

WELDING, TUNGSTEN ARC, INERT GAS
(GTAW Method)

1. SCOPE: This specification defines the requirements for joining metals and alloys using the gas-tungsten-arc welding (GTAW) methods.
 - 1.1 Application: Primarily for joining metallic components.
 - 1.2 Classification: Weldments produced in accordance with this specification shall be of the following classes as specified on the applicable drawing:
 - 1.2.1 Class A: Weldments whose fractures would cause injury to personnel, loss of a vehicle or system, failure to complete an assigned mission task, or welds considered highly stressed.
 - 1.2.2 Class B: All weldments that are not classified Class A.
 - 1.2.3 Where no class is specified, Class B shall apply.
 - 1.3 Safety - Hazardous Materials: While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.
2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.
 - 2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

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2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2635 - Radiographic Inspection
AMS 2640 - Magnetic Particle Inspection
AMS 2645 - Fluorescent Penetrant Inspection
AMS 2646 - Contrast Dye Penetrant Inspection
AMS 2750 - Pyrometry
AMS 4901 - Titanium Sheet, Strip, and Plate, 70,000 psi (485 MPa) Yield Strength

2.2 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19103.

2.2.1 Federal Specifications:

BB-H-1168 - Helium, Technical

2.2.2 Military Specifications:

MIL-A-18455 - Argon, Technical

2.2.3 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of
MIL-STD-1595 - Qualification of Aircraft, Missile, and Aerospace Fusion Welders

2.3 AWS Publications: Available from American Welding Society, P.O. Box 351040, Miami, FL 33135.

AWS A2.4 - Welding Symbols
AWS A3.0 - Welding Terms and Definitions

3. TECHNICAL REQUIREMENTS:

3.1 Materials and Equipment:

3.1.1 Base Metal: Shall be as specified.

3.1.2 Filler Metal: Shall be as specified. When not specified, filler metal shall be as recommended by the basis metal manufacturer, and shall be specified in the welding procedure. For joints consisting of two or more base metals, the filler metal shall be as agreed upon by purchaser and vendor.

3.1.3 Backing: May be used on root sides of welds only when specified by purchaser, but shall be completely removed before inspection of welds and shall be part of the weld procedure.

- 3.1.4 Shield Gasses: Areas to be welded and heat affected zones of the base metal shall be shielded with argon conforming to MIL-A-18455 or helium conforming to BB-H-1168, or mixtures thereof.
- 3.1.4.1 Shielding of Reactive Metals, Manual Welding: Titanium alloys and refractory metal alloys (Mo, Cb, Ta, W, Zr) shall be welded in rigid or flexible chambers. After purging the chamber, a test weld bead, made using no supplementary shielding, on AMS 4901 titanium, or equivalent, shall be silver or light straw color on the surface of the weld deposit and heat affected zone.
- 3.1.4.2 Shielding of Reactive Metals, Automatic Welding: Welds may be made outside of a chamber using appropriate leading, trailing, and/or other inert gas shielding devices provided welds meet the color requirements of 3.1.4.1.
- 3.1.5 Post Weld Heat Treatment: Shall be done in ovens or furnaces in accordance with the weld procedure. Base metals supplied in cold worked or heat treated tempers shall not be post-heated to a temperature that produces softening in areas outside of the heat affected zone.
- 3.1.5.1 Steels that produce hardnesses in excess of 36 HRC in the weld or heat affected zone shall be tempered before inspection. For heat treatable and work hardened alloys, pyrometry shall conform to AMS 2750.
- 3.2 Welder and Welding Operator Qualifications: All welding shall be performed by welding operators qualified in accordance with MIL-STD-1595.
- 3.3 Terminology, Symbols, and Definitions: Shall be in accordance with AWS A2.4 and AWS A3.0.
- 3.4 Preparation for Welding and Preweld Cleaning:
- 3.4.1 Cleaning and Surface Preparation: Surfaces to be joined shall be cleaned before welding, by abrasive blasting, wire brushing, chemical etching, suitable solvents, or a combination of these, as specified by the welding procedure. Surfaces, before welding, shall be free from paint, platings and coatings, oxides and scale, and other foreign material. Materials used for surface preparation shall have no contaminating effect on the base metal or joint.
- 3.4.2 Setup for Welding: Parts may be positioned in a locating fixture, but the fixture shall not contaminate or react with the molten weld metal during welding. Parts may be tack welded but tack welds shall be fully consumed by the final weld and shall not detract from the final weld appearance. Run-on and run-off tabs may be used, but when used, shall be of the same base metal as the metal being joined, and shall be removed before inspection.

3.5 Weld Procedure: A welding procedure, such as a process specification or an instruction or operation sheet, shall be established for processing of each weld. This procedure shall cover all significant operations and parameters and shall include not less than the following:

Base Metal(s): Alloys and metal thicknesses including applicable base metal specifications

Filler Metal: Alloy including applicable material specifications, and, wire size for automatic welding

Type of Joint: Fillet, groove, plug, edge, flare, or other as applicable

Cleaning procedures for pre- and post-weld cleaning

Tools and fixtures required

Tack welds, locations and sizes

Run-off and run-on tabs where applicable

Type of Arc: AC, DC, electrode positive or negative, pulse width and rate when used

Type of tungsten, and size for automatic welding

Weld position as defined by MIL-STD-1595

Inert gas shielding provisions: inert gas type, and nozzle and flow rate ranges

Welding schedule including all applicable welding equipment control settings

Preheat and interpass heating requirements, including temperature ranges permitted when required

Postweld heat treatment or stress relief including required temperature range, time, and environment where not otherwise specified by purchaser in accordance with an applicable heat treatment specification.

3.5.1 Rework Welding: A procedure shall be established for processing of each rework and shall include the significant parameters and operations defined in 3.5. Where applicable, this may be the same as the original weld procedure.

3.5.1.1 Rework: Shall be permitted to the extent that the assembly fully conforms to engineering drawing requirements upon completion. Weld rework for assemblies that are not re-solution-treated, fully annealed, or austenitized after welding, shall be done only once in any location. Rework shall be done before heat treatment or plating or other coating.

3.5.1.2 Repairs: Must be authorized by purchaser.

3.5.2 Procedure Qualification: Where filler metal or post-weld heat treatment is specified by purchaser, the welding procedure need not be qualified.

3.5.2.1 Where no filler metal and no post-weld heat treatment is specified by purchaser, the welding procedure shall be qualified. Qualification shall consist of visual, radiographic, penetrant, or magnetic particle inspection of the initial weld, and, transverse weld tensile specimens of the same alloy(s), weld techniques, selected filler metals and post-weld heat treatments as required for the actual parts. Tensile strength from not less than three specimens, shall be as specified by purchaser, or, if not specified, not less than 85% of the base metal.

3.6 Inspection:

3.6.1 Cleaning: Titanium assemblies shall be inspected and accepted before post-weld cleaning.

3.6.2 Visual Inspection: All welds shall be visually inspected on all accessible surfaces. In the following paragraphs, the symbol “t” means nominal thickness of the base metals in the joint.

3.6.3 General Appearance: Welds shall be uniform in quality and condition, free from abrupt changes in size and contour, sound, clean, and free from foreign materials and other imperfections detrimental to fabrication or performance of assemblies. Welds containing overlaps, folds, incomplete fusion, or cracks are not acceptable.

3.6.4 Groove Welds: Shall be free from the following:

3.6.4.1 Incomplete or insufficient penetration.

3.6.4.2 Underfill.

3.6.4.3 Undercut as follows:

CLASS A: Depth exceeding 0.05t or 0.002 inch (0.51 mm), whichever is less at any location, or length exceeding 10% of weld length for any depth.

CLASS B: Depth exceeding 0.1t or 0.003 inch (0.76 mm), whichever is less at any location, or length exceeding 20% of weld length for any depth.

3.6.4.4 Mismatch:

3.6.4.4.1 For material under 0.063 inch (1.60 mm), mismatch at any location exceeding 0.25t for Class A welds or 0.35t for Class B welds.

3.6.4.4.2 For material 0.063 inch (1.60 mm) and over; mismatch, at any location, exceeding 0.1t for Class A welds, or 0.25t or 0.12 inch (3.0 mm), whichever is less for Class B welds.

3.6.4.5 Weld reinforcement in excess of that shown in Table I.

3.6.5 Fillet Welds: Shall conform to the following:

3.6.5.1 Leg size of fillet welds shall not be less than “t”. Legs shall not be more than 3t or t + 0.25 inch (t + 6.4 mm), whichever is less for material 0.063 inch (1.60 mm) and over, and for t under 0.063 inch (1.60 mm), legs shall not be greater than 6t or t + 0.063 inch (t + 1.60 mm), whichever is less.

3.6.5.2 Actual weld throat size shall be not less than 0.7t.

3.6.5.3 Lack of fusion to the root of the joint shall be limited as follows, measured from the theoretical root along either member.

3.6.5.3.1 For t under 0.063 inch (1.60 mm); 0.3 times actual throat size for Class A and Class B welds.

3.6.5.3.2 For t 0.063 inch (1.60 mm) and over; Class A joints, 0.15 times the actual throat size but not exceeding 10% for the joint length total.

3.6.5.3.3 For t 0.063 inch (1.60 mm) and over; Class B joints, 0.15 times the actual weld throat.

3.6.5.3.4 For any thickness and class, fillet welds between two members, disposed at an angle of 80 degrees or less, do not require root fusion provided the actual weld throat is greater than $0.7t$.

3.6.5.4 For t 0.063 inch (1.60 mm) and over; fusion at any sheet or tube surface opposite the weld is unacceptable. For t under 0.063 inch (1.60 mm), weld metal at a sheet or tube surface opposite the welding extending more than t beyond the sheet or tube at any location is unacceptable.

3.6.5.5 Undercut in excess of $0.05t$ in depth or more than 10% of the weld length is unacceptable in Class A welds. For Class B welds, undercut shall be limited to $0.1t$ depth and 20% of the weld.

3.6.5.6 When destructively examined, the weld shall penetrate into the base metal by $0.01t$ or more at all locations where fusion is required.

3.6.6 Plug and Slot Welds: Shall conform to the following:

3.6.6.1 Face reinforcement shall not exceed t or $3/32$ inch (2.4 mm), whichever is less.

3.6.6.2 Weld fusion at the internal corners shall meet the following:

3.6.6.2.1 For t under 0.063 inch (1.60 mm), lack of fusion shall not exceed $0.2t$.

3.6.6.2.2 For t equal to 0.063 inch (1.60 mm) and over; lack of fusion shall not exceed $0.15t$ or 0.03 inch (0.8 mm), whichever is less.

3.6.7 Edge and Flange Welds: Actual weld throat shall not be less than " t ".

3.7 Tests:

3.7.1 Radiography: Class A groove welds, and Class A fillet welds when specified by purchaser, shall be produced under radiographic control. Examination shall consist of inspection of all welds in accordance with AMS 2635 until suitable techniques are established, and thereafter at a frequency specified on the applicable drawing or as agreed upon by purchaser and vendor.

3.7.1.1 Groove Welds:

- 3.7.1.1.1 Inclusions shall be considered as porosity.
- 3.7.1.1.2 Porosity with tails, sharp-cornered inclusions, discontinuities, and internal defects with a length more than three times its width, are not acceptable.
- 3.7.1.1.3 Maximum pore size shall be 0.3 t.
- 3.7.1.1.4 Linear porosity consisting of four or more pores in an approximate straight line spaced less than four pore diameters apart based on the largest pore in the group, are not acceptable if the group length exceeds t.
- 3.7.1.1.5 Disregard pores under 0.002 inch (0.05 mm) for t under 0.063 inch (1.60 mm) or pores under 0.005 inch (0.13 mm) for t equal to or greater than 0.063 inch (1.60 mm). The total projected area of pores and inclusions shall not exceed 5% of the projected weld area in any inch (25 mm) of weld or fraction of an inch.
- 3.7.1.2 Fillet Welds (When Specified):
- 3.7.1.2.1 Inclusions shall be considered as porosity.
- 3.7.1.2.2 Porosity with tails, sharp-cornered inclusions, discontinuities, and internal defects with a length more than three times its width, are not acceptable.
- 3.7.1.2.3 Maximum pore size shall be 0.35 t.
- 3.7.1.2.4 Weld root fusion shall conform to 3.6.5.3.
- 3.7.1.2.5 Porosity shall be evaluated as in 3.7.1.1.5.
- 3.7.2 Surface Non-Destructive Tests: Welds shall be subjected to magnetic particle inspection in accordance with AMS 2640 and/or to fluorescent penetrant inspection in accordance with AMS 2645. For Class B welds, contrast dye penetrant examination in accordance with AMS 2646 is permitted.
- 3.7.3 Destructive (Fillet, Plug and Slot Welds Only):
- 3.7.3.1 At least two metallographic cross-sections shall be examined. At least 5% of the length of fillet weld joints shall be subjected to a bend test. Fillet welds that do not break in the bend test need not be examined further.
- 3.7.3.2 Porosity detected during metallographic examination shall not exceed 5% of the cross-sectional area with no pore greater than 0.3t for groove welds or 0.35t for fillet welds.

3.8 Imperfections and Repairs: Should any are a of a welded assembly fail to conform to the specified requirements, the welding fabricator shall notify the purchaser in writing of the location and extent of each imperfection, stating the number of units in which each is located. Reprocessing shall be in accordance with the qualified procedures of 3.5. Repaired areas shall be subjected to radiographic, magnetic particle, or fluorescent penetrant or contrast dye penetrant inspection as applicable. Additionally, all other units of the lot shall be radiographically inspected in any area where imperfections were detected in one unit of the lot.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The welding fabricator shall supply all samples for fabricator's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that welded assemblies conform to the requirements of this specification. Records of welder's qualification tests, thermal processing cycles used, and weld procedure qualification tests when required shall be maintained for two years from date of shipment and shall be made available for review by purchaser upon request.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for quality (3.6.2 and 3.7.2) are classified as acceptance tests and shall be performed on each weld.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for qualification of welding operators (3.2) are classified as periodic tests and shall be performed at a frequency selected by the welding fabricator unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests and shall be performed prior to or on the first-article shipment of a welded part to a purchaser, when a change in processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement, substantiating test data, and when requested, preproduction test welds shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling: Shall be in accordance with the following; a lot shall be all parts of the same alloy(s) of one configuration processed at one time in sequence and presented for vendor's inspection at one time:

4.3.1 For Acceptance Tests: All production weldments.

4.3.2 For Periodic Tests: As agreed upon by purchaser and vendor.