

S9074-AQ-GIB-010/248

NAVSEA Technical Publication

REQUIREMENTS FOR WELDING AND BRAZING PROCEDURE AND PERFORMANCE QUALIFICATION



DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND

1 AUGUST 1995

S9074-AQ-GIB-010/248

RECORD OF REVISIONS

<u>REVISION NO.</u>	<u>DATE</u>	<u>ENTERED BY</u>
0	1 August 1995	Complete Reprint Incorporated

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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 and machine 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.

1.2 Except as required by 1.2.1, 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: (1) he has 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 (2) 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.

1.2.1 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.

1.3 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 For existing welding procedures and personnel qualifications in accordance with NAVSEA 250-1500-1, those qualifications 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 which 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.

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2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. Unless otherwise specified, the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this document to the extent specified herein.

SPECIFICATIONS

FEDERAL

- O-F-499 - Flux Brazing, (Silver Brazing Filler Metal, Low Melting Point).
- QQ-A-200 - Aluminum Alloy, Bar, Rod, Shapes, Structural Shapes, Tube and Wire, Extruded: General Specification for.
- 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 - Aluminum and Aluminum Alloy Bar, Rod, Wire, or Special Shapes; Rolled, Drawn, or Cold Finished; General Specification for.
- 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 - Aluminum and Aluminum Alloy Plate and Sheet: General Specification for.
- 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-B-626 - Brass, Leaded and Nonleaded: Rod, Shapes, Forgings, and Flat Products with Finished Edges (Bar and Strip).
- QQ-B-639 - Brass, Naval: Flat Products (Plate, Bar, Sheet, and Strip).
- QQ-B-654 - Brazing Alloys, Silver.
- QQ-C-390 - Copper Alloy Castings (Including Cast Bar).
- 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.
- QQ-S-763 - Steel Bars, Wire, Shapes, and Forgings, Corrosion Resisting.
- WW-P-404 - Pipe, Steel, (Seamless and Welded, Black and Zinc-Coated (Galvanized)).

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FEDERAL (Continued)

- WW-T-700 - Tube, Aluminum and Aluminum Alloy, Drawn, Seamless, General Specification for.
- WW-T-700/1 - Tube, Aluminum, Drawn, Seamless, 1100.
- WW-T-700/2 - Tube, Aluminum, Alloy, Drawn, Seamless, 3003.
- WW-T-700/5 - Tube, Aluminum Alloy, Drawn, Seamless, 5086.

MILITARY

- MIL-T-1368 - Tube and Pipe, Nickel-Copper Alloy, Seamless and Welded.
- 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-W-6858 - Welding, Resistance: Spot and Seam.
- MIL-T-8504 - Tubing Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded.
- 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-T-15005 - Tubes, 70-30 and 90-10 Copper Nickel Alloy, Condenser and Heat Exchanger.
- MIL-B-15382 - Bolt, Firebrick Anchor.
- MIL-C-15726 - Copper-Nickel Alloy, Rod, Flat Products (Flat Wire, Strip, Sheet, Bar, and Plate) and Forgings.
- MIL-S-16216 - Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100).
- 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-N-17163 - Nickel-Copper Alloy, Wrought; (55-60 Percent Nickel) Low 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-19933 - Electrodes and Rods - Welding, Bare, Chromium and Chromium-Nickel Steels.
- MIL-T-20219 - Tube, Brass, Voice and Pneumatic.
- 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-E-21562 - Electrodes and Rods - Welding, Bare, Nickel Alloy.
- MIL-S-21952 - Steel (HY-80 and HY-100) Bars, Alloy.
- MIL-E-22200 - Electrodes, Welding, Covered; General Specification for.
- MIL-E-22200/1 - Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium and High Tensile Steel, As Welded or Stress-Relieved Weld Application.
- MIL-E-22200/2 - Electrodes, Welding, Covered (Austenitic Chromium-Nickel Steel).
- MIL-E-22200/3 - Electrodes, Welding, Covered: Nickel Base Alloy; and Cobalt Base Alloy.
- MIL-E-22200/4 - Electrodes, Welding, Covered, Copper-Nickel Alloy.
- MIL-E-22200/5 - Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen, Low-Alloy Steel for Hardening and Tempering Heat Treatment Applications Only.

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MILITARY (Continued)

- MIL-E-22200/6 - Electrodes, Welding, Mineral Covered, Low-Hydrogen, Medium and High Tensile Steel.
- MIL-E-22200/7 - Electrodes, Welding, Covered, Molybdenum Alloy Steel Application.
- MIL-E-22200/8 - Electrodes, Welding, Covered, Low-Hydrogen, and Iron-Powder Low-Hydrogen, Chromium-Molybdenum Alloy Steel and Corrosion Resisting Steel.
- MIL-E-22200/9 - Electrodes, Welding, Mineral Covered Low-Hydrogen or Iron-Powder, Low-Hydrogen, Nickel-Manganese-Chromium-Molybdenum Alloy Steel for Producing HY-130 Weldments for As-Welded Applications.
- MIL-E-22200/10 - Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium, High Tensile and Higher-Strength Low Alloy Steels.
- MIL-S-22698 - Steel Plate and Shapes, Weldable Ordinary Strength and Higher Strength: Hull Structural.
- MIL-S-23008 - Steel Castings, Alloy, High Yield Strength (HY-80 and HY-100).
- MIL-S-23009 - Steel Forgings, Alloy, High Yield Strength (HY-80 and HY-100).
- MIL-S-23193 - Steel, Corrosion Resistant; Castings.
- MIL-S-23194 - Steel Forgings Carbon and Alloy.
- MIL-S-23195 - Steel Bars and Forgings Corrosion Resistant.
- MIL-S-23196 - Steel Plate, Sheet and Strip, Corrosion Resistant.
- MIL-T-23226 - Tube and Pipe, Corrosion-Resistant Steel, Seamless.
- MIL-T-23227 - Tube and Pipe, Nickel-Chromium-Iron Alloy.
- MIL-N-23228 - Nickel Chromium Iron Alloy Plate, Sheet and Strip.
- MIL-N-23229 - Nickel-Chromium-Iron Alloy Bars and Forgings.
- MIL-S-23284 - Steel Forgings, Carbon and Alloy, for Shafts, Sleeves, Couplings, and Stocks (Rudders and Diving Planes).
- MIL-I-23413 - Inserts, Welding, Filler Material, Coiled and Solid Rings.
- MIL-F-23467 - Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding, Austenitic Corrosion-Resistant Steel.
- MIL-F-23508 - Fittings and Flanges, Wrought Seamless, Butt and Socket Welding, Nickel Chromium Iron Alloy.
- MIL-F-23509 - Fittings and Flanges, Wrought Seamless Butt and Socket Welding, Nickel Copper Alloy.
- MIL-T-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, 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).

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MILITARY (Continued)

- MIL-N-24114 - Nickel Chromium Iron Age Hardenable Alloy Bars, Rods, and Forgings.
- MIL-L-24128 - Low Carbon Chromium Steel Bars, Rods and Forgings.
- MIL-S-24149 - Studs, Arc Welding, and Arc Shields (Ferrules), General Specification for.
- MIL-S-24149/1 - Studs, Arc Welding, and Arc Shields (Ferrules); Type I, Class 1, 2, 3, and Type II, Class 1, 4, 5, 5A, 6, Carbon Steel, for Direct Energy Arc Welding.
- MIL-S-24149/2 - Studs, Arc 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, Arc 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, Arc Welding, Type VI, Class 1, 2, 3, Carbon Steel, for Stored Energy (Capacitor Discharge) Arc Welding.
- MIL-S-24149/5 - Studs, Arc Welding; Type VII, Class 1, 2, 3, Aluminum Alloy, for Stored Energy (Capacitor Discharge) Arc Welding.
- MIL-S-24149/6 - Studs, Arc Welding; Type VIII, Class 1, 2, 3, Corrosion-Resistant, 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-F-24339 - Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding Carbon Steel.
- MIL-F-24342 - Fitting and Flange, Wrought Seamless, Butt and Socket Welding 70-30 Copper Nickel Alloy.
- 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-E-24403 - Electrodes - Welding, Flux Cored General Specification for.
- MIL-E-24403/1 - Electrodes - Welding, Flux Cored, Ordinary Strength and Low Alloy Steel.
- MIL-E-24403/2 - Electrodes - Welding, Flux Cored, Low-Alloy Steel.
- MIL-S-24451 - Steel Heat Treated Heads, Alloy Structural, High Yield Strength (HY-80 and HY-100).
- MIL-B-24480 - Bronze, Nickel Aluminum (UNS No. C95800) Castings for Seawater Service.
- MIL-S-24645 - Steel Plate, Sheet or Coil, Age-Hardening Alloy, Structural, High Yield Strength (HSLA-80).
- 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)

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MILITARY (Continued)

- MIL-F-24669/8 - Forgings and Forging Stock, Steel for Integral Steam Turbine Rotors.
- 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-C-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.

STANDARDS

MILITARY

- MIL-STD-22 - Welded Joint Designs.
- MIL-STD-271 - Requirements for Nondestructive Testing Methods.
- MIL-STD-1628 - Fillet Weld Size, Strength, and Efficiency Determination.
- MIL-STD-1681 - Fabrication, Welding, and Inspection of HY-130 Submarine Hull.
- MIL-STD-1688 - Fabrication, Welding, and Inspection of HY-80/100 Submarine Applications.
- MIL-STD-1689 - Fabrication, Welding, and Inspection of Ships Structure.
- MIL-STD-2035 - Nondestructive Testing Acceptance Criteria.

2.1.2 Other Government publications. The following other Government publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues shall be those in effect on the date of the solicitation.

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

- 0900-LP-001-7000 - Fabrication and Inspection of Brazed Piping Systems.
- 0910-LP-331-5300 - Repair and Overhaul Main Propulsion Boilers.
- 250-1500-1 - Welding Standard

(Copies of specifications, standards, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DoDISS.

AEROSPACE MATERIALS SPECIFICATION (AMS)

- AMS 6530 - Tubing Seamless-0.55 Ni-0.50 Cr-0.20 Mo (0.28-0.34C).

(Application for copies should be addressed to the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.)

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AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- A 176 - Stainless Steel and Heat-Resisting Chromium Steel, Plate, Sheet and Strip
- A 178 - Standard Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler Tubes. (DoD adopted)
- A 182 - Standard Specification for Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service. (DoD adopted)
- A 213 - Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat-Exchanger Tubes. (DoD adopted)
- A 216 - Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High Temperature Service. (DoD adopted)
- A 217 - Martensitic Stainless Steel and Alloy Steel Castings for Pressure-Containing Parts Suitable for High-Temperature Service. (DoD adopted)
- A 240 - Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels. (DoD adopted)
- A 276 - Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes.
- A 302 - Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum Nickel. (DoD adopted)
- A 335 - Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service.
- A 370 - Standard Test Methods and Definitions for Mechanical Testing of Steel Products. (DoD adopted)
- A 473 - Standard Specification for Stainless and Heat-Resisting Steel Forgings. (DoD adopted)
- A 487 - Standard Specification for Steel Castings Suitable for Pressure Service.
- A 494 - Standard Specification for Castings, Nickel and Nickel Alloy.
- A 515 - Standard Specification for Pressure Vessel Plates, Carbon Steel for Intermediate- and Higher-Temperature Service. (DoD adopted)
- A 516 - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service. (DoD adopted)
- A 537 - Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel. (DoD adopted)
- A 743 - Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application. (DoD adopted)
- A 744 - Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service. (DoD adopted)
- A 757 - Ferritic and Martensitic Steel Castings for Pressure-Containing and Other Applications for Low-Temperature Service.
- B 16 - Free-Cutting Brass Rod, Bar, and Shapes for use in Screw Machines. (DoD adopted)
- B 21 - Naval Brass Rod, Bar, and Shapes. (DoD adopted)
- B 26 - Aluminum-Alloy Sand Castings. (DoD adopted)
- B 36 - Brass Plate, Sheet, Strip, and Rolled Bar. (DoD adopted)
- B 43 - Seamless Red Brass Pipe, Standard Sizes. (DoD adopted)
- B 88 - Seamless Copper Water Tube. (DoD adopted)
- B 98 - Copper-Silicon Alloy Rod, Bar, and Shapes. (DoD adopted)
- B 121 - Leaded Brass Plate, Sheet, Strip, and Rolled Bar. (DoD adopted)

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ASTM (Continued)

- B 124 - Copper and Copper-Alloy Forging Rod, Bar, and Shapes. (DOD adopted)
- B 138 - Manganese Bronze Rod, Bar, and Shapes. (DoD adopted)
- B 139 - Phosphor Bronze Rod, Bar, and Shapes. (DoD adopted)
- B 150 - Aluminum Bronze Rod, Bar, and Shapes. (DoD adopted)
- B 152 - Copper Sheet, Strip, Plate, and Rolled Bar. (DoD adopted)
- B 166 - Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600 and N06690) Rod, Bar, and Wire. (DoD adopted)
- B 169 - Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar. (DoD adopted)
- B 209 - Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate. (DoD adopted)
- B 265 - Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate.
- B 283 - Copper and Copper-Alloy Die Forging (Hot-Pressed). (DoD adopted)
- B 337 - Standard Specification for Seamless and Welded Titanium and Titanium Alloy Pipe. (DoD adopted)
- B 338 - Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers. (DoD adopted)
- B 348 - Standard Specification for Titanium and Titanium Alloy Bars and Billets.
- B 363 - Standard Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings.
- B 367 - Standard Specification for Titanium and Titanium Alloy Castings.
- B 369 - Copper-Nickel Alloy Castings. (DoD adopted)
- B 381 - Standard Specification for Titanium and Titanium Alloy Forgings.
- B 443 - Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip.
- B 444 - Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) Pipe and Tube.
- B 446 - Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Rod and Bar.
- B 564 - Standard Specification for Nickel Alloy Forgings. (DoD adopted)
- B 574 - Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium Alloy Rod.
- B 575 - Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium Alloy Plate, Sheet, and Strip.
- B 622 - Standard Specification for Seamless Nickel and Nickel Cobalt Alloy Pipe and Tube.
- E 172 - Standard Practice for Describing and Specifying the Excitation Source in Emission Spectrochemical Analysis.
- E 354 - Standard Test Methods for Chemical Analysis of High Temperature Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys.
- E 604 - Standard Test Method for Dynamic Tear Testing of Metallic Materials. (DoD adopted)

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

AMERICAN WELDING SOCIETY (AWS)

- A3.0 - Standard Welding Terms and Definitions. (DoD adopted)
- A5.1 - Specification for Covered Carbon Steel Arc Welding Electrodes. (DoD adopted)
- A5.2 - Specification for Iron and Steel Oxyfuel Gas Welding Rods. (DoD adopted)

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AWS (Continued)

- A5.4 - Specification for Covered Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes. (DoD adopted)
- A5.5 - Specification for Low Alloy Steel Covered Arc Welding Electrodes. (DoD adopted)
- A5.6 - Specification for Covered Copper and Copper Alloy Arc Welding Electrodes. (DoD adopted)
- A5.7 - Specification for Copper and Copper Alloy Bare Welding and Electrodes. (DoD adopted)
- A5.8 - Specification for Filler Metals for Brazing and Braze Welding.
- A5.9 - Specification for Corrosion Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Welding Electrodes and Welding Rods. (DoD adopted)
- A5.10 - Specification for Aluminum and Aluminum Alloy Bare Welding Rods and Electrodes. (DoD adopted)
- A5.11 - Specification for Nickel and Nickel Alloy Covered Welding Electrodes.
- A5.13 - Specification for Solid Surfacing Welding Rods and Electrodes. (DoD adopted)
- A5.14 - Specification for Nickel and Nickel Alloy Bare Welding Rods and Electrodes.
- A5.16 - Specification for Titanium and Titanium Alloy Bare Welding Rods and Electrodes. (DoD adopted)
- A5.23 - Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding. (DoD adopted)
- A5.27 - Specification for Copper and Copper Alloy Rods for Oxyfuel Gas Welding.
- A5.28 - Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding. (DoD adopted)
- B4.0 - Standard Methods for Mechanical Testing of Welds. (DoD adopted)

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

AMERICAN SOCIETY FOR NONDESTRUCTIVE TESTING (ASNT)

ASNT Publication No. 103 - Glossary of Terms Frequently Used in Nondestructive Testing.

(Application for copies should be addressed to the American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518.)

(Nongovernment standards are generally available for reference from libraries. They are also distributed among nongovernment standards bodies and using Federal agencies.)

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.

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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 A3.0.
- (b) Except as noted herein, nondestructive testing nomenclature and definitions shall conform to ASNT publication No. 103.

3.1.2 Acceptable. An item is acceptable when it complies with or conforms to the applicable standard or specification.

3.1.3 Activity. The term 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. The quality assurance manual shall contain a paragraph approved by an authorized representative, specifically addressing the transfer of qualified procedures from one site to another within the activity.

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 shall be 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.
- (b) For commercial shipyards: The delegated representative of the Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP), or the American Bureau of Shipping when specified in the Ship's specifications for a particular ship. This includes all applicable areas in the shipyard and applicable items furnished to the shipyard by subcontractors.
- (c) For Government purchase items: The delegated representative of the Commanding Officer, Naval Ship Systems Engineering Station (NAVSSSES), Philadelphia or of the Officer in Charge, NAVSSSES Detachment, Mechanicsburg, or of the Officer in Charge, NAVSSSES Detachment, Norfolk.
- (d) When delegated by NAVSEA, the representative of the Defense Contract Administration Services Management Area (DCASMA).
- (e) Technical representative specifically authorized by NAVSEA.

3.1.7 Essential elements. Essential elements are those elements, either material or process, 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 Inspector. An inspector is any contractor, Naval shipyard and other Government agency employee or American Bureau of Shipping Surveyor qualified as required by this document to accept or reject materials or workmanship on the basis of specified test results.

3.1.9 Performance qualification. A performance qualification is an action by which welders and welding operators are evaluated by nondestructive and destructive methods for their demonstrated ability to produce welds which meet

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the requirements of this specification. Also included are requirements for qualification record keeping.

3.1.10 Procedure. A procedure is a written fabrication instruction which contains all the applicable essential elements listed in this document.

3.1.11 Procedure qualification. Procedure qualification is an 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.

3.1.12 Qualified. The term "qualified" means that the item under consideration has been approved as required by this document.

3.1.13 Straw (color). Straw is a color occurring on titanium welds from slight contamination whose hue ranges from pale yellow through brass.

3.2 Terms related to welding.

3.2.1 Build-up. Build-up is a surfacing variation in which surfacing metal is deposited to restore base material or weld surface dimensions.

3.2.2 Buttering. Buttering is a surfacing variation that deposits surfacing 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 which differ sufficiently in metallurgical and physical properties to require special consideration in procedure qualification and inspection (see section 4 for exceptions).

3.2.5 Hardfacing. Hardfacing refers to a surfacing variation in which surfacing metal is deposited to reduce wear.

3.2.6 Internal tube-to-header welds. These are welds between various types of boiler tubes and their respective headers (or drums), such as economizer headers, superheater headers, and so forth. These welds are located on the interior of the header (or drum). Integrity of the tube-to-header connection is usually provided by a combination of welding and rolling the tube.

3.2.7 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.

3.2.8 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.

3.2.9 Oscillation. Defining characteristics:

- (a) Amplitude. Amplitude is the distance normal to the direction of welding between the outermost positions which 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.

3.2.10 Seal weld. Seal weld is a weld provided for a fluid containment function only, as in a closure where strength is provided by a separate device.

3.2.11 Socket weld. Socket welds are MIL-STD-22, P-13, -14, -15, -16, -17, -42 and -80 joint design welds in pressure containing piping.

3.2.12 Special welds. Special welds are welds involving:

- (a) Base materials not covered in table I of this document.
- (b) Filler materials not covered in table II of this document.
- (c) Material thickness above those specified in table VI of this document or
- (d) Processes which are not specified in table III of this document.

3.2.13 Surfacing. Surfacing is the application by welding, brazing, or thermal spraying of a layer of material to a surface to obtain desired properties or dimensions, as opposed to making a joint. (See also buildup, buttering, cladding and hardfacing.)

3.2.14 Tube-to-tubesheet weld. Welds between tubing (usually heat transfer tubing) and the respective tube sheet usually occurring in some type of heat exchanger (see also 3.2.6).

3.2.15 Welding speed (travel speed). Welding speed is the rate of progression of the welding arc along the weld axis.

3.2.16 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.

3.2.17 Wormhole porosity. Wormhole porosity refers to gas inclusions having an elongated form known as "wormholes" or "pipes" usually oriented almost perpendicular to the weld surface.

3.3 Terms related to brazing.

3.3.1 Brazement. 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 with his hands.

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. Peel test is a destructive method of inspection where a lap joint is mechanically separated by peeling (see figure 20).

3.3.6 Preplaced brazing alloy. Preplaced brazing alloy is any form (shims, wire, rings, and so forth) of brazing alloy which is placed in a joint prior to brazing.

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4. WELDING PROCEDURE QUALIFICATION

4.1 Scope. This section provides general requirements for the qualification of welding procedures. Specific qualification requirements for the categories listed below shall be as specified in 4.4.

- (a) Groove welds and fillet welds (manual, semi-automatic, automatic and machine welding).
- (b) Fillet welds - welding over primer coated surfaces.
- (c) Weld surfacing.
- (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 tube sheet welds.
- (i) Special welds.

4.2 General requirements.

4.2.1 Responsibility. When this document is specified by the applicable fabrication document, each activity qualifying procedures under the requirements of this document shall prepare written welding procedures and perform the required tests to qualify these procedures. The activity shall notify the authorized representative a minimum of 48 hours prior to the conduct of procedure qualification testing and afford him the opportunity to observe the welding of the test assemblies and the performance of the required nondestructive and destructive testing. The 48-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.

4.2.2 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 and that the welding procedure meets all requirements of this document and the applicable fabrication document. Qualification tests and data containing deviations from requirements may be submitted for approval if such deviations are specifically identified as deviations, and the technical justification for each deviation is provided. Procedure qualifications previously prepared for other Government agencies, American Bureau of Shipping (ABS), 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.

4.2.2.1 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 for approval. Procedures are the activity's responsibility. Prior to production application of the welding procedure, the activity shall obtain approval (see 3.1.5) of the procedure qualification data. 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 information in accordance with the appendix. The submittal shall be made to NAVSEA if required per 4.2.5.

4.2.3.1 Requirements. The following requirements shall apply for welding procedure and welding procedure qualification test report.

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4.2.3.1.1 Welding procedure qualification test report. The welding procedure qualification test report shall be in accordance with 4.6.1.

4.2.3.1.2 Welding procedure. The welding procedure shall be in accordance with 4.3.

4.2.3.2 Lot conformance testing for mechanical properties, toughness, weldability, cleanliness, and so forth, for any filler material not classified in table II (for example, submerged-arc welding fluxes covered by table II, note 5) shall also be described in the submittal for approval.

4.2.4 Vendor qualification. It shall be the responsibility of each activity to assure that its subcontractors have qualified procedures based on approved qualification data.

4.2.5 Approval of procedure qualification for special welds. NAVSEA approval of procedure qualification data shall be obtained for special welds as defined in 3.2.12 for the following areas:

- (a) Surface ship primary structure.
- (b) Submarine pressure hull structure.
- (c) Submarine intermediate pressure tanks.
- (d) P-1 and P-IT piping.
- (e) A-1, A-2, A-F and A-LT pressure vessels.

In addition to the procedure qualification test data, the submittal shall include a description of the welding process, evaluation method and the proposed welding performance qualification tests.

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 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. When this document is specified in the applicable fabrication document, procedure qualification is required for base materials as listed in table I, filler materials as listed in table II, welding processes and special welds as listed in 4.2.5 except as permitted by 4.2.6 and table III. Table III 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 combinations 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 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. 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 4.5. 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. Qualification tests shall qualify for welding positions as specified in 4.2.8.

4.2.7.3 Level II. This qualification level is intended to permit procedure approval for a variation in a procedure, as outlined in 4.8, which has already been qualified by qualification level I. Approval of the required level II welding procedure qualification shall be obtained from the authorized representative. The required level II testing is as follows: When a plate assembly is used, at least 15 inches of weld shall be inspected by radiography and ultrasonics (when required) as specified in table VII. If pipe is used for qualification, the largest size used in production shall be employed but need not

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be greater than nominal 3 inches in diameter and shall be inspected by radiography and ultrasonics (when required) as specified in table VII. Where thickness or geometry is such that radiography cannot be used, ultrasonic examination and two macro sections shall be substituted. Inspection requirements and acceptance standards shall be as specified in 4.5.1 and 4.5.2.6. Thickness of test assembly joint design and welding position to be used for the qualification shall be at the discretion of the qualifying activity. As an alternate, 15 inches of production weld or the largest size pipe used in production may be inspected by radiography and ultrasonics (when required) as specified in table VII for level II qualification. For weld surfacing, Level I qualification testing shall be performed except that for A-45 materials, composition testing is not required.

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 on figure 1. Procedure qualification test assemblies welded in a given position shall qualify the procedure as shown in table IV.

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, 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) No cracks, other than crater-cracks, may 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.

4.2.10 Transferral of welding procedure qualification. Requalification of previously qualified procedures shall be required for procedures transferred from one activity to another.

4.2.10.1 Transfer of qualified procedures between sites of an activity shall be governed by requirements stated in the activity's quality assurance manual (see 3.1.3) and shall require approval by the authorized representative.

4.2.10.2 Transfer of qualified procedures from one Navy shipyard to another Navy shipyard shall require NAVSEA approval.

4.2.10.3 Procedures contained in NAVSEA technical manuals for specific applications may be used without requalification provided:

- (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 which meets the requirements of this document and has the approval of the activity's welding engineering representative.
- (d) The activity demonstrates its ability to produce welds, to the satisfaction of the authorized representative, using the final procedure.

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4.3 Written welding procedure content.

4.3.1 Essential elements of a welding procedure. Unless otherwise specified in the applicable fabrication document, the welding procedure shall include at least the applicable essential elements listed in table V.

4.4 Specific qualification requirements. This paragraph provides 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.

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, pipe or other material as specified in table VI.

4.4.1.2 Test assembly size. Typical test assemblies are shown in figures 2 and 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).

4.4.1.3 Test assembly joint design. The test assembly shall employ a butt weld joint in accordance with MIL-STD-22 or other applicable fabrication document. Joint design requirements for HAZ toughness testing shall be as shown on figure 24. A test assembly for preplaced filler metal insert joints shall include a consumable insert of the same material and shape as that to be used in production.

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 VII, note 13).

4.4.1.5 Material thickness qualification limits. Table VI 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 VI, that is, 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 Post weld heat treatment. Test assemblies shall be subjected to the same post weld heat treatment as that required for production weld joints.

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 4.4.7, 4.4.9, 4.7.3 and 4.8.

4.4.1.8 Evaluation of procedure qualification test results. Evaluation of procedure qualification weldments shall be in accordance with 4.5.

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/machine welding. Welding procedure qualification tests shall meet the requirements of 4.4.1.10.1 through 4.4.1.10.3.

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4.4.1.10.1 Pipe. One weld in each qualifying position 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 qualification testing employing a 5-inch diameter, 3/8-inch wall pipe or larger, shall qualify for all larger pipe (both diameter and thickness) within the limits of table VI. Both the small and large pipe shall be nondestructively tested and the larger pipe shall be destructively tested in accordance with table VII. Socket weld qualification shall be as specified in 4.4.7.1.

4.4.1.10.2 Plate. A qualification test assembly weld of sufficient length to provide the required test specimens shall be made to each qualifying position. The qualification test assemblies shall be tested as required by 4.5.

4.4.1.10.3 Special automatic/machine welds. Qualification requirements shall be as specified in 4.2.5.

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 4.4.7) may be qualified in accordance with figure 8. The test assembly shall be welded with the type and largest diameter electrode to be used. Weld quality shall be considered acceptable provided visual examination of fractured weld surface discloses no cracks and no more than five porosity indications (including both "wormholes" and "porosity") larger than 1/16 inch in diameter in any 1 inch of weld. Any indication larger than 3/32 inch is unacceptable and the test assembly shall be rejected. Fillet weld qualifications in accordance with figure 8 are limited to those base metal/filler metal combinations acknowledged in MIL-STD-1628. Butt weld qualification may also qualify for fillet weld joints.

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 an additional qualification in accordance with figure 9. The test assembly shall be welded with the type and the largest diameter electrode to be used. Weld quality shall be considered acceptable provided visual examination of the fractured weld surface does not disclose more than 5 porosity indications (including both "wormholes" and "porosity") larger than 1/16 inch diameter in any 1 inch of weld. Any indication larger than 3/32 inch is unacceptable and the test assembly shall be rejected.

4.4.2 Qualification requirements for weld surfacing. Buildup or buttering is qualified by qualification of a groove-weld procedure. Weld cladding shall be qualified as specified in 4.4.2.1. Hardfacing shall be qualified as specified in 4.4.2.2. Weld surfacing qualifications shall not be limited to a maximum thickness of base material on which to weld, except that the weld deposit shall not exceed the thickness of the base material qualified by the limitations of table VI.

4.4.2.1 Weld cladding for corrosion resistance. The test assemblies shall duplicate the production cladding with respect to the base material, filler material type, and welding positions except that base and filler material groupings of tables I and II and the cross qualification rules of table III shall apply. Position limitations for qualifications shall be as outlined in 4.2.8. The clad area and thickness shall be as shown on figures 4 or 5 as applicable and for A-45 materials, figure 4a. The requirements of figure 4a shall be met for A-45 materials. Testing shall be as specified in table VII. The weld clad surface shall be finish machined and liquid penetrant inspected. The test assembly shall meet the acceptance standards for weld overlay class 1 (finished machined surface) of MIL-STD-2035. The macro-specimens shall be examined and evaluated as specified in 4.5.2.6.

4.4.2.2 Hardfacing for wear resistance. The test assemblies shall duplicate the production hardfacing with respect to the base material, filler material type, and welding positions except that base and filler material grouping of tables I and II shall apply. Position limitations for qualifications shall be as outlined in 4.2.8. The hardfaced area shall be at least 4 inches by 1 inch finished surface area of weld metal (see figure 6). The hardfacing surface shall

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be machined to the finished dimensions shown on figure 6 prior to hardness testing. Testing shall be as specified in table VII. The hardness of any hardfacing weld deposit shall be as specified in the applicable Military specification, commercial specification, manufacturer's data sheet, or note 6 to table II, as applicable. After hardness testing, the assembly shall be sectioned to provide a minimum of three coupons for macro-examination in accordance with 4.5.2.6.

4.4.3 Dissimilar metal welds. The test assembly shall be the joint design shown on figure 7 or a standard butt joint design as specified in the applicable fabrication document or MIL-STD-22. The type and number of test specimens to be removed from the test assemblies shall be as specified in table VII. For the purposes of tables VII and VIII, 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 and S-11B.
- (b) S-21, S-22, S-25 and S-26.
- (c) S-35, S-36A and S-36B.
- (d) S-37A and S-37B.

The range of base material thickness qualified by the test assemblies shall be as specified in table VI. 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.

4.4.4 Resistance welding. Procedure qualification for resistance welding shall be in accordance with the requirements of MIL-W-6858.

4.4.5 Stud welding. Stud welding procedure qualification record shall include the following:

- (a) Intended application.
- (b) Equipment used.
- (c) Stud material and size.
- (d) Base material.
- (e) Gas shield and flow.
- (f) Timer range setting.
- (g) Maximum cable length.
- (h) Amperage range or machine settings.
- (i) Current and polarity.
- (j) Results of bending, flattening or torque testing.

4.4.5.1 Method of qualification. Studs as specified in MIL-S-24149/1 through MIL-S-24149/6, shall be welded for each material combination and each nominal weld base diameter to be used in production. 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 (a) or (b) below. For stud diameters greater than 3/8-inch, another five studs shall be welded in each position and tested per (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. Required axial load or torque shall be not less than the value listed in table XVI 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° and the entire

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inner surface of the stud is within one diameter of the test plate or until the stud itself fails. The welds shall exhibit no cracks. In the case of collared studs, remove a portion of the collar in order 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 1/4-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 10.

- (c) Section each stud-weld junction through the diameter along the long axis of the stud. Polish, etch and examine the weld and HAZ under 5X to 10X magnification. Linear indications 1/16 inch and greater in length shall be cause for rejection.

4.4.5.2 Procedure requirements. The stud welding procedure shall contain as a minimum the requirements listed in 4.4.5. For S-51, S-52, and S-53 materials, procedures shall include:

- (a) Details of stud and base material contact area preparation and cleaning.
- (b) Statement of workmanship standards including welding environment, material storage, and handling.

4.4.6 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 plus or minus 10 percent.

4.4.7 Seal welds, pipe socket welds and tube-to-tubesheet welds (except internal tube-to-header welds in boiler components; for internal tube-to-header welds, see 4.4.9).

4.4.7.1 Socket welds and fillet type seal welds in pipe with nominal wall thickness less than 3/16-inch, tube-to-tubesheet welds and seal welds (except other fillet type and edge) shall be qualified by welding a test assembly (mock-up) which incorporates the base and filler materials, and weld joint design of the production weldment for the positions involved.

4.4.7.1.1 As a minimum the tube-to-tubesheet mock-up shall consist of 10 consecutively welded joints in each position to be qualified. The mock-up shall simulate the production application in all aspects (that is, same tube hole pattern, tube outside diameter (od) and wall thickness, tube sheet thickness (except 2 inches need not be exceeded), tube hole ligaments joint variables, number of passes, filler material diameter and any other variable which contributes to the integrity of the joint). All mock-up variables and any variation desired for production welding shall be identified in the submittal.

4.4.7.2 For socket welds and fillet type seal welds in pipe 3/16-inch and greater in thickness, other fillet type seal welds and edge seal welds, qualification shall be as above or by butt weld qualification in accordance with section 4.

4.4.7.3 For all socket welds. If the base material/filler material combination involved is not covered by MIL-STD-1628, a butt weld qualification in accordance with section 4 is required. This butt weld qualification shall be in addition to the tests required for 4.4.7.1. For automatic and machine welded socket welds, two mock-ups shall be prepared in accordance with 4.4.1.10 and inspected in accordance with 4.4.7.5.

4.4.7.4 In vertical pipe axis or 45-degree inclined pipe axis position socket welds, the fitting shall be on top of the pipe.

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4.4.7.5 Mock-ups shall be visual and dye penetrant inspected in accordance with 4.5. Then each weld shall be sectioned into quadrants to provide 4 macro-etch specimens 90 degrees apart; pipe less than 0.840-inch nominal outside diameter may be sectioned in half to provide 1 macro-etch specimen. All specimens shall be evaluated in accordance with 4.5.2.6.

4.4.7.6 Seal weld qualification shall not be limited to a maximum base material thickness. Qualified thickness for socket welds shall be per table VI and for tube-to-tubesheet welds per 4.4.7.1.1.

4.4.7.7 Welding procedure and qualification test data for tube-to-tube sheet welding shall be submitted for approval to NAVSEA.

4.4.8 Special welds. Special welds as defined in 3.2.11 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 to NAVSEA for approval. Refer to 4.2.5 for approval of procedure qualification for special welds.

4.4.9 Internal tube-to-header welds in boiler components. Welding procedures shall conform to NAVSEA 0910-LP-331-5300 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 4.4.8.

4.4.9.1 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. Reentrant angle between weld and sidewall shall be 90 degrees minimum and surface condition shall be as specified in (f) below.
- (f) Completed welds shall be inspected visually and with dye penetrant in accordance with 4.5. Root pass and final welds shall also be inspected to the requirements of NAVSEA 0910-LP-331-5300 for size, surface condition and other controlled attributes.
- (g) After completion of required NDT, 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 (c).
- (h) The remaining three welds (and tubes) shall be machined down to 1/32 inch plus 1/32, minus 0 below the base material surface, examined, then machined to 1/32 inch plus 0 minus 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 NDT 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 any inspection or test 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 (that is, six tube joints) mock-up.

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 destructive tests required for each assembly are shown in table VII.

4.5.1 Nondestructive tests. Prior to performing any destructive tests all procedure qualification test assemblies shall be non-destructively tested as required in table VII.

4.5.1.1 Visual. Visual examination shall ensure suitability of the weld surface for performance and evaluation of the required nondestructive testing. Grinding of weld surface is permitted to meet the acceptance criteria of MIL-STD-2035.

4.5.1.1.1 Prior to any cleaning, titanium and titanium alloy welds shall also be inspected for appearance, and shall meet the following criteria:

- (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: Straw color shall be removed. Other conditions, such as loss of luster, or other colors like blue or gray, shall be corrected by removing the affected weld bead and surrounding 1/16 inch of material, and rewelding. In all cases, the welding and shielding deficiencies shall be corrected prior to further welding. The qualification weldment shall be rejected if any color except straw occurs a second time. A third occurrence of straw shall cause rejection of the qualification weldment.
- (b) Areas beyond 1/32 inch from the weld toes should not exhibit any discoloration. Gray color is unacceptable and shall be removed. A second occurrence of gray shall cause 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.

4.5.1.2 Radiography, magnetic particle, liquid penetrant and ultrasonic. Radiography, magnetic-particle, and liquid-penetrant inspection shall be performed in accordance with MIL-STD-271. Ultrasonic inspection shall be performed in accordance with MIL-STD-271. Backing bars, if employed, may be removed and weld reinforcement ground smooth, prior to radiography and ultrasonic inspection.

4.5.1.3 Acceptance standards. Acceptance standards for magnetic-particle, liquid penetrant, and visual examination shall be based on the requirements of MIL-STD-2035, class I. For acceptable visual appearance for titanium and titanium alloy welds refer to 4.5.1.1. Acceptance standards for radiography shall be based on the requirements of class I of MIL-STD-2035. Acceptance standards for ultrasonic testing shall be class I of MIL-STD-2035.

4.5.2 Destructive tests. Required specimen preparation, dimensions, and mechanical testing 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.

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4.5.2.1 Transverse weld tension tests. For acceptance, transverse weld tension test specimens shall have a tensile strength that is not less than:

- (a) The minimum specified in the applicable base material specification. If materials of different minimum tensile strengths are used, the strength of the weaker material governs.
- (b) 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.
- (c) The maximum yield strength specified for the weakest of the two base materials for weldments made of materials without specified ultimate tensile strengths (such as HY-80).

In the above cases, 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 castings, see note 1 of table VII.

4.5.2.2 Weld metal tension tests. For acceptance, 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 VII, joints of similar materials shall be tested by transverse bends, and joints of dissimilar materials shall be tested by longitudinal or transverse bends.

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 heat affected zone shall not be cause for rejection.

4.5.2.4 Impact test. When specified in notes to table VII, specimens shall be prepared and tested. Weld metal Charpy V-notch specimens shall be taken transverse to the axis of the weld groove with one surface of each specimen not less than 1/16 inch below the finished surface of the weld after the removal of the weld reinforcement. The length of the notch shall be perpendicular to the surface of the weld. Base metal and heat affected zone (HAZ) specimens shall be removed in accordance with figure 2 and figure 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. Dynamic tear testing shall be in accordance with ASTM E 604 and may be substituted for Charpy V-notch testing as allowed in note 14 of table VII.

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.

4.5.2.5 Hardness test. Specimens shall be prepared and evaluated in accordance with 4.4.2.2.

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 a minimum of 5X 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 not permitted. Certain wear resistant

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alloys are subject to fine cracking which does not defeat the intended purpose. Accordingly, this fine cracking will 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 minimum allowable 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 allowances of MIL-STD-2035, Section 4.
- (c) Tube-to-tubesheet and tube-to-header welds. 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. All macro-etch specimens shall be free of cracks.

4.5.3 Special tests. When tests, such as explosion-bulge, dynamic tear 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.

4.6 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 essential elements of the welding procedure, as specified in table V, the destructive and nondestructive test results, and the repair data required in 4.2.9, if applicable, in sufficient detail to assure compliance with the requirements of tables III and VI. When heat affected zone (HAZ) Charpy V-notch (CVN) testing is performed, photomicrographs of CVN-HAZ specimens, and notch location shall be submitted with the test report (see figure 24). A sample for welding procedure qualification test report with form for data accumulation is provided for guidance only (see figure 11). The report shall contain a certification statement in accordance with 4.2.2.

4.6.1.1 For A-45 filler materials, the information required by note 9 to table II shall be submitted along with procedure qualification data. For cladding procedures involving A-45 filler materials also include, (1) clad weld chemical composition test results, (2) Fe, Mo, and Cr composition of filler material used, and (3) number of weld layers, clad weld thickness at which composition testing was performed and macro-etch specimens or photomicrographs (see figure 4a).

4.6.2 Maintenance of records. The approved procedure 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 nondestructive test result reports including radiographs until written approval of the qualification data is obtained.

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, 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 4.7.10 require requalification of the welding procedure for qualification level I.

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4.7.1 Base material.

- (a) Unless as shown in table III, a change from a base material listed under one S-number in table I to a material listed under another S-number, or to any other material not listed in table I (unless considered a part of a group in accordance with note 1 of table I). For base materials within the same S number having toughness requirements, see table VII, note 2.
- (b) A change in the base material thickness to a thickness outside the limits for which the procedure was qualified (see table VI).
- (c) In plasma-arc welding when joints 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) In group S-11A, a change from HY-80 steel to HY-100 steel except as permitted by table III (see note 5, table III).
- (e) A change to a UNS number 06625 base material (i.e. any Inconel 625 type alloy) from any other base material (including other S-43 group materials).

4.7.2 Filler material.

- (a) Unless permitted by table III, a change from a filler material listed under one A-number in table II 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 note 1 of table II) except as follows:
 - (1) For A-2C materials, the following applies:
 - a. 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).
 - b. 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.
 - c. A change from neutral to active flux and vice versa for multilayered weld deposits.
 - (2) For MIL-120 and MIL-140 series filler materials, see table II, footnote 13.
- (b) In submerged-arc process, a change in the type flux used, except as permitted in table II.
- (c) In plasma-arc process, the addition or deletion of supplementary powdered filler metal.
- (d) In plasma-arc process, a change in the form of filler metal from solid to fabricated wire, flux cored wire, powdered metal or vice versa.
- (e) In plasma-arc weld surfacing, a change from a homogeneous powdered metal to a mechanical mixed powdered metal or vice versa.
- (f) For internal tube-to-header welds in boiler components.
 - (1) A change in electrode coating classification, that is, MIL-XX15 to MIL-XX16 or MIL-XX18, and so forth, and vice-versa; or:
 - (2) An increase in electrode diameter of 1/32 inch or more from that qualified for any weld pass.
- (g) In stud welding, a change in the nominal weld base diameter of the stud.

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- (h) For weld surfacing applications, when using the automatic or mechanized 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.
- (i) See table II, note 2.
- (j) For submerged-arc process, a change in the flux trade name when the flux is not classified in table II. Also a change in the flux type (for example, neutral to active and vice-versa) for multilayer welds in S-1 or S-2 materials.
- (k) See table II, note 11, for A-45 filler materials.
- (l) In plasma arc weld surfacing, a change in the powdered metal particle size range recorded in the procedure qualification record.

4.7.3 Joint design.

4.7.3.1 For full penetration joints welded from one side only:

- (a) The omission of a backing ring or backing strip.
- (b) The addition or omission of a preplaced filler metal insert, except that welding a full penetration joint with or without a preplaced filler metal insert qualifies also for welding joints with a backing ring or backing strip.
- (c) Change in the shape of a consumable insert.
- (d) 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 preplaced filler metal insert, also qualify for welding full penetration joints welded from both sides and partial penetration joints.

4.7.3.2 In tube-to-header joints for boiler components:

- (a) A 1/32 inch or more decrease in root opening from that qualified. (Root opening is one-half the difference between nominal tube 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 less, 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.

4.7.4 Process.

- (a) A change from one welding process to another process (shielded metal-arc, gas metal-arc, oxyacetylene, gas tungsten-arc, flux cored-arc, and so forth).
- (b) For gas tungsten-arc process and plasma-arc process, 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 such as gas metal-arc spray or pulsed spray transfer to shortcircuiting arc transfer or vice versa, or electro-slag to electrogas or vice versa. A change to or from the pulsed arc mode in gas tungsten-arc welding.
- (d) A change from machine/automatic to semiautomatic and vice versa.

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- (e) A change from single-arc to multiple-arc, or vice-versa, or a change to another type of multiple-arc (for example, from series to parallel-arc).
- (f) A change from manual to machine, automatic or semi-automatic and vice versa.
- (g) In plasma-arc process a change in the arc from transferred to non-transferred or vice versa.
- (h) In automatic plasma-arc process the addition or elimination of an oscillating motion of the torch or filler wire.
- (i) In automatic weld surfacing with oscillation the addition or deletion of a dwell period in the oscillation.
- (j) In automatic weld surfacing a change from a simple harmonic to a constant velocity oscillating motion or vice versa.
- (k) In plasma-arc process a change in the type or model of welding equipment.
- (l) In plasma arc weld surfacing a change of 10 percent or more in the diameter of the constricting orifice in the torch.
- (m) In automatic or machine plasma arc weld surfacing, a change of more than ± 15 percent in the travel speed range recorded in the procedure qualification record.
- (n) In automatic or machine weld surfacing a change of more 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 automatic or machine weld surfacing 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 automatic or machine weld surfacing with oscillation, a change in the frequency of oscillation greater than plus or minus 20 percent beyond the frequency used for qualification.
- (q) In automatic or machine weld surfacing 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.

4.7.5 Electrical characteristics.

- (a) Except for a shielded metal-arc process, a change in the welding current from alternating current (ac) to direct current (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. The heat input shall be measured by the following formula:

$$\text{Heat input (joules/inch)} = \frac{\text{voltage} \times \text{amperage} \times 60}{\text{travel rate (inches/minute)}}$$

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

- (c) For qualification of socket and fillet type 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 to qualify the procedure for a specific pipe wall thickness.
- (d) In plasma arc weld surfacing a change of more than 10 percent in the welding current or voltage recorded in the procedure qualification record.
- (e) In plasma arc weld surfacing a change of more 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.

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- (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. Specific cooling rate values are not required to be determined. 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.

4.7.6 Position. A change to a position other than one already qualified as specified in 4.2.8. Also a change in weld progression from vertical up to vertical down, or vice versa, for any base material having toughness requirements (except root pass welds which are completely removed by backgouging).

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 either, (1) a change in the orifice gas composition, or (2) a change of more than 5 percent in the flow rate of orifice gas, or (3) a change of more 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 plus or minus 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 of more than 10 percent or 5 cubic feet per hour (whichever is larger) in the rate of gas flow below that used during qualification for 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, and S-53 materials, see 4.7.7 (1) below):
- (1) Welds rewelded 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 (that is, purge) gas or gas mixture.
- (j) See note 8 of table II.
- (k) For S-51, S-52, and S-53 materials, a change from welding in a chamber to welding outside of a chamber.
- (l) For S-51, S-52, and S-53 materials welded outside of a chamber, the omission of a trailing shield or backing (purge) gas.

4.7.8 Heat treatment.

- (a) A decrease in preheat or interpass temperature below the minimum temperature specified by the applicable fabrication document.
- (b) An increase in preheat or interpass temperature above the maximum temperature specified by the applicable fabrication document except for S-1 materials.
- (c) The addition or omission of post-weld stress-relief heat treatment, except for S-1 materials (unless required by (e) below).
- (d) A change in post-weld heat treatment outside the temperature range specified in the applicable fabrication document for the materials involved.

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- (e) For base metals and weld metals having impact requirements, a change in the post-weld heat treatment temperature and time range from that recorded in the procedure qualification record. The procedure qualification test 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 of more than 25 percent in the total stress relief holding time beyond that used for qualification.

4.7.9 Procedure changes requiring level 1 requalification for cladding with A-45 materials. The following changes also require Level I requalification of procedures for cladding for corrosion resistance using A-45 filler materials.

4.7.9.1 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 post-weld heat treating temperature.
- (c) A reduction in the number of layers used for qualification. (See figure 4a, note 1).
- (d) A decrease in thickness of production weld cladding below the minimum thickness used for qualification as shown in figure 4a.
- (e) For base material thickness less than 1 inch, a decrease in nominal base material thickness below that used for qualification.
- (f) For manual welding, a change from a stringer bead type of deposition to weaving in excess of 3 times the core diameter of the electrode, and vice versa. For semiautomatic welding, a change of more than 30 percent in bead width from that used for qualification.
- (g) An increase in heat input of more than 10 percent or an increase in volume of weld metal deposited per unit length of weld of more than 10 percent over that used for qualification. The increase may be measured by either of the following:

(1) Heat input (J/in.)

$$= \frac{\text{voltage} \times \text{amperage} \times 60}{\text{travel speed (in./min.)}}$$

(2) Volume of weld metal = an increase in bead size or a decrease in length of weld bead per unit length of electrode.

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

4.7.9.2 For shielded metal arc welding:

- (a) A change in the nominal electrode diameter used for the first layer of deposit.
- (b) An increase of more than 10 percent in the amperage used in application for the first layer.

4.7.9.3 For gas metal arc welding and gas tungsten arc welding:

- (a) The addition or omission of supplementary filler metal to the welding arc.
- (b) For automatic or mechanized welding, the addition or elimination of oscillation; a change of more than ± 20 percent in the oscillation displacement used for qualification. However, a procedure qualified using a minimum oscillation displacement

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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 of more than 10 percent.
- (d) For gas tungsten arc welding, a change of more 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 which do not completely remove the initial welds and the associated base metal heat affected zones shall require qualification to the maximum extent and for the maximum number of weld repair cycles to be used on the production application. (Note: in order to accommodate this requirement, the repair welding technique shall be qualified in the manner of the thin plate described in paragraph 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 rewelded for the maximum number of cycles of repair to be allowed during construction.)

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 bare electrode, rod or wire diameter, of more than 0.015 inch for gas metal-arc or more than 1/32 inch for gas tungsten-arc and plasma-arc than that previously qualified.
- (b) An increase in covered electrode diameter of over 1/32 inch for horizontal, vertical, and overhead welding and an increase in diameter of over 1/16 inch for flat position welding or horizontal fillets.
- (c) In automatic/machine or semi-automatic welding, a decrease of more than 20 percent in the included angle of the welding groove beyond that qualified.
- (d) A change in particle size of flux used in automatic, machine or semi-automatic submerged-arc welding.
- (e) In tube-to-tube sheet 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 of more than plus or minus 25 percent in the welding current or voltage from the range qualified for automatic, machine or semi-automatic welding.
- (h) For materials not having toughness requirements (see 4.7.6) a change in weld progression from vertical-up to vertical-down or vice versa (except for root pass welds which are completely removed by backgouging).
- (i) In automatic or machine plasma arc welding a change of more than 15 percent in the travel speed range recorded in the procedure qualification record.
- (j) For automatic welding with oscillation a change in the amplitude, dwell or frequency of oscillation greater than plus minus 20 percent from that used for qualification. Requalification is not required for oscillation parameter changes when oscillation amplitude remains less than the nominal electrode diameter.
- (k) In automatic or machine welding or weld surfacing by circumferential deposition, a change in the torch offset greater than a distance which moves the torch plus or minus 5 degrees of the circumference beyond the offset used during qualification.

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- (l) In automatic or machine welding, the omission of self-regulating arc length or voltage control if the procedure was qualified with such control.
- (m) For the plasma-arc 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 internal tube-to-header welding a change of more than plus or minus 10 percent in the actual amperage recorded during qualification.
- (o) For the automatic or mechanized gas tungsten arc or plasma arc process, a change in filler metal feed rate of more than ± 10 percent for powder metal and electrically hot wire or ± 20 percent for cold wire from the feed rate used for qualification, except for changes requiring Level I requalification for weld surfacing see 4.7.2(h).
- (p) For welding S-44 or cladding for corrosion resistance with A-45, the following changes shall also apply:
 - (1) In automatic or mechanized welding employing pulsed current, a change in equipment type which results in a change in nominal waveform (e.g., a change from a square wave to a triangular wave) or a change in the pulse frequency greater than ± 25 percent or 2 Hz, 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 automatic or mechanized welding, a change in the tilt or lead angles greater than ± 5 degrees beyond the angles used for qualification.
 - (3) For clad welding, a decrease of more than 100°F from the preheat temperature used for qualification.
- (q) For S-51, S-52, and S-53 materials a change in the material used (other than austenitic stainless steels, copper alloys, or aluminum alloys) for the trailing shield.

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5. WELDING PERFORMANCE QUALIFICATION

5.1 Scope. This section provides the requirements for qualification testing of welders and welding operators. 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 his ability to produce welds which meet the requirements of this section. Welder or operator qualification is not required for operators of stud welding and spot welding equipment.

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, 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 section 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 section. 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. Method of establishing qualification is as follows:

- (a) Each welder and welding operator shall know the workmanship and visual inspection requirements of all fabrication documents to which the welder will be working. To assure 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.
- (b) Ensuring that each welder and welding operator has satisfactorily welded the applicable performance qualification test assemblies.
- (c) Inspecting each qualification test assembly in accordance with the requirements of this section.
- (d) Evaluating the results of either the destructive or nondestructive tests or both in accordance with the applicable standards unless otherwise specified in this document.
- (e) Maintaining current records of the extent of each welder and welding operator qualification (see 5.5.1).

5.2.3.1 Training shall be administered in accordance with a program approved by one of the activity's MIL-STD-271 certified level III nondestructive test examiners or other NAVSEA-approved individual. 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 welding is performed.
- (c) Examinations covering detail workmanship and visual inspection requirements to be passed by each person with a grade of no less than 75 percent.

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- (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, and certifying signature of test administrator.
- (f) Re-testing of each welder or welding operator every 3 years.
- (g) Auditing of the entire program by the level III examiner or other NAVSEA approved individual to ensure adequacy. Audits shall be conducted at least once in every 2 years and, where applicable, the audit shall be extended to specifically address titanium welders.

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 which is radiographically or ultrasonically inspected and found satisfactory. Permission 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, and S-53 materials.
- (b) Welding satisfactory procedure qualification test assemblies subject to the limitations of performance qualifications in section 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 qualification may be attained by qualifying as outlined in table VIII. When radiography is used for evaluation, S-1 material may be used except as otherwise noted in table VIII. 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 IX.

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.

5.2.8 Repair to test assemblies. Test assemblies, other than those for automatic and machine welding, may be repair welded under the following conditions.

- (a) No cracks, other than crater cracks, may 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 which failed to meet the requirements, shall be recorded on the permanent test record. Qualification test assemblies for automatic and machine 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.

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- (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 Transferral 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. Evidence of maintenance of qualification, consisting of at least one verification of process use (that is, fabricator certification of use of "manual metal arc", "gas metal arc," and so forth) during each three-month period or calendar quarter, shall be maintained. In addition, for titanium welders and welding operators, verification of process used on titanium base metal during each 6-month or two consecutive calendar quarters shall also be maintained.

5.2.11.1 Renewal of qualification. Renewal of qualification due to 3-month or calendar quarter 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 XI. 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 had previously qualified with the welding process 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.

5.2.11.1.1 Each welder and welding operator shall be re-tested every 3 years in accordance with 5.2.3(a).

5.2.11.2 Loss of qualification. Requalification is required when the authorized representative has specific reason to question the ability of the welder or welding operator to make welds that meet the requirements of the applicable fabrication document.

5.2.12 Vision test requirements. Each welder and welding operator (except for tack, fillet, spot 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, and S-53 materials shall include a color perception test on workmanship samples displaying the colors and shades expected in titanium welds. As a minimum, these colors and shades shall include silver, straw, light blue, dark blue, purple, and gray. The standard of acceptance for vision tests 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, and S-53 materials.

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5.3 Performance qualification test requirements.

5.3.1 Manual, semi-automatic, automatic, and machine 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 X with limitations as indicated. Test assemblies employing butt joint designs specified in MIL-STD-22 may be used in lieu of those on figures 14, 15 and 22 provided the thickness requirements of table X are met. Test assemblies which simulate production assemblies may be used in lieu of those specified in table X in which case the qualification will 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 and machine welding. Welding operators shall qualify using equipment possessing control features similar to those of the equipment which will be used to make the production welds and shall be required to set the equipment with regard to adjustments and settings which affect the welding characteristics and weld-bead placement. Welders qualified to a multiple position semi-automatic process shall be qualified to machine/automatic weld multiple positions by performing a single position performance test using the machine/automatic process equipment.

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 12 and 13 as applicable. Qualification position limitations shall be as specified in table IX. Test assembly shall be tested and evaluated as specified in 5.4.

5.3.3 Tack and fillet welder.

5.3.3.1 Base material form and size. Qualification tests shall conform to the requirements of table X, test no. 8. The positions for which a test assembly welded in a given position qualify are shown in table IX. Test assembly shall be tested and evaluated as specified in 5.4.

5.3.3.2 Extent of qualification. Tack and fillet welders shall be qualified as required by table VIII.

5.3.4 Weld surfacing (hardfacing and corrosion-resisting). Qualification for weld surfacing shall be obtained as permitted by table IX or alternately by table X, test no. 9. Test no. 9 assembly shall be tested and evaluated by visual, dye penetrant and macroetch examination as specified in 5.4.

5.3.5 Seal, socket and tube-to-tubesheet welds.

5.3.5.1 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 4.4.7 except as follows:

- (a) Qualified positions, materials and thicknesses shall be in accordance with section 5.
- (b) Tube-to-tubesheet test assemblies shall consist of a minimum of six joints.
- (c) The requirements of 4.4.7.3 do not apply.

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- (d) For the socket weld test, the smallest pipe size to be welded in production shall be used, except that 1/2 NPS schedule 10 shall qualify all sizes and thicknesses of 0.058 inch and greater. This test shall be designated as number 3S.

5.3.5.2 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 section 5:

- (a) For socket welds with wall thickness 3/16 inch or greater - pipe butt weld test.
- (b) For 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 IX or socket weld test.

5.3.6 Internal tube-to-header welding of boiler components. Welders shall be qualified on a test assembly consisting of four joints which are welded in the sequence of 4.4.9. Joint design shall simulate the production joint except as specified by 4.4.9.1(b). S-1 material may be used. The requirements of this paragraph apply only to manual welding. Qualification shall otherwise be in accordance with 4.4.9. The requirements of this paragraph do not negate any additional requirements as may be imposed by specific component fabrication or repair documents.

5.3.6.1 Welding shall be performed under the space restrictions depicted by figure 25. The entire space restriction assembly shall be held at 400 degrees Fahrenheit (°F) minimum for the entire test. The welder shall perform all grinding and any repair weld preparation in the heated assembly. After completion of all welding and grinding of all joints, the test assembly shall be removed and cooled as required for root and final weld NDT inspection.

5.3.6.2 The root pass and finished welds of the test assembly shall be nondestructively tested in accordance with 4.4.9.1(e), (f) and (i). Undercut of 1/32 inch maximum is permissible along the plate weld toes.

5.3.6.3 After successful nondestructive testing, all four welds shall be macrosectioned and examined in accordance with 4.4.9.1(g) and (i).

5.3.6.4 Qualification position shall be in accordance with table IX.

5.3.6.5 Failure of either the root pass or final weld by any inspection or test on any joint shall constitute failure of the qualification test. Repair of the test assembly as a result of a root pass defect shall preclude further repair (see 5.2.8(b)).

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 XI. For suggested removal of destructive test specimens (when used), see figures 12 through 17.

5.4.1 Nondestructive inspection.

5.4.1.1 Visual examination. Visual examination shall be performed for weld surface geometry and weld surface soundness. For titanium and titanium alloy welds, refer to 4.5.1.1 except that the rejection of the qualification tests for multiple occurrences of straw color is not applicable. However, if the straw color occurs more than once, the cause shall be determined and corrected.

5.4.1.2 Nondestructive test performance. Nondestructive testing shall be performed in accordance with MIL-STD-271. 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 magnetic-particle, liquid penetrant, and visual examination shall be based on the requirements of MIL-STD-2035, class I. For acceptable visual appearance of titanium and titanium

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alloy welds refer to 4.5.1.1. Acceptance standards for radiography shall be based on the requirements of class I of MIL-STD-2035. Acceptance standards for ultrasonic testing shall be class I of MIL-STD-2035. For plate assemblies, 1 inch of weld at each end of the test assembly need not be evaluated.

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 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 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 examined without magnification. Evidence of cracks, incomplete root fusion in excess of 10 percent of the weld length, wormholes or porosity in excess of three pores over 1/16 inch diameter in any 1 inch of fillet weld, or an accumulation of more than 10 pores in 8 inches of the test plate shall be cause for rejection.

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 a minimum of 5X 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 18).

5.5.1 Records. The welder qualification test record shall include at least the following information:

- (a) Welder or welding operator identification (name, clock number or social security number).
- (b) Date of test.
- (c) Qualification test number, process, position, base material type, and filler metal type and size.
- (d) Results of qualification test.
- (e) Record of omission of space restriction when not used in pipe tests.
- (f) Certifying signature by fabricator.

5.5.1.1 The examination specified in 5.2.3(a) shall also be maintained as part of the welder qualification record.

5.5.2 Radiographs, test assemblies, and metallographic sections required for welding personnel qualifications need not be retained.

5.5.3 Detailed records of maintenance of personnel qualification (see 5.2.11) need only be retained for the current and preceding calendar quarter.

5.6 Changes requiring requalification of welder or welding operator. Requalification of welder or welding operator is required for the changes specified in 5.6.1 through 5.6.7.

5.6.1 Base material. A change from one base material thickness to a thickness outside the limits specified in table X and figures 12 and 13.

5.6.2 Filler material.

- (a) A change from a filler material listed under one A-number in table II to a filler material listed under another A-number, except as permitted by table VIII. Filler materials conforming to AWS, ASTM, ASME, and so forth, classifications, and for which there is a qualified procedure (see 5.2.5), may be grouped with the appropriate A-number of table II, and the extent of welder

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performance crossqualification by A-numbers shall be as permitted by table VIII.

- (b) For internal tube to header weld joints, a change in electrode coating classification, that is, MIL-XX15 to MIL-XX16 or MIL-XX18, and so forth, and vice versa.
- (c) For internal tube to header 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, powdered metal or vice versa.
- (e) For MIL-120 and MIL-140 series filler materials, see table II, footnote 13.

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, except as follows: 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) For plasma-arc, a change from welding to weld surfacing and vice versa.
- (e) A change from one welding process to any other welding process (as defined in the master chart of welding and allied processes - AWS A3.0).

5.6.4 Position. Except as permitted for 5G position pipe welding by table IX, note 10, a change to a welding position other than one already qualified (see table IX) or a change in progression from vertical up to vertical down or vice versa.

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 X.
- (c) In internal tube-to-header joints for boiler components:
 - (1) A 1/32 inch or more 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.

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 (12 inches and under) accessibility and the existing qualification was made under no restriction (over 12 inches). Refer to figure 21 for layout and construction of restricted accessibility qualification test assembly positions.

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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 or more than 25-percent carbon-dioxide or to straight carbon-dioxide and vice versa.
- (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, and S-53 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, and S-53 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, and S-53 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.

5.6.8 Fabrication documents 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).

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6. BRAZING

6.1 Scope. This section 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.

6.2 General requirements. The purpose of these qualification requirements is to ensure that qualified procedures are used with adequate equipment by properly trained personnel. Each activity performing work within the scope of this document shall direct and supervise the necessary qualification tests. 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 section. 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.

6.2.1 Specifications covering brazing filler metals require the following caution label, as a minimum, to be prominently displayed in legible type on all individually packaged units.

CAUTION

Welding, including brazing, may produce fumes and gases hazardous to health. Avoid breathing these fumes and gases. Use adequate ventilation.

All brazing procedures and instructions to brazers and brazing operators should carry this or a similar statement and appropriate safety measures should be taken to ensure that brazing is performed under optimum conditions of ventilation.

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.
- (b) Qualify the proposed brazing procedure by brazing test assemblies and performing nondestructive and destructive tests in accordance with the requirements of this section. Except as noted herein, procedure qualification tests are not required for oxy-fuel manual torch brazing with base materials, brazing alloys and flux combinations specified by table XII. Qualification tests shall be performed for manual torch brazing procedures that specify materials not classified in table XII and for all other brazing processes including those listed in 6.3.1(c) which specifies heating sources other than manual-torch.
- (c) Other brazing processes:
 - (1) Mechanical-torch
 - (2) Furnace
 - (3) Induction
 - (4) Electrical resistance
 - (5) Dip brazing - salt and flux bath

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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. In as much 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 American Society of Mechanical Engineers (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, American Bureau of Shipping (ABS), American Society of Mechanical Engineers (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 and data provision requirements. When qualification testing is required, the activity shall submit the essential elements of the brazing procedure and detail qualification test results to NAVSEA or its authorized representative for approval. Procedures are the activity's responsibility but shall be submitted for information. Resubmission of procedures for changes which do not involve requalification is not required. 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 brazing procedure and 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 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 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 Transferral of brazing procedure qualification. Requalification of previously qualified procedures shall be required for procedures transferred from one activity to another.

6.3.7.1 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 Transfer of qualified procedures between Navy shipyards shall be the same as for welding procedures (see 4.2.10.2).

6.3.7.3 Procedures contained in NAVSEA technical manuals shall be the same as for welding procedures (see 4.2.10.3).

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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 (pipe/tubing and fitting).
 - (1) Type
 - (2) Specification
 - (3) Thickness range qualified
- (b) Brazing process (see 6.3.1(c)).
- (c) Brazing alloy - specification and classification (as specified in table XIV).
- (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 - that is, 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, and so forth).
- (l) Fixturing.
- (m) Placement of brazing alloy - method of applying the brazing alloy (face feeding, insert ring, shims, and so forth).
- (n) Joint fit-up - maximum clearances.
- (o) Nondestructive testing requirements (reference to inspection procedure of fabrication plan).
- (p) Applicable thicknesses.
- (q) For procedures involving use of minimum flux technique: fluxing technique and internal purge requirements (if used).

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 XIII and XIV. 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. Material thickness limits are shown in table XV. Butt or scarf joints shall qualify for lap joints and vice versa. Type and number of tests shall be as specified in table XV.

6.3.9.2 Qualification assembly destructive test evaluation.

6.3.9.2.1 Tension test. Reduced specimens conforming to figure 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.

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- (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 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 evaluation. Brazements shall be limited to visual examination without magnification 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.

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 6.3.10.7 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 6.3.10.7 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 XIII to a material classified under another P-number in table XIII, or to any other base material not classified in table XIII. 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 XV.

6.3.10.2 Brazing alloy. A change from a brazing alloy classified under one F-number in table XIV to a brazing alloy classified under another F-number, or to a brazing alloy not classified in table XIV, 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(c) to another process listed in 6.3.1(c) or to a brazing process not listed except as permitted in 6.3.1(b).

6.3.10.4 Flux. A change in type of flux except as permitted by table XII.

6.3.10.5 Furnace atmosphere. A change in the furnace atmosphere from one basic type to another basic type.

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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 plus or minus 50 percent of the range qualified.

6.3.10.7 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. 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) Ensuring that each brazer and brazing operator has satisfactorily brazed the applicable performance qualification test assemblies.
- (c) Inspecting each qualification test assembly in accordance with the requirements of this section.
- (d) Evaluating the results of either the destructive or nondestructive tests or both in accordance with the applicable standards unless otherwise specified in this document.
- (e) Maintaining current records of the extent of each brazer and brazing operator qualification (see 6.4.10).

6.4.3.1 Training shall be administered in accordance with a program approved by one of the activity's MIL-STD-271 certified level III non-destructive 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 agent 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.

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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 ultrasonically 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, American Bureau of Shipping, or ASME, within the limits covered by the qualification tests passed, provided evidence of qualification is verified and approved.

6.4.5 Transferral 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 23) with the thickness a minimum of 1/8 inch. Each joint when peeled or ultrasonically tested shall show bonding on at least 70 percent of the lapped area. Qualification with any one base material, any one flux and any one brazing alloy qualifies for all combinations listed in table XII for a given process.

6.4.6.1 Fabrication documents 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).

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 brazer or brazing operator has had at least 4 hours of training or practice designed to correct the reasons for previous failures.

6.4.8 Maintenance of qualification. Each activity shall establish that an active qualification status is maintained for each qualified brazer or brazing operator. Evidence consisting of at least one verification of process use (that is, fabricator certification of use of "manual torch brazing", or "induction brazing") at any time during each 3-month or calendar-quarter period, shall be maintained. The intent of this requirement is to cause verification of each production brazer's or brazing operator's use of the qualified processes once in each calendar-quarter subsequent to the quarter in which he was qualified and four times in each subsequent calendar year.

6.4.8.1 Renewal of qualification. Renewal of performance qualification is required (1) when a brazer or brazing operator has not used the specific brazing process in the preceding calendar quarter, or (2) when 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 was previously qualified, unless otherwise specified by the authorized representative.

6.4.8.1.1 Each brazer and brazing operator shall be retested every 3 years in accordance with 6.4.3(a).

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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 XIII except as permitted by note 1 thereto.
- (b) Brazing alloy. A change to a brazing alloy not listed in table XIV except as permitted by note 1 thereto.

6.4.10 Test records. Qualification test records of each brazer or brazing operator, together with identification data, shall be kept by the activity. These records shall include the following information:

- (a) Brazer or brazing operator identification (name, clock number or social security 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.

6.4.10.1 Detailed records of maintenance of personnel qualification (see 6.4.8) need only be retained for the current and preceding calendar quarter.

6.4.10.2 The examination of 6.4.3(a) shall also be maintained as part of the brazer qualification record.

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.

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7. NOTES

7.1 Cancelled specifications. The following are cancelled or superseded specifications for materials. They are listed in this document to identify applicable requirements for welding, NDT, etc., when the materials are encountered, such as in existing ships and components.

FEDERAL

- QQ-A-601 - Aluminum Alloy Sand Castings.
- 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 Plate).
- QQ-B-750 - Bronze, Phosphor; Bar, Plate, Rod, Sheet, Strip, Flat Wire, and Structural and Special Shaped Sections.
- 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-766 - Steel, Stainless and Heat Resisting, Alloys, Plate, Sheet, and Strip.
- 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 Castings, Molybdenum Alloy.
- MIL-S-8699 - Steel Bars and Forging Stock (4330) Vanadium Modified, Aircraft Quality.
- MIL-S-15083 - Steel Castings.
- MIL-C-15345 - Castings, Nonferrous, Centrifugal.
- MIL-S-15464 - Steel, Alloy, Chromium-Molybdenum; Castings.
- MIL-B-16541 - Bronze, Valve: Castings.
- MIL-S-16993 - Steel Castings (12-Percent Chromium).
- MIL-S-17509 - Steel Castings, Austenitic, Chromium-Nickel, Low Magnetic Permeability.
- 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-B-21230 - Bronze, Nickel Aluminum and Manganese-Nickel Aluminum: Castings, Ship Propeller Application.
- MIL-S-24412 - Steel, Special Structural Shape, Weldable, High Tensile (HT); for Submarine Hulls.
- MIL-B-24059 - Bronze, Nickel Aluminum; Rod, Flat Products with Finished Edges, Shapes, and Forgings.

TABLE I. Grouping of base materials (welding). 1/

Letter number	Applicable document	Class or type
S-1	Carbon steel	
	ASTM A 216 ASTM A 515 ASTM A 516 WW-P-404 MIL-S-15083 MIL-T-16286 ASTM A 178 MIL-S-24093 MIL-T-20157 MIL-S-24412 MIL-F-20236 MIL-F-20670 MIL-S-22698 MIL-S-23194 MIL-S-23284 MIL-S-24238 MIL-P-24338 MIL-F-24339 MIL-P-24691/1 MIL-C-24707/1	WCB Grade 55 (plate) Grade 60 (plate) Grade 65 (plate) Grade 70 (plate) Grade 70 (plate) Pipe seamless and welded Grade 70-36 (cast) Grade 65-35 (cast) Grade CW (cast) Grade B (cast) Class a (tube seamless) Class g (tube seamless) Tubes welded Type V (forgings) Type E (tube and pipe) Grade HT (shape) Flanges, pipe Flanges, pipe Plate, bar and shapes Composition C (forgings) Class 3 Class 4 Composition C (plate) Pipe Fittings and flanges Grade B (tube and pipe) ASTM A757, grade A1Q (castings) grade A2Q ASTM A216, grade WCA (castings) grade WCB grade WCC
S-2	Quenched and tempered carbon steel	
	ASTM A 537	Class 2
	Carbon molybdenum steel	
S-3	MIL-S-870 DOD-F-24669/2 MIL-T-16286 DOD-F-24669/1 MIL-T-20155 MIL-P-24707/2	CMo (cast) CMo class a (forgings) CMo class b (forgings) CMo class d (tube) CrNi type 8620 (bar and forgings) CMo (tube and pipe) ASTM A217 grade WC1 (castings)

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	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 A 302 MIL-S-23194 MIL-S-24238	MnMo grade B (plate) NiCrMo Comp. A (forgings) NiMnMo Comp. A (plate)
S-4	Alloy steels (Cr content 3/4 - 2 percent, total alloy not to exceed 2-3/4 percent)	
	AMS 6530 MIL-T-6736 MIL-S-8699 MIL-S-15464 ASTM A 182 ASTM A 213 DOD-F-24669/1 MIL-P-24691/2 DOD-F-24669/2 MIL-C-24707/2 MIL-S-18728 MIL-S-18729	CrNiMo, type 8630 (tube) CrMo, type 4130 (tube) CrMoV, type 4330 (bar, forging) CrMo class 1 (casting) F11 Grade T11 (tube) CrMo type 4130 (bar) CrMo, grade P11 (tube and pipe) CrMo, class a (forgings) ASTM, A217, grade WC6 (casting) CrNiMo, type 8630 (plate) CrMo, type 4130 (plate)
S-5	Alloy steels (total alloy content 10 percent max)	
	ASTM A 182 ASTM A 213 MIL-S-860 MIL-S-15464 MIL-T-16286 MIL-P-24691/2 DOD-F-24669/2 MIL-F-24669/8 DOD-F-24669 MIL-C-24707/2	F22 T22 CrMoV, grade F (forgings) CrMo, class 2 (casting) CrMo, class e (tube) CrMo, grade P22 (tube and pipe) CrMo, class b (forging) CrMoV, grade F (forgings) CrMo (bar and forgings) ASTM A217, grade WC9 (casting)
S-6	High alloy steels (martensitic)	
	MIL-L-24128 QQ-S-763 QQ-S-766 DOD-F-24669/7	403 (bars, rods, forgings) 403, (bars, rods, forgings) 410 414 420 410, (plate, sheet, strip) 420 403 (bars) 410

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type
S-6 (Cont'd)	DOD-F-24669/6 MIL-S-16993 MIL-C-24707/6	403 (bars) 410 414 420 12 percent Cr, class 1 (casting) 12 percent Cr, class 2 (casting) ASTM A217, grade CA-15 (casting) ASTM A487, grade CA-15M, class A
S-6A	High alloy steels (martensitic)	
	ASTM A 182 ASTM A 176 ASTM A 240 ASTM A 473 ASTM A 487	F6NM (forgings) 410S (plate, sheet, strip) 410S (plate, sheet, strip) 410S (forgings) CA-6NM (castings)
S-7	High alloy steels (ferritic)	
	QQ-S-763 QQ-S-766	405 (bar, shapes, forgings) 430 430 (plate, sheet, strip)
S-8	High alloy steels (austenitic)	
	QQ-S-763 QQ-S-766 MIL-S-867	304 (bar, shapes, forgings) 304L 309 310 316 316L 321 347 304 304L 309S 310S 316 316L 321 347 348 Class I (castings) Class II Class III

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type	
S-8 (Cont' d)	MIL-P-24691/3	304 (pipe) 304L 316 316L 321 347	
	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-S-23195	304 (bar and forgings) 304L 347 348	
	MIL-S-23196	304 (plate, sheet, strip) 304L 347 348	
	MIL-T-23226	304 (tube and pipe) 304L 347 348	
	MIL-F-23467	304 (fittings/flanges) 304L 347 348	
	MIL-C-24707/3	ASTM A744, grade CF-8 (castings) ASTM A744, grade CF-8C ASTM A744, grade CF-8M	
	ASTM A 240	304 304L 309S 310S 316 321 347 348	
	ASTM A 743	CN-7M (castings) CM-7MS	
	ASTM A 744	CN-7M (castings) CN-7MS	
	S-10H	High alloy steel (duplex stainless)	
		A 240	Alloy 2205, UNS 31803 (plate) <u>4/</u>
A 276		Alloy 2205, UNS 31803 (bar) <u>4/</u>	

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type
S-11A	Quenched and tempered alloy steels	
	MIL-S-16216	HY-80 (plate) HY-100
	MIL-S-23008	HY-80 (castings) HY-100
	MIL-S-21952	HY-80 (bars) HY-100
	MIL-S-23009	HY-80 (forgings)
	MIL-S-23284	Class 1 Class 2
	MIL-L-24451	HY-80 (heads) HY-100
S-11B	Quenched and tempered alloy steels	
	MIL-S-24371	HY-130 (plate, castings, bars, forgings, extrusions and shapes)
S-11C	Age hardening alloy steel	
	MIL-S-24645	HSLA-80 (plate, sheet or coil)
S-11D	Age hardening alloy steel	
	MIL-S-24645	HSLA-100 (plate, sheet or coil)
S-21	Aluminum and aluminum base alloys	
	QQ-A-200/1	3003 (extruded bars, rods)
	QQ-A-225/1	1100 (bars, rods)
	QQ-A-225/2	3003 (bars, rods)
	QQ-A-250/1	1100 (plate)
	QQ-A-250/2	3003 (plate and sheet)
	WW-T-700/1	1100
WW-T-700/2	3003	
S-22	Aluminum and aluminum base alloys	
	QQ-A-200/6	5454 (extruded bar, rods)
	QQ-A-225/7	5052 (bar, rod)
	QQ-A-250/8	5052 (plate)
	QQ-A-250/10	5454
S-25	Aluminum and aluminum base alloys	
	QQ-A-200/5	5086 (extruded bar, rod)
	QQ-A-200/4	5083
	QQ-A-200/7	5456
	QQ-A-250/6	5083
	ASTM B 209	5086
	ASTM B 209	5456
WW-T-700/5	5086 (seamless tube)	

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type
S-26	Aluminum and aluminum base alloys	
	ASTM B26	Alloy A03550 (castings) Alloy A03560 Alloy A05140 Alloy A24430
	QQ-A-601	B443 (castings) 514 355 356
	MIL-A-21180	A356 (castings)
S-31	Copper and copper base alloys	
	ASTM B152	Alloy C10200 (plate, bar) Alloy C10400 Alloy C10500 Alloy C11000 Alloy C11300 Alloy C11400 Alloy C12200 Alloy C12300
S-32	Brass	
	ASTM B21 ASTM B124 ASTM B283 QQ-C-390 QQ-B-637 QQ-B-639	Alloy C46400 (rod/bar/shapes) Alloy C46400 (forging rod/bar/shapes) Alloy C46400 (die forgings) Alloy C85700 (castings) Naval brass (alloy 464) (rod/bar/forgings) Naval brass alloy (rod, bar and forgings) Alloy 462 Alloy 464
S-33	Silicon bronze	
	ASTM B98 ASTM B124 QQ-C-390 QQ-C-591	Alloy C65500 (rod/bar/shapes) Alloy C65500 (forging rod/bar/shapes) Alloy C87200 (castings) Alloy 655 (rod, shapes, flats)

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type	
S-34	Copper nickel		
	ASTM B369	Alloy C96200 (castings)	
	MIL-T-15005	Alloy C96400 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-F-24342	70/30 (fittings and flanges)	
S-35	Aluminum bronze		
	ASTM B124	Alloy C64200 (forging rod, bar, and shapes)	
	ASTM B150	Alloy C60600 (rod, bar, and shapes) Alloy C61400 Alloy C64200	
	ASTM B169	Alloy C61400 (plate, sheet, strip, and rolled bar)	
	ASTM B283	Alloy C64200 (die forgings)	
	QQ-C-390	Alloy C95200 (castings)	
	QQ-C-450	Alloy 606 (plate, bar) Alloy 613, 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	
	S-36A	Nickel-aluminum bronze	
		ASTM B124	Alloy C63000 (forging rod, bar, shapes) Alloy C63200
		ASTM B150	Alloy C63000 (rod, bar, shapes) Alloy C63200
ASTM B283		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	

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type
S-36B	Manganese-nickel-aluminum bronze	
	MIL-B-21230	Alloy 2 (castings)
S-37A	Manganese bronze	
	ASTM B138 QQ-B-728 QQ-C-390	Alloy C67000 (rod, bar, and shapes) Alloy C67500 Class A Class B 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 QQ-C-390	Castings Alloy C94700
S-39	Phosphor bronze	
	ASTM B139 QQ-B-750 MIL-T-3595	Alloy C51000 (rod, bar, and shapes) Alloy C52400 Composition A Composition D Composition D (tubing)
S-42	Nickel and nickel base alloys	
	A 494 QQ-N-281 MIL-N-24106 QQ-N-288 MIL-T-1368 MIL-T-23520 MIL-C-15345 MIL-N-17163 MIL-F-23509 MIL-C-24723	Comp. M-30C (casting) NiCu, class A (bar, plate, rod, forging) Class B NiCu, class A (bar, rods, forgings) NiCuSiCb, composition E (casting) NiCu (tubing) NiCu (tube and pipe) NiCuSiCb, Alloy 19 (casting) NiCu (bar, rod, plate, forging) Fittings and flanges Comp. M-30C (casting)

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type
S-43	Nickel-chromium iron	
	MIL-F-23508 ASTM B 166 ASTM B 564 MIL-B-15382 MIL-T-23227 MIL-N-23228 MIL-N-23229 MIL-N-24271 ASTM A 494 ASTM A 494 ASTM B 443 ASTM B 444 ASTM B 446	Fittings and flanges Bar, rod, forging Bar and rod Tube and pipe Condition A (plate) Condition A (bar, rod, forging) Castings GR CW-6MC GR CW-6MC MOD 2/ UNS N06625 (plate) UNS N06625 (pipe and tube) UNS N06625 (bar and rod)
S-44 3/	Nickel-molybdenum-chromium alloy	
	ASTM B 574 ASTM B 575 ASTM B 622	UNS N10276 (rod) UNS N10276 (plate, sheet, strip) UNS N10276 (pipe, tube)
S-51	Titanium and titanium base alloys	
	MIL-T-9046 ASTM B 265 ASTM B 337 ASTM B 338 ASTM B 348 ASTM B 363 ASTM B 381	CP-3 (sheet, strip, plate) CP-4 (sheet, strip, plate) Grade 7 (sheet, strip, plate) Grade 1 (pipe) Grade 2 (pipe) Grade 7 (pipe) Grade 1 (tubing) Grade 2 (tubing) Grade 7 (tubing) Grade 1 (bars, billets) Grade 2 (bars, billets) Grade 7 (bars, billets) WPT 1 (fittings) WPT 2 (fittings) WPT 7 (fittings) Grade F-1 (forgings) Grade F-2 (forgings)
S-52	Titanium and titanium base alloys	
	MIL-T-9046 MIL-T-9047 ASTM B 337 ASTM B 338 ASTM B 363 ASTM B 367	CP-1 (sheet, strip, plate) CP-2 (sheet, strip, plate) CP-70 (bars, reforging stock) Grade 3 (pipe) Grade 3 (tubing) WPT 3 (fittings) Grade C-2 (castings) Grade C-3 (castings)

See footnotes at end of table.

TABLE I. Grouping of base materials (welding). 1/ - Continued

Letter number	Applicable document	Class or type
S-53	Titanium and titanium base alloys	
	MIL-T-9046	AB-1 (sheet, strip, plate)
	MIL-T-9047	AB-2 (sheet, strip, plate)
	ASTM B 265	6Al-4V (bars, forgings)
	ASTM B 367	6Al-4V (ELI) (bars, forgings)
	ASTM B 381	Grade 5 (sheet, strip, plate)

- 1/ If material of similar chemistry and mechanical properties is not listed under an "S" group, it may be considered as part of a group upon approval.
- 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 toughness, composition, and heat treatment requirements imposed by the component specification.

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding). 1/

Group	Applicable document	Filler material type
A-1A	Low and medium carbon steel (covered electrodes)	
	AWS A5.1	6010 6011 6012 <u>2/</u> 6013 <u>2/</u> 6020 6027 7024 <u>2/</u>
A-1B	Low and medium carbon steel (bare rod)	
	AWS A5.2	Class RG-60 Class RG-65
A-2A	Carbon and low alloy steel (covered electrode)	
	MIL-E-22200/1	MIL-7018
	MIL-E-22200/6	MIL-7015 MIL-7016
	MIL-E-22200/7	MIL-7010-A1 MIL-7011-A1 MIL-7018-A1 MIL-7020-A1
	MIL-E-22200/10	MIL-7018M
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) <u>3/</u> MIL-70S-2 (wire) <u>3/</u> MIL-70S-3 (wire) <u>3/</u> MIL-70S-4 (wire) <u>3/</u> MIL-70S-5 (wire) <u>3/</u> MIL-70S-6 (wire) <u>3/</u> MIL-70S-7 (wire) <u>3/</u> MIL-70S-8 (wire) <u>3/</u> MIL-70S-9 (wire) <u>3/</u> MIL-70S-F (flux) <u>3/</u>
	MIL-E-23765/4	MIL-F6A2-EL12 (flux/wire) <u>3/</u> MIL-F6A2-EM12K (flux/wire) <u>3/</u> MIL-F7AZ-EM12K (flux/wire) <u>3/</u> MIL-F7A2-EM12K (flux/wire) <u>3/</u>

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding). 1/ - Continued

Group	Applicable document	Filler material type
A-2D	Low alloy steel (flux cored electrodes)	
	MIL-E-24403/1	MIL-70T-1 MIL-71T-1 MIL-70T-5 MIL-71T-5 MIL-70T-6 MIL-70T-8 MIL-71T-8 MIL-71T8-Ni1
A-3A	Carbon and low alloy steel (low hydrogen covered electrodes)	
	MIL-E-22200/6	MIL-8015-C3 MIL-8016-C3 MIL-10015 MIL-10016
	MIL-E-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-E-24403/1	MIL-80T1-Ni1 MIL-80T1-Ni2 MIL-81T1-Ni1 MIL-81T1-Ni2
A-4A	Low alloy, high yield steel (covered electrode)	
	MIL-E-22200/5	MIL-10018-N1 <u>4/</u>
A-5A	Low alloy, high yield steel (covered electrode)	
	MIL-E-22200/1	MIL-9018-M MIL-10018-M MIL-11018-M
	MIL-E-22200/10	MIL-10018-M1
	MIL-E-22200/9	MIL-12018-M2 <u>13/</u> MIL-14018-M1 <u>13/</u>
A-5B	Low alloy, high yield steel (bare electrode)	
	MIL-E-23765/2	MIL-100S-1 MIL-100S-2 MIL-120S-1 <u>13/</u>
	MIL-E-24355	MIL-140S-1 <u>13/</u>
A-5C	Low alloy, high yield steel (bare electrode and flux)	
	MIL-E-23765/2	MIL-100S-1 (wire) MIL-100S-1F (flux) MIL-100S-2 (wire) MIL-100S-2F (flux) MIL-120S-1 (wire) <u>13/</u> MIL-120S-1F (flux) <u>13/</u>

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding). 1/ - Continued

Group	Applicable document	Filler material type
A-5D	Low alloy, high yield steel (flux cored electrode)	
	MIL-E-24403/2	MIL-100TC <u>7/</u> , <u>8/</u> , <u>2/</u> MIL-100TM <u>7/</u> , <u>8/</u> , <u>2/</u> MIL-100TS <u>7/</u> , <u>2/</u> MIL-101TC <u>8/</u> , <u>2/</u> MIL-101TM <u>8/</u> , <u>2/</u> MIL-101TS <u>2/</u> MIL-110TC <u>7/</u> , <u>8/</u>
A-6A	CrMo steel (1.0 to 2.5 percent Cr, 0.4 to 1.2 percent Mo) (covered electrode)	
	MIL-E-22200/8 AWS A5.5	MIL-80XX-B2L or B2 MIL-90XX-B3L or B3 E80XX-B2L or B2 E90XX-B3L or B3
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 AWS A5.23 AWS A5.28	MIL-515 MIL-521 EB2 EB3 ER80S-B2L ER80S-B2 ER90S-B3L ER90S-B3
A-7A	CrMo steel (4.0-13.5 percent Cr, 0.4-1.4 percent Mo) (covered electrode)	
A-7A-1	MIL-E-22200/8	MIL-502-XX MIL-502-XX-L MIL-505-XX
A-7A-2	MIL-E-22200/8	MIL-410-XX MIL-410-NiMoXX
A-7B	CrMo steel (4.0-13.5 percent Cr, 0.4-1.4 percent Mo) (bare electrode, rod and insert)	
A-7B-1	MIL-I-23413	MIL-505
A-7B-2	MIL-E-19933	MIL-410 MIL-410 NiMo <u>5/</u>
A-7C	High alloy steel (ferritic) (chromium 15-18 percent) (covered electrode)	
	AWS A5.4	E430
A-7D	High alloy steel (ferritic) (chromium 15-18 percent) (bare electrode and rod)	
	AWS A5.9	ER430

See footnotes at end of table.

TABLE II. 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	ER-5183 ER-5356 ER-5554 ER-5556 ER-5654
	MIL-I-23413 (inserts)	MIL-5356
A-23B	Aluminum alloy (bare electrode, rod and insert)	
	ANSI A5.10 AWS A5.10 MIL-I-23413 (inserts)	4043 ER-4043 MIL-4043
A-24B	Aluminum alloy (bare electrode and rod)	
	AWS A5.10	ER-2319
A-31B	Copper alloy (bare electrode and rod)	
	AWS A5.7	ER Cu
A-32A	Copper alloy (silicon bronze covered electrode)	
	AWS A5.6	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	E CuSn-A E CuSn-C
A-33B	Copper-tin alloy (phosphor bronze) (bare electrode and rod)	
	MIL-E-23765/3 AWS A5.7	MIL-CuSn-C 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-I-23413 (insert)	MIL-EN67 <u>5/</u> MIL-RN67 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 II. 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 AWS A5.13	ECuAl-A2 ECuAl-B ECuAl-C ECuAl-D ECuAl-E
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 MIL-RNiCr-C MIL-PNiCr-B-2 (powder) MIL-PNiCr-C-2 (powder)
A-39A	Surfacing alloys (covered electrode)	
	AWS A5.13	ECoCr-A <u>6/</u> ECoCr-C
A-39B	Surfacing alloys (bare rod) (metal powder)	
	MIL-R-17131	MIL-RCoCr-A <u>6/</u> MIL-RCoCr-C MIL-PCoCr-E-1 (powder) MIL-PCoCr-E-2 (powder)
A-41A	Nickel (covered electrode)	
	MIL-E-22200/3	MIL-4N11
A-41B	Nickel (bare electrode, rod and insert)	
	MIL-E-21562	MIL-EN61 <u>5/</u> 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 <u>5/</u> MIL-RN60
	MIL-I-23413 (insert)	MIL-60
A-43A	Nickel base alloys (covered electrode)	
	MIL-E-22200/3	MIL-1N12 MIL-3N12 MIL-4N12 MIL-4N1A MIL-8N12 MIL-8N12H

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding). 1/ - Continued

Group	Applicable document	Filler material type
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/ MIL-RN625
	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 10/ 11/ (covered electrode)	
	AWS A5.11 (UNS-W80276)	ENiCrMo-4 9/
A-45B	Nickel-Molybdenum-Chromium Alloy 10/ 11/ 12/ (bare electrode)	
	AWS A5.14 (UNS-N10276)	ER NiCrMo-4 9/
A-51B	Titanium-unalloyed (bare electrode)	
	AWS A5.16	ER Ti-1 ER Ti-2 ER Ti-3 ER Ti-7
A-53B	Titanium base alloys (bare electrode)	
	AWS A5.16	ER Ti-5 ER Ti-5ELI

- 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.
- 3/ See 4.7.2(a)(1).
- 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.
- 7/ Use in any position other than that specified for qualification testing in MIL-E-24403/2 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 for this electrode shall require separate qualification and NAVSEA approval.

- 9/ Conformance test requirements for procurement of filler materials shall be submitted along with the welding procedure and associated qualification data. As a minimum the requirements of AWS A5.01 for schedule J testing to the applicable filler material specification shall be done. For other than cladding for corrosion resistance applications these requirements shall include testing for tensile properties (tensile, yield, elongation and reduction of area), which assure minimum base material property requirements are met, unless otherwise approved by NAVSEA.
- 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/ 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/ Welding procedure and personnel 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.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/

Category	Base material <u>3/</u>		Filler material <u>11/</u>	Qualified for categories <u>4/</u>
	A	B		
Ferritic materials/shielded metal arc process <u>5/ 14/ 17/</u>				
1	S-11B	S-11B	A-5A (MIL-14018 only)	1 through 6, 13, 17 through 19 and 24
2	S-11B	S-11A-2	A-5A (MIL-14018 or 12018)	2 through 6, 13, 17 through 19 and 24
3	S-11B	S-11D	A-5A (MIL-14018 or 12018)	3 through 6, 13, 17 through 19 and 24
4	S-11B	S-11A-1	A-5A (MIL-14018, 12018, or 10018)	4 through 6, 13, 17 through 19 and 24
5	S-11B	S-11C	A-5A (MIL-14018, 12018, or 10018)	5, 6, 13, 17 through 19 and 24
6	S-11B	S-2 S-1	A-5A or the A-3A or A-2A electrodes specifically permitted by MIL-STD-1681	6, 13, 17 through 19 and 24
7	S-11A-2	S-11A-2	A-5A (MIL-12018 only)	7 through 19 and 24
8	S-11A-2	S-11D	A-5A (MIL-12018 only)	8, 11 through 19 and 24
9	S-11A-2	S-11A-1	A-5A (MIL-12018 or 10018)	9 through 13, 15 through 19 and 24
10	S-11A-1	S-11A-1	A-5A (MIL-10018 only)	10 through 13, 16 through 19 and 24
11	S-11A-1	S-11D	A-5A (MIL-12018 or 10018)	11 through 13, 15 through 19 and 24
12	S-11A-2 S-11A-1	S-11C	A-5A (MIL-12018 or 10018)	12, 13, 16 through 19 and 24

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Ferritic materials/shielded metal-arc process (continued) 5/ 14/ 17/				
13	S-11A-2 S-11A-1	S-2 S-1	10/ A-5A (MIL-12018 or 10018); or A-3A or A-2A electrodes specifically permitted by MIL-STD-1688 or MIL-STD-1689	13, 17 through 19 and 24
14	S-11D	S-11D	A-5A (MIL-12018 only)	14 through 19 and 24
15	S-11D	S-11C	A-5A (MIL-12018 or 10018)	15 through 19 and 24
16	S-11C	S-11C	A-5A (MIL-10018)	16 through 19 and 24
17	S-11D S-11C	S-2 S-1	10/ A-5A (MIL-12018 or 10018); or A-3A or A-2A electrodes specifically permitted by MIL-STD-1689	17 through 19 and 24
18	S-2	S-2	10/ A-3A or A-2A (MIL-7018A1 or 7018 or 7016)	18, 19 and 24
19	S-2	S-1	10/ A-3A or A-2A (MIL-7018A1 or 7018 or 7016)	19 and 24
20	S-3A	S-3A	10/ A-3A or A-2A (MIL-7018A1)	20 through 24
21	S-3A	S-3 S-1	10/ A-3A or A-2A (MIL-7018A1 or 7018 or 7016)	21 through 24
22	S-3	S-3	10/ A-3A or A-2A (MIL-7018A1 or 7018 or 7016)	22 through 24
23	S-3	S-1	10/ A-3A or A-2A (MIL-7018A1 or 7018 or 7016)	23 and 24
24	S-1	S-1	A-2A	24
25	S-5	S-5	10/ A-7A-1 or A-6A	25 through 29
26	S-5	S-4	10/ A-7A-1 or A-6A	26 through 29

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Ferritic materials/shielded metal-arc process (continued) 5/ 14/ 17/				
27	S-5	S-3 S-1	10/ A-6A or A-3A or A-2A (MIL-7018A1 or 7018 or 7016)	27 and 29
28	S-4	S-4	A-6A	28 and 29
29	S-4	S-3 S-1	10/ A-6A or A-3A or A-2A (MIL-7018A1 or 7018 or 7016)	29
30	S-6	S-6	A-7A-2 (MIL-410XX only)	30
31	S-6	S-6	A-7A-2 (MIL-410 NiMo XX only)	31 through 33
32	S-6	S-6A	A-7A-2 (MIL-410 NiMo XX only)	32 and 33
33	S-6A	S-6A	A-7A-2 (MIL-410 NiMo XX only)	33
Ferritic materials/gas tungsten-arc, gas metal arc and plasma-arc processes 5/ 17/				
1	S-11B	S-11B	A-5B (MIL-140S-1 only)	1 through 6, 13, 17 through 19 and 24
2	S-11B	S-11A-2	A-5B (MIL-140S-1 or 120S-1)	2 through 6, 13, 17 through 19 and 24
3	S-11B	S-11D	A-5B (MIL-140S-1 or 120S-1)	3 through 6, 13, 17 through 19 and 24
4	S-11B	S-11A-1	A-5B (MIL-140S-1 or 120S-1 or 100S-1)	4 through 6, 13, 17 through 19 and 24
5	S-11B	S-11C	A-5B	5, 6, 13, 17 through 19 and 24
6	S-11B	S-2 S-1	10/ A-5B; or A-3B or A-2B types specifically permitted by MIL-STD-1681	6, 13, 17 through 19 and 24
7	S-11A-2	S-11A-2	A-5B (MIL-120S-1 only)	7 through 19 and 24
8	S-11A-2	S-11D	A-5B (MIL-120S-1 only)	8, 11 through 19 and 24

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Ferritic materials/gas tungsten-arc, gas metal arc and plasma-arc processes - (continued) 5/ 17/				
9	S-11A-2	S-11A-1	A-5B (MIL-120S-1 or 100S-1)	9 through 13, 15 through 19 and 24
10	S-11A-1	S-11A-1	A-5B (MIL-100S-1 only)	10, through 13, 16 through 19 and 24
11	S-11A-1	S-11D	A-5B (MIL-120S-1 or 100S-1)	11 through 13, 15 through 19 and 24
12	S-11A-2 S-11A-1	S-11C	A-5B (MIL-120S-1 or 100S-1)	12, 13, 16 through 19 and 24
13	S-11A-2 S-11A-1	S-2 S-1	10/ A-5B (other than MIL-140S types); or A-2B types specifically permitted by MIL-STD-1688 or MIL-STD-1689	13, 17 through 19 and 24
14	S-11D	S-11D	A-5B (MIL-120S-1 only)	14 through 19 and 24
15	S-11D	S-11C	A-5B (MIL-120S-1 or 100S-1)	15 through 19 and 24
16	S-11C	S-11C	A-5B (MIL-100S-1 only)	16 through 19 and 24
17	S-11D S-11C	S-2 S-1	10/ A-5B (other than MIL-140S types); or A-3B or A-2B types specifically permitted by MIL-STD-1689	17 through 19 and 24
18	S-2	S-2	10/ A-3B or A-2B	18, 19 and 24
19	S-2	S-1	10/ A-3B or A-2B	19 and 24
20	S-3A	S-3A	10/ A-3B or A-2B	20 through 24
21	S-3A	S-3 S-1	10/ A-3B or A-2B	21 through 24
22	S-3	S-3	10/ A-3B or A-2B	22 through 24
23	S-3	S-1	10/ A-3B or A-2B	23 and 24
24	S-1	S-1	A-2B	24

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Ferritic materials/gas tungsten-arc, gas metal arc and plasma-arc processes - (continued) 5/ 17/				
25	S-5	S-5	10/ A-7B-1 or A-6B	25 through 29
26	S-5	S-4	10/ A-7B-1 or A-6B	26 through 29
27	S-5	S-3 S-1	10/ A-7B-1 or A-6B or A-3B or A-2B	27 and 29
28	S-4	S-4	A-6B	28 and 29
29	S-4	S-3 S-1	10/ A-6B or A-3B or A-B	29
30	S-6	S-6	A-7B-2 (MIL-410 only)	30
31	S-6	S-6	A-7B-2 (MIL-410 NiMo only)	31 through 33
32	S-6	S-6A	A-7B-2 (MIL-410 NiMo only)	32 and 33
33	S-6A	S-6A	A-7B-2 (MIL-410 NiMo only)	33
Ferritic materials/submerged-arc process 5/ 17/				
1	S-11A-2	S-11A-2	A-5C (MIL-120S-1 wire and 1F flux)	1 through 13 18
2	S-11A-2	S-11D	A-5C (MIL-120S-1 wire and 1F flux)	2, 5 through 13 and 18
3	S-11A-2	S-11A-1	A-5C (MIL-120S-1 wire and 1F flux or 100S-1 wire and 1F flux)	3 through 7, 9 through 13 and 18
4	S-11A-1	S-11A-1	A-5C (MIL-100S-1 wire and 1F flux)	4 through 7, 10 through 13 and 18
5	S-11A-1	S-11D	A-5C (MIL-120S-1 wire and 1F flux or 100S-1 wire and 1F flux)	5 through 7, 10 through 13 and 18
6	S-11A-2 S-11A-1	S-11C	A-5C (MIL-120S-1 wire and 1F flux or 100S-1 wire and 1F flux)	6, 7, 10 through 13 and 18

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Ferritic materials/submerged-arc process (continued) 5/ 17/				
7	S-11A-2 S-11A-1	S-2 S-1	10/ A-5C (MIL-120S-1 wire and 1F flux or 100S-1 wire and 1F flux) or A-3C or A-2C wire and flux specifically permitted by MIL-STD-1688 or MIL-STD-1689	7, 11 through 13 and 18
8	S-11D	S-11D	A-5C (MIL-120S-1 wire and 1F flux)	8 through 13 and 18
9	S-11D	S-11C	A-5C (MIL-120S-1 wire and 1F flux or 100S-1 wire and 1F flux)	9 through 13 and 18
10	S-11C	S-11C	A-5C (MIL-100S-1 wire and 1F flux)	10 through 13 and 18
11	S-11D S-11C	S-2 S-1	10/ A-5C (MIL-120S-1 wire and 1F flux or 100S-1 wire and 1F flux) or A-3C or A-2C wire and flux specifically permitted by MIL-STD-1689	11 through 13 and 18
12	S-2	S-2	12/ A-2C	12, 13 and 18
13	S-2	S-1	A-2C unless qualified by category 12, see note 12/	13 and 18
14	S-3A	S-3A	A-3C	14 through 17
15	S-3A	S-3 S-1	A-3C	15 through 17 (qualification with A-2C qualifies categories 15 through 18 with A-2C)
16	S-3	S-3	A-3C	16 through 17 (qualification with A-2C qualifies categories 16 through 18 with A-2C)

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Ferritic materials/submerged-arc process (continued) 5/ 17/				
17	S-3	S-1	A-3C	17 (qualification with A-2C qualifies categories 17 and 18 with A-2C)
<u>13/</u> 18	S-1	S-1	A-2C	18
19	S-6	S-6	A-7B-2 (MIL-410 NiMo only) <u>9/</u>	19 through 21
20	S-6	S-6A	A-7B-2 (MIL-410 NiMo only) <u>9/</u>	20 and 21
21	S-6A	S-6A	A-7B-2 (MIL-410 NiMo only) <u>9/</u>	21
Ferritic materials/flux cored-arc process 5/				
1	S-11A-1	S-11A-1	A-5D	1 through 7 and 12
2	S-11A-1	S-11C	A-5D	2 through 7 and 12
3	S-11A-1	S-2 S-1	<u>10/</u> A-5D; or A-2D or 3D electrodes specifically permitted by MIL-STD-1688 or MIL-STD-1689	3, 5 through 7 and 12
4	S-11C	S-11C	A-5D	4 through 7 and 12
5	S-11C	S-2 S-1	<u>10/</u> A-5D; or A-2D or A3D electrodes specifically permitted by MIL-STD-1689	5 through 7 and 12
6	S-2	S-2	<u>10/</u> A-2D or 3D	6, 7, and 12
7	S-2	S-1	<u>10/</u> A-2D or 3D	7 and 12
8	S-3A	S-3A	A-3D	8 through 12
9	S-3A	S-3 S-1	<u>10/</u> A-2D or 3D	9 through 12
10	S-3	S-3	<u>10/</u> A-2D or A-3D	10 through 12
11	S-3	S-1	<u>10/</u> A-2D or A-3D	11 and 12
12	S-1	S-1	A-2D	12

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
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 13/ 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 13/	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
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 13/ S-4	A-8B (MIL-309 or ER-309L or MIL-310 types only)	2 and 4
3	S-8	S-3/3A 13/	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
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 13/ S-4	A-8B (MIL-309 or ER-309L or MIL-310 types only)	2 and 4
3	S-8	S-3/3A 13/	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

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Copper-nickel and nickel base alloys/shielded metal-arc 15/				
1	S-34	S-34	A-34A	1 through 6
2	S-34	S-43	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	A-43A or A-42A	5 and 6
6 15/	S-43	S-43	A-43A	6
Copper-nickel and nickel base alloys/gas metal arc, gas tungsten and plasma-arc 15/				
1	S-34	S-34	A-34B	1 through 6
2	S-34	S-43	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	A-43B or A-42B	5 and 6
6	S-43	S-43	A-43B	6
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 9/	1 and 4
2	S-34 S-42 S-43	S-5 13/ S-4	A-42A or A-43A 9/	2 and 4
3	S-34 S-42 S-43	S-3 S-3A 13/	A-42A or A-43A 9/	3 and 4
4	S-34 S-42 S-43	S-2 S-1	A-42A or A-43A 9/	4 and 1
Copper-nickel and nickel base alloys to ferritic materials/gas tungsten-arc, gas metal-arc, plasma-arc				
1	S-34 S-42 S-43	S-11B S-11A S-11D S-11C	A-42B or A-43B 9/	1 and 4

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Copper-nickel and nickel base alloys to ferritic materials/gas tungsten-arc, gas metal-arc, plasma-arc. (continued)				
2	S-34 S-42 S-43	S-5 13/ S-4	A-42B or A-43B 9/	2 and 4
3	S-34 S-42 S-43	S-3 S-3A 13/	A-42B or A-43B 9/	3 and 4
4	S-34 S-42 S-43	S-2 S-1	A-42B or A-43B 9/	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
Brass and bronze alloys/gas metal-arc, gas tungsten-arc and plasma-arc 8/				
1	S-32 S-35 S-36A S-37A S-37B	S-32 S-35 S-36A S-37A S-37B	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

See footnotes at end of table.

TABLE III. Grouping of base/filler materials for welding procedure cross-qualification. 1/ 2/ 7/ - Continued

Category	Base material 3/		Filler material 11/	Qualified for categories 4/
	A	B		
Brass and bronze alloys/gas metal-arc, gas tungsten-arc and plasma-arc 8/ (continued)				
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
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 16/	1 through 3 6/
2	S-26	S-26 S-25 S-22 S-21	A-23B	2 through 3 6/
3	S-21	S-21 S-22 S-25 S-26	A-21B	3 6/
Titanium and titanium alloys/gas metal-arc, gas tungsten-arc or plasma arc				
1	S-53	S-53	A-53B	1 through 5
2	S-53	S-51 S-52	A-51B	2 through 5
3	S-52	S-52	A-51B	3 through 5
4	S-52	S-51	A-51B	4 and 5
5	S-51	S-51	A-51B	5

1/ See 4.7 for limitations on applications for qualification coverage.
 2/ Procedure qualification for any base material-filler material combination within a material group or within the limits specified in this table shall constitute approval for repairing, buildup, or overlay other than cladding for corrosion resistance.

- 3/ Procedure qualification with any material listed in column A 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-11A2 or S-11A1 to S-1 or S-2 (category 13) and also categories 17, 18, 19 and 24.
- 4/ Qualification on one material within an S-group qualifies for welding all materials in that S-group except as follows: 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.
- 5/ The split of S-11A into S-11A-1 (HY-80) and S-11A-2 (HY-100) applies only to this table for purposes of weld procedure cross qualification.
- 6/ For groups S-21, S-22, and S-25, qualification covers only the qualified temper and those of lower strength.
- 7/ Base metal/filler metal combinations not listed in table III require separate procedure qualification.
- 8/ If the S-36A material is to be post-weld temper-annealed, A37B filler materials shall be used.
- 9/ Filler materials A-43A and A-43B apply only for S-43 base materials to materials in column B.
- 10/ The higher number A-group material qualifies the lower number A groups material but not vice-versa.
- 11/ 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.
- 12/ Separate qualification of this category is required when the base material and filler material both have toughness requirements and thickness exceeds 1/2-inch.
- 13/ The higher number S-group material in column B of this category qualifies the lower number S-group but not vice-versa. For this purpose S-3A is higher than S-3.
- 14/ MIL-11018 and MIL-10018 are equivalent for the purpose of this table.
- 15/ S-43, UNS number N06625 type material requires separate qualification.
- 16/ A-23B shall not be used for welding S-25 to S-25 or S-22 materials.
- 17/ For MIL-120 and MIL-140 series filler materials, see table II, footnote 13.

TABLE IV. Welding procedure qualification position limitation.^{1/} ^{4/} ^{5/} ^{6/}

Forms of base material qualified	Positions to be qualified (grooves and fillets)	Positions used during qualification (see figure 1)	
		Using plate (weld-axis)	Using pipe
Plate, castings, and forgings	All positions	Vertical ^{2/}	Horizontal-fixed ^{2/} ^{3/} pipe (5G)
	Flat and vertical	Vertical	Horizontal-fixed pipe
	Flat and horizontal	Horizontal	Vertical-fixed pipe (2G)
	Flat and overhead	Overhead	Horizontal-fixed pipe
	Horizontal (fillets only) and flat	Flat	Horizontal-rolled pipe (1G)
Pipe	All positions	Vertical ^{2/}	Horizontal-fixed pipe ^{3/}
	Horizontal-fixed pipe and horizontal-rolled pipe	Vertical	Horizontal-fixed pipe
	Vertical-fixed pipe and horizontal-rolled pipe	Horizontal	Vertical-fixed pipe
	Horizontal-rolled pipe	Flat	Horizontal-rolled pipe

- ^{1/} Automatic pipe welding qualification shall be performed on pipe or other cylindrically shaped material forms listed in table IV.
- ^{2/} For semi-automatic gas metal-arc welding using the pulsed spray-arc or short circuiting-arc process the horizontal position for plate and the vertical-fixed position for pipe must be run to qualify for all positions. However, only non-destructive testing as specified for level no. II qualification shall be required for the horizontal plate and the vertical-fixed position pipe.
- ^{3/} The 45 degree inclined position (6G) may be substituted for horizontal fixed pipe position.
- ^{4/} When welding in the vertical plane, in either plate or horizontal fixed pipe, welding shall be in the up direction, (except in automatic pipe welding where direction of rotation, required by the procedure, shall be qualified).
- ^{5/} See table II note 7.
- ^{6/} (a) Except as specified below, the addition of other welding positions than already qualified for weld surfacing for corrosion resistant and hardsurface applications. Qualification in the horizontal, vertical, or overhead position shall qualify also for the flat position. Qualification in the horizontal fixed position, 5G, shall qualify for the flat, vertical, and overhead positions. Qualification in the horizontal, vertical, and overhead positions shall qualify for all positions. Qualification in the inclined fixed position, 6G, shall qualify for all positions.
- (b) For tube-to-tubesheet and internal tube-to-header welding, a change in the position of welding from that used for qualification (see figure 1).
- (c) An activity who does 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 plus or minus 15 degrees is permitted in the inclination of the weld axis and the rotation of the weld face.

TABLE V. Essential elements of a welding procedure.

	Arc-welding <u>1/</u>			Fuel gas welding
	Manual	Semi-automatic	Automatic <u>3/</u> and machine	
<u>Base material 5/ 7/</u> Specification and type or class or chemical analysis, thickness, and condition	X	X	X	X
<u>Filler material</u> Specification, type or chemical analysis, diameter, wire or powder	X	X	X	X
<u>Flux</u> Specification, size, type	-	X	X	X
Base material cleaning	X	X	X	X
<u>Applicable joint designs</u> (reference or sketches)	X	X	X	X
Process <u>8/</u>	X	X	X	X
Machine, model or type	-	X	X	-
<u>Electrical characteristics 6/</u> current, arc voltage range, polarity	X <u>2/</u>	X	X	-
Travel speed	- <u>6/</u>	- <u>6/</u>	X	-
Position (including progression vertical up or down)	X	X	X	X
Torch type	X <u>4/</u>	X	X	X Torch tip size only
<u>Torch shielding gases</u> Type and flow rates	X <u>4/</u>	X	X	-
<u>Purge gases</u> Type and flow rates	X	X	X	-
Postheat treatments	X	X	X	X
Preheat and interpass temperature limits	X	X	X	X
<u>Torch oscillation</u> (amplitude, and frequency and dwell)	-	-	X	-
<u>Torch position</u> (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	-

See footnotes at top of next page.

1/ The following shall also be specified as essential elements:

- (a) Details of current slope, if used.
- (b) For the gas tungsten arc process, detailed description of pulsed welding current, if used, including all pulsed current and voltage parameters which can be varied by adjustment of pulsed power supply controls; manufacturer and model number of pulsed power supply.
- (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.
- (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 (that is, 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 automatic and machine 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, and S-53 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, and S-53 materials, a statement of workmanship standards including welding environment, material (filler wire, tools, etc.) storage and handling, and in-process quality control.
- (j) For cladding procedures involving A-45 filler materials, all parameters corresponding to each of the items of 4.7.9 and 4.8 (p). For manual and semi-automatic welding, deposition technique (stringer or dimensioned weaving) shall also be specified. Any essential element which differs from one layer to another shall be specified on a per layer basis.
- (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 nontransferrable; (4) diameter of arc constricting orifice; (5) type and model of welding equipment; (6) type and size of electrode; (7) for automatic and machine welding, electrode spacing; (8) powder metal size; (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.

3/ For all automatic welding, any machine setting, when used alone to control the process parameters, shall be specified in the procedure. For automatic pipe welding, the setting for each pipe size to be welded in production shall be required.

4/ For plasma-arc process and gas tungsten-arc process.

5/ See base material restriction in table VII, note 2. The welding procedure shall specify this restriction for each specific material affected.

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. 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, and S-53 materials, details of how joints including weld repair excavations are prepared, including 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.

TABLE VI. Welding procedure qualification material thickness limits.
1/, 2/, 4/, 7/, 8/, 9/, 10/, 11/, 12/

Pipe <u>3/</u>	
Test material thickness (T)	Thickness (T) qualified
1/8 inch to and including 3/8 inch	0.058 inch to 2T <u>6/</u>
Over 3/8 inch	1/8 inch to unlimited
Other <u>5/</u>	
Less than 3/4 inch	T or 1/8 inch (whichever is less) to 2T
3/4 inch and greater but less than 3 inches	3/16 inch to 2T
3 inches or greater	3/16 inch to unlimited

- 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-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 note 6. For fillets see note 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: T is the depth of weld deposit; however, there is no lower thickness limit.
- 3/ Not applicable to root layer qualification (see 4.4.1.5) or to autogenous welds (see 4.4.6).
- 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.
 - (c) When weld pass thickness is greater than 1/2 inch.
 - (d) When welding pipe using an automatic process.
 - (e) When the short circuiting mode of gas metal-arc welding is used.
- 5/ Other includes all material other than pipe (such as structural plate, shapes and castings).
- 6/ Thickness qualified may be extended below 0.058 inch by welding a test assembly of the production thickness (less than 0.058 inch). For socket and fillet seal weld qualifications performed on pipe with wall thickness in the range of 0.058 to 3/16 inch the minimum wall thickness qualified shall be 20 percent below the pipe wall thickness welded and maximum thickness shall be 2T.
- 7/ 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 have been made. For multiple processes the qualified thickness of each process shall not be additive in determining the maximum thickness of the production joint

- to be welded. 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 and 4.7 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, the 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.
- 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 sufficient thickness and size to permit preparation of impact test specimens (see table VII, note 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 limited to the thickness used during qualification. See also 4.7.5(f).
- 12/ For welds in S-51, S-52, and S-53 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 thickness 2 inches and above requires that the test plate be at least 90.9 percent of the maximum thickness to be welded.

TABLE VII. Welding procedure qualification assembly test requirements.

Material types	S number group	Destructive testing <u>1/</u> <u>2/ 3/ 4/ 5/ 14/ 15/</u>			Nondestructive testing <u>15/ 16/ 19/ 21/</u>			
		Tensile <u>6/</u>	Guided bends <u>7/</u>	Macro-etch <u>8/ 13/</u>	Radio-graphic	Liquid penetrant	Magnetic particle	Ultra-sonic <u>20/</u>
Carbon-steel	S-1	2	3	-	X	-	X	X
Quenched and tempered carbon-steel	S-2	2	3	-	X	-	X	X
	S-3/3A	2	3	-	X	-	X	X
	S-4	2	3	-	X	-	X	X
Alloy steel	S-5	2	3	-	X	-	X	X
High alloy steels	S-6	2	3	-	X	-	X	X
	S-6A	2	2	-	X	-	X	X
	S-7	2	3	-	X	-	X	X
	S-8	2	3	-	X	X	-	-
	S-10H <u>23/</u>	2	3	-	X	X	-	X
Quenched and tempered alloy steel	S-11A	2	3	-	X	-	X	X
	S-11B	2	3 <u>9/</u>	-	X	-	X	X
Age hardening alloy steels	S-11C	2	2	-	X	-	X	X
Aluminum and aluminum base alloys	S-21	2	3	-	X	X	-	-
	S-22	2	3	-	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	-	-
Titanium and titanium alloys	S-51	2	3 <u>17/</u>	2	X	X	-	-
	S-52	2	3 <u>17/</u>	2	X	X	-	-
	S-53	2	3 <u>17/</u>	2	X	X	-	-
Dissimilar metals	-	2	1 <u>10/</u>	2	X	X	-	-
Weld/cladding, corrosion-resisting <u>11/ 22/</u>	-	-	2	2	-	X	-	-

See footnotes at end of table.

TABLE VII. Welding procedure qualification assembly test requirements. - Continued

Material types	S number group	Destructive testing <u>1/</u> <u>2/ 3/ 4/ 5/ 14/ 15/</u>			Nondestructive testing <u>15/ 16/ 19/ 21/</u>			
		Tensile <u>6/</u>	Guided bends <u>7/</u>	Macro-etch <u>8/ 13/</u>	Radio-graphic	Liquid penetrant	Magnetic particle	Ultra-sonic <u>20/</u>
Hardfacing, wear resisting <u>12/</u>	-	-	-	3	-	X	-	-
Manual tube-to-header welds <u>18/</u>	-	-	-	<u>18/</u>	-	X	X	-

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 impact tests shall be performed under any of the following conditions:

- (a) For production welding of 1/2 inch and over in material 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 1/2-inch material 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 thickness.

3/ See 4.4.7.1 and 4.4.9.1.

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.

5/ When Charpy impact tests are required by note 2 above, sets of five impact specimens shall be prepared from the weld metal, sets of three impact specimens shall be prepared from the heat affected zone (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 only) materials. 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. When double beveled butt weld test assemblies are employed, weld metal impact specimens shall be removed from each side of the joint (that is, 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.
1/2 to 2 inch incl.	1	1	1	5	3	3
Over 2 to 4 inch 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 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, and S-53 base materials welded to themselves or to each other which are 3/4 inch and over in thickness, tensile tests shall include two transverse weld tensiles and two all weld 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 3/4 inch, two root bends and two face bends may be tested in lieu of side bends. If the procedure is for full penetration pipe butt joints welded from one side without backing rings or preplaced inserts, root bends with the root surface in the as welded condition (that is, no machining, grinding, and so forth) are required when the root is welded without the addition of filler metal or without internal inert gas purge.
- 8/ Acceptance standards shall be as specified in 4.5.2.6.
- 9/ Use a 3T bend for S-11B base material.
- 10/ See 4.4.3.
- 11/ Liquid penetrant inspection required (see 4.4.2.1) prior to destructive testing. Chemical testing for corrosion-resistance shall be performed only when specified in the applicable fabrication document.
- 12/ Hardness testing is required for hardfacing for wear resistance as specified in 4.4.2.2.
- 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 radiographic, tensile and bend tests. If the procedure is for full penetration pipe butt joints welded from one side without backing rings or preplaced inserts, root bends with the root surface in the as welded condition (that is, no machining, grinding, and so forth) 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 E 604 may be substituted for Charpy V-notch when the material specification (base or filler) or fabrication document provides for dynamic tear testing.
- 15/ Only visual and liquid penetrant 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/ Visual inspection of all test assemblies shall be performed prior to other nondestructive testing.
- 17/ For S-51 and S-52 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 4.4.9.
- 19/ Inspect 100 percent of weld when radiographic or ultrasonic inspection is specified.
- 20/ Ultrasonic inspection shall be performed on material 1 inch thick and greater in accordance with 4.5.
- 21/ 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 MIL-STD-271 for normal UT inspection and for S-8 materials, six transverse macro-specimens shall be substituted for UT inspection.

- 22/ When weld cladding for corrosion resistance with A-45 weld filler material, quantitative chemical testing shall be required for the following elements with specified acceptance values for procedure qualification. Removal of material for testing shall be as specified in figure 4a.

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 verification to be supplied with weld procedure qualification.
- ** Weld procedures developed for clad welding Nickel-Molybdenum-Chromium Alloy to Ferrous base materials (such as HY-100) which exceed the dilution requirements for Ni, Mo or Cr may be approved by NAVSEA or its authorized government agent on a case basis.

Chemical analysis shall be made by using the wet chemical method per ASTM E354, or spectrochemical method per ASTM E172. In case of a dispute, the wet chemical analysis method shall be the referee method.

- 23/ 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 practical 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 heat affected zone, 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.

TABLE VIII. Grouping of filler metals and process combinations for welder or welding operator (performance qualification). 1/

Category <u>2/</u>	Filler metal group <u>5/</u>	Category for which tests qualify welder <u>3/</u>	
		Shielded metal arc	
1	A-5A	1 through 3	
2	A-2A, 3A, 4A, 6A, 7A1, 7A2	2 and 3	
3	A-1A	3	
4	A-8A, A-43A, A-9A	4	
5	A-34A, 41A, 42A, 43A, 45A	5	
Category <u>2/</u>	Filler metal group <u>5/</u>	Gas metal-arc <u>6/</u>	Gas tungsten-arc, plasma-arc <u>6/</u>
1	A-5B	1 through 2	1 through 2
2	A-1B, 2B, 3B, 6B, 7B	2	2
3	A-8B, A-43B, A-7B-2, A-9B	3	3
4	A-34B, 41B, 42B, 43B, 45B	4	4
5	A-31B, 32B, 33B, 35B, 36B, 37B	5	5
6 <u>4/</u>	A-21B, 22B, 23B, 24B	6	6
7	A-51B, A-53B	7	7
Category <u>2/</u>	Filler metal group <u>5/</u>	Submerged-arc <u>6/</u>	
1	A-5C	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	
Category <u>2/</u>	Filler metal group <u>5/</u>	Flux-cored-arc <u>6/</u>	
1	A-5D	1 and 2	
2	A-2D	1 and 2	

- 1/ For hard surfacing, a welder qualified on test number 9 with any hard surfacing 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 VIII 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 II.
- 6/ For automatic machine welding a welding operator qualified to weld with one qualified procedure is also qualified to weld in accordance with other qualified procedures, using the same welding process and equipment.

TABLE IX. Performance qualification - position limitations. 1/ 5/ 8/ 9/

Qualification test		Position and type weld qualified <u>1/</u> <u>4/</u> <u>6/</u> <u>7/</u> <u>8/</u>		
		Groove		Fillet
Weld	Position	Plate and pipe over 24 inches OD	Pipe	Plate and pipe
Plate - groove <u>3/</u>	1G	F	F <u>2/</u>	F, H <u>2/</u>
	2G	F, H	F <u>2/</u>	F, H <u>2/</u>
	3G	F, V	F <u>2/</u>	F, H, V <u>2/</u>
	4G	F, O	F <u>2/</u>	F, H, O <u>2/</u>
	3G and 4G 2G, 3G, and 4G	F, V, O All	F <u>2/</u> F <u>2/</u>	All <u>2/</u> All <u>2/</u>
Plate - fillet	1F	...	...	F <u>2/</u>
	2F	...	...	F, H <u>2/</u>
	3F	...	...	F, H, V <u>2/</u>
	4F	...	...	F, H, O <u>2/</u>
	3F and 4F	...	...	All <u>2/</u>
Pipe - groove <u>3/</u>	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	1F	...	...	F
	2F	...	...	F, H
	2FR	...	...	F, H
	4F	...	...	F, H, O
	5F	...	...	F, V
	5F, 4F	...	...	All

- 1/ Test positions for qualification welding are as shown on figure 1. The following are weld positions qualified, and are as defined in AWS 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/ Including weld 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 on figure 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 plus 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 a separate qualification test (see 4.7.6 and 4.8) except that automatic or machine, 5G position pipe qualification employing 360 degree uninterrupted progression qualifies such progression for the passes involved.

TABLE X. 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 <u>1/</u>	Test no. 1 or 2 <u>9/</u> (figure 12 or 14)
Pipe <u>2/ 3/ 4/ 5/ 6/ 13/ 14/</u>	0.058 inch to 2T <u>1/</u> 0.058 inch and greater	Test no. 3 or 5 <u>9/</u> (figure 15 or 22) Test no. 4 or 6 <u>9/</u> (figure 15 or 22)
Pipe or plate <u>12/</u>	All thicknesses	Test no. 8 <u>8/</u> (figure 16 for tack and fillet welds)
Pipe or plate	All thicknesses	Test no. 9 (figure 17 for weld surfacing only)
Pipe or plate <u>10/</u>	See footnote <u>11/</u>	Test no. 10 (figure 26)

- 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 numbers 3, 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 (1) the root, or root plus one layer in preplaced filler metal insert root butt joints, (2) full penetration joints welded from one side with no backing ring or preplaced insert, and (3) joints requiring separate qualifications by 5.3.5 and 5.3.6.
- 3/ A welder or welding operator may perform only part of the preplace filler metal insert or other root performance qualification test, that is, just the root, root plus one layer or subsequent layers, but he shall be qualified only for that part of the insert joint he 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 (1) the insert root or insert root plus one layer of preplaced filler metal insert root butt joints, (2) all full penetration joints welded from one side with no backing ring or preplaced insert and (3) joints requiring separate qualification by 5.3.5 and 5.3.6.
- 5/ Qualification test numbers 5 or 6, that is, 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 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 (see table IX note 2 for structural pipe size limit).
- 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.
- 11/ Qualification with joint-A, figure 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 qualified for tack welding socket welds on pipe with nominal thickness 3/16-inch and above. For required test assemblies, see 5.3.5 for tube-to-tubesheet welds, seal welds, and socket welds and 5.3.6 for internal tube-to-header welds for boiler components. The minimum thickness qualified shall be 20 percent below the nominal pipe wall thickness welded 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; for thickness 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.
- 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 automatic and machine welding qualification in either thickness range qualifies for thicknesses 0.058 inch and greater.

TABLE XI. Performance qualification test evaluation requirements.

Test assembly	Evaluation requirements <u>1/</u> <u>2/</u> <u>3/</u> <u>4/</u> <u>5/</u> <u>6/</u>
Test no. 1 or 2A or 2B (figures 12 and 14)	Radiography or bend tests <u>9/</u>
Test no. 3 or 3B (figure 15 or 13)	Radiography or bend tests <u>7/</u> <u>9/</u>
Test no. 4 (figure 15)	Radiography or bend tests <u>7/</u> <u>9/</u>
Test no. 5 (figure 22)	Radiography <u>7/</u> <u>9/</u>
Test no. 6 (figure 22)	Radiography <u>7/</u> <u>9/</u>
Test no. 8 (figure 16)	Break test
Test no. 10 (figure 26)	Radiography or bend tests <u>7/</u> <u>9/</u>
Automatic/machine pipe assembly	(a) Butt: radiography <u>7/</u> <u>9/</u> (b) Fillets: PT and two macro-etch specimens
Automatic/machine plate assembly	Radiography <u>9/</u>
Manual tube-to-header weld <u>8/</u> (figure 25)	Dye penetrant or magnetic particle and macro-etch examinations
Weld surfacing test no. 9 (figure 17)	Macro-etch examination and dye penetrant
Special weld	As proposed in procedure qualification submittal <u>9/</u>
Pipe socket welds tube-to-tubesheet welds, seal welds	See 5.3.5

- 1/ Visual evaluation shall be made on each test assembly. For titanium and titanium alloy welds see 5.4.1.1.
- 2/ Ultrasonic inspection, when performed and evaluated in accordance with MIL-STD-2035 for welds in plate and MIL-STD-271 for welds in pipe, may be substituted for radiographic inspection. Class I acceptance standards from MIL-STD-2035 shall be used.
- 3/ See 5.2.5.
- 4/ Radiography of pipe shall be 360 degrees. Radiography of plates shall be the entire length, except that 1 inch on each end of the weld will not be evaluated. Acceptance criteria shall be in accordance with MIL-STD-2035, class 1.
- 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 MIL-STD-271 for normal UT inspection and for S-8 materials, six transverse macro-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 radiography or bend tests. When joint is welded without addition of filler metal or without internal purge, root bends as described in note 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, and so forth) 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 and S-53 materials:

- a) Bend tests shall be used in lieu of radiography except that both bend tests and radiography are required for test no. 5 and 6 and for joints welded from one side with no backing or consumable insert.
- b) Two macroetch specimens separated by 90 degrees for pipe or 2 inches for blade are required for all joint types.

TABLE XII. Material combinations and brazing alloy requirements. 4/

Material (P-no.)	Material (P-no.)					
	P-101 <u>2/</u>	P-102 <u>3/</u>	P-107 <u>2/</u>	P-108 <u>1/</u>	P-110 <u>2/</u>	P-111 <u>3/</u>
P-101 <u>2/</u>	F-101	F-102	F-101	F-101	F-101	F-101
P-102 <u>3/</u>	F-102	F-102	F-102	F-102	F-102	F-102
P-107 <u>2/</u>	F-101	F-102	F-101 or F-103	F-101 or F-103	F-101	F-101
P-108 <u>1/</u>	F-101	F-102	F-101 or F-103	F-101 or F-103	F-101	F-101
P-110 <u>2/</u>	F-101	F-102	F-101	F-101	F-101	F-101
P-111 <u>3/</u>	F-101	F-102	F-101	F-101	F-101	F-101

- 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 equivalent).
- 2/ Flux shall conform to type A or B or equivalent of O-F-499.
- 3/ Grade V alloy shall be used for any brazed joint where one or both of the metals joined is stainless steel.
- 4/ F-103 brazing alloys shall not be used on ferrous alloys, nickel base alloys or stainless steel.

TABLE XIII. 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 0.90 percent	
	MIL-S-24093 MIL-P-24691/1 MIL-S-22698 WW-P-404	Carbon steel Carbon steel Carbon steel Carbon steel
P-102	Ferrous alloys with chromium content 0.90 percent or greater	
	ASTM A240 MIL-P-24691/3 MIL-S-23195 MIL-T-23226 QQ-S-763 QQ-S-766	Type 304, 316, 321, and 347 Type 304, 316, 321 and 347 Type 304 and 347 Type 304 and 347 Class 304, 316, 321 and 347 Class 304, 316, 321 and 347
P-107	Copper alloys with aluminum content less than 0.50 percent	
	ASTM B16 ASTM B21 ASTM B36 ASTM B43 ASTM B88 ASTM B121 ASTM B124 ASTM B138 ASTM B139 ASTM B283 MIL-T-15005 MIL-C-15726 MIL-T-16420 MIL-T-20168 MIL-T-20219 MIL-T-24107 QQ-B-626 QQ-B-637 QQ-B-639 QQ-B-728 (class A) QQ-B-750 (comp. A and D) MIL-T-24107 WW-T-799 QQ-C-390 (alloys 903 and 922)	Brass, C36000 Naval brass, C46200, C46400, C48200, and C48500 Brass, C23000, C24000, C26000, C26800, C27200, and C28000 Red brass Copper Leaded brass, C35300 Naval brass, C46400, C48200, and C48500 Manganese bronze, C67500 Phosphor bronze, C51000, and C52400 Naval brass, C46400, C48200, and C48500 Copper nickel Copper nickel Copper nickel Brass Brass Copper Brass Naval brass Naval brass Manganese bronze Phosphor bronze Copper Copper Tin bronze

See footnote at end of table.

TABLE XIII. 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 ASTM B138 ASTM B150 ASTM B169 ASTM B283 QQ-C-390 MIL-B-24480 MIL-B-21230 MIL-C-15345 QQ-C-450 QQ-B-728 (class B) QQ-C-465	Copper aluminum alloy C63000 and C64200 Manganese bronze, C67000 Copper aluminum alloys C60600, C61400, C63000, and C64200 Copper aluminum alloy C61400 Copper aluminum alloys C63000 and C64200 Aluminum bronze Nickel aluminum bronze Nickel aluminum bronze Aluminum bronze Copper aluminum alloy Manganese bronze Copper aluminum alloys 606, 614, 630, and 642
P-110	Nickel alloys with chromium content less than 1 percent	
	A494 MIL-T-1368 MIL-N-17163 MIL-T-23520 MIL-C-24723 QQ-N-281 QQ-N-288 (comps. A and E)	Nickel copper, comp. M-30C Nickel copper Nickel copper Nickel copper Nickel copper, comp. M-30C Nickel copper Nickel copper
P-111	Nickel alloys with chromium content 1 percent or greater	
	MIL-B-15382 MIL-T-23227 MIL-N-23228 MIL-N-23229 MIL-N-24114	Nickel chromium iron Nickel chromium iron Nickel chromium iron Nickel chromium iron Nickel chromium iron

1/ For purposes of qualification, alloys classified under identical ASME P-numbers or alloys having similar chemical compositions may be included in the categories listed above when approved.

TABLE XIV. Groupings of brazing alloys for procedure and performance qualification. 1/

Group	Specification	Alloy classification	AWS classification
F-101	QQ-B-654	Grade IV Grade VII	BAG-1a BAG-1
F-102	QQ-B-654	Grade I Grade II Grade V Grade VIII	BAG-5 BAG-3 BAG-2
F-103	QQ-B-654	Grade III	BCuP-5
	AWS A5.8	FS B CuP-2 FS B CuP-3 FS B CuP-4	BCuP-2 BCuP-3 BCuP-4

1/ If brazing alloys of similar chemistry and mechanical properties not listed under a F-number group are to be used, they may be considered as a group upon approval.

TABLE XV. 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, inches	1/2t to 2t	3/8 to 2t	3/4 to 2t
<u>Type and number of tests required</u>			
Reduced section tension	2	2	2
Peel 1/	2	2	2

1/ Ultrasonic testing may be used in lieu of peel testing.

TABLE XVI. Axial load and torque values for procedure qualification. 1/ 2/

Stud size	Carbon steel					
	UNC, NC class 2A			UNF, NF class 2A		
	Minor dia.	Axial load, lbs	Torque in-lbs	Minor dia.	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.	Axial load, lbs	Torque in-lbs	Minor dia.	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.	Axial load, lbs	Torque in-lbs	Minor dia.	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

TABLE XVI. Axial load and torque values for procedure qualification. 1/ 2/
 - Continued

Stud size	Titanium alloy		
	UNC, NC Class 2A		
	Minor dia.	Axial load, lbs	Torque in-lbs
1/4	0.1876	3317	93
3/8	.2970	8314	370
1/2	.4041	15390	933

1/ Torque calculated using stud minor diameter (root of threads) and 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

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.

$$\text{Axial load (Pounds)} = \frac{D^2 \pi \times TS}{4}$$

$$\text{Torque (inch-pounds)} = \text{Axial load} \times D \times k$$

where:

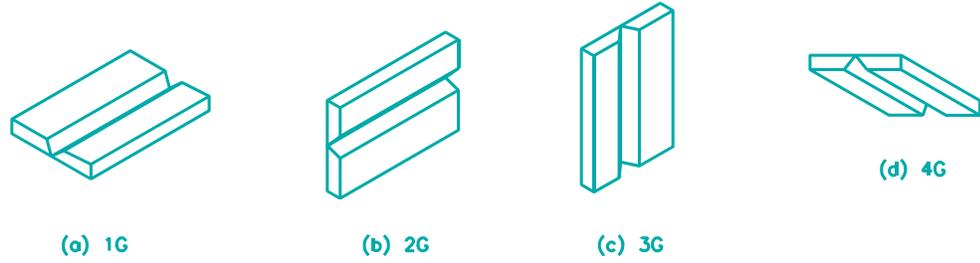
- D = Stud minor diameter (inches)
- TS = Tensile strength as specified in the applicable stud or material specification (pounds per square inch).
- k = Lubrication factor. To ensure the weld is loaded primarily in tension, the threads of the stud shall be lubricated with molybdenum disulfide, graphite base or comparable lubricant in which case k = 0.15.

For information, the following tensile strength values may be used.

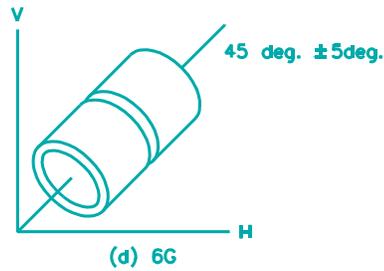
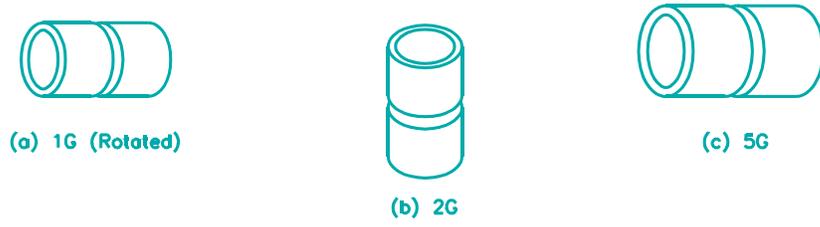
HY 80	95,000 psi
HY 100	115,000 psi

2/ If austenitic corrosion resistant steel studs are welded to carbon steel plate, the torque values for carbon steel studs may be used.

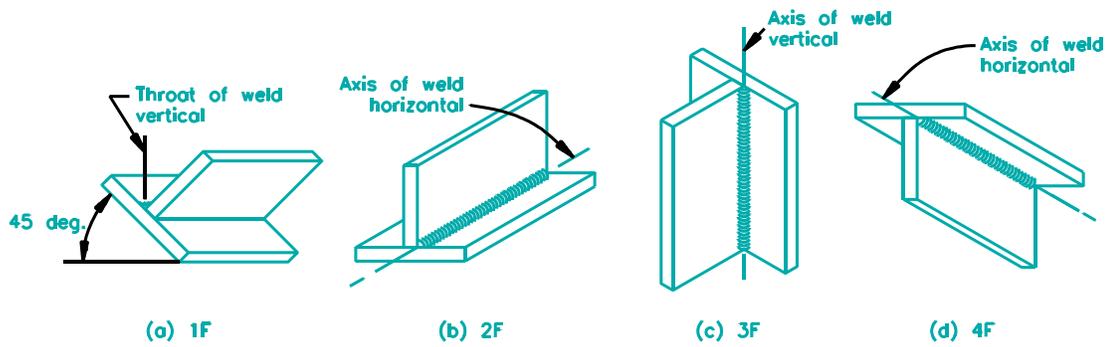
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GROOVE WELDS IN PLATE - TEST POSITIONS



GROOVE WELDS IN PIPE - TEST POSITIONS

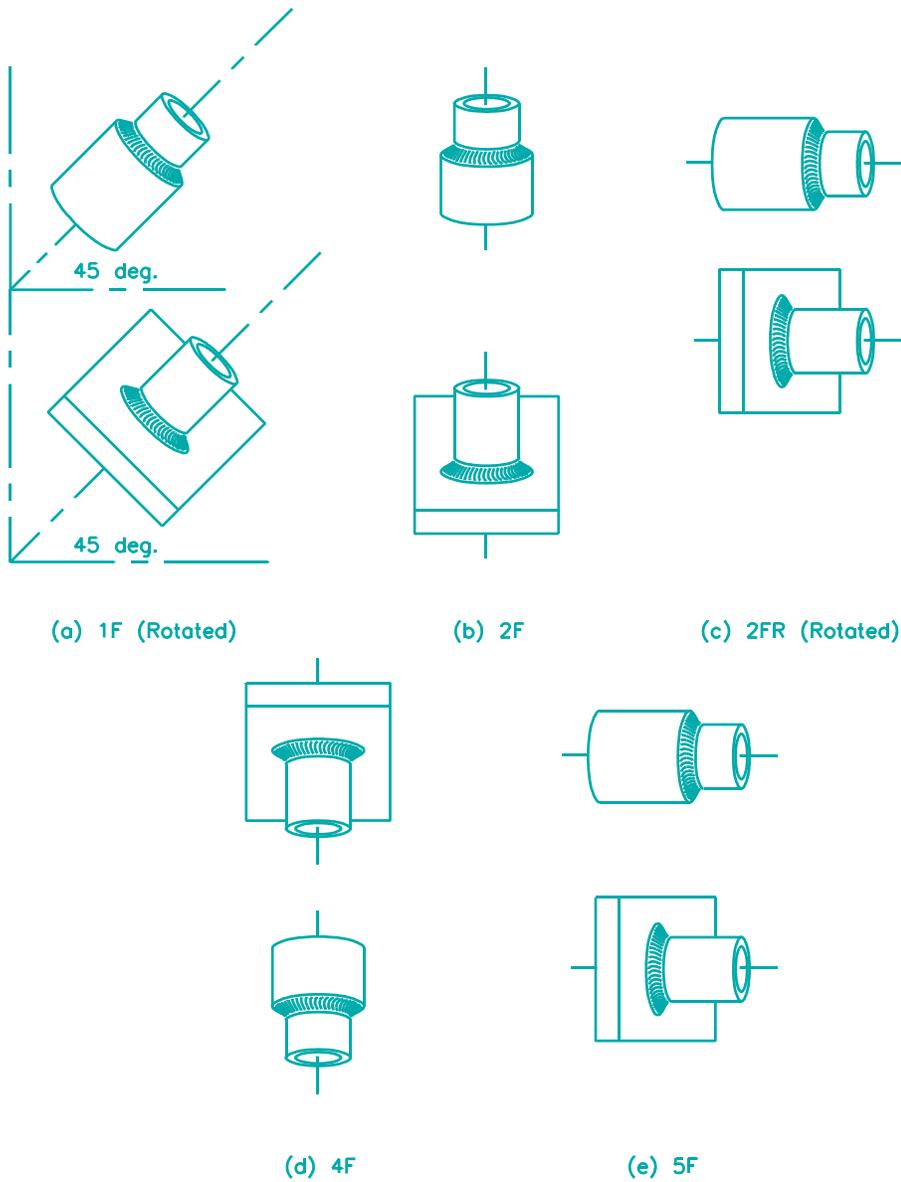


FILLET WELDS IN PLATE-TEST POSITIONS

SH 13203109

FIGURE 1. Positions of welding.

S9074-AQ-GIB-010/248



SH 13203109

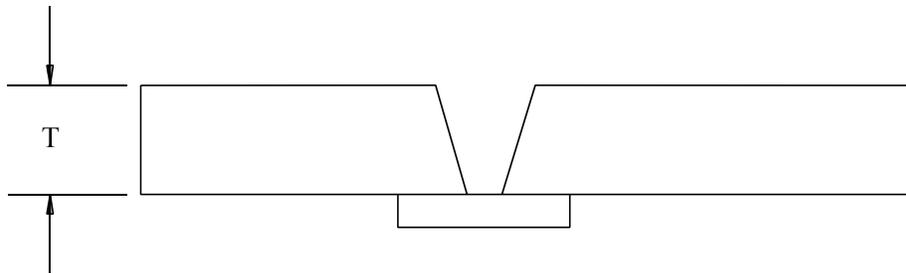
FILLET WELDS IN PIPE – TEST POSITIONS

NOTE: Rotation of the weld face plus or minus 15 degrees about the axis of the weld from the orientation shown does not change the classification of the welding position.

FIGURE 1. Positions of welding. - Continued

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Discard							
Reduced Section tensile							4/
Side bend							
Charpy impact							5/
							All weld tensile 4/
Charpy impact							5/
Side bend							
							All weld tensile 4/
Charpy impact							5/
Side bend							
Reduced Section tensile							4/
Discard							



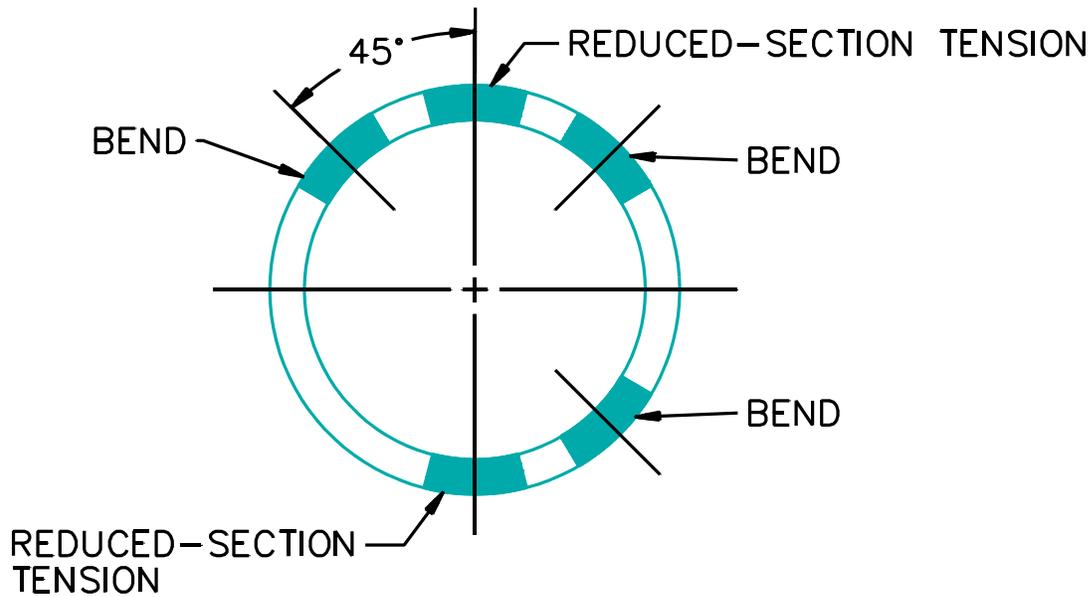
SH 9310

NOTES:

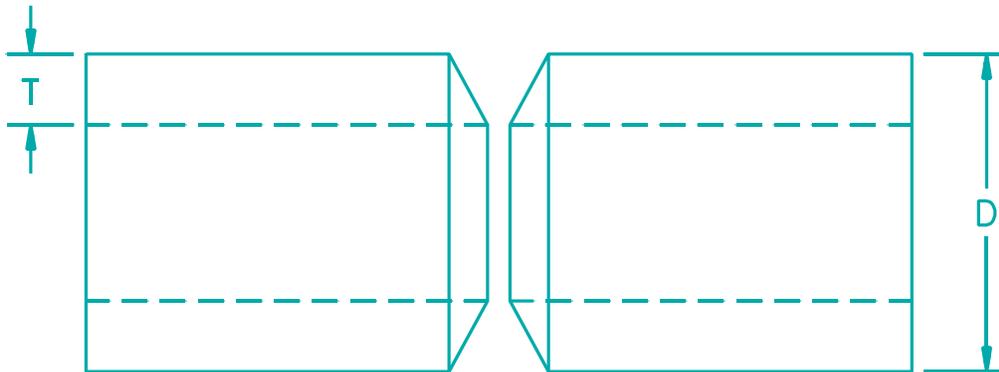
1. Joint design (see 4.4.1.3).
2. Test assembly material (see 4.4.1.1).
3. Test assembly size (see 4.4.1.2).
4. Tensile specimen requirements are specified in footnote 6 of table VII.
5. When HAZ toughness testing is required a straight wall joint design is preferred. Material for specimens shall be removed as indicated. See figure 24 for preparation of HAZ Charpy impact specimens.

FIGURE 2. Typical welding procedure qualification test plate and recommended locations for removal of test specimens.

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**SUGGESTED ORDER OF REMOVAL OF
TRANSVERSE TEST SPECIMENS FROM WELDED PIPE**



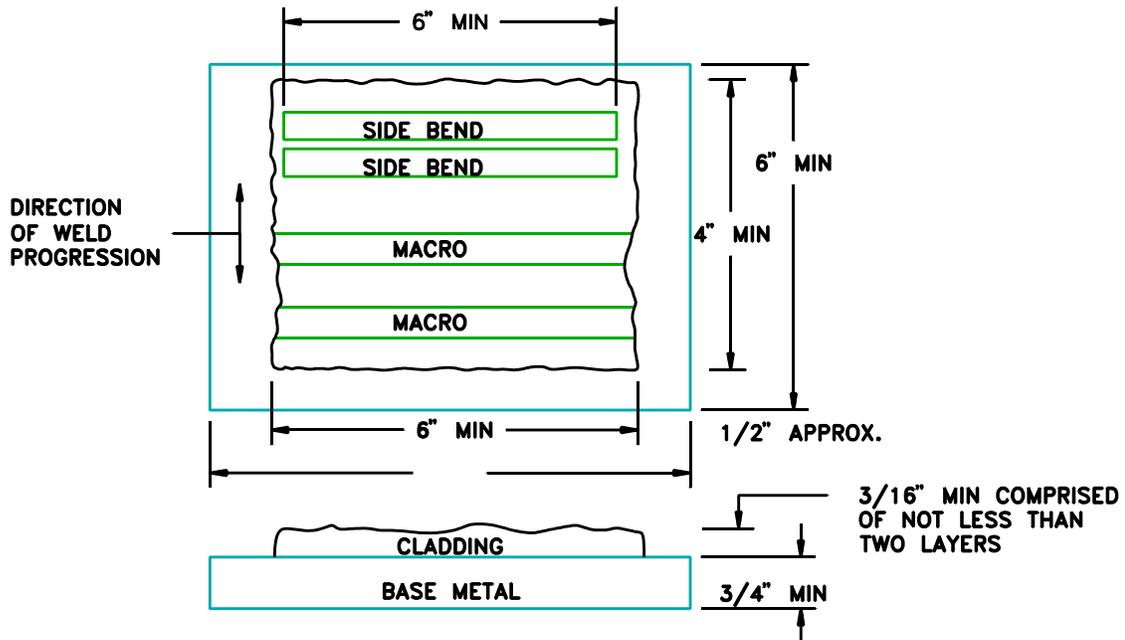
SH 9311

NOTES:

1. Diameter (D) (see 4.4.1.2).
2. Joint design (see 4.4.1.3).
3. Test assembly material (see 4.4.1.1).

FIGURE 3. Typical welding procedure qualification pipe test assembly.

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SH 9312

NOTES:

1. The surface of the weld cladding shall be machined and liquid penetrant inspected as required in 4.4.2.1 prior to removal of macro specimens and side bends.
2. Macro-examination and side bending shall be in accordance with table VII and 4.4.2.1.
3. For manual GTAW, clad weld, area may be reduced to 2 by 3 inches by two layers thick.

FIGURE 4. Test assembly for procedure qualification of cladding for corrosion-resistance except for circumferential welding applications on shafting.

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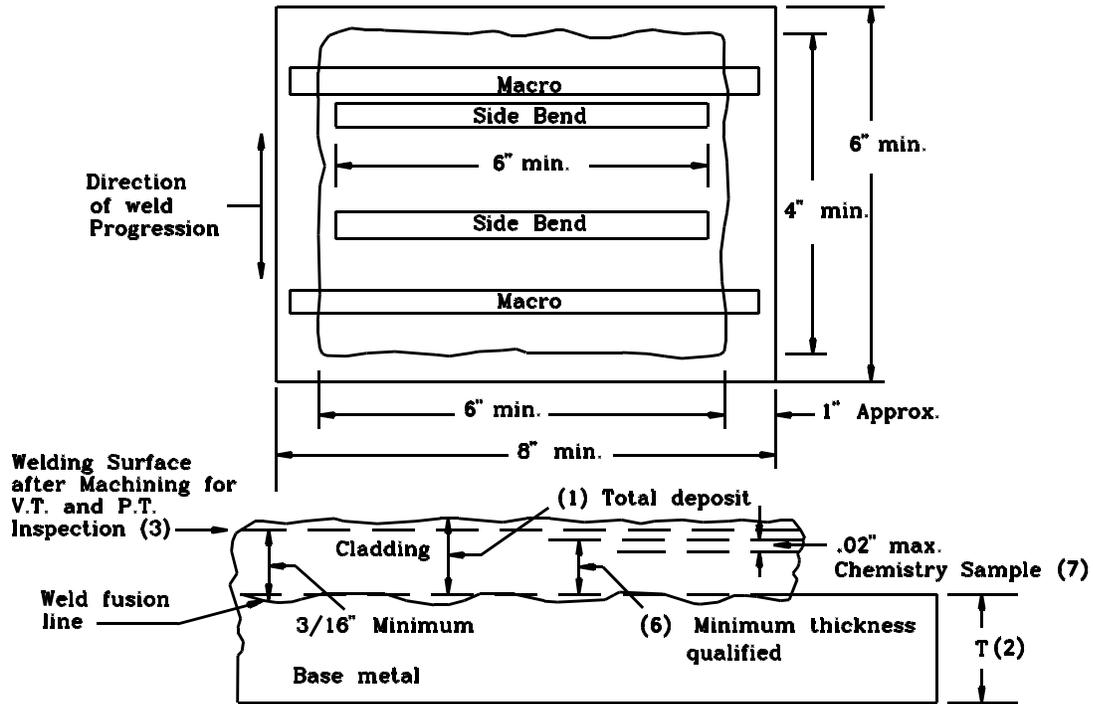


FIGURE 4a. Test assembly for procedure qualification of A-45 cladding for corrosion-resistance

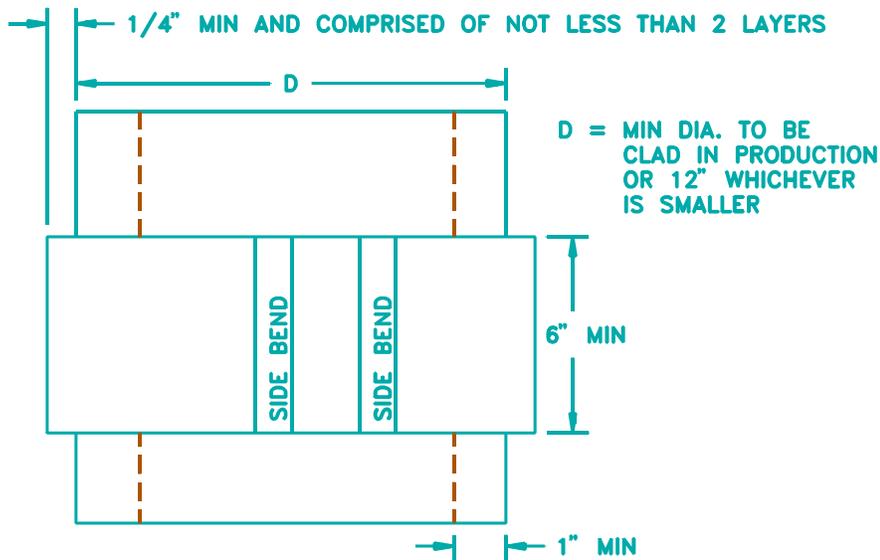
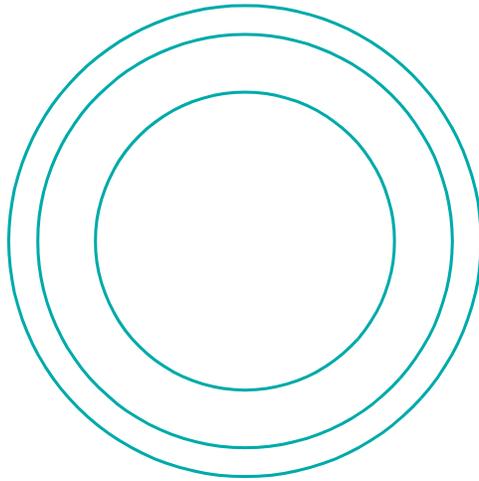
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Notes to figure 4a:

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 required minimum thickness. The number of weld layers at the minimum thickness used for qualification (see note 6) shall equal the minimum number of layers to be used in production.
2. Thickness (T) is the nominal base plate thickness. For production base metal thicknesses:
 - (a) 1 inch and greater: T= any thickness
 - (b) Less than 1 inch: T= the minimum thickness to be welded in production.
3. The surface of the weld cladding shall be machined. The weld cladding shall then be visual (VT) and liquid penetrant (PT) inspected as required in 4.4.2.1 prior to removal of macro specimens and side bends. 3/16 inch minimum cladding thickness is required for destructive tests.
4. Macro-examination and side bending shall be in accordance with table VII and 4.4.2.1. Submit macro-etch specimens (or photo macrographs of these specimens) along with other procedure qualification test data for approval.
5. For manual GTAW, clad weld areas may be reduced to 2" x 3".
6. From a suitable portion of the test assembly, machine the weld clad material down to the minimum clad thickness to be allowed for production and test the resultant cladding surface for material chemistry. Any distortion in the test assembly shall not increase the machined clad thickness for this test. The thickness shown is the minimum production weld cladding 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.
7. The depth from which the sample is taken shall be limited to the top 0.020 inch of weld cladding.

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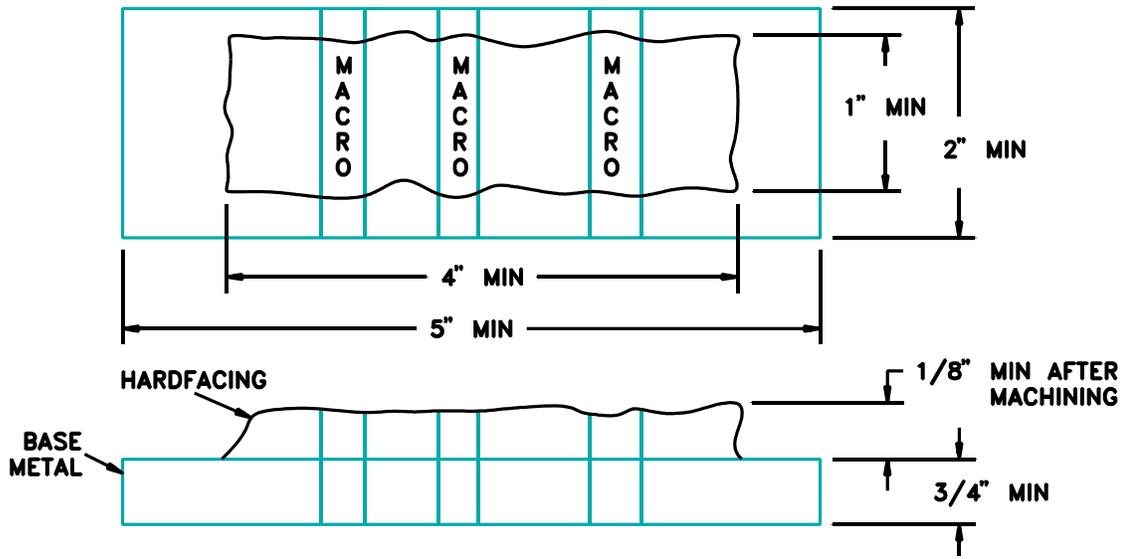
SH 13203113

NOTES:

1. The surface of the cladding shall be machined and liquid-penetrant inspected as required in 4.4.2.1 prior to removal of macro specimens and side bends.
2. Macro-examination and side bending shall be in accordance with table VII and 4.4.2.1.
3. For clad welding with A-45 materials, all requirements of figure 4a shall be met.

FIGURE 5. Test assembly for procedure qualification of cladding for circumferential welding of shafting.

S9074-AQ-GIB-010/248

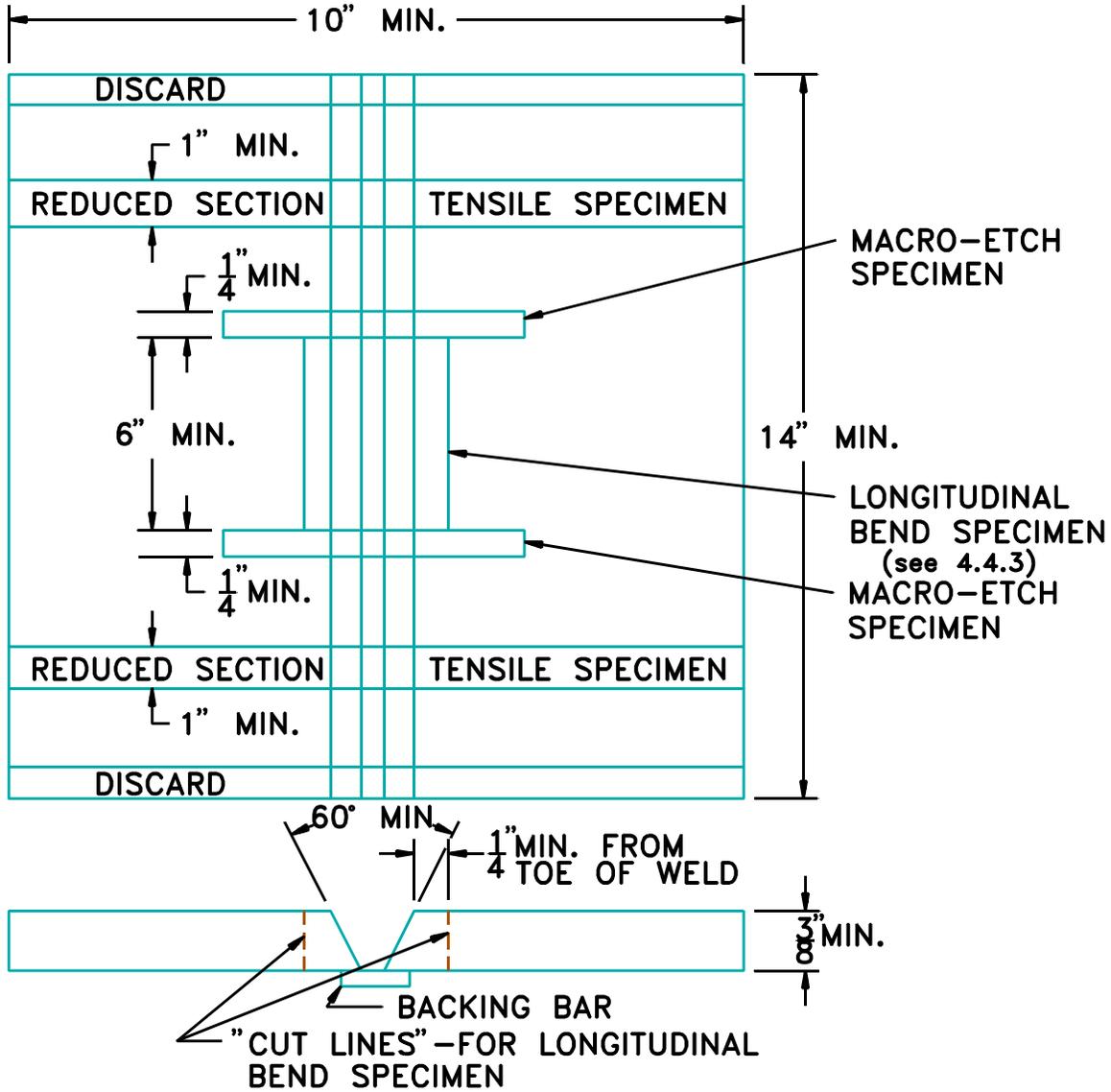


SH 9313

NOTES:

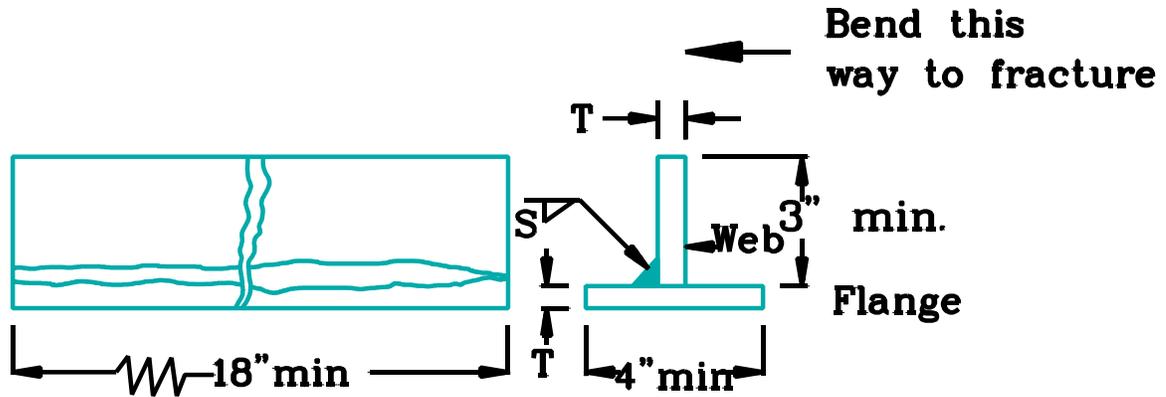
1. Macro-specimen shall be made after other testing is completed.
2. Hardness testing shall require at least 5 random readings (averaged).
3. Testing requirements shall be as specified in table VII and 4.4.2.2.
4. The surface of the hardfacing shall be machined and liquid penetrant inspected as required in 4.4.2.2.

FIGURE 6. Procedure qualification test plate for hardfacing.



SH 9314

FIGURE 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 lesser

S = Maximum size single pass fillet to be used in production

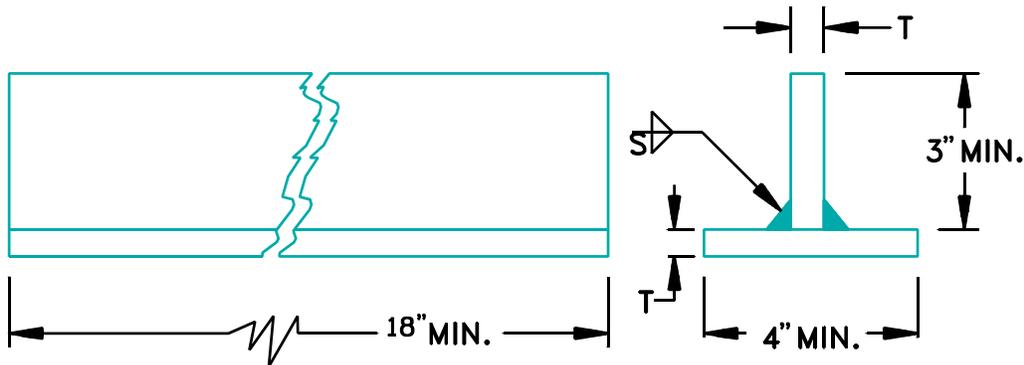
SH 13203116

NOTES:

1. Positions qualified shall be in accordance with table IV.
2. Test assembly may be cut into shorter lengths after welding to facilitate testing.

FIGURE 8. Test assembly for welding bare surfaces.

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T = MAXIMUM THICKNESS TO BE USED IN PRODUCTION, OR 3/8 INCH, WHICHEVER IS THE LESSER.

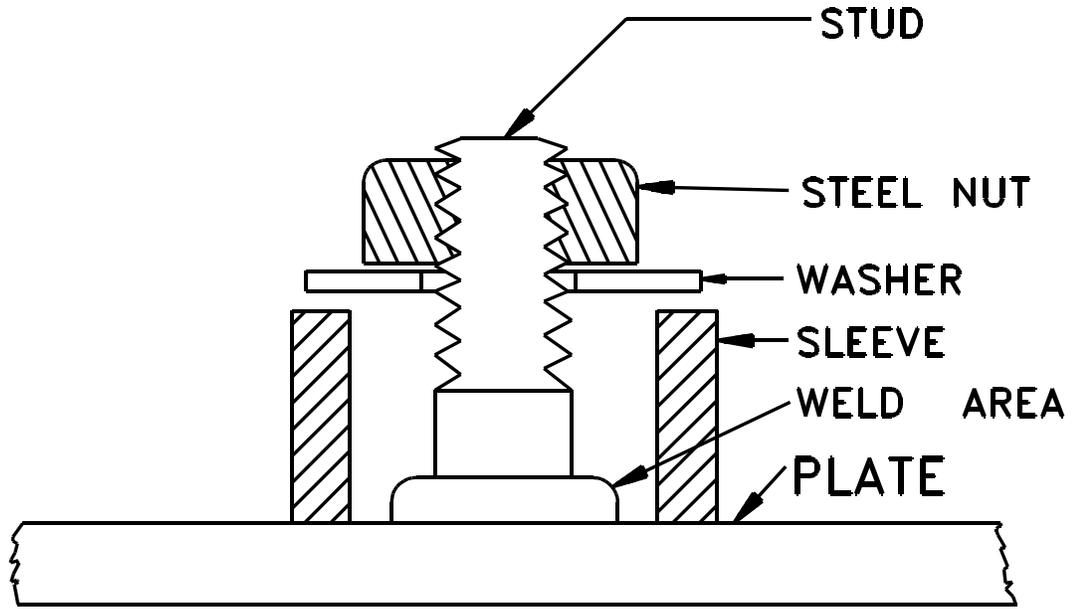
S = MAXIMUM SIZE SINGLE PASS FILLET TO BE USED IN PRODUCTION.

SH 9315

NOTES:

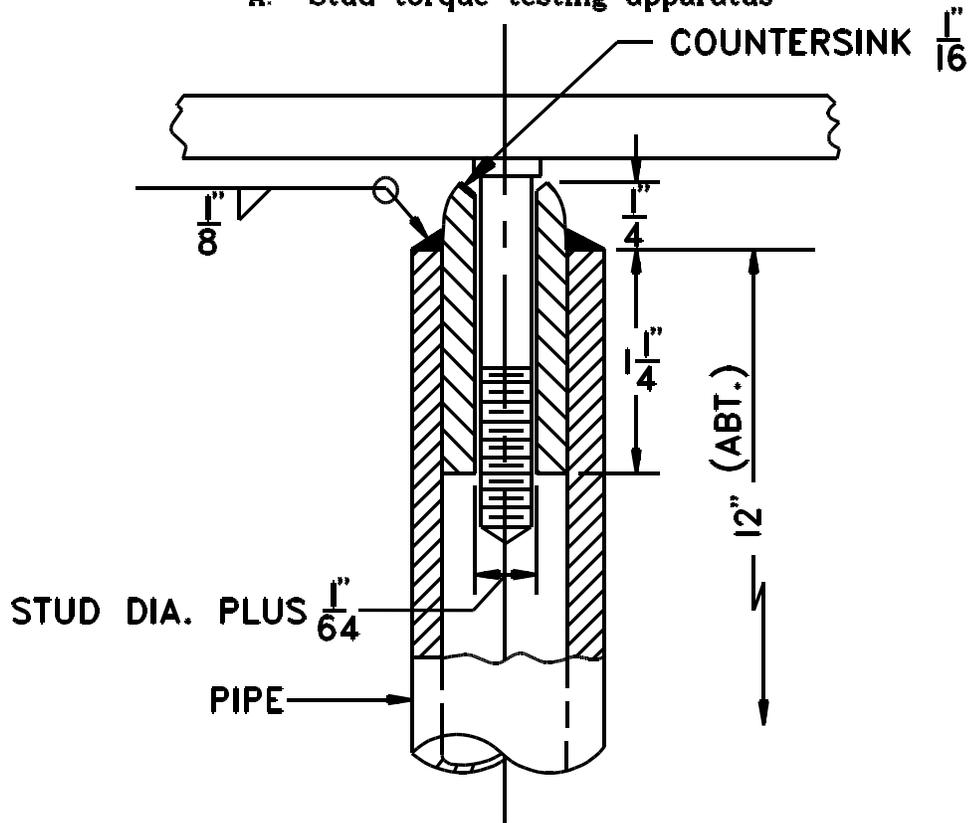
1. Plating shall be either ordinary or higher strength steel as specified in MIL-S-22698 which qualifies the procedure for use on these materials.
2. Plating shall be primer-coated to maximum thickness which will be applied in production.
3. Plate shall be welded in the horizontal position and shall 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 9. Test assembly for welding over primer-coated surfaces.



A. Stud torque testing apparatus

SH 9320



B. Device for bending welded studs.

SH 9320

FIGURE 10. Stud testing apparatus.

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DATE: _____

WELDING PROCEDURE QUALIFICATION DATA

WELDING PROCESS: _____ PLATE PIPE CASTING OTHER _____
 NOTE: SPECIFY OTHER _____
 BASE MAT'L: (1) SPEC. _____ FILLER METAL: (1) GOVT SPEC. _____
 (2) GRADE OR CLASS _____ (2) MIL-TYPE _____
 (3) THICKNESS _____ (3) DIAMETER _____
 (4) GROUP NO. (S-NO.) _____ (MAX SIZES TO BE USED IN PRODUCTION)

JOINT/DESIGN: _____ (REF. NO. OR SKETCH) _____
 METHOD OF EDGE PREPARATION: _____
 WELDING POSITION: _____
 POWER SOURCE (FOR INFO ONLY) _____

SKETCH OF JOINT _____ WELDING CURRENT RANGE: _____ (SEE NOTE 1)
 TRAVEL SPEED RANGE (IPM): _____ FLUX: (1) GOVT SPEC. _____
 TORCH GAS: _____ (2) MIL-TYPE _____
 TORCH TIP SIZE (OXY-FUEL): _____ (3) SIZE _____
 CUP SIZE: _____

SHIELDING GAS: (1) COMPOSITION: _____
 (2) FLOW RATE RANGE _____
 PURGE GAS: (1) COMPOSITION _____
 (2) FLOW RATE RANGE _____

MINIMUM PREHEAT TEMPERATURE: _____ MAXIMUM INTERPASS TEMPERATURE: _____
 POST-WELD HEAT TREATMENT/TEMPERATURE: _____ TIME _____
 WELDER/WELDING OPERATOR: _____

NONDESTRUCTIVE TEST RESULTS _____ *DESTRUCTIVE TEST RESULTS: _____
 APPLICABLE ACCEPTANCE STANDARD _____

	U.T.S.	Y.S	EL.	BEND TEST
M.T. _____				
P.T. _____				
M.T. _____				
U.T. _____				
VISUAL _____				

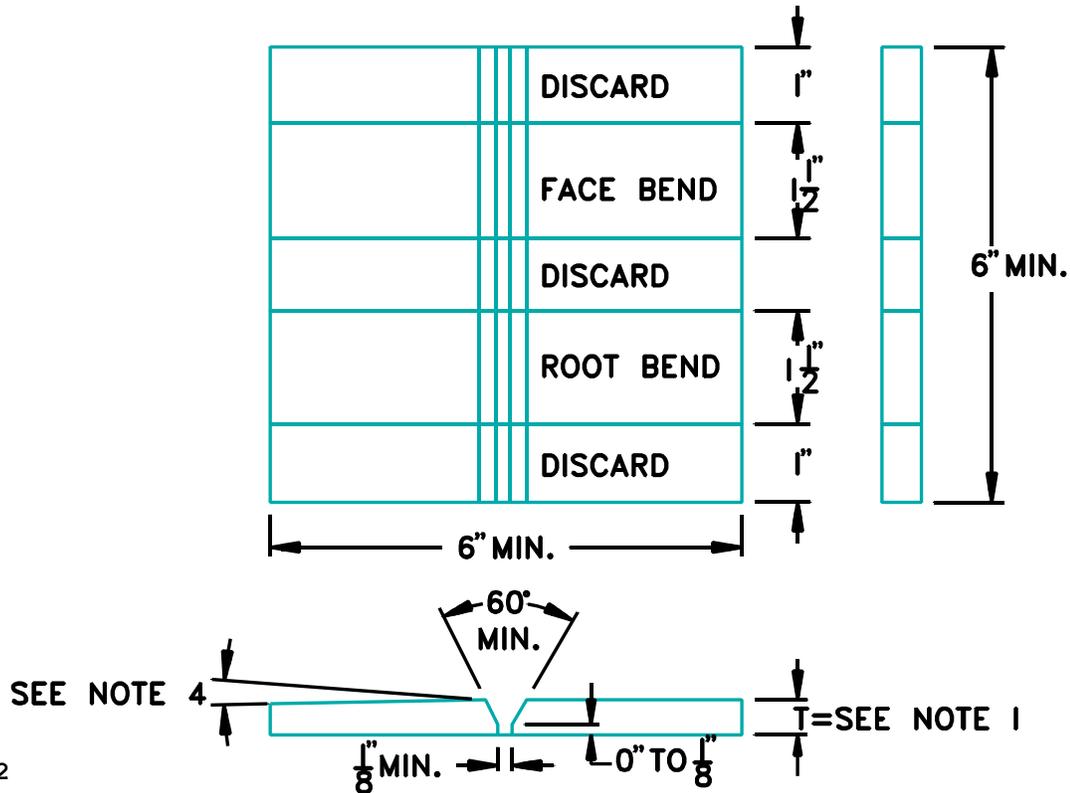
*CHARPY IMPACT TEST SHALL BE PERFORMED ON WELD AND RECORDED WHEN REQUIRED BY TABLE VII, FOOTNOTE 2

TEST APPROVED BY: _____ AT LABORATORY: _____
 DATE OF CERTIFICATION: _____ VERIFIED BY: _____
 (QUALIFYING ACTIVITY)
 APPROVED BY: _____
 (AUTHORIZED REPRESENTATIVE)

- NOTES:
1. In processes where amperage controls, arc voltages will be recorded for information only; and where voltage controls, amperage will be recorded for information only.
 2. Any of the above items not applicable should be so indicated by "N/A".

FIGURE 11. Sample for reporting qualification data.

S9074-AQ-GIB-010/248



SH 9322

NOTES:

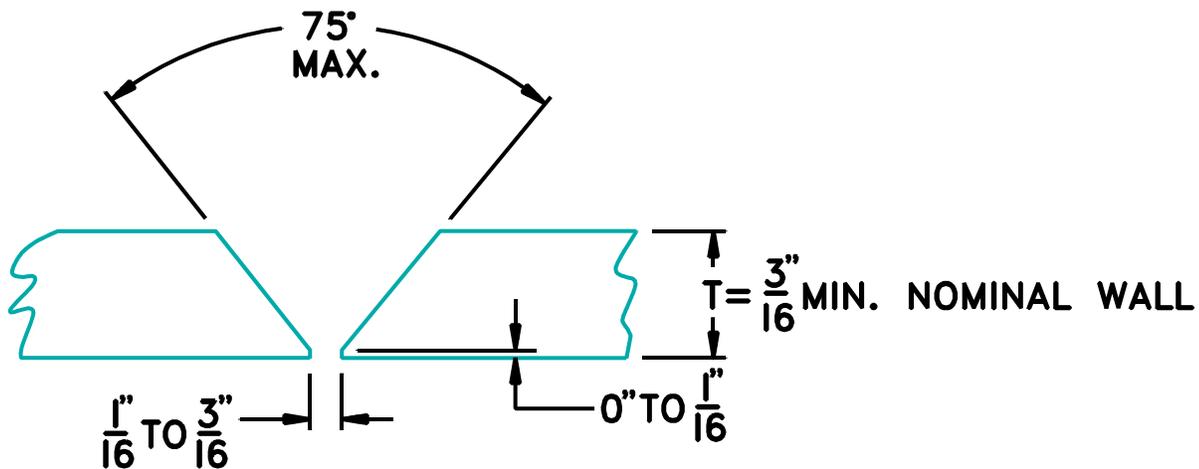
1. Performance qualification assembly thickness and thickness range qualified shall be as follows:

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 shall 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. Plates shall not be more than 5 degrees out of parallel after welding.
5. Reinforcement shall be removed flush prior to destructive testing. Undercutting shall not be removed. No repair welding from the root side shall be permitted.
6. Two guided-bend test specimens shall be removed from the test plate if nondestructive testing is not employed.
7. Bend specimens may be machined or oxygen-cut from the plate.
8. Edges of bend specimens shall be broken to a radius of T/6 maximum.

FIGURE 12. Performance qualification test nos. 2A and 2B for fuel gas welding (plate).

S9074-AQ-GIB-010/248



SH 9323

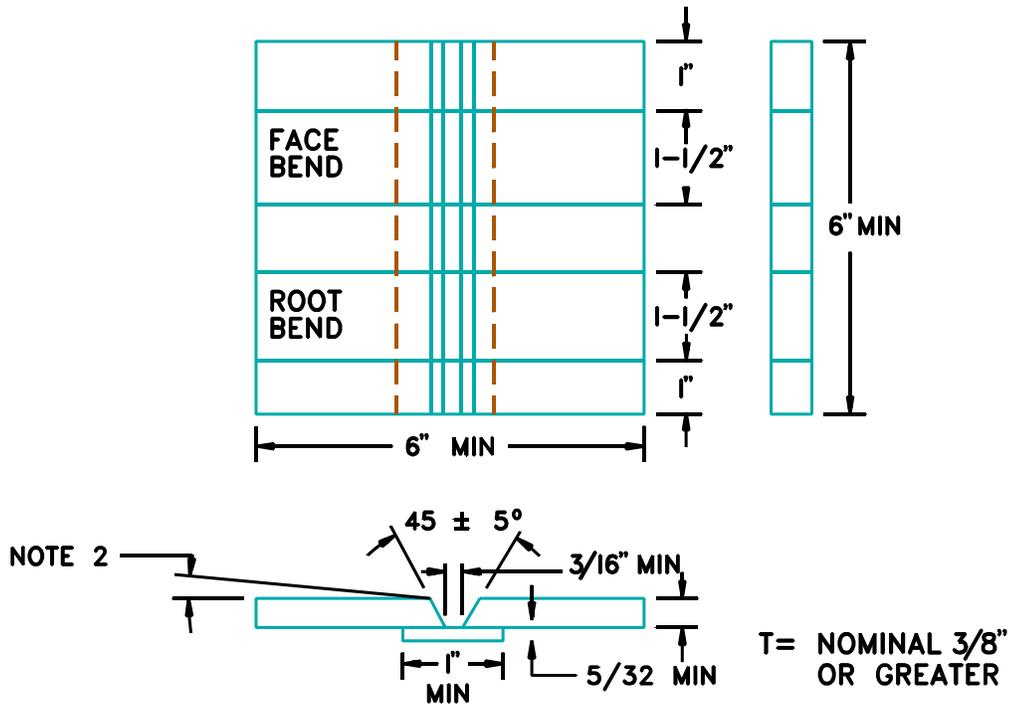
Qualification range limitation: 1/16 inch to 3/16 inch pipe wall

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 21). This limitation shall be entered in the qualification records.
3. The weld shall 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. Weld reinforcement and backing ring, when used, may be removed prior to destructive testing. Undercutting shall not be removed. When nondestructive testing is not employed for qualification evaluation, bend testing shall be conducted as follows:
 - (a) Horizontal-fixed position pipe.
 - (1) Face bends from the 45 degree and 225 degree positions (see figure 21).
 - (2) Root bends from the 135 degree and 315 degree positions (see figure 21).
 - (b) Vertical-fixed position pipe.
 - (1) Face bend from the 225 degree position (see figure 21).
 - (2) Root bend from the 135 degree position (see figure 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, but in considering the 2T maximum of the qualified thickness range, the welder would be qualified to 3/8 inch nominal pipe wall.

FIGURE 13. Performance qualification test no. 3B for fuel gas welding (pipe).

S9074-AQ-GIB-010/248



SH 9324

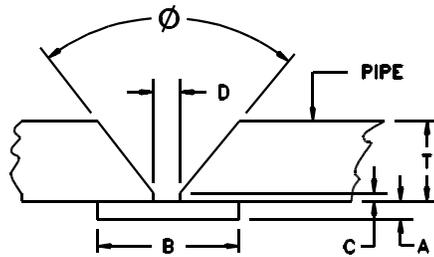
NOTES:

1. Weld shall 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. Weld reinforcement and backing strip may be removed flush prior to destructive testing. Undercutting shall not be removed. No repair welding shall be permitted on the backing strip side.
4. Two guided-bend test specimens shall be removed from the test plate if nondestructive testing 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 X. 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 plus or minus 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 14. Performance qualification test no. 1 for arc welding.

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SH 13203122



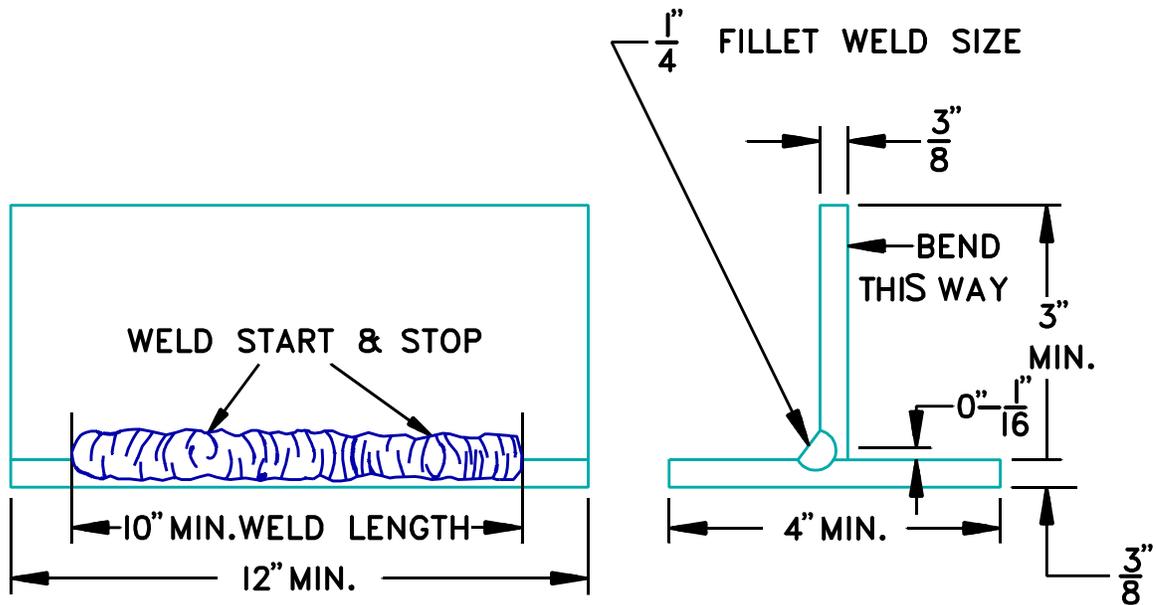
TEST	θ	A	B	C	D	T (min)
3	$75 \pm 5^\circ$	Note 7	Note 7	0 to 1/16	5/16 max	3/16 min (nom wall thickness)
4	$75 \pm 5^\circ$	Note 7	Note 7	0 to 1/16	5/16 max	3/8 min (nom wall thickness)

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 21). This limitation shall be entered in the qualification records.
3. The weld shall 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. Weld reinforcement and backing ring may be removed flush prior to destructive testing. Undercutting shall not be removed. When nondestructive testing is not employed for qualification evaluation, bend testing shall be conducted as follows:
 - (a) Horizontal-fixed position pipe.
 - (1) Face bend from the 45 degree and 225 degree positions (see figure 21).
 - (2) Root bends from the 135 degree and 315 degree positions (see figure 21).
 - (b) Vertical-fixed position pipe.
 - (1) Face bend from the 225 degree position (see figure 21).
 - (2) Root bend from the 135 degree position (see figure 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 15. Performance qualification tests nos. 3 and 4 for arc welding (pipe).

S9074-AQ-GIB-010/248



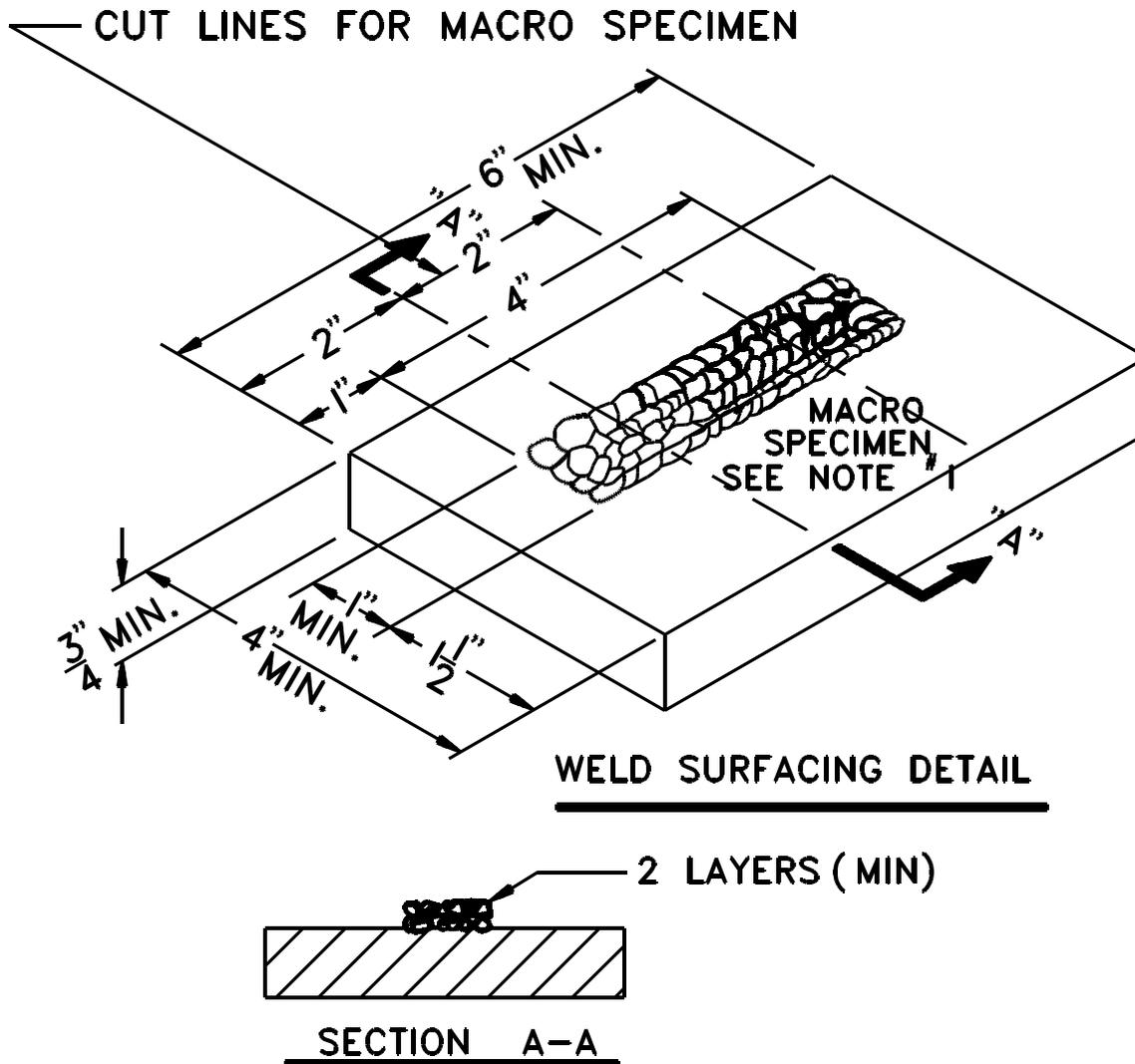
SH 9326

NOTES:

1. Weld shall 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 which is weldable with the electrode to be employed in the test.

FIGURE 16. Performance qualification test no. 8 for tack welders.

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SH 9327

NOTES:

1. Etch both faces of macro specimen.
2. Welds shall be made with the maximum size of filler metal suitable for the position of the test plate.

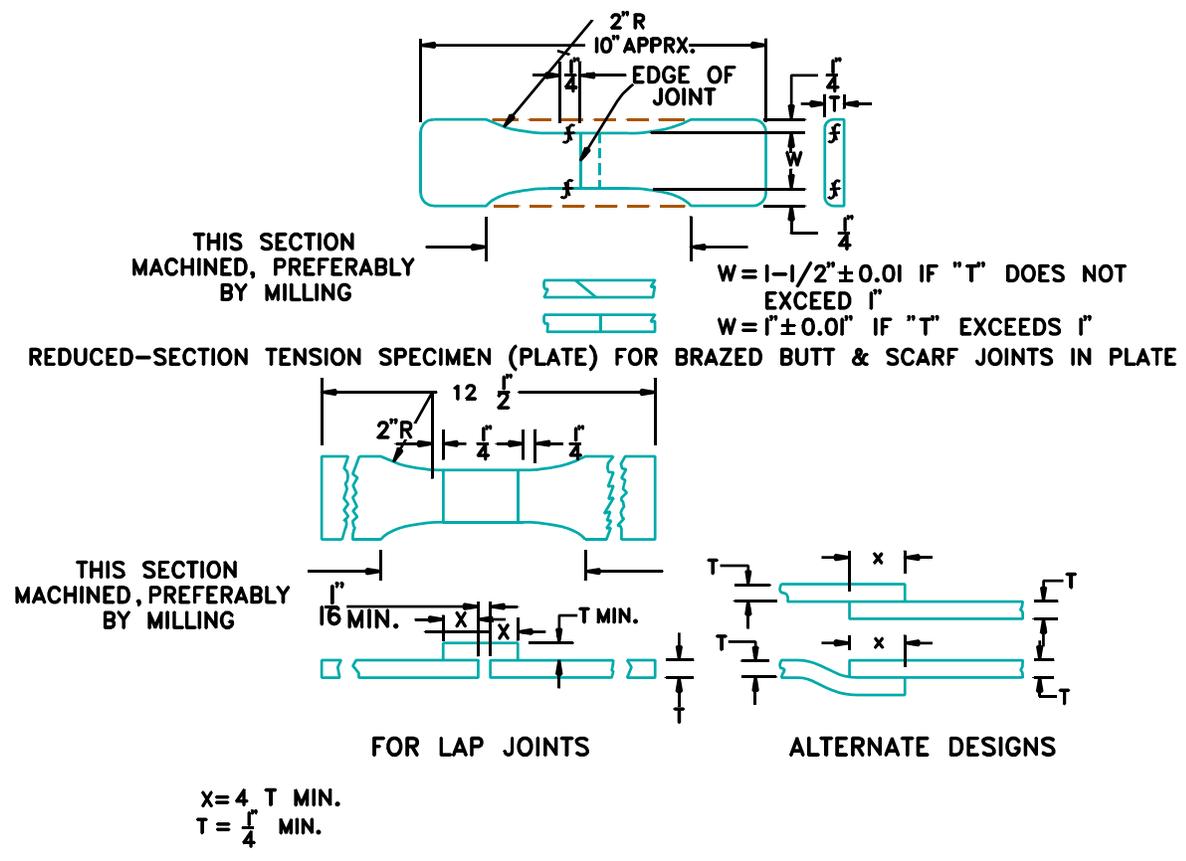
FIGURE 17. Performance qualification test no. 9 for weld surfacing.

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TEST REQUEST		Date of request	
Welder or welding operator (name, clock no. or social security no.)		Vision test date:	
		Corrective aids:	
Performance qualification test no.		Welding process	
Position-plate Vertical-up Overhead Vertical-down Horizontal Flat Position-pipe Vertical-fixed 6G Horizontal-fixed Restricted accessibility Rolled		Base material type	
Filler metal type and size			
Date of test			
PERFORMANCE QUALIFICATION TEST RESULTS			
Qualified		Not Qualified	
(X)	RESULTS - Satisfactory, unsatisfactory or not applicable		
	Visual examination		Dye penetrant test
	Physical		Magnetic-particle test
	Radiographic test		Ultrasonic test
	Macro exam of weld nugget		Other (describe under remarks)
Remarks (explanation of unsatisfactoriness)			
Fabricator certifying signature		Date	

FIGURE 18. Sample performance qualification record.

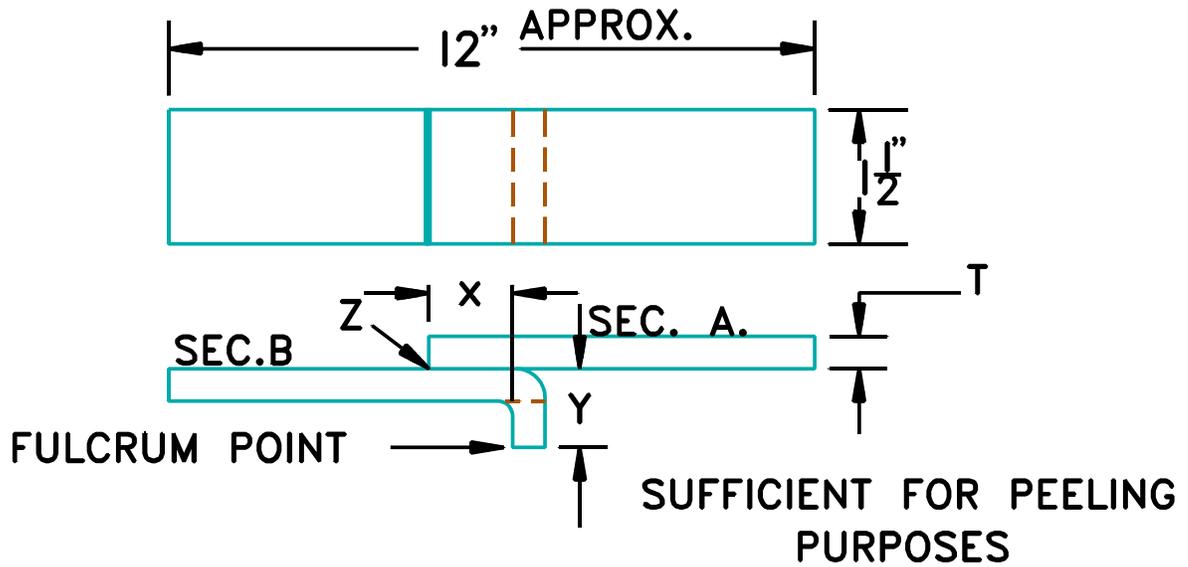
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SH 9329

FIGURE 19. Reduced section tension specimen (plate) for brazed lap-type joints.

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LAP JOINT PEEL SPECIMEN

SH 9330

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 20. Lap joint peel specimen.

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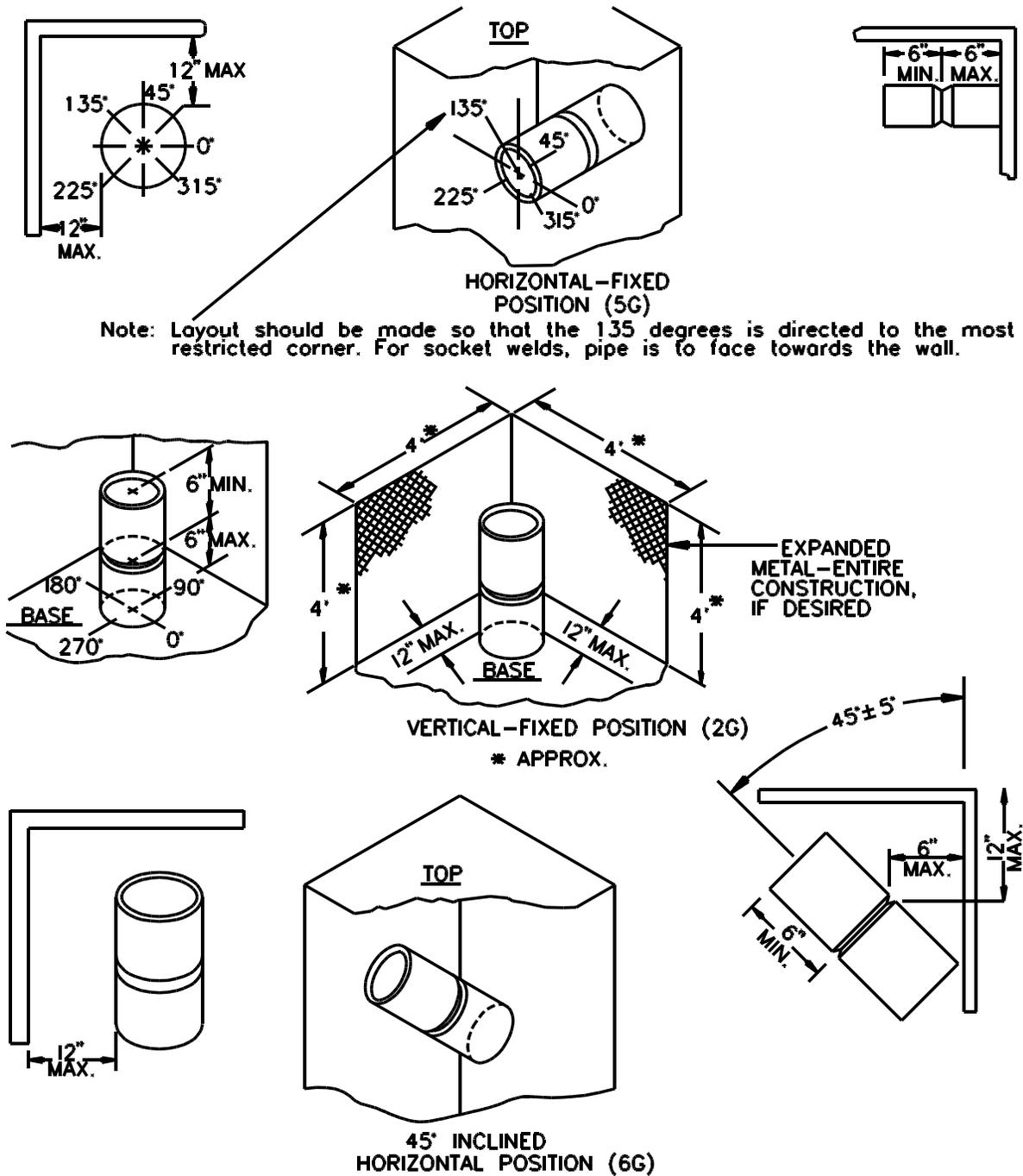
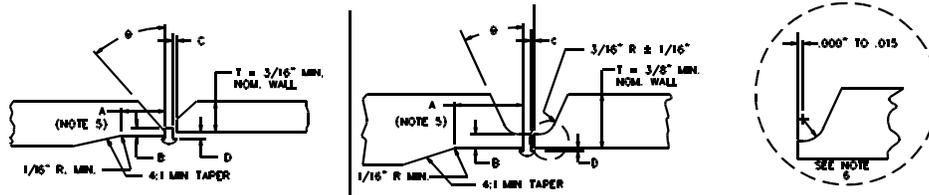


FIGURE 21. Typical layout and construction for restricted accessibility qualification test assembly positions.

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SH 13203128

TEST NO. 5

TEST NO. 6

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 note 8 and 10
5	0.010 \pm 0.005	0.030 \pm 0.005	0.031 max	0.031 max	40 \pm 5°
6	0.010 + 0.003	0.030 + 0.005	0.031 max	0.031 max	25 \pm 3°

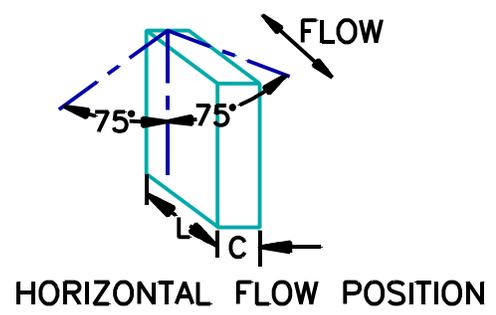
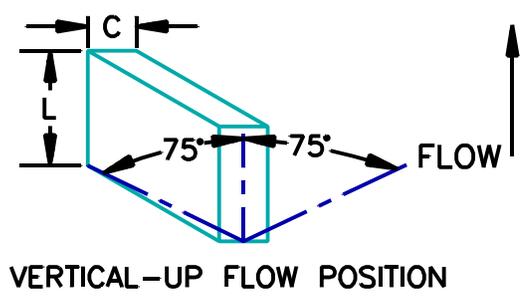
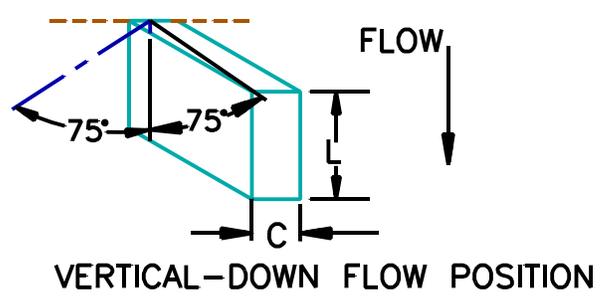
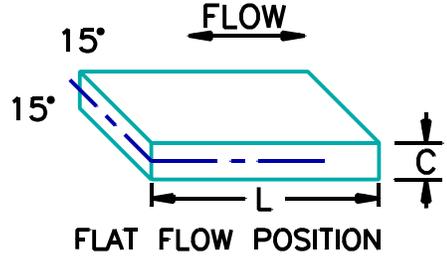
NOTES:

1. The maximum difference in inside of diameter of the pipes to be joined shall be 0.031 inch.
2. Welds shall 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 and 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 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 \pm 2-1/2 degrees for test no. 5.
9. For joints of nickel-copper (S-42) and nickel-chromium-iron (S-43) materials dimensions "B" may be changed to 1/16 \pm 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 \pm 3 degrees for test no. 5.
 - (b) 8 \pm 3 degrees for test no. 6.

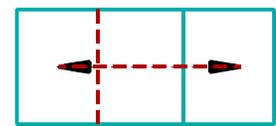
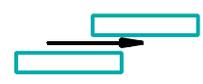
FIGURE 22. Performance qualification tests nos. 5 and 6 for arc welding (pipe).

FLOW OF ALLOY THRU JOINT

C = JOINT CLEARANCE
L = LENGTH OF LAP OR THICKNESS



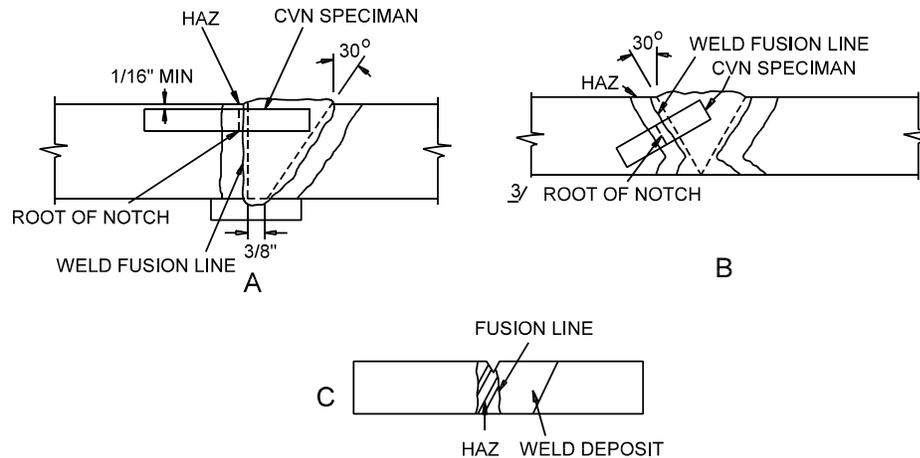
TYPICAL BRAZED JOINTS SHOWING FLOW OF ALLOY



SH 13203129

FIGURE 23. Brazing positions.

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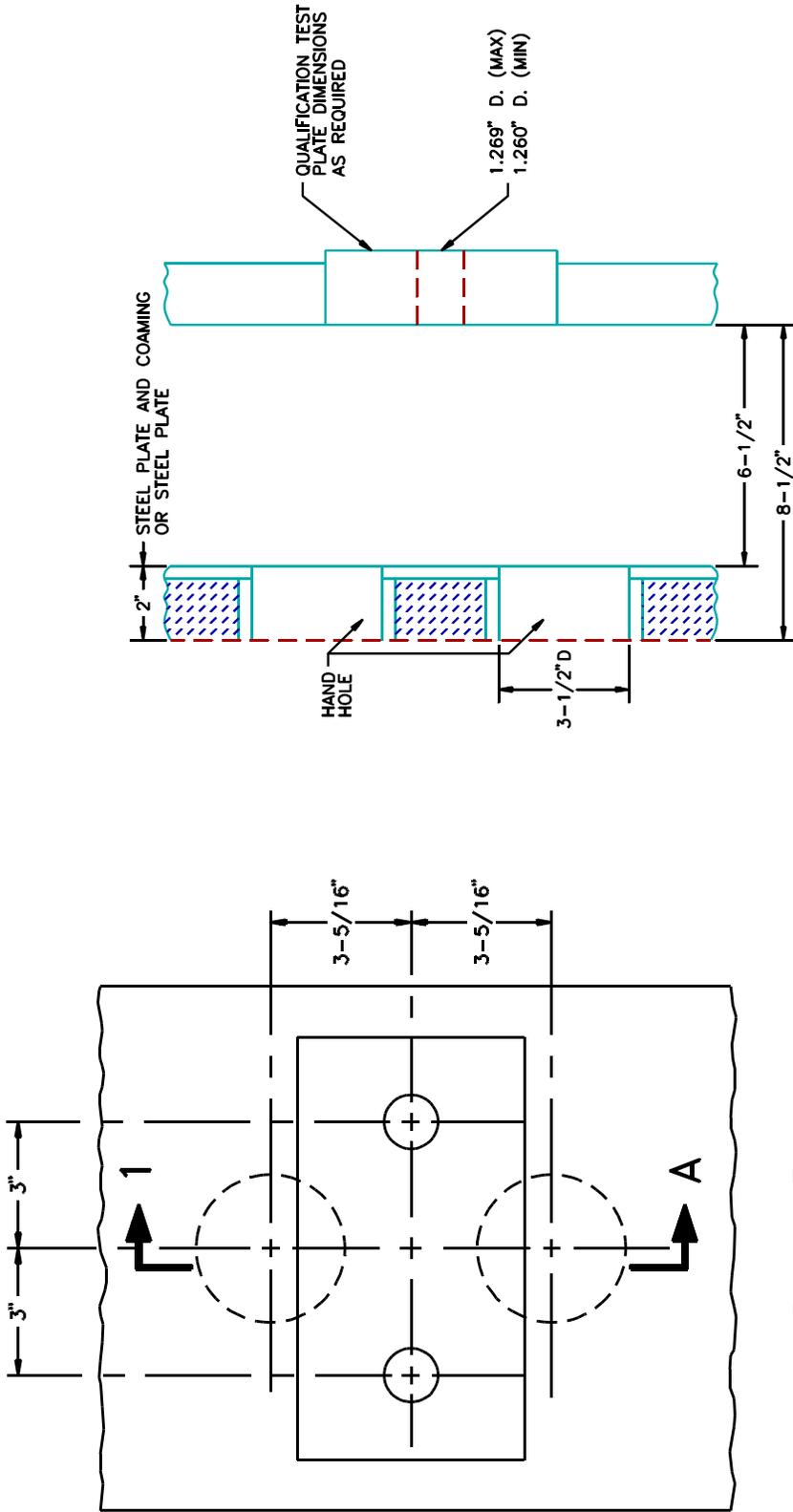
SH 13203130

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.
2. The specimens shall be removed from a location as near as practical 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 heat affected zone impact specimens shall be taken transverse to the axis of the weld and polished and etched to define the heat affected zone prior to machining the notch. The notch of the Charpy V-notch specimen shall then be cut approximately normal to the material surface. Unless inclined specimens are used as permitted below, a straight wall joint design similar to that shown in A shall be used for obtaining HAZ specimens. Where material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to align parallel to the fusion line as shown in B. Material at least 1-1/2 inches thick is required for a single side, 30 degree bevel weld joint.
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 heat affected zone values with base material values, Charpy V-notch specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat affected zone specimens, and the axis of the notch shall be normal to the surface of the base material.
5. Testing and acceptance criteria shall be in accordance with 4.5.
6. Before testing, take photomicrographs of the side view of all CVN-HAZ specimens showing the root of the notch and the etched HAZ below the notch (see figure 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 24. Heat affected zone (HAZ) Charpy notch location.

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SECTION I-A

PLAN VIEW
 SUPERHEATER HEADER MOCK-UP

SH 13203132

NOTE: Orientation of 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).

FIGURE 25. Mockup and orientation of assembly for performance qualification for manual welding of tube-to-header joint welds.

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NOTES:

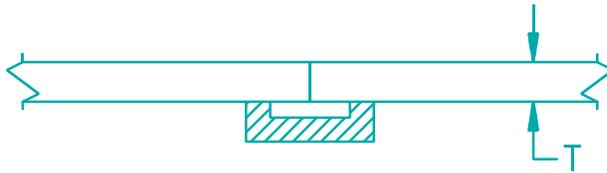
1. Header mock-up shall be fabricated from steel with top, bottom and all sides closed except as necessary for electrical lighting. Either pipe or plate may be used (plate shown) and thickness may be selected as necessary to achieve specified space restrictions except material thickness shall be 3/16 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 so as to permit easy removal of test plate for nondestructive test 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 welder will experience in production. Inside surfaces of mock-up shall not be insulated.
4. Hand hole diameter and all other dimensions are without 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 plus or minus 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) Additional hand holes 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).

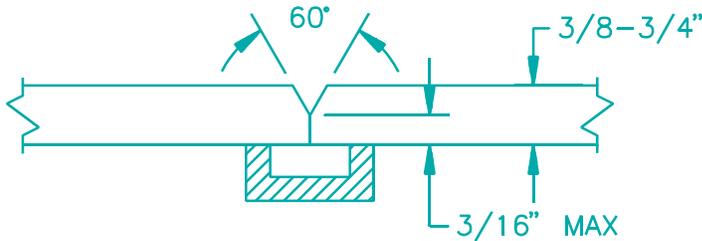
9. The orientation set by designation of "TOP" is for welding with the header mock-up positioned vertically, that is, the tube is in the horizontal fixed position.

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	MANUAL	MECHANIZED
T	1/8" MAX	1/4" MAX



A. Weld joint for manual or mechanized weld



SH 13203133

B. Weld joint for mechanized weld ^{1/}

^{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 26. Performance qualification test no. 10, plasma-arc welding - keyhole technique.