Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 2680

Issued 4-1-81
Revised

ELECTRON-BEAM WELDING
For Fatigue Critical Applications

1. SCOPE:

1.1 Purpose: This specification defines the procedures and requirements for joining metals and alloys using the electron-beam welding process.

1.2 Application: Primarily for high-quality, electron-beam welding of aerospace components, the failure of which could cause loss of the aerospace vehicle or one of its major components, loss of control, or significant injury to occupants of a manned aerospace vehicle.

1.2.1 The procedure covered by this specification uses square groove and square scarf-butt joints for fatigue critical applications. Fatigue data must be available for the joint design, materials, and procedures selected. If not available, it must be established prior to use of this specification for welding procedure qualification.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) and Aerospace Recommended Practices (ARP) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2630 - Ultrasonic Inspection
AMS 2631 - Ultrasonic Inspection of Titanium Alloys
AMS 2635 - Radiographic Inspection
AMS 2640 - Magnetic Particle Inspection
AMS 2645 - Fluorescent Penetrant Inspection

2.1.2 Aerospace Recommended Practices:

ARP 1317 - Electron Beam Welding
ARP 1333 - Nondestructive Testing of Electron Beam Welded Joints in Titanium-Base Alloys

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E8 - Tension Testing of Metallic Materials

Printed in U.S.A.

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Specifications:

MIL-I-6866 - Inspection, Penetrant Method of
MIL-I-6868 - Inspection Process, Magnetic Particle

2.3.2 Military Standards:

MIL-STD-453 - Inspection, Radiographic
MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

2.4 ANSI Publications: Available from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B46.1 - Surface Texture

2.5 AIA Publications: Available from National Standards Association, Inc., 4827 Rugby Avenue, Washington, DC 20014.

NAS 976 - Electron Beam Welding Machine

2.6 AWS Publications: Available from American Welding Society, 2501 N.W. 7th Street, Miami, FL 33125.

AWS A3.0 - Welding Terms and Definitions

3. TECHNICAL REQUIREMENTS:

3.1 Materials:

3.1.1 Parent Materials: Shall be as specified on the applicable part drawing and shall include aluminum alloys, titanium alloys, steels, iron alloys, refractory alloys, nickel alloys, and cobalt alloys.

3.1.2 Filler Materials: When required, filler metal shall be as specified on the part drawing or in the certified welding schedule.

3.1.3 Cleaning Materials: Cleaning materials, chemical solvents, or etching solutions shall be as specified on the part drawing or in the certified welding schedule.

3.2 Equipment:

3.2.1 Electron-Beam Welding Equipment: Shall conform to NAS 976 or to other appropriate specifications and shall be capable of producing welds meeting the requirements of 3.6 and 3.7.

3.2.2 Jigs and Fixtures: All holding fixtures shall be capable of maintaining the desired configuration and tolerances during welding, providing back-up as required, and allowing required work space between the work piece and the electron gun. Back-up material used to deflect or absorb residual electron-beam energy shall be of the same alloy as the part being welded except that alternate back-up materials may be used when approved by procedure certification as in 3.4.2. Tooling within 6 in. (150 mm) of the weld joint shall be made from nonmagnetic materials or be degaussed to acceptable limits (See 3.2.3).

3.2.3 Degaussing: Ferromagnetic materials and tooling shall, prior to welding, be demagnetized to a level established by procedure certification (3.4.2) which prevents electron beam deflections while welding the joint.

3.3 Preparation: Joint and surface preparation, prior to welding, shall be as follows and shall be included as part of the approved procedure certification:

3.3.1 Joint Preparation: Joints shall be prepared to conform to requirements specified on the part drawing.

3.3.2 Edge Preparation: Edges shall be machined square and parallel to ensure proper fit-up. Joints shall have no rounded-off edges, but shall be deburred after machining. Unless otherwise specified, faying surfaces of joints shall have a surface texture of 32 - 125 microin. (0.8 - 3.2 µm), determined in accordance with ANSI B46.1. Witness lines, when specified, shall be applied in accordance with part drawing requirements (See ARP 1333 for guidelines).

3.3.3 Weld Start and Run-Off Tabs: Tabs, when used, shall be of the same alloy as the detail parts being welded and shall be cleaned in the same manner as the parts. Tabs shall be integral with the part, either being machined in, or welded to, the part pieces prior to assembly.

3.3.4 Surface Preparation: Surfaces of parts to be welded shall be prepared using alkaline cleaners, solvents (non-halogenated for titanium alloys), pickling, or combinations thereof as applicable to the alloy being welded. Welding should commence within 40 hr after surface preparation, unless otherwise permitted by purchaser.

3.3.4.1 Parts, after surface preparation, shall be handled in the joint area with clean, lint-free gloves and shall be covered or otherwise protected to prevent contamination except during set-up, welding, and inspection.

3.3.5 Joint Edges: Immediately prior to assembly for welding, joint edges may be additionally prepared, depending on the alloy being welded, by either acid pickling, solvent cleaning (non-halogenated for titanium alloys), wire brushing with a stainless steel brush and solvent (non-halogenated for titanium alloys) cleaning, or, for aluminum alloys, scraping of joint faying surfaces.

3.3.6 Accessory Equipment Preparation: Jigs, fixtures, and measuring devices shall be free of scale, grease, protective coatings, oxides, dust, oil, and other foreign materials detrimental to the welding process.

3.3.6.1 Handle cleaned surfaces only with clean, lint-free gloves.

3.3.7 Pre-Weld Fit-Up: The joint fit-up shall conform to the following, unless otherwise specified.

3.3.7.1 Gap: Shall not exceed gap distance used for procedure certification as in 3.4.2. For small diameter electron beams (high voltage guns), a suggested maximum allowable gap is 0.001 in. (0.02 mm). For larger diameter electron beams (low or medium voltage guns), the suggested maximum allowable gaps are 0.001 in. (0.02 mm) for material thicknesses up to 0.020 in. (0.50 mm) and 0.005 in. (0.10 mm) for thicker material.

3.3.7.2 Mismatch: For plate over 0.250 in. (6.35 mm) in nominal thickness, mismatch shall not exceed 10% of the joint thickness or 0.030 in. (0.75 mm), whichever is less. For sheet and plate over 0.150 in. (3.81 mm) and up to 0.250 in. (6.35 mm) in nominal thickness, mismatch shall not exceed 10% or 0.020 in. (0.50 mm), whichever is less. For sheet and plate up to 0.150 in. (3.81 mm) in nominal thickness, mismatch shall not exceed 10% or 0.010 in. (0.25 mm), whichever is less.

3.4 Procedure:

3.4.1 Qualification of Welding Operators: Electron-beam welding shall be performed only by certified operators qualified in accordance with procedures approved by purchaser.

3.4.1.1 Personnel performing welding in accordance with this specification shall be qualified under the cognizance and supervision of the designated welding activity and approved by the cognizant quality control activity. Qualified personnel shall be assigned a stamp with a number or symbol that shall be used to identify all weldments made by such personnel.

3.4.1.2 An operator undergoing qualification testing may weld a certification plate in accordance with 3.4.2 according to a pre-established schedule as part of the test. If the operator successfully qualifies, the weld schedule shall also be automatically certified.

3.4.2 Procedure Certification: Prior to production, a separate weld schedule shall be established for each joint and alloy or alloy combination to be welded. The schedule shall be prepared for each alloy penetration weld joint configuration, and for each cosmetic pass configuration, if required, according to Table I as a minimum requirement.

3.4.2.1 For the penetration weld joint, a test plate conforming to Fig. 1 shall be welded in accordance with the prepared weld schedule and submitted to the cognizant quality control activity for tensile testing in accordance with 3.6.1. Where the test plate of Fig. 1 is not an appropriate representation of the parts to be welded, as in the case of forgings, castings, tubing, or other geometric considerations, the schedule shall be established on actual or simulated parts as agreed upon by purchaser and vendor.

3.4.2.2 For the cosmetic pass configuration, a test plate conforming to Fig. 2 shall be welded in accordance with the prepared weld schedule and submitted for metallurgical examination in accordance with 3.6.2.2. The cosmetic pass configuration shall be made as a bead-on-previously-deposited full-penetration weld. The cosmetic pass configuration test sample may also be taken from a simulated or actual part as specified by purchaser.

3.4.2.3 Upon acceptance of the test plate (either Fig. 1, actual part, or simulated part) for either a full-penetration or (Fig. 2) a cosmetic-pass weld, the cognizant quality control activity shall certify the weld schedule and forward copies to other cognizant agencies.

3.4.2.4 Test Plate Preparation and Testing: The weld schedule certification test plate (either Fig. 1, actual part, or simulated part) shall be of the same material and condition and shall be prepared and cleaned in the same manner as the production part. Welding shall be performed using the same welding position and joint configuration (thickness and angle) representative of that used on the production part. The welding operator's ID number shall be metal impression stamped on each plate welded for certification. Testing shall be accomplished in accordance with 3.6 and 3.7.

3.4.2.5 Tacking/Locking Passes: A tacking pass may be used to restrict relative motion in the weld assembly prior to the first full penetration pass. Weld schedule certification of a tacking pass is not required provided all evidence of the tack welding is obliterated by the actual weld through fusion.

3.4.2.5.1 A tacking pass, other than a full-penetration pass and made with a power density setting substantially reduced from the certified settings, may be used over any portion of the weld joint up to and including the full length of the weld.

3.4.2.5.2 A full-penetration tacking pass using certified parameters may be utilized but shall not exceed 10% of the weld joint length. This locking pass shall terminate in the starting or stopping tabs, when applicable.

3.4.2.6 Cosmetic Pass: Cosmetic passes for the purpose of correcting unacceptable underfill conditions may be applied at any time after completion of the initial full-penetration pass. Cosmetic passes, if used, shall be certified in accordance with 3.4.2.2.

3.4.3 Procedure Recertification: Recertification of weld schedules shall be required for failed test welds and when any change is made to the following parameters:

3.4.3.1 When a change in base metal composition or thickness in excess of ±10% is made (not applicable to cosmetic-pass-weld configuration).

3.4.3.2 When a change is made in joint design (not applicable to cosmetic-pass-weld configuration), but not necessarily after changes in length or diameter of joint.

3.4.3.3 When the welding position (relationship between the gun angle and the work angle) is changed in excess of 10 degrees.

3.4.3.4 When a change is made in any one of the machine settings, items 12 and 14 through 19, or in the energy input, item 21 of Table I.

3.4.3.4.1 The use of the beam-deflection switch, item 18 of Table I, need not be considered when used for the purpose of scanning or beam alignment.

3.4.4 Production Welding: Production parts shall be welded in accordance with the parameters established in the certified weld schedule of 3.4.2.

3.4.4.1 Welding Environment: Electron-beam welding shall be performed in a vacuum at 1×10^{-4} mm Hg or better. Venting of the chamber after welding shall not occur less than 2 min. after completion of welding, unless otherwise established in the procedure certification.

3.4.5 Marking and Identification: Each weld shall be traceable to the date of welding and identifiable to the welding operator, and shall be recorded, unless waived by purchaser.

3.4.6 Rework: A rework shall be a full or partial electron-beam penetration weld accomplished subsequent to the full-penetration weld. Rework of imperfections, such as cosmetic passes for correction or underfill or bead appearance improvement, as well as full-penetration passes for correction of a missed joint, and other defects may be accomplished by electron-beam welding in accordance with a certified welding schedule. Restarting of the electron beam after an arc-out shall not be classified as a rework but the reason, location, and method shall be recorded.

3.5 Post Treatment:

3.5.1 Machining: Machining of face surface, root surface, or both, shall be as specified by the applicable part drawing, the certified weld schedule, or both.

3.5.2 Heat Treatment: Weldments requiring heat treatment shall be processed in accordance with part drawing requirements.

3.6 Properties: Specimens taken from test plates, actual parts, or simulated parts produced for procedure certification as in 3.4.2.1 and 3.4.2.2 shall conform to the following requirements:

3.6.1 Tensile Strength: Specimens shall conform to and be tested in accordance with ASTM E8. The weld is acceptable when failure occurs at a stress equal to or greater than the minimum tensile strength for basis metal specified in the procurement specification or as specified by purchaser. Specimens failing at the bond line of the weld or in the weld metal are acceptable only when examination of the fracture surface at 15X magnification reveals it to be free of defects.

3.6.2 Metallurgical Examination for Soundness, Bead Shape, and Weld Width:

3.6.2.1 Macro-sections of the weld shall conform to the requirements of 3.7.1. Sections shall be taken transverse (See Fig. 1) to the weld direction and shall be examined at 3 to 10X magnification. Minimum weld bead width shall be established and recorded and witness line acceptance criteria for scarf joints shall also be noted.

3.6.2.2 Micro-sections of cosmetic welds, examined at not less than 100X magnification, shall meet the acceptance criteria of 3.7.1 and 3.7.2. Sections shall be taken parallel and transverse to the weld direction (See Fig. 2).

3.6.3 Special Properties: When special tests are required to establish nondestructive acceptance criteria as in 3.7.2, the tests and specimens shall be established as agreed upon by purchaser and vendor.

3.7 Quality: Electron-beam welds shall conform to the following requirements, unless otherwise specified (See 8.1 for defect definitions):

3.7.1 Visual Inspection: All weldments, examined at 3X magnification or greater, shall meet the following:

3.7.1.1 Color: The weld bead and adjacent parent metal shall have a color similar to that of the unwelded parent material. In the case of titanium, this color shall be a bright silver or light straw-colored appearance; blue-gray or gray discoloration or the presence of loose scale is not acceptable. Discoloration due to vapor deposition is acceptable. Cosmetic passes shall not be used to change color.

3.7.1.2 Penetration: Joints shall have complete penetration; on special designs, however, complete penetration may be achieved by post-weld machining.

3.7.1.3 Incomplete Fusion: Incomplete fusion or missed joints are not acceptable. Not less than 0.010 in. (0.25 mm) of parent metal from each side of the joint shall be included in the welded area (See ARP 1333 for procedure).

3.7.1.4 Cracks: Not acceptable in the weld-heat affected zone or adjacent parent metal except where microfissuring is specifically permitted by the engineering drawing (See 3.7.2.1).

3.7.1.5 Voids and Pores: Voids and pores open to the surface are not acceptable unless they are subsequently to be removed by machining or blending.

3.7.1.6 Underfill and Concave Root Surface: The cumulative depths of underfill or face and root surfaces shall not exceed the post-weld machining allowances specified on the part drawing. The allowable underfill for each surface not machined after welding shall be 10% of the joint thickness or as specified on the drawing.

3.7.1.7 Undercut and Root Notches: Where permissible, shall not exceed engineering drawing tolerances. When not specifically noted, undercut or root notches shall not exceed 10% of material thickness total and shall be blended to have not less than 0.06 in. (1.5 mm) root radius.

3.7.1.8 Overlaps: Not acceptable.

3.7.1.9 Witness Lines: When specified on the part drawing, witness lines shall be applied to the face and root sides of the weld joint (See ARP 1333 for procedure).

3.7.1.9.1 Face Side: Joint interface (seam) as established by witness lines shall fall within the central one-third of the weld beam. If the face side witness line examination indicates that the joint interface does not fall within the central one-third of the weld bead, the witness line data shall be evaluated for acceptance by the cognizant electron-beam weld activity to ensure compliance with 3.7.1.3.

3.7.1.9.2 Root Side: Joint interface (seam), as established by witness lines, shall fall at least one-half space within the weld bead width. In addition, the difference between unmelted witness line spaces on each side of the weld bead shall be one space or less. Weld bead locations which show a difference of more than one space (0.030 in. (0.75 mm) displacement) shall be evaluated for acceptance to ensure compliance with 3.7.1.3.

3.7.1.9.3 Witness line joint interface locations on the weld face shall be evaluated and accepted before any cosmetic passes are made.

3.7.1.9.4 For scarf joints, the requirements of 3.7.1.9.1 and 3.7.1.9.2 shall apply, unless otherwise specified. Witness line acceptance criteria for all scarf joints shall be as specified on the pertinent electron-beam certification (EBC).

3.7.1.10 Welder's Identification Stamp: The presence of a welder's identification stamp is required in the vicinity of the weld joint. The method of applying the welder's designation shall be as specified on the part drawing or as specified by purchaser. The method selected should ensure that the identification cannot be lost or obliterated during subsequent processing.

3.7.2 Radiographic Inspection: All electron-beam welds shall be radiographically inspected in accordance with AMS 2635 or MIL-STD-453 to determine conformance to the following acceptance standards. In addition, radiographic inspection shall be used as the referee technique for identifying, locating, and determining the size of indications disclosed by ultrasonic inspection as in 3.7.3.

3.7.2.1 Cracks: The presence of cracks, as a result of welding, in the weld-heat-affected zone or adjacent parent metal are not acceptable. Should microfissuring be acceptable in any specific alloy (e.g., Inconel 718), acceptance criteria shall be specified by purchaser.

3.7.2.2 Porosity, Voids, and Inclusions: Weld discontinuities, such as porosity, voids, and inclusions (metallic and nonmetallic), within the weld metal or immediately adjacent in the parent metal shall be restricted and sized as follows:

3.7.2.2.1 The size of internal porosity, cavities, voids, and inclusions shall be determined by its largest dimension.

3.7.2.2.2 Inclusions (metallic or nonmetallic) shall be treated the same as porosity.

3.7.2.2.3 Interconnected porosity, inclusions, and cavities (voids) shall be considered as one single pore for sizing purposes.

3.7.2.2.4 Pores and voids identified with the welding operation are acceptable provided they do not exceed the limits of 3.7.2.3.

3.7.2.3 Internal Discontinuity Limits:

3.7.2.3.1 Maximum Pore Diameter: Two or more adjacent discontinuities, other than aligned (3.7.2.3.3), shall be treated as a single discontinuity (excluding the space between them) when the spacing between them is less than 3 times the greatest dimension of the smaller adjacent discontinuity. The allowable limits for various parent metal thicknesses are established in Table II, Column B (2), for aluminum alloys, and in Table II, Column B(1), for all other materials covered by this specification (See 3.1.1).

3.7.2.3.2 Maximum Defect Area: Shall be the sum of the areas of the pores totally within a 1.0-in. (25-mm) length of weld not to exceed the limits of Table II, Column C(2), for aluminum alloys, and Table II, Column C(1), for all other materials (See 3.1.1).

3.7.2.3.2.1 Pores less than 0.010 in. (0.25 mm) shall not be considered in calculating total defect area for thicknesses 0.25 in. (6.2 mm) or greater.

3.7.2.3.3 Maximum Aligned Defect Area: Shall be any group of 5 or more individual pores within a 1.0-in. (25-mm) length of weld whose images can be intersected by a straight line (regardless of orientation within the weld) and the distance between adjacent discontinuities within the group being considered is less than 4 times the longest dimension of the smaller adjacent discontinuity. The limits of aligned defects are established in Table II, Column C(4), for aluminum alloys, and in Table II, Column C(3), for all other materials (See 3.1.1).

3.7.3 Ultrasonic Inspection: When specificed by purchaser, all electron-beam welds, including weld certification tests, shall be ultrasonically inspected in accordance with AMS 2630 or, for titanium, AMS 2631. Acceptance criteria shall be as specified in 3.7.2.1 and 3.7.2.2, and as follows:

3.7.3.1 Discontinuities or isolated ultrasonic responses, which by a reanalysis of witness line data and reinspection are shown not to be missed joints, shall be acceptable. Discontinuities which cannot be confirmed by radiographic inspection as in 3.7.2 in the area of the ultrasonic indication shall be referred to the cognizant engineering activity for disposition of the weld joint.

3.7.3.2 Where "zoning" of critical welds is established, both ultrasonic and radiographic inspection shall be performed on critical welds. Less critical (lower stress) welds shall be subjected to either ultrasonic or radiographic inspection, whichever provides adequate results for the particular joint.

3.7.4 Fluorescent Penetrant Inspection: All electron-beam welds, including weld certification tests, of non-magnetic materials shall be fluorescent penetrant inspected in accordance with AMS 2645 or MIl-I-6866 to locate imperfections open to the surface. No defects are permissible except as permitted by 3.7.1.5, unless otherwise authorized by the cognizant engineering activity.

3.7.5 Magnetic Particle Inspection: All electron-beam welds, including weld certification tests, of magnetic materials shall be magnetic particle inspected in accordance with AMS 2640 or MIL-I-6868. No defects are permissible unless otherwise authorized by the cognizant engineering activity.

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 such confirmatory testing as he deems necessary to ensure that welded assemblies conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for quality (3.7) 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 (3.4.1) and properties (3.6) 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 on the first-article shipment of a welded part to a purchaser, when a change in processing requires reapproval of the welded part 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 material shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be in accordance with the following; a lot shall be all parts or assemblies 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.

4.3.3 For Preproduction Tests: Not less than three welds for procedure certification (3.4.2) representative of each joint in the part or assembly using production facilities or facilities representative of those to be used in production. When preproduction test welds are made on actual hardware, the number and location of test specimens shall be as designated by purchaser.

4.4 Approval:

4.4.1 Sample welded parts or assemblies and the welding schedule shall be approved by purchaser before welded parts or assemblies for production use are supplied, unless such approval be waived.

4.4.2 The processor of production parts or assemblies shall use processing techniques and methods of routine inspection which conform to the approved welding schedule. If necessary to make any change in processing procedures (See Table I) or methods of inspection, the welding processor shall submit for reapproval details of the proposed changes in processing and, when requested by purchaser, sample welded parts or assemblies. Production parts or assemblies incorporating the revised procedure shall not be shipped prior to receipt of reapproval.

4.5 Reports: The vendor of welded parts or assemblies shall furnish with each shipment three copies of a report showing the results of tests on each lot to determine conformance to the acceptance test requirements and, when performed, to the periodic test requirements of this specification and stating that the parts or assemblies have been processed in accordance with the approved welding schedule by certified welding operators. This report shall include the purchase order number, AMS 2680, part or assembly number, and quantity.

5. PREPARATION FOR DELIVERY:

5.1 Identification: Welded parts or assemblies shall be identified as specified on the part drawing or as agreed upon by purchaser and vendor.

5.2 Protective Treatment: When required, welded parts or assemblies shall be given a suitable protective treatment as specified in the process schedule or by the part drawing.

5.3 Packaging:

5.3.1 Welded parts or assemblies shall be handled and packaged in such a manner as will ensure that the required physical characteristics of the parts or assemblies are preserved.

5.3.2 Packages of parts or assemblies shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the parts or assemblies to ensure carrier acceptance and safe delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

5.3.3 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-794, Level A or Level C, as specified in the request for procurement. Commercial packaging as in 5.3.1 and 5.3.2 will be acceptable if it meets the requirements of Level C.

6. ACKNOWLEDGMENT: A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Parts or assemblies not welded in accordance with this specification or with modifications authorized by purchaser will be subject to rejection.

8. NOTES:

8.1 Defect Definitions: Shall conform to standard definitions as shown in AWS A3.0 and as follows:

8.1.1 Bursts: This type of defect is a disc-shaped flaw on the weld centerline. The length and depth usually range between ten and twenty times its width.

8.1.2 Cracks: Fracture-type discontinuities characterized by a sharp tip and high ratio of length and width to opening displacement.

8.1.3 Lack of Fusion (Incomplete Fusion): This is fusion which is less than complete.

8.1.4 Overlap: The protrusion of weld metal beyond the toe, face, or root of the weld.

8.1.5 Porosity: This consists of round (or oval, within 2:1) shaped voids, typical of the porosity found in all welding processes; they may be isolated, linear, or stacked in the weld-depth dimension.

8.2 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Part or assembly number of parts to be welded
Quantity of parts to be welded
Applicable level of packaging (See 5.3.3)

8.3 This process has been classified under Federal Stock Class FSC THJM.

TABLE I

MINIMUM PARAMETERS TO BE RECORDED IN WELDING SCHEDULE

1. Applicable Electron-Beam Certification (EBC) Number
2. Parent Metal Alloy
3. Parent Metal Thickness
4. Pre-Weld Cleaning Procedure, Applicable Cleaning Specification, or both
5. Surface Preparation at Weld Joint
6. Filler Metal Type, Specification, or both
7. Automatically Fed Filler Metal Diameter
8. Filler Wire Feed Speed (±10%)
9. Operator and ID Stamp
10. Welding Speed, in. per min. (mm/s) (±5%)
11. Sketch of Set-Up Including All Angles (±0.5 deg)
12. Distance of Gun to Work (±1/8 in. (±3 mm))
13. Beam Current (±5%)
14. High Voltage (±5%)
15. Focusing Current (±5%)
16. Tacking/Locking Passes
17. Beam Deflection - On _____ Off _____
18. Cathode to Anode Spacer
19. Witnessing Inspectors Name and Stamp
20. Quality Control Certification
21. Energy Input in Kilojoules/Inch (kJ/mm) (±5%)
    Energy input is calculated by the equation:

$$H = \frac{(kV) \times (Ma) \times 60}{Ipm \times 1000}$$

where,
H = Kilojoules/Inch (kJ/mm)
kV = High Voltage
Ma = Beam Current
Ipm = Welding Speed, in. per min. (mm/s)

TABLE II

INTERNAL DISCONTINUITY LIMITS

A	B		C			
	Maximum Pore Diameter (3.7.2.3.1) Inch		Plan Area of Image, Sq in. x 10,000			
			Total Discontinuities (3.7.2.3.2)		Aligned Discontinuities (3.7.2.3.3)	
Final Weld Thickness Inch	Column 1	Column 2	Column 1	Column 2	Column 3	Column 4
0.010	0.0010	0.0025	3	7	1	3
0.025	0.0025	0.0063	8	16	3	6
0.050	0.0050	0.0125	15	32	5	13
0.075	0.0075	0.0188	18	47	8	18
0.100	0.010	0.025	25	63	10	25
0.125	0.013	0.031	31	78	13	31
0.150	0.015	0.038	37	94	15	38
0.175	0.018	0.044	43	109	18	44
0.200	0.020	0.050	50	125	20	50
0.225	0.023	0.056	56	125	23	56
0.250	0.025	0.063	62	125	25	63
0.500	0.050	0.063	125	125	50	63
0.750 & Over	0.050	0.063	125	125	63	63

NOTES:
1. Interpolate between final weld thicknesses where necessary.
2. The effective image areas for various discontinuities are shown in Table III.
3. Example for use of Table II:
   a) For final weld thickness of 0.500 in. in titanium.
   b) Radiograph indicates that the greatest concentration and magnitude of internal discontinuities in any one linear inch of weld includes:
      1 discontinuity 0.041 - 0.050 in. diameter
      4 discontinuities 0.031 - 0.040 in. diameter
      5 discontinuities 0.010 - 0.020 in. diameter
   c) Calculate the sum of the areas of the discontinuities, using the factors in Table III.
      1 x 20 = 20
      4 x 10 = 40
      5 x 2 = 10
      70
   d) From Table II, Column C(1), the acceptable area of total discontinuities in titanium is 125; because the calculated area was 70, the weld is acceptable from the standpoint of total discontinuities.
   e) If, however, the discontinuities were so aligned that they could be intersected by a straight line (3.7.2.3.3), the allowable limit for the titanium example weld (Column C(3)) is 50 while the calculated area was 70 and the weld would not be acceptable.