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MILITARY STANDARD
WELDING OF ALUMINUM ALLOY ARMOR



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MIL-STD-1946(MR)

DEPARTMENT OF DEFENSE
Washington, DC 20360

Welding of Aluminum Alloy Armor

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1. This Military Standard is approved 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: Director, Army Materials Technology Laboratory ATTN: SLCMT-MSR-ES, Watertown, Massachusetts 02172-2719, 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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FOREWORD

This standard covers the welding of aluminum alloy armor. Included in this document are the welding processes, requirements for welding procedure details, ballistic shock testing of welds and radiographic inspection for evaluation of weldments employed in the fabrication of aluminum alloy armor.

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(Data item descriptions related to this standard, and identified in section 6 will be approved and listed as such in DoD 5000.19-L., Vol. II, AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the Contracting Officer.)"

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1. SCOPE

1.1 Scope. This standard covers requirements for the welding of specified aluminum alloy armor including ballistic shock testing, weld design criteria, and acceptance standards for evaluation of weldments.

1.2 Classification. Welding methods covered are:

Method A - Gas metal-arc

Method B - Gas tungsten-arc

1.2.1 Other methods. Other methods may be employed provided the necessary approval of the procuring activity is obtained, on a case-by-case basis; and the additional data required for the particular process is documented.

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2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-I-6866	- Inspection, Penetrant Method of
MIL-A-45225	- Aluminum Alloy Armor, Forged
MIL-A-46027	- Aluminum Alloy Armor Plate, Weldable 5083 and 5456
MIL-A-46063	- Armor Plate, Aluminum Alloy, 7039
MIL-A-46083	- Aluminum Alloy Armor, Extruded Weldable
MIL-A-46118	- Aluminum Alloy Armor, 2219, Rolled Plate and Die Forged Shapes.

STANDARDS

Military

DOD-STD-100	- Engineering Drawing Practices
MIL-STD-367	- Armor Test Data Reporting
MIL-STD-1895(AT)	- Reference Standards and Radiographic Procedures for Partial-Penetration Aluminum Welds.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following document(s) form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and the supplement thereto, if applicable.

AMERICAN WELDING SOCIETY (AWS) STANDARDS

AWS A2.4	Welding and Nondestructive Testing, Symbols for
AWS A3.0	Welding Terms and Definitions
AWS D1.2	Structural Welding Code of Aluminum
ANSI/AWS A5.10	Aluminum and Aluminum Alloy Bare Welding Rods and Electrodes.

(Application for copies should be addressed to the American Welding Society, 550 Northwest LeJeune Road, P.O. Box 351040, Miami, Florida 33126.)

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AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS

ASTM E 340 Macroetching Metals and Alloys

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

(Industry association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

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3. DEFINITIONS

3.1 Contractor and manufacturer. The term "contractor" as used in this standard is defined as the organization having a contract with a Government activity. The term "manufacturer" is defined as the organization actually performing the operations covered by this specification. The contractor may or may not be the manufacturer.

3.2 Welding symbols. Symbols for welding shall be as specified in AWS A2.4.

3.3 Welding terms and definitions. Welding terms and definitions shall be as specified in AWS A3.0.

3.4 Weld joint design. Joint design is defined as the joint geometry together with the required dimensions of the welded joint.

3.5 Weldment. Weldment, as used in this document, refers to any unit whose parts are joined by one or more welds.

3.6 Certification. Certification is defined as the acceptance of a manufacturer's welded product by the government contracting officer based on workmanship and ballistic test results and acceptance of the manufacturer's recorded weld procedure. Procuring activity certification is required prior to production welding.

3.7 Routine positions. Routine positions are those established in critical weld areas and are to be radiographed on each weldment selected for examination.

3.8 Random positions. Random positions are those other than routine as defined in 3.7 that are selected at the discretion of the Government.

3.9 Critical weld. Critical welds are any of the following: A ballistic weld joint, a highly stressed weld or welded joints where failure would result in loss of mission.

3.10 Defect. A rejectable discontinuity.

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4. GENERAL REQUIREMENTS

4.1 Preparation of joint welding procedure and drawings. Prior to the production fabrication of any weldment, the contractor or manufacturer shall prepare engineering drawings or sketches of the structure showing the location of each joint, and shall prepare a recorded joint welding procedure that covers all welding (including a repair procedure of base metal and welded joints). Each joint-welding procedure shall contain, as a minimum, a reference to the location of the joint as shown on the engineering drawings, a detailed cross-section sketch of the joint, and shall include the factors in Table I and 4.3. This information shall be prepared in duplicate, in accordance with MIL-STD-367 and submitted to the procuring activity for conditional acceptance pending the results of ballistic tests. The cover sheet shall be signed by the manufacturer and the contractor and shall be submitted to the procuring activity for review, approval, and certification(see6.1).

4.2 Applicable welding processes.

Type A - Gas metal-arc

Type B - Gas tungsten-arc

4.2.1 Other welding processes. Procedures for other welding processes, such as plasma and electron beam shall be submitted for approval. The data shall be sufficient to insure weld integrity.

4.3 Repair welding practice. Repair of damaged base plate by thermal means may reduce the mechanical properties of aluminum armor plate and should be avoided. Scratches and gouges which do not penetrate beyond the minimal dimensional tolerances for the plate may be removed by grinding or smoothing. Repair of defects by welding shall be in accordance with a standard repair welding procedure accepted by the procuring activity. Standard welding procedures for repair of welded joints and base metal shall be prepared, signed and submitted in accordance with 4.1. The procedures shall include all factors listed in Table 1 and in addition shall include the following:

- a. Method to be used (chipping or other) for removal of defect.
- b. Sketch of typical contour of cavity prior to welding showing minimum root dimension and included angle.
- c. Use of backing or spacer strip in case of complete removal of the weld.
- d. Inspection method to determine complete removal of defect (dye penetrant, visual, radiographic, etc.).
- e. Type of aluminum plug material used to fill mislocated holes when the use of such material is authorized by the procuring activity.

4.4 Armor requirements. This standard is applicable to welds in aluminum alloy armor meeting the requirements of MIL-A-45225, MIL-A-46027, MIL-A-46063, MIL-A-46083 and MIL-A-46118.

4.5 Material for attachments. The attachments to be used in welded construction covered by this document shall conform to the requirements specified in the drawing or contract.

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TABLE - I. Requirements for the joint-welding procedure.^{1/}

Factors required:	The recorded joint welding procedure shall be recertified when:
1. Composition of base metal	A change is made in composition outside the material specification.
2. Thickness of base metal for each joint type	When basic thickness dimensions and plus tolerances fall outside the basic material specification.
3. Welding process	(a) A change from manual to semi-automatic or vice-versa. (b) A change is made from semi-automatic to automatic (including robotic).
4. Filler metal alloy	A change in the filler metal alloy is made or when a change in brand of the same filler metal alloy is made except when the new brand is certified under ANSI/AWS A 5.10.
5. Electrode (GTAW)	Any change of diameter is made. Any change of electrode type is made.
a. Diameter b. Type	
6. Filler metal size for each weld pass.	The filler metal diameter is changed.
7. Position of welding. Alternate welding positions may be listed.	There is a change in the position of welding (see AWS A 3.0).
8. Joint geometry with applicable AWS 2.4 symbols	Any change
9. Shielding gas composition.	A change in the composition of the gas involving one or more of the following: (1) a change from one inert gas to another (2) a change from mixed to non-mixture or reverse, or a change of more than 5% of any component of any gas mixture.

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TABLE - I. Requirements for the joint-welding procedure. (Cont'd)

Factors required:	The recorded joint welding procedure shall be recertified when:
10. Shielding gas flow and nozzle size	A change of more than 15 percent is made in the rate of gas flow for each nozzle size as shown in the welding procedure.
11. Number and sequence of weld passes	A change is made from single to multi-pass or reverse, except as required due to fitup variations. The sequence may be changed to prevent distortion.
12. Ranges of welding current and arc-voltage for each weld pass and also travel speed for each pass when welds are mechanized.	The values are outside the range or limits of the established recorded joint welding procedure.
13. Type of current, A.C. or D.C. and polarity of D.C. if used. (a) If pulsed-arc- all required control parameters must be specified.	The type or current or polarity is changed. Any change in controls.
14. Method of edge preparation	Method of edge preparation recertification is required when a change is made from mechanical to thermal or a combination of mechanical and thermal to thermal.
15. Method of preparing root of joint before welding the second side	A change is made from a mechanical to a thermal method but not vice versa.
16. Backing or spacer strip	Backing or spacer strip is removed; or basic type of material of backing or spacer strip is changed.
17. Preheat (starting), interpass and postheating temperature ranges.	Range is changed.
18. Method of pre-weld and inter-pass cleaning.	The cleaning method is changed.

1/ Figure 1 illustrates a recommended format for recording and displaying a joint design in a welding procedure.

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Base Metal	AA 5083 to AA 5083 (MIL-A-46027)
Base Metal Thickness	1.25"
Welding Process	GMAW
Filler Metal	5356 (Alcoa)
Filler Metal Size	0.045"
GMAW Electrode Type and Size	N/A
Position	Vertical up
Shielding Gas Type	75% Ar / 25% He
Gas Flow/Nozzle Size	60 CFM/10
Weld Passes	6
Current Polarity and Amperage	DCRP/275A
Voltage	27 V
Travel Speed	14 in/min
Edge Preparation	Machined and Degreased
Back Gouging	N/A
Backing	N/A
Pre/Post Heat and Interpass Temperature	Ambient / 200°F Max.
Cleaning	Stainless steel wire brush between each pass
WELDING PROCEDURE COMPANY NAME	JOINT DETAIL FOR SECTION A-A DRAWING NO. 257 A-R
PREPARED BY : JOHN SMITH (SIGNATURE), TITLE, DATE ACCEPTED BY: JOHN DOE (SIGNATURE), GOVT. REP., DATE	

Figure 1. Illustrates a recommended format for recording and displaying a joint design in a welding procedure.

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4.6 Filler metal : The aluminum alloy filler metal shall be compatible with the base material to be welded and it shall be approved as part of the contractor's welding procedure.

4.7 Shielding gas. The shielding gas used shall be suitable for the welding of aluminum.

4.8 Welded attachment procedures. Drawings and lists shall be prepared, grouping attachments which require the same size fillet weld - for all attachments in the fighting compartments of military combat vehicles, and attachments on other parts of such vehicles when failure of the attachment may affect the mechanical operation of the vehicles. For each group the lists shall indicate the alloy and size of the filler wire, kind and range of current and welding position(see 6.1).

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5. DETAILED REQUIREMENTS

5.1 Certification.

5.1.1 Ballistic test samples and workmanship specimens. Ballistic testing will be carried out, in accordance with Appendix A, at a Government Test Agency, (Aberdeen Proving Ground), by Government personnel. The contractor/manufacturer shall fabricate ballistic test samples (see 5.2) and workmanship specimens (see 5.5) at each plant where production welding is to be performed, using conditional acceptance of the joint-welding procedures and prior to beginning production. Certification shall be dependent on acceptable performance of the material submitted as determined by the procuring activity. Only weldments subject to direct ballistic attack shall be ballistically qualified.

5.1.2 Recertification. Unless otherwise specified, when a change in any factor of the recorded joint welding procedure outside the limitations specified in table 1 is desired by the contractor/manufacturer subsequent to the original certification, a revised, recorded joint welding procedure, shall be prepared by the manufacturer and submitted in duplicate for review (see 6.1). Recertification shall be conducted in the same manner as in the original certification procedure.

5.2 Number and selection of ballistic test samples. Ballistic weld joints will be categorized by armor material types and joint design. Representative samples of each type will be selected considering material thickness and plate obliquity. Fit-up gap tolerances shall be ballistically qualified.

5.3 Fabrication of ballistic test samples. Ballistic test samples shall be welded by the contractor/manufacturer's recorded joint-welding procedure for the joint represented. Geometry and dimensions of the test sample shall be specified by the procuring activity. Figure A-1 of Appendix A illustrates types of ballistic test samples.

5.3.1 Radiographic inspection of test samples. The contractor/manufacturer, shall radiograph and inspect ballistic test sample plates prior to submission for ballistic testing. The radiographs shall be made in accordance with the radiographic position chart and shall be sent to the Government Test Agency with the ballistic test samples.

5.4 Marking of test samples.

5.4.1 Original submissions. Each ballistic test sample shall be marked for easy identification. Marking shall be in letters, digits or both, clearly legible and shall include the specimen identification, submission date, and contractor's name or trademark. The information shall be marked on the top edge of the specimen or as otherwise specified. The impact side of each sample shall be marked "IMPACT SIDE" with letters at least 25.4 mm (1 inch) high.

5.4.2 Retest samples. Retest samples shall be marked with the original test sample identification, and any additional identification specified. This will be followed by the letter "R" to indicate retest.

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5.5 Submission of data. Unless otherwise specified the joint welding procedure data and the radiographic inspection report, prepared in accordance with formats IV & V of MIL-STD-367, plus (a) thru (e) in the following listing shall be submitted with each ballistic test sample(see 6.1):

- a. Ballistic plate number
- b. Manufacturers name and address
- c. Contract number
- d. Thickness of plates
- e. Plate specification number

5.6 Preliminary ballistic testing. The ballistic test sample submitted to the Government Test Agency for ballistic shock testing shall first be subjected to a radiographic inspection (see Appendix B) at the Government Testing Agency. On passing the radiographic inspection requirement (see 20.2.6 of Appendix B) it shall then be subjected to the ballistic shock test in accordance with Appendix A.

5.6.1 Request for retest. If the ballistic test sample fails to pass, the contractor, upon notification can immediately request a retest. If no request is made within 10 days after notification, the joint welding procedure and or joint design (new vehicles only) shall be rejected.

5.6.2 Retest sample submission. If the contractor requests a retest, two additional test specimens shall be submitted to the Government test agency for test. The samples shall be welded by the established joint welding procedure used for the original test specimen and marked in accordance with (5.4.2). Failure of either sample in the retest shall be cause for rejection of the welding procedure represented.

5.7 Workmanship.

5.7.1 Number and type of test specimens. One workmanship specimen shall be made for each type of joint included in the recorded joint-welding procedure. Examples of the workmanship samples required are shown in Figures 2, 3 4 and 5.

5.7.2 Workmanship specimen preparation and identification. The workmanship specimens shall be prepared by the manufacturer using the recorded welding procedure. Workmanship specimens prepared to represent multi-pass welds shall be prepared in such a manner as to have at least 38.1 mm (1 1/2 inches) of each pass exposed. The specimens shall be cross sectioned as shown in Figures 2, 3, 4, and 5 and macroetched in accordance with ASTM E 340 or as otherwise specified. Both sections shall be identified and shall be available to the government for inspection, unless otherwise specified.

5.7.3 Visual examination of workmanship specimens. Unless otherwise specified, the procuring activity shall approve the workmanship specimens. Unless otherwise specified the workmanship specimens shall be maintained in the immediate fabrication area. Unless otherwise specified, the workmanship specimens shall meet the visual inspection criteria as contained in AWS D1.2 for non-tubular statically loaded structures. The crossectioned specimen shall show no evidence of lack of fusion or lack of penetration and shall meet the effective throat requirements specified on the drawings. Specimens shall be polished and etched to display the degree of penetration of the filler metal into the base metal.

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5.8 Capability of welders.

5.8.1 Contractor responsibility. The contractor shall be responsible for determining the capability of the welders or welding operators to satisfactorily perform welding as prescribed in the contractor's or manufacturer's recorded welding procedure. The contractor upon request, shall provide the government inspector records of test results associated with specimens welded identifiable with the welder or weld operator.

5.8.2 Welder qualifications. Prior to the welding of aluminum armor, responsible welders and operators shall prepare a qualification specimen as depicted in figure 4 of this standard. The dimensions of the plates shall be approximately .152 X 0.305 meters (6 X 12 inches). The weld shall be made in the lengthwise direction of the plate. The plate thickness shall correspond to the thickest weldment in the production on vehicle or assembly. The joint configuration shall be either a double-V or double bevel, partial penetration weldment with the minimum included angle and the maximum effective throat as required in production weldments. Separate qualifications shall be prepared for gas tungsten arc (GTA) and gas metal arc (GMA) welding process as applicable. Welding in the vertical or overhead position will require additional qualification plates. Radiographic inspection shall be done in accordance with MIL-STD-453. The weldment shall comply with Standard 3 of MIL-STD-1895(AT). Test reports and radiographs shall be made available to the Government upon request. Rejection by the Government of a lot submitted for final Government acceptance due to inadequate visual weld workmanship will require requalification of all responsible welders. Objective evidence of prior welder qualification to AWS D1.2 for similar weld joint configurations may be accepted as equivalent to the above qualification procedure, subject to approval of the procuring activity.

5.9 Quality control of production weldments.

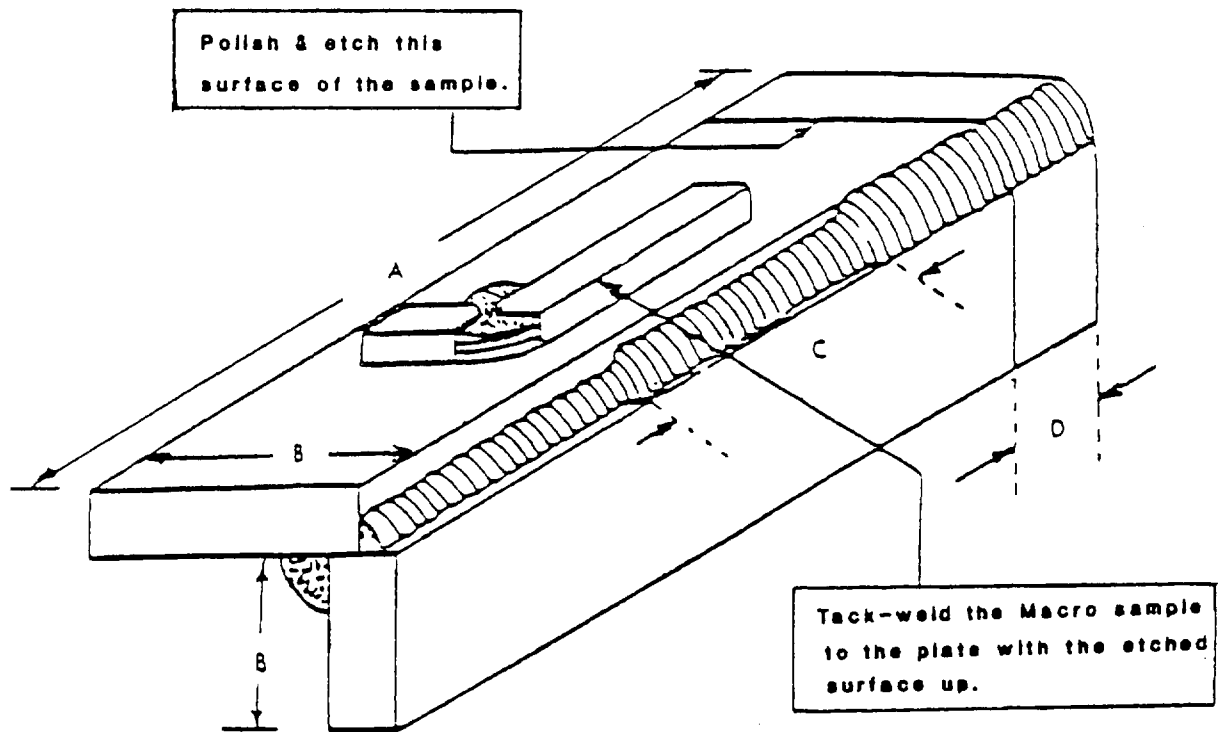
5.9.1 Radiographic and visual inspection. Radiographic and visual inspection of weldments shall conform to Appendix B.

6. NOTES

6.1 Data requirements. "When this standard is used in an acquisition which incorporates a DD Form 1423, Contract Data Requirements List (CDRL), the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved CDRL incorporated into the contract. When the provisions of the DoD FAR Supplement, part 27, subpart 27.410-6 are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this standard is cited in the following paragraphs:

<u>Paragraph No.</u>	<u>Data Requirements</u>	<u>Applicable DID No.</u>
4.1, 4.8, 20.1.1	Drawings, Engineering and Associated Lists	DI-E-7031
4.1, 4.3, 5.1.2, 5.5 20.1.3	Armor Material Test Report Certification Data/Report	DI-MISC-80073 UDI-A-23264

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DIMENSIONS (Minimum)

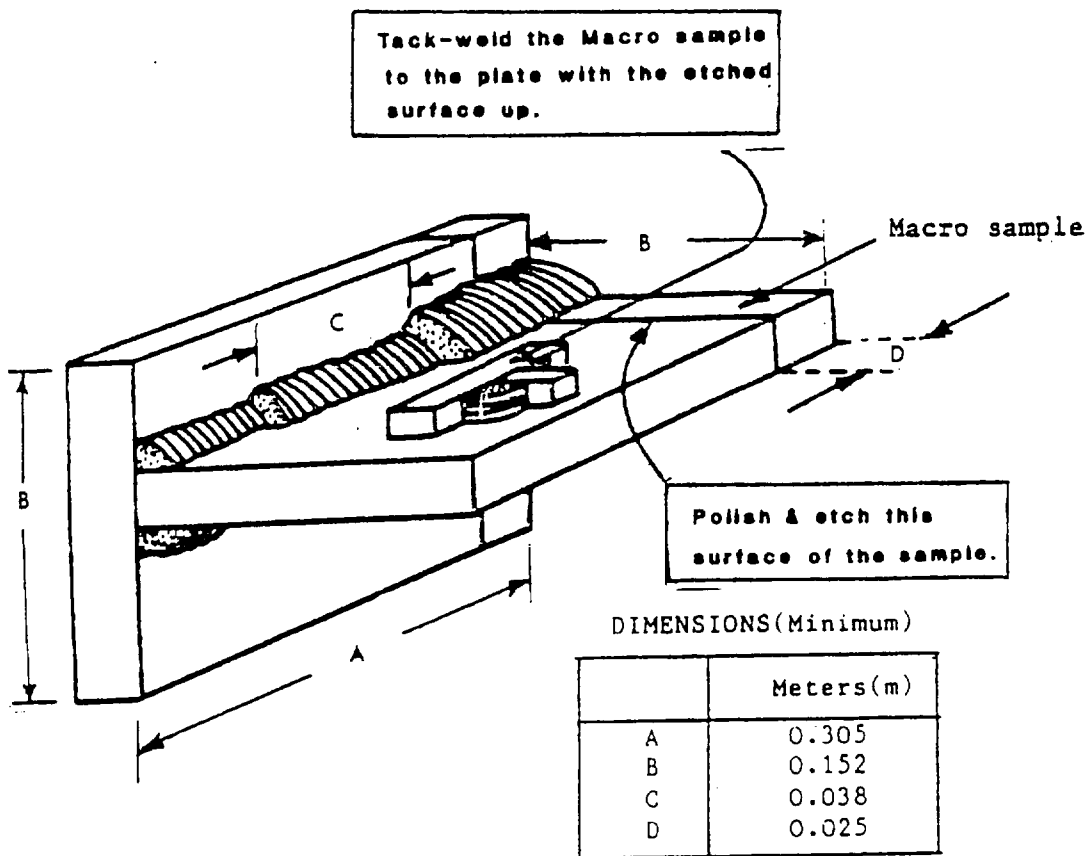
	Meters (m)
A	0.305
B	0.152
C	0.038
D	0.025

Note: 1 meter = 39.37 inches.

NOTE: Weld joint details of actual specimens shall conform to the details of the contractor's recorded joint welding procedure for each type of joint involved.

Figure 2. General configuration of workmanship specimens for corner joints.

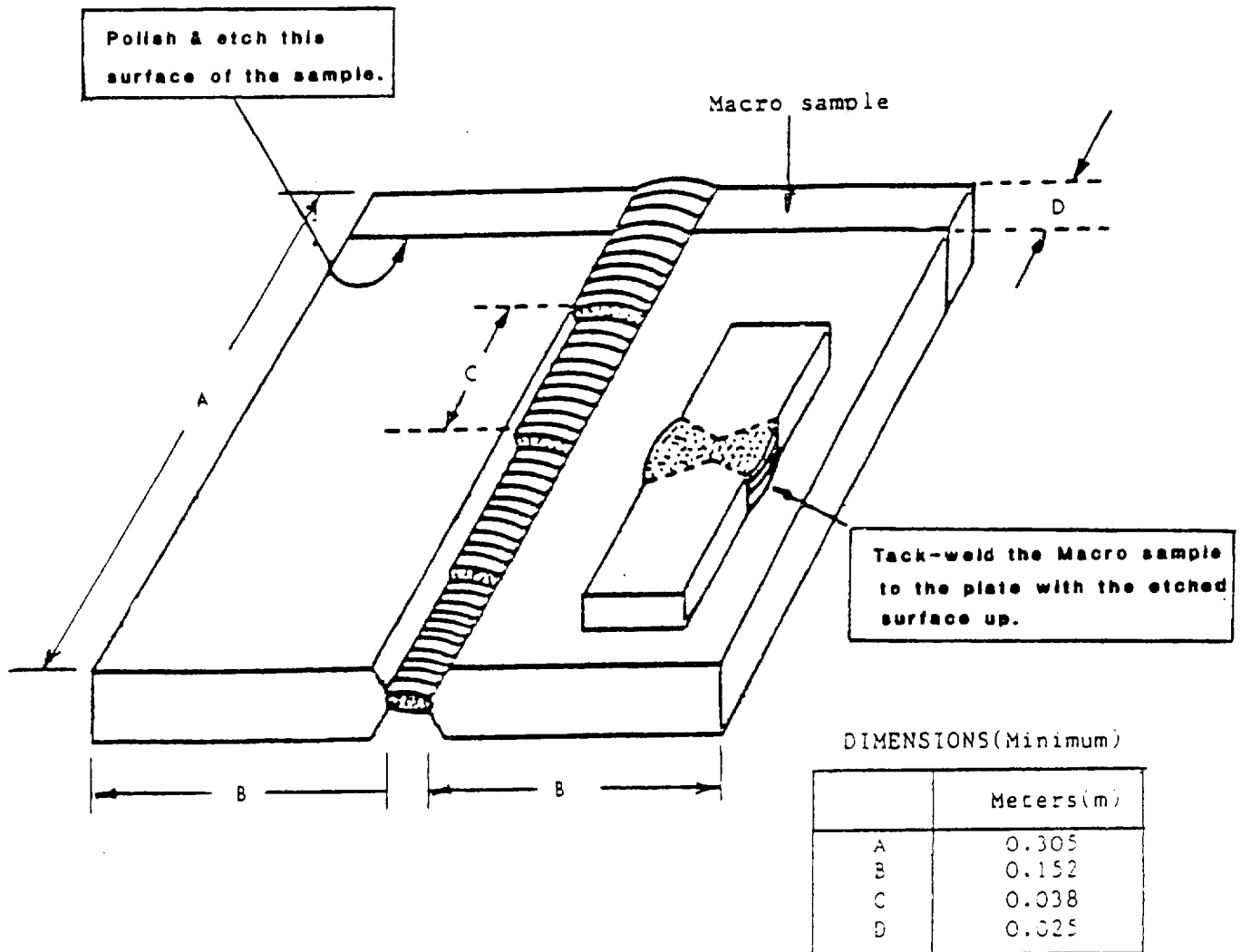
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NOTE: Weld joint details of actual specimens shall conform to the details of the contractor's recorded joint welding procedure for each type of joint involved.

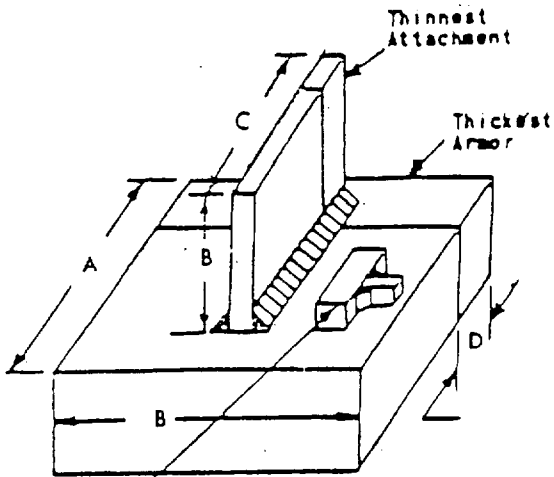
Figure 3. General configuration of workmanship specimens for tee-joints.

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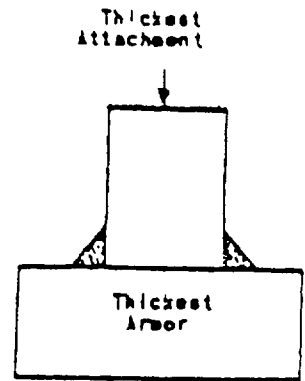
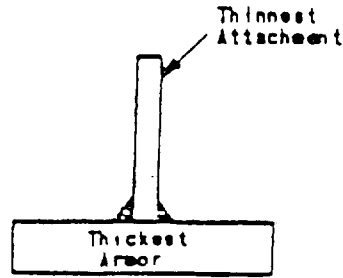


NOTE: Weld joint details of actual specimens shall conform to the details of the contractor's recorded joint welding procedure for each type of joint involved.

Figure 4. General configuration of workmanship specimens for butt joints.

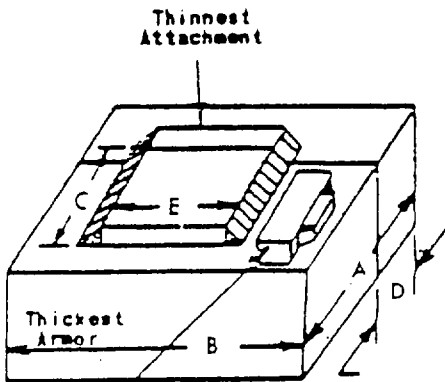


Tack-weld the Macro Sample to the Plate, with Etched Surface Up.

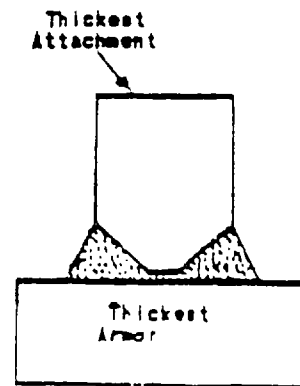
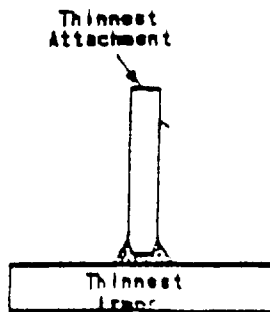
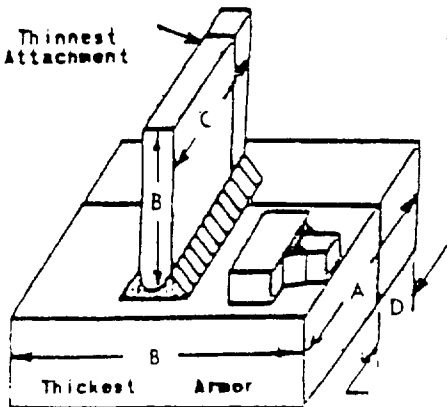
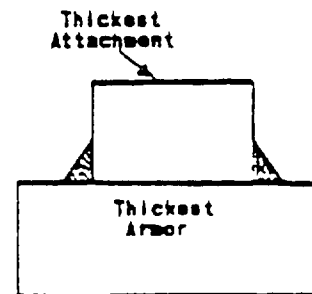
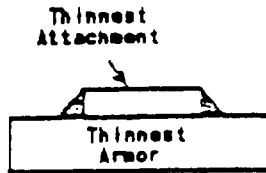


DIMENSIONS (Minimum)	
	Meters (m)
A	0.305
B	0.152
C	0.254
D	0.025
E	0.076

Note: 1 meter = 39.37 inches.



Tack-weld the Macro Sample to the Plate, with Etched Surface Up.



NOTE: Weld joint details of actual specimens shall conform to the details of the contractor's recorded joint welding procedure for each type of joint involved.

Figure 5. General configuration of workmanship specimens for fillet welds.

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APPENDIX A
BALLISTIC SHOCK TEST

10 Test Procedure

10.1 Temperature conditioning of samples. Prior to the ballistic shock test, the welded joint test sample shall be held at a temperature of $22 \pm 8^{\circ}\text{C}$ ($72 \pm 15^{\circ}\text{F}$) for at least eight hours. Testing shall be conducted immediately upon completion of the hold period at an ambient temperature of $22 \pm 8^{\circ}\text{C}$ ($72 \pm 15^{\circ}\text{F}$).

10.2 Welded joint armor thickness. Unless otherwise specified, the test thickness ranges using 75 mm M1002A, aluminum plate proofing projectiles against the 5083 and 7039 aluminum alloy armor are as shown in tables A-I and A-II. The test thickness ranges using the 57 mm M1001A aluminum plate proofing projectiles against the same alloys are as shown in tables A-III and A-IV.

10.2.1 Test sample thickness measurement. Unless otherwise specified, each of the two components making up the welded joint shall be measured for thickness in at least four locations at least 25mm (1 inch) from the edges. Thickness shall be read to the nearest 0.025mm (0.001 inch) using a micrometer. The average of the readings taken on each component shall be considered as the thickness (of plate, forging or extrusion).

10.3 Test fixture. The ballistic test sample shall be supported rigidly using wedges as necessary in an appropriate test fixture selected by the test director.

10.4 Test obliquity. The line of fire shall be perpendicular to the sample surface at the impact location (zero degrees obliquity).

10.5 Test projectile. Unless otherwise specified, the test projectile shall be the 75mm M1002A aluminum plate proofing projectile.

10.6 Fair impact. A fair impact is an impact which meets the requirements of 10.4, 10.5, 10.7, 10.8, and 10.

10.7 Impact location.

10.7.1 Corner joints (various angles). Unless otherwise specified, the impact location shall be such that the center of the projectile impact is within $50 \pm 12\text{mm}$ ($2 \pm 1/2$ inch) from an edge of the weld either on the impact side or from the projected center of the impact on the back side of the target. The aiming point for the center of the impact shall be $330 \pm 2\text{mm}$ (13 ± 1 inches) from the top or bottom of the target, or as otherwise required by the test director.

10.7.2 Flat weldments. Unless otherwise specified, the impact location shall be no further than 127 mm (1/2 inch) from the centerline of the weld and between 305 mm (12 inches), and 330 mm (13 inches) from the top or bottom of the test sample.

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10.8 Direction of impact. The direction of impact shall be the same as could be expected from a battlefield threat (projectile, mine, grenade, HE fragment, etc.) as specified by the purchaser.

10.9 Striking velocities.

10.9.1 Corner joints. Striking velocities shall be chosen from Table A-I for impacts on 5083 alloy armor and from Table A-II for impacts on 7039 alloy armor. Striking velocity on other armor types shall be as agreed upon in the contract.

10.9.2 Flat weldments.

10.9.2.1 Weldment made of two plates of same material and thickness. Striking velocities shall be chosen from Table A-I for impacts on 5083 alloy armor and from Table A-II for impacts on 7039 alloy armor. Striking velocity on other armor types shall be as agreed upon in the contract.

10.9.2.2 Weldment made of two plates of different alloys but same thickness. The striking velocity shall be that which is required for the weaker alloy.

10.9.2.3 Weldment made of two plates of different alloys and thicknesses. The striking velocity shall be the lower of the two considering the alloy and thickness.

10.10 Number of impacts. One fair impact is required on each of the two pieces making up the welded joint. Should a third round be required, the procedure of 10.15 shall be followed.

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TABLE A-I. Striking velocity requirements for 5083 aluminum alloy using the 75-MM aluminum M1002A plate proofing projectile.

Thickness (In.) (mm)	Striking Velocities ^(a)	
	(fps)	(mps)
.625 15.88	595	181.36
0.750 19.10	770	234.70
1.000 25.40	800	243.84
1.125 28.58	900	274.32
1.250 31.75	985	300.23
1.375 34.93	1065	324.61
1.500 38.10	1155	352.04
1.625 41.28	1310	399.29
1.750 44.28	1420	432.82

TABLE A-II. Striking velocity requirements for 7039 aluminum alloy using the 75-MM aluminum, M1002A plate proofing projectile.

Thickness (In.) (mm)	Striking Velocity ^(a)	
	(fps)	(mps)
.875 22.22	550	167.64
1.000 25.40	780	237.74
1.125 28.58	855	260.6
1.250 31.75	936	285.3
1.375 34.93	954	290.8
1.500 38.10	972	296.3
1.625 41.28	1188	362.1
1.750 44.45	1305	397.8
1.875 47.63	1323	403.2
2.000 50.80	1341	408.8

(a) \pm 33 fps (10.24 mps)

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TABLE A-III. Striking velocity requirements for 5083 aluminum alloy using the 57-MM aluminum M1001A plate proofing projectile

<u>Thickness</u> <u>(In.) (mm)</u>		<u>Striking Velocities^(a)</u> <u>(fps) (mps)</u>	
.500	12.7	(a)	
.625	15.88	(a)	
.750	19.10	(a)	

(a) To be determined.

TABLE A-IV. Striking velocity requirements for 7039 aluminum alloy using the 57-MM aluminum, M1001A plate proofing projectile

<u>Thickness</u> <u>(In.) (mm)</u>		<u>Striking Velocities^(a)</u> <u>(fps) (mps)</u>	
0.500	12.7	693	211.2
0.625	15.88	920	280.4
0.750	19.10	(a)	
0.875	22.20	(a)	

(a) To be determined.

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10.11 Selection of plate or component for first impact. The thinner of the two plates or components shall be impacted first.

10.12 Photographic record and inspection of impact area. Close up photographs of the front and back of the impacted area showing any cracks present, shall be taken after each impact by Government personnel conducting ballistic tests, and the impact area shall be inspected with liquid dye penetrant in accordance with MIL-STD-6866 whenever visual crack length approaches the maximum permitted.

10.13 Excessive cracking on first impact. Excessive cracking (see 10.17) shall be cause for rejection of the welding procedure or the joint design.

10.14 Second impacts

10.14.1 After excessive cracking on first impact. At the request of, or with the concurrence of the manufacturer and the procuring activity, a second round may be placed on the sample for information purposes provided that cracking due to the first impact does not extend beyond the center of the length of the weld.

10.14.2 After a first round fair impact without excessive cracking. The second impact shall be on the plate not previously impacted and at the opposite end of the sample (see 10.7).

10.14.3 Excessive cracking on second impact. Should excessive cracking occur on the second impact, it shall be cause for rejecting the weld procedure or the joint design.

10.15 Third rounds. Should a third round be needed due to a previous "No Test" condition (see 10.16) the third round impact location shall be midway between the first two rounds ± 50 mm (± 2 inches) and on the plate which sustained the "No Test" impact. No more than three impacts shall be placed on a ballistic welded joint sample for acceptance purposes. When additional retest specimens are required, the procedure specified in 10.18 shall be followed.

10.16 "No test" conditions. When test results are inconclusive in determining the acceptability of the joint-welding procedure or weld joint design, a "No test" decision will be rendered. The conditions under which a "No test" may occur are as follows:

- (1) The projectile impact is not located within the prescribed limits of distance from the weld.
- (2) The projectile striking velocity is below the minimum required by the test and does not develop excessive cracking.
- (3) The projectile striking velocity is above the maximum allowed and develops excessive cracking in the weld.
- (4) The location of the center of the projectile is less than 330 ± 25 mm (13 ± 1 inches) from the top or bottom of the test sample and excessive cracking occurs including cracks extending to the closest end of the sample.

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- (5) Excessive cracking is developed on a specimen by a third impact when more than two impacts are required.
- (6) Should the material forming part of the weld joint design fail in shear due to a reduction of the material thickness in the joint, a "No test" condition will be rendered on the welding procedure and a recommendation will be made to redesign the joint and to resubmit the redesigned joint for testing.

10.17 Evaluation of results. The maximum allowable combined total length of weld, fusion zone, or heat-affected zone cracking, either on the impact side or on the opposite side, caused by a fair impact shall be $330 + 25$ mm ($13 + 1$ inches). Cracking in excess of $330 + 25$ mm ($13 + 1$ inches) shall be considered excessive cracking. Cracks in the armor parallel to the weld and within 3.2 mm ($1/8$ inch) of the edge of the weld will be considered in the total cracking. Any total length of cracking within 3.2 mm ($1/8$ inch) of the edge of the weld which exceeds the acceptable limit of $330 + 25$ mm ($13 + 1$ inches) as a result of a fair impact shall be cause for rejection of the welding procedure provided that the material (plate, forging, extrusion) forming part of the joint has not failed. Should the material forming part of the joint design fail in shear and more than $330 + 25$ mm ($13 + 1$ inches) of cracking (weld fusion zone and heat affected zone) occurs, see paragraph 10.16. Cracking of the armor (plate, forging, extrusion) outside of the heat affected zone shall not be reason for rejection of the welding procedure. A fair impact shall be recorded when the test projectile impacts the target at 0° obliquity within the prescribed dimensional limits from the proper direction at a striking velocity less than the minimum required by the test, and excessive weld cracking occurs. Such an impact will be cause for rejection. In addition a fair impact shall be recorded when the projectile strikes the target at 0° obliquity within the prescribed dimensional limits from the proper direction at a striking velocity greater than the maximum required by the test; and no excessive weld cracking occurs.

10.18 Retest samples.

10.18.1 "No test" result. An additional test sample shall be provided by the manufacturer when firing results are inconclusive because of "no test" impacts.

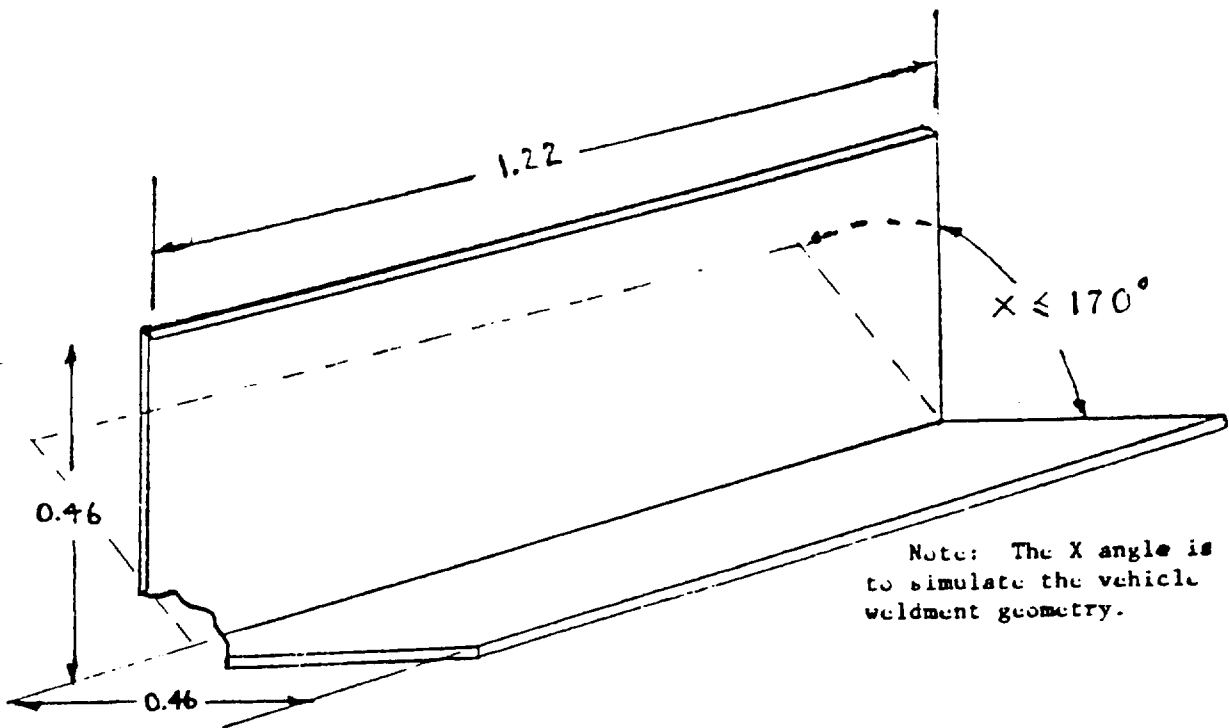
10.18.2 Welding procedure rejection. When a supplier requests a retest of his product after an initial rejection, he shall submit two samples for firing tests. The test sample shall be prepared by the revised welding procedure and shall be marked in accordance with paragraph 5.4.2. Failure of either one of the retest specimens shall be cause for rejection of the welding procedure represented.

10.19 Documentation of test data. The Government ballistic test agency will record round by round data and prepare a firing record.

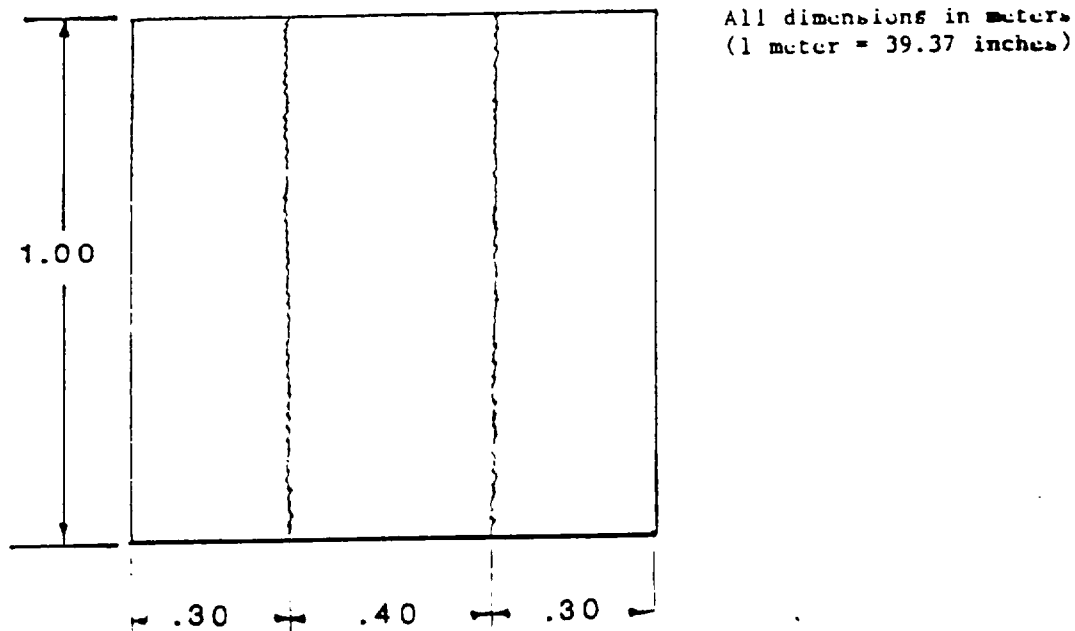
10.20 Disposition of test specimens. Ballistic test specimens are the property of the contractor. Arrangements shall be made at the time the specimens are submitted by the contractor to have them returned at his expense at the conclusion of the ballistic tests or to authorize, in writing, the scrapping of the specimens by the proving ground making the tests.

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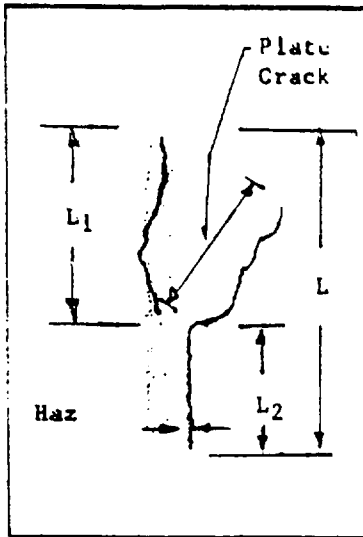
A. Corner joint sample for ballistic shock test.



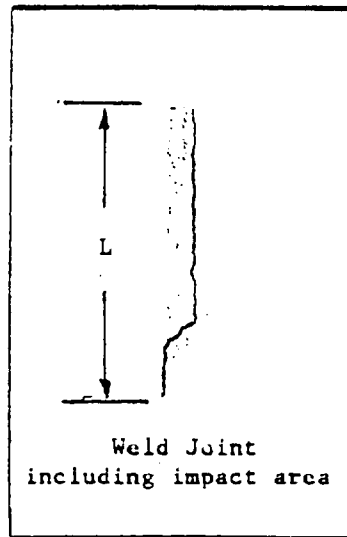
B. Flat weldment sample for ballistic shock test.
(For vertex angles less than 10 degrees)

Figure A-1 Example of specimen size and orientation for ballistic test.

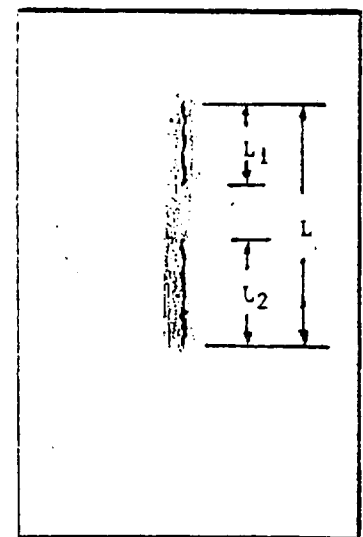
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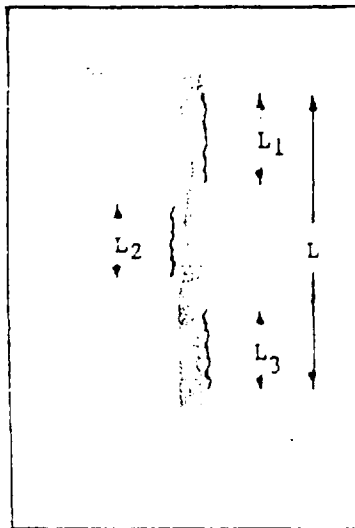
TOTAL W.C. = L



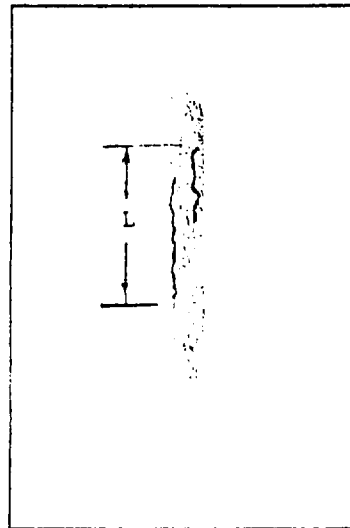
TOTAL W.C. = L



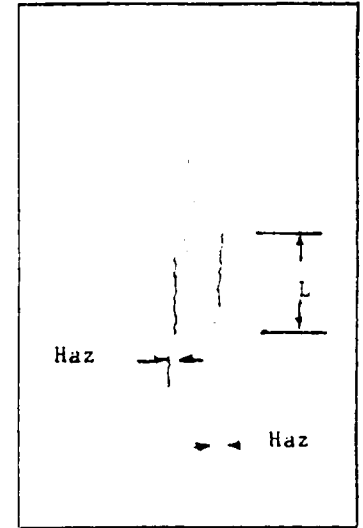
TOTAL W.C. = L



TOTAL W.C. = L



TOTAL W.C. = L



TOTAL W.C. = L

Figure A-2 Some weld cracks (W.C.) that may occur as a result of projectile impact. Measurement of total weld crack length for acceptance purposes. (See Table IV)

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APPENDIX B
INSPECTION OF WELDMENTS20. Radiographic inspection.20.1 Radiographic procedure.

20.1.1 Radiographic position drawings. A radiographic position drawing and welding assembly drawings, prepared in accordance with MIL-STD-100 shall be submitted to the procurement activity for review and approval in establishment of radiographic standards and "Routine Positions" (see 3.7). This radiographic drawing shall be prepared by the design agency and contain the following(see 6.1):

- (a) An isometric or plan view or both of the weldment.
- (b) Identification, by letter or number(s) of the joint(s) to be radiographed as identified on the assembly drawing.
- (c) Identification of positions by letter or number.
- (d) Cross-section of the joint(s) showing the identification and type of the joint(s), by symbol and the thickness of the mating pieces.
- (e) A table entitled "Routine Positions" containing five columns entitled "Position, front", "Position, rear", "Position, left side", "Position, right side", and "Film size".
- (f) A table entitled "Random Positions" (see 3.8) containing two columns entitled "Positions" and "Film size".
- (g) Notes, reading as follows:
 - (1) "Random shots" to be selected by the Government in accordance with 20.2.5.7.
 - (2) Unless otherwise specified, the requirements and discontinuity types specified in MIL-STD-1895(AT) shall serve as a basis for the radiographic acceptance standards to be prepared by the procuring or design agency. The radiographic acceptance standards shall be indicated on the applicable radiographic position chart, drawing or contract requirement when MIL-STD-1895(AT) is not applicable. Radiographic quality of welded joints shall comply with the minimum acceptable standards specified in a suitable document issued by the Engineering Office of the procuring activity. NOTE: Radiographic standards obtained from preproduction experience indicating the minimum level of acceptance for each different type of discontinuity for each different joint type will be forwarded to procuring activity for review and approval. These radiographs properly identified by vehicle number, joint type, and other information as needed will be reproduced for inclusion in the radiographic standards document. This practice will be followed pending the publication of a military specification on radiographic standards.

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- (3) "Routine position, left side" will be radiographed alternately with "Routine position, right side" on consecutive weldments taken from production for radiographic inspection within the limits established in 5.13.2.1 through 5.13.2.7.
- (4) If the radiographs appear questionable as to acceptability, additional radiographs shall be taken.

20.1.2 First production weldment. Radiographic examination shall be performed on all joints identified on the radiographic drawings for all first production weldments.

20.1.3 Films and position chart. The films for initial weldments shall be submitted to the procuring activity with the approved radiographic position chart (see 20.1.1, 20.1.3.1) to which the following has been added:

- (a) Location of each film on the radiographed item
- (b) Direction of radiation
- (c) Stage of assembly, type of weld and identification
- (d) Equipment used
- (e) Type of film
- (f) Size and location of filter
- (g) Source-film distance
- (h) Processing procedure for film
- (i) Applicable radiographic standard(s)
- (j) Penatrameter used
- (k) Millivoltage, milliamperage and exposure time

20.1.3.1 Certification data/report. Certification data and reports are required to assure that weldments are radiographed in accordance with approved procedures and that in addition the details and results of radiographic inspection are available for examination by the Government(see 6.1).

20.1.4 Radiographic inspection frequency. With the addition shown in 20.1.3, the chart becomes a radiographic procedure and, in conjunction with the radiograph of the initial weldment, becomes the basis for establishing the radiographic frequency to be used in production.

20.2 Inspection of production weldments.

20.2.1 Welding procedures. All procedures used in the fabrication of weldments shall be subject to inspection for compliance with the recorded joint-welding procedure.

20.2.2 Visual inspection of welds. All welds shall be subject to visual inspection according to the drawing or standards agreed upon in the contract. In no case shall the acceptance criteria be less than that specified in AWS D 1.2..

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20.2.3 Marking of repairs to weldments. All repairs to be made to weldments shall be indicated on the weldments by suitable markings, easily legible, and of such nature that the marking shall not be obliterated in handling. The system of marking shall be subject to approval by the Government.

20.2.4 Inspection of weldments subjected to straightening. All weldments subject to straightening, shall have welded joints in the straightened area inspected by a dye penetrant. Less than 100 percent inspection may be permitted when an adequate statistical quality control system has been established by the contractor or manufacturer and has been approved by an authorized Government inspector.

20.2.5 Radiographic.

20.2.5.1 Spot checking. Joints subject to direct ballistic attack shall be spot checked by radiography in accordance with 20.2.5.2 through 20.2.5.6 and with supplementary requirements to be determined by the procuring activity after examination of the radiographs. The supplementary requirements concern the number of exposures, radiographic position, and radiographic standards. Information about such requirements shall be submitted in accordance with 20.1.2 and 20.1.3.

20.2.5.2 Daily exposure requirements. The minimum number of radiographs required each 24 hour period shall be specified in the contract.

20.2.5.3 Selection of joints for radiography. Usually, only one radiograph shall be required on any specific joint, with a frequency to be determined by the procuring activity according to the relative importance of the joint in the weldment. Thus, spot checking will not usually require radiographing of all joints in a single weldment.

20.2.5.4 Rejectable joints. What constitutes a rejectable discontinuity shall be agreed upon between the contractor and the procuring activity. When the radiographic spot check of a weldment indicates a rejectable discontinuity in a particular joint, the remainder of the joint shall be radiographed. All rejectable discontinuities then found in the joint shall be repaired and these repaired areas subsequently radiographed. The repaired areas shall conform to the radiographic standard established for the joint.

20.2.5.5 Checking of consecutive weldments. When the radiographs required by 20.2.5.4 indicate a rejectable discontinuity, identified by MIL-STD-1895(AT) or by paragraph 20.1.3 (g) of this standard, the corresponding joint on the next weldment and preceding weldments shall be completely radiographed. If no rejectable discontinuities are found, spot checking shall be resumed. If rejectable discontinuities are found, the corresponding joint on the weldment immediately following (in production) shall be completely radiographed. Complete radiography of the corresponding joint shall be continued, subject to the requirements of 20.2.5, with each consecutive weldment produced until a joint with no rejectable discontinuities

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is obtained. All rejectable discontinuities in each rejectable joint shall be repaired. Radiographs of the repaired areas shall conform to the radiographic standard established for the particular joint.

20.2.5.6 Corresponding joints. On the next weldment designated for spot checking, the joint found rejectable in 20.2.5.4 will require spot checking in addition to the other joints selected for radiography. Should a rejectable discontinuity be found, the remainder of the joint shall be radiographed. All rejectable discontinuities then found in the joint shall be repaired, and the repaired areas subsequently radiographed. The repaired areas shall conform to the radiographic standard established for the particular joint.

20.2.5.7 Checking at intervals. When the total number of radiographs required daily by 20.2.5.5 exceeds the maximum number required by the contract, radiographs of weldments required by 20.2.5.5 shall be selected at intervals, rather than consecutively, in order not to interfere with the production schedule under the contract (see 3.1). These intervals shall be established by the Government and shall be determined by the production schedule, the number of joints for which radiographs are simultaneously required in accordance with 20.2.5 through 20.2.5.5, and the relative importance of the joints as indicated by the frequency of spot checking required by 20.2.5.3.

20.2.6 Quality control. It shall be the full responsibility of the contractor to maintain the quality control procedures and inspection standards necessary to assure that each part, assembly, subassembly or end product meets the requirements of the drawing and the contract.

INSTRUCTIONS: In a continuing effort to make our standardization documents better, the DoD provides this form for use in submitting comments and suggestions for improvements. All users of military standardization documents are invited to provide suggestions. This form may be detached, folded along the lines indicated, taped along the loose edge (*DO NOT STAPLE*), and mailed. In block 5, be as specific as possible about particular problem areas such as wording which required interpretation, was too rigid, restrictive, loose, ambiguous, or was incompatible, and give proposed wording changes which would alleviate the problems. Enter in block 6 any remarks not related to a specific paragraph of the document. If block 7 is filled out, an acknowledgement will be mailed to you within 30 days to let you know that your comments were received and are being considered.

NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification 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.

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DEPARTMENT OF THE ARMY



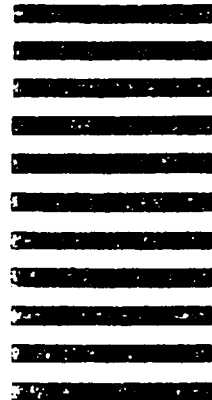
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(See Instructions - Reverse Side)

1. DOCUMENT NUMBER MIL-STD-1946(MR)		2. DOCUMENT TITLE	
3a. NAME OF SUBMITTING ORGANIZATION		4. TYPE OF ORGANIZATION (Mark one)	
b. ADDRESS (Street, City, State, ZIP Code)		<input type="checkbox"/> VENDOR	
		<input type="checkbox"/> USER	
		<input type="checkbox"/> MANUFACTURER	
		<input type="checkbox"/> OTHER (Specify): _____	
5. PROBLEM AREAS			
a. Paragraph Number and Wording:			
b. Recommended Wording:			
c. Reason/Rationale for Recommendation:			
6. REMARKS			
7a. NAME OF SUBMITTER (Last, First, MI) - Optional		b. WORK TELEPHONE NUMBER (Include Area Code) - Optional	
c. MAILING ADDRESS (Street, City, State, ZIP Code) - Optional		3. DATE OF SUBMISSION (YYMMDD)	