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26 January 1987
SUPERSEDING
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(See 16.9)

MILITARY STANDARD

WELDING AND CASTING STANDARD

AMSC N/A AREA THJM

DEPARTMENT OF THE NAVY

NAVAL SEA SYSTEMS COMMAND
Washington, DC 20362-5101

Welding and Casting Standard

1. This standard is approved for use by the Naval Sea Systems Command (NAVSEA) and is available for use by all Departments and Agencies of the Department of Defense. The standard establishes the requirements for the fabrication, welding, and inspection of weldments, and for casting inspection and repair for machinery, piping, and pressure vessels in ships of the United States Navy.

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

FOREWORD

1. This standard provides instructions for the fabrication, welding, and inspection of machinery, piping, and pressure vessels in ships of the United States Navy. It also contains requirements for the inspection and repair welding of castings.

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1. SCOPE

1.1 This standard contains the welding and allied processes (except brazing) and casting requirements including inspection for the fabrication, alteration, or repair of any item or component of machinery, piping, and pressure vessels in ships of the United States Navy.

1.2 Requirements for welding and inspection of HY-80/100 submarine structure and surface ship structure are contained in MIL-STD-1688 and MIL-STD-1689, respectively.

1.3 Weldments made principally of sheet metal (such as electrical boxes; ventilation and air conditioning ducts; and protective covers for gears, belts, and chain drives) are excluded from the requirements of this standard. Weldments of vents, overflows, and drains are also excluded.

1.4 This document contains both mandatory requirements and guidance information. The mandatory requirements, indicated by the words "shall" or "is required", are designed to serve as standards applicable to materials, workmanship, inspection, and quality control. Guidance information is indicated either by the word "should" or "may". Where specific approval by the Naval Sea Systems Command (NAVSEA) is required, it is so noted (see 1.6).

1.5 Reference in this document to a particular paragraph or section number shall include all applicable subparagraphs under that paragraph or section number. For example: The reference to paragraph 4.4 shall include subparagraphs 4.4.1 and 4.4.2.

1.6 Requirements subject to NAVSEA approval. Any requirements contained in this standard specifically requiring NAVSEA approval shall be forwarded to Naval Sea Systems Command, Washington, DC 20362-5101 via the authorized representative. Subcontractors shall submit such items to the contracting activity in accordance with the contract or purchase order. Contracting activities and authorized representative shall thoroughly review and make recommendations as to the acceptability of the requirement submitted.

1.7 Document precedence. Unless otherwise specified herein, in the event of conflict between this standard and other documents, the following order of precedence shall apply:

(a) Ship specifications for a particular ship or class, or Deep Diving General Overhaul Ship Specifications (DDGOSS), as appropriate (this includes plans and drawings).
(b) Equipment or component specifications.
(c) This standard.
(d) Other referenced documents.

1.8 Upon acceptance by an activity, this issue of the standard shall be used in its entirety. Previously approved deviations from earlier issues are not applicable unless approved for use with this issue.

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 standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

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-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-639 - Brass, Naval: Flat Products (Plate, Bar, Sheet, 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-390 - Copper Alloy Castings (Including Cast Bar).

FEDERAL (Continued)

QQ-C-450 - Copper-Aluminum Alloy (Aluminum Bronze) Plate, Sheet, Strip, and Bar (Copper Alloy Numbers 606, 610, 613, 614, and 630).
QQ-C-465 - Copper-Aluminum Alloys (Aluminum Bronze) (Copper Alloy Numbers 606, 614, 630, 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-E-450 - Electrodes, Welding, Covered: Mild Steel.
QQ-N-281 - Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections.
QQ-N-288 - Nickel-Copper Alloy and Nickel-Copper-Silicon Alloy Castings.
QQ-S-763 - Steel Bars, Wire, Shapes, and Forgings, Corrosion-Resisting.
WW-P-404 - Pipe, Steel, (Seamless and Welded, Black and Zinc-Coated (Galvanized)).
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-E-278 - Electrodes, Welding, Covered, Aluminum Bronze.
MIL-S-860 - Steel Forgings for Steam Turbine Rotors.
MIL-S-861 - Steel Bars, Corrosion Resisting, Naval Steam Turbine Parts Use.
MIL-S-862 - Steel Bars, Corrosion Resisting, and Steel Billets, Corrosion Resisting; Reforging Application.
MIL-S-867 - Steel Castings, Corrosion Resisting Austenitic.
MIL-S-870 - Steel Castings, Molybdenum Alloy.
MIL-S-872 - Steel Bars, Billets, and Forgings - Carbon-Molybdenum Alloy.
MIL-P-1144 - Pipe, Corrosion-Resistant, Stainless Steel, Seamless or Welded.
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.

MILITARY (Continued)

MIL-T-8504 - Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded.
MIL-E-8697 - Electrodes, Welding, Covered, Low-Hydrogen, Heat-Treatable Steel.
MIL-S-8699 - Steel Bars and Forging Stock (4330) Vanadium Modified, Aircraft Quality.
MIL-T-9046 - Titanium and Titanium Alloy, Sheet, Strip, and Plate.
MIL-T-9047 - Titanium and Titanium Alloy Bars (Rolled or Forged) and Reforging Stock, Aircraft Quality.
MIL-T-15005 - Tubes, 70-30 and 90-10 Copper Nickel Alloy, Condenser and Heat Exchanger.
MIL-S-15083 - Steel Castings.
MIL-C-15345 - Castings, Nonferrous, Centrifugal.
MIL-S-15464 - Steel, Alloy, Chromium-Molybdenum; Castings.
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-B-16541 - Bronze, Valve: Castings.
MIL-S-16974 - Steel Bars, Billets, Blooms and Slabs; Carbon and Alloy (for Reforging or Other Operations Before Heat Treatment).
MIL-S-16993 - Steel Castings (12-Percent Chromium).
MIL-R-17131 - Rods and Powders, Welding, Surfacing.
MIL-N-17163 - Nickel-Copper Alloy, Wrought; (55-60 Percent Nickel) Low Permeability.
MIL-T-17188 - Tube, Carbon Steel, Electric Resistance Welded, Marine Boiler.
MIL-S-17509 - Steel Castings, Austenitic, Chromium-Nickel, Low Magnetic Permeability.
MIL-T-18165 - Tube and Pipe, Chromium-Molybdenum Alloy Steel, Seamless.
MIL-E-18193 - Electrodes, Welding, Carbon Steel and Alloy Steel, Bare, Coiled.
MIL-F-18251 - Fluxes, Welding, Submerged Arc Process Carbon and Low-Alloy Steel Application.
MIL-S-18410 - Steel Bars, Billets, and Forgings - Chromium-Molybdenum Alloy.
MIL-S-18728 - Steel Plate, Sheet and Strip, Alloy 8630, Aircraft Quality.
MIL-S-18729 - Steel Plate, Sheet, and Strip, Alloy 4130, Aircraft Quality.

MILITARY (Continued)

MIL-F-19922 - Fluxes, Welding (Compositions), Submerged Arc Process with Type "B" Electrodes, Carbon and Low-Alloy Steel Application.
MIL-E-19933 - Electrodes and Rods - Welding, Bare, Chromium and Chromium-Nickel Steels.
MIL-T-20155 - Tube and Pipe, Carbon-Molybdenum Alloy Steel, Seamless (ASTM A-335-55T, Grade P-1).
MIL-T-20157 - Tube and Pipe, Carbon Steel, Seamless.
MIL-C-20159 - Copper-Nickel Alloy Castings (UNS No. C96200 and C96400).
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.
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).

MILITARY (Continued)

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, Air Melted or Vacuum Remelted.
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 - Fitting and Flanges, Wrought, Seamless, Butt and Socket Welding, Austenitic Corrosion-Resistant Steel.
MIL-P-23508 - Plating, Tin-Cadmium (Electrodeposited).
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 Alloy 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, Welding, Bare, Copper and Copper Alloy.
MIL-S-24093 - Steel Forgings, Carbon and Alloy Heat Treated.
MIL-N-24106 - Nickel-Copper Alloy Bars, Rods, and Forgings.
MIL-L-24128 - Low Carbon Chromium Steel Bars, Rods and Forgings.
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.

MILITARY (Continued)

MIL-S-24412 - Steel, Special Structural Shape, Weldable, High Tensile (HT); for Submarine Hulls.
MIL-S-24451 - Steel Heat Treated Heads, Alloy Structural, High Yield Strength (HY-80 and HY-100).
MIL-B-24480 - Bronze, Nickel-Aluminum (UNS No. C95800) Castings, for Seawater Service.
MIL-C-24615 - Castings, Nickel-Chromium-Molybdenum-Columbium Alloy.
MIL-C-24637 - Castings, Steel, Martensitic, Corrosion-Resistant (Non-Pressure Service).
MIL-S-24645 - Steel Plate, Sheet, or Coil, Age-Hardening Alloy, Structural, High Yield Strength (HSLA-80).
MIL-H-81200 - Heat Treatment of Titanium and Titanium Alloys.

STANDARDS

MILITARY

MIL-STD-22 - Welded Joint Design.
MIL-STD-248 - Welded and Brazing Procedure and Performance Qualification.
MIL-STD-271 - Nondestructive Testing Requirements for Metals.
MIL-STD-276 - Impregnation of Porous Nonferrous Metal Castings.
MIL-STD-438 - Schedule of Piping, Valves, Fittings, and Associated Piping Components for Submarine Service.
MIL-STD-777 - Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships.
MIL-STD-1627 - Bending of Pipe or Tube for Ship Piping Systems.
MIL-STD-1628 - Fillet Weld Size, Strength, and Efficiency Determination.
MIL-STD-1681 - Fabrication, Welding, and Inspection of HY-130 Submarine Applications.
MIL-STD-1687 - Thermal Spray Processes for Naval Ship Machinery and Ordnance Applications.
MIL-STD-1688 - Fabrication, Welding, and Inspection of HY80/100 Submarine Applications.
MIL-STD-1689 - Fabrication, Welding, and Inspection of Ships Structure.
DOD-STD-2138 - Metal Sprayed Coating Systems for Corrosion Protection Aboard Naval Ships. (Metric)

2.1.2 Other Government publications. The following other Government publications form a part of this standard to the extent specified herein.

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

0900-LP-001-7000 - Fabrication and Inspection of Brazed Piping Systems.
0900-LP-003-8000 - Metals Surface Inspection Acceptance Standards.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) (Continued)

0900-LP-003-9000 - Radiographic Standards for Production and Repair Welds.
0900-LP-006-3010 - Structure Production and Repair Welds - 23 Ultrasonic Inspection Procedures.
0900-LP-999-9000 - Surface Finish of Flame or Arc Cut Material, Acceptance Standards for.
0951-LP-031-8010 - Repair and Overhaul, Main Boilers, 1200 PSI Steam Propulsion Plant.
0951-LP-038-6030 - 1200 PSI Pressure Fired Boiler and Supercharger, Vol. 3, Repair and Overhaul.
392-0755 - Seal Welding Manual.

(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 standard 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.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A 176 - Standard Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip. (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.
A 216 - Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service. (DoD adopted)
A 234 - Standard Specification for Pipe Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures. (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 302 - Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel. (DoD adopted)
A 336 - Standard Specification for Steel Forgings, Alloy, for Pressure and High-Temperature Parts.
A 487 - Standard Specification for Steel Castings Suitable for Pressure Service.
A 515 - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service. (DoD adopted)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) (Continued)

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, Nickel-Base, Corrosion-Resistant, for General Application. (DoD adopted)
A 744 - Standard Specification for Castings, Iron-Chromium-Nickel, Nickel-Base, Corrosion Resistant, for Severe Service. (DoD adopted)
B 166 - Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600 and N06690) Rod, Bar, and Wire. (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 337 - Seamless and Welded Titanium and Titanium Alloy Pipe.
B 338 - Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers.
B 367 - Standard Specification for Titanium and Titanium Alloy Castings.
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)
E 155 - Standard Reference Radiographs for Inspection of Aluminum and Magnesium Castings.
E 186 - Standard Reference Radiographs for Heavy-Walled (2 to 4-1/2-in. (51 to 114-mm)) Steel Castings. (DoD adopted)
E 192 - Standard Reference Radiographs of Investment Steel Castings for Aerospace Applications. (DoD adopted)
E 272 - Standard Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings.
E 280 - Standard Reference Radiographs for Heavy-Walled (4-1/2 to 12-in. (114 to 305-mm)) Steel Castings. (DoD adopted)
E 310 - Standard Reference Radiographs for Tin Bronze Castings.
E 446 - Standard Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness. (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)

A2.4 - Symbols for Welding and Nondestructive Testing Including Brazing. (DoD adopted)
A3.0 - Welding Terms and Definitions Including Terms for Brazing, Soldering, Thermal Spraying, and Thermal Cutting. (DoD adopted)
A5.01 - Filler Metal Procurement Guidelines.
A5.2 - Specification for Iron and Steel Oxyfuel Gas Welding Rods. (DoD adopted)
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 Rods and Electrodes. (DoD adopted)
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)
A5.13 - Specification for Solid Surfacing Welding Rods and Electrodes. (DoD adopted)
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 Covered Copper and Copper Alloy Gas Welding Electrodes. (DoD adopted)
A5.28 - Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding. (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.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

AMS 6530 - Steel Tubing, Seamless 0.50Cr - 0.55Ni - 0.20Mo (0.28 - 0.33C) (SAE 8630). (DoD adopted)

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

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY, INC.

SP-55 - Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components (Visual Method).

(Application for copies should be addressed to the Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street, N.E., Vienna, VA 22180.)

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

3. GENERAL REQUIREMENTS

3.1 Responsibility. Each activity that accomplishes work in accordance with this standard shall be familiar with its provisions and referenced specifications to the extent that they apply to the work being performed.

3.2 Engineering drawings. Drawings shall indicate essential fabrication details. Weld joints shall be identified by symbols in accordance with AWS A2.4 and joint design selection shall be in accordance with section 9. Nondestructive tests for welded joints shall be identified by symbols in accordance with AWS A2.4 except that single symbol PT may be used in lieu of DPT (dye penetrant) or FPT (fluorescent penetrant).

3.2.1 Referencing this standard. Drawings shall carry a note stating that welding and inspection shall be in accordance with this standard and give the applicable welding class, except those drawings related to components for which inspection requirements are covered by sections 14 and 15.

3.3 Nomenclature and definitions. Welding nomenclature and definitions used in the preparation of drawings, welding procedure specifications, and correspondence related to welding shall be in accordance with AWS A3.0.

3.3.1 Definitions. The following definitions are applicable to this standard:

3.3.1.1 Activity. Activity refers to all sites of an organization under the same quality assurance management and using the same quality assurance plan performing work to which this standard is applicable.

3.3.1.2 Approved (approval). Approval refers to when the item under consideration has been accepted by NAVSEA or its authorized representatives.

3.3.1.3 Arc-strike. Arc-strike is any inadvertent change in the characteristics of the finish weld or adjacent base material resulting from an arc of heat generated by the passage of electrical energy between the surface of the finished weld or base material and a current source, such as welding electrodes or magnetic particle inspection prods.

3.3.1.4 Authorized representative. Authorized representative is any Government representative specifically authorized to approve equipment, material, or procedures within the scope of this standard 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 (other than Government shipyards): The delegated representative of the Commanding Officer, Naval Ship Systems Engineering Station (NAVSSES), Philadelphia.
(d) When delegated by (a), (b), or (c) above, the representative of Defense Contract Administration Services Management Area (DCASMA).
(e) Technical representative specifically authorized by NAVSEA.

3.3.1.5 Diving life support piping systems. Diving life support piping systems are piping systems for breathing gases (delivery and exhaust) for divers.

3.3.1.6 Dissimilar metal welds. Dissimilar metal welds are welds between two metals which differ sufficiently in metallurgical and physical properties to require special consideration in welding qualification and inspection. Welds made by either direct joining of the dissimilar metals or by use of weld deposited buttering are considered dissimilar metal welds.

3.3.1.7 Essential elements. "Essential elements" is defined as the essential elements specified in MIL-STD-248.

3.3.1.8 Fabrication welds. Fabrication welds are welds required to fabricate a weldment or welded system. These welds include designed weld joints; weld buildups; overlay cladding for corrosion resistance, hardfacing, and wear resistance; and weld deposited buttering.

3.3.1.9 Government inspector. Government inspector is a Government official who is charged with the responsibility for assuring that the materials, processes, fabrication techniques, inspections, tests, and testing personnel meet specification and contractual requirements. In this regard, he shall be the authorized representative or the following:

(a) When delegated by the authorized representative, the DCASMA inspector.
(b) For forces afloat: The Squadron Commander or his delegated representative.
(c) For Naval repair facilities: The commanding officer or his delegated representative.

3.3.1.10 Lethal fluids. Lethal fluids are poisonous gases or liquids of such nature that a very small amount of the gas or vapor of the liquid mixed or unmixed with air is dangerous to human life when inhaled. For purposes of piping system classification, lethal includes substances of this nature which are stored under pressure or which may generate a pressure if stored in a closed vessel. Some such substances are hydrocyanic acid, carbonyl chloride, cyanogen chloride gas, and xylyl bromide. For the piping system classification purposes of this standard, ammonia, natural or manufactured gas, any liquefied petroleum gas (such as propane, butane, or butadiene) and vapors of any other petroleum products are not classified as lethal substances.

3.3.1.11 Organization inspector. The organization inspector shall be the inspector of a contractor, Naval shipyard, or Government agency who has been authorized by the organization to inspect and accept or reject materials and workmanship and to witness tests and validate test data. In process, visual inspectors can be production personnel.

3.3.1.12 Pressure containing. Pressure containing shall refer to that area of a component or weld which prevents contained liquid or gas from escaping.

3.3.1.13 Procedure qualification. A welding procedure qualification is an action by which test assemblies are prepared in accordance with a proposed procedure and evaluated either by destructive or nondestructive tests or both.

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

3.3.1.15 Seal welds. Seal welds are welds provided for a fluid containment function only, as in a closure where strength is provided by a separate device. This definition does not apply to boiler, economizer, and superheater tube-to-header "seal" welds.

3.3.1.16 Tube-to-header "seal" welds. Tube-to-header "seal" welds 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 provided by a combination of welding and rolling the tube. Tube-to-header "seal" welds shall be performed in accordance NAVSEA 0951-LP-031-8010 in addition to the requirements specified herein.

3.3.1.17 Welding deposited buttering. Welding deposited buttering is weld metal deposited on base metal prior to completing the weld to permit the final portion of a dissimilar metal weld to be completed as a similar metal weld.

3.3.1.18 Weld deposited overlay cladding. Weld deposited overlay cladding is weld metal which is deposited for the purpose of corrosion protection only.

3.3.1.19 Weld deposited hard surfacing. Weld deposited hard surfacing is weld metal which is deposited for the purpose of providing wear resistance.

3.3.1.20 Welded fabrication or weldment. Welded fabrication or weldment is any assembly where component parts are joined by welding.

3.3.1.21 Welding procedure. Welding procedure is written instructions designed for use in production welding and repair welding, delineating all the essential elements and guidance to produce reliable welds.

3.3.2 Classification. The following classifications are applicable to this standard:

(a) Machinery, class M.

(1) Class M-1. Class M-1 machinery includes welds in moving parts, such as gears, rotors, impellers and shafting (except propulsion shafting and rudder stocks) that transmit torque or thrust.

(2) Class M-2. Class M-2 machinery includes welds in stationary non-pressurized assemblies or structures, such as sub-bases for turbines, engines, motors, and pumps.

Cleaning prior to and during welding

Each of these sub-classes shall be further categorized as to criticality in accordance with the following:

a. Category A. Safety and mission of the ship.

Safety. Includes machinery forming part of, or directly supporting, watertight integrity or machinery the failure of which would cause loss of ship control, propulsion, or weight handling equipment.

Mission. Machinery essential to the mission of the ship, such as weapon and fire control systems, navigation/communication systems, and major auxiliary support systems.

b. Category B. Normal operation of the ship. Machinery essential to the normal operation of the ship.

c. Category C. Non-essential items. Includes parts of components in categories A and B having welded joints that do not transmit the principal operating load or support any type of pressure boundary.

(b) Piping, class P. Class P piping includes all piping, tubing, and fittings for conveying fluids. Classes P-1, P-2, and P-LT apply to welded systems. Class P-3 applies to brazed systems.

(1) Class P-1. Class P-1 includes fabrication welds for design pressures exceeding 300 pounds per square inch (lb/in^2) or design temperatures exceeding 650 degrees Fahrenheit (°F), or both, such as steam lines, hydraulic systems, boiler generating tubes, superheater and economizer elements, other pressure retaining tubes and piping (excluding nozzle or root connections to pressure vessels, which are covered under the appropriate classification), and all piping systems for conveying oxygen, gasoline, and lethal gases or liquids regardless of pressure and temperature. This class also includes fabrication welds in piping systems which transmit oxygen, helium, mixed gases, air, water and exhaust of diving life support systems. Also included are any structural welds made to the internal or external surfaces of a fluid boundary subject to system pressure but which do not form a part of the fluid boundary. This includes any any weld made to a weld deposited pad or cladding on the fluid boundary as well as the weld deposited pad or cladding beneath the weld itself. This does not include cladding other than cladding beneath the weld nor does it include welds which join clips, nameplates, insulation supports, or other nonstructural members to the fluid boundary. Specifically excluded are pipe joints meeting the classification criteria of class P-LT.

(2) Class P-2. Class P-2 includes fabrication welds for design pressures and design temperatures not exceeding 300 lb/in^2 and 650°F. It also includes all open ended piping that has no isolation capability from its origin to its terminus regardless of the design temperature or pressure. Specifically excluded are pipe joints meeting the classification criteria of class P-LT.

(3) Class P-LT. Class P-LT includes fabrication welds for all piping of design pressures greater than 50 lb/in^2 and service temperatures of minus 20°F and below.

(4) Class P-3. Class P-3 piping includes all brazed piping of unlimited pressures and 425°F maximum design temperature. Fabrication and inspection of brazed piping systems shall be in accordance with NAVSEA 0900-LP-001-7000.

(c) Pressure vessels and tanks, class A. Class A pressure vessels and tanks includes the fabrication welds for parts of drums, tanks, or closed receptacles (including nozzle attachments) and valves which are designed to contain gases or liquids. This includes all feed tanks, lubricating oil storage tanks, and similar vessels which contain only the static head of the obtained liquid. It does not include tubing or piping that joins to the pressure vessel, which are subject to the requirements of class P piping. Valves to be installed in class P-1 piping system shall be fabricated and inspected in accordance with class A-2 pressure vessel requirements. Valves to be installed in other classes of piping systems shall be fabricated and inspected in accordance with the appropriate pressure vessel category as determined by design temperatures and pressures.

(1) Class A-F. Class A-F includes fabrication welds for fired and unfired pressure vessels for all pressures and temperatures that are specifically designed for a finite fatigue life and, as a consequence, are required to undergo low cycle fatigue evaluations. Also included are any structural welds made to the internal or external surfaces of a fluid boundary subject to system pressure but which do not form a part of the fluid boundary. This includes any weld made to a weld deposited pad or cladding on the fluid boundary as well as the weld deposited pad or cladding beneath the weld itself. This does not include cladding other than cladding beneath the weld nor does it include welds which join clips, nameplates, insulation supports, or other nonstrucutal members to the fluid boundary. Examples of pressure vessels in this class are all submergence pressure sea water cooled submarine heat exchangers and catapult steam receivers.

(2) Class A-1. Class A-1 includes fabrication welds for fired pressure vessels, drums, and headers, in which steam is generated by the application of heat resulting from the combustion of fuel. It includes economizer and superheater headers. Specifically excluded are welds of pressure vessels meeting the classification criteria of classes A-2, A-3, A-4, or A-LT.

(3) Class A-2. Class A-2 consists of fabrication welds for unfired pressure vessels with design pressures or design temperatures exceeding 400 lb/in^2 or 650°F, respectively, for liquids at 300°F or higher, and for lethal gases and liquids at any temperature or pressure. Class A-2 also includes valves to be installed in class P-1 piping systems. Specifically excluded are welds of pressure vessels meeting the classification criteria of classes A-3, A-4, or A-LT.

(4) Class A-3. Class A-3 consists of fabrication welds for unfired pressure vessels with design pressures and design temperatures not exceeding 400 lb/in^2 and 650°F. Specifically excluded are welds of pressure vessels meeting the classification criteria of classes A-4 or A-LT.

(5) Class A-4. Class A-4 consists of fabrication welds for unfired pressure vessels with design pressures or design temperatures not exceeding 150 lb/in^2 and 450°F, including tanks subject only to the static head or the liquid contained. Specifically excluded are welds for pressure vessels meeting the classification criteria of class A-LT.

(6) Class A-LT. Class A-LT consists of fabrication welds for pressure vessels with design pressures greater than 50 lb/in^2 and service temperatures of minus 20°F and below.

(d) Steam turbines, class T. Class T steam turbines consist of fabrication welds for steam turbine components or parts (except piping) listed in table XXI. Since steam turbines consist of components subject to service conditions varying from high pressure to vacuum, class T is broken down as follows:

(1) Class T-1. Class T-1 consists of fabrication welds subject to operating pressures of 300 lb/in^2 or greater.

(2) Class T-2. Class T-2 consists of fabrication welds subject to less than 300 lb/in^2 and fabrication welds in structural members.

4. QUALITY ASSURANCE AND QUALIFICATION PROVISIONS

4.1 Quality assurance.

4.1.1 General. This section contains the minimum requirements for assuring that components and systems meet inspection criteria specified in this standard.

4.1.2 Material control. The activity is responsible to inspect material upon receipt to assure that it meets the specified mechanical and chemical requirements. Receipt inspection shall consist of, but not be restricted to, comparing the contractor's data with the specified requirements and sampling of the received material to establish a reasonable confidence in the reliability of the contractor's data. An identification system shall be established and maintained which includes the specification number and type or grade of the material. Periodic internal audits of the inventories, stocking facilities, and shops shall

be performed to assure that materials are correctly identified. A system shall be established that requires visual verification prior to fabrication or installation to ensure that the identification of the material corresponds to that specified by the applicable drawing or document.

4.1.2.1 Quality assurance system. Each organization shall maintain a quality assurance system adequate to assure NAVSEA or its authorized representative, or the Government inspector that all of the requirements of this standard have been and are continuously being met. Written procedures shall be prepared to assign responsibility and provide accountability for performing work and inspections.

4.1.3 Records - applicable to classes A-F, A-1, A-2, A-3, A-LT, P-1, P-LT, M-1, and T-1. When specified in the contract or order, the quality control system shall include preparing and maintaining written records (see 16.7) of at least the following items for each welded joint that undergoes nondestructive test (NDT) inspection, excluding hydrostatic tests, of weld classes A-F, A-1, A-2, A-3, A-LT, P-1, P-LT, M-1, and T-1. The records shall be traceable to the hardware or weld joint and from the hardware or weld joint to the records.

(a) Joint identification.
(b) Joint design.
(c) Base material type (including heat or lot or level I identification when required by the applicable system or component specification).
(d) Filler material type (including heat or lot or level I identification when required by the applicable system or component specification).
(e) Fitup.
(f) Welding procedure identification.
(g) Heat treatments (including preheat, interpass, and post-weld heat treatment temperatures).
(h) Welder identification.
(i) NDT methods and results.
(j) Disposition of welds.
(k) Cycles of repairs to weld.
(l) Inspection procedures.
(m) NDT personnel identification.

NOTE: See sections 10 and 13 for inspection and record requirements for base material weld repairs.

4.1.3.1 Record form. When specified in the contract or order, a record format shall be prepared prior to the commencement of the operation which it covers (see 16.7). Operations shall be recorded prior to the commencement of the next operation. Items (i), (j), (l), and (m) of 4.1.3 shall be signed or stamped by the activity's inspector and dated except that 5X magnification visual inspections of weld root layers may be performed by qualified production personnel. All other items shall be signed and dated by production personnel or inspection personnel. When a specific item on the record form is not applicable, the letters "N.A." (Not Applicable) shall be entered. Final acceptance of a weldment shall not be permitted until all items on the record formats are marked as specified above.

4.1.3.2 Maintenance of records. Unless otherwise specified, all required records shall be maintained by the activity and be available to NAVSEA or its authorized representative throughout the life of the contract and for 3 years after delivery. At the expiration of the record retention period, NAVSEA or its authorized representatives shall be given a written notification. Disposition of records shall be as agreed upon by NAVSEA and the contractor.

4.1.4 Nonconformance. If NAVSEA or the Government inspector has evidence that the requirements of this standard are not being met, they can suspend upon written notification the use of any questionable materials, equipment, procedures, personnel, and so forth, on work covered by this standard until conformance with the requirements of this standard is judged satisfactory by NAVSEA or the Government inspector.

4.2 Welding qualification (procedure, welder, and operator requirements).

4.2.1 Welding procedure. When specified in the contract or order, prior to production welding, welding procedures in accordance with the requirements of MIL-STD-248 and this standard shall be prepared by the activity (see 16.7). Welding procedures shall assure conformance with this standard and shall be submitted for information when procedure qualification test data are submitted to the authorized representative for approval (see 4.2.1.2) or whenever the welding procedures are revised. Procedures qualified in accordance with NAVSEA 392-0755 may be used for welding of seal welds without separate qualification in accordance with MIL-STD-248.

4.2.1.1 Conditions governing welding procedure qualification tests. Welding procedure qualification tests are required where fabrication drawings or specifications invoke this standard, except qualification tests are not mandatory where the following conditions are met.

(a) Either classes M-1 category C, M-2 category C, A-4, P-2 (except for joint designs welded from one side only with no backing), or T-2 weldments are involved, and the base materials being joined are of the same "S-number" group (except S-11A/B and S-52) listed in table I (or a comparable ASME P-number group, if approved) and the corresponding filler materials listed in table III are used with the following manual or semi-automatic processes.

(1) Shielded metal-arc.
(2) Gas tungsten-arc.
(3) Gas metal-arc.

(4) Flux core.
(5) Submerged-arc.
(6) Oxyacetylene where group S-1 materials 3/16 inch or less in thickness are joined.

(b) Fabrication entails welding of assemblies, the possible failure of which is remote and would not result in danger to ship personnel, shipboard components or equipment, or ship structure. Items in this category include but are not limited to name plates, galley equipment, furniture, fixtures, and tack welds.

4.2.1.2 Approval of procedure qualification data. When specified in the contract or order, prior to production welding, procedure qualification test data obtained in accordance with MIL-STD-248 shall be submitted for approval (see 16.7). The welding procedure upon which the qualification test assemblies are made shall also be submitted for review (see 4.2.1).

4.3 Welder, tack welder, and welding operator qualification. Welders, tack welders, and welding machine operators shall be qualified in accordance with MIL-STD-248.

4.3.1 For welding of internal tube to header (or drum) welds in boiler components the following shall apply:

(a) Welders who have not performed internal tube-to-header welding within 6 months shall perform one tube-to-header weld in accordance with MIL-STD-248 except that the subject test assembly need only be subjected to visual inspection of the root pass and visual and PT inspection of the finished weld.
(b) Any reject will require full recertification in accordance with MIL-STD-248.
(c) Certification of completion of this test or identification of performed work with the preceding 6-month period shall be added to MIL-STD-278 weld joint history records.

4.4 Welding equipment. Welding equipment in the hands of qualified welders, tack welders, and welding operators shall produce welds that meet the applicable acceptance criteria under production conditions.

4.4.1 If the authorized representative doubts the capability of any particular item of welding equipment, he shall for a stated cause require it to be tested in accordance with the applicable equipment specification or joint welding procedure tests. If the requirements cannot be met, the equipment shall not be used for production work until satisfactory repairs or adjustments have been made.

4.4.2 The fabricator shall devise, direct, and supervise the testing of any item of equipment (see 4.4.1) and shall bear the expense of conducting these tests. The fabricator shall notify the Government and arrange a time and place for conducting the tests so the Government inspector may be present.

4.5 NDT personnel. NDT procedures and personnel shall be qualified in accordance with MIL-STD-271.

5. MATERIALS

5.1 General. This section contains requirements for base and filler materials fabricated under this standard.

5.2 General requirements. Base materials fabricated under this standard and filler materials used in welding shall be in accordance with tables I and II, respectively unless otherwise approved in accordance with 5.2.1.

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

Letter no.	Applicable document	Class or type
S-1	Carbon steel	
	ASTM A 216	WCB
	ASTM A 515	Grade 55 (plate) Grade 60 (plate) Grade 65 (plate) Grade 70 (plate)
	ASTM A 516	Grade 70 (plate)
	WW-P-404	Pipe seamless and welded
	MIL-S-15083	Grade 70-36 (cast) Grade 65-35 (cast) Grade CW (cast) Grade B (cast)
	MIL-T-16286	Class a (tube seamless) Class g (tube seamless)
	MIL-T-17188	Tubes welded
	MIL-S-24093	Forgings
	MIL-T-20157	Type E (tube and pipe)
	MIL-S-24412	Grade HT (shape)
	MIL-F-20236	Flanges, pipe
	MIL-F-20670	Flanges, pipe

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-1	Carbon steel	
	MIL-S-22698	Plate and shapes
	MIL-S-23194	Composition C (forgings)
	MIL-S-23284	Class 3 Class 4
	MIL-S-24238	Composition C (plate)
	MIL-P-24338	Pipe
	MIL-F-24339	Fittings and flanges
	ASTM A 234	Fittings
S-2	Quenched and tempered carbon steel	
	ASTM A 537	Class 2
S-3	Carbon molybdenum steel	
	MIL-S-870	CMo (cast)
	MIL-S-872	CMo class a (forgings) CMo class b (forgings)
	MIL-T-16286	CMo class d (tube)
	MIL-S-16974	CrNi type 8620 (bar and forgings)
	MIL-T-20155	CMo (tube and pipe)
S-3A	Alloy steels (Cr content not to exceed 3/4 percent, total alloy not to exceed 2 percent).	
	ASTM A 302	MnMo, grade B (plate)
	MIL-S-23194	Comp A, types Ia; Ib and II Comp C, type II
	MIL-S-24238	NiMnMo, comp A (plate)

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-4	Alloy steels (Cr content 3/4 percent - 2 percent, total alloy content 2-3/4 percent maximum)	
	AMS 6530	CrNiMo (tube)
	MIL-T-6736	CrMo, type 4130 (tube)
	MIL-S-8699	CrMoV, 4330 (bar, forging)
	MIL-S-15464	CrMo class 1 (casting)
	ASTM A 182	F11
	ASTM A 213	Grade T11 (tube)
	MIL-S-16974	CrMo type 4130 (bar)
	MIL-T-18165	CrMo class 1 (tube and pipe)
	MIL-S-18410	CrMo class a (forgings)
	MIL-S-18728	CrNiMo type 8630 (plate)
	MIL-S-18729	CrMo type 4130 (plate)
S-5	Alloy steels (total alloy content 10 percent maximum)	
	ASTM A 182	F22
	ASTM A 213	T22
	MIL-S-860	CrMoV, grade F (forgings)
	MIL-S-15464	CrMo class 2 (casting)
	MIL-T-16286	CrMo class e (tube)
	MIL-T-18165	CrMo class 2 (tube and pipe)
	MIL-S-18410	CrMo class b (forging)
	ASTM A 336	CrMo class F5 (bar and forgings)

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-6	High alloy steels (martensitic)	
	MIL-L-24128	403 (bars, rods, forgings)
	QQ-S-763	403 (bars, rods, forgings) 410 414 420
	ASTM A 176 ASTM A 240	410 and 410S (plate, sheet, strip)
	MIL-S-861	403 (bars) 410
	MIL-S-862	403 (bars) 410 414 420
	MIL-S-16993	12 percent Cr class 1 (casting) 12 percent Cr class 2 (casting)
2/S-6A	ASTM A 182 ASTM A 487	F6NM (forgings) CA6NM (castings)
	MIL-B-16993 MIL-C-24637	12 percent Cr, 4 percent Ni, class 3 (castings) 12 percent Cr, 4 percent Ni (castings, non-pressure)
S-7	High alloy steels (ferritic)	
	QQ-S-763	405 (bar, shapes, forgings) 430
	ASTM A 176 ASTM A 240	Annealed

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-8	High alloy steels (austenitic)	
	QQ-S-763	304 (bars, shapes, forgings) 304L 309 310 316 316L 321 347
	ASTM A 167 ASTM A 240	Annealed
	MIL-S-867	Class I (castings) Class II Class III
	MIL-P-1144	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 19-9 Composition B 19-10 Composition C 19-10
	MIL-S-23195	304 (bar and forgings) 304L 347 348
	MIL-S-23196	304 (plate, sheet, strip) 304L 347 348

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-8	High alloy steels (austenitic)	
	MIL-T-23226	304 (tube and pipe) 304L 347 348
	MIL-F-23467	304 (fittings and flanges) 304L 347 348
	ASTM A 744	CN-7M, CN-7MS (castings)
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	MIL-S-24645	HSLA-80 (plate and sheet)

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
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 ASTM B 209	5086 5456
	WW-T-700/5	5086 (seamless tube)

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-26	Aluminum and aluminum base alloys	
	QQ-A-601	B443 514 355 356
	MIL-A-21180	A 356 (castings)
S-31	Copper and copper base alloys	
	QQ-C-576	99.9 Cu (plate, bar)
S-32	Brass	
	QQ-C-390	Alloy C85700 (casting)
	QQ-B-637	Naval brass (alloy 464) (rod, bar, and forging)
	QQ-B-639	Naval brass alloy (rod, bar, and forging) Alloy 462 Alloy 464
S-33	Silicon bronze	
	QQ-C-390	Alloy C87200 (castings)
	QQ-C-591	Alloy 655 (rod, shapes, flats)
S-34	Copper nickel	
	MIL-T-15005	70/30 (tube) 90/10
	MIL-C-15726	70/30 (plate, bar, rod) 90/10
	MIL-T-16420	70/30 (tube) 90/10
	MIL-C-20159	C96400 C96200
	MIL-P-24342	70/30 (fittings and flanges)

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-35	Aluminum bronze	
	QQ-C-390	Alloy C95200 (castings)
	QQ-C-450	Alloy 606 (plate, bar) Alloy 612, 614
	QQ-C-465	(Rod, bar, plate, strip, flats and forgings) Alloy C60600 Alloy C61400 Alloy C64200
	MIL-C-15345	Alloy 13 (castings) Alloy 15
S-36A	Nickel-aluminum bronze	
	QQ-C-390	Alloy C95500 (castings)
	QQ-C-465	Alloy C63000 (bar, rod, plate, strip, forging)
	MIL-C-15345	Alloy 14 (castings) Alloy 15
	MIL-B-24480	Castings
S-36B	Manganese-nickel-aluminum bronze	
	MIL-B-21230	Alloy 2 (castings)

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-37A	Manganese bronze	
	QQ-B-728	Class A Class B
	QQ-C-390	Alloy C86100 Alloy C86200 Alloy C86300 Alloy C86400 Alloy C86500
S-37B	Nickel manganese bronze	
	QQ-C-390	Alloy C86800
S-38	Tin bronze	
	MIL-B-16541	Castings
	QQ-C-390	Alloy C90300 (castings) Alloy C90500 Alloy C90700 Alloy C92200 Alloy C92300 Alloy C92500 Alloy C94700 Alloy C94800
S-39	Phosphor bronze	
	QQ-B-750	Composition A Composition D
	MIL-T-3595	

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-42	Nickel-copper	
	QQ-N-281	NiCu, class A (bar, plate, rod, forging) Class B
	MIL-N-24106	NiCu, class A (bar, rods, forgings)
	QQ-N-288	NiCuSiCb, composition E (casting)
	MIL-T-1368	NiCu (tubing)
	MIL-T-23520	NiCu (tube and pipe)
	MIL-C-15345	NiCuSiCb, alloy 19 (casting)
	MIL-N-17163	NiCu (bar, rod, plate, forging, and so forth)
	MIL-F-23509	Fittings and flanges
S-43	Nickel-chromium-iron and nickel-chromium-molybdenum-columbium	
	MIL-F-23508	Fittings and flanges
	ASTM B 166	Rod and bar
	ASTM B 564	Forgings
	MIL-N-23227	Tube and pipe
	MIL-N-23228	Condition A (plate)
	MIL-N-23229	Condition A (hot worked and annealed)
	MIL-N-24271	Castings
	ASTM B 443	UNS N06625 (plate)
	ASTM B 444	UNS N06625 (pipe and tube)
	ASTM B 446	UNS N06625 (bar and rod)

See footnotes at end of table.

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

Letter no.	Applicable document	Class or type
S-43	Nickel-chromium-iron and nickel-chromium-molybdenum-columbium	
	MIL-C-24615	NiCrMoCb (casting)
3/S-51	Titanium and titanium alloys	
	ASTM B 337	Grade 1, 2, and 7 (pipe)
	ASTM B 338	Grade 1, 2, and 7 (tube)
3/S-53	Titanium alloys	
	MIL-T-9046	Type III, composition C (sheet, plate)
	MIL-T-9047	Composition 6 (bars, forgings)
	ASTM B 265	Grade 5 (sheet, strip, plate)
	ASTM B 367	Grade C5 (castings)

1/ If material of similar chemistry and mechanical properties not listed under an "S" group is to be used, it may be considered as a part of a group upon approval.
2/ Welding procedures utilizing this material require specific approval from NAVSEA.
3/ The use of titanium for applications covered by this standard requires specific approval from NAVSEA.

TABLE II. Grouping of filler materials (welding).1/6/

Group	Applicable document	Filler material type5/
A-1A	Low and medium carbon steel (covered electrodes)	
	QQ-E-450	6010 C6010 6011 C6011 6012 6013 6020 6027 7024

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
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	2/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-1
A-2C	Carbon and low alloy steel (bare electrode and flux)	
	MIL-E-18193 MIL-F-18251	MIL-A1 (wire) MIL-F1 (flux) MIL-F3 (flux)
	MIL-E-23765/1	MIL-70S-7 (wire) 3/MIL-70S-8 (wire) 3/MIL-70S-9 (wire) MIL-70S-1 (wire) MIL-70S-2 (wire) MIL-70S-3 (wire) MIL-70S-4 (wire) MIL-70S-5 (wire) MIL-70S-6 (wire) MIL-70S-F (flux)

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
A-2C	Carbon and low alloy steel (bare electrode and flux)	
	MIL-E-18193 MIL-F-19922 MIL-F-18251	MIL-B1 (wire) MIL-B20 (flux) MIL-B80 (flux) MIL-F2 (flux) MIL-F4 (flux)
	MIL-E-18193 MIL-F-19922	MIL-B2 (wire) MIL-B3 (wire) MIL-B5 (wire) MIL-B80 (flux)
A-2D	Low alloy steel (flux cored electrodes)	
	4/MIL-E-24403/1	MIL-70T-1 MIL-71T-1 MIL-70T-5 MIL-70T-6 MIL-70T-8 MIL-71T-8 MIL-71T-8A MIL-71T8-K6 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-1F (flux) MIL-80S-2 (wire) MIL-80S-2F (flux)

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).[1/][6/] - Continued

Group	Applicable document	Filler material type[5/]
A-3D	Carbon and low alloy steel (flux cored electrodes)	
	[4/]MIL-E-24403/1	MIL-80T1-Ni1 MIL-80T1-Ni2 MIL-81T1-Ni1 MIL-81T1-Ni2
A-4A	Low alloy, high-yield steel (covered electrodes)	
	MIL-E-22200/5	MIL-10018-N1
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-12018-M2
	MIL-E-22200/9	MIL-14018-M1
A-5B	Low alloy, high yield steel (bare electrode)	
	MIL-E-23765/2	MIL-100S-1 MIL-100S-2 MIL-120S-1
	MIL-E-24355	MIL-140S-1
A-5C	Low alloy, high strength 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) MIL-120S-1F (flux)

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
A-5D	Low alloy, high yield steel (flux cored electrode)	
	MIL-E-24403/2	MIL-100TC MIL-100TM MIL-100TS MIL-101TC MIL-101TM MIL-101TS MIL-110TC
A-6A	CrMo steel (1.0 to 2.5 percent Cr, 0.4 to 1.2 percent Mo) (covered electrode)	
	MIL-E-22200/8	MIL-80XX-B2L MIL-90XX-B3L
	AWS A5.5	E8018-B2L E9018-B3L
	MIL-E-8697	HT-4130
A-6B	CrMo steel (1.0 to 3.0 percent Cr, 0.4 to 1.2 percent Mo) (bare electrode, rod and insert)	
	MIL-I-23413	MIL-515 MIL-521
	AWS A5.23	EB2 EB3
	AWS A5.28	ER90S-B2L ER90S-B3L
A-7A	CrMo steel (4.0-13.5 percent Cr, 0-5.0 percent Ni, 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 NiMo-XX
A-7B	CrMo steel (4.0-13.5 percent Cr, 0-5.0 percent Ni, 0.4-1.4 percent Mo) (bare electrode, rod and inserts)	

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
A-7B-1	MIL-I-23413	MIL-505
A-7B-2	MIL-E-19933 AWS A5.9	MIL-410 ER410NiMo
A-7C	High alloy steel (ferritic) (chromium 15-18 percent) (covered electrode)	
	AWS A5.4	B430
A-7D	High alloy steel (ferritic) (chromium 15-18 percent) (bare electrode and rod)	
	AWS A5.9	ER-30
A-8A	High alloy steel (austenitic) (covered electrode)	
	MIL-E-22200/2	MIL-16.8.2-XX MIL-308-XX MIL-308L-XX MIL-308HC-X MIL-309-XX MIL-309Cb-XX MIL-310-XX MIL-312-XX MIL-316-XX MIL-316L-XX MIL-317-XX MIL-318-XX MIL-330-XX MIL-347-XX MIL-347HC-XX MIL-349-XX
	AWS A5.4	E320

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
A-8B	High alloy steel (austenitic) (bare electrode rod and insert)	
	MIL-E-19933	MIL-308 MIL-308L MIL-308HC MIL-309 MIL-310 MIL-312 MIL-316 MIL-316L MIL-317 MIL-318 MIL-321 MIL-347
	AWS A5.9	ER320
	MIL-I-23413 (inserts)	MIL-308 MIL-308L MIL-310 MIL-312 MIL-316 MIL-316L MIL-348
A-21B	Aluminum alloy (bare electrode, rod and insert)	
	AWS A5.10	1100
	AWS A5.10	ER 1100
	MIL-I-23413 (insert)	MIL-1100
A-22B	Aluminum alloy (bare electrode, rod and insert)	
	AWS A5.10	5183 5356 5554 5356 5654

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).[1/6/] - Continued

Group	Applicable document	Filler material type[5/]
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)	
	AWS A5.10	ER-4043
	MIL-I-23413 (inserts)	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	ERCu
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-CuSi
A-33B	Copper tin alloy (phosphor bronze) (bare electrode and rod)	
	MIL-E-23765/3	MIL-CuSn-C

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
A-34A	Copper nickel (covered electrode)	
	MIL-E-22200/4	MIL-CuNi (70/30)
A-34B	Copper nickel (bare electrode, rod and insert)	
	MIL-E-21562	MIL-EN67 MIL-RN67
	MIL-I-23413 (insert)	MIL-67
A-35B	Copper-zinc alloy (bare rod)	
	MIL-E-23765/3	MIL-CuSn-C
	AWS A5.27	RCuZn-B RCuZn-C RCuZn-D
A-36B	Copper aluminum alloy (aluminum bronze) (bare electrode and rod)	
	MIL-E-23765/3	MIL-CuAl-A2
A-37A	Copper aluminum alloy (aluminum bronze) (covered electrode)	
	MIL-E-278	MIL-E-CuAl-A MIL-E-CuAl-B MIL-E-CuAl-C MIL-E-CuAl-D MIL-E-CuAl-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)	
	MIL-R-17131	MIL-RNiCr-B MIL-RNiCr-C MIL-PNiCr-B-2 MIL-PNiCr-C-2

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
A-39A	Surfacing alloys (covered electrode)	
	AWS 5.13	ECoCr-A ECoCr-C
A-39B	Surfacing alloys (bare rod)	
	MIL-R-17131	MIL-RCoCr-A MIL-RCoCr-C MIL-PCoCr-E-1 MIL-PCoCr-E-2
A-41A	Nickel (covered electrode)	
	MIL-E-22200/3	MIL-4N11
A-41B	Nickel (bare electrode, rod and insert)	
	MIL-E-21562	MIL-EN61 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 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

See footnotes at end of table.

TABLE II. Grouping of filler materials (welding).1/6/ - Continued

Group	Applicable document	Filler material type5/
A-43B	Nickel base alloys (bare electrode, rod and inserts)	
	MIL-E-21562	MIL-EN62 MIL-RN62 MIL-EN82 MIL-RN82 MIL-EN6A MIL-RN6A MIL-EN625 MIL-RN625
	MIL-I-23413	MIL-62 MIL-82
A-44A	Nickel-cobalt alloys (covered electrodes)	
	MIL-E-22200/3	MIL-3N1B MIL-3N1C MIL-4N1W MIL-3N1N MIL-3N1L
A-51B	Titanium-unalloyed (bare electrode)	
	AWS A5.16	ER Ti-1 ER Ti-2 ER Ti-3
A-53B	Titanium base alloys (bare electrode)	
	AWS A5.16	ER Ti-6Al-4V ER Ti-6Al-4V-1

1/ If filler material of similar chemistry and mechanical properties is not listed under an A-group, it may be considered as a part of a group upon approval.
2/ To be also used for welding ordinary strength steel to HY-80 steel.
3/ To be used with neutral flux.
4/ Electrodes with an "HY" suffix are also suitable for welding ordinary or higher strength steel to HY-80 steel or to HY-100 steel.
5/ A filler material type containing an "X" in the designation allows various options; for example, "MIL-309-XX" permits "MIL-309-01, -02, or -03".
6/ Use of AWS filler material shall require compliance with 5.2.1 where the same military specification filler material type exists. If there is no military specification filler material type, conformance testing of each lot of electrode shall be accomplished in accordance with AWS A5.01. As a minimum, schedule J shall be employed. Test requirements shall be submitted for approval in accordance with 5.2.1.

5.2.1 Material substitution approval. Unless otherwise covered in the Government equipment specifications, materials acquired in accordance with AWS, ASTM, or ASME standards (or approved substitution material list) may be used for materials listed in tables I and II subject to the following provision:

(a) To ensure compliance to the governing material specification, quality assurance and inspection requirements shall be established by the contractor and submitted to NAVSEA or authorized representative for approval. After obtaining approval, the contractor shall invoke the requirements in purchase orders for materials or perform the required inspection upon receipt of material or prior to its use in fabrication.

5.2.2 Specification deviations. Unless otherwise covered in the Government specification, deviations from specification requirements of governing material specifications shall be submitted to NAVSEA or authorized representative for review and approval.

5.2.3 Exceptions. Approvals required by 5.2.1 and 5.2.2 will be granted only by NAVSEA when materials related to sections 13, 14, and 15 are involved.

5.3 Material inspection. In addition to the requirements of 4.1.2, material records shall be verified to assure conformance of the material with the applicable specifications. Verification shall be accomplished by checking mill or inspection reports against the applicable specification requirements and material marking, as applicable, against the material received. Additionally, for material supplied from a warehouse or jobber (not directly from the manufacturer), the user activity (construction) shall conduct periodic independent testing to establish reasonable confidence in the reliability of contractor test data in accordance with a written procedure. If the contractor's quality conformance inspection records are not available, the construction activity shall establish specification conformance of the material in accordance with a written procedure.

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

5.3.2 Filler material inspection. When specified in the contract or order, lot inspection test reports covering tests conducted by the manufacturer shall be verified by the contractor for conformance with specification requirements (see 16.7). If the manufacturer's quality conformance inspection records are not available, the construction activity shall establish specification conformance of the material.

6. WELDING REQUIREMENTS AND CONTROLS

6.1 General. This section contains the requirements or controls that are essential for ensuring satisfactory welds in machinery, piping, pressure vessels, and steam turbines hereinafter referred to as M, P, A, and T.

6.1.1 Gas metal-arc welding - short circuiting transfer (GMAW short arc) restriction. This process shall not be used unless approved otherwise for a specific application, on a case-by-case basis, by NAVSEA.

6.1.2 Non-structural welds such as name plates, clips and insulation supports on class P-1, PL-T, A-F, A-1, A-2, A-3, A-LT, T-1, and M-1 components shall be made by welders qualified for butt or fillet welds. These welds shall be inspected in accordance with section 10.

6.2 Welding processes and filler materials. Acceptable welding processes and compatible filler materials are shown in table III. Specific filler materials for steam service applications shall be in accordance with 6.2.5.1. Processes and materials not listed in table III and material not in accordance with 6.2.5.1 shall be permitted where applicable welding procedure qualification data are approved by NAVSEA and authorized for the particular production applications. Aluminum alloys shall be welded only by the inert gas metal-arc and the inert gas tungsten arc processes. The root pass of S-8 piping welds in which the reverse side of the weld cannot be visually examined and is exposed to water shall be welded with a gas shielded welding process.

TABLE III. Welding filler material chart.

Base metal	Welding processes and compatible filler material[1]						
	S number group	Shielded metal-arc	Submerged arc	Gas shielded processes (gas metal-arc, gas tungsten arc, and flux cored)	Oxygen acetylene	Insert materials	Plasma arc
Carbon-steel	S-1	A-1A, A-2A, A-3A	A-2C[6]	A-2B, A-3B, A-2D	A-1B	A-2B	
Quenched and tempered carbon-steel	S-2	A-2A, A-3A	A-2C A-3C	A-2B, A-3B, A-2D	--	A-2B	
Alloy steel (CR < 3/4 percent)	S-3 S-3A	A-2A[2], A-3A, A-6A[2/3]	A-2C A-3C	A-2B, A-3B	--	A-2B	
Alloy steel (Cr 3/4-2 percent)	S-4	A-6A[9]	A-6B[5]	A-6B	--	A-6B	
High alloy steel (alloy not > 10 percent)	S-5	A-6A[9] A-7A-1	A-6B[5]	A-6B	--	A-6B	
High alloy steel (martensitic)	S-6 S-6A	A-7A-2 A-7A-2[10]	A-7B-2[5], [11], [12] A-7B-2[5], [10], [12]	A-7B-2[11] A-7B-2[10]	--	-	
High alloy steels (ferritic)	S-7	A-7A-2	-	-	--	-	
(austenitic)	S-8[7]	A-8A[7]	A-8B[5]	A-8B[7]	--	A-8B	
Quenched and tempered alloy steel	S-11[13]				--	-	

See footnotes at end of table.

TABLE III. Welding filler material chart. - Continued

Base metal	Welding processes and compatible filler material[1/]						
	S number group	Shielded metal-arc	Submerged arc	Gas shielded processes (gas metal-arc, gas tungsten arc, and flux cored)	Oxygen acetylene	Insert materials	Plasma arc
Aluminum and aluminum-base alloys	S-21	-	-	A-21B	-	A-21B	
	S-22	-		A-22B	-	A-22B	
		-	-	A-22B	-	A-22B	
	S-25	-	-	A-22B	-	A-22B	
	S-26	-	-	A-23B, A-24B	-	-	
Copper and copper-base alloys	S-31	-	-	A-31B	A-31B	-	
	S-32	A-32A	-	A-32B	A-32B, A-35B	-	
	S-33	A-32A	-	A-32B	A-32B	-	
	S-34	A-34A	A-34B[5/]	A-34B	-	A-34B	
	S-35	A-37A	-	A-37B, A-36B	-	-	
	S-36A	A-37A[4/]	-	A-37B	-	-	
	S-36B	-	-	A-37B	-	-	
	S-37A	A-37A	-	A-36B, A-37B	A-35B	-	
	S-37B	A-37A	-	A-36B, A-37B	-	-	
	S-38	-	-	A-32B	A-35B	-	
	S-39	-	-	A-33B	-	-	
Nickel and nickel-base alloy	S-42	A-42A	A-42B[5/]	A-42B	-	A-42B	
	S-43	A-43A	A-43B[5/]	A-43B	-	A-43B	
Hardsurfacing	-	A-39A[8/]	-	A-38B, A-39B	A-38B, A-39B	-	A-38B A-39B
Titanium	S-51	-	-	A-51B	-	-	
Titanium alloy	S-53	-	-	A-53B	-	-	

See footnotes at top of next page.

1/ This table is intended to assist in selecting filler material for the various welding processes (see table II to identify "A" numbers).
2/ Electrodes of MIL-E-22200/7 only.
3/ When joining S-3 materials whose minimum tensile requirements are 80,000 lb/in^2.
4/ Not to be used for welding of MIL-B-24480.
5/ When used with flux in accordance with qualified procedure.
6/ Filler material A-2B is permitted when used with flux in accordance with qualified procedure.
7/ For welding CN-7M or CN-7MS material, E-320 and ER-320 filler materials should be used for SMAW and GMAW/GTAW, respectively.
8/ Deposition technique must yield a surface hardness of R_c 35 minimum.
9/ See 6.2.5.1.1.
10/ Type 410 NiMo only.
11/ For 410 and 410S steel only.
12/ Where approved by NAVSEA for the specific application.
13/ See 6.5.

6.2.1 Oxyacetylene restrictions. Except as permitted by 11.6, oxyacetylene or fuel gas welding processes shall not be used for welding on chromium-molybdenum (S-4, S-5), chromium alloy (S-6, S-7), chromium-nickel (S-8), quenched and tempered alloy steels (S-11) and aluminum or aluminum alloys (S-21, S-22, S-25 and S-26).

6.2.2 Class P material thickness limitation. The shielded metal arc process may be used for wall thickness of 0.109 inch or over when welded on board ship and 0.083 inch or over when welded in the shop. Other welding processes will be permitted for thinner walls on the basis of welding procedure qualification tests.

6.2.3 Covered electrodes for class P-1 carbon steel pipe. Class P-1 carbon steel pipe shall be welded with electrode types MIL-7018, MIL-7018-A1, MIL-7015 or MIL-7016 (A-2A) except when nominal wall thickness is 1/2 inch or less MIL-7010-A1 electrodes A-1A may be used.

6.2.4 Prohibited electrodes. Unless specifically approved, types MIL-6010, 6012 or 6013 electrodes of QQ-E-450 shall not be used for M, P, and A applications.

6.2.5 Selection of filler materials. Filler materials shall be selected for compatibility with the base material on the basis of chemical composition, mechanical properties, post weld heat treatment requirements, and component/system operating conditions and requirements. Tables II and III identify specifications in which guidelines may be found to assist in selecting compatible filler materials for more commonly used base materials.

6.2.5.1 Filler materials for steam service applications.

6.2.5.1.1 Ferritic and martensitic steel filler metals for the base materials commonly used in steam service applications shall be as follows:

Base material S-group no.	Filler metal A-group no.
For S-1 materials	- A-2A, A-2B, A-2D, A-1B, and A-1A (MIL-7010-A1 only as noted in 6.2.3)
For S-3 materials	- A-2A (MIL-7010-A1, 7011-A1, 7018-A1, and 7020-A1 only)
For S-3A materials	- A-3A, A-3B, A-3C
For S-4 materials	- A-6A (80XX-B2L only) A-6B (MIL-515, EB2, or ER80S-B2L only)
For S-5 materials	- A-6A (90XX-B3L only) A-6B (MIL-521, EB3, or ER90S-B3L only)
For S-6 and S-7 materials	- A-7A-2 or A-7B-2
For S-6A materials	- A-7A-2 (MIL-410-NiMo-XX only), A-7B-2

6.2.5.1.2 For welding of different combinations of the base materials as specified in 6.2.5.1.1, the welding filler metal shall be specified for either of the base materials involved except for covered electrodes, only the low hydrogen types XX-15, XX-16, and XX-18 shall be used with S-3A, S-4, S-5, S-6 and S-7 base materials.

6.2.5.1.3 For joining base materials under groups S-1, S-3, S-3A, S-4, S-5, S-6 and S-7 to base materials under group S-8, the following filler metals shall be used:

Nickel base alloys
A-43A (MIL-8N12 only)
A-43B (MIL-82, EN82 and RN82 only)

High alloy steel (austenitic)
A-8A (MIL-309-XX, MIL-309Cb-XX, and MIL-310-XX only)
A-8B (MIL-309 and MIL-310 only)

Where post weld heat treatment is required by component or equipment specifications, or where design service temperature exceeds 400°F, only the above listed A-43A or A-43B filler metals shall be used.

6.2.5.1.4 For surfacing applications to resist steam cutting, the filler metals specified in 6.2.5.1.3 may be used on base materials under groups S-1, S-3, S-3A, S-4, S-5, S-6 and S-7. Where subsequent post heat treatment of these base materials is required, only the MIL-8N12, EN-82 and RN82 filler metals shall be used.

6.2.6 Number of weld passes. Unless otherwise approved, no less than two layers shall be used for all pressure containing weld joints.

6.2.7 Weld root shielding. Inner root surface of all consumable insert type welds and all full penetration butt welds not employing a backing ring shall be shielded by inert gas. Internal purge shall be continued until after completion of the third layer or a thickness of 3/16 inch, whichever is greater. This requirement does not apply to P-2 type weld joints in P-2 piping systems of materials other than S-21 through S-26, S-51 and S-53, provided it can be demonstrated to the satisfaction of the authorized representative that the internal surface of the weld meets the visual requirements of NAVSEA 0900-LP-003-8000.

6.2.8 Age hardenable alloys. Welding of age hardenable alloys is subject to approval.

6.3 Preheat and interpass temperatures. Preheat and interpass temperatures shall be as specified in tables IV and V unless otherwise approved by welding procedure qualification.

TABLE IV. Preheat and interpass temperature for welded ferrous alloys.

Material group number	Material identification	Minimum preheat temperature °F 1/, 2, 3/	Maximum interpass temperature °F	Supplementary provisions for preheat and interpass temperature
S-1	Carbon steel	175	-	Where both carbon content in base metal is greater than 0.30 percent and thickness exceeds 1 inch
		60	-	For all other S-1 materials
S-2	Quenched and tempered carbon steel	60	300	Minimum preheat and interpass temperature for all thicknesses
S-3	Carbon molybdenum	175	-	Where either the specified minimum tensile strength is greater than 70,000 lb/in^2 or thickness is greater than 5/8 inch
		60	-	For all other S-3 materials
S-3A	Manganese molybdenum and NiMnMo	300	500	For all thicknesses
S-4	Chromium molybdenum steel	250	-	Where either the specified minimum tensile strength is greater than 60,000 lb/in^2 or thickness is greater than 1/2 inch
	Cr 3/4-2 percent	60	-	For all other S-4 materials
S-5	Chromium molybdenum steel Cr > 2 percent	400	-	Where either the specified tensile strength is greater than 60,000 lb/in^2 or has both specified chromium content greater than 6.0 percent and thickness greater than 1/2 inch
		300	-	For all other S-5 materials

See footnotes at end of table.

TABLE IV. Preheat and interpass temperature for welded ferrous alloys. - Continued

Material group number	Material identification	Minimum preheat temperature °F 1/, 2, 3/	Maximum interpass temperature °F	Supplementary provisions for preheat and interpass temperature
S-6 5/	High alloy steel martensitic	400	-	For all S-6 materials except as permitted below
		300	500	For 410 welded with 410NiMo
		200	500	For 410S welded with 410NiMo unless otherwise permitted below
		60 4/	500	For 410S welded by SMAW with 410NiMo, with 0.03C% maximum, or when using GMAW or GTAW for 410S with 410NiMo filler material
S-6A	High alloy steel martensitic	200	500	For all S-6A material except as permitted below
		60 4/	500	For thickness less than 1.5 inches; and SMAW with 410NiMo electrode with 0.03C% maximum or when using GTAW or GMAW and 410NiMo filler material
S-7	High alloy steel ferritic	-	-	Preheat is not mandatory - The preheat and interpass temperature used in qualifying the welding procedure shall be an essential element of that procedure, to be applied in production welding
S-8	High alloy austenitic steel	-	350	Preheat and interpass temperature shall not exceed 350°F for all S-8 materials except as provided for in footnote 2
S-11	-	-	-	See 6.5

1/ Where consumable inserts are used, preheat temperatures for GTA root welding (tacking and consuming the insert) can be the temperatures established in approved welding procedure qualification tests.

2/ Preheat and interpass temperatures for dissimilar metal welds, where specified temperatures for the different materials are not within the same range, shall be established by approved welding procedure qualification tests except as provided for in footnote 3.

3/ Where different combinations of S-1, S-3, S-3A, S-4, S-5, S-6, S-6A, and S-7 are welded, the preheat temperatures shall be the higher required for the materials involved except as provided for in footnote 1.

4/ These lower preheat temperatures are only permissible for SMAW when electrodes are specially procured to 0.03% maximum carbon content. Applicable welding procedures shall specify this requirement. Records required by 4.1.3 shall list the heat and lot number of all electrodes used with these lower preheat temperatures. A procedure for purchasing electrodes to this requirement and for segregating all such electrodes from high carbon content electrodes shall be developed by the activity and submitted for approval in accordance with 5.2.1 prior to use.

5/ The maximum interpass temperature for welding with all 410NiMo type filler materials shall be 500°F.

TABLE V. Preheat and interpass temperature for welded nonferrous alloys.

Material group number	Material identification	Minimum preheat temperature °F	Maximum interpass temperature °F	Supplementary provisions for preheat and interpass temperature 1/
S-21 S-22 S-26	Aluminum and aluminum base alloys	60	-	Preheating may be used to control distortion and prevent cracking providing the preheat and interpass temperature is supported by qualification tests. To prevent sensitization to corrosion in alloys 5086 and 5456 temperatures between 150°F and 400°F should be avoided.
S-33	Silicon-bronze	60	-	Preheating may be used to control distortion and prevent cracking providing the preheat and interpass temperature is supported by qualification tests.
S-34	Copper-nickel	-	350	Preheating is not required
S-35	Aluminum-bronze	300	-	--------
S-36A	Nickel-aluminum-bronze	-	-	Preheat is not mandatory. The preheat and interpass temperature used in qualifying the welding procedure shall be an essential element of that procedure to be applied in production welding.

See footnote at end of table.

TABLE V. Preheat and interpass temperature for welded nonferrous alloys. - Continued

Material group number	Material identification	Minimum preheat temperature °F	Maximum interpass temperature °F	Supplementary provisions for preheat and interpass temperature 1/
S-36B	Manganese-nickel-aluminum-bronze	-	-	Preheat is not mandatory. The preheat and interpass temperature used in qualifying the welding procedure shall be an essential element of that procedure to be applied in production welding.
S-37A	Manganese-bronze	300	-	Depending on welding process used, preheat and interpass temperature from 500°F to 800°F may be necessary to ensure crack-free weldments.
S-37B	Nickel-manganese-bronze	-	-	Preheat is not mandatory. The preheat and interpass temperature used in qualifying the welding procedure shall be an essential element of that procedure to be applied in production welding.
S-38	Tin-nickel-bronze	-	-	Preheat is not mandatory. The preheat and interpass temperature used in qualifying the welding procedure shall be an essential element of that procedure to be applied in production welding.
S-39	Phosphor-bronze	-	-	Preheat is not mandatory. The preheat and interpass temperature used in qualifying the welding procedure shall be an essential element of that procedure to be applied in production welding.
S-42	Nickel and nickel base alloys	-	350	Preheating is not required.
S-43	Nickel-chromium-iron	-	350	Preheating is not required.

See footnote at end of table.

TABLE V. Preheat and interpass temperature for welded nonferrous alloys. - Continued

Material group number	Material identification	Minimum preheat temperature °F	Maximum interpass temperature °F	Supplementary provisions for preheat and interpass temperature 1/
S-51 S-53	Titanium and titanium alloys	60	-	Preheat is not mandatory. The preheat and interpass temperature used in qualifying the welding procedure shall be an essential element of that procedure to be applied in production welding.

1/ Preheat and interpass temperatures for dissimilar metal joints shall be those established by welding procedure qualification tests and approval.

6.3.1 Methods of preheating and interpass temperature control. Preheat may be applied by any method which ensures uniform temperature of the joint to be welded. Cyclic heating and severe temperature gradients in the welding area shall be avoided. Interpass temperature shall be controlled by:

(a) Proper placement of preheat elements and control of power input.
(b) Proper welding sequences.
(c) Proper distribution of welders.

Welding operations shall be shielded from wind and inclement weather until the weldment has cooled to within ambient temperature plus 50°F, unless post weld stress relieving is required and is to be performed immediately upon completion of welding. Where gas torch flame is used for low temperature preheating, there shall be no condensation in way of welding.

6.3.2 Verifying temperatures. Preheat and interpass temperature shall be verified by periodic checks using such indicating devices as crayons or electrical potentiometers. Use of low melting metallic alloys for temperature measurement is prohibited. Crayon marks shall be located a minimum of 1 inch away from the weld area.

6.4 Postheating. Unless otherwise approved, postheat of welded joints to relieve stresses and to improve the metallurgical and corrosion resisting properties of the heat affected zone shall be performed in accordance with table VI (ferrous alloy materials), section 8, and 6.4.1 through 6.4.4 (nonferrous alloys). For dissimiliar thicknesses, post weld heat treatment shall be based on the thicker member. Holding time at temperature shall be based on weld metal thickness, including reinforcement.

TABLE VI. Post heat requirements for welded ferrous alloys.

Applicable supplementary provisions and exceptions					
Material group number	Material identification[1/]	Holding temperature °F[2/, 3/]	Machinery class M[1/]	Pressure vessels, turbines classes A-F, A-LT, A-1, A-2, A-3, A-4, T-1 and T-2	Piping class P
6/[4/] S-1	Carbon steel	1100-1250	Thermal stress relief shall be performed where required for dimensional stability.	Thermal stress relief is required for all carbon steel pressure vessel classes except it is not mandatory for classes A-3 and A-4 of weld thickness 3/4 inch and less provided (a) that carbon is less than 0.35 percent, (b) there are no nozzles with finished inside diameter greater than 2 inches or connections forming ligaments that require increase shell or head thickness, (c) that if cellulose coated electrodes are used the joints shall be preheated to 200°F minimum and this preheat maintained during welding.	Thermal stress relief required when one or more of the following conditions apply: (a) Carbon content is over 0.35 percent. (b) Weld thickness is in excess of 3/4 inch. (c) Joints 2-1/2 inches nominal pipe size (nps) and larger are welded with cellulose coated electrodes and the preheat or interpass temperature was below 200°F.
S-2	Quenched and temper carbon steel	1000-1050	Thermal stress relief shall be performed where required for dimensional stability.	Thermal stress relief is required for all classes without exception.	Not applicable.

See footnotes at end of table.

TABLE VI. Post heat requirements for welded ferrous alloys. - Continued

Applicable supplementary provisions and exceptions					
Material group number	Material identification 1/	Holding temperature °F 2/, 3/	Machinery class M 1/	Pressure vessels, turbines classes A-F, A-LT, A-1, A-2, A-3, A-4, T-1 and T-2	Piping class P
6/ 4/ S-3	Carbon molybdenum alloy steels chromium <3/4 percent	1100-1250	Thermal stress relief mandatory should S-3 be used to fabricate class M machinery parts.	Thermal stress relief is mandatory for Mn-Mo steel welded fabrication in all classes; it is not mandatory for class A-3 when carbon-molybdenum steel is welded in thicknesses up to and including 5/8 inch. Thermal stress relief is required for all thicknesses over 5/8 inch except that it is not mandatory for nonpressure type attachment welds to pressure parts when the latter's carbon does not exceed 0.25 percent, and fillet welds that have throats 1/2 inch and less in thickness are used.	Thermal stress relief required for welded carbon-molybdenum piping only when one or more of the following apply: (a) carbon is over 0.25 percent, (b) wall thickness is in excess of 5/8 inch, (c) pipe size exceeds 4 inches maximum nominal outside diameter.
6/ S-3A	Mn-moly	1100-1175			

See footnotes at end of table.

TABLE VI. Post heat requirements for welded ferrous alloys. - Continued

Applicable supplementary provisions and exceptions					
Material group number	Material identification 1/	Holding temperature °F 2/, 3/	Machinery class M 1/	Pressure vessels, turbines classes A-F, A-LT, A-1, A-2, A-3, A-4, T-1 and T-2	Piping class P
6/ 7/ S-4	Alloy steel (Cr content 3/4 - 2 percent, total alloy content 2 - 3/4 percent maximum)	1250-1375	Thermal stress relief mandatory should S-4 materials be used to fabricate class M machinery parts.	Thermal stress relief required. No exceptions. All attachments or parts welded thereto shall be stress relieved.	Except as specified in footnotes 5 and 7, thermal stress relief is required when any one of the following apply: (a) carbon content is over 0.15 percent, (b) wall thickness is in excess of 5/8 inch, (c) pipe size exceeds 4 inches maximum nominal outside diameter, (d) preheat and interpass temperature was below 250°F.
6/ 7/ S-5	Alloy steel (total alloy content 10 percent maximum)	1350-1400	Thermal stress relief mandatory should S-5 materials be used to fabricate class M machinery parts.	Thermal stress relief required. No exceptions. All attachments or parts welded thereto shall be stress relieved.	Except as specified in footnotes 5 and 7, thermal stress relief is required when any one of the following apply: (a) carbon content is over 0.15 percent, (b) chromium content is over 2.75 percent, (c) wall thickness is in excess of 5/8 inch, (d) pipe size exceeds 4 inches maximum nominal outside diameter, (e) preheat or interpass temperature was below 300°F.

See footnotes at end of table.

TABLE VI. Post heat requirements for welded ferrous alloys. - Continued

Applicable supplementary provisions and exceptions					
Material group number	Material identification 1/	Holding temperature °F 2/, 3/	Machinery class M 1/	Pressure vessels, turbines classes A-F, A-LT, A-1, A-2, A-3, A-4, T-1 and T-2	Piping class P
S-6	High alloy steel martensitic	1250-1400 9/ 1100-1150 10/ 1st: 1225-1275 2nd: 1100-1150	Thermal stress relief mandatory should S-6 materials be used to fabricate class M machinery parts.	Thermal stress relief required. No exceptions. All attachments or parts welded thereto shall be stress relieved.	Thermal stress relief required for welds in all sizes of piping.
S-6A	High alloy steel martensitic	8/ 1100-1150	Thermal stress relief mandatory should S-6A materials be used to fabricate class M machinery parts.		
S-7	High alloy steel ferritic	1350-1425	Thermal stress relief mandatory should S-7 materials be used to fabricate class M machinery parts.	Thermal stress relief required. No exceptions. All attachments or parts welded thereto shall be stress relieved.	Thermal stress relief required for welds in all sizes of piping.

See footnotes at end of table.

TABLE VI. Post heat requirements for welded ferrous alloys. - Continued

Applicable supplementary provisions and exceptions					
Material group number	Material identification 1/	Holding temperature °F 2/, 3/	Machinery class M 1/	Pressure vessels, turbines classes A-F, A-LT, A-1, A-2, A-3, A-4, T-1 and T-2	Piping class P
S-8	High alloy austenitic	-	Weldments of austenitic corrosion resistant steel shall not be post-weld heat treated unless otherwise specified herein or in the controlling component specification. Annealing or solution treating of austenitic corrosion resistant steel shall be done only for putting precipitated carbides back into solution and only for those weldments that can be entirely water quenched immediately after heating. When such heat treatment is required, the weldment shall be heated to a temperature of between 1950 and 2050°F, held at that temperature for 1 hour for each inch or fraction thereof of thickness at the thickest part, and then the entire weldment shall be water quenched. Post weld heat treatment of CN-7M or CN-7MS stainless steel castings is required to restore the corrosion resisting properties of the material. Heat treatment shall consist of heating the casting to 2050°F minimum, hold for sufficient time to heat the casting to temperature, and then quench in oil or water. However, post weld heat treatment is not required for welding on the non-wetted surface (casting surface which is not exposed to sea water) where such welding can be accomplished without causing any portion of the wetted surface to be heated to a temperature exceeding 800°F.		
S-11	Low alloy quenched and tempered	-	See 6.5		

See footnotes at top of next page.

1/ Materials used in the fabrication of machinery components and not covered in this table shall be stress relieved in accordance with the conditions established by approved welding procedure qualification tests.

2/ For quenched and tempered or normalized and tempered alloys, stress relief temperatures shall not exceed base metal tempering temperatures and, in general, should be approximately 50°F below tempering temperature.

3/ Minimum holding time at temperature shall be 1 hour per inch of thickness. For thicknesses less than 1 inch, the holding time shall be proportional to the thickness but not less than 30 minutes.

4/ When it is impractical to post-weld heat treat at temperatures specified in table VI, it is permissible to use lower temperatures for longer periods of time as follows:

Temperature decrease below specified temperature °F	Minimum holding time at decreased temperature, hours per inch of thickness
50	2
100	3
150	5
200	10

5/ Where carbon content of pipe or fitting exceeds 0.15 percent but is not greater than 0.20 percent, stress relief is not required for socket welds 2 inches nps and under, provided welding is done with the low carbon type electrodes (80XX-B2L for 1-1/4 Cr-1/2 Mo; and 90XX-B3L for 2-1/4 Cr-1 Mo).

6/ The post weld thermal stress relief requirement of the ASME Code, sections I and VIII, as applicable, may be used provided the holding temperature ranges specified in this table are used. The table selected shall be used in its entirety, exclusive of the others.

7/ Stress relief is not required for the following welds in 2-1/4 Cr-1 Mo and 1-1/4 Cr-1/2 Mo boiler superheaters when welded in accordance with NAVSEA 0951-LP-031-8010 or NAVSEA 0951-LP-038-6030, as applicable, using low carbon (0.05 maximum carbon content) filler materials:

(a) External superheater tube-to-header welds of NAVSEA 0951-LP-038-6030 figure 7-2 and repairs to these welds which are no deeper than maximum design weld joint depth.

(b) Internal superheater tube-to-header "seal" welds which have a maximum groove depth, before welding, of 1/4 inch or less, where tubes are fully rolled into the header prior to welding. For the purpose of this requirement, groove depth shall be determined at the location of minimum counterbore depth.

(c) Weld repairs to internal superheater tube-to-header "seal" welds which extend no deeper below the header inside surface than "b" above.

(d) Tube plug seal welds of 1/4-inch maximum throat thickness.

(e) Handhole plate seal welds of 5/16-inch maximum throat thickness where handhole plates are entirely secured by an integral threaded system.

Omission of stress relief for any other welds (that is, internal tube-to-header "seal" welds of greater than 1/4-inch groove depth, tube hole repairs, minor header repairs, and so forth) shall require specific approval by NAVSEA.

8/ Part must be cooled to ambient temperature before final heat treatment. Minimum hold time at temperature shall be 2 hours. Above 2 inch thickness add 1 hour for each additional inch, or fraction, of thickness. A double temper heat treat cycle with 1250 ± 25°F for the first temper is permissible. The final temper shall be 1125 ± 25°F. Minimum hold time for each temper shall be 2 hours plus 1 hour for each inch, or fraction, of thickness over 2 inches.

9/ This holding temperature shall be used for 410 or 410S steel welded with 410NiMo weld metal. Part must be cooled to ambient temperature before final heat treatment. Minimum hold time at temperature is 4 hours. Above 4 inches add 1 hour for each additional inch, or fraction, of thickness. Separate welding procedure qualification using these temperatures is required; HAZ toughness testing shall be performed.

10/ An alternate double temper heat treat cycle for 410 or 410S steel welded with 410NiMo weld metal. Part must be cooled to ambient temperature before 1st and 2nd parts of heat treat cycle. Minimum time at temperature for each part of heat treat cycle is 2 hours. Above 2 inches add 1 hour for each additional inch, or fraction, of thickness. Separate welding procedure qualification using these temperatures is required.

6.4.1 Nickel alloys. Postweld heat treatment of the following nonferrous alloys shall not be performed unless it is necessary for dimensional stability, in which case temperatures shall be as indicated:

Materials	Holding temperatures °F	Holding time
Nickel-copper alloy (S-42)	1150 ± 25	1 hour per inch of thickness. For thicknesses less than 1 inch, the holding time shall be proportional but not less than 30 minutes.
Copper-nickel alloy (S-34)	575 ± 25	
Nickel-chromium-iron (S-43)	1650 ± 25	

NOTE: Weldments to be post-weld heat treated shall not contain weld deposits made with electrode type 3N10 or 8N10 of MIL-E-22200/3. Precipitation hardened nickel-copper weldments shall not be stress relief heat treated. Copper-nickel alloy welded with copper-nickel or nickel-copper filler materials may be stress relief heat treated for dimensional stability (subject to the prohibitions against types 3N10 and 8N10 electrodes).

6.4.2 Aluminum alloys. Post-weld heat treatment shall not be performed on wrought aluminum alloys.

6.4.3 Alloys not specifically covered. Post-weld heat treatment of alloys not covered by this standard shall be considered for approval on the basis of the qualification tests where such post-weld heat treatment is an essential element of the welding procedure.

6.4.4 Age hardenable alloys. Where the specified aging heat treatment cannot be performed or where filler metals are used that do not respond to aging heat treatment, a design review shall be performed to ensure that the weldment satisfies design requirements and NAVSEA approval for repair shall be obtained.

6.4.5 Copper alloys. In general, copper alloy castings do not require post-weld heat treatment to improve corrosion resistance. An exception to this is nickel-aluminum bronze in accordance with MIL-B-24480, where a post-weld temper anneal heat treatment is required if the weld is made on any surface exposed to seawater or where the heat-affected zone extends to within 1/4 inch of this surface. Post-weld heat treatment is not required for non-seawater applications. When required, temper annealing shall consist of holding the casting at 1250 ± 25°F for 6 hours minimum, followed by air cooling.

6.5 Special requirements for welding and forming high yield low alloy steels. Welding and forming of high yield alloys (HY-80 or HY-100) and STS shall be in accordance with MIL-STD-1688 or MIL-STD-1689 as applicable. Welding and forming of S-11B materials shall be in accordance with MIL-STD-1681. Welding and forming of S-11C materials shall be in accordance with MIL-STD-1689.

6.6 Electrode handling and storage.

6.6.1 General. Welding electrodes, including covered types and bare spooled electrode (wire form) shall be handled so as to prevent damage. Where containers show evidence of damage, their contents shall be examined and electrodes with cracked or flaked-off coatings, or damaged spools of filler metal shall not be used for production welding. Covered electrodes and bare electrodes (wire form) and rods shall be stored under clean dry conditions to prevent damage from contamination, moisture, or water.

6.6.1.1 Covered electrodes (excluding MIL-types 9018, 10018, 11018, 12018, 10018-N1, and 410NiMo). Low hydrogen types, including ferritic, austenitic and nonferrous alloy types, except MIL-types 9018, 10018, 11018, 12018, 10018-N1, and 410NiMo or similar AWS or ASTM types (see 6.6.2) shall be used within 9 hours after removal from hermetically sealed containers or holding oven. The holding oven shall be a vented type and a temperature of 150 to 350°F shall be maintained. Electrodes exposed to ambient conditions for more than 9 hours after removal shall be held for at least 8 hours at 150 to 350°F in a vented oven prior to reissue.

6.6.2 Conditioning electrodes (MIL-types 9018, 10018, 11018, 12018, 10018-N1, and 410NiMo. Electrode MIL-types 9018, 10018, 11018, 12018, 10018-N1, and 410NiMo shall be conditioned in accordance with 6.6.2.1 through 6.6.2.4.

6.6.2.1 Exposed electrodes. Electrodes removed from holding ovens or hermetically sealed containers shall not be used if they are exposed to the atmosphere for more than 5 hours. Electrodes which have been exposed for more than 5 hours shall be stored in the holding oven for at least 8 hours or baked in accordance with 6.6.2.3. Electrodes which meet the moisture and moisture resistance requirements as specified in MIL-E-22200/10 may be used for a period of 9 hours without baking.

6.6.2.2 Storage in holding ovens. Electrodes should be stored in holding ovens upon opening the hermetically sealed containers. Electrodes which have been baked shall be transferred to holding ovens before cooling to 150°F. The temperature of the holding oven shall be 225 to 300°F.

6.6.2.3 Baking. Electrodes shall be conditioned by baking at temperatures of 800 ± 50°F (625 ± 25°F for MIL-410NiMo-XX) for 1/2 to 1 hour in a forced convection or circulation oven. The oven temperature at time of loading shall not exceed 300°F and the electrodes should be spread in thin layers on trays. During baking, the temperature shall not be raised more than 300°F for each hour when oven temperatures are 500°F and above. Ovens should be automatically controlled and calibration shall be checked periodically at intervals of not more than 6 months.

6.6.2.3.1 Rebaking. Rebaking of electrodes is permitted, provided tests are performed on each electrode brand to confirm that the number of rebaking cycles to be used does not adversely affect weld deposit quality in accordance with governing specification requirements.

6.6.2.4 Moisture test. Moisture test of electrode coatings at the jobsite is not required.

6.6.3 Submerged arc granular flux for general welding.

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

6.6.3.2 Reuse. Except as specified in 6.6.4, unfused granular flux may be reused subject to the following conditions:

(a) Flux shall be collected from clean, dry work pieces.
(b) Flux should be mixed with new flux.

6.6.4 Submerged-arc granular flux for welding high hardenable alloys.

6.6.4.1 Preparation for use. Prior to the start of any welding operation, granular flux shall be heated to 250°F minimum and used while warm to the touch. Flux shall be heated in clean, uncoated metal containers. Requirements for flux for S-11A and S-11C materials shall be in accordance with MIL-STD-1689 or MIL-STD-1688 as applicable.

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

(a) Flux shall be collected from clean, dry work pieces.
(b) Flux should be mixed with approximately 50 percent new flux.
(c) If flux is not warm to the touch, it shall be reheated to 250°F minimum.

7. WORKMANSHIP REQUIREMENTS

7.1 General. This section contains the minimum requirements for workmanship practices and methods to ensure sound welded joints.

7.2 Cleaning prior to and during welding. The joint members to be welded, including the base metal surfaces, shall be cleaned to remove foreign material for a minimum of 1 inch from the weld edge. Mill scale or metallic oxides shall be removed from surfaces on which weld metal will be deposited. Slag shall be removed from all weld metal surfaces prior to depositing subsequent passes or layers and upon completion of the weld.

7.2.1 Seal welding in areas having threaded connections. Threads in the seal weld and inspection areas of threaded connections shall be removed prior to welding and subsequent inspection.

7.3 Peening of welds. Welds may be peened to help control distortion, to relieve stresses, or to improve weld quality. When peening is performed on weld layers subject to nondestructive evaluation, all visual evidence of peening or smeared metal shall be removed. Peening of the first or last layer of pipe welds shall not be performed. Peening shall be performed using a round or blunt nosed tool of circular or oblong cross section. Welds shall not be overpeened, causing flaking and laps or reducing the cross section of the adjacent base metal. Surface slag, slag inclusions, cracks, porosity, and other weld defects shall be removed prior to peening.

7.4 Butt welds. Butt welds shall be as follows:

(a) Welds shall have complete penetration, when required, for the full length. Undercutting, overlapping, and sharp-ridged or deep-valleyed surface conditions shall be avoided. The reinforcement need not be removed except as required to meet reinforcement requirements. Where nonremovable backing strips are used, such strips are not considered to be weld reinforcements.

(b) Before applying weld metal on the reverse side of double welded joints, the joint shall be prepared for welding by chipping, grinding, machining, or arc-air gouging to remove all unsound weld metal, except as permitted in section 9. Proper contouring and cleaning shall be achieved as preparation for sound reverse root welding (see 9.3.2.1.1).

7.5 Thermal cut surfaces. Thermal cut surfaces for welding shall meet the acceptance standards of 11.3 and NAVSEA 0900-LP-999-9000.

7.6 Alignment of joint members. Joints shall be fitted and aligned in position. Tack welds or mechanical devices may be used to retain the alignment during welding. Tack welds shall be removed by suitable methods so that they do not become part of the welded joint unless they are made using approved welding procedures and meet the requirements of 10.3.8.

7.7 Repair of weld defects. Weld defects, defined herein as unacceptable and detected by visual test (VT) or NDT methods, shall be removed and repaired only to the extent necessary to render the area acceptable. All visual evidence of arc-strikes, weld or MT prod, shall be removed by grinding and repaired if necessary to meet minimum thickness requirements. Arc-strikes which reduce metal thickness below the minimum design requirement shall be repair welded. Discoloration on metal surfaces due to MT inspection shall be disregarded. Excavations resulting from defect removal shall not require repair welding unless the depth and extent of the excavation exceeds the allowable depth and extent of acceptable weld undercut allowed by NAVSEA 0900-LP-003-8000 for the class of welding, or unless any portion of the excavation reduces the remaining metal thickness below the minimum design thickness for the part or weldment.

7.7.1 Excavations not requiring repair welding shall blend smoothly and gradually with the adjacent weld metal or base material. Excavations not requiring repair welding shall be magnetic particle test (MT) or PT examined if MT/PT inspection is a requirement for the class of welding.

7.7.2 Excavations requiring repair welding shall be MT/PT examined or visually examined at 5X magnification, prior to repair welding, if MT/PT inspection is a requirement for the class of welding. Excavations requiring repair welding shall be welded only to the extent necessary to restore minimum design thickness or to achieve a condition equivalent to acceptable depth and extent of weld undercut. Repair welds of excavations, if required, shall be inspected by the same NDT method as the original weld. Except where the repair welded excavation of previously accepted radiographed or ultrasonically tested welds does not exceed 3/16 inch or 20 percent of the base metal thickness, whichever is less, the repair may be MT/PT inspected in lieu of radiographic testing (RT) or ultrasonic testing (UT). The total thickness, repair weld plus base metal, shall be used for determining the approved acceptance criteria.

7.8 Marking. Marking of welds for identification purposes, such as may be required in mapping of joints, record keeping, and establishing responsibilities for workmanship and quality of welding, shall be done preferably with an electro-etch pencil or vibro-tool method. Where it may be necessary to retain identification markings and the electro-etch pencil or vibro-tool methods are inadequate due to application of paint or other coatings which may tend to obliterate such marking, the low-stress round-bottom impression stamping method may be used in lieu of vibro-tool or electro-etch methods. Where the stamping method is used, impressions should be placed on the thicker joint member, such as fittings in piping systems or the lowest stressed surfaces of other classes of welding. Pipe and tubing shall not be stamped. The maximum allowable depth of the impression shall be 0.01 inch and the impression tool shall be in accordance with the following requirements:

Character size (inches)	Minimum character face radius (inches)
1/16	0.005
3/32	0.006
1/8	0.007
3/16	0.008
1/4	0.010

The depth of the impressions shall not reduce material thickness below the minimum thickness required by design. Marking shall be located so as not to interfere with interpretations of radiography.

7.9 Defect removal. Defects, whether from weld or base material, may be removed by grinding, machining, or filing with clean tools. The removal process shall not deposit iron, lead or other deleterious contaminents on the surface of corrosion resistant material. If weld repair is not required to meet minimum thickness specifications the excavation shall be blended smoothly into the adjacent material.

8. POST WELD HEAT TREATMENT

8.1 General. Unless otherwise specified in the qualified welding or heat treatment procedure, post-weld thermal stress relief heat treatment shall be performed in accordance with table VI, 6.4.1 through 6.4.3 and this section.

8.2 Special requirements.

8.2.1 Dissimilar metal joints. When parts of two different S-number groups are joined by welding, the post-weld heat treatment temperatures shall be selected on the basis of preserving the mechanical properties of the more critical of the two materials for the application concerned.

8.2.2 Post-weld heat treatment for different thicknesses of plate in pressure vessels. When the welded joint connects parts of pressure vessels that are of different thicknesses, the thickness to be used in applying the requirements for post-weld heat treatment shall be as follows:

(a) The thinner of two adjacent butt-welded plates including head to shell connections.
(b) The thicker of the shell or head plate in connections to intermediate heads.
(c) The thickness of the shell in connections to tube sheets, flat heads, covers, or similar constructions.
(d) The thickness of the shell or head plate in nozzle attachment welds.
(e) The thickness of the nozzle neck at the joint in nozzle neck to flange connections.
(f) The thickness of the pressure part, at the point of attachment, where a nonpressure part is welded to a pressure part.

8.3 Ferrous material. Post-weld heat treatment for ferrous materials shall be in accordance with table VI.

8.4 Nonferrous material. Post-weld heat treatment for nonferrous materials shall be in accordance with 6.4.1 through 6.4.3.

8.5 Post-weld heat treatment procedures (furnace).

8.5.1 Loading temperature. The furnace temperature shall not exceed 800°F at the time weldment is placed in it.

8.5.2 Rate of heating. The rate of heating above 800°F shall be not more than 400°F per hour divided by the maximum metal thickness of the component or vessel in inches, but in no case more than 400°F per hour (see 8.5.7).

8.5.3 Temperature variation during heating and cooling cycles. During the heating and cooling period, the portion of the weldment being heated shall not vary more than 250°F between the highest and lowest reading.

8.5.4 Holding temperature variation. Holding temperature shall be considered the mean between the highest and the lowest thermocouple readings. Thermocouple readings shall be within the temperature ranges specified for the materials involved: table VI for ferrous materials, nickel alloys (see 6.4.1), and other alloys as approved. During the holding time at the specified stress-relieving temperature, the maximum temperature difference between any two points on the weldment shall not exceed 100°F.

8.5.5 Preventing oxidation and distortion. During the heating and holding periods the furnace atmosphere shall be controlled to minimize surface oxidation. Flame shall not impinge directly on the weldment for which support shall be provided if required to minimize sagging due to their weight and the effect of high temperatures.

8.5.6 Rate of furnace cooling. Except for materials that are quenched from post-weld heat treatment temperatures, cooling above 800°F shall be done in a closed furnace or cooling chamber at a rate not greater than 200°F per hour. From 800°F, vessel or component may be cooled in still air provided it is protected from inclement conditions and drafts (see 8.5.7).

8.5.7 Special considerations (heating or cooling rates). The rates of heating and cooling need not be less than 100°F per hour. However, consideration of closed chambers and complex structures may indicate the need to reduce loading temperatures and rates of heating and cooling to avoid structural damage due to excessive thermal gradients.

8.5.8 Post-weld heat treatment of titanium and titanium alloys shall be performed in accordance with MIL-H-81200.

8.6 Post-weld heat treatment procedures (local).

8.6.1 Heating method. Post-weld heating shall be accomplished by electric inductance or electrical resistance devices, or other approved local heating methods.

8.6.2 Heating rate, holding temperature variation, and cooling rate. The heating rate of localized heating shall not exceed 40°F per 5-minute period. Holding temperature variation and rate of cooling shall be in accordance with 8.5.4 and 8.5.6 respectively.

8.6.3 Postheating piping welds. The width of circumferential band to be heated shall be at least equal to 3 times the wall thickness, but in no case less than 1-1/2 times the width of the weld face, on each side of the joint. Where a pipe is welded to a valve, the width of the heated zone may be decreased on the valve side to a minimum distance, measured from the edge of the weld, equal to the width of the weld face.

8.6.4 Postheating pressure vessels. Circumferential welded joints may be heat treated by uniformly heating a circumferential band having a minimum width of 6 times the material thickness on each side of the joint. Nozzles or other welded attachments for which post-heat treatment is required may be treated by locally heating a circumferential band around the entire vessel with the connection at the center of the band. The band width shall be a minimum of 6 times the material thickness on each side of the attachment. Local postheat treatment for applications other than those listed above will not be permitted without approval by the contracting activity of the detailed procedure.

8.7 Postheating repaired welds in pressure vessels and piping. Unless otherwise approved, vessels or parts of vessels and piping that have been heat treated in accordance with section 8 shall again be postweld heat treated after repair or alterations have been made.

8.8 Temperature measuring methods.

8.8.1 Pyrometric equipment. Pyrometric recording equipment shall be provided to indicate the temperature of the weldment and not the furnace except as specified in 8.8.4. The average of the observed temperatures of the weldment is considered to be the temperature of the weldment provided all observed temperatures are within the temperature range specified in table VI.

8.8.2 Locating thermocouples. Thermocouples shall measure the temperature at the anticipated hottest point on the weldment and at the anticipated coolest point. The number of thermocouples provided shall assure complete coverage of the weldment and adequate temperature history. If more than one weldment is to be stress relieved at the same time, thermocouples shall be attached to each weldment. In no case, however, shall more than six thermocouples be required for a furnace charge. For local heating operations, not less than two thermocouples shall be attached to the weldment. When only two thermocouples are used, they shall be separated by a distance equal to 3 times the width of the weld reinforcement with the weld centered between them. For flange to pipe joints, one thermocouple shall be attached to the flange side of the joint.

8.8.3 Installing thermocouples. Thermocouple wires shall be electrically insulated except at their hot junctions. In order to avoid erroneous readings, thermocouples shall be so arranged that flames do not impinge on the junctions of the wires themselves. When the electrical resistance heating method is used, the thermocouple provided to control the operation shall be covered by a protective wrapping to prevent direct radiation of the heating elements on its hot junction. Thermocouples shall be attached to the weldment by a method which ensures that the thermal junction is held firmly.

8.8.4 Pyrometrically controlled furnaces. For furnace stress relief of weldments, when a recording pyrometric control furnace has been calibrated and it is verified that the temperature variation within the furnace is within the stress relieving temperature range for the materials involved, the furnace control thermocouples may be used as the indication of the temperature of the part being treated in lieu of thermocouples attached to the component.

9. DESIGN REQUIREMENTS FOR WELDED JOINTS

9.1 General. This section contains the minimum requirements for the design of welded joints for machinery, piping, pressure vessels, and turbines (M, P, A and T). Piping schedules and fabrication details for specific piping systems of surface ships and submarines are covered in MIL-STD-777 and MIL-STD-438 respectively. Within this document design group classifications consist of butts, tees, corners and partial penetration type joint designs.

9.2 Joint design. Unless otherwise approved or unless otherwise modified by the application and limitations of MIL-STD-777 or MIL-STD-438, the design of welded joints for classes M, P, A, and T shall be as shown in table VII. Figure 1 gives examples of acceptable nozzle and flange joint locations for radiography.

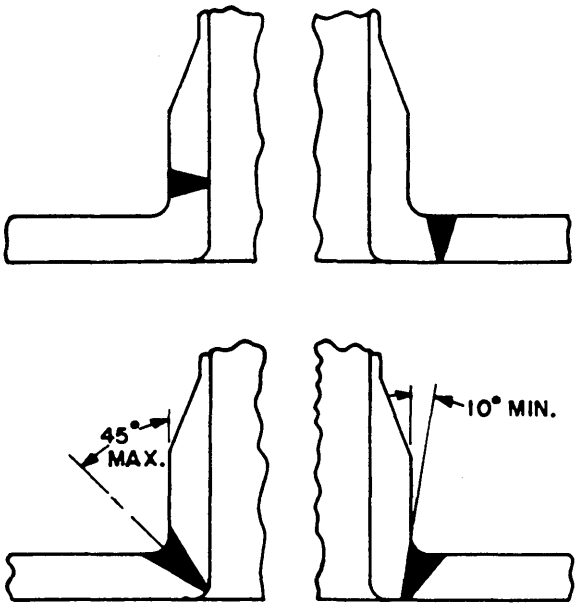

FIGURE 1. Examples of acceptable weld joint locations.

TABLE VII. Approved weld joint designs.1/

Service classification	Approved joint efficiencies and notes	Joint identification numbers (MIL-STD-22)
Machinery class M	100 percent efficiency	B1V.1 B2V.1 B2U.5 C1V.5 C1V.12 C2J.1 C2S.1 T2J.2 B1V.2 B2V.3 B2J.1 C1V.6 C2V.1 C2J.2 C2S.2 B1V.3 B2S.1 B2J.2 C1V.7 C2V.2 C2J.3 T1V.1 B1V.5 B2U.1 B2J.3 C1V.8 C2V.3 C2J.4 T1V.2 B1V.6 B2U.2 B2J.4 C1V.9 C2V.4 C2J.5 T2V.1 B1V.7 B2U.3 B2(S)V.2 C1V.10 C2V.5 C2J.6 T2V.2 B1S.2 B2U.4 B2(S)V.4 C1V.11 C2V.6 C2U.1 T2J.1
	80 percent efficiency	B1S.1 C1V.2 C1V.4 C1J.1 C1J.3 C1J.5 C1S.2 T1J.1 C1V.1 C1V.3 C1U.1 C1J.2 C1J.4 C1S.1 T1V.3
	2/	E1V.1 E1U.1 PT2S.1 PT2S.3 PT2V.2 PT2J.2 L1V.2 L1S.2 E1S.1 E1U.2 PT2S.2 PT2V.1 PT2J.1 L1V.1 L1S.1 L2S.1
Pressure vessel classes A-1, A-2, A-3, A-4, A-F, A-LT	100 percent efficiency 3/ 4/ 5/ 6/ 13/	B1V.1 B1V.7 B2U.3 B2J.3 C2V.2 C2J.5 P-70 V-9 B1V.2 B2V.1 B2U.4 B2J.4 C2V.5 C2J.6 P-71 V-11 B1V.3 B2V.3 B2U.5 B2(S)V.2 C2V.6 P-14 P-72 V-12 B1V.5 B2U.1 B2J.1 B2(S)V.4 C2U.1 P-63 V-7 V-27 B1V.6 B2U.2 B2J.2 C2V.1 C2J.4 P-64 V-8 V-28

See footnotes at end of table.

TABLE VII. Approved weld joint designs.1/ - Continued

Service classification	Approved joint efficiencies and notes	Joint identification numbers (MIL-STD-22)
Pressure vessel classes A-3, A-4	100 percent efficiency 3/ 5/ 6/	V-4 V-25 V-5 V-26 V-6 V-21 V-22
Pressure vessel class A-4	100 percent efficiency 3/ 5/ 6/	B2S.1 C1V.8 C2V.1 C2V.6 C2J.5 T1V.1 T2J.2 B2(S)V.2 C1V.9 C2V.2 C2J.1 C2J.6 T1V.2 PT2S.1 C1V.5 C1V.10 C2V.3 C2J.2 C2S.1 T2V.1 V-23 C1V.6 C1V.11 C2V.4 C2J.3 C2S.2 T2V.2 V-24 C1V.7 C1V.12 C2V.5 C2J.4 C2U.1 T2J.1
Piping classes P-1, P-2, P-LT	7/ 8/ 10/ 11/	P-3 P-8 P-13 P-68 P-74 P-4 P-9 P-14 P-70 P-75 P-5 P-10 P-15 P-71 P-76 P-6 P-11 P-17 P-72 P-77 P-7 P-12 P-67 P-73
Piping class P-2	9/ 10/ 12/ 13/	P-1 P-61 P-2 P-62 P-16 P-63 P-42 P-64 P-60 P-66
Steam turbines class T-1	Welded joints shall be full penetration (see MIL-STD-22 for guidance)	
Steam turbines class T-2	Joint designs of the same types used for previous Navy turbines are acceptable. New joint designs, not proven in service, shall be reviewed and commented on by NAVSEA prior to production application. MIL-STD-22 may be used for guidance.	

1/ The application of the listed joint designs to a specific service classification is subject to the applications and limitations of MIL-STD-777 for surface ships and MIL-STD-438 for submarines.
2/ These joints may be used when specifically approved.
3/ Pressure vessel joints: Welded joints for all pressure vessels shall be of 100 percent efficiency (see 9.3). Circumferential and longitudinal joints shall be welded from both sides or consumable inserts or backing strips shall be used to assure complete weld penetration. Welds shall be made with multiple layers of deposited metal.

4/ Welded joints for openings in class A-1, A-2, A-F, and A-LT pressure vessels including nozzles, handholes, manholes, or other penetrations of sizes 2-1/2 inch nps and greater shall be of a design and in a location which permits radiography in accordance with MIL-STD-271.

5/ Butt welding plates of unequal thicknesses shall be in accordance with the applicable figure of MIL-STD-22.

6/ The joints listed are applicable to welds in the pressure containing envelope of the vessel except for systems subject to submergence pressure where welds shall be full penetration. The designer is not limited to these joints or 100 percent efficiency requirement for internal or external structural attachments except where required by component or system specifications.

7/ Class P-1 piping butt joints shall be designed, welded and inspected to assure complete weld penetration. P-1 piping butt joints in submarine seawater systems shall be the consumable insert type except that backing rings may be used for closure welds where allowed by drawings or specifically approved. Joint P-73 may have θ = 45 degrees plus or minus 5 degrees for copper-nickel seawater systems. Joints P-13, P-14 and P-15 shall be limited to 2-inch nps and smaller for class P-1 piping systems (except that socket weld designs shall not be used in systems where 100,000 or more cycles of pressure variation, of more than 2/3 normal operating pressure, are expected) and a reference mark suitably located shall be established as a benchmark for verifying fillet weld size by an appropriate gauge measuring device.

8/ Joints such as P-3, P-13, P-14, and P-15 shall not be permitted on materials subject to crevice corrosion except as permitted by footnote 10.

9/ Except as permitted by footnote 10 joints such as P-1, P-2, P-12, P-60, P-61, P-62, P-67, and P-68 shall not be permitted on materials subject to crevice corrosion unless the inside surface of the weld is visually inspected to assure complete weld penetration.

10/ Joints addressed by footnotes 8 and 9 are satisfactory for use in seawater service when the material of fitting and pipe is copper-nickel, 70-30 or 90-10 alloys or a combination of both.

11/ P-67 joint and P-68 joint 4 inches and smaller welded from one side only may be used for class P-1 where the following conditions are met:

(a) Branch connection fit-up, welding processes, and final inspection ensures complete root penetration and an acceptable weld contour on inner surface. Welding of such joints requires separate welding procedures and welder qualifications in accordance with MIL-STD-248.

(b) The PT or MT (as applicable) inspection methods shall be used for the root weld layer and both final weld surfaces. Visual examination at 5X magnification may be substituted for MT/PT of the root weld pass in the grooved side.

12/ P-42 joints shall not be used with butterfly valves, spiral wound gaskets, or flanged joints in oil systems.

13/ Unreinforced branch connections such as P-60, P-61, P-62, P-63, and P-64 joints shall not be used in any systems where the design gauge pressure is over 150 lb/in^2 or the design temperature is over 449°F. Reinforcement shall not be obtained by weld buildup and any branch connection fabricated by the use of welding only shall be considered as unreinforced.

9.3 Joint efficiency. The efficiency of a welded joint shall be based on the minimum tensile strength of the weaker member where the weaker member is defined to be the member whose product of thickness times its minimum tensile strength has the lower value.

9.3.1 Fillet welds.

9.3.1.1 Continuous double fillet tee or continuous double fillet lap welded joints. When it is necessary to calculate the size, strength, or efficiency of a continuous double fillet welded tee or lap joint, the resulting data shall be considered as the allowable ultimate design values regardless of the direction of application of the load. The sizes, strength, and efficiencies of double fillet welds shall be determined by using the applicable formulas and the appropriate filler metal shear strength data of MIL-STD-1628.

9.3.1.2 Fillet joints welded all around. For those cases where the fillet weld is continuous around the ends of the member; such as in the case of a round or rectangular tube, bar, or rod whose end is welded to a plate or similar member; the weld shall be sized to develop the strength required by the design. Calculations for the sizes, strengths, and efficiencies of these joints shall be made in accordance with MIL-STD-1628, giving full credit for the length and location of the fillet and the sectional properties of the tube, bar, rod, and so forth.

9.3.2 Joints other than fillet welds.

9.3.2.1 Full penetration joints. Full penetration welds, where compatible weld metal of equivalent or greater ultimate tensile strength is used, are considered to be 100 percent efficient welds.

9.3.2.1.1 Full penetration joints welded from both sides. Full penetration joints welded from both sides shall have the root layer back-gouged, chipped, ground, or machined to sound metal prior to welding the second side; however, joints may be welded without such cleaning when qualified procedures and techniques (such as twin arc and submerged arc) are approved for such application.

9.3.2.1.2 Full penetration joints welded from one side. Full penetration joints welded from one side only without backing bars or consumable inserts may be rated 100 percent efficient when fabricated using a qualified welding procedure. Joints of this type not conforming to the above shall be rated at efficiency values which do not exceed 80 percent.

9.3.2.2 Partial penetration joints. Where partial penetration welded joints are required, the weld shall be sized to develop the strength required by the design.

9.3.2.2.1 For class M-2 and class A applications, the thickness limitations of MIL-STD-22 do not apply.

9.3.2.2.2 Joints within the same design group may be interchanged without drawing changes provided weld joint efficiencies are not reduced.

9.3.2.2.3 Full penetration joint designs may be used where partial penetration joint designs are specified. When this is done, the inspection requirements for the partial penetration joint design apply.

10. INSPECTION REQUIREMENTS

10.1 General. This section contains the minimum requirements for inspection of welded joints in machinery, piping, and pressure vessels. This section is not applicable to components listed in sections 12, 13, 14, and 15.

10.2 Performing NDT. NDT shall be performed in accordance with MIL-STD-271. When RT is specified and the geometry of the part or weld is such that RT is not technically practical, an alternate inspection system shall be approved by NAVSEA. Where MT or PT inspection methods are applied, both root (backside when accessible) and finished weld surface shall be so inspected. Pneumatic testing may be used in lieu of hydrostatic testing (for pressure test) for pneumatic systems.

10.3 Extent of inspection and methods.

10.3.1 Class M machinery. Welded joints in class M machinery components, except welded joints in turbines and propulsion and auxiliary gears (see sections 13 and 14), shall be inspected as specified in table VIII.

TABLE VIII. Class M machinery inspection requirements.

Machinery class	Category	Welded joint type	Required examinations and tests					
			VT		MT/PT test		RT4/	
			Root layer	Final weld	Root layer	Final weld	Final weld	Extent
M-1	A	Butts	—	X	X1/	X2/	X	100 percent
		All others	—	X	X1/	X2/	3/	--
	B	All	--	X	X1/	X2/	3/	--
	C	All	X	X	--	3/	--	--
M-2	A	All	--	X	X1/	X2/	3/	--
	B	All	--	X	X1/	X2/	--	--
	C	All	X	X	--	3/	--	--

See footnotes at top of next page.

1/ For joints welded from one side only, MT/PT inspect the root pass. For double welded joints, MT/PT inspect the backchipped, gouged, ground, or machined root area prior to welding the second side. VT at 5X magnification may be substituted for MT/PT inspection. Linear discontinuities shall be unacceptable. Root layer inspection may be deleted if the weld is given a 360 degree (or 100 percent) RT or UT inspection.
2/ When post weld heat treatment or stress relief is performed, this inspection shall be accomplished after heat treatment or stress relief. Where accessible, the inner face shall be MT/PT inspected and the inspection shall be performed after any machining operations.
3/ Inspection required when specified in drawing, shipbuilding, or component specification.
4/ UT may be substituted for RT when approved.

10.3.2 Class P piping. Welded joints in class P piping systems shall be inspected as specified in table IX.

TABLE IX. Class P piping inspection requirements.1/2/

Piping class	Welded joint type	Pipe size, inches nps	Required examination and tests						
			VT		MT/PT test		RT		Pressure
			Root layer	Final weld	Root layer	Final weld5/	Final weld3/	Extent 15/	11/
Lethal or gasoline	Butt	All	—	X	X4/	X	X	360 deg.	X
P-1 and P-LT	Butt	>3-1/2	—	X	X4/	X	X13/	360 deg.	X
		2-1/2 to 3-1/2 inclusive	—	X	X4/	X	X6/ 7/8/13/	60 deg. min.	X
12/		<2-1/2	—	X	X4/	X	X6/ 7/8/9/ 13/	60 deg. min.	X
	Sockets, fillets14/, and other attachments	All	—	X	X4/	X	—	—	X

See footnotes at end of table.

TABLE IX. Class P piping inspection requirements.1/2/ - Continued

Piping class	Welded joint type	Pipe size, inches nps	Required examination and tests						
			VT		MT/PT test		RT		Pressure
			Root layer	Final weld16/	Root layer	Final weld5/	Final weld3/	Extent 15/	11/
P-2	Butt	2-1/2 and>	—	X	—	10/	10/	—	X
		<2-1/2	—	X	—	10/	—	--	X
	Sockets and edge fillets	All	—	X16/	--	10/	—	--	X

NOTE: X indicates that the test is required.

1/ This table does not apply to piping used in components or accessories covered in sections 13, 14, and 15, which specifically list inspection requirements.

2/ Where new welds in piping intersect existing or older welds, the latter welds shall be inspected for a distance of 6 inches or a distance equal to 50 percent of the pipe size diameter, whichever is less, as measured from points of intersection. The existing or older weld and adjacent base material shall be free from cracks. Where non-intersecting adjacent existing welds are inadvertently radiographed, only cracks shall be cause for rejection.

3/ For the following applications or systems, MT or PT may be substituted for RT provided the inspection requirements of footnote 4 are met:

(a) Piping for gas turbine and diesel engine exhaust system, except that section in submarines between the inboard and outboard exhaust valves which is subject to submergence pressure.
(b) Incinerator up-takes.
(c) Exhaust relief valve which dumps to the bilge or the atmosphere.
(d) Trim and drain pump suction piping welds which are not in the reactor compartment.

4/ For joints welded from one side only, MT/PT inspect the root pass. For double welded joints, MT/PT inspect the back chipped, gouged, ground, or machined root area prior to welding the second side. VT at 5X magnification may be substituted for MT/PT inspection except for boiler tube to drum joints and superheater tubes to header joints. Linear discontinuities shall be unacceptable. Root layer inspection may be deleted if the weld is given a 360 degree (or 100 percent) RT or UT inspection. Root layer inspection is not required for welds, such as bosses and removable backing, where the root layer will be removed.

5/ Where accessible, the inner face shall be MT/PT inspected, and the inspection shall be performed after machining operations. When postweld heat treatment or stress relief is performed, this inspection shall be accomplished after heat treatment or stress relief.

6/ RT of welds on piping in the horizontal fixed position shall represent a sector which was welded in the vertical or overhead position.

7/ In lieu of 60-degree RT, PT or MT may be performed on the inside of a joint where the weld is within 2-1/2 nominal pipe diameters from the open end and is back welded, has backing ring removed, or used consumable insert.

8/ Boiler generating tubes, superheater, economizer elements, and blow down lines welded inside the casing (i.e., field welds) may be MT/PT inspected in lieu of RT.

9/ RT is required only when the design pressure exceeds 575 lb/in^2, except that boiler generating tubes, superheater, and economizer elements welded inside the casing (such as field welds) may be MT/PT inspected in lieu of RT.

10/ PT inspection shall be required for seawater systems in submarines on completed P-70 through P-72 type copper-nickel welds as defined in MIL-STD-22. Other systems shall require MT/PT and RT only when specified in the shipbuilding or component specification.

11/ (a) Refer to the applicable system or component specifications for test requirements. Testing shall be conducted on uncoated piping welds.

(b) For repairs to systems that have passed a hydrostatic test, rehydrostatic test is not required where repairs do not exceed 3/16 inch or 20 percent of base metal thickness, whichever is less. This exception does not apply if the repair weld is subjected to postweld heat treatment.

12/ For class P-LT piping constructed of cryogenic compatible materials such as aluminum alloys or 300 series stainless steel, the inspection requirements shall be as follows:

(a) Butt joints and other full penetration welds - 60 degrees minimum shall be subjected to RT in addition to VT and PT inspection.

(b) Socket welded joints and other partial penetration joints - VT and PT inspection.

13/ For hydraulic systems, RT is required only when the design pressure exceeds 600 lb/in^2.

14/ Includes boiler tube to drum joints and superheater tube to header joints.

15/ Where unacceptable defects in pipe welds are located by partial radiography, the entire circumference of these welds shall be radiographed.

16/ See footnote 9 of table VII.

10.3.3 Class A pressure vessels and class T turbines. Welded joints in class A pressure vessels shall be inspected as specified in table X, except welds in forced draft blowers shall be inspected in accordance with section 16. Welds in class T turbines shall be inspected in accordance with section 14.

TABLE X. Class A pressure vessel inspection requirements.1/

Pressure vessel class	Weld joint type	Required examination and tests						
		VT		MT/PT test		RT		Pressure
		Root layer	Final weld	Root layer	Final weld7/	Final weld7/	Extent8/	2/
A-F A-1 A-2	Butt and other complete penetration welds	X	X	X3/	X4/	X	100 percent of all long. and circ. welds	X
	Nozzles 2-1/2 inches and greater	X	X	X3/	X4/	X	360 deg.	X
	Nozzles less than 2-1/2 inches, pads and other attachments	--	X	X3/	X4/	--	--	X
A-3 A-LT	Butt and other complete penetration welds	--	X	X3/	X4/	X 5/ 6/	10 percent of all long. and circ. welds	X
	All nozzles, pads, and other attachments	--	X	X3/	X4/	--	--	X

See footnotes at end of table.

TABLE X. Class A pressure vessel inspection requirements.1/ - Continued

Pressure vessel class	Weld joint type	Required examination and tests						
		VT		MT/PT test		RT		Pressure
		Root layer	Final weld	Root layer	Final weld7/	Final weld7/	Extent8/	2/
A-4	Butt and other complete penetration welds	X	X	—	—	—	—	X
	All nozzles, pads, and other attachments	X	X	—	—	—	—	X

NOTE: X indicates that test is required.

1/ Where new welds in pressure vessels intersect or terminate on existing or older welds, the latter welds shall be RT inspected for a distance of 6 inches (each side of intersection), measured from the point of intersection. The existing or older weld and adjacent base material shall be free of cracks. Where non-intersecting adjacent existing welds are inadvertently radiographed, only only cracks shall be cause for rejection.

2/ Welded vessels shall be subjected to hydrostatic pressure test in accordance with the requirements for pressure vessels of their type and held for sufficient time to permit VT of all welds. Pressure tests shall be conducted on uncoated pressure vessels.

3/ For joints welded from one side only, MT/PT inspect the root pass. For double welded joints, MT/PT inspect the back chipped, gouged, ground, or machined root area prior to welding the second side. VT at 5X magnification may be substituted for MT/PT inspection. Linear discontinuities shall be unacceptable. Root layer inspection may be deleted if the weld is given a 360 degree (or 100 percent) RT or UT inspection. Root layer inspection is not required for welding such as bosses and removable backing, where the root layer will be removed.

4/ Where accessible, the inner face shall be MT/PT inspected, and the inspection shall be performed after any machining operations. When post weld heat treatment or stress relief is performed, this inspection shall be accomplished after heat treatment or stress relief.

5/ Where both longitudinal and circumferential weld joints are used, the intersection of these welds shall be included in the 10 percent radiographed.

6/ RT is not required when the nominal operating pressure does not exceed 125 lb/in^2, even though the relief valves are set at gauge pressures greater than 150 lb/in^2.

7/ For HY 80/100 and STS final weld inspection shall be performed no sooner than following:

RT (butt welds only): a minimum of 8 hours after reaching ambient temperature.

MT (all welds): a minimum 24 hours after reaching ambient temperature.

8/ Where unacceptable defects in pressure vessel welds are located by partial radiography, the entire length of these welds shall be radiographed.

10.3.4 Repaired welds. Completed weld repairs of weld defects, if required as specified in 7.7, shall be inspected by the same nondestructive method required for the original weld. Where additional weld metal has been deposited on the surface of previously accepted RT or UT welds and finished repair weld thickness does not exceed 3/16 inch or 20 percent of base metal thickness, whichever is less, the finishing layer may be inspected by the MT or PT method. The acceptance criteria shall be those specified for the weld class involved.

10.3.5 Base metal repair. Surface defects and damaged base material may be repair welded provided the repair weld and adjacent metal is inspected by the same methods as required for the class of welding. Excavations on the pipe within the socket bore depth of socket welds are not required to be repaired. Excavations in way of the fillet weld of socket welds may be restored during welding of and considered part of the fillet weld. Weld repairs not in excess of those defined for minor casting repair (see 13.2.2) can be made on wrought material at the discretion of the fabricator provided all requirements of this standard are met. More extensive weld repairs shall require approval except that no approval shall be required for repairs made with an approved standard repair procedure including welding parameters, inspection, and record requirements meeting all the requirements specified herein and in MIL-STD-248. Where RT is a requirement for the class of welding, MT or PT may be used in lieu of RT where finished weld thickness does not exceed 3/8 inch or half the design thickness of the base material, whichever is less. In addition, where RT would normally be required for the class of welding involved and the repair falls within a non-fluid boundary area (such as misdrilled flange bolt holes and so forth), case basis approval to delete RT may be obtained from the authorized representative. Repairs on P-1, P-LT, A-1, A-2, A-3, A-F or A-LT components shall be documented and records maintained available to the authorized representative for review. These repair records shall include the following: name and identification of component; description of defects repaired (location, length, width, and depth of excavation); base material; welding filler metal; post heat treatment (where applicable); and final inspection results.

10.3.5.1 Arc strikes and removal sites of welded attachments shall be ground to fair smoothly into base material surfaces. Where grinding reduces thickness below design requirements, areas shall be restored by welding and grinding. Finish ground areas, whether repair welded or not, shall be inspected by MT, PT, or VT at 5X magnification where any of the following apply: weldment is class P-1, P-LT, A-1, A-2, A-3, A-F, or A-LT; or base material is S-1 (with carbon content 0.35 percent or greater), S-3, S-3A, S-4, S-5, S-6, or S-11.

10.3.5.2 Base metal weld repairs of class P-3 brazed piping system components shall be inspected in accordance with 10.3.5 using the appropriate equivalent welded piping system classification (P-1, P-2, or P-LT) for the system after matching the brazed piping system fluid, operating pressure, and operating temperature to the equivalent welded piping system classification for those system conditions.

10.3.6 Weld deposited cladding, hardsurfacing, and buttering. Weld deposited cladding or hardsurfacing shall be VT and PT inspected; acceptance criteria shall be in accordance with 10.4.2. Buttering shall be inspected by MT or PT method, as applicable. Where joint edges are buttered prior to joint welding and the joint requires RT inspection, the buttered edges shall also require RT inspection. The buttered area and the completed weld can be radiographed at the same time. Where MT or PT inspection of the completed joint is required, all exposed surfaces of the buttered area shall also be inspected during the inspection of the finished weld joint. In addition, weld deposited buttering that forms part of a pressure boundary subject to submergence pressure shall also require UT inspection to detect defects and lack of bond prior to joint welding. UT inspection shall be in accordance with MIL-STD-271 as modified by 10.4.4.1. Acceptance criteria shall be in accordance with 10.4.4.2.

10.3.7 Loss of preheat and interpass. Welds for which the preheat and interpass temperature is permitted to drop below temperatures specified in table IV before completion shall require reheating as necessary, prior to resumption of welding. If the drop in temperature for S-4, S-5, S-6, S-7, and S-11 is more than 100°F below the minimum specified in table IV when welding with ferromagnetic filler material, the partially completed welds shall be MT inspected prior to resuming welding. Inspection records are not required.

10.3.8 Tack welds. Tack welds to be incorporated into the final weld shall be visually examined and defects, such as cracks, excessive undercut, entrapped slag, and excessive surface roughness, shall be corrected to the extent necessary to assure that final weld quality requirements will be met. All cracks shall be removed except cracked or broken tack welds need not be removed provided: (a) they were made by the GTA process, (b) they will not permit movement of joint components which causes the joint to exceed fit-up requirements, (c) they will be completely re-melted in deposition of the first layer, and (d) the first layer is made by the GTA process.

10.3.9 Seal welds. The final layer of seal welds shall be inspected by the PT method if MT/PT is required for the class of welding for the system involved or is specified by governing equipment or system specification. Other system seal welds shall be visually inspected.

10.3.10 Substitution of VT inspection. VT inspection at a magnification of 5X may be performed in lieu of PT inspection within 1/4 inch of open ends of welds or repairs to the root layer of partial penetration welds which would permit entrapment of penetrant materials.

10.3.11 Non-structural welds. Non-structural welds covered by 6.1.2 shall be MT, PT or 5X visual inspected to assure freedom from cracks.

10.4 Acceptance standards.

10.4.1 Visual examination. Acceptance of completed welds subjected to visual examination shall be based on conformance with the standard and class requirements specified in table XI.

TABLE XI. Acceptance standards and classes.

Weld application 1/	NAVSEA 0900-LP-003-8000 VT and MT/PT 2/	NAVSEA 0900-LP-003-9000 RT	NAVSEA 0900-LP-006-3010 UT
	Class	Class	Class
Class M-1	2	2	2
Class M-2	3	3/ 3	3
Class P-1, P-LT	1	1	-
Class P-2	2	3/ 2	-
Class A-1, A-2	1	1	-
Class A-3, A-4	2	3/ 2	-
Class A-F, A-LT	1	1	-

1/ Where unacceptable defects in pipe welds are located by partial radiography, the entire circumference of these welds shall be radiographed. For other applications of partial radiography, where defects in excess of the standard are found, the welds shall be radiographed until the full extent of defective welding has been located.

2/ In general, MT shall be used on ferrous materials and PT on nonferrous and austenitic corrosion resisting steels.

3/ Acceptance is to be based on conformance with the requirements of the indicated class where the specific inspection method is required by a governing component or equipment specification.

10.4.1.1 General. VT inspection shall be performed using a written procedure and qualified personnel in addition to the requirements of MIL-STD-271. VT inspection qualification and training shall be documented in a written procedure. VT inspection shall be accomplished without the use of magnifying glasses or other visual aids except for corrective aids to restore normal vision.

10.4.1.2 Welds. VT inspection of welds shall be performed after slag removal and with the weld in the final surface condition.

10.4.1.3 Base material. The surface to be inspected shall be in a clean condition. Surfaces which have been cleaned and painted with one coat of primer are considered suitable for inspection.

10.4.2 MT and PT inspection. Acceptance of welds and the adjacent base metal subjected to MT or PT inspection shall be in accordance with the standard and class requirements specified in table XI. Acceptance criteria for cladding or weld overlay shall be in accordance with the class specified for the weld application; however, where weld cladding is used to provide corrosion resistance for gasket seats or similar applications, the following acceptance criteria apply:

(1) O-ring or gasket seating surfaces plus 1/8 inch to either side of the designed gasket location or line of contact -- class 1.
(2) Other cladding normally subjected to liquid pressure -- class 2.
(3) Other cladding normally dry (for example, on the low pressure side of the gasket) -- class 3.

10.4.2.1 Adjacent casting base material. PT indications in casting base material adjacent to fabrication welds may be evaluated as follows:

(1) Castings requiring PT inspection in accordance with the footnotes to the tables in section 12 may be evaluated to the applicable casting acceptance standard.
(2) Castings not requiring PT inspection in accordance with the footnotes to the tables in section 12 may be evaluated in accordance with 13.2.9.

10.4.3 Radiography. Radiographs for welds shall be compared with the standard for radiography and classes in accordance with table XI.

10.4.4 UT inspection. Acceptance of welds subjected to UT inspection shall be in accordance with the applicable standard and classes specified in table XI.

10.4.4.1 UT inspection of weld deposited buttering. Prior to UT inspection of the weld deposited buttering for defects and lack of bond, the test equipment shall be calibrated by using a calibration block which has been fabricated by buttering using the same process, filler metal, and base metal as the production part. (Equivalent S number base metal may be used. For this purpose, S-1, S-2, S-3, S-4, S-5, and S-11 material are considered equivalent.) Calibration block shall have equivalent weld thickness and surface finish as the production part and shall be sufficiently thick to accomodate the required calibration holes needed to establish the distance amplitude correction (DAC) curve.

10.4.4.1.1 Calibration for inspecting weld deposited buttering for both weld metal defects and lack of bond.

(a) Holes shall be drilled into the block as follows:

Either 1/8-inch diameter flat bottomed holes shall be drilled from the base metal side with their axes perpendicular to the sound beam entry surface or 1/16-inch diameter holes at least 1-1/2 inches long shall be drilled parallel to the sound beam entry surface. The holes shall be positioned so that the following test metal distances (TMD) from the sound beam entry surface to the nearest surface of a hole are obtained:

(1) Deposited thickness up to and including 1/2 inch:

1/16 inch TMD
T/2 TMD $\pm$ 1/32 inch
(T) TMD $\pm$ 1/16 inch

Where T = Deposited thickness or 1/2 inch, whichever is less.

For deposits less than 7/16 inch thick, the T/2 TMD hole may be omitted.

(2) Deposited thickness (T) over 1/2 inch:

1/2 inch TMD
(T/2 inch + 1/4 inch) TMD $\pm$ 1/32 inch
(T) TMD + 1/16 inch

For deposits greater than 1/2 inch and less than 1 inch, the (T/2 + 1/4 inch) TMD hole may be omitted.

All holes in the test block shall be separated sufficiently to preclude acoustic or mechanical interference with calibration.

(b) In the case of deposited metal 1/2 inch or less in thickness, the test equipment shall be adjusted to provide an indication 85 to 90 percent of full screen height from the hole at T/2 TMD. At this equipment setting, the signal amplitudes received from the other two holes shall be marked on the screen and all three signals shall be connected by means of straight lines to provide a DAC curve. If the T/2 TMD hole is omitted, the test equipment shall be adjusted to provide an indication 85 to 90 percent of full screen height from the hole which reflects the greatest signal amplitude. The peaks of the signals received from the two holes will be connected by a straight line to form the DAC. In the case of deposited metal thicker than 1/2 inch, the test equipment shall be adjusted to provide an indication 85 to 90 percent full screen height from the hole which reflects the greatest signal amplitude. At this equipment setting, the indications from the remaining holes (or hole) shall be marked on

the screen and a DAC curve made. When inspecting production hardware, the first 1/2 inch of weld deposited metal shall be evaluated using the DAC curve specified in (a)(1) and the remaining thickness shall be evaluated using the DAC curve specified in (a)(2). The horizontal sweep shall be adjusted so that the position of the indication from the calibration hole at TMD + 1/16 inch is at least 25 percent of full screen width.

10.4.4.2 Acceptance criteria for weld defects and lack of bond in weld deposited buttering:

(a) Indications greater than the DAC curve specified in 10.4.4.1.1 are unacceptable.
(b) Indications greater than 50 percent of the DAC curve and longer than that permitted by figure 2 are unacceptable.
(c) Separate indications greater than 50 percent of the DAC curve shall be separated by a minimum distance of 2 inches in any direction.
(d) Indications greater than 50 percent of the DAC curve shall be recorded on the UT report as to amplitude, extent, and location.

10.5 Disposition of rejected welds. Welds not meeting the specified acceptance criteria shall be rejected until repaired and reinspected to the applicable criteria.

11. ALLIED PROCESSES

11.1 General. This section contains the minimum requirements for welding processes allied to those processes used for welded joints.

11.2 Thermal spraying. Thermal spraying shall be performed in accordance with MIL-STD-1687 for machinery and DOD-STD-2138 for corrosion protection.

11.3 Thermal cutting. Thermal cutting may be employed in the preparation of plates, piping, and fabrication subject to the restrictions specified herein. Carbon steels and low alloy steels having a carbon content less than 0.35 percent may be thermal cut. Higher alloy steels shall not be thermal cut. Wherever practicable, machine thermal cutting shall be used to cut materials greater than 1/2 inch in thickness. After cutting, all scale and slag on the cut surfaces shall be removed by mechanical means prior to further fabrication or use. The discoloration which may remain on the cut surface is not considered to be detrimental oxidation. Thermal cut surfaces to be welded shall not contain gouges or other irregularities detrimental to making of sound welds. Preheating, as necessary, shall be done to avoid cracking.

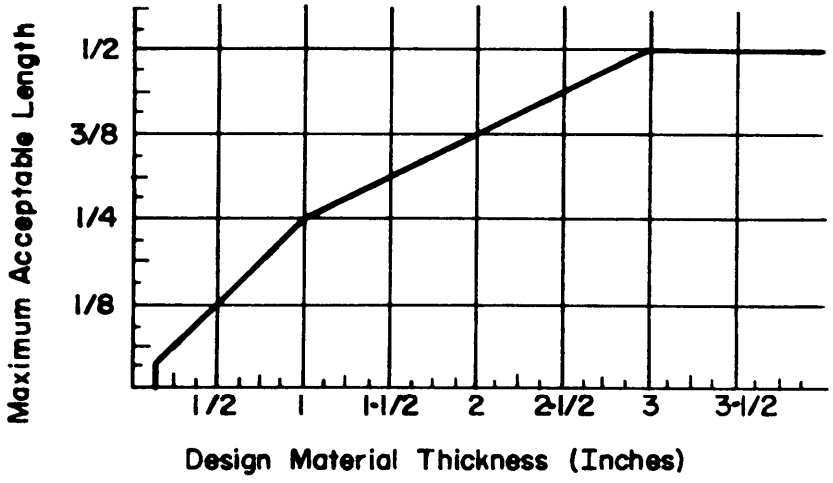

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FIGURE 2. Maximum acceptable ultrasonic indication length for weld deposited buttering.

11.4 Resistance welding. Resistance welding shall be performed with automatically-timed machinery capable of producing welds of acceptable strength, ductility, and corrosion resistance. Qualification of both procedure and equipment shall be required before any production work is undertaken. The strength, location, and spacing of the welds proposed shall be clearly shown on the drawings submitted for acceptance. Welding shall be in accordance with MIL-W-6858.

11.5 Stud welding.

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

11.5.1.1 Bend testing. If bend testing is performed, the studs to be tested shall be welded to a piece of material of the same S-group thickness and position as the production application. Bending of production studs is prohibited. Studs shall be bent to an angle of 15 degrees and return using a device similar to that shown on figure 3.

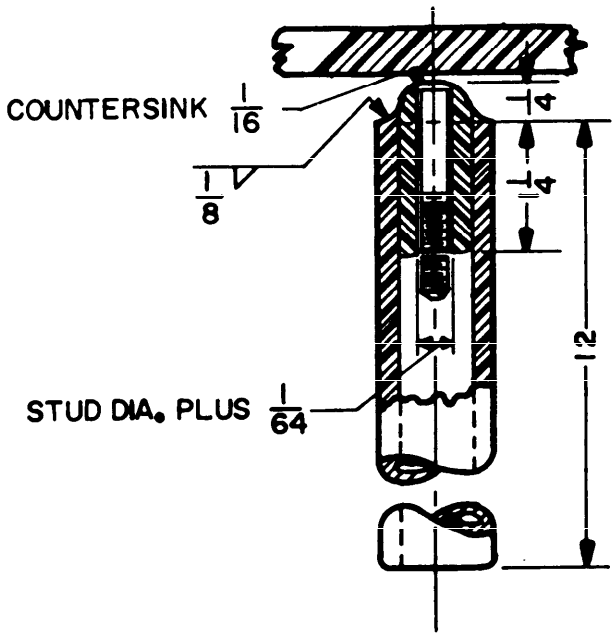

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FIGURE 3. Device for testing welded studs.

11.5.1.2 Torque testing. Torque test shall be performed on production studs. Studs shall be tested using any convenient means for applying the tensile load axially to the stud, 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. Studs shall be tested to 90 percent of the yield strength of the stud material. The stud cross section at the stud base or the root of the threads (whichever is less) shall be used as the basis for testing. Table XII provides axial (tensile) load and torque values based on thread root diameter for commonly used carbon steel and aluminum stud sizes.

TABLE XII. Torque-tension table (90 percent of yield).

Stud size	Base diameter	Carbon steel (50 klbs/in^2 yld)		Stainless steel (40 klbs/in^2 yld)		UNS N06625 (80 klbs/in^2 yld)		Aluminum (15 klbs/in^2 yld)	
		Torque	Tension	Torque	Tension	Torque	Tension	Torque	Tension
NC/NF	inches	ft-lbs	lbs	ft-lbs	lbs	ft-lbs	lbs	ft-lbs	lbs
10-24	0.158	2.3	758	1.9	606	3.7	1,212	0.7	227
10-32	.165	2.6	900	2.1	720	4.2	1,440	----	-----
1/4-20	.217	5.8	1,414	4.7	1,131	9.4	2,262	1.8	424
1/4-28	.217	6.7	1,613	5.3	1,290	10.7	2,580	----	-----
5/16-18	.271	11	2,325	9.0	1,860	18	3,720	3.5	698
5/16-24	.271	12	2,587	10	2,070	20	4,140	----	-----
3/8-16	.312	21	3,450	17	2,760	34	5,520	6.5	1,035
3/8-24	.312	24	3,900	19	3,120	38	6,240	----	-----
7/16-14	.375	34	4,687	27	3,750	54	7,500	10	1,400
7/16-20	.375	38	5,325	31	4,260	61	8,520	----	-----
1/2-13	.438	51	6,300	41	5,040	83	10,080	15.5	1,890
1/2-20	.438	59	7,125	47	5,700	95	11,400	----	-----
5/8-11	.500	104	10,125	83	8,100	166	16,200	31	3,038
5/8-18	.500	118	11,400	94	9,120	188	18,240	----	-----
3/4-10	.625	187	15,000	150	12,000	300	24,000	----	-----
3/4-16	.625	206	16,500	165	13,200	330	26,400	----	-----
7/8-9	.750	292	20,625	234	16,500	468	33,000	----	-----
7/8-14	.750	330	22,500	264	18,000	528	36,000	----	-----
1.0-8	.875	431	26,250	345	21,000	690	42,000	----	-----
1.0-14	.875	488	30,000	390	24,000	780	48,000	----	-----
1-1/8-7	1.000	581	34,500	465	27,600	930	55,200	----	-----
1-1/8-12	1.000	645	37,500	516	30,000	1,031	60,000	----	-----

11.5.1.3 Rejection procedure.

(a) Beginning of set-up or shift. If any of the five studs tested show signs of failure, the conditions causing failure shall be rectified and the test repeated.

(b) End of shift or set-up. If any of the five studs tested show signs of failure, a sampling plan shall be used to determine the extent of defective stud welding performed during the shift or set-up. The conditions causing failure shall be corrected and all defective studs welded during the shift or set-up shall be replaced.

11.5.2 Pressure containing applications. In addition to the testing required by 11.5.1, studs used in connection with openings in watertight, oil tight, gas or air tight, or pressure containing applications shall also be tested as follows:

(a) Ten percent of the studs, but not less than two per opening, shall be torque tested in accordance with 11.5.1.2. The sample tested shall include the first and last studs welded for each opening. If any of the studs tested show signs of failure, all of the studs for the opening shall be tested. Studs showing signs of failure shall be removed and new studs welded and tested.

11.5.3 Nonpressure containing applications. For permanent nonpressure containing applications, the inspection requirements of 11.5.1 apply.

11.5.4 Temporary attachments. No testing is required for temporary attachment studs.

11.5.5 Repair to studs. Undercutting or lack of fusion up to 1/4 of the stud diameter may be ground and repair welded using shielded metal-arc or gas tungsten-arc welding processes. Undercutting or lack of fusion greater than 1/4 of the stud diameter indicates poor stud welding technique for which the cause shall be determined and corrected. Studs whose defects exceed 1/4 of the stud diameter shall be removed and the plate surface ground smooth. Each stud that has been repair welded shall be inspected in accordance with 11.5.1.2.

11.6 Hard surfacing valve parts. Hard surfacing alloys are overlayed on valve part areas subjected to abrasion, corrosion, impact, and seizure in service. Hard surfacing alloys may be applied by shielded metal arc, oxyacetylene, gas tungsten-arc, and plasma-arc welding processes. Use of the oxyacetylene process for S-8 materials shall be limited to low carbon or stabilized grades only. Applicable welding procedures shall list only these grades.

11.6.1 Preheating and heat treatment of carbon and alloy steel. Preheating shall be at least to the minimum preheat temperature specified in table IV. Upon completion of welding, the part shall be covered and allowed to cool slowly. Weldments may be post weld heat treated immediately upon completion of welding, without prior cooling. Postheat stress relieving of austenitic stainless steels shall be restricted to the stabilized and low carbon grades and shall require specific approval as specified in table VI. Stress relief for S-1, S-3, S-4, and S-11 materials is not required but may be performed for dimensional stability. For other alloy steels, stress relief shall be performed if required by table VI.

11.6.2 Inspection. Hard surfacing welds shall be visually examined and PT inspected in accordance with MIL-STD-271.

11.6.3 Acceptance. Hard surfacing welds shall be in accordance with visual acceptance requirements and criteria for PT tests specified in NAVSEA 0900-LP-003-8000.

11.7 Pipe and tube bending. Pipe and tube bending shall be in accordance with MIL-STD-1627.

12. CASTING INSPECTION

12.1 General. This section contains the minimum requirements for inspecting castings and repairing defects to the extent necessary to meet the applicable acceptance standard. Sections 2, 3, 4, 5, 6, 7, and 8 as related to castings shall be applied in this section.

12.1.1 Castings purchased or manufactured by the contractor shall be in accordance with the specifications and standards specified herein, except NDT requirements shall be as specified herein. If no specifications or standards are referenced, drawings for castings which are subject to stress in service shall include the following information:

Chemical composition of material.
Required mechanical properties.
Melting process to be used.
Heat treatment, including aging or stabilizing treatments.
Cleaning methods to be used.
Pressure or proof test, if required.
RT, MT, or PT inspection requirements.
Identification markings.

12.2 Definitions.

12.2.1 Pressure containing. For purposes of section 12, pressure containing means a casting area which prevents contained fluid from escaping.

12.2.2 Sub-category. Sub-category designations (for example: A, A1, B, B1, C, C1, and so forth as shown in tables XIII, XIV, and XV for category 1, 2, and 3 castings) are assigned to simplify reference to the various application rules specifying which castings are to be inspected by which inspection rules.

TABLE XIII. Category 1, non-pressure containing castings in machinery or pressure vessels.[1/]

Sub cat	Application rules	Stress due to	Stress level percent of yield	NDT requirements			Sub cat
				RT	MT/PT[2/]	VT	
A[3/]	Castings which by failure of any one casting would prevent normal steering, diving, or propulsion and for which there is no standby capability	Dynamic[4/] loads	All	X	X	X	A1
		Hi impact shock grade A	>2/3	X	X	X	A2
			2/3 and<	-	X	X	A3
		Static loads	All	-	X	X	A4
B	Castings which by failure of any one casting would reduce the capability of the ship to launch, land, or transfer aircraft between flight and hangar decks	Dynamic[4/] loads	All	X	X	X	B1
		Hi impact shock grade A	>2/3	X	X	X	B2
			2/3 and<	-	X	X	B3
		Static loads	All	-	X	X	B4
C	Castings for weapons handling systems, which by failure of any one casting would: (a) Result in dropping or damaging a weapon or (b) Result in reduction of weapons service to any space, launcher, or aircraft by 50 percent or more	Dynamic[4/] loads	All	X	X	X	C1
		Hi impact shock grade A	>2/3	X	X	X	C2
			2/3 and<	-	X	X	C3
		Static loads	All	-	X	X	C4

See footnotes at end of table.

TABLE XIII. Category 1, non-pressure containing castings in machinery or pressure vessels.1/ - Continued

Sub cat	Applications	Stress due to	Stress level percent yield	5/6/Weight	NDT requirements			Sub cat
					RT	MT/PT2/	VT	
D	Other than A, B, and C	Dynamic4/7/ loads or Hi impact shock grade A	>2/3	>100 lbs	X	X	X	D1
				100 lbs and<	-	X	X	D2
			2/3 and<	All	-	-	X	D3
		Static8/ load	All	All	-	-	X	D4

1/ This table does not apply to castings used in components and accessories covered by sections 14, 15, and 16 in which the NDT requirements are specifically listed for the castings involved.
2/ MT is required for ferrous castings.
3/ Ship propellers shall be subjected to VT with PT used only as an aid in locating discontinuities as specified in NAVSEA 0900-LP-003-8000 (RT not required).
4/ For purposes of clarification, castings stressed by dynamic loads are castings with areas which are designed for normal service dynamic loads of a degree and frequency that such loads are used in the strength equations which determine dimensions of the area (note: Hi impact shock is not a dynamic load for purposes of this rule).
5/ "Weight" is design weight (when design weight is not calculated, actual weight of finished part may be used).
6/ All weights of aluminum shall be subjected to RT and VT (PT not required).
7/ Includes static or dynamic loaded castings in weight handling equipment where the stress level under maximum test conditions exceeds 2/3 percent of the minimum specified yield strength of the material.
8/ Except for static loaded castings addressed by footnote 7.

TABLE XIV. Category 2, pressure containing castings - machinery or pressure vessel castings.[1/]

Application rules	Pressure[2/] (lb/in^2)	Size[3/] (inches)	NDT requirements[5/]				Sub cat
			RT	MT/PT[4/]	Pressure[7/]	VT	
Lethal or gasoline service	All	All	X	X	X	X	A
Oxygen or hydrogen service	All	All	X	X	X	X	B
Steam service	300 and>	2-1/2 and>	X	X	X	X	C
Gas (other than lethal, oxygen, or hydrogen),	1000 and>[6/]	2-1/2[8/] and>	X	X	X	X	D[6/]
Water or hydraulic service	300 to<1000	2-1/2 and>	-	X	X	X	E
Special shipboard systems: (a) Weapon service - all ships casting for weapons handling systems	All	All	X	X	X	X	F
(b) Submarine service: pressure castings associated with hull boundary and subject to submergence pressure	All	All	X	X	X	X	G
(c) Aircraft carrier service: castings, failure of which would reduce the capability to launch, land, or transfer aircraft between the flight and hangar decks	All	2-1/2 and>	X	X	X	X	H
(d) Combatant surface ships: castings for normal steering systems	All	2-1/2 and>	X	X	X	X	I
Castings not covered above	-	-	-	-	X	X	J

See footnotes at top of next page.

1/ Table XIV does not apply to castings used in components and accessories covered by sections 14, 15, and 16 in which the NDT requirements are specifically listed for the castings involved.
2/ "Pressure" is the design pressure of the system in which the casting is used.
3/ For machinery and pressure vessel castings, the size shown is the inside diameter (or an equivalent cross sectional area).
4/ MT or PT is required for ferrous castings. For nonferrous castings, PT inspection is required only on submergence pressure boundary surfaces where stresses due to normal working loads would exceed 2/3 of the yield strength of the casting material; otherwise PT inspection is not required.
5/ Where NDT requirements of the component specifications differ from those specified in this table, the former shall govern.
6/ Exception: Subcategory "D" NDT requirements shall apply to main feed water pump castings of design pressure of 550 lb/in^2 and greater.
7/ Refer to the applicable system or component specifications for pressure test requirements. Pressure tests shall be conducted on uncoated castings.
8/ For hydraulic components with cylindrical datum features, this size is the largest diameter subject to normal operating pressure. For components with non-cylindrical datum features, the size shall be the largest dimension of the largest cross-sectional area subject to normal operating pressure.

TABLE XV. Category 3, pressure containing castings - piping system castings - valves, fittings, flanges and auxiliary equipment.1/

Application rules	Pressure2/ (lb/in^2)	Nps3/ size (inches)	NDT requirements5/				Sub cat
			RT	MT/PT4/	Pressure8/	VT	
Lethal or gasoline service	All	All	X	X	X	X	A
Oxygen or hydrogen service	100 and>	1/2 and>	X	X	X	X	B
Other than lethal or gasoline and oxygen or hydrogen services	>3400	1 and>	X	X	X	X	C
	300 thru 3400	2-1/2 and>	X	X	X	X	D
	300 thru 3400	<2-1/2	-	-	X	X	E
Submarine service6/ (a) castings associated with pressure hull boundary and subject to submergence pressure	-	All	X	X	X	X	F

See footnotes at end of table.

TABLE XV. Category 3, pressure containing castings - piping system castings - valves, fittings, flanges and auxiliary equipment.1/ - Continued

Application rules	Pressure2/ (lb/in^2)	Nps3/ size (inches)	NDT requirements5/				Sub cat
			RT	MT/PT4/	Pressure8/	VT	
(b) castings in sea connected systems from the inboard flange of the backup valve outboard to the hull	-	All	X	X	X	X	G
(c) castings in sea connected systems inboard of the back-up valve which are open to the sea below 200 feet submergence depth during any normal mode of operation	-	4 and>7/	X	X	X	X	H
Castings not covered above	-	-	-	-	X	X	I

1/ Table XV does not apply to flange connections and fittings integral with components covered by sections 14, 15, and 16 and auxiliary equipment furnished with the basic equipment and specifically listed for the equipment involved.
2/ "Pressure" is the design pressure of the system in which the casting is used.
3/ For piping system castings, the size shown is nps size.
4/ MT or PT is required for ferrous castings. For nonferrous castings, PT inspection is required only on submergence pressure boundary surfaces, where stresses due to normal working loads would exceed 2/3 of the yield strength of the casting material.
5/ In event of conflict in NDT requirements between applications, the more stringent NDT requirements shall be invoked.
6/ RT of cast valve discs and balls is required only where such discs or balls form a part of the hull boundary and failure could permit direct flooding inside ship, except RT is not required for centrifugally cast balls.
7/ Castings of sizes less than 4 inches shall be RT inspected where their failure would result in the loss of propulsion power due to lack of cooling water necessitated by the closing of the hull and back-up valves in the main sea-water system for the purpose of isolating defective castings.
8/ Refer to the applicable system or component specification for pressure test requirements. Pressure tests shall be conducted on uncoated castings.

12.3 Inspection details.

12.3.1 General. Tables XIII, XIV, and XV summarize the inspection requirements for cast nonpressure and pressure containing castings based on application, service conditions, size and, in some cases, stress. "X" indicates that the specific NDT test is required for the application and conditions described by the applicable pertinent horizontal data.

12.3.2 Visual examination. Each casting shall be visually examined for conformance with specified dimensions and surface conditions. Identification markings shall be checked to assure accuracy.

12.3.2.1 Inspection qualification. Visual examination shall be performed by personnel who have successfully passed the vision test in accordance with MIL-STD-271.

12.3.3 NDT. NDT shall be conducted in accordance with MIL-STD-271. Except as specified in 12.3.2 castings described for applications listed in tables XIII, XIV, XV regardless of material shall be inspected by the NDT method indicated. Where MT/PT is indicated, materials which are magnetic at ambient temperatures shall be inspected by MT; materials which are non-magnetic shall be inspected by PT.

12.3.4 Radiographic standard shooting sketches. Shooting sketches prepared in accordance with MIL-STD-271 shall be provided to assist in interpretation of the applicable radiographics. Approval of the sketches is required.

12.3.5 Substitution of tests. When RT is specified and the geometry of the castings is such that inspection by radiography is not meaningful or cannot be performed in accordance with MIL-STD-271, MT or PT, as applicable, may be substituted when approved. PT may be substituted for MT when a casting surface location or condition is such that it is inaccessible for MT or may be injured or contaminated by the MT method. UT, in accordance with an approved written test procedure, may be substituted for RT when approved for the application.

12.4 Acceptance criteria.

12.4.1 Visual examination. Casting surfaces shall be free from cracks, tears, laps, shrinkage, inclusions, gas holes, and other harmful or injurious defects. Ferrous castings shall meet the requirements of SP-55.

12.4.2 MT, PT and RT. Acceptance criteria for MT, PT and RT shall be as specified in tables XVI, XVII, XVIII, XIX and XX.

TABLE XVI. Acceptance criteria for MT and PT.1/

Cast material	Finished metal thickness	MT	PT
	(Inches)	NAVSEA 0900-LP-003-8000	
FERROUS CASTINGS			
Corrosion-resistant steel	Less than 1	Class 1	Class 1
Carbon steel	1 to 3	Class 2	Class 2
Alloy steels	over 3	Class 3	Class 3
NONFERROUS CASTINGS			
Nickel base alloys Copper-nickel Aluminum-bronze Nickel-aluminum-bronze Manganese-bronze	1 and less over 1	--- ---	Class 2 Class 3
Tin-bronze	1/2 and less over 1/2	--- ---	Class 2 Class 3
Aluminum	---	---	Class 2

1/ It is characteristic of some castings to be subject to superficial surface craze cracking. MT or PT indications of such craze cracking shall not be prejudicial when they do not exceed 5/16 inch in length. Indications beyond this length shall require removal, except that such indications may be approved subject to technical evaluation for acceptability dependent on intended application service conditions.

TABLE XVII. RT acceptance criteria for aluminum castings.

Casting category	Cast material	Metal thickness (plan dimensions for finished parts) inches	Hot cracks, cold cracks, cold shuts, misruns	Radiography 1/													
				Type of discontinuity													
						Gas porosity				Shrinkage				Foreign material			
				Gas holes		Round		Elongated		Cavity		Sponge		Less dense		More dense	
				Plate	Grade	Plate	Grade	Plate	Grade	Plate	Grade	Plate	Grade	Plate	Grade	Plate	Grade
1,2,3	Aluminum	1/2 and less	None	Inches 1.1-1/4	3	Inches 1.21-1/4	4	Inches 1.22-1/4	4	Inches 2.1-1/4	3	Inches 2.2-1/4	4	Inches 3.11-1/4	3	Inches 3.12-1/4	3
		Over 1/2 thru 1-1/4	None	1.1-3/4	5	1.21-3/4	5	1.22-3/4	5	2.1-1/4	4	2.2-3/4	4	3.11-3/4	4	3.12-3/4	4
		Over 1-1/4 thru 2	None	1.1-3/4	6	1.21-3/4	6	1.22-3/4	6	2.1-1/4	5	2.2-3/4	5	3.11-3/4	5	3.12-3/4	5
		Over 2 thru 3	None	1.1-3/4	7	1.21-3/4	7	1.22-3/4	7	2.2-1/4	7	2.2-3/4	6	3.11-3/4	6	3.12-3/4	6
		Over 3	None	1.1-3/4	8	1.21-3/4	8	1.22-3/4	8	2.1-1/4	8	2.2-3/4	8	3.11-3/4	7	3.12-3/4	7

See footnote at top of next page.

1/ ASTM E 155, reference radiographs (films) shall be applied as specified. Reference films listed provide a basis for acceptability by comparison with production radiographs. Discontinuities shown in the reference film are acceptable in any unit area as defined below and may be accepted when discontinuities in production radiographs are concentrated in an area the size of the reference film (2 by 2 inches) provided the balance of the unit area is clear. The unit area shall be a square, 4 inches on each side. Areas less than a unit area shall be judged proportionately to the unit area.

TABLE XVIII. RT acceptance criteria for steel (carbon, alloy and corrosion resistant) and titanium alloy castings.

Thickness (inches)	Criticality 1/ level	ASTM 2/ standard	Maximum severity level				
			Shrinkage	Porosity	Inclusion	Hot tear, crack	Insert, chaplet
Less than 1	1	E 446	CA 2 CB 2 CC 2 CD 2	A 2	B 2	None	None
	2	E 446	CA 3 CB 3 CC 3 CD 3	A 3	B 3	None	3/ EA 2
	3	E 446	CA 4 CB 4 CC 4 CD 4	A 4	B 4	None	3/ EA 2
1 to 2	1	E 446	CA 3 CB 3 CC 3 CD 3	A 3	B 3	None	None
	2	E 446	CA 4 CB 4 CC 4 CD 4	A 4	B 4	None	3/ EA 3
	3	E 446	CA 5 CB 5 CC 5 CD 5	A 5	B 5	None	3/ EA 3

See footnotes at end of table.

are applicable.

TABLE XVIII. RT acceptance criteria for steel (carbon, alloy and corrosion resistant) and titanium alloy castings. - Continued

Thickness (inches)	Criticality 1/ level	ASTM 2/ standard	Maximum severity level				
			Shrinkage	Porosity	Inclusion	Hot tear, crack	Insert, chaplet
Over 2 to 4-1/2	1	E 186	CA 3 CB 3 CC 3	A 3	B 3	None	None
	2	E 186	CA 4 CB 4 CC 4	A 4	B 4	None	EA 3, EB 3
	3	E 186	CA 5 CB 5 CC 5	A 5	B 5	None	EA 4, EB 4
Over 4-1/2	1	E 280	CA 2 CB 2 CC 2	A 3	B 3	None	None
	2	E 280	CA 3 CB 3 CC 3	A 4	B 4	None	EA 3, EB 3
	3	E 280	CA 5 CB 5 CC 5	A 5	B 5	None	EA 4, EB 4

1/ Criticality level 1: Areas requiring 75 percent minimum RT coverage (see 12.5.3).
Criticality level 2: Areas requiring 50 percent minimum RT coverage (see 12.5.3).
Criticality level 3: Areas not requiring RT but are inadvertently radiographed or radiographed for information purposes.

2/ Evaluation of radiographs for acceptance shall be in accordance with the applicable ASTM standard.

3/ ASTM E 186 shall be used for evaluation purposes.

acceptance standard. When radiographs are made after repair exca-

TABLE XIX. RT acceptance criteria for nonferrous castings. 1/

(a) Nickel base alloys.
(b) Copper-nickel.
(c) Aluminum-bronze.
(d) Nickel-aluminum-bronze.
(e) Manganese-bronze.

Criticality level			Severity level											
			ASTM E 272										ASTM E 186 (except as noted)	
			Shrinkage			Dross		Porosity		Inclusions		Chaplets		
Thickness	Level	Level definitions	Type	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source	ASTM standard	Reference radiograph	
1 inch and less	1	Areas requiring 75 percent and > RT coverage (see 12.5.3)	Feathery Spongy Linear	Cd 2 Cd 2 Ca 2	X-ray Gamma Gamma	Bb 1	X-ray	A3	X-ray	Ba 3	X-ray	None acceptable		
	2	Areas requiring 50 percent min. RT coverage (see 12.5.3)	Feathery Spongy Linear	Cd 3 Cd 3 Ca 3	X-ray Gamma Gamma	Bb 2	X-ray	A4	X-ray	Ba 4	X-ray	E 186	EA 4	
	3	Areas not requiring RT but inadvertently radiographed or radiographed for information purposes	Feathery Spongy Linear	Cd 4 Cd 4 Ca 4	X-ray Gamma Gamma	Bb 3	X-ray	A5	X-ray	Ba 5	X-ray	E 186	EA 5	

See footnote at end of table.

TABLE XIX. RT acceptance criteria for nonferrous castings.1/ - Continued

(a) Nickel base alloys.
(b) Copper-nickel.
(c) Aluminum-bronze.
(d) Nickel-aluminum-bronze.
(e) Manganese-bronze.

Criticality level			Severity level											
			ASTM E 272										ASTM E 186 (except as noted)	
			Shrinkage			Dross		Porosity		Inclusions			Chaplets	
Thick-ness	Level	Level definitions	Type	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source	Reference radiograph	Source		ASTM standard	Reference radiograph
Over 1 inch	1	Same as level 1 as defined above	Feathery Spongy Linear	Cd 3 Cd 3 Ca 3	X-ray Gamma Gamma	Bb 2	Gamma	A3	Gamma	Ba 3	Gamma		None acceptable	
	2	Same as level 2 as defined above	Feathery Spongy Linear	Cd 4 Cd 4 Ca 4	X-ray Gamma Gamma	Bb 3	Gamma	A4	Gamma	Ba 4	Gamma		E 186	EA 4
	3	Same as level 3 as defined above	Feathery Spongy Linear	Cd 5 Cd 5 Ca 5	X-ray Gamma Gamma	Bb 4	Gamma	A5	Gamma	Ba 5	Gamma		E 186	EA 5

See footnote at top of next page.

1/ ASTM E 272 and E 186 reference radiographs (films) shall be applied as specified. Reference films in ASTM E 272 are identified by two thickness ranges: (a) up to 2 inches and (b) 2 to 6 inches. Films are shown for the various discontinuity types in both thickness ranges. Three types of shrinkage are shown, designated (a) Feathery, (b) Spongy and (c) Linear. Only feathery type is shown in the up to 2-inch thickness range, and spongy and linear types are shown in the 2-inch to 6-inch thickness range. Films from both thickness ranges have been used without regard to applicable thickness specified herein in order to provide the best coverage and gradation of discontinuities. Since film identification designations are duplicated in the two thickness ranges, they are further identified in the table by stating the source. Where "X-Ray" appears under source in the table, this indicates that the "Low Voltage X-Ray Film" is applicable. Where "gamma" appears under source in the table, this indicates that the "2 MEV X-Ray or Cobalt-60 Gamma Ray Film" is applicable. Reference films specified shall be used for all production radiography sources.

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

Criticality level			Severity level					
			ASTM E 310				ASTM E 186 (except as noted)	
			Shrinkage		Porosity	Inclusions	Chaplets	
Thickness	Level	Level definitions	Type	Reference radiograph	Reference radiograph	Reference radiograph	ASTM standard	Reference radiograph
1/2 inch and less	1	Areas requiring 75 percent and > RT coverage (see 12.5.3)	Linear	Ca 2	A2	B1	None acceptable	
			Feathery or Spongy	Cd 1				
	2	Areas requiring 50 percent min. RT coverage (see 12.5.3)	Linear	Ca 3	A3	2/ B3	None acceptable	
			Feathery or Spongy	Cd 2				
	3	Areas not requiring RT but inadvertentiy radiographed or radiographed for information purposes	Linear	Ca 4	A4	B2, 2/ B4	E 186	EA 3
			Feathery or Spongy	Cd 3				
Over 1/2 inch	1	Same as level 1 as defined above	Linear	Ca 3	A3	2/ B3	None acceptable	
			Feathery or Spongy	Cd 3				
	2	Same as level 2 as defined above	Linear	Ca 4	A4	B2, 2/ B4	E 186	EA 3
			Feathery or Spongy	Cd 3				
	3	Same as level 3 as defined above	Linear	Ca 5	A5	B5	E 186	EA 4
			Feathery or Spongy	Cd 4				

See footnotes at top of next page.

1/ ASTM E 310 and E 186 reference radiographs (films) shall be applied as specified. The specified films shall be used for all production radiography sources.
2/ For the inclusion films, the discontinuities of film B2 are considered to be more severe than those of B3. Those of B2 and B4 are considered to be approximately equal, with those of B4 being fewer in number but larger in size.

12.4.2.1 RT evaluations. Production radiographs shall be evaluated for acceptance by comparing them with the applicable ASTM reference radiographs listed in tables XVII, XVIII, XIX, and XX.

12.4.2.2 Investment castings. Investment castings shall meet the number 5 acceptance level of ASTM E 192 except that filamentary type shrinkages contained therein are not permitted. For double-wall radiography a reference radiograph with a wall thickness compatible with the thickness of both walls of the casting being radiographed shall be used; however, the number 4 acceptance level shall then be used for evaluation purposes.

12.4.3 Pressure test. Pressure test acceptance criteria shall be in accordance with the applicable material, system, or equipment specification.

12.4.4 UT. UT acceptance criteria shall be approved on a case basis.

12.5 Extent of NDT.

12.5.1 VT. VT shall be conducted on all casting surfaces or areas which comprise the finished part. Gates, risers, test coupons, temporary test flanges, or similar extensions used as part of foundry procedure are excluded.

12.5.2 Pressure tests. Pressure tests shall be applied to all pressure containing areas.

12.5.3 Extent of radiography. Castings shall receive complete coverage, when required, in accordance with tables XIII, XIV, and XV. Insofar as casting configurations and thickness variations prevent attainment of the required film density in some locations, and for the purpose of defining coverage required, a casting is considered to contain the following areas:

(a) 75 percent minimum radiographic coverage areas. Areas include pressure containing areas, areas designed for dynamic loads in accordance with footnote 4, table XIII and areas stressed to 2/3 or more of the yield strength under high-impact shock.
(b) 50 percent minimum radiographic coverage areas. Remaining areas in the casting.

The 75 or 50 percent minimum coverage is defined as casting areas in the film which are within the specified density limits and are interpretable. It is not the intent that only 75 or 50 percent of casting be radiographed and that any specific area be excluded. Noncritical areas need not be radiographed when approved.

12.5.4 Extent of MT or PT inspection for ferrous castings. Ferrous castings for which radiography is required in accordance with tables XIII, XIV, or XV shall receive in addition to radiography, 100 percent MT inspection of all accessible areas. Ferrous castings for which MT or PT inspection is required in accordance with tables XIII, XIV, or XV and radiography is not specified shall receive 100 percent MT or PT inspection of all accessible surface areas. Static loaded ferrous castings shall receive 100 percent MT or PT inspection of all accessible surfaces which are subject to static loading.

12.5.5 Extent of VT and related requirements for nonferrous castings. Except as required by footnote 4 to tables XIII and XV, the areas of nonferrous castings for which radiography is required shall receive, in addition to radiography, 100 percent VT of all accessible surfaces. Nonferrous castings for which radiography is not specified in 12.3.3 shall receive 100 percent VT of all accessible surfaces. Static loaded nonferrous castings shall receive 100 percent VT of all accessible surfaces which are subject to static loading.

12.5.6 Records for NDT of castings. Records of casting inspection by VT and NDT methods shall be as follows:

(a) Casting identification, including drawing and serial numbers.
(b) Material identification by specification number and class or alloy.
(c) Inspection methods and results.
(d) For submarines, extent of inspection and traceability.

Inspection records for castings shall include casting repair records as specified in 13.2.10.

12.6 NDT responsibilities.

12.6.1 Designer responsibility. Where 100 percent inspection is not required, the casting designer shall implement the requirements of 12.5.3 and 12.5.4 by identifying areas requiring NDT on engineering drawings by appropriate assignment of symbols conforming to AWS A2.4.

12.6.2 Contractor responsibility. The foundry or activity performing the radiography shall prepare the radiographic shooting sketch in accordance with MIL-STD-271 based on requirements established by the designer (see 12.1.1). Prior to preparation, the design requirements for radiography shall be reviewed to ensure feasibility from the fabricator point of view. When disagreements arise between the designer and foundryman concerning areas for which radiography is required, but considered impractical by the foundryman, a meeting of both parties shall be arranged to resolve any controversial issues. Drawings shall be modified to reflect the decisions mutually reached by the designer and foundryman. Since a variety of processes are permitted under MIL-STD-271, the shooting sketches will necessarily depend not only on the coverage requirements but the equipment and procedures of the particular radiographic facility.

12.6.3 Approvals.

12.6.3.1 Engineering drawings. Casting drawings marked for RT coverage as required by 12.6.1 shall be forwarded to the acquisition activity for acceptance. Copy of transmittal letter shall be forwarded to the DCASMA.

12.7 Weldability tests. When required by the applicable cast material specification, weldability tests shall be performed to demonstrate that a particular heat of metal is of a composition that is readily weldable.

12.8 Sample castings. Except for castings covered in sections 13, 14, and 15, prior to production of a number of similar castings for which foundry methods or techniques have not been established, one or more sample castings shall be produced and subjected to NDT sampling agreed to by the designer and foundry. The results of this NDT shall be reviewed by both designer and foundry prior to production of the remaining castings. Significant changes to casting procedures, thereafter, shall be subject to a similar sample casting review for the area affected by the change.

13. REPAIR OF CASTINGS

13.1 Impregnation of aluminum base and copper base alloys. Impregnation of castings will be permitted to seal off minor leakage due to micro-porosity or other casting defects only after NAVSEA approval and when the defective castings are shown by radiography to be structurally sound. The suitability of aluminum base alloy casting for impregnation shall be based on review of the individual radiographs. Copper-base alloy castings which conform to the applicable classification of radiographic standards are considered satisfactory for impregnation. Copper-nickel castings shall not be impregnated. Welding shall not be permitted on castings which have been impregnated.

13.1.1 Impregnation authority. Authority to impregnate castings shall be obtained from NAVSEA. Requests for authority to impregnate shall be accompanied by radiographs of the defective areas of the particular casting or representative casting in the case of a large lot, together with complete information as to the condition of the castings including marked drawings where applicable, the percentage of castings of each type requiring impregnation, the service for which intended, the name of the foundry or contractor, and the contract or order number.

13.1.2 Impregnation procedure. The impregnation of castings, when approved by NAVSEA, shall be performed in accordance with MIL-STD-276. Each casting which has been impregnated shall be stamped "IMP" on the stamping pad or in a conspicuous place that will not impair the strength or serviceability of the casting.

13.2 Repair welding.

13.2.1 General. This section contains requirements for repair of weldable castings. Repair welding shall be accomplished by welders and procedures qualified in accordance with section 4. In the event of a conflict between requirements specified herein and those contained in casting material specifications, the requirements specified herein shall govern.

13.2.2 Minor repairs. Minor repairs are those repairs which do not exceed the following limits:

(a) Maximum depth does not exceed 20 percent of the casting thickness or 1-inch depth, whichever is less, and individual repair areas do not involve more than 4 percent of the casting surface.
(b) Weld build-up for correction of casting dimensions or machining discrepancies not exceeding 10 percent of the total area of the castings may be made at the discretion of the contractor or foundry when the weld build-up is within the following limitations:

(1) 3/16-inch maximum build-up for wall thicknesses 1 inch and under; or
(2) 20 percent of wall thickness maximum build-up for wall thicknesses over 1 inch but not to exceed 3/8 inch.

NOTE: These thickness limitations apply to the finished condition.

13.2.3 Nominal repairs. Nominal repairs are repair welds in excess of those outlined in 13.2.2 but which do not exceed 1/2 the casting thickness.

13.2.4 Special repairs. Special repairs are those repairs for which excavations of defects are more extensive than those classified as nominal repairs or those that extend through the thickness of the casting, or for which the use of cast inserts may be desired.

13.2.5 Authority for repair of castings. Authority to perform repair on castings by welding shall be as follows:

(a) Minor repairs may be made at the discretion of the contractor or foundry.
(b) Nominal repairs of castings may be accomplished without obtaining approval provided that in addition to the records required (see 13.2.10), the manufacturer shall record the casting identification number, welding procedure number or title, welder identification, and name of the representative.
(c) Special repairs require advance approval of the authorized representative.

The authorized representative shall be notified that repair welding has commenced. The Government representative reserves the right to reject castings where there is evidence that the provisions of this section are violated.

NOTE: For nickel-aluminum-bronze castings, weld repairs (including post weld heat treatment) shall be in accordance with MIL-B-24480 (see 6.4.5).

13.2.5.1 Repair procedures and report. Casting repairs shall be completed in accordance with 13.2.5. Upon completion of nominal and special repairs copies of records required by 13.2.10 shall be made available upon request.

13.2.6 Heat treated weld repairs. For ferrous castings which are to be heat treated at temperatures above the critical transformation temperature, weld repair using weld metal which is responsive to heat treatment may be accomplished prior to such heat treatment provided castings are given a preliminary anneal or softening treatment to avoid welding in the as-cast condition, and the following operations may be performed in this condition:

(a) Radiography of the casting.
(b) Weld repair of the casting.
(c) Re-radiography of weld repairs.

Responsiveness of the filler metal to the specific heat treatment employed shall be established by procedure qualification test. Heat treatment as appropriate shall be performed after the foregoing operations. Required MT inspection shall be performed after such heat treatment. Should any weld repairs develop by reason of the MT inspection, repair shall be accomplished and re-radiography of the repair shall be performed if required. Post weld treatment shall then be either re-heat treatment or stress relief treatment as appropriate. MT inspection shall be performed following the final thermal treatment operation. Stress relief of repair welded castings shall be in accordance with table VI and section 8. In this regard where the term weldment is used, it shall be construed to include repair welded castings.

13.2.7 Stress relief of weld repairs. When stress relieving of repair welded castings is performed in furnaces having recording pyrometric controls, the furnaces shall be calibrated to verify that the temperature variation within the furnace does not exceed 75°F. Calibration of the furnace shall be maintained by a recheck at intervals of no less than 6 months or after any changes or repairs to the furnace that might affect its temperature distribution. Holding temperatures, time and cooling rates shall be as established by the approved welding or heat treatment procedure.

13.2.7.1 Alternate temperature measuring methods for furnace and local stress relief. Alternate temperature measuring methods specified in section 8 are applicable.

13.2.8 Inspection of repair welds.

13.2.8.1 Exploration and repair of cracks. Visual evidence of cracks shall be explored at 5X magnification or by PT inspection and the cracks shall be removed and repaired by welding (see 13.2.8.2) or faired in or radiused providing wall thickness is not reduced below the specified allowable thickness.

13.2.8.2 Surface passes. Completed repair welds, including the adjacent casting surface for a distance of 1/2 inch from the weld edge, shall be inspected by the MT or PT methods, as may be applicable except as noted in 13.2.8.2.1.

13.2.8.2.1 For non-ferrous castings where PT inspection is not required by footnote 4 to tables XIV and XV, the adjacent casting surface (1/2 inch from weld edges) shall be visually examined. For the heat affected zone (3/16 inch from weld edges), the visual examination shall be at 5X minimum magnification. Where the surfaces within 1 inch of weld edges are PT inspected inadvertently during the inspection of the weld deposit, suspect indications within the 1-inch area shall be noted; then the developer and penetrant shall be removed and suspect areas visually examined at 5X minimum magnification. Linear indications greater than 1/16 inch shall be cause for rejection by the visual examination specified herein.

13.2.8.3 Radiography of completed repair. After the repair weld has acceptably passed MT inspection or PT inspection, as applicable, and if the repaired area of the casting originally required radiography, the repaired area shall be radiographed except in the following cases:

MT inspection or PT inspection, as applicable, is acceptable for 3/16-inch maximum (final thickness after machining) weld deposited overlay/cladding/build-up on casting surfaces which were previously accepted by radiography when the overlay/cladding build-up is to correct minor rough machining errors or minor casting dimensional errors. MT or PT inspection, as applicable, is acceptable for weld repairs or minor casting surface defects that were not revealed by radiography.

13.2.9 Acceptance standards for repair welds. Acceptance criteria for repair welds shall be as follows:

Inspection method	Acceptance standard
RT	(See note 1)
MT	NAVSEA 0900-LP-003-8000
PT	NAVSEA 0900-LP-003-8000

NOTES:

1. Repair of casting radiographic indications is required only to the extent of bringing such indications within the applicable casting acceptance standard. When radiographs are made after repair excavations, and prior to weld repair to determine the extent of any remaining discontinuities, the acceptance standard for the design thickness of the casting in the excavated area shall apply. UT inspection employed in accordance with an approved procedure may be used for such thickness determination. For post weld repair radiography, discontinuities occurring in the weld metal shall be judged for acceptance to the applicable reference radiograph for casting defects. If the combination of weld defects and casting defects does not exceed the discontinuities allowed in the applicable referenced radiograph for castings, the area shall be accepted. Cracks, lack of fusion and incomplete penetration in the area of weld repair shall be rejected. Slag and porosity shall be judged as sand inclusions and gas, respectively.

2. MT and PT of repair welds shall be in accordance with the following:

Repair welds in	Finished material thickness inches	Acceptance criteria MT	Acceptance criteria PT
		NAVSEA 0900-LP-003-8000	
Ferrous castings			
Corrosion-resistant steel	Less than 1	Class 1	Class 1
Carbon steel	1 to 3	Class 2	Class 2
Alloy steels	3 and over	Class 3	Class 3
Nonferrous castings			
Nickel-base alloys			
Copper-nickel			
Aluminum-bronze	1 and less	-----	Class 2
Nickel-aluminum-bronze	Over 1	-----	Class 3
Manganese-bronze			
Tin-bronze			
Aluminum castings	All	-----	Class 2
1/ **Special-alloy casting (S-8)**			
CN-7M	All		Class 3
CN-7MS			

1/ It is characteristic of these castings to be subject to superficial surface craze cracking. MT or PT indications of such craze cracking shall not be prejudicial when they do not exceed 5/16 inch in length. Indications beyond this length shall require removal, except that such indications may be approved subject to technical evaluation for acceptability dependent on intended application service conditions.

13.2.10 Records. Records of weld repairs shall be maintained and shall include the following (except as modified in sections 14, 15 and 16):

(a) A sketch showing the size (length, width, and depth) and location of all nominal and special repairs.
(b) Record of post weld heat treatment (when applicable).
(c) Record of weld repair inspection results.
(d) Record of material weldability test when required by the applicable material specification.
(e) Records shall be retained as required by 13.2.10.1.

13.2.10.1 Maintenance of records. Unless otherwise specified, required records shall be maintained by the activity and be available to the NAVSEA representative throughout the life of the contract and for 3 years after delivery (see 16.7). At the expiration of the record retention period, NAVSEA or its authorized representatives shall be given a written notification. Disposal of records shall be as agreed upon by NAVSEA and the contractor.

13.2.11 Repair welding on existing shipboard castings. Repair welds made on existing shipboard castings shall be inspected by the MT or PT method, as specified in 13.2.8.2. RT shall also be performed when repair welding is located in an area for which radiography was specified for the casting in new condition, except radiography is not required where the following provisions are met:

(a) Weld overlay is used to restore surface material lost through corrosion, erosion, and wear.
(b) Depth of area prepared for welding does not exceed the allowable depth of a nominal repair (see 13.2.3).
(c) Finished weld thickness is 3/8 inch or less.

Where the provisions of (a), (b) and (c) apply to castings of S-1 material, post weld stress relief is not required. For repair welding on nickel-aluminum-bronze see the special note to 13.2.5.

14. NDT REQUIREMENTS FOR TURBINE PARTS

14.1 General. This section contains the minimum inspection requirements for welds, weldments, and castings used in auxiliary and main propulsion turbine components and accessories.

14.2 Inspection requirements.

14.2.1 Turbine components or parts (fabrication, welds, and castings) shall be inspected in accordance with table XXI.

TABLE XXI. NDT inspection of turbine parts.1/

Part or service	MT/PT	RT	HT	UT	VT
Bearing pedestals and caps:					
(a) Weld joints	X-3	-	-	-	X
(b) Castings	X-3	-	-	-	X
Ahead casings and steam chests:2/					
(a) Below 300 lb/in^2	X-3	-	X	-	X
(b) 300 to 900 lb/in^2	X-2	3/X-1	X	-	X
(c) Above 900 lb/in^2	X-1	3/X-1	X	-	X
Astern castings and nozzle chamber:2/					
(a) Below 300 lb/in^2	X-3	-	X	-	X
(b) 300 to 900 lb/in^2	X-2	-	X	-	X
(c) Above 900 lb/in^2	X-1	-	X	-	X

See footnotes at end of table.

TABLE XXI. NDT inspection of turbine parts.[1/] - Continued

Part or service	MT/PT	RT	HT	UT	VT
Inner shells and nozzles chambers[2/]	X-2	-	-	-	X
Diaphragms	X-3	-	-	-	X
Control mechanism and operating gear	X-3	-	-	-	X
Supports, flexible	X-2	-	-	-	X
Support girders for turbines (fabrications, welds and castings)	X-2	-	-	-	X
Control valves					
(a) Seating surface of valve and seat weld overlay/inlay	X-1	-	-	-	X
Expansion joints (cross-over)	X-3	-	X	-	X
Gland seal regulator body (hyraulic type)	X-3	-	X	-	X
Piping butt welds: (steam)					
(a) Below 300 lb/in^2	X-2	-	X	-	X
(b) 300 lb/in^2 and above <2-1/2 inches	X-1	-	X	-	X
(c) 300 lb/in^2 and above (2-1/2 inches and above)[2/]	X-1	X-1	X	-	X
Piping fillet welds (steam) 300 lb/in^2 and above	X-1	-	X	-	X
Piping and piping welds (oil)	-	-	X	-	X
Weld overlay/inlay (for erosion resistance)	-	-	-	-	X
Valve bodies (trip throttle, astern, guard, strainer, maneuvering, and non-return)[2/]					
(a) Below 300 lb/in^2	X-2	-	X	-	X
(b) 300 lb/in^2 and above	X-1	[3/] X-1	X	-	X
Valve seat seal weld	X-2	-	-	-	X

See footnotes at top of next page.

1/ Inspections required do not eliminate requirements of applicable material specifications.

X - Indicates test required
X - Followed by number indicates acceptance class or level

2/ Records as specified in 13.2.10 are required.
3/ Applicable to castings with an inside diameter 2-1/2 inches or greater (or an equivalent cross sectional area).

14.2.2 Radiography of castings and steam chests. Radiography of castings and steam chests shall be as follows:

(a) External pressure boundary walls above valve seats (nozzle control and by-pass).
(b) Steam inlet.
(c) Steam chest flange and cover (castings only).
(d) Front wall and first stage shell area (horizontal flange excluded) where inlet gauge pressure to chest is 900 lb/in^2 or greater.
(e) All fabrication welds in the above areas.

14.3 Performing NDT inspection.

14.3.1 NDT inspection shall be performed in accordance with MIL-STD-271.

14.3.2 Radiographic standard shooting sketches. Shooting sketches in accordance with MIL-STD-271 shall be provided to assist in interpretation of the applicable radiographs; however, approval of the sketches is not required.

14.4 Acceptance standards for NDT inspection.

14.4.1 Radiography. Radiography of welded joints and repair welds in castings shall be compared and shall be in accordance with class 1 of NAVSEA 0900-LP-003-9000. Castings radiographs shall conform to table XXI.

14.4.2 MT and PT inspection of welds. Inspection for surface discontinuities in welds and adjacent areas shall be performed by MT or PT method. In general, the MT method shall be used on ferrous materials and the PT method on nonferrous materials and austenitic corrosion resistant steels. Acceptance criteria for welds shall be in accordance with NAVSEA 9000-LP-003-8000.

14.4.3 MT and PT inspection of castings. There shall be 100 percent MT or PT inspection of all accessible areas for items shown in table XXI. Acceptance standards shall be in accordance with NAVSEA 0900-LP-003-8000, except that footnote 1 of table II does not apply.

14.5 UT inspection.

14.5.1 UT inspection in accordance with an approved written test procedure and acceptance standards may be substituted for radiography when approved for the application.

14.6 Additional inspection for ferritic materials.

14.6.1 Ferritic castings and fabrication welds thereto which are subject to NDT prior to stress relief, as permitted by MIL-STD-271, shall be subjected to MT after stress relief. Acceptance standards shall be as required for the parts or welds involved.

15. NDT INSPECTION REQUIREMENTS FOR PROPULSION REDUCTION GEARS AND STEAM TURBINE DRIVEN AUXILIARY GEARS

15.1 General. This section contains the minimum inspection requirements for welds and castings used in the fabrication of propulsion reduction gears.

15.2 Inspection requirements.

15.2.1 Propulsion reduction gear components or parts shall be inspected in accordance with table XXII.

TABLE XXII. NDT inspection of propulsion reduction gear parts (including steam turbine driven auxiliary gears).

Part or service	MT/PT	HT	UT	LT	VT	Reference notes
Main element forgings for: Pinions, gears, gear rims, shafts, annulus, carrier	X-VA	--	X-VA	--	--	1/ 2/
Teeth of main elements	X-VA	--	--	--	--	2/ 3/
Piping welds						
(a) Small sections of low pressure such as lube oil supply, including welds joining nipple to casing	X-VA	--	--	--	X	--
(b) All other low pressure lube oil piping welded joints made by the gear manufacturer	--	X	--	--	X	4/ 5/
Welds, fabricated gear elements						
(a) Strength welds	X-2	--	--	--	X	6/
(b) All other welds	--	--	--	--	X	--
Welds, casing						
(a) Strength welds	X-3	--	--	--	X	6/
(b) Oil tight welds	--	--	--	X	X	--
(c) All other welds	--	--	--	--	X	--
Hubs, cast	X-VA	--	X-VA	--	X	--
Thrust bearing housing and caps	X-3	--	--	--	X	--
Lube oil sump	--	--	--	X	X	7/

See footnotes at top of next page.

1/ UT shall be in both radial and longitudinal directions using either a shear or longitudinal wave depending upon the geometry of the forging.
2/ Steel forgings shall be examined by the MT method; nonmagnetic materials shall be examined by the PT method.
3/ Inspection shall be performed after cutting or grinding teeth, as applicable, but before shot peening for through-hardened elements.
4/ Piping which is furnished in sections by the gear manufacturer for installation welding at the shipyard will not require hydrostatic testing by the gear manufacturer where the final assembly is pressure tested by the shipbuilder.
5/ Test pressure shall be a gauge pressure of 150 lb/in^2.
6/ A strength weld transmits propulsion torque or propulsion thrust.
7/ Test shall consist of filling sump with water or clean hot oil and visually examining for leakage. Leaks shall be cause for rejection pending corrective repairs and retest to assure a sound leak-free sump.

X - Indicates test required.
X - Followed by number indicates acceptance level.
X - Followed by VA indicates vendor levels as approved by NAVSEA.
LT - Leak test (gravity).

15.3 Performing NDT inspection.

15.3.1 NDT inspection shall be performed in accordance with MIL-STD-271.

15.4 Acceptance standards for NDT inspection.

15.4.1 MT and PT inspection of welds. Inspection for surface discontinuities in welds and adjacent areas shall be performed by MT or PT method. In general, the MT method shall be used on ferrous materials and the PT method on nonferrous materials and austenitic corrosion resistant steels. Acceptance criteria for welds shall be in accordance with NAVSEA 0900-LP-003-8000.

15.4.2 MT and PT inspection of castings. There shall be 100 percent MT or PT inspection of all accessible areas for the items shown in table XXII. Acceptance standards shall be in accordance with NAVSEA 0900-LP-003-8000.

15.5 UT inspection.

15.5.1 UT inspection in accordance with an approved written test procedure and acceptance standards may be used when approved for the application.

15.6 Additional inspection for ferritic materials.

15.6.1 Ferritic castings and fabrication welds thereto which are radiographed prior to stress relief, as permitted by MIL-STD-271, shall be subjected to MT inspection after stress relief. Acceptance standards shall be as required for the parts or welds involved.

16. NDT INSPECTION REQUIREMENTS FOR FORCED DRAFT BLOWERS

16.1 General. This section contains the minimum inspection requirements for welds and casting used in the fabrication of forced draft blowers.

16.2 Inspection requirements.

16.2.1 Forced draft blower components or parts shall be inspected in accordance with table XXIII.

TABLE XXIII. NDT inspection requirements for forced draft blowers.

Part or service	MT/PT	RT	HT	UT	VT
Cylinders	--	--	X	--	X
Blade rings (compressor stator)	X-3	--	--	--	X
Packing casings	X-3	--	--	--	X
Supports, flexible	X-2	--	--	--	X
Control valves:					
Seating surface of valve and seat	X-1	--	--	--	X
Discs - turbine and propeller	X-VA	--	--	X-VA	X

X - Indicates test required
X - Followed by number indicates acceptance class
X - Followed by VA indicates vendor levels as approved by NAVSEA

16.3 Performing NDT inspection.

16.3.1 NDT inspection shall be performed in accordance with MIL-STD-271.

16.3.2 Radiographic standard shooting sketches. Shooting sketches in accordance with MIL-STD-271 shall be provided to assist in interpretation of the applicable radiographs; however, approval of the sketches is not required.

16.4 Acceptance standards for NDT inspection.

16.4.1 Radiography. Radiography of welded joints and repair welds in castings shall be compared with class 1 of NAVSEA 0900-LP-003-9000. Casting radiographs shall conform to table XVIII.

16.4.2 MT and PT inspection of welds. Inspection for surface discontinuities in welds and adjacent areas shall be performed by MT or PT method. The MT method shall be used on ferrous materials and the PT method on nonferrous materials and austenitic corrosion-resistant steels. Acceptance criteria shall be in accordance with NAVSEA 0900-LP-003-8000.

16.4.3 MT and PT inspection of castings. There shall be 100 percent MT or PT inspection of all accessible areas for items shown in table XXIII. Acceptance standards shall be in accordance with NAVSEA 0900-LP-003-8000, except that footnote 1 of table II does not apply.

16.5 UT inspection.

16.5.1 UT inspection in accordance with an approved written test procedure and acceptance standards may be substituted for radiography when approved for application.

16.6 Additional inspection for ferritic materials.

16.6.1 Ferritic castings, and fabrication welds thereto which are subject to NDT prior to stress relief, as permitted by MIL-STD-271, shall be subjected to MT inspection after stress relief. Acceptance standards shall be as required for the parts or welds involved.

16.7 Data requirements. When this standard is used in an acquisition and data are required to be delivered, the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved Contract Data Requirements List (CDRL), incorporated into the contract. When the provisions of DoD FAR Supplement, Part 27, Sub-Part 27.410-6 (DD Form 1423) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this standard are cited in the following paragraphs.

Paragraph no.	Data requirement title	Applicable DID no.	Option
4.1.3, 4.1.3.1, 5.3.2, 13.2.10.1	Reports, test	DI-T-2072	----
4.2.1	Procedure, welding	UDI-H-23383	----
4.2.1.2	Qualification data, welding procedure	UDI-H-23384	----

(Data item descriptions related to this standard and identified in section 6 will be approved and listed as such in DoD 5010.12-L., AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

16.8 Subject term (key word) listing.

Casting
Fabrication
Machinery inspection
Nondestructive testing
Piping
Repair welding
Ultrasonic inspection

16.9 Changes from previous issues. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project THJM-N239)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-STD-278F(SH)	WELDING AND CASTING STANDARD

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR
b. ADDRESS *(Street, City, State, ZIP Code)*	☐ USER
	☐ MANUFACTURER
	☐ OTHER *(Specify)*:

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 82 MAR 1426

PREVIOUS EDITION IS OBSOLETE.