SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2685D

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Superseding AMS 2685C

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:

This welding process has been used typically for joining metallic components.

1.2 Classification:

Weldments covered by the specification are classified as follows:

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.

Class B: All weldments that are not classified Class A.

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.

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2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2750	Pyrometry
AMS 4901	Titanium Sheet, Strip, and Plate, Commercially Pure, Annealed, 70 ksi (485 MPa) Yield Strength
AMS-STD-1595	Qualification of Aircraft, Missile, and Aerospace Fusion Welders

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM E 1220	Visible Penetrant Examination Using the Solvent - Removal Process
ASTM E 1417	Liquid Penetrant Examination
ASTM E 1444	Magnetic Particle Examination
ASTM E 1742	Radiographic Examination

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094 or www.dsp.dla.mil.

BB-H-1168	Helium, Technical
MIL-A-18455	Argon, Technical

2.4 AWS Publications:

Available from American Welding Society, 550 NW LeJeune Road, Miami, FL 33126 or www.aws.org.

AWS A2.4	Welding Symbols
AWS A3.0	Welding Terms and Definitions
AWS D17.1	Fusion Welding for Aerospace Applications

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 AWS D17.1 or AMS-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 AWS D17.1 or AMS-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
Postweld protective treatment, if applicable.

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 final 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 or 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. Alternatively, an actual or simulated part may be used in lieu of tensile testing, provided that part is proof tested to not less than 100% of its intended maximum structural load.

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 penetration, or, insufficient penetration where depth of penetration is defined by the engineering drawing.

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 1.

3.6.5 Fillet Welds: Shall conform to the following:

TABLE 1 - Maximum Allowable Weld Reinforcement[1]

Base Metal Thickness t, inch (mm)	Face [2]Base Metal Group	Face Any Location	Root [2]Base Metal Group	Root Any Location
0.063 (1.60 mm) and under	All	0.020 inch (0.51 mm) + t or 0.050 inch (1.27 mm)	IV and V	0.030 inch (0.76 mm) + t or 0.070 inch (1.78 mm)
			Ia, Ib, IIa, IIb, IIIa, IVb, VI, and VII	0.020 inch (0.51 mm) + t or 0.050 inch (1.27 mm)
Over 0.063 (1.60 mm)	All	0.8t or 0.25 inch (6.4 mm)	IV and V	1t or 0.25 inch (6.4 mm)
			Ia, Ib, IIa, IIb, IIIa IIIb, VI, and VII	0.8t or 0.25 inch (6.4 mm)

[1]The applicable maximum is the smaller of the two values given in the body of the table.
[2]Base metal groups are defined in AMS-STD-1595 and AWS D17.1.

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 and suckback (backside shrinkage) 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 and suckback shall be limited to 0.1t depth and 20% of the weld length.

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 ASTM E 1742 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 longitudinal cross-sectional area in any 1 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 ASTM E 1444 and/or to fluorescent penetrant inspection in accordance with ASTM E 1417. For Class B welds, contrast dye penetrant examination in accordance with ASTM E 1220 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 area 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.