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MILITARY SPECIFICATION

RADIOGRAPHIC INSPECTION, SOUNDNESS REQUIREMENTS FOR FUSION WELDS IN ALUMINUM AND MAGNESIUM MISSILE COMPONENTS

This specification is approved for use by the U.S. Army Missile Command, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the methods for defining soundness and freedom from defects of manual or automatic shielded inert gas arc welds in aluminum and magnesium as determined by radiographic inspection.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, U.S. Army Missile Command, ATTN: AMSMI-RD-SE-TD-ST, Redstone Arsenal, AL 35898-5270 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A AREA NDTI

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).

SPECIFICATIONS

MILITARY

MIL-R-11470 - Radiographic Inspection: Qualification of Equipment, Operators and Procedures

STANDARDS

MILITARY

MIL-STD-453 - Inspection, Radiographic

(Unless otherwise indicated, copies of the federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Ave., 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 155 - Inspection of Aluminum and Magnesium Castings, Standard Reference Radiographs for

ASTM E 505 - Inspection of Aluminum and Magnesium Die Casting, Standard Reference Radiographs for

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

(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.)

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.

3. REQUIREMENTS

3.1 Type of identification. Type radiographs of defects, which ;are part of this specification, bear identification numbers to which references are made in tables I and II.

3.2 Designation of standards. Tables I and II provide five standards for the soundness of welds, depicting gradations of soundness conditions. The designations of the standards shall be used in connection with the radiographic position charts to indicate the standard of soundness required in each area to be inspected radiographically.

3.3 Comparison of type radiographs. Radiographs of production welded units submitted for inspections shall be compared with the type radiographs forming part of the specification. The soundness condition represented by the type radiographs shall be considered: acceptable, borderline, or unacceptable, as indicated in tables I and II, for the standard which is applicable to the area being inspected.

3.4 Acceptance criteria. When a particular standard is called for at any location in a position chart, the defect indicated as unacceptable, as indicated in tables I and II, shall be grounds for rejecting the weldment.

3.4.1 Borderline. When fusion or linear porosity conditions are passable, but at the limit of acceptability as defined by rules 1 through 7, inclusive (see 4.4) the defect shall be regarded as borderline for the purpose of this specification.

3.4.2 Acceptability. The following instructions shall apply in determining acceptability according to the standard where borderline conditions exist according to tables I and II, and where one or more types of defects are found in any weld.

3.4.2.1 Single type of defects. When the production radiographs show but one type of defect which is equal to or better than the borderline for the acceptable standard, the corresponding portion of the weldment shall be acceptable without repair. If the defects are larger or more numerous than indicated by the borderline for the standard, the weldment shall be rejected.

TABLE I. Classification of weld defects

Defect	Type	Reference Radiographs	Standard I	Standard II	Standard III	Standard IV	Standard v
Porosity	1. Scattered	A1-1 to 5	SEE		TABLE		II
	2. Linear	A2-1 to 3 (typical)	SEE		TABLE (Figure 3)		III
	3. Isolated Voids	A3-1 to 2	U	0.50T Maximum	0.50T Maximum	0.50T Maximum	0.50T Maximum
Cracks	1. Transverse	B1-1	U	U	U	U	U
		B1-2	U	U	U	B	B
	2. Longitudinal	B2-1	U	U	U	U	U
		B2-2	U	U	U	U	U
	3. Crater	B3-1	U	U	U	B	B
Fusion	1. Incomplete Penetration	C1-1	U	U	See Figure 2 & Rule 1	See Figure 2 & Rule 1	See Figure 1, 2 & Rule 2
		C1-2	U	U			
			U	U			
	2. Imperfect fusion at weld interface faying surface junction for fillet welds	C2-1	U	U	(Acceptance in accordance with reference radio-graphs) (See ASTM E 155 & ASTM E 505)		
		C2-2	U	U			
		C2-3	U	U			
	3. Imperfect fusion at weld interface faying surface junction for butt welds with backup strips.	C3-1	U	U	(Acceptance in accordance with reference radio-graphs) (See ASTM E 155 & ASTM E 505)		
		C3-2	U	U			
Foreign Materials	1. More Dense	D1-1	U		See Notes		
	2. Less Dense	D2-1	U		See Notes		
Under-cutting	All	E1-1	0.10T Maximum	0.10T Maximum	0.10T Maximum	0.10T Maximum	0.10T Maximum

TABLE II Scattered porosity

Reference Radiograph	Thickness "T" (inches)	Standard I	Standard II	Standard III	Standard IV	Standard V
A1-1	< 0.126	A	A	A	A	A
	0.126 - 0.250	A	A	A	A	A
	> 0.250	A	A	A	A	A
A1-2	< 0.126	B	A	A	A	A
	0.126 - 0.250	A	A	A	A	A
	> 0.250	A	A	A	A	A
A1-3	< 0.126	U	B	B	A	A
	0.126 - 0.250	U	B	A	A	A
	> 0.250	B	A	A	A	A
A1-4	< 0.126	U	U	U	B	A
	0.126 - 0.250	U	U	B	A	A
	> 0.250	U	U	U	A	A
A1-5	< 0.126	U	U	U	U	U
	0.126 - 0.250	U	U	U	B	B
	> 0.250	U	U	U	B	A

A = Acceptable B = Borderline U = Unacceptable

3.4.2.2 More than one type of defect. When a single production radiograph shows more than one type of defect, the following procedure shall be used in determining acceptability.

3.4.2.2.1 Governing defect. When one type of defect predominates and the other types are equal to or better than an acceptable condition for the applicable standard, the predominating defect shall govern without regard to the other types of defects present.

3.4.2.2.2 No governing defect. When two or more types of defects are present to an extent equal to the borderline condition for each type, all borderline defects shall be unacceptable and the weldment shall be rejected.

3.5 Inspection and equipment. Unless otherwise specified by the procuring agency, qualification of equipment, operators, and procedures shall be conducted in accordance with MIL-R-11470. Radiographic inspection shall be conducted in accordance with MIL-STD-453.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, not does it commit the Government to accept defective material.

4.2 Inspection records. The supplier shall maintain exposed radiographic negatives and written radiographic inspection records in accordance with the requirements of the procuring agency (see 6.2) for each article or unit of manufacture that has been radiographed. These exposed radiographic negatives and inspection

records shall be made available for examination by the procuring activity for the period specified in the contract.

4.3 Sampling. Unless otherwise specified by the procuring activity, longitudinal and circumferential butt welds or fillet welds in missile components shall be radiographed 100 percent.

4.4 Test criteria.

4.4.1 Rule 1. Imperfect fusion or incomplete penetration shall be rejectable under standards III and IV (see table III) when the greatest summation end-to-end (see figure 2) of all defect lines is greater than a length of T/3 in any weld length of 6T.

4.4.2 Rule 2. Imperfect fusion or incomplete penetration shall be rejectable under standard V welds (see table III) when the greatest summation end-to-end (see figure 2) of all defect lines is greater than a length of 3T/4 in any weld length of 6T.

4.4.3 Rule 3. Linear porosity shall be classified as a condition in which there are images of two or more connected voids or a series of inline voids distributed in a line parallel to the longitudinal axis (in some cases, transverse to the longitudinal axis). The acceptable maximum average diameter and closest distance of approach of the individual images in linear porosity shall be as indicated in table III. Cases where fine linear porosity is aligned in a series with a length not greater than 0.25 inch and in which greater than 50 percent (%) of the length if occupied by voids, regardless of the size of the individual voids, shall be unacceptable.

4.4.3.1 Scattered porosity. Scattered porosity shall be cause for rejection if it is greater than the amount indicated on the reference radiograph for the specific recommended standard (see table II). Isolated voids greater than 0.05T of the parent metal for standards II, III, IV and V shall be cause for rejection.

4.4.4 Rule 4. All longitudinal cracks shall be unacceptable. Greatest occurrence of these cracks are at weld junctions. Transverse cracks are unacceptable, except to the extent indicated in table I, where the crack does not extend completely across the weld. Crater cracks shall be unacceptable for standards I, II, and III (see table III), and classified as borderline for standards IV and V (see table III), depending upon the severity of the crack and the requirements of the weldments.

TABLE III. Acceptable limits of linear porosity.

Standard	Sheet Thickness (inches)	Average Diameter of Images (in inches) of Individual Cavities *	Average Distance (in inches) of Closest Approach in 3 Linear inches of Weld
I	All	None Acceptable	None Acceptable
II	< 0.126	0.0625 Minimum - 0.094 Maximum	0.75
	0.126 - 0.250	0.0312 Minimum - 0.0469 Maximum	0.75
	> 0.250	0.0469 Minimum - 0.0625 Maximum	0.75
III	< 0.126	Same as Standard II	0.50
	0.126 - 0.250		0.50
	> 0.250		0.50
IV	< 0.126	0.0625 Maximum	0.50
	0.126 - 0.250	0.0625 Minimum - 0.094 Maximum	0.50
	> 0.250	0.0625 Minimum - 0.125 Maximum	0.50
V	< 0.126	0.0625 Maximum	0.25
	0.125 - 0.250	0.0625 Minimum - 0.094 Maximum	0.25
	> 0.250	0.0625 Minimum - 0.125 Maximum	0.25

* Individual cavities shall not exceed 0.50T

4.4.5 Rule 5. Imperfect fusion and incomplete penetration defects occur when the molten weld metal fails to fuse due to oxide or other impurities, or when the molten metal fails to penetrate the full thickness of the sheet due to insufficient heat. These defects shall be graded according to rules 1 and 2 and figures 1 and 2.

4.4.5.1 Fillet welds. Acceptability limits for imperfect fusion at weld interface for standard III (see figure 3) fillet welds shall be in accordance with the referenced radiographs (see table I). Because of the difficulty in differentiating between incomplete penetration and imperfect fusion in fillet welds, either or both conditions shall be cause for rejection if in excess of the limits shown in the referenced radiographs.

4.4.5.2 Butt welds with back-up-strips. Acceptability limits for imperfect fusion at weld interface for standard II (see table IV) butt welds shall be in accordance with the referenced radiographs (see table I).

4.4.6 Rule 6 - Foreign materials. More dense inclusions in aluminum arc welds are usually present in the form of tungsten from the electrode (TIG). Less dense inclusions are generally impurities resulting from poor cleaning, improper shielding gas mixture or pressures (see table I).

4.4.7 Rule 7 - Undercutting. Undercutting shall be cause for rejection if greater than of 0.10T in depth for any 1 inch weld length. Undercutting may be observed on the radiographs but is measured by mechanical means (see table I).

4.5 Special rules applicable to use of back-up-strips.

4.5.1 Sheet thickness - determination. For purposes of determining acceptability limits of welds with back-up-strips, the thickness (T) shall be defined as the thickness of the thinner sheet being jointed.

4.5.2 Isolated voids. In reference to Paragraph 4.4.3.1, isolated voids shall be cause for rejection if the diameter of the void is in excess of 0.66T.

5. PACKAGING

5.1 There are no applicable requirements for packaging.

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 processes covered by this specification are intended for use in establishing quality requirements and inspection procedures for determining the quality of fusion welds in aluminum and magnesium.

6.2 Acquisition requirements. Acquisition documents must specify the following:

a. Title, number, and date of the specification

b. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1)

c. Required period for maintaining inspection records (see 4.2).

d. Sampling other than specified (see 4.3)

6.3 Limitations. Where weld quality exceeding the radiographic acceptance limits specified in this specification is required, the limitations will be specified in the contract or on the applicable drawing. Where special penetrameters are required, the special requirements will be specified in the contract or on the applicable drawings.

6.4 Metrication. Metric equivalents in accordance with FED-STD-376 are acceptable for use in this specification.

6.5 Subject term (keyword) listing.

Metal Casting
Penetrameters
Penetration testing

6.6 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodian:
Army - MI

Preparing Activity
Army - MI

Project No. NDTI-A068

A1-1 STANDARD I

A1-2 STANDARD II

A1-3 STANDARD III

A1-3 STANDARD IV

A1-5 STANDARD V

A2-1 EXAMPLE OF LINEAR POROSITY AND INCOMPLETE PENETRATION COMBINED

A2-2 LINEAR POROSITY (EXAMPLE)

A2-3 LINEAR POROSITY (EXAMPLE)

E1-1 UNDERCUTTING - SHADED AREA AT FUSION LINE DENOTES UNDERCUT

A3-1 ISOLATED VOIDS (TYPICAL EXAMPLE)
(SEE 4.4.3.1 AND TABLE III IF LINEAR)

A3-2 ISOLATED VOIDS AND/OR LINEAR POROSITY (SEE 4.4.3.1 AND TABLE III)

B-1-1 TRANSVERSE CRACK - UNACCEPTABLE FOR ALL CASES

B1-2 TRANSVERSE CRACK - BORDERLINE FOR CLASSES IV AND V

B2-1 LONGITUDINAL CRACK - AT WELD JUNCTION - UNACCEPTABLE FOR ALL CLASSES

B2-2 LONGITUDINAL CRACK - UNACCEPTABLE FOR ALL CASES

B3-1 CRATER CRACK - BORDERLINE FOR ALL CLASSES IV AND V

C1-1 FINE LINEAR POROSITY FORMING LACK OF FUSION. (THIS IS NOT A STANDARD BUT ILLUSTRATES TYPICAL OCCURRENCE)

C1-2 LACK OF PENETRATION IN FILLET WELD (SEE SKETCH BELOW) (TYPICAL - NOT A STANDARD)

C2-1 ACCEPTABLE CLASS III
DISCONTINUOUS IMPERFECT FUSION
AT WELD INTERFACE-FAYING SURFACE
JUNCTION OF FILLET WELDS

C2-2 NOT ACCEPTABLE CLASS III
DISCONTINUOUS IMPERFECT FUSION
AT WELD INTERFACE-FAYING SURFACE
JUNCTION OF FILLET WELDS

C2-3 NOT ACCEPTABLE CLASS III
CONTINUOUS IMPERFECT FUSION
AT WELD INTERFACE-FAYING SURFACE
JUNCTION OF FILLET WELDS

C3-1 ACCEPTABLE CLASS III
ONE OR BOTH SIDES OF WELD

C3-2 UNACCEPTABLE CLASS III
ONE OR BOTH SIDES OF WELD

CONTINUOUS IMPERFECT FUSION AT WELD INTER-FACE-FAYING SURFACE JUNCTION OF BUTT WELDS WITH BACK UP STRIP

D1-1 FOREIGN INCLUSIONS - MORE DENSE SHOWS TYPICAL TUNGSTEN INCLUSIONS. ISOLATED INCLUSIONS ACCEPTABLE IF NOT EXCEEDING T/2. SCATTERED INCLUSIONS AS SHOWN ABOVE SHALL BE REGARDED AS A FORM OF SCATTERED POROSITY.

D1-2 FOREIGN INCLUSIONS - LESS DENSE MAY BE REGARDED SAME AS GAS POROSITY.