesses and associated tolerances to be welded in production.
b. Define the method used to track material thickness, probe length, plunge depth, and heel plunge depth to ensure that the maximum probe-to-anvil gap is not exceeded.
c. Define the method and frequency used to inspect, clean, and measure probe length.
d. Define the method and frequency used to evaluate material thickness(es).

A-3.6.1.3 Work Instructions. All work instructions or other documents referenced in the qualification procedure or test report that contain essential element information shall be submitted along with the procedure qualification data.

A-3.7 CHANGES REQUIRING LEVEL I REQUALIFICATION OF PROCEDURE. New procedure qualification test data shall be submitted to the authorized representative for approval when any of the changes listed herein are made in the FSW or FSP procedure. For changes to repair procedures for friction stirred material, see A-3.8. For all procedures, changes other than those listed in this paragraph and A-3.8 for level II qualification may be made in a procedure without the necessity for requalification; however, the revised procedure with all changes identified shall be submitted for information to the authorized representative. The changes specified in A-3.7.1 through A-3.7.6 require requalification of the procedure for level I qualification.

A-3.7.1 Base Material (Alloy, Product Form, Coating, and Thickness).

a. A change from one base material alloy to any other base material alloy.
b. A change from one base material form to another base material form.
c. The addition or omission of base material coating.
d. For FSW, a change in the maximum or minimum nominal base material thickness reported in the qualification test report(s).
e. An increase in anvil gap.

A-3.7.1.1 Effective Processing Size. For FSP, a change in effective processing size (see figure A-1) from that reported in the qualification test report.

A-3.7.2 Filler Material.

a. A change in filler material.
b. A change in filler metal form; consumable FS tool, metal plug or stud, wire, or other forms.
c. Addition or omission of filler material.

A-3.7.3 Joint Design.

A-3.7.3.1 Butt Joints.

a. A change from partial penetration to full penetration or vice versa.
b. A change from integral backing to a joint without backing and vice versa.
c. A change from an unbacked joint to a joint with backing and vice versa.
d. A change in the form of welded backing.
e. An increase in joint gap of more than that recorded in the procedure test report.

A-3.7.3.2 Joint Type. A change in joint type. A-2.1.24 may also apply.

A-3.7.4 FS Variant, FS Tool Class, and Control Method.

A-3.7.4.1 FS Variant. A change from FSW to FSP or vice versa.

A-3.7.4.1.1 FS Tool Class. A change from one of the following listed methods to another listed method or to a method not listed:

a. Single-sided, fixed probe.
b. Double-sided, fixed probe, single spindle (single pass on each side, welded or processed in sequence).
c. Double-sided, fixed probe, double spindle (single pass on each side, welded or processed in parallel).
d. Retractable probe.
e. Self-reacting (fixed gap bobbin or adjustable gap).

A-3.7.4.2 Control Method. A change in one of the following listed process controls to another listed or a process control not listed:

a. Force control.
b. Position control.
c. Temperature control.

A-3.7.5 Equipment Variables.

A-3.7.5.1 Machine Model and Type. A change in manufacturer or manufacturer model number from that recorded in the qualification test report.

A-3.7.5.2 FS Tool Holder Design and Type. A change in FS tool holder design and type from that recorded in the qualification test report.

A-3.7.5.3 Anvil. A change in anvil material or design, or a decrease in cross-sectional area from that recorded in the qualification test report. See A-3.7.3.1 for integral backing requirements.

A-3.7.5.4 FS Tool (Material, Design, Life).

a. A change in FS tool material or coating.
b. An increase in FS tool life exceeding 5 percent of the FS tool life used for qualification welding.

c. A change from one FS tool design to another FS tool design (e.g., threaded conical probe to a cylindrical probe without threads, or convex shoulder with features to a smooth concave shoulder).

A-3.7.6 Welding Parameters.

A-3.7.6.1 Plunge Depth. For the position-control method only, a change in the plunge depth position outside the limits from that recorded in the qualification test report.

A-3.7.6.2 Force (Load). For the force-controlled method only, a change outside the limits from that recorded in the qualification test report.

A-3.7.6.3 Lateral FS Tool Offset for FSW. An increase in FS tool offset from that recorded in the procedure qualification test report (see A-3.4.1.3.1). A change in lateral FS tool offset to the opposite side of the joint from that recorded in the procedure qualification test report.

A-3.7.6.4 Thermal Management. A change in the thermal management method from that recorded in the procedure qualification test report.

A-3.8 CHANGES REQUIRING LEVEL II REQUALIFICATION PROCEDURE. For FSW, FSP, and repair of friction stirred material, one qualification test assembly as specified in A-3.2.3.3 shall be welded for each set of desired changes to the essential elements listed below from that recorded in a procedure previously qualified under level I.

A-3.8.1 Seam Tracking. A change from automatic to manual seam tracking or vice versa.

A-3.8.2 Travel Speed. A change greater than ±10 percent in the travel speed recorded in the procedure qualification test report.

A-3.8.3 FS Tool Rotational Direction. For direction-specific designed FS tools, any change in FS tool rotational direction from that recorded in the procedure qualification test report. For non-monolithic FS tools, any change in rotational relationship between the FS tool parts from that recorded in the procedure qualification test report.

A-3.8.4 FS Tool Rotational Speed. A change greater than ±10 percent in the FS tool rotational speed recorded in the procedure qualification test report.

A-3.8.5 Tilt Angle. A change greater than ±0.5 degrees in tilt angle from that recorded in the procedure qualification test report.

A-3.8.6 Side Tilt Angle. A change greater than ±0.2 degrees in side tilt angle from that recorded in the procedure qualification test report.

A-3.8.7 Shielding Gas.

a. A change from a mixture of gases to another mixture of gases, or to a single gas or vice versa.

b. A change from using a shielding gas to no use of shielding gas.

A-3.8.8 Base Material Thickness. For FSW, for thicknesses between the minimum and maximum nominal thickness qualified (see A-3.7.1.d), a change in nominal base material thickness from that recorded in the qualification test report(s). For repair of friction stirred material, base material thickness limits shall be as specified in table A-4 and A-3.4.3.4.

A-3.8.9 Joint Gap. A change in joint gap to a gap outside the limits from that recorded in the qualification test report.

A-3.8.10 Number of Passes and Direction of Passes. A change in the number of passes from that recorded in the procedure qualification test report. In multipass welds or programmed paths, a change in the direction of travel from that recorded in the procedure qualification test report from one pass in relation to the preceding pass.

A-3.8.11 Discard Length. Discard length less than that recorded in the qualification test report.

A-3.8.12 Repair of Friction Stirred Material. Any change in fusion welding process, FS variant, FS tool class, or sequence of applied processes, variant, or tool class from that employed for previously qualified procedure. A change from a partial thickness repair to a full thickness repair and vice versa.

A-3.8.13 Interpass Step-Over Distance and Direction for FSP. An increase in lateral step-over distance from that recorded in the procedure qualification test report. Also, a change in the direction of the lateral step-over to the opposite side of the FS pass from that recorded in the procedure qualification test report.

A-3.8.14 Thickness Mismatch. An increase in thickness mismatch from that recorded in the procedure qualification test report. A change in the location of the thicker member from one side of the joint to the other side of the joint from that recorded in the procedure qualification test report (i.e., a change in the location of the thicker member of a joint in relation [i.e., left or right joint side] to the FS tool travel direction).

A-3.8.15 Weld Joint Mismatch. An increase in weld joint mismatch from that recorded in the procedure qualification test report.

A-4 FSW PERFORMANCE QUALIFICATION.

A-4.1 SCOPE. This section provides the additional requirements for qualification of FS operators. Also included are the requirements for qualification records with suggested record format and forms for data accumulation and reporting.

A-4.2 GENERAL REQUIREMENTS.

A-4.2.1 Method of Establishing Qualification. The method for establishing qualification of friction stir operators is as follows:

a. Each FS operator shall know the FS workmanship and visual inspection requirements of all fabrication documents to which the FS operator will be working. To ensure this knowledge, each FS operator shall be trained and tested in accordance with a program meeting the requirements of A-4.2.1.1.
b. Each FS operator shall have satisfactorily FS welded, processed, or repaired the applicable performance qualification test assemblies.
c. Each qualification test assembly shall be inspected in accordance with the requirements of this section.
d. The results of either the destructive or nondestructive tests, or both, shall be evaluated in accordance with the applicable standards, unless otherwise specified in this document.
e. Current records of the extent of each FS operator qualification shall be maintained (see A-4.5.1).

A-4.2.1.1 Training Program. Each activity's training program shall be as specified in 5-2.3.1 and the following:

a. Training in FS workmanship and detailed visual inspection requirements of all fabrication documents to which FS is performed to NAVSEA T9074-AS-GIB-010/271.
b. Auditing of the entire program by authorized representatives to ensure adequacy. Audits shall be conducted at least once every 2 years and the audit shall specifically address FS operators.

A-4.2.1.2 FS Personnel. All personnel working with FSW, FSP, and repairs of friction stirred material shall be given formal instruction, within the limits of their discipline, on procedures for FSW, FSP, and repair of friction stirred material to attain the highest quality product. FS personnel shall include FS operators, nondestructive inspection personnel, the various inspectors responsible for work performance, and materials/welding engineers in production or support positions. Records of personnel training and test results shall be maintained with appropriate review to keep qualification current. A training plan, including methods of review to ensure continuous compliance, shall be submitted for NAVSEA approval.

A-4.2.2 Alternative Qualification Methods. As an alternative to A-4.2.1.a, qualification requirements for FS operators shall be satisfied by FSW, FSP, or repairing satisfactory procedure qualification test assemblies.

A-4.2.3 Qualification Limits by Material, Thickness, and Filler Material. Performance qualification limits shall be as listed in tables A-4 and A-5.

A-4.2.4 Requirements for Special Welds. For special welds, the proposed performance qualification program shall be included with the procedure qualification test data submitted for approval (see A-3.2.2).

A-4.2.5 Repair to Test Assemblies. Test assemblies may not be repair welded.

A-4.2.6 Maintenance of Qualification.

A-4.2.6.1 Renewal of Qualification Due to Lack of Process Use. Renewal of qualification due to lack of FS use not exceeding 1 year shall be made by making only one test assembly with all the essential elements used on any of the FS operator's previous qualification test assemblies. The test assembly shall be nondestructively inspected in accordance with table A-2 and destructively tested by one macro-etch specimen, one root bend, and one transverse weld tensile test in accordance with A-3.5. Successful completion of this test will re-establish the FS operator's qualification for all conditions for which the operator previously qualified with the FS variant employed. Renewal of qualifications under all other conditions shall be in accordance with initial qualifications required by this document except where lesser requirements are approved by the authorized representative.

A-4.3 PERFORMANCE QUALIFICATION TEST REQUIREMENTS.

A-4.3.1 FSW and FSP. Test assemblies shall be friction stirred with a qualified FSW or FSP procedure, as applicable.

A-4.3.1.1 Repairs to Friction Stirred Material. Personnel performing FS repair of friction stirred material shall be qualified for FSW or FSP, as applicable. Qualification of personnel performing fusion weld repair of friction stirred material shall be in accordance with Chapter 5, as applicable, for the fusion welding process involved.

A-4.4 TEST AND EVALUATION OF QUALIFICATION TEST ASSEMBLIES. This section provides the requirements for evaluation of qualification test assemblies. The tests required for each assembly are as specified in table A-2.

A-4.4.1 Nondestructive Inspection.

A-4.4.1.1 Visual Examination. Visual examination shall be performed prior to removal of flash and shall be performed for FS pass surface geometry and surface soundness in accordance with NAVSEA T9074-AS-GIB-010/271.

A-4.4.1.2 Nondestructive Test Performance. Nondestructive testing shall be performed in accordance with NAVSEA T9074-AS-GIB-010/271. Test assembly welds shall be 100-percent inspected except as permitted by A-4.4.1.3.

A-4.4.1.3 Acceptance Standards. Acceptance standards for liquid penetrant testing, visual examination, radiography, and UT shall be based on the requirements of MIL-STD-2035, class 1. Areas identified as discard in the qualified weld procedure need not be evaluated.

A-4.4.2 Destructive Tests. Required specimen preparation, dimensions, and mechanical testing shall be in accordance with A-3.5.

A-4.4.2.1 Bend Tests. Acceptance standards for bend tests shall be as specified in A-3.5.2.2.

A-4.4.2.2 Macro-Etch Specimen. Specimens shall be as specified in A-3.5.2.3.

A-4.5 DATA AND RECORDS. This section provides the requirements for performance qualification data accumulation and maintenance of records.

A-4.5.1 Records. The FS operator qualification test record shall include the information specified in 5-5.1 and the following:

a. Qualification test number
b. FS variant
c. FS tool classes, base material alloy, and temper

A-4.5.2 Retention of Objective Quality Evidence. Radiographs, test assemblies, and metallographic sections required for performance qualification shall be retained for a 1-year period after completion of contract.

A-4.6 CHANGES REQUIRING REQUALIFICATION OF FS OPERATOR. Requalification of FS operators to the requirements specified herein is required for the changes specified in A-4.6.1 and table A-5.

A-4.6.1 Fabrication Document Requirements. A change in fabrication document requirements shall be as specified in 5-6.9.

Table A-1. Grouping of Base Materials and Minimum Mechanical Property Limits for FS Butt Welded Aluminum [1/]

Letter No.	Applicable Document	Alloy	Ultimate Tensile Strength (ksi)	Yield Strength (ksi)
S-22	ASTM B221	5454-H111	31	16
	ASTM B209	5454-H112	31	12
	ASTM B209	5454-H32, H34	31	16
S-23	ASTM B221	6061-T6 [2/]	24	8
		6082-T4	24.6	8
		6082-T5	24.6	8
		6082-T6	24.6	8
S-25	ASTM B221	5083-H111	39	21
	ASTM B928/B928M	5083-H116, H321	40	24
S-25	ASTM B221	5086-H111	35	18
	ASTM B209	5086-H112 ¼ inch to ½ inch	35	17
	ASTM B209	5086-H112 ½ inch to 1 inch	35	16
	ASTM B209	5086-H112 greater than 1 inch	35	14
	ASTM B209	5086-H32, H34	35	19
	ASTM B928/B928M	5086-H116	35	19
S-25	ASTM B221	5456-H111	41	24
	ASTM B209	5456-H112	41	19
	ASTM B928/B928M	5456-H116, 321	42	26

NOTES:

1/ If material of similar chemistry and mechanical properties is not listed under an "S" group, it may be considered as a part of a group upon NAVSEA approval.

2/ Joining 6061 to 6082 requires NAVSEA approval per A-2.1.24 and A-3.2.2.

Table A-2. Procedure and Performance Qualification Test Plate Test and Inspection Requirements

Qualification Type	Qualification Level	Destructive Testing				Nondestructive Testing [4/, 5/, 9/]		
		Tensile	Guided Bend Test [2/]		Macro-etch [3/]	Radio-graphic	Liquid Penetrant [6/, 7/]	Ultrasonic [8/]
			Face	Root				
FSW and FSP procedure	I [1/]	3	3	3	3	X	X	X
	II	1	1	1	1	X	X	X
Repair of friction stirred material procedure	II [10/]	1	1	1	1	X	X	X
Operator performance	Initial	1	1	1	1	X	X	X
Operator performance	Requalification	1	1	1	1	X	X	X

NOTES:

1/ Specimens shall be taken from the approximate start, middle and end of the weld as shown in figure A-2.

2/ For welds fabricated from both sides, side bend testing shall be used in lieu of root bend tests for thicknesses greater than ½ inch.

3/ Macro-etch specimens shall be prepared as specified in A-3.5.2.3.

4/ Visual inspection of all test assemblies shall be performed per A-3.5 prior to other nondestructive testing and any destructive testing.

5/ Inspect 100 percent of friction stirred material when radiographic, ultrasonic, or liquid penetrant testing is specified, except for discarded areas.

6/ NAVSEA approval of the pre-penetrant chemical etch procedure in accordance with NAVSEA T9074-AS-GIB-010/271 shall be obtained prior to PT inspection of assemblies.

7/ Liquid penetrant inspection shall be performed prior to ultrasonic testing.

8/ Ultrasonic inspection shall only be performed on base material thickness ¼ inch and greater.

9/ For full penetration FS, both surfaces of the friction stirred region, including ½ inch of the adjacent base material, shall be inspected by VT and PT.

10/ Test specimens shall be taken from the repaired region of the test assembly that contained the defect.

Table A-3. Essential Elements of an FS Procedure [1/, 2/]

Element	FSW	FSP	Repair of Friction Stirred Material
Base material Specification and temper, or chemical analysis and condition	X	X	X
Base material product form Sheet, plate, extrusion, etc.	X	X	X
Base material thickness Nominal thickness and tolerances	X	X	X
Base material coating or cladding	X	X	X
Base material cleaning [3/]	X	X	X
Effective processing size (see figure A-1)	--	X	X
Filler material Specification, type or chemical analysis, diameter, wire, powder, or plug	X	X	X
Position For portable friction stir machine only, orientation of machine (overhead, vertical, flat [in-plane], etc.)	X	X	X
Raster pattern Sketch or diagram	--	X	X
Joint design Reference or sketches	X	--	X
Joint gap Nominal gap and tolerances	X	--	--
Weld joint mismatch Mismatch (out-of-plane mismatch)	X	--	--
Thickness mismatch (in-plane thickness mismatch)	X	--	--
FS variant FSW or FSP	X	X	X
FS tool class Standard, fixed probe (single or double spindle), retractable, self-reacting (fixed gap bobbin or adjustable)	X	X	X
Control method Force control, position control, temperature control, or other control scheme	X	X	X
Machine model and type Machine type (robotic, C-frame, gantry, etc.), manufacturer, and model	X	X	X
FS tool holder model and design FS tool holder design (geometry and material) and indication whether holder employs active cooling	X	X	X
Seam tracking Methodology (automatic, manual, or combination), equipment (cameras, gates, sensors, alarms, tooling, etc.) for maintaining the centerline of the FS tool at the desired distance from the centerline of the joint or programmed path	X	X	X

See footnotes at end of table.

Table A-3. Essential Elements of an FS Procedure [1/, 2/] - Continued

Element	FSW	FSP	Repair of Friction Stirred Material
Fixturing method and arrangement Method of fixturing (hydraulic, roller, manual clamps, etc.) and arrangement	X	X	X
Anvil design and material Material, design, and cross-sectional area	X	X	X
FS tool material Material, coatings, and surface treatment of the FS tool (probe, shoulder if not integral, etc.)	X	X	X
FS tool design FS tool drawing (assembly and components), nominal dimensions and tolerances of shaft, shoulder, and probe features, including probe length	X	X	X
FS tool life Measured in length of weld	X	X	X
FS tool cleaning [2/] Inspection, frequency, and method	X	X	X
Axial position control method For position control, workpiece surface sensor, anvil position sensor, welding head position sensor, etc.	X	X	X
Pounce position Programmed position of FS tool prior to initiation of plunging FS tool into material.	X	X	X
Plunge depth Axial position of FS tool within material	X	X	X
Dwell times Dwell time at the start and end of weld	X	X	X
Travel speed Nominal travel speed and tolerances	X	X	X
Force (load) Programmed load and axis of applied load for load controlled FS tool paths only	X	X	X
FS tool rotational direction Clockwise (CW) or counter-clockwise (CCW) when viewed from the spindle towards the travel direction	X	X	X
FS tool rotational speed Nominal FS tool rotational speed and tolerances	X	X	X
FS tool tilt angle (travel angle) Angle of FS tool tilt from the workpiece in the direction of travel	X	X	X
FS tool side tilt angle (work angle) Angle of FS tool tilt from the workpiece in the direction transverse to the direction of travel	X	X	X

See footnotes at end of table.

Table A-3. Essential Elements of an FS Procedure [1/, 2/] - Continued

Element	FSW	FSP	Repair of Friction Stirred Material
Lateral FS tool offset Nominal lateral FS tool offset distance from joint and direction (see figure A-5)	X	--	X
Interpass step-over distance and direction Step-over distance between passes and direction (advancing or retreating side) relative to the preceding pass or weld	--	X	X
Number of passes and direction Total number and travel direction of each pass relative to the preceding pass	X	X	X
Shielding gas Composition, flow rate	X	X	X
Thermal management method Specification of method employed for active or auxiliary heating or cooling of the friction stir tool, fixturing, base material(s), or machine component(s)	X	X	X
Preheat and interpass temperature limits	X	X	X
Post weld heat treatments	X	X	X
Post weld surface dressing	X	X	X
Exit hole placement	X	X	X
Exit hole removal procedure Mechanical means of removal intended during production	X	X	X
Tack welding procedure Essential elements, method, length and frequency along length of joint line	X	X	X
Type and description of defect to be repaired	--	--	X
Qualified FSW, FSP, or fusion welding procedure being used in repair procedure	--	--	X
Discard length Length of material removed from the ends of the qualification test assembly. The discard length shall be representative of the length of material to be removed in production.	X	X	X
Probe-to-anvil gap (see figures A-7 and A-8) Maximum probe-to-anvil gap, including maximum material thickness, minimum probe length, plunge depth, and minimum heel plunge depth	X	X	X
Heel plunge depth (see figure A-7)	X	X	X
Bottom radius width and sidewall angle [4/]	--	--	X
Sidewall angle [4/]	--	--	X

See footnotes at end of table.

Table A-3. Essential Elements of an FS Procedure [1/, 2/] - Continued

NOTES:

1/ The fusion welding process shall use a qualified procedure conforming to other applicable sections herein. The qualified fusion welding procedure shall be submitted with the qualification package.

2/ See A-3.6.1.1 for FS tool life, inspection, etc.

3/ The FS activity shall notify NAVSEA of any changes in base material cleaning. The revised work instruction and procedure shall be provided to the authorized representative for review. The authorized representative may require requalification if the authorized representative has a concern.

4/ Only applicable to fusion weld repairs of FS welds.

Table A-4. Base Material Thickness Qualification Limits

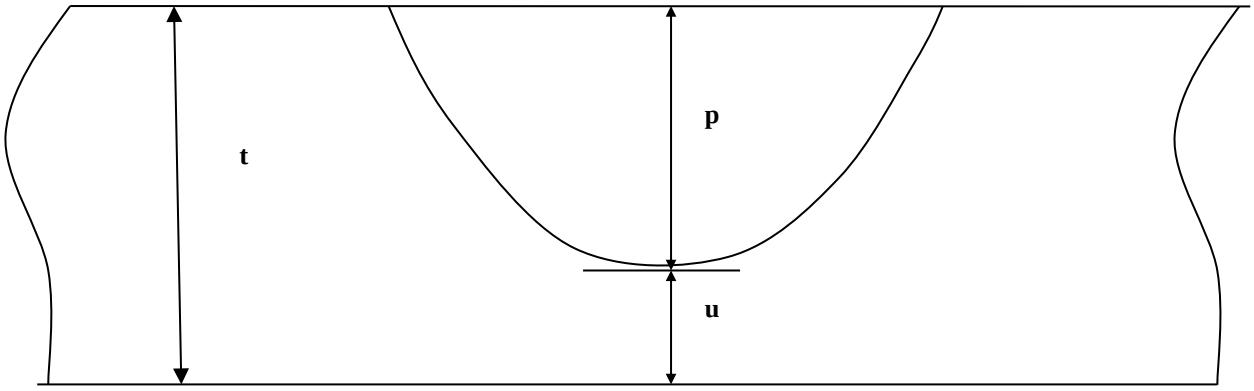
Condition	Test Material Thickness (T)	Thickness (T) Qualified	Required Qualification of Test Assembly
Level I - FSW procedure			
--	Minimum nominal thickness	Minimum nominal thickness	Test no. 1 (figure A-2)
--	Maximum nominal thickness	Maximum nominal thickness	Test no. 1 (figure A-2)
Level II – FSW procedure			
--	Each nominal material thickness between the maximum and minimum nominal thickness qualified for level I	Each nominal thickness used in production	Test no. 2 (figure A-3)
Level I – FSP procedure			
--	Minimum and maximum effective processing size to be used in production	Minimum and maximum effective processing size	Test no. 1 (figure A-2)
Level II – FSP procedure			
--	Each effective processing size between the minimum and maximum effective processing size qualified	Each effective processing size to be used in production	Test no. 2 (figure A-3)
Level II – Repair of friction stirred material procedure			
Repair of surface defect	Any thickness	Unlimited	Test no. 2 (figure A-3)
Repair of defects other than surface defects	Minimum and maximum nominal thickness used in production	All material thickness between the minimum and maximum base material thickness qualified	Test no. 2 (figure A-3)
Repair by fusion welding	See A-3.4.3.4.3	See A-3.4.3.4.3	Test no. 2 (figure A-3)
Performance qualification			
--	Any thickness	Unlimited	Test no. 3 (figure A-6)

Table A-5. Performance Qualification Test Limits [1/]

Element	Qualification Limit	Changes Requiring Requalification	Required Requalification Test Assembly
Base material form	Base material form employed for qualification testing	Change from plate to extrusion. Change from extrusion to multi-void hollow extrusion	Test no. 3 (figure A-6)
Machine	Machine employed for qualification testing	Change to different machine from that employed for qualification testing	Test no. 3 (figure A-6)
FS variant	FS variant employed for qualification testing	Change from FSW to FSP or vice versa	Test no. 3 (figure A-6)
FS tool class	FS tool class employed for qualification testing	Change from one method to another as listed in A-3.7.4.1.1	Test no. 3 (figure A-6)
Control method	Control method employed for qualification testing	Change from one method to another as listed in A-3.7.4.2	Test no. 3 (figure A-6)
Thermal management	Thermal management employed for qualification testing	Change in thermal management method from that recorded in the procedure qualification test report	Test no. 3 (figure A-6)
Seam tracking	Manual or automatic	Change from manual to automatic or vice versa	Test no. 3 (figure A-6)
Shielding gas	Shielding gas employed for qualification testing	Change to the use of shielding gas	Test no. 3 (figure A-6)
Filler material	Filler material employed for qualification testing	Change to the use of filler material	Test no. 3 (figure A-6)

NOTE:

1/ Performance qualification assemblies shall be evaluated in accordance with A-3.5 and table A-2.



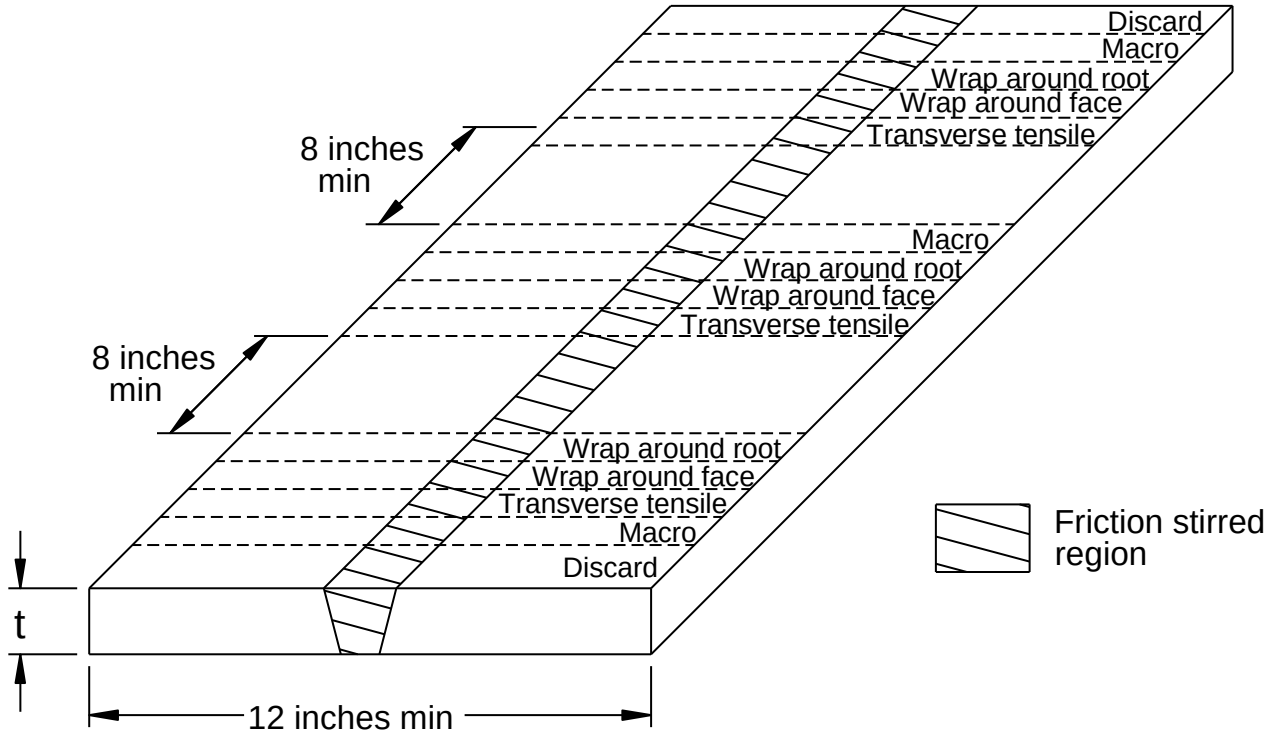
NOTES:

t = base material minimum nominal thickness

p = plunge depth

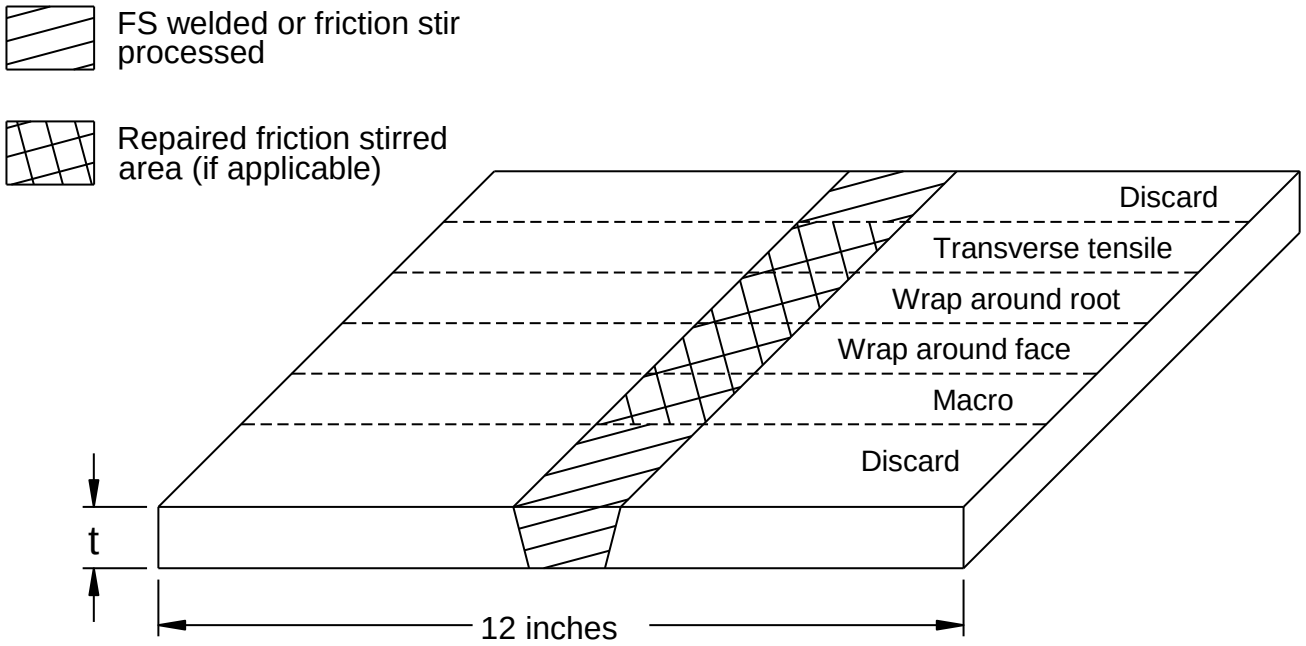
u = unprocessed depth

Figure A-1. Schematic Illustrating the Effective Processing Size Defined by Ratio of (p/t)



NOTES:
1. Test assembly size shall be as specified by A-3.4.1.2 for FSW and A-3.4.2.2 for FSP.
2. Test assembly fabrication shall be as stated in A-3.4.1.3 for FSW and A-3.4.2.3 for FSP.
3. The discard length recorded in the qualification test report does not need to be evaluated by NDT.

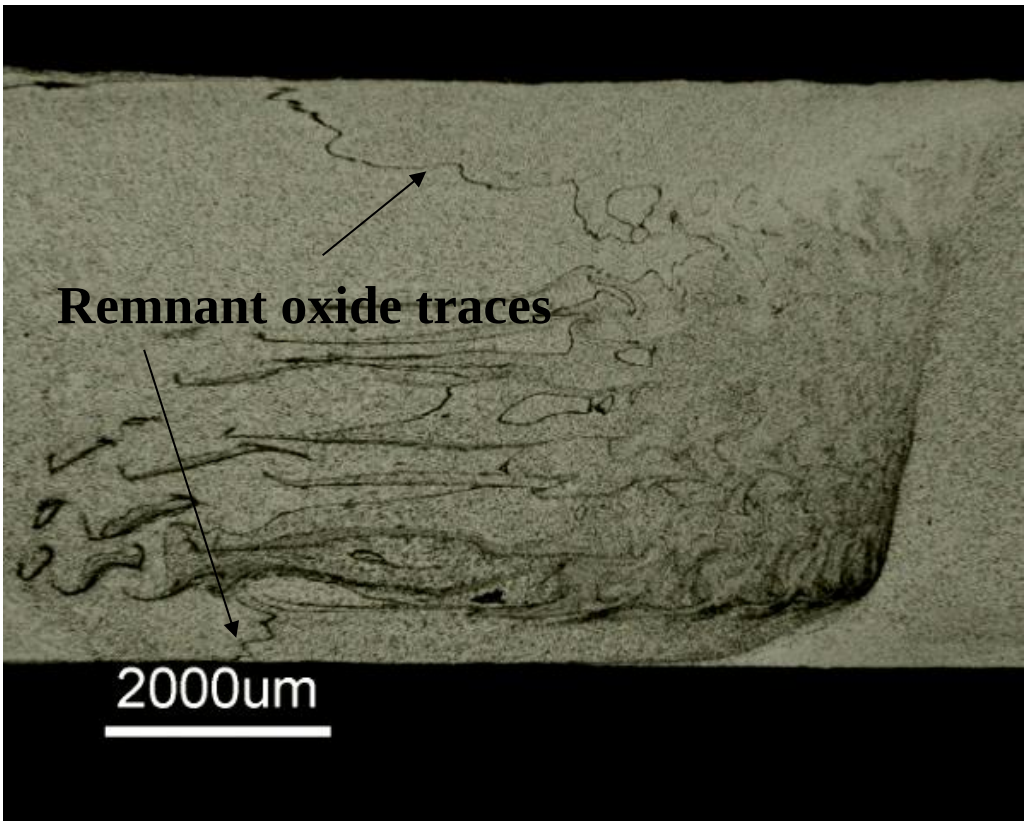
Figure A-2. Schematic of Test No. 1 for FSW Procedure and FSP Procedure Qualification Test Assembly



NOTES:

1. Test assembly size shall be as specified by A-3.4.1.2 for FSW, A-3.4.2.2 for FSP, and A-3.4.3.2 for repairs.
2. Test assembly fabrication shall be as stated in A-3.4.1.3 for FSW, A-3.4.2.3 for FSP, and A-3.4.3.3 for repairs.
3. Exit hole repair procedures only require one macro-etch specimen taken transverse to the weld at the center of the exit hole.
4. The discard length recorded in the qualification test report does not need to be evaluated by NDT.

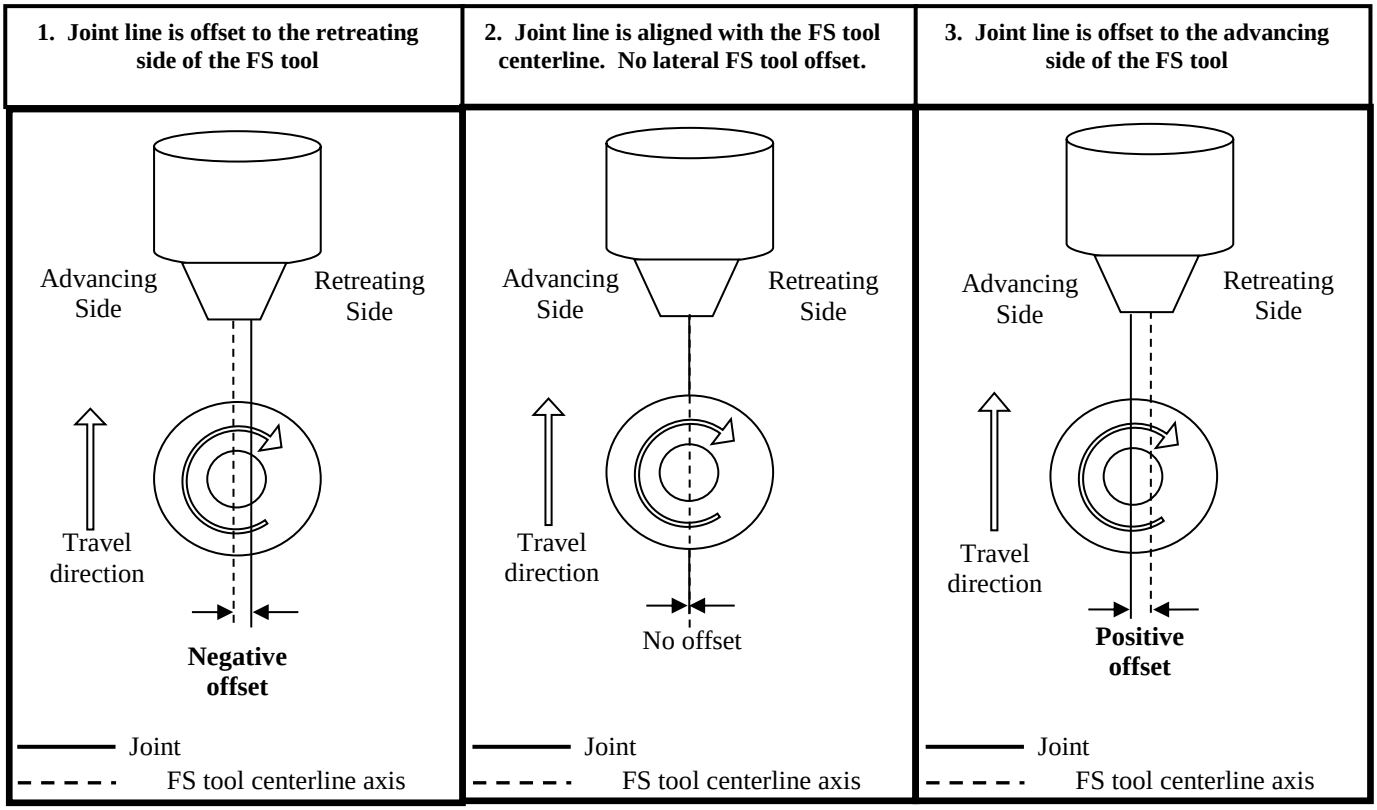
Figure A-3. Schematic of Test No. 2 for Level II FS Procedure Qualification Test Assembly



NOTE:

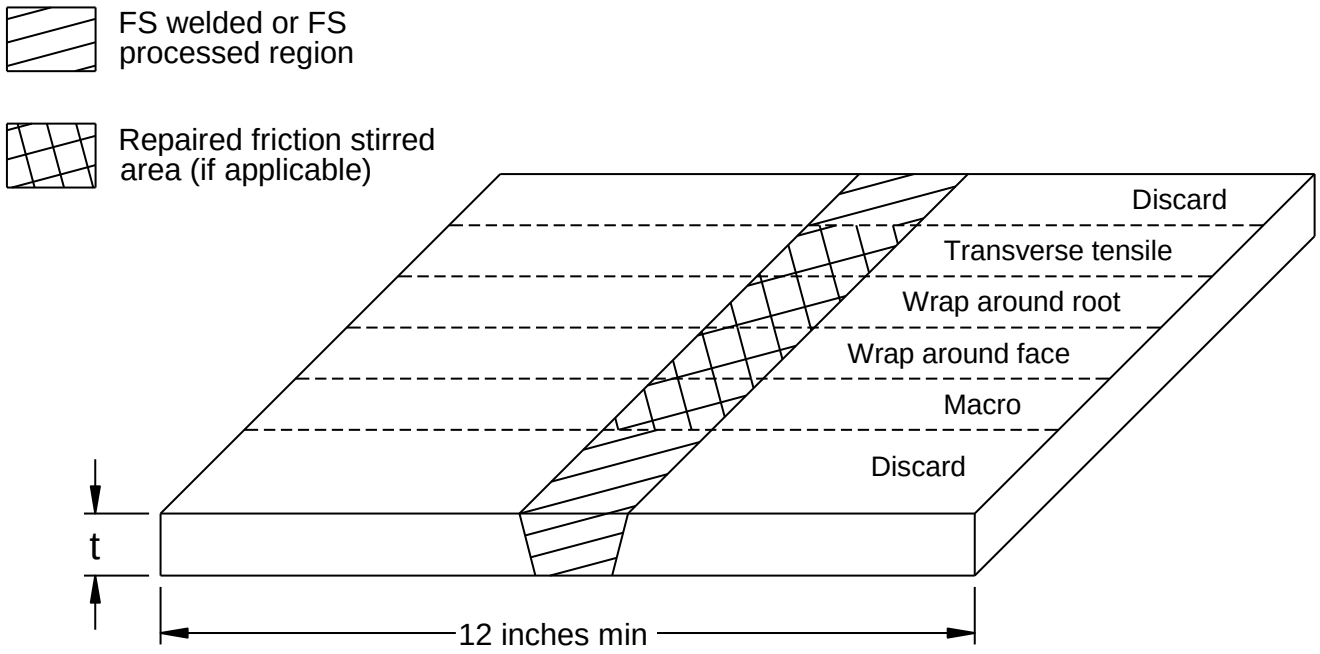
1. Macro-etch specimen at 12.5× showing remnant oxide trace within an FS weld nugget. The acceptance criteria for remnant oxides are specified in A-3.5.2.3.

Figure A-4. Macro-Etch Specimen



NOTES:
Panel 1 shows a schematic of a joint line that is offset to the retreating side of the FS tool.
Panel 2 shows a schematic of a joint line that is aligned with the FS tool centerline. In this case, there is no lateral FS tool offset.
Panel 3 shows a schematic of a joint line that is offset to the advancing side of the FS tool.

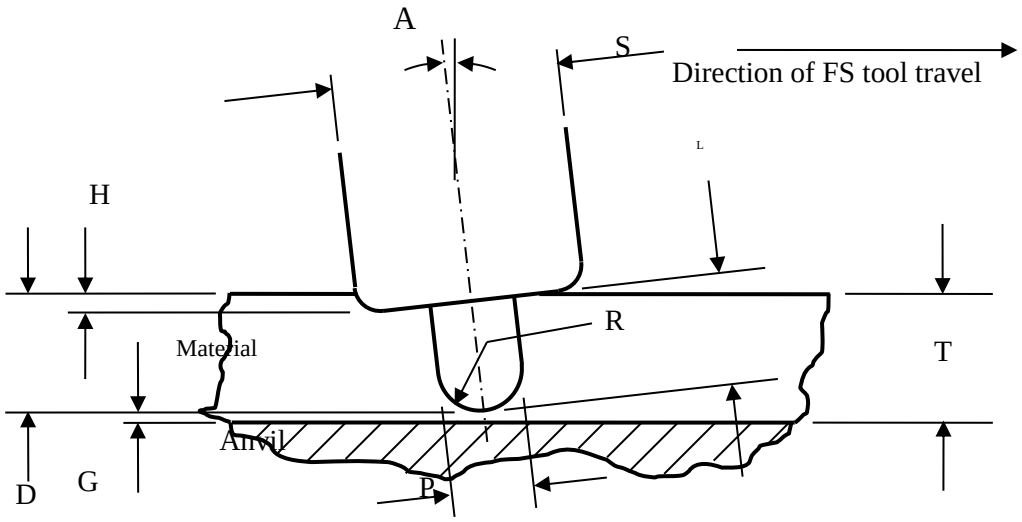
Figure A-5. Schematic Showing the Protocol for Referencing Lateral FS Tool Offset in Welding Procedures



NOTES:

1. All NDT shall be completed prior to destructive testing. All required test specimen preparation, dimensions, and mechanical testing shall be per A-3.5.
2. Test assembly size shall be as specified by A-3.4.1.2 for FSW, A-3.4.2.2 for FSP, and A-3.4.3.2 for repairs.
3. Test assembly fabrication shall involve the base material form to be qualified (see A-4.6.1) and may be of any alloy, temper and thickness specified in the qualified FS procedure being used. See A-3.4.1 for other fabrication details.
4. Exit hole repair procedure only requires one macro-etch specimen taken transverse to the FS pass at the center of the exit hole.
5. The discard length recorded in the qualification test report does not need to be evaluated by NDT.

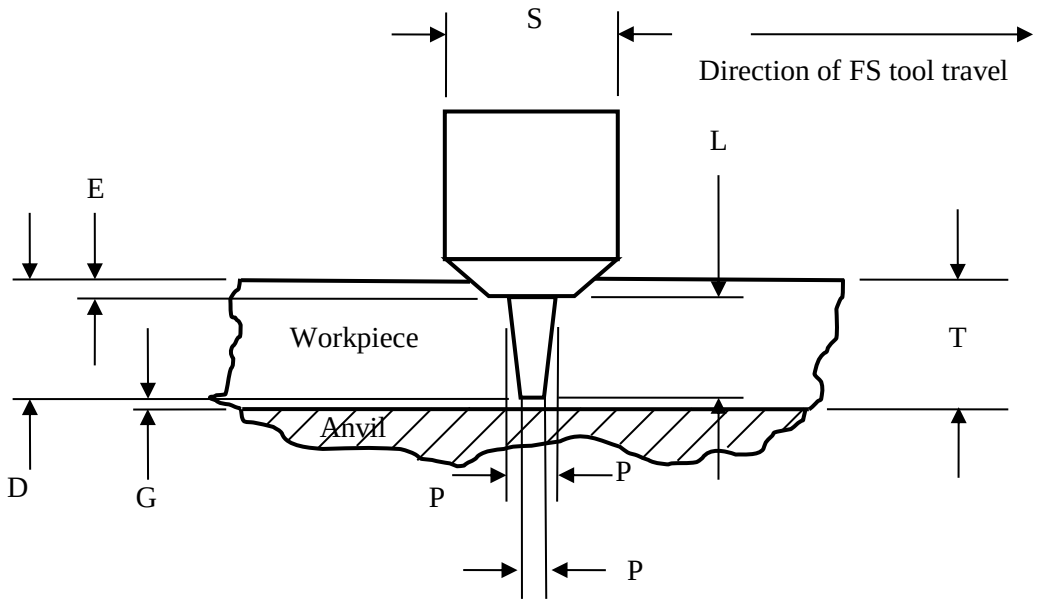
Figure A-6. Schematic of Test No. 3 for Performance Qualification



A = Tilt angle
D = Plunge depth
G = Probe-to-anvil gap
H = Heel plunge depth
L = Probe length

P = Probe diameter
R = Probe tip radius
S = Shoulder diameter
T = Material thickness

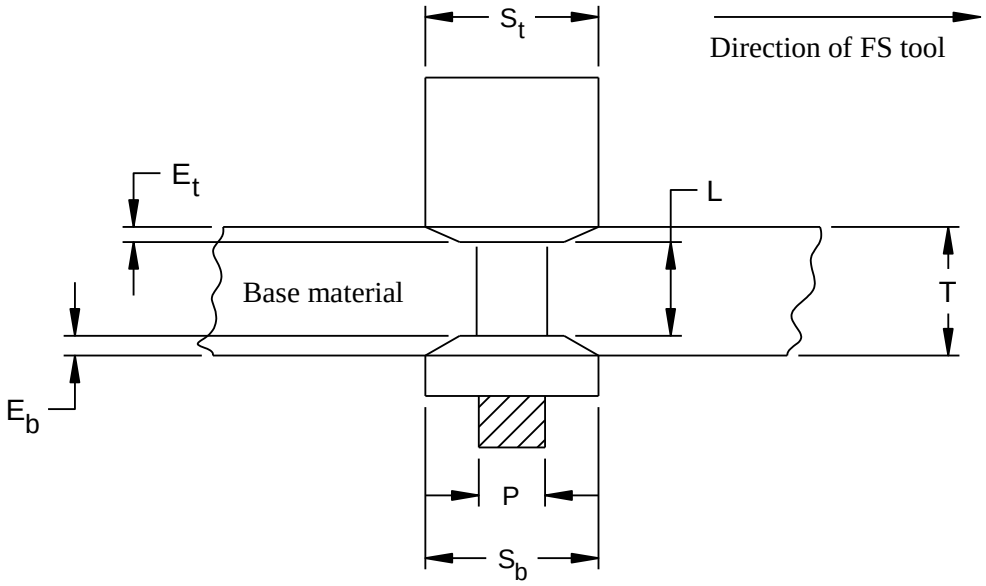
Figure A-7. Definitions of Key Variables for Tilted Axis FS



E = Embed distance
D = Plunge depth
G = Probe to anvil gap
L = Probe length

P = Probe diameter
S = Shoulder diameter
T = Workpiece thickness

Figure A-8. Definitions of Key Variables for Tapered-Shoulder FS



E_t = Embedded distance to top of shoulder
E_b = Embedded distance to bottom of shoulder
P = Probe diameter
L = Probe length
S_t = Diameter of top shoulder
S_b = Diameter of bottom shoulder
T = Base material thickness

Figure A-9. Definitions of Key Variables for Tapered-Shoulder Self-Reacting FS

APPENDIX B
TESTED MATERIAL COMBINATIONS FOR FILLET WELD PROCEDURE QUALIFICATIONS

Tested Base Metal and Filler Metal Fillet Weld Combinations																								
Filler Metal Group	**Covered Electrodes**													**Bare Electrodes**										
Process	**Shielded Metal Arc**													**Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)**										
Base Metal Combination	**MIL-12018-M2**	**MIL-11018-M [2/]**	**MIL-10018-M**	**MIL-9018-M**	**MIL-80XX-C3**	**MIL-70XX**	**MIL-60XX**	**MIL-309-XX**	**MIL-316L-15**	**MIL-8N12**	**MIL-9N10**	**MIL-1N12**	**MIL-CuNi**	**MIL-140S-1**	**MIL-120S-1**	**MIL-100S-1**	**MIL-70S-1**	**MIL-A1**	**MIL-309**	**MIL-316L**	**MIL-EN82**	**MIL-EN82H**	**MILEN60**	**MIL-EN625**	**MIL-EN67**
HY-130 to HY-130	✓	✓	✓	✓										✓	✓	✓									
HY-130 to HY-100 [1/]	✓	✓	✓	✓										✓	✓	✓									
HY-130 to HY-80 [1/]	✓	✓	✓	✓										✓	✓	✓									
HY-130 to STS	✓	✓	✓	✓				✓						✓	✓	✓			✓						
HY-130 to S-2	✓	✓	✓	✓	✓	✓								✓	✓	✓	✓								
HY-130 to S-1	✓	✓	✓	✓	✓	✓								✓	✓	✓	✓								
HY-130 to S-8								✓		✓									✓		✓				
HY-130 to NiCu										✓	✓										✓	✓	✓		
HY-130 to CuNi										✓	✓										✓	✓	✓		
HY-130 to NiCrFe										✓		✓									✓	✓		✓	
HY-130 to NiCrMoCb										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes											
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)											
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
HY-100 to HY-100 [1/]	✓	✓	✓	✓											✓	✓									
HY-100 to HY-80 [1/]	✓	✓	✓	✓											✓	✓									
HY-100 to STS [1/]	✓	✓	✓	✓				✓							✓	✓			✓						
HY-100 to S-2 [1/]	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓							
HY-100 to S-1 [1/]	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓							
HY-100 to S-8 [1/]								✓		✓									✓						
HY-100 to NiCu [1/]										✓	✓										✓	✓	✓		
HY-100 to CuNi [1/]										✓	✓										✓	✓	✓		
HY-100 to NiCrFe [1/]										✓		✓									✓	✓		✓	
HY-100 to NiCrMoCb [1/]										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes											
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)											
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
HY-80 to HY-80 [1/]		✓	✓													✓									
HY-80 to STS [1/]		✓	✓					✓								✓			✓						
HY-80 to S-2 [1/]		✓	✓	✓	✓	✓										✓	✓	✓							
HY-80 to S-1 [1/]		✓	✓	✓	✓	✓										✓	✓	✓							
HY-80 to S-8 [1/]								✓											✓						
HY-80 to NiCu [1/]										✓	✓										✓	✓	✓		
HY-80 to CuNi [1/]										✓	✓										✓	✓	✓		
HY-80 to NiCrFe [1/]										✓		✓									✓	✓		✓	
HY-80 to NiCrMoCb [1/]										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes											
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc or Submerged Arc (As Applicable)											
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
STS to STS		✓	✓					✓								✓			✓						
STS to S-2		✓	✓	✓	✓	✓		✓								✓	✓		✓						
STS to S-1		✓	✓	✓	✓	✓	✓	✓								✓	✓		✓						
STS to S-8								✓		✓									✓		✓	✓			
STS to NiCu										✓	✓										✓	✓	✓		
STS to CuNi										✓	✓										✓	✓	✓		
STS to NiCrFe										✓		✓									✓	✓		✓	
STS to NiCrMoCb										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes											
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)											
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
S-2 to S-2					✓	✓											✓	✓							
S-2 to S-1					✓	✓	✓										✓	✓							
S-2 to S-8								✓											✓						
S-2 to NiCu										✓	✓										✓	✓	✓		
S-2 to CuNi										✓	✓										✓	✓	✓		
S-2 to NiCrFe										✓		✓									✓	✓		✓	
S-2 to NiCrMoCb										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes											
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)											
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
S-1 to S-1					✓	✓	✓										✓	✓							
S-1 to S-8								✓											✓						
S-1 to NiCu										✓	✓										✓	✓	✓		
S-1 to CuNi										✓	✓										✓	✓	✓		
S-1 to NiCrFe										✓		✓									✓	✓		✓	
S-1 to NiCrMoCb										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HLSA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes											
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)											
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
S-8 to S-8								✓	✓										✓	✓					
S-8 to NiCu										✓											✓	✓			
S-8 to CuNi																									
S-8 to NiCrFe										✓		✓									✓	✓		✓	
S-8 to NiCrMoCb										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes										
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)										
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
NiCu to NiCu											✓												✓		
NiCu to CuNi											✓		✓										✓		✓
NiCu to NiCrFe										✓	✓	✓									✓	✓	✓	✓	
NiCu to NiCrMoCb										✓	✓	✓									✓	✓	✓	✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes											
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)											
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
CuNi to CuNi													✓												✓
CuNi to NiCrFe										✓	✓	✓									✓	✓	✓	✓	
CuNi to NiCrMoCb										✓	✓	✓									✓	✓	✓	✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes													Bare Electrodes										
Process	Shielded Metal Arc													Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)										
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
NiCrFe to NiCrFe										✓		✓									✓	✓		✓	
NiCrFe to NiCrMoCb										✓		✓									✓	✓		✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Covered Electrodes												Bare Electrodes										
Process	Shielded Metal Arc												Gas Metal Arc, Gas Tungsten Arc, or Submerged Arc (As Applicable)										
Base Metal Combination	MIL-12018-M2	MIL-11018-M [2/]	MIL-10018-M	MIL-9018-M	MIL-80XX-C3	MIL-70XX	MIL-60XX	MIL-309-XX	MIL-316L-15	MIL-8N12	MIL-9N10	MIL-1N12	MIL-CuNi	MIL-140S-1	MIL-120S-1	MIL-100S-1	MIL-70S-1	MIL-A1	MIL-309	MIL-316L	MIL-EN82	MIL-EN82H	MILEN60	MIL-EN625	MIL-EN67
NiCrMoCb to NiCrMoCb												✓												✓	

[1/] For the purposes of this table, HSLA-100 is equivalent to HY-100, and HSLA-80 is equivalent to HY-80.

[2/] For the purposes of this table, MIL-10718-M is equivalent to MIL-11018-M.

Tested Base Metal and Filler Metal Fillet Weld Combinations - Continued

Filler Metal Group	Bare Electrodes	
Process	Gas Metal Arc or Gas Tungsten Arc (As Applicable)	
Base Metal Combination	MIL-5356	MIL-5556
5083 to 5456	✓	✓
5083 to 5454	✓	✓
5083 to 5086	✓	✓
5083 to 5083	✓	✓
5086 to 5456	✓	✓
5086 to 5454	✓	✓
5086 to 5086	✓	✓
5454 to 5456	✓	✓
5454 to 5454	✓	✓
5456 to 5456	✓	✓

APPENDIX C
USE OF STANDARD WELDING PROCEDURE SPECIFICATIONS FOR NAVAL APPLICATIONS (SWPS-N)

C-1 GENERAL.

Where this document is specified for use, SWPS-Ns may be used by activities for production welding subject to the requirements of this appendix. Requirements regarding SWPS-Ns specified by a fabrication document shall be in addition to those specified herein unless there is a conflict, in which case, see C-1.3. Except for repairs, only one SWPS-N shall be used to weld a joint; in addition, no other welding procedure of the activity shall be used for welding along with a SWPS-N in the same joint. For repair of weld defects, a different SWPS-N from that used for initial welding, or an activity's qualified weld procedure, may be used. A full list of published AWS-NAVSEA SWPS-Ns can be found by searching "AWS-NAVSEA" at the AWS Online Bookstore (https://pubs.aws.org).

C-1.1 SWPS-NS NOT ACCEPTABLE FOR USE IN TOUGHNESS APPLICATIONS. Where governing specifications restrict base material and welding filler material for a given system, component, part, etc. to only those grades/types having toughness requirements, SWPS-Ns may only be used as a template or guide for an activity to write its own welding procedure and perform full qualification welding and testing, including toughness testing, in accordance with all requirements of Chapter 4.

C-1.2 ACTIVITY ACCEPTANCE OF SWPS-NS. For each SWPS-N, the activity performing the welding shall enter the name of the activity and each fabrication document on the SWPS-N for which the SWPS-N will be used. All SWPS-N requirements shall be met and those requirements shall not be modified, except that values of essential elements more restrictive than those listed in the SWPS-N may be specified if needed; supplemental requirements not affecting essential elements or other technical requirements of the SWPS-N may be added as necessary.

C-1.3 FABRICATION DOCUMENT REQUIREMENTS. All fabrication document requirements shall be met in addition to the requirements of the SWPS-N. In the case of conflict between a SWPS-N requirement and a fabrication document, the fabrication document shall take precedence.

C-1.4 ACTIVITY CERTIFICATION OF SWPS-NS FOR USE. The activity performing welding shall certify their acceptance of each SWPS-N and their ability to produce sound welds in conformance with the SWPS-N and all listed fabrication documents by having the activity's responsible official sign and date the SWPS-N prior to use.

C-1.5 SWPS-N REVISIONS. From time to time, revisions to a SWPS-N may be issued. Activities having earlier revisions of SWPS-Ns are encouraged to use the most current SWPS-N revision, but may continue to use its earlier revisions unless that SWPS-N revision is withdrawn from use by AWS. Activities implementing new revisions shall use the latest revision in effect at the time of their contract or order.

C-2 PREREQUISITES TO PRODUCTION USE OF SWPS-NS.

Prior to production use of each SWPS-N, activities shall also complete the actions stated in C-2.1 through C-2.5.

C-2.1 TEST WELDING AND INSPECTION. The activity shall weld and test one butt weld assembly following the SWPS-N requirements and the following:

a. Pipe shall be used for test welding for SWPS-Ns primarily intended for pipe, and plate shall be used for SWPS-Ns primarily intended for plate.
b. For plate assemblies, the weld length shall not be less than 12 inches in length. For pipe assemblies, the largest size used in production should be employed but need not be greater than nominal 3 inches in diameter.
c. Test assembly thickness shall be at least ⅜ inch or, if the SWPS-N maximum thickness limit is lower, a lesser thickness may be welded.
d. Test welding shall be in the 3G (plate), or 5G or 6G (pipe), positions for all position welding procedures.
e. Joint design shall be any butt joint specified by the SWPS-N.

f. If the SWPS-N covers both as-welded and post weld heat treated conditions, and post weld heat treatment (PWHT) is intended for production welding:

(1) The test assembly shall be subject to PWHT following the SWPS-N.

(2) If PWHT is not originally intended/tested but is to be added later, an additional test assembly with PWHT shall be tested and results submitted in accordance with this appendix.

g. The completed weld shall be inspected by VT, RT, and MT or PT per 4-5. Additionally, UT per 4-5 shall be performed when required by table 7-7, footnotes 20 and 21; where UT is exempted by footnote 21, six macro-etch specimens shall be examined as specified therein.

h. Repair of test assemblies shall be per 4-2.9.

i. Personnel performing the welding and equipment used for welding shall conform to 4-2.1.2.

j. The authorized representative shall be notified prior to test welding per 4-2.1.

NOTE

The qualification limits for a SWPS-N for all essential elements shall be the values/ranges specified by the SWPS-N and not those specified by 4-7; for instance, when welding a ⅜-inch test weld per C-2.1.c above, the maximum thickness is not 2T as normally prescribed by 4-7.1 but instead shall be the maximum thickness specified by the SWPS-N (unless the user imposes a more restrictive limit per C-1.2).

C-2.2 RECORDING AND SUBMISSION OF TEST RESULTS. The actual values/information used for test welding for all essential elements of the SWPS-N (e.g., amperage range, base material thickness, specification and type, joint design, position welded, etc.) shall be recorded on a form along with the inspection results and dated, certified, and submitted to the authorized representative for review along with the complete, certified SWPS-N. The requirements of 4-6 shall apply for this form. A suggested form is a copy of the SWPS-N, with specific test weld values and information inserted, and re-titled indicating a test verification weld record and supplemented at the end with the required inspection and, if applicable, repair information. A written response from the authorized representative regarding this form is not required. This form should be submitted along with or after the welding personnel training procedure of 5-2.3.1.a if approval of the training procedure has not been previously obtained.

C-2.3 RETENTION OF RECORDS FOR SWPS-NS. The test welding record of C-2.2 shall be retained per 4-6.

C-2.4 VENDORS. Activities shall ensure that subcontractor SWPS-Ns and associated test results comply with this document before submission to the authorized representative.

C-2.5 WELDING PERFORMANCE QUALIFICATION. Welding personnel shall be qualified per Chapter 5.

APPENDIX D
ADDITIONAL QUALIFICATION FOR TEMPERATURE CONTROLLED AREAS (TCA)

D-1 GENERAL.

Where minimum distances of production welding from TCAs (see 3-2.18) will violate 4-4.10, qualification testing and related actions as specified in this appendix shall be met in addition to the requirements of Chapter 4.

D-1.1 QUALIFICATION TEST ASSEMBLY. The test assembly shall employ a butt weld in the flat (1G) position if groove welding will be performed in production; otherwise, a fillet weld in the horizontal (2F) position consisting of three passes minimum shall be employed. The test assembly should represent the production configurations involved and the minimum base material thickness expected for production; for plate type products, the minimum length shall be 15 inches. A different test assembly may be used if approved. The test assembly shall be thermocoupled at the beginning, middle, and end of the weldment, perpendicular to the weld axis, at a distance from the planned nearest final weld toe no greater than the minimum distance production welding will be allowed to occur from a TCA. This distance shall be listed as an essential element of the welding procedure and test report (see D-1.4.1.a).

D-1.2 QUALIFICATION WELDING AND TEMPERATURE CONTROL. A test assembly shall be welded and tested with each procedure to be used on TCA members. Welding shall be performed to cause maximum allowable heating of adjacent material areas and required methods of artificial cooling, if any, shall be employed; time delays between segments of beads, other than normal stop cleaning, shall not be permitted unless recorded as an essential element. Maximum heat input (see 4-4.1.13) shall be used. The qualification test assembly shall be held at the maximum interpass temperature during all welding. Thermocouples shall be monitored during welding.

D-1.3 TESTING AND INSPECTION. The test assembly shall be subject to the same nondestructive testing as required by table 7-7 for the weld type involved (i.e., butt or fillet). Also, the maximum temperature shall not exceed that allowed by the governing material specification (e.g., for bi-metallic transition products), the fabrication document, or component or system specification. Where no temperature requirement exists, justification for the maximum recorded temperature shall be included in the submittal of D-1.4.3; where questionably high heating occurs, proposed nondestructive and destructive testing of sample TCA material subjected to simulated heating shall be included to verify degradation does not occur. The property/soundness requirements of the governing TCA material specification may be used as a guide. Upon approval, the additional testing shall be conducted and results submitted for approval per D-1.4.3.

D-1.4 PROCEDURES, REPORTING, AND APPROVAL OF QUALIFICATION TEST DATA.

D-1.4.1 Qualification Welding and Temperature Control. In addition to table 7-5, the following items shall be essential elements for welding procedures qualified per this appendix:

a. Minimum distance from welds to TCAs.
b. Maximum heat input.
c. Maximum allowable temperature for TCAs.
d. Method of controlling temperature of TCAs (e.g., bead length limits, artificial cooling).
e. Method of monitoring temperature of TCAs, if different than interpass temperature.
f. Allowance or restriction for welding on insulated base material.

D-1.4.2 Qualification Test Data. Qualification test data shall be per 4-6 and the additional essential elements of this appendix. Test results shall include thermocouple distance and maximum recorded temperatures and a description of the test assembly.

D-1.4.3 Submittal and Approval. Submittal of qualification test data and welding procedures, and approval, shall be per 4-2.3.

D-1.4.4 Welding Procedure Changes Requiring Re-Qualification per Appendix D. For welding procedures qualified in accordance with this appendix, the following changes in essential elements from those used for qualification welding shall require re-qualification in accordance with this appendix; for other changes, requalification shall be per 4-7 and 4-8, and requalification to this appendix is not required:

a. A change in welding process, except that GMAW spray shall qualify other GMAW transfer modes.
b. A change in base material type per 4-7.1.a, excluding subparagraphs.
c. An increase in maximum heat input.
d. An increase in interpass temperature.
e. A decrease in TCA distance of ½ inch or more.
f. Elimination of artificial cooling.
g. Addition of insulation.

Ref: NAVSEAINST 4160.3 NAVSEA S0005-AA-PRO-010/TMMP

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