

## WELDING AND ALLIED PROCESSES

### 1. SCOPE

1.1 Intent. This standard specification and appendices describe the general requirements for welding, fabrication, brazing, inspection, and associated processes on Coast Guard vessels and equipment.

1.2 Appendices.

PROCESS STANDARD	APPENDIX
Commercial Welding Standards	A
Welding And Inspection - Naval Sea Systems Command And Military Standards	B
Structural Boundary Tests And Nondestructive Inspection	C
Bimetallic bonded joint Welding Requirements	D

1.3 Definitions. The following definitions are applicable to this document or referencing work items:

1.3.1 American Welding Society (AWS). Information concerning certification of welding inspectors, welders, and accredited test facilities for AWS welder certification is available on the world wide web internet at <http://www.aws.org>.

1.3.2 Approved (approval). Approval refers to when American Bureau of Shipping(ABS), United States Coast Guard or authorized representatives have accepted the item under consideration.

1.3.3 Applicable data sheets. Refers to welding process data sheets or welding procedure specifications approved by ABS, Mechanical Contractors Association of America National Certified Pipe Welding Bureau (NCPWB) established welding regulatory code or their authorized representative.

1.3.4 Authorized representative. Authorized representative is any representative specifically authorized to approve equipment, material, or procedures for the referenced regulatory agency.

1.3.5 Critical welds. Critical welds include but are not limited to welds on vessel hull plate, tank tops, structural decks and bulkheads, structural framing, and weight handling equipment.

1.3.6 Corrugated plate. Plate with a repetitive pattern utilizing bends in the plate as stiffeners, usually used in structural bulkheads.

1.3.7 Flat plate. A flat plate is considered as any plate that does not require pre-forming before installation.

1.3.8 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 COTR or delegated representative.

1.3.9 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.

1.3.10 Qualified. The term “qualified” means that the item under consideration has been approved as required by the applicable regulatory agency or authorized representative.

1.3.11 Qualifier. The qualifier is an individual or test facility designated by the applicable welding regulatory agency or contractor as responsible for conducting, supervising and accepting welder qualification testing. The qualifier shall be certified by the regulatory agency as a Certified Weld Inspector (CWI) or at a minimum be a competent individual meeting all the education and experience requirements of a CWI as defined by AWS QC1.

1.3.12 Shaped plate. A shaped plate is a plate that requires mechanical or other manipulation to pre-form the shape prior to the installation procedure.

1.3.13 Shell plate. A shell plate is a plate forming the outer skin of the hull.

1.3.14 Sheet metal. A sheet metal is any material identified by the Manufacturers' Standard Gage for Sheet Steel, at a weight of 41.82 pounds per square foot per inch of thickness (e.g., 5.23 pounds per square foot per 1/8 inch of thickness) whose thicknesses are below 1/4 inch.

1.3.15 Welding procedure specification (WPS). A written document providing direction to a welder for use in production and repair welding, delineating all of the Code essential elements and necessary guidance to assure repeatable quality joints by properly trained welders.

## 2. REFERENCES

### COAST GUARD DRAWINGS

None.

### COAST GUARD PUBLICATIONS

Coast Guard Commandant Instruction (COMDTINST) M10360.3 (series), Coatings and Color Manual

### OTHER REFERENCES

American Bureau of Shipping (ABS), 2004, Guide for Nondestructive Inspection of Hull Welds

American Society for Nondestructive Testing (ASNT) SNT-TC-1A, 2006, Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

ASTM Internationals (ASTM) E94, 2004, Standard Guide for Radiographic Examination

ASTM Internationals (ASTM) E114, Reapproved 2005, Standard Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method

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- ASTM Internationals (ASTM) E164, 2008, Standard Practice for Contact Ultrasonic Testing of Weldments
- ASTM Internationals (ASTM) E165, 2002, Standard Test Method for Liquid Penetrant Examination
- ASTM Internationals (ASTM) E587, 2005, Standard Practice for Ultrasonic Angle-Beam Examination by the Contact Method
- ASTM Internationals (ASTM) E709, 2008, Standard Guide for Magnetic Particle Testing
- ASTM Internationals (ASTM) E1417, 2005, Standard Practice for Liquid Penetrant Testing
- ASTM Internationals (ASTM) E1444, 2005, Standard Practice for Magnetic Particle Testing
- ASTM Internationals (ASTM) F1076, Reapproved 2004, Standard Practice for Expanded Welded and Silver Brazed Socket Joints for Pipe and Tube
- American Society of Mechanical Engineers (ASME) B31, 2006, Codes for Pressure Piping
- American Society of Mechanical Engineers (ASME) B31.5, 2006, Refrigeration Piping and Heat Transfer Components
- American Society of Mechanical Engineers (ASME), Section IX, 2008, Qualifications Standard for Welding and Brazing, and Welding and Brazing Operators
- American Welding Society (AWS) A2.4, 2007, Standard Symbols for Welding, Brazing, and Nondestructive Examination
- American Welding Society (AWS) A3.0, 2001, Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying
- American Welding Society (AWS) A5.8, 2004, Specification for Filler Metals for Brazing and Braze Welding
- American Welding Society (AWS) A5.12/A5.12M, Reapproved 2007, Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting
- American Welding Society (AWS) B1.10, 1999, Guide for Nondestructive Examination of Welds
- American Welding Society (AWS) B1.11, 2000, Guide for the Visual Examination of Welds
- American Welding Society (AWS) D1.1/D1.1M, 2008, Structural Welding Code - Steel
- American Welding Society (AWS) D1.2/D1.2M, 2008, Structural Welding Code – Aluminum
- American Welding Society (AWS) D3.5, 2000, Guide for Steel Hull Welding
- American Welding Society (AWS) D10.12, 2000, Guide for Welding Mild Steel Pipe
- American Welding Society (AWS) QC1, 2007, Standard for AWS Certification of Welding

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### Inspectors

ASTM International (ASTM) E797, 2005, Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

Federal Specification (Fed Spec) BB-C-101, Jan 2004, Carbon Dioxide (CO<sub>2</sub>): Technical and USP

Federal Specification (Fed Spec) QQ-B-654, Feb 1991, Brazing Alloys, Silver

Federal Specification (Fed Spec) BB-H-1168, Jul 2006, Helium, Technical

MIL-STD-22, Mar 1991, Welded Joint Design

MIL-STD-777, Jul 2002, Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships

MIL-STD-1627, Sep 1994, Bending of Pipe or Tube for Ship Piping Systems

MIL-STD-1689, Nov 1990, Fabrication, Welding, and Inspection of Ships Structure

MIL-STD-2035, May 1995, Nondestructive Testing Acceptance Criteria

MIL-A-18455, Jun 1991, Argon, Technical

Naval Sea Systems Command (NAVSEA) 0900-LP-001-7000, May 1979, Fabrication and Inspection of Brazed Piping Systems

Naval Sea Systems Command (NAVSEA) 0900-LP-060-4010, Jan 1971, Fabrication, Welding and Inspection of Metal Boat and Craft Hulls

Naval Sea Systems Command (NAVSEA) S0300-BB-MAN-010, Jun 2002, US Navy Underwater Cutting & Welding Manual

Naval Sea Systems Command (NAVSEA) S9074-AQ-GIB-010/248, Aug 1995, Requirements for Welding and Brazing Procedure and Performance Qualification

Naval Sea Systems Command (NAVSEA) S9074-AR-GIB-010/278, Aug 1995, Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

Naval Sea Systems Command (NAVSEA) T9074-AS-GIB-010/271, Feb 1999, Requirements for Nondestructive Testing Methods

The Society for Protective Coatings (SSPC), 01 June 1996, Paint Application Specification No. 2 (PA-2), Measurement of Dry Coating Thickness with Magnetic Gages

### 3. REQUIREMENTS

#### 3.1 General.

3.1.1 Compliance. The Contractor shall select a welding code and adhere to all requirements of the selected code for each welding procedure specification, as well as the requirements of this standard and applicable appendix. The Contractor may select different regulating codes for different weld procedures; however, all documentation, welding and welder requirements for each procedure (for example, the WPS, the Procedure Qualification Records (PQRs) and the welder qualification and testing of the welds) must follow the same code.

3.1.2 Welding documentation. The Contractor shall provide the COTR copies of the following information for all intended work to be performed:

- A list of Contractor WPS's and revision dates. The list shall at a minimum include all weld processes applicable to the solicitation.
- Welder qualification documentation to include the last date the welder performed the indicated process.
- When requested by the COTR, supporting PQRs and WPS documentation.

#### 3.1.3 Stray current protection.

3.1.3.1 Grounds. The Contractor shall use adjustable ground clamps that are free of defects which could damage structure or components, and shall have the ground return (work lead) connection in the immediate vicinity of the work to ensure that current does not flow through bearings, pipe hangers, or other areas where arcing could occur. The cross sectional area of the ground return cable (work lead) shall be 1,000,000 Circular Mils minimum per 1,000 amps for each 100 feet. The cross sectional area of the ground return and electrode lead cables shall be a minimum of 85,037 circular mils. For vessels constructed of non-magnetic materials, the ground return (work lead) cable shall be connected directly to the component being welded.

3.1.3.2 Electronic equipment protection. The Contractor shall work with the COTR to safeguard electronic equipment before welding to prevent damage from stray current and electromagnetic interference. Electrically isolate or disconnect ungrounded or sensitive equipment as necessary. Locate all welder ground connections as close to the work area as possible.

3.2 Advance notice. The Contractor shall provide the COTR with 24 hours advance written notice of all work planned including the weld procedure to be used.

3.3 Joints. The Contractor shall ensure the following:

3.3.1 Dimensions. Joint design and fit-up dimensions are in accordance with the applicable drawings, work item, welding code or requirements of MIL-STD-22.

3.3.2 Welding nomenclature and symbols. Welding terms, definitions, and symbols shall be interpreted in accordance with AWS A2.4, AWS A3.0, and ASTM F1076, as applicable.

3.4 Filler material restrictions. The Contractor shall be aware that low ductility shielded metal arc welding electrodes, including AWS classification E6010, E6012, E6013, E7014 and E7024, are not approved for joints in critical welds (see 1.3.5 (Critical welds)).

3.5 Temperature-indicating crayons. The Contractor shall not use temperature crayons that contain elements such as lead, sulfur, zinc, cadmium, or mercury.

3.6 Process restrictions. The Contractor shall not use gas metal-arc welding (GMAW) utilizing short circuiting arc transfer technique (the consumable electrode is deposited during repeated short circuits) for welds in ship structure above 0.25-inch material thickness, unless the process and application are specifically approved by the Contracting Officer.

3.7 Surface preparation. Contractor shall clean to bare metal all surfaces out to one inch on both sides of the weld joint to remove all foreign materials, unless otherwise directed by the work item or appendix. Scale and metallic oxides shall be removed from surfaces on which weld metal is to be deposited.

3.8 Nondestructive inspection (NDI). When inspecting welds using visual inspection (VT), liquid penetrant inspection (PT), and magnetic particle inspection (MT); the Contractor shall ensure that the weld surface shall be clearly visible, i.e. free of paint, grease, etc. Inspection shall be in the final surface condition. Inspection of repairs to base materials or welds shall be to the same requirements as the original base material or weld.

3.9 Surface preservation. The Contractor shall prepare and coat all new and disturbed exterior and interior surfaces to match existing adjacent surfaces, in accordance with COMDTINST M10360.3, Appendix A (Cutter and Boat Exterior Paint Systems) and Appendix B (Cutter and Boat Interior Paint Systems).

3.10 Repair of holes. The Contractor may repair holes by welding closed, provided the original hole diameter does not exceed 2-1/2 inches and the material thickness is 1/4 inch or greater. Holes 1/2 inch or less in diameter shall be opened to greater than 1/2 inch diameter. The opening shall be shaped to 20 degrees minimum included angle before welding. Holes greater than 2-1/2 inches original diameter shall be repaired by expanding the hole size for an insert.

3.11 Zinc coatings. The Contractor shall remove metallic zinc from all joint surfaces on which welds are to be deposited and for a distance which will be at least 1 inch from the edges of the finished welds. The localized heating technique shall not be used for removing zinc coatings from HY-80/100/130, STS or similar chemistry, or quenched and tempered low alloy high strength materials.

3.12 Requirements for High Yield (HY) materials HY-80, HY-100, HY-130 and high-hardenable materials. The Contractor shall not use oxyfuel gas gouging for HY-80, HY-100, HY-130, and high-hardenable materials. Torch heating for HY-80, HY-100, HY-130, and high-hardenable material shall be confined to tack or temporary welding or to those applications involving welding within a localized area. When torch heating is used for welding operations other than for tack welding, the base material shall slowly be brought up to preheat temperature with sufficient time allowed for heat to penetrate the thickness of the parts being welded. The heated area should extend approximately 6 inches beyond the weld site directions. When torches are used for low temperature (60°F to 125°F) preheating, maintain metal temperature above ambient temperature for a few minutes before welding in order to minimize condensate caused by the flame.

3.13 Cut edges. The Contractor shall ensure that cut edges of plate do not have gouges or irregularities

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unsuitable for welding. These edges shall be made free of slag scale by mechanical means before welding.

3.14 Tack welds. The Contractor shall ensure that tack welds are of the same grade electrode as root and final pass. Tack welds shall not interfere with the smooth completion of the final weld, and do not need to be removed provided they are thoroughly cleaned before final welding and found free of defects.

3.15 Peening of welds. The Contractor shall ensure that peening is not be performed on single-pass welds, nor on the root or final pass of multi-pass welds. When required, peening shall be performed immediately after depositing and cleaning each pass of filler metal.

3.16 Welding arc marks. The Contractor shall ensure that striking an arc on any principle hull or deck plate is prohibited unless the arc site is to be incorporated into a welded joint. Marks left by an accidental arc strike shall be ground smooth without reduction to surrounding plate thickness.

3.17 Documentation. The Contractor shall submit to the COTR, within 24 hours after completing the repair work, a written report in accordance with quality assurance requirements of applicable appendix. For welding accomplished in accordance with Appendix A, adhere to quality assurance requirements of the Appendix C. For welding accomplished in accordance with Appendix B, adhere to quality assurance requirements of the code.

## APPENDIX A

# COMMERCIAL WELDING STANDARDS

## A1. SCOPE

A1.1 Intent. This appendix contains the general requirements for welding, fabrication, brazing, inspection, and associated processes on Coast Guard vessels and equipment in accordance with commercial practices of AWS, ASME and ASTM.

## A2. REQUIREMENTS

### A2.1 General.

A2.1.1 Code selection. The Contractor shall select a commercial welding code and follow all requirements of the selected code for each WPS.

A2.1.2 Mixing of code requirements. The Contractor may select different regulating codes for different weld procedures; however, all associated documentation, welding and welder requirements for each procedure (e.g., the WPS, the PQR and the welder qualification and testing of the welds) must follow the same code.

A2.1.3 Code compliance. The Contractor shall be aware that the Coast Guard maintains the right to review all documentation and welder performance to ensure code compliance. For contractor developed welding processes following a self-regulating code (e.g., AWS or ASME), the Coast Guard will make the final decision on code compliance.

A2.1.4 ABS documentation. When ABS approved weld procedures and welder qualifications are to be used, the Contractor shall ensure that all weld procedures and qualifications are approved by the ABS Technical Office (located in Houston) in addition to the local surveyor. Be aware that the Coast Guard reserves the right for final approval of ABS weld procedures and welder qualifications.

### A2.2 Welding procedures.

A2.2.1 Welding procedure specification. The Contractor shall have written welding procedures that comply with their quality program for special processes and the requirements of the applicable regulatory agency code. Commercial welding codes offer sample welding forms that are industry accepted for documentation of welding processes and procedures in AWS D1.1, AWS D1.2 and ASME Section IX. The regulating code shall be identified on each WPS. The format of the welding procedure specification, specification test record, procedure qualification record, welder qualification test record, and nondestructive inspection of weld documents are Contractor's choice, but shall delineate all of the essential elements and guidance required to produce and inspect acceptable welds.

A2.2.2 Prequalified welding procedures. The Contractor shall not use welding procedures developed and identified by AWS as “Prequalified Welding Procedure Specifications” on critical welds. For these applications, all weld procedures must be qualified by testing in accordance with the chosen regulatory code.

A2.2.3 Standard weld procedures. Welding procedures developed and identified by AWS as “Standard Welding Procedures” are authorized for use in critical weld areas without procedure re-qualification.

A2.2.4 Welding filler materials. Filler materials shall meet the requirements of the applicable specification essential elements. See 3.4 (Filler material restrictions) for additional limitations on fillers in critical welds.

A2.3 High strength steels. Where applicable drawings specify high strength, high tensile, special treatment steel or in particular HY material used in hull plate, structural members attached to the hull or weight handling equipment, the applicable weld data sheets or welding process specification shall be specifically approved by the regulatory agency for the intended application and accepted by the government inspector prior to production welding.

A2.4 Welder qualification.

A2.4.1 Welder performance qualification. The Contractor shall ensure that all welding and brazing is accomplished by trained welders who have been certified by the applicable regulatory code performance qualification procedures. Performance qualification procedures may be in accordance with AWS or ASME, except as noted. Additionally, welders may be certified by a second tier agency, such as the Mechanical Contractors Association of America NCPWB, if such agency maintains uniform processes, and applicable data sheets including qualification and welding procedures which conform with ASME Boiler and Pressure Vessel Code Section IX, the ASME B31 Codes for Pressure Piping, or American Welding Society standards. Contractor records must document the welder has been actively welding using a process once every six months to maintain qualification.

A2.4.2 Method of establishing qualification. The Contractor shall ensure that each welder has satisfactorily completed a performance qualification test for the welds they are to perform. Performance qualification shall require completion of a standard test weldment in accordance with a qualified weld procedure, as well as evaluation and acceptance of the test weldment in accordance with applicable regulatory code. The following restrictions apply to welder performance qualification:

A2.4.2.1 Standard test weldments shall be in accordance with all requirements of a qualified weld procedure. The welder is not allowed to make exception to any of the essential variables for welders.

A2.4.2.2 Qualification by workmanship test is not authorized. Workmanship weldments are normally accepted or rejected on the basis of visual examination without radiography, bend test, bend-break test or macro-examination. This process does not provide acceptable evaluation of welder performance.

A2.4.2.3 Qualification of multiple welders or welding operators on one test weldment is not authorized.

A2.4.3 Qualification by standard test is authorized on a production weld where the governing agency examination requirements permit the use of radiography in lieu of bend tests. The production weldment shall be evaluated and accepted by radiography in accordance with applicable regulatory code and requirements of this document.

A2.4.4 Welding Qualifier. The welding qualifier shall meet the requirements of paragraph 1.3.11 (Qualifier).

A2.4.5 Individual qualification record (IQR). IQR certification and documentation shall be maintained by the Contractor for each welder in accordance with requirements of the certifying regulatory agency.

**NOTE**

**Depending upon the chosen regulatory code and welding/brazing process, the documentation of continuous qualifications ranges from monthly to several years.**

A2.5 Brazing requirements.

A2.5.1 Joint design. Brazed joints shall be of the socket or sleeve type. The sleeve type fittings shall be used only where restriction prevents the use of socket type fittings for final closure joints. Fitting dimensions shall be as shown on approved drawings. Fittings for pipes and tubings larger than 0.840" O.D. shall be of the type having pre-inserted rings of brazing alloy. Except in applications listed below, face-fed type fittings shall not be used specific approval of the COTR.

- Joints in freon (halocarbon) refrigerant systems.
- Joints for voice tube and pneumatic tube systems.
- Joints for bellmouth to pipe for tailpipes within tanks.
- Face-fed fittings shall not be used in other applications without specific approval of the COTR.

A2.5.2 Brazing filler materials. The filler metals used in brazing shall conform to the requirements of ASTM F1076, Section 5, or AWS 5.8 Filler Metals Specification. Filler metals shall be limited to Fed Spec QQ-B-654 Grades III, IV, V and VIII. Filler metal conforming to Fed Spec QQ-B-654 Grade III shall be limited to joining copper and copper based alloys.

A2.5.3 Assembly. Assembly of joints shall be in accordance with ASTM F1076.

A2.5.4 Cleaning joint after brazing. Upon completion of brazing and cooling, remove excess flux and scale from the external surfaces of the brazed joint by either washing with water or wire brushing. No filing or grinding is allowed on any portion of the joint or adjacent piping except when required for preparation of surfaces for ultrasonic inspection.

A2.5.5 Cleaning and flushing. After cooling and prior to performance of pressure or leak testing, completed piping systems shall be cleaned and flushed to the extent necessary to ensure satisfactory operation of the system and components in service. Special cleaning, when required, shall be in accordance with specified requirements in the shipbuilding, overhaul, or component specification.

A2.5.6 Repair of joints.

A2.5.6.1 General repair process. The brazing alloy used in the repair shall be the same grade as used in brazing the joint. The joint area at the face of the fitting shall be re-fluxed before heating for repair brazing. All repaired joints and adjacent joints where re-flowing of the brazing alloy has occurred shall be subjected to the same nondestructive tests as required for the original joint. A total of only two repair attempts are permitted on a single joint. When repairs cannot be effected after two repair attempts, the joint shall be disassembled and re-brazed.

A2.5.6.2 Repairs to improve bond or align fitting. Repairs to improve percentage of bond or align a

fitting may be made by re-heating and re-flowing the alloy in the joint. Joints may be repaired by rotating, adding additional flux and/or supplemental face feeding and filleting. This method is applicable to newly fabricated joints or joints which have been exposed to fresh water, cleaning solutions, refrigerant or nitrogen. No more than two repair attempts shall be made.

A2.5.6.3 Repair to fix leaks or weeps. Leaks or weeps may be repaired by re-heating to re-flow the alloy in the joint and/or supplemental face feeding and filleting. This method is applicable to newly fabricated joints or joints which have been in service regardless of the fluid which the system conveyed. No more than two repair attempts shall be made.

A2.5.7 Re-use of fittings and pipe.

A2.5.7.1 Re-use of fittings. Fittings may be re-used subject to the limitations of ASTM F1076 and NAVSEA 0900-LP-001-7000.

A2.5.7.2 Re-use of pipe. Unless otherwise specified, pipe may be re-used without inspection. Copper-nickel alloy pipe, intended for re-use shall be inspected as follows. After sizing, liquid penetrant inspect or visually inspect at 5X magnification entire periphery of pipe for length of 2D (nominal) or 2 inches (whichever is less) plus the socket depth. Cracked pipe or tubing shall not be used. If the previously brazed pipe is cut back for a distance of 2D (nominal) or 2" (whichever is less) plus the socket depth, this additional inspection is not required..

A2.5.8 Brazed joint restrictions. All heating for torch brazing shall be accomplished with an oxyfuel gas. No brazing shall be performed on non-ferrous piping greater than 4 inches NPS or on piping systems with wall thicknesses of 0.250 inch or greater without written Coast Guard Naval engineering approval.

A2.5.9 Quality Assurance. Inspection of all joints shall be performed by nondestructive methods such as radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection in accordance with requirements of appendix C.

APPENDIX B

WELDING AND INSPECTION

NAVAL SEA SYSTEMS COMMAND AND MILITARY STANDARDS

**B1. SCOPE**

B1.1 Intent. This appendix contains the general requirements for welding, fabrication, brazing, inspection, and associated processes on Coast Guard vessels and equipment in accordance with NAVSEA S9074-AR-GIB-010/278, MIL-STD-1689, and NAVSEA 0900-LP-001-7000.

**B2. REQUIREMENTS**

B2.1 General.

B2.1.1 Machinery, piping and pressure vessels. Welding and inspection for machinery, piping, pressure vessels and components shall comply with the requirements of NAVSEA S9074-AR-GIB-010/278 technical manual except as amended by this appendix.

B2.1.2 Ship structure. Welding and inspection of ship structure shall comply with the requirements of MIL-STD-1689 except as amended by this appendix.

B2.1.3 Boat structure. Fabrication, welding and inspection of boat structure shall comply with the requirements of NAVSEA 0900-LP-060-4010, except as amended by this appendix

B2.1.4 Piping systems. Brazing and inspection for piping systems shall comply with the requirements of NAVSEA 0900-LP-001-7000 except as amended by this appendix. AWS D10.12 provides additional guidance for welding mild steel pipe.

B2.1.5 Responsibility. The Contractor shall be responsible for submitting detailed welding procedures that comply with applicable NAVSEA technical manuals or Military Standards. In addition, the Contractor shall ensure that all subcontractors have qualified procedures based on approved qualification data. Prior to production application of the welding procedures, the Contractor shall obtain approval in accordance with welding procedure qualification requirements of NAVSEA S9074-AQ-GIB-010/248.

**NOTE**

**Welding procedure approval in accordance with NAVSEA S9074-AQ-GIB-010/248 requires submittal of the welding procedure qualification test report to the authorized NAVSEA representative and submittal of the corresponding welding procedure to the authorized NAVSEA representative.**

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B2.1.6 Welding procedures. Welding procedure qualifications previously prepared for other Government agencies, AWS, ABS, ASME, or other established regulatory codes may be submitted for approval to the NAVSEA authorized representative in accordance with limitations of NAVSEA S9074-AQ-GIB-010/248.

B2.1.7 Welding nomenclature. All references to weld joint symbols shall be interpreted in accordance with MIL-STD-22 and AWS A2.4. Welding nomenclature and definitions shall be interpreted in accordance with AWS A3.0.

B2.1.8 Applicable materials.

B2.1.8.1 Base materials. Base materials shall meet the requirements of the applicable material specification listed in NAVSEA S9074-AR-GIB-010/278, MIL-STD-777, or MIL-STD-1689. The following material designators used in U.S. Coast Guard drawings and working documents are equivalent for selecting weld data sheets and filler materials.

Ordinary Strength Steel	OSS
Carbon Steel, CS	OSS
Mild Steel	OSS
High Strength Steel	HSS
High Tensile Steel	HTS/HSS
High Hardenable/Special Treatment Steel	STS

B2.1.9 Welding filler materials. Filler materials shall meet the requirements of the applicable specification essential elements. See 3.4 (Filler material restrictions) for additional limitations on fillers in critical welds.

B2.1.10 Commercial filler specifications. Commercial filler materials for which there are no military specifications may be used when specified by the COTR. Such materials shall be procured to the designated specification and receipt inspected prior to use.

B2.1.11 Shielding gases and electrodes. Argon gas shall conform to the requirements of MIL-A-18455. Helium gas shall conform to the requirements of Fed Spec BB-H-1168, Grade A. Carbon dioxide gas shall conform to the requirements of Fed Spec BB-C-101. Tungsten electrodes shall conform to the requirements of AWS A5.12, EWTH-2, 2% thoriated.

B2.1.12 Brazing filler materials. The filler metals used in brazing shall conform to the requirements of ASTM F1076, Section 5, or AWS A5.8 Filler Metals Specification. Filler metals shall be limited to Fed Spec QQ-B-654 Grades III, IV, V and VIII. Filler metal conforming to Fed Spec QQ-B-654 Grade III shall be limited to joining copper and copper based alloys.

B2.2 Welder qualification. All welder and weld operators shall be trained and performance qualified in accordance with requirements of NAVSEA S9074-AQ-GIB-010/248. All brazing procedures, brazers, and brazing operators shall be qualified in accordance with NAVSEA 0900-LP-001-7000.

B2.3 IQR. IQR certification and documentation shall be maintained by the Contractor for each welder in

accordance with requirements of NAVSEA S9074-AQ-GIB-010/248. All records of qualification shall be made available to the government inspector prior to production welding.

**B2.4 Joint design and fit-up.** Weld joint design and fit-up dimensions shall be in accordance with the applicable drawings, specification requirements or the authorized joint design of MIL-STD-22. All brazed joint designs shall be interpreted in accordance with NAVSEA 0900-LP-001-7000 except as detailed below.

**B2.5 Brazed joint requirements.** All new or replaced pipe and tube bends shall conform to MIL-STD-1627, and brazed joints shall be of the socket or sleeve types. The sleeve type fittings shall be used only where restriction prevents the use of socket type fittings or for final closure joints. Fittings for pipes and tube larger than 0.840" O.D. shall be of the type having pre-inserted rings of brazing alloy, except the following joints may be of the face-fed type.

- Joints in freon (halocarbon) refrigerant systems.
- Joints for voice tube and pneumatic tube systems.
- Joints for bellmouth to pipe for tailpipes within tanks.
- Face-fed fittings shall not be used in other applications without specific approval of the COTR.

**B2.5.1 Brazed joint restrictions.** All heating for torch brazing shall be accomplished with an oxyfuel gas. No brazing shall be performed on non-ferrous piping greater than 4 inches NPS or on piping systems with wall thicknesses of 0.250 inch or greater without written Coast Guard Naval engineering approval.

**B2.6 Joining requirements.**

**B2.6.1 General.** Welding shall be performed in accordance with the NAVSEA approved data sheets. The welding parameters on the data sheets may be used for other than the designated joint designs when specified by NAVSEA or cognizant Coast Guard engineering.

**B2.6.2 Process restrictions.** GMAW utilizing short circuiting arc transfer technique (the consumable electrode is deposited during repeated short circuits) shall not be used for welds in surface ship structure, unless the process and application are specifically approved by NAVSEA and the Coast Guard Contracting Officer.

**B2.6.3 Joint preparation.** In addition to weld buildup to correct oversize root openings, weld buildup may be used on surfaces or edges of materials in way of penetrations or connections prior to making joint fit-up. In all cases involving welding to correct excessive root opening, the joint edges shall not be joined until the oversize root opening is corrected to within the requirements of the applicable joint design.

B2.6.4 Joint Efficiency. All welding shall have a regular and uniform surface with a minimum of reinforcement and shall be free from injurious defects, overlap, undercut, lack of penetration, cracks and porosity. Welds shall be 100 percent efficient (full penetration) for shell plating, decks, bulkheads, supporting structures, floors and foundations. See Table XVII of MIL-STD-1689 for joint efficiency exceptions.

**NOTE**

**When welding from both sides is required, the root of the first weld deposit shall be chipped, ground or air-arc gouged to sound metal prior to welding the second side of the joint.**

B2.6.5 Requirements for HY-80, HY-100, HY-130, and high-hardenable materials. The Contractor shall perform all HY-80, HY-100, HY-130, and high-hardenable materials preheat and welding in accordance with MIL-STD-1689, Section 13.5. See 3.12 (Requirements for HY-80, HY-100, HY-130 and high-hardenable materials) for additional limitations on oxyfuel gas gouging and touch heating.

B2.6.6 Removal of austenitic or nonferrous weld material. When it is necessary to make ferritic welds over areas that previously contained austenitic or nonferrous welds, ensure complete removal of the austenitic or nonferrous weld metal.

B2.6.7 Underwater repairs. Contractor shall perform underwater welding and cutting in accordance with NAVSEA S0300-BB-MAN-010.

B2.7 Quality assurance.

B2.7.1 General. All inspections of welded joints in machinery, piping and pressure vessels shall be performed in accordance with NAVSEA S9074-AR-GIB-010/278 except as modified in this appendix. All inspections of brazed joints shall be conducted in accordance with NAVSEA 0900-LP-001-7000 except as modified in this appendix.

B2.7.2 Inspection requirements. Unless otherwise stated by NAVSEA S9074-AR-GIB-010/278 or NAVSEA 0900-LP-001-7000, inspections shall be performed in the final surface condition. Repairs to base materials or welds are to be inspected to the same requirements as the original base material or weld. Inspection shall be made when the material or weld is accessible for inspection to the degree necessary to confirm the joint is acceptable.

B2.7.3 Methods. All inspections shall be as required within applicable specifications and shall be accomplished in accordance with the following procedures. Unless otherwise specified all acceptance criteria shall be in accordance with MIL-STD-2035 Class 3 acceptance standards.

- Visual Inspection, NAVSEA T9074-AS-GIB-010/271.
- Magnetic Particle Inspection, ASTM E1444.
- Liquid Penetrant Inspection, ASTM E1417.
- Radiographic Inspection (RT), NAVSEA T9074-AS-GIB-010/271.
- Ultrasonic Inspection (UT), NAVSEA T9074-AS-GIB-010/271.

B2.7.4 Visual inspection. As a minimum, all welds shall be visually inspected. Welds requiring MT, PT, UT or RT shall in addition be visually inspected prior to final acceptance.

B2.7.5 MT inspection.

B2.7.5.1 General. Inspection shall be conducted in accordance with ASTM E1444. PT inspection may be substituted for MT where MT is impractical.

B2.7.5.2 Final inspection. Final inspection of ferritic material shall be performed after all required machining or grinding has been completed, or may be performed prior to final machining when the inspected surface is within 1/32 inch of the final surface and the MT DC continuous method is used.

B2.7.5.3 MT inspection exceptions. MT inspection is not required for backgouged roots. Additionally, MT inspection is not required for arc strike removal site, fabrication scars, nicks or gouges prior to repair welding.

B2.7.6 PT inspection.

B2.7.6.1 Weight handling equipment. PT inspection shall be performed on all completed welds deposited with austenitic or nonferrous electrodes in weight-handling fittings or fixtures supporting over 1 ton, unless the fitting or fixture is proof load tested after installation. Overlay or clad welding deposited on primary hull structure with austenitic or nonferrous weld metal for corrosion-resistance applications shall be PT inspected.

B2.7.6.2 PT inspection exception. PT inspection is not required for clad welds used for wear-resistant applications.

B2.8 Report. The Contractor shall document all weld inspections in accordance with welding surveillance inspection requirements of the applicable welding specification. All records of inspections shall be submitted to the COTR, within 24 hours after completing the welding work.

**APPENDIX C**

**STRUCTURAL BOUNDARY TESTS AND NONDESTRUCTIVE INSPECTION**

**C1. SCOPE**

C1.1 Intent. This appendix describes the requirements for structural boundary testing and nondestructive inspection on Coast Guard vessels and equipment.

**C2. REQUIREMENTS**

C2.1 Structural boundary testing.

C2.1.1 Air test.

C2.1.1.1 Precaution. The Contractor shall place a sign on each access of the space to be tested that clearly states the following phrases in upper case letters: **“DANGER, DO NOT ENTER, AIR TESTING IN PROGRESS”**. See C3.1 (Notices).

C2.1.1.2 Set-up. Install the following at the test connection:

- One vent valve.
- Two relief valves arranged in parallel and set at 15 percent above test pressure.
- Two independent pressure gauges, each with a range such that the test pressure is in the middle of the scale.
- An air supply of not more than 25 psig with a supply capability less than the exhaust capability of either relief valve.

C2.1.1.3 Isolation. Isolate the space to be tested by blanking and/or plugging all openings including lines and vents going to and from the space.

C2.1.1.4 Pressurization. Apply a two psig test pressure for 10 minutes. Observe the allowable pressure drop specified in Table C1. Hold the test pressure in the space for at least 15 minutes to allow the temperature to stabilize prior to conducting the 10 minute test.

**TABLE C1 - ALLOWABLE TEST PRESSURE DROP**

SPACE TO BE TESTED	ALLOWABLE PRESSURE DROP
Tanks, voids, cofferdams	None
All others	0.1 psig

C2.1.1.5 Leak detection. When the allowable test pressure drop is exceeded, the Contractor shall locate the leaks and repair as required. Retest space to Table C1 requirements.

C2.1.1.6 Completion. After the air test, relieve the pressure and remove all blanks and plugs.

C2.1.2 Water hose test.

C2.1.2.1 Precaution. Prior to conducting a water hose test, the Contractor shall ensure all adjacent equipment is protected so no damage will occur from any spray or fluid collection.

C2.1.2.2 Procedures. The Contractor shall conduct a water hose test by directing fresh water against the boundary being tested. The water hose nozzle shall be no less than 1/2" in diameter and the pressure at the nozzle no less than 50 psi. The nozzle shall be within 10 feet of the structure being tested.

C2.1.2.3 Acceptance criteria. Successful test shall be noted by no evidence of water on the opposite side of the structure.

C2.1.3 Air hose test.

C2.1.3.1 Precaution. Safety glasses shall be worn at all times.

C2.1.3.2 Procedures. The Contractor shall conduct an air hose test by directing an air stream against the boundary being tested in a manner most likely to disclose leaks. An air pressure of 90 psi shall be supplied through a nozzle of 3/8 inch diameter. The nozzle shall be held as close as possible to the joint or boundary being tested.

C2.1.3.3 Acceptance criteria. Apply a soap solution to the opposite side of the structure to detect and locate leaks. A successful test shall be noted by no formation of bubbles in the soapy solution.

C2.1.4 Chalk test.

C2.1.4.1 Procedures. The Contractor shall ensure the door or hatch being tested is properly adjusted prior to conducting the chalk test. Chalk the bearing surface or knife edge and close the door or hatch by normal procedures. When the door or hatch is opened, the chalk from the knife edge will have been transferred to the gasket.

C2.1.4.2 Acceptance criteria. A successful test is noted by a uniform and continuous chalk mark on the door's or hatch's gasket (100 percent gasket contact). Irregularities or breaks in the chalk mark are cause for failure.

C2.1.5 Hydrostatic test. The Contractor shall make provision to relieve pressure trapped downstream of the installed system. At least one manually actuated valve shall be provided for overpressure protection during all hydrostatic tests. At least one relief valve shall also be provided as automatic overpressure protection.

C2.1.5.1 Welded piping system and pressure vessel hydrostatic tests. The Contractor shall hydrostatically test welded piping systems and pressure vessels to 135 percent of the system design operating pressure for 15 minutes, using clean, fresh water, except where specified in Table C2, with no allowable leakage or permanent deformation of pressure-containing parts.

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C2.1.5.2 Refrigeration system tests. The Contractor shall perform a system integrity test using a dry, inert gas, such as nitrogen or anhydrous carbon dioxide. Test piping and connections at 50% of system design operating pressure, but not more than 15 psig for R-11 refrigerant systems, 50 psig for R-114 systems, 100 psig for R-124 systems, or 75 psig for R-12, R-22, and 134a systems. Inspect all joints and connections in the system using a soap bubble solution. After leaks are repaired, and prior to initial system charging, the piping installation shall be inspected and tested in accordance with ASME B31.5.

C2.1.5.3 Atmospheric system tests. The Contractor shall perform a hydrostatic water test of atmospheric and gravity systems including deck drains, plumbing drains, vents and overflow piping. Piping shall be subjected to a 10-foot minimum head of water for 15 minutes, without leakage. If the system is tested in sections, at least 10 feet of the higher section shall be retested, except the uppermost 10 feet, or less, of the system. In conjunction with the hydrostatic test, or separately, each plumbing fixture and drain shall be operated to assure unobstructed flow and traps maintain the required water seal.

C2.1.5.4 Mechanical joined piping system operational tests. The Contractor shall test mechanical system joints (i.e. threaded, bolted, etc.) by performing an operational test of the piping system at the system design operating pressure for 15 minutes, using clean, fresh water, except where specified in Table C2, with no allowable leakage.

C2.1.5.5 Tank hydrostatic tests. The Contractor shall hydrostatically test all feed tanks, storage tanks and similar vessels that contain only static head of the acquired liquid to a pressure of 2 psig and hold the pressure for 15 minutes. Use clean, fresh water, or dry air except where specified in Table C2, with no allowable leakage.

**TABLE C2 - SYSTEM TEST MEDIA**

<b>SYSTEM</b>	<b>TEST MEDIA</b>
Lube Oil	System fluid
Hydraulic Oil	System fluid
Contaminated Oil, Ballast, or Seawater Systems	Seawater

C2.1.5.6 Fuel filling system. Before conducting hydrostatic testing of fuel filling systems, the Contractor shall ensure all manifold/stop valves, flow control valves, drain valves, and cross-connecting valves to other systems are properly closed. If any of these boundary valves to be closed have a pressure rating of 100 psi or less, they shall remain open to prevent disc distortion during testing. Install a blank flange downstream of the valve to provide the required test boundary.

### C2.2 Nondestructive inspection of welds.

C2.2.1 Inspection methods. Inspection of welded joints shall be performed by nondestructive methods such as radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection. Radiographic or ultrasonic inspection, or both, is to be used when the overall soundness of the weld cross section is to be evaluated. Magnetic particle, liquid penetrant, or other AWS welding inspection methods are to be used when investigating the outer surface of welds, or may be used as a check of intermediate weld passes. Inspection of welds shall be in accordance with general guides AWS B1.10, and AWS B1.11. Inspection shall be in accordance with the following procedures:

C2.2.2 VT. Inspection shall be in accordance with AWS B1.11 or ABS Rules for Nondestructive Inspection of Hull Welds.

C2.2.3 MT.

C2.2.3.1 General. Inspection shall be in accordance with ASTM E709 and ASTM E1444 or ABS Rules for Nondestructive Inspection of Hull Welds. PT inspection may be substituted for MT where MT is impractical. MT inspection may be performed using wet or dry method, fluorescent or non-fluorescent particles and magnetic fields of circular or longitudinal method. No cracks are allowed.

C2.2.3.2 Final inspection. Final inspection of ferritic material shall be performed after all required machining or grinding has been completed, or may be performed prior to final machining when the inspected surface is within 1/32 inch of the final surface and the MT DC continuous method is used. For inspection purposes, weld surface areas designed to be covered by other structural weldments (such as areas of longitudinal butt weld surfaces under frame welds or frame or stiffener weld areas covered by intercostals) are not considered finished welds until the covering weldment has been completed.

C2.2.4 PT. Inspection shall be in accordance with ASTM E1417 and ASTM E165 or ABS Rules for Nondestructive Inspection of Hull Welds. No cracks are allowed.

C2.2.5 RT. Inspection shall be in accordance with ASTM E94 or ABS Rules for Nondestructive Inspection of Hull Welds.

C2.2.6 UT. Inspection shall be in accordance with ASTM E164, ASTM E587 or ABS Rules for Nondestructive Inspection of Hull Welds.

C2.2.7 Surface preparation for NDI. Inspection of completed welds shall be accomplished after slag removal and with the weld in the final surface condition. Power driven wire brushes shall not be used on surfaces that are to be liquid penetrant inspected unless the resulting surface is removed using an approved abrasive material prior to performing the inspection.

C2.3 Weld examinations. The following welds shall be inspected:

C2.3.1 All welds. All welds shall be visually inspected. Inspection prior to welding shall, at a minimum, include joint preparation, fit-up, and cleanliness. In process inspections, when required, shall be in the presence of the COTR.

C2.3.2 Weight handling equipment welds. PT inspection shall be performed on all completed welds deposited with austenitic or nonferrous electrodes in weight-handling fittings or fixtures supporting over 1 ton, unless the fitting or fixture is proof load tested after installation.

C2.3.3 Overlay or clad welding. Overlay or clad welding deposited on primary hull structure with austenitic or nonferrous weld metal for corrosion-resistance applications shall be PT inspected.

C2.3.4 Water and oil tight welds. In addition to the visual inspection requirements, the Contractor shall perform NDI, in the presence of the Coast Guard inspector, on all final welds in shell plating, decks, watertight bulkheads and oil-tight bulkheads.

C2.3.5 Fillet welds 3/8 inch size and greater. The Contractor shall accomplish a surface examination, by an appropriate NDI method in the presence of the Coast Guard Inspector, of fillet welds 3/8 inch size and greater.

C2.3.6 Multi pass welds. For multi-pass full penetration welds, the Contractor shall examine the root pass in addition to the final surface pass by an appropriate NDI method in the presence of the Coast Guard Inspector.

C2.3.7 Loss of preheat. If the preheat temperature drops below minimum on incomplete welded joints in or to HY-80/100/130 (1-1/8 inches and over) or high hardenable materials (1" and over) the partially completed welds shall be VT/MT inspected.

C2.4 Nondestructive inspection of components. Inspection of components (plate, pin, etc.) shall be performed by nondestructive methods such as ultrasonic, magnetic particle, or liquid penetrant inspection.

C2.4.1 UT inspection shall be used when the overall soundness of the component cross section is to be evaluated, following the following guidance:

C2.4.1.1 Ultrasonic apparatus, procedure requirements, and report shall be in accordance with ASTM E797. Report results shall additionally include the following information for each test point, unless otherwise stated in a work item:

- Location.
- Original metal thickness.
- Measured metal thickness.
- Percent deterioration (calculation is based on the original metal thickness).

C2.4.1.2 For plate thickness greater than .250", the Contractor has the option of taking the UT measurements on bare metal, primed metal, or fully coated metal; however precaution must be taken precautions to ensure that bare steel metal is not left unprotected long enough for corrosion to form. For plate thicknesses less than .250", UT measurements must be taken on bare metal.

C2.4.1.3 When testing fully coated metal, prove calibration of the instrument on a sample of known thickness before and after testing. Actual thickness of coating may be measured in accordance with SSPC-PA 2. Ensure that film thickness measurement is taken with a suitable eddy current gauge, for non-magnetic substrate

C2.4.1.4 Ultrasonic equipment standardization shall be in accordance with ASTM E797, Section 7 (Standardization of Apparatus) and Section 8 (Technical Hazards).

C2.4.2 MT, PT, or other AWS inspection methods are to be used when investigating the outer surface of components.

C2.5 Inspector qualifications. All individuals performing visual or other NDI operations shall be knowledgeable concerning each of the principles and methods of inspection required on the weldment. The qualification and certification of these inspectors shall be documented through the administration of written and hand-on practical examinations as performed by one of the following methods:

- AWS Senior Certified Welding Inspector (SCWI) or CWI program.
- American Society for Nondestructive Testing (ASNT) Qualification and Certification of

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NDT Personnel, as provided for in SNT-TC-1A Table 1A, 1B, 1C or 1D.

- The inspector shall be at a minimum certified to the ASNT Central Certification Program (ACCP) Level II certification.

C2.6 NDI acceptance criteria. The criteria for determining the acceptability of NDI discontinuities in welds and components shall be in accordance with MIL-STD-2035 Class 3. The criteria for determining the acceptability of NDI discontinuities in brazed joints shall be in accordance with NAVSEA 0900-LP-001-7000. The Contractor shall repair all defects.

C2.7 Reports. Within 24 hours after completing the test, the Contractor shall submit a written report to the COTR stating the test results and identifying the location and extent of the leaks, if any.

C2.8 Touch-up preservation. The Contractor shall prepare and coat all disturbed exterior and interior surfaces to match existing adjacent surfaces, in accordance with COMDTINST M10360.3, Appendix A (Cutter and Boat Exterior Painting Systems) and Appendix B (Cutter and Boat Interior Painting Systems), respectively, and as applicable. Abide by all touch-up requirements outlined in SFLC Std Spec 0000, Appendix A (Requirements for Preservation of Ship Structures).

### **C3. NOTES**

C3.1 Notices. Before compartment air testing, the Coast Guard Inspector will announce on the ship's public address system that compartment air testing is in progress in the designated space and that personnel shall stand clear.

## APPENDIX D

**BIMETALLIC BONDED JOINT WELDING REQUIREMENTS****D1. SCOPE**

D1.1 Intent. This appendix provides the requirements for joining aluminum and steel plate or sheet using bimetallic bonded joints (consisting of aluminum alloy bonded to steel with an aluminum interlayer) on Coast Guard cutters and boats.

**D2. REQUIREMENTS**

D2.1 Welding Process. The Contractor shall perform all aluminum bimetallic bonded joint welding using the direct current, reverse polarity GMAW process, or gas tungsten arc (GTAW) processes. Perform all steel to steel bimetallic bonded joint welding using the GMAW, GTAW, or Shielded Metal Arc Welding (SMAW) processes.

D2.1.1 Shielding Gas. For welds to the aluminum side of the bimetallic bonded joint, use a shielding gas with a welding grade mixture of 75% helium and 25% argon. For the steel welds to the steel side of the bimetallic bonded joint, use CO<sub>2</sub> shielding gas (use argon or helium shielding gas with gas tungsten arc process).

D2.1.2 Electrode Materials.

D2.1.2.1 Aluminum. For welding aluminum on the bimetallic bonded joint, use either AWS 5356 alloy or AWS 5556 alloy electrode materials.

D2.1.2.2 Steel. For welding steel on the bimetallic bonded joint, the welding specification shall comply with AWS D3.5.

D2.1.3 Joint Preparation. Maintain minimum material separation at the joints to minimize distortion. Figure 1 shows the bimetallic bonded joint material type.

D2.1.4 Minimum Bend Radius. The bimetallic bonded joint bars may be bent around a curved surface. The minimum bend radius in either the vertical or horizontal plane shall not be less than 3T, where T is the bar thickness or width.

D2.1.5 Temperature Control. Do not preheat the bimetallic bonded transition joint. Monitor interpass so that the temperature at the aluminum-steel bond remains below 600 degree F. \

**NOTE**

**At temperatures in excess of 600 degree F, brittle intermetallic compounds may form at the bond zone due to interdiffusion of aluminum and iron. In typical GMAW welding of a structural member of the design shown in Figure 1(a), the bond zone temperature will rarely exceed 450 degree F.**

VARIOUS DESIGNS FOR JOINING ALUMINUM AND STEEL PARTS USING DETACOUPLE TRANSITION JOINTS

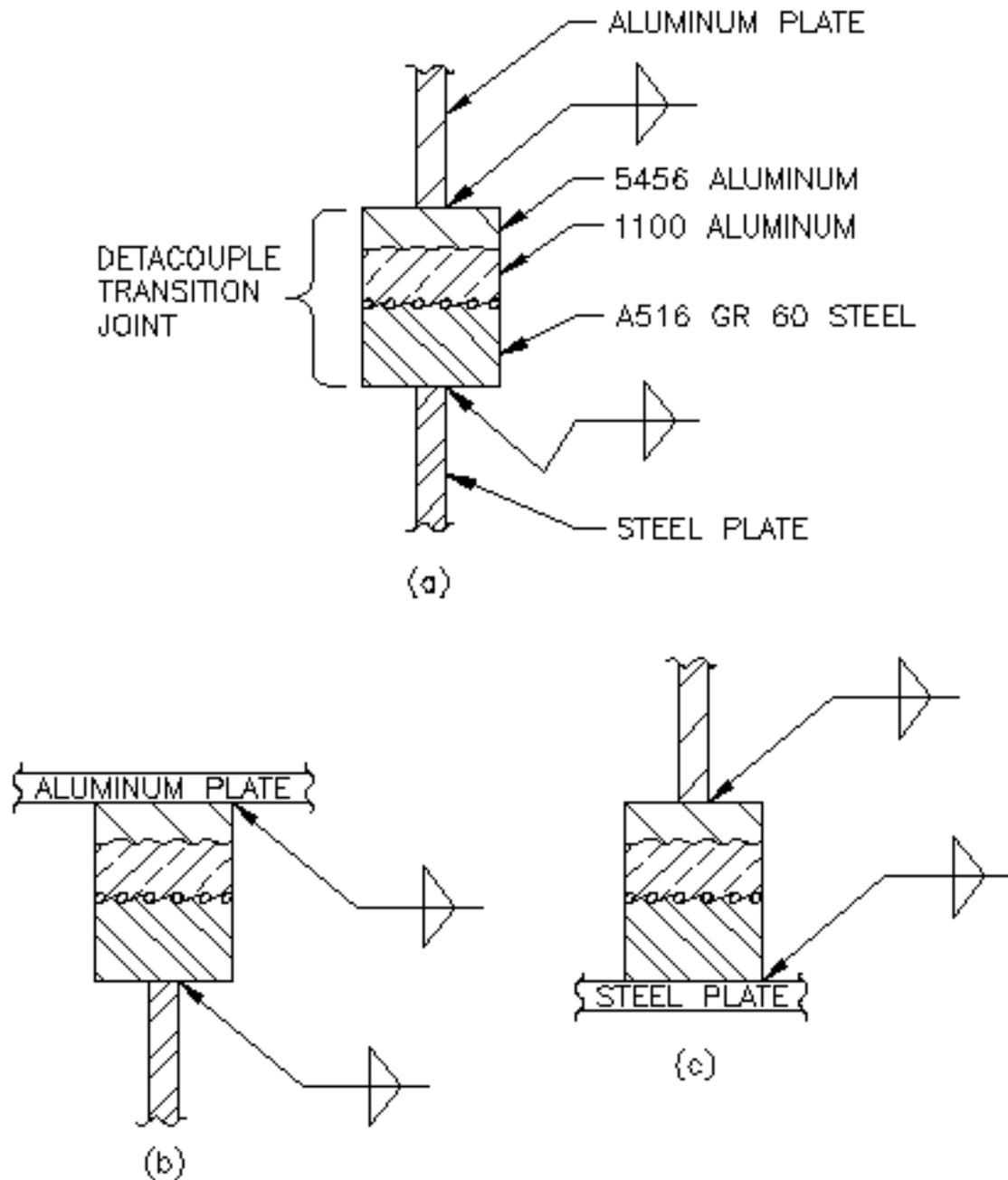


FIGURE 1