

INCH-POUND

MIL-STD-2103(OS)

7 March 1990

SUPERSEDING

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MILITARY STANDARD

WELDING, ELECTRON BEAM,  
REQUIREMENTS FOR



AMSC A4916

AREA THJM

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## **MIL-STD-2103(OS)**

### **FOREWORD**

1. This military standard is approved for use by the Naval Sea Systems Command, Department of the Navy and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commanding Officer, Naval Ordnance Station, Standardization Branch (3730), Indian Head, MD 20640-5000, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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### 1. SCOPE

**1.1 Scope.** This standard covers the requirements for welding rocket motor case components by the electron beam (EB) welding process.

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### 2. APPLICABLE DOCUMENTS

#### 2.1 Government documents.

**2.1.1 Specifications, standards and handbooks.** The following specifications, standards and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

#### STANDARDS

##### MILITARY

MIL-STD-453     Inspection, Radiographic

MIL-STD-1949     Inspection, Magnetic Particle

(Unless otherwise indicated, copies of federal and military specifications, standards and handbooks are available from: Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

**2.2 Non-Government publications.** The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

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

ASTM E 8     Tension Testing of Metallic Materials (DoD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

#### AMERICAN WELDING SOCIETY (AWS)

AWS A3.0     Welding Terms and Definitions (DoD adopted)

(Application for copies should be addressed to the American Welding Society, Inc., 550 NW LeJeune Road, P.O. Box 351040, Miami, FL 33135.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)



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**2.3 Order of precedence.** In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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### 3. DEFINITIONS

**3.1 General definitions.** Unless otherwise defined herein, the definition of welding terms used in this standard are in accordance with AWS A3.0.

**3.2 Incomplete penetration.** Incomplete penetration is a lack of fusion in the root of the weld or gap left by a failure of the weld metal to fill the root. Incomplete penetration appears on the radiograph as a dark continuous or intermittent line in the middle of the weld (see figure 1).

**3.3 Crack.** A crack is a discontinuity produced by a fracture in the metal, and appears as a fine dark line, straight or wandering in direction (see figure 2).

**3.4 Underfill.** An underfill is a depression on the face of the weld or root surface extending below the surface of the adjacent base metal (see figure 3).

**3.5 Sharp weld edge.** A sharp weld edge occurs at the edge of the weld bead and may be caused by either the grinding operation or the welding operation or both such as the back-up plate. A sharp weld edge has a sharp edge that does not blend in with the parent material. The sharp weld edge appears on the radiograph as a sharp indication but may not have a density change on the film (see figure 4).

**3.6 Sharp-tail porosity.** A sharp-tail porosity is any cavity having a sharp tail-like indication (see figure 5).

**3.7 Porosity.** Porosity is a cavity caused by entrapped gas (see figure 6).

**3.8 Lack of fusion.** Lack of fusion is a defect caused by lack of union between the weld metal and parent metal or both. Lack of fusion appears on the radiograph as a thin dark line with sharply defined edges. Depending upon the orientation of the defect with respect to the X-ray beam, the line may tend to be wavy and diffuse (see figure 7).

**3.9 Undercut.** A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal (see figure 8).

**MIL-STD-2103(OS)****4. GENERAL REQUIREMENTS**

**4.1 Welding process.** The electron beam (EB) welding process shall be in accordance with the requirements specified in this standard.

**4.2 EB welding equipment.** All welding shall be performed on EB welding machines certified as specified in 5.1.1. The equipment shall be capable of supplying sufficient power to penetrate the maximum weldable thickness in a single pass.

**4.2.1 Focusing target.** Unless otherwise specified in the welding procedure (see 4.4), the welding machines shall be equipped with a tungsten beam-focused target. The target shall be kept in good repair.

**4.2.2 Calibration.** The voltage and current meters of welding machines shall be calibrated at a frequency that will assure reproducibility and operational consistency of the production welds. The contractor shall control the accuracy of the measuring and test equipment for tests specified herein.

**4.3 Materials.**

**4.3.1 Base material.** Alloys and alloy combinations, heat-treat condition, and material thickness shall be as specified on the applicable drawing.

**4.3.2 Beam back-up material.** Unless otherwise specified in the welding procedure (see 4.4), electron beam back-up material shall be copper or of the same alloy as the material being welded.

**4.4 Welding procedures.** All welding shall be accomplished using weld procedures as specified herein. A welding procedure shall be established for each production welding machine and each weldment prior to welding the first production part. The welding procedure shall be certified as specified in 5.1.2 and shall be adhered to in all subsequent production welding of that part, except as provided in 5.3.4.

**4.4.1 Cleaning.** All fine scale, film, coatings, plating, carburization, nonfused, or nonbound materials, oil, grease, contamination, or materials that will cause difficulty in obtaining the desired vacuum or will contaminate the weld shall be removed prior to the EB welding. The surface shall be inspected to assure good metal-to-metal contact.

**4.4.2 Magnetism.** All ferromagnetic materials to be welded shall be checked for residual magnetism. Assemblies found to display any residual magnetism shall be demagnetized prior to welding. The residual magnetism level shall not exceed  $\pm 0.5$  division from zero on a magnaflex field-strength indicator.

**MIL-STD-2103(OS)****4.4.3 Welding.**

**4.4.3.1 Tack welds.** Temporary (tack) welds shall be used only if impractical to fixture-fit the joining materials or if necessary to protect the joint alignment and pre-weld joint spacing. Cleaning requirements for temporary welds shall be the same as for permanent welds.

**4.4.3.2 Welding log.** A welding log shall be maintained for all welding performed on each component (see 5.2.4).

**4.4.4 Post-weld thermal treatment.** As soon as practical after welding, the welded assembly shall receive the following thermal treatments. Preheating shall be allowed.

**4.4.4.1 Before component heat treatment.** Weldments made before component heat treatment shall be heat treated in accordance with the applicable drawing.

**4.4.4.2 After component heat treatment.** Weldments made after component heat treatment shall be stress relieved at the lowest initial tempering temperature of the welded components.

**4.4.5 Workmanship.** Welds shall be of complete penetration unless other-wise specified on the applicable drawing. Welds shall be clean and free from scale, dirt, foreign particle inclusion, porosity, undercutting, concavity, and discontinuities within the limits specified in table I.

**4.4.6 Inspection.** All welds shall be visually inspected and nondestructively inspected to ensure compliance with the requirements of this standard. The contractor shall ensure all inspection requirements have been met prior to submitting the welded items to the contracting activity for acceptance (see 5.3).

**4.4.7 Repair welds.** Unless otherwise specified in the welding procedures (see 4.4), defects in the completed weldments exceeding the limits of table I may be repaired by electron beam welding. Where parts are originally welded in the heat treated condition, annealing shall not be performed prior to weld repair.

**4.4.7.1 Weld repair procedure.** All repair welding shall be in accordance with the certified welding procedure (see 4.4).

**4.4.7.2 Post-weld treatment.** The repair welds and heat affected zones shall receive post-weld thermal treatments of 4.4.4, as applicable.

**4.4.7.3 Repair welding log.** A repair welding log shall be maintained for all weld repairs (see 5.2.5).

**4.5 EB welding operators.** All welding shall be performed by EB welding operators certified as specified in 5.1.3.

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TABLE 1. Allowable discontinuities in weldments.

Classification	Limits of Acceptability
Subsurface porosity (see 3.7)	<p>a. Size and Shape Limits. The maximum dimension of a single void shall not exceed 25 percent of the average parent material, or 0.025 inch, whichever is less. Elongated porosity whose longest accumulative dimension is greater than five times the width of the smallest dimension is unacceptable.</p> <p>b. Adjacent Porosity. Voids of 0.015 inch maximum dimension, and greater shall be separated by a minimum of three times the maximum dimension of the largest void. Voids that appear overlapping, touching, or connected when viewed normal to the weld surface shall be treated as a single void. There shall be no more than 10 voids in any 1 inch of weld regardless of size.</p> <p>c. Linear Discontinuities. Three or more voids, regardless of size, grouped in a line are unacceptable if the line extends more than 0.25 inch and the voids occupy more than 50 percent of the line length.</p>
Surface porosity	<p>d. Size and Shape Limits. The maximum dimension of a single void shall not exceed 0.025 inch. Elongated porosity whose longest accumulative dimension is greater than three times the width of the smallest dimension is unacceptable.</p> <p>e. Adjacent Porosity. Voids of 0.015 inch maximum dimension, and greater shall be separated by a minimum of three times the maximum dimension of the largest void. Voids that appear overlapping, touching, or connected shall be treated as a single void. There shall be no more than five voids in any 1 inch of weld regardless of size.</p> <p>f. Linear Discontinuities. Linear discontinuities shall meet the requirements of c. above.</p>

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TABLE I. Allowable discontinuities in weldments - Continued.

Classification	Limits of Acceptability
Other indications	<p data-bbox="618 485 1349 548">Any of the following items shall be cause for rejection:</p> <ul style="list-style-type: none"><li data-bbox="553 575 1154 606">g. Incomplete penetration (see 3.2).</li><li data-bbox="553 634 894 665">h. Cracks (see 3.3).</li><li data-bbox="553 693 943 724">i. Underfill (see 3.4).</li><li data-bbox="553 751 1040 783">j. Sharp weld edge (see 3.5).</li><li data-bbox="553 810 1105 842">k. Sharp-tail porosity (see 3.6).</li><li data-bbox="553 869 927 900">m. Undercut (see 3.9).</li><li data-bbox="553 928 1317 991">n. Concavity that would reduce thickness below minimum requirements of applicable drawing.</li></ul>

**MIL-STD-2103(OS)****5. DETAILED REQUIREMENTS****5.1 Certification.**

**5.1.1 EB welding machines.** All EB welding machines shall be certified by demonstrations performed by the contractor to verify that welding equipment is in satisfactory condition and that the vacuum systems, control function, and power source are operating within the original design criteria of the machine specifications. The certification procedures shall be prepared as specified in the contract or order (see 6.3). This certification shall be performed annually.

**5.1.2 Welding procedure.** Unless otherwise specified on the applicable drawing, welding procedures shall be certified by testing representative sample welds taken from a welded part. The part shall be made using the alloy, thickness, joint design, heat treat condition, and procedure prescribed for the actual weld. Unless otherwise specified on the applicable drawing, the part shall be radiographically inspected in accordance with MIL-STD-453 and magnetic particle inspected in accordance with MIL-STD-1949 prior to taking the test coupons and shall meet the acceptance limits specified in table 1.

**5.1.2.1 Test coupons.** The test part, prepared for welding procedure certification, shall contain a sufficient weld length to provide the following test coupons:

- a. Five tensile coupons in accordance with ASTM E 8, except that the grip size may vary at the contractor's option.
- b. One macro specimen.

**5.1.2.1.1 Tensile coupons.** Tensile coupons, after being heat treated to the applicable drawing requirements for the actual weld, shall exhibit ultimate tensile strength and yield strength at 0.2 percent offset equal to or greater than the minimum requirements of the applicable drawing. All tensile tests shall be pulled perpendicular to the weld with the weld in the center of the gage length.

**5.1.2.1.2 Macro specimens.** Macro-section specimens, cut transverse to the direction of welding, shall be polished to suitable fineness, etched, and examined for full penetration and fusion, macro-defects, and weld geometry.

**5.1.2.2 Welding procedure data.** The welding procedure data shall be as specified in the contract or order (see 6.3).

**5.1.2.3 Welding procedure acceptance.** Welding procedures shall be considered acceptable for welding of production parts if:

- a. The weld procedure certification test specimens meet all applicable requirements of this standard and any additional requirements specified on the applicable drawing.
- b. The weld procedure data has been approved by the contracting activity (see 5.1.2.2).

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- c. The first production part welded in accordance with the welding procedure satisfactorily passes 100 percent visual inspection, 100 percent radiographic inspection, and 100 percent magnetic particle inspection as specified herein.

**5.1.3 Operators.** An EB welding operator, to achieve qualified status and certification, shall be given training on EB welding machine controls, the functions and relationships, and shall demonstrate the required ability by welding the type of test joints to be welded in production. The joints shall be welded in accordance with the certified and approved welding procedures (see 5.1.2) and shall conform to the quality requirements specified in table 1. An EB welding operator shall be classified as an Electron Beam Welder. Once qualified, an EB welder may operate any EB welding machine of similar make and for the type joints for which the welder is qualified. EB welders need not be qualified in any manual welding process.

**5.1.3.1 Initial machine settings.** The EB welding operator shall demonstrate the ability to operate the equipment by starting on a machine which: (1) the column is out of alignment; (2) the filament has been removed; and (3) the machine settings are not set in accordance with the weld procedure.

**5.1.3.2 Welding operator reexamination.** An EB welding operator shall require a reexamination and be requalified in accordance with 5.1.3 if the welder has not operated EB equipment on production or research and development projects for a continuous period greater than 90 days.

**5.1.3.3 Welding operator recertification.** An EB welding operator shall be recertified at a period of time not exceeding 6 months from the previous certification date by a review of the work performance. Acceptable radiographs of a typical weld shall meet this requirement.

## **5.2 Records.**

**5.2.1 Welding procedures.** The approved weld procedure data, along with macro sections and photomacrographs, shall be maintained and made available to the welding operator each time parts or joints covered by the procedure are welded in production. Any weld procedure changed after initial approval shall require recertification approval in accordance with the requirements specified in 5.1.2.

**5.2.2 Welding operator identification.** The contractor shall maintain a list of all certified EB welding operators and their identifying symbols.

**5.2.3 Certifications and tests.** The contractor shall maintain records of all certifications and tests performed in accordance with this standard (see 6.3).

**5.2.4 Welding logs.** Welding logs shall be maintained as specified in 4.4.3.2. The log shall record and define the welding operations and shall include but not be limited to the following:

- a. Component identification and serial number.
- b. Welding operator's identification.
- c. Weld procedure name.
- d. Welding amperage and voltage.
- e. Number of passes to accomplish original weld.
- f. Gun to work distance.



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- g. Beam focus.
- h. Speed of travel.
- i. Total number of weld repairs including length, location, and number of passes.

**5.2.5 Repair welding logs.** Repair welding logs shall be maintained as specified in 4.4.7.3. Information contained therein shall include, but not be limited to the following:

- a. Weld schedule.
- b. Welder identification.
- c. Component identification and serial number.
- d. Location of rework.
- e. Cause of rework: cracking, porosity, or other defects.
- f. Maximum length, width, and depth of each rework grindout.
- g. Total number of repairs per weld.

**5.2.6 Rejection records.** Records covering rejected welds and the corrective action taken shall be maintained by the contractor.

**5.3 Inspection.**

**5.3.1 Visual examination.** All welded joints shall be visually examined for conformance to the requirements of 4.4.5.

**5.3.2 Radiographic inspection.** Each weld shall be radiographically inspected in accordance with MIL-STD-453 for conformance to the requirements of 4.4.5.

**5.3.3 Magnetic particle inspection.** All welds shall be inspected in accordance with MIL-STD-1949 for conformance to the requirements of 4.4.5.

**5.3.4 Procedure review due to weld rejection.** Failure of a production weld to meet quality requirements shall be cause for review of the established weld procedure. The cause of the unsatisfactory welding shall be determined. If investigation results in any change to the weld procedure, the changed weld procedure shall be recertified and approved in accordance with this standard. If the unsatisfactory welding is found to be the result of faulty equipment, defective materials, or noncompliance with the weld procedure, corrections shall be made as required. Any repair or modification of welding equipment shall require recertification and approval in accordance with this standard.

**MIL-STD-2103(OS)****6. NOTES**

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

**6.1 Intended use.** The electron beam welding process covered in this standard is intended for use in the manufacture of case components of the Standard Missile Mk 104 Dual Thrust Rocket Motor.

**6.2 Issue of DODISS.** When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1 and 2.2).

**6.3 Consideration of data requirements.** The following data requirements should be considered when this standard is applied on a contract. The applicable Data Item Descriptions (DID's) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DID's are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

<u>Reference paragraph</u>	<u>DID Number</u>	<u>DID Title</u>	<u>Suggested Tailoring</u>
Appendix. 10.1. 5.1.1, 5.1.2.2 and 5.2.3 of basic text	DI-MISC-80678	Certification/ Data Report	See appendix. 30.1, 30.2 and 30.3

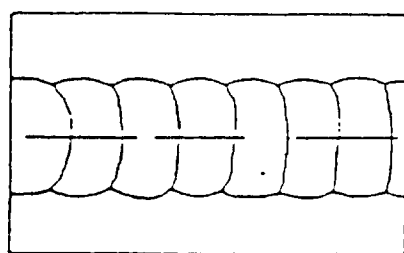
The above DID was cleared as of the date of this standard. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

**6.4 Tailoring guidance.** To ensure proper application of this standard, invitations for bid, requests for proposals, and contractual statements of work should tailor the requirements in sections 4 and 5 of this standard to exclude any unnecessary requirements.

**6.5 Subject term (key word) listing.**

Rocket Motor, Dual Thrust, Mk 104  
Standard Missile

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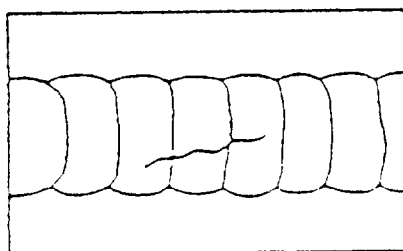


Radiographic projected appearance



Cross section of weld

FIGURE 1. Incomplete penetration.



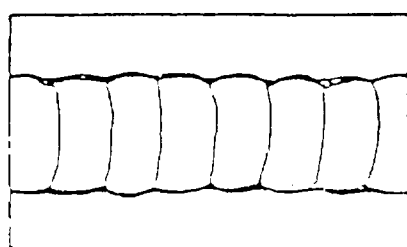
Radiographic projected appearance



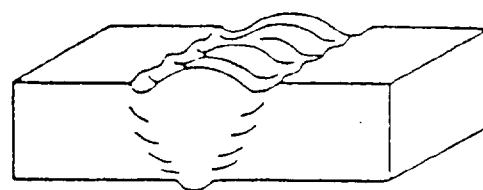
Cross section of weld

FIGURE 2. Cracks.

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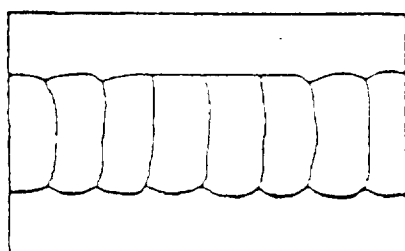


Radiographic appearance



Cross section  
of weld

FIGURE 3. Underfill



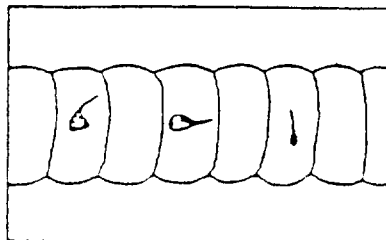
Radiographic appearance



May appear on top  
or bottom bead

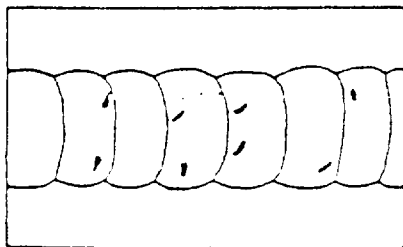
FIGURE 4. Sharp weld edge

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Radiographic appearance

FIGURE 5. Sharp-tail porosity.



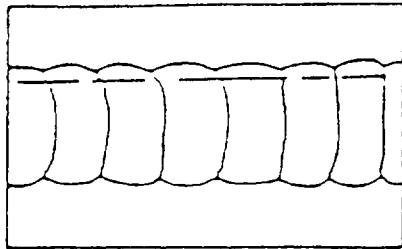
Radiographic projected  
appearance



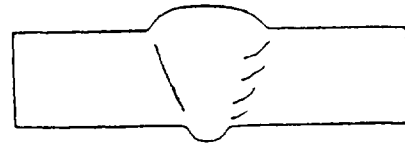
Cross section of weld

FIGURE 6. Porosity.

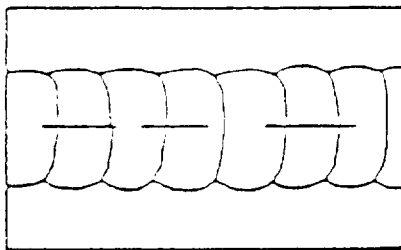
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Radiographic appearance



Lack of fusion at  
edge of weld

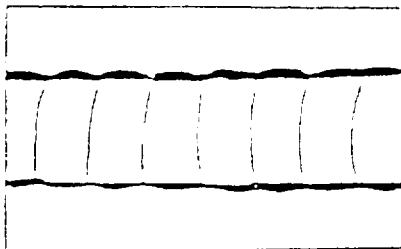


Radiographic appearance



Lack of fusion at center of  
weld. Note complete penetration.

FIGURE 7. Lack of fusion.



Radiographic appearance



FIGURE 8. Undercut.

**MIL-STD-2103(OS)****APPENDIX****CERTIFICATION DATA/REPORT****TECHNICAL CONTENT REQUIREMENTS****10. SCOPE**

**10.1 Scope.** This appendix details the technical content of certification data/report covering the contractor's electron beam welding (EB) process control for the welding of rocket motor case components. This appendix is mandatory only when data item description DI-MISC-80678 is cited in the contract or order (see 6.3).

**20. APPLICABLE DOCUMENTS**

This section is not applicable to this appendix.

**30. TECHNICAL CONTENT REQUIREMENTS**

**30.1 Certification procedures for EB welding machines.** The certification procedures shall detail the contractor's method of certifying EB welding machines in accordance with the requirements of 5.1.1 of this standard.

**30.2 Welding procedure data.** The welding procedure data shall include the following information as applicable to the welding procedure to be certified as specified in 5.1.2 of this standard:

- a. Welding machine: manufacturer, type, and serial number.
- b. Settings: amperage, voltage, positioner or carriage speed of travel, electron beam focus settings, gun position, and beam mode.
- c. Preheat and postheat: temperature, time, and method.
- d. Multipass operations: description, number of passes.
- e. Joint: sketch, joint geometry, surface condition.
- f. Cleaning: method and sequence.
- g. Welding: method and detailed welding sequence including tacking operations.
- h. Repair welding: method and sequence.

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- i. Heat treatment: condition prior to welding.
- j. Part: drawing number and any other data pertinent to the welding operation.
- k. Tooling: fixture description, back-up method, and material.

**30.2.1 Weld center location.** A procedure shall be included for relocating and aligning welds for rework of defect areas. The procedure shall be included in the weld repair procedure. The method of identifying weld location shall be such that no notching or carbon addition is made to the surface.

**30.3 Certificate of compliance.** The certificate of compliance shall include a statement by the contractor certifying that all parts submitted for acceptance by the contracting activity are produced by operators, equipment, and procedures certified in accordance with the requirements of this standard.

Preparing activity:  
Navy-OS  
(Project THJM-N275)



## STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

## INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

<b>I RECOMMEND A CHANGE:</b>		1. DOCUMENT NUMBER <b>MIL-STD-2103(OS)</b>	2. DOCUMENT DATE (YYMMDD) <b>900307</b>
3. DOCUMENT TITLE <b>WELDING, ELECTRON BEAM, REQUIREMENTS FOR</b>			
4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)			
5. REASON FOR RECOMMENDATION			
6. SUBMITTER			
a. NAME (Last, First, Middle Initial)		b. ORGANIZATION	
c. ADDRESS (Include Zip Code)		d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	7. DATE SUBMITTED (YYMMDD)
8. PREPARING ACTIVITY			
a. NAME <b>COMMANDING OFFICER NAVAL ORDNANCE STATION</b>		b. TELEPHONE (Include Area Code) (1) Commercial <b>(301)743-4510</b> (2) AUTOVON <b>364-4510</b>	
c. ADDRESS (Include Zip Code) <b>ATTN: CODE 3730 INDIAN HEAD, MD 20640-5000</b>		IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5703 Leesburg Pike, Suite 1403 Falls Church, VA 22041-3496 Telephone: (703) 755-7340 FAX: (703) 755-7340	

