INCH-POUND

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DEPARTMENT OF DEFENSE HANDBOOK

METAL-ARC WELDING OF HOMOGENEOUS ARMOR

This handbook is for guidance only. Do not cite this document as a requirement.

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FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

3. MIL-HDBK-1941 prescribes the classification of methods for the welding of homogeneous steel armor by metal-arc processes. Included in the document are joint-welding procedure details, welders qualification requirements, and ballistic and inspection criteria for the evaluation of weldments employed in the fabrication of homogeneous rolled and cast armor.

4. All information and data contained in this handbook have been coordinated with industry and the U.S. Army, Navy, Air Force and DLA prior to publication.

5. Copies of this document and revisions thereto may be obtained from the Defense Automated Printing Service, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

6. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, U.S. Army Research Laboratory, Weapons and Materials Research Directorate, ATTN: AMSRL-WM-M, Aberdeen Proving Ground, MD 21005-5069, by using the 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 handbook covers the requirements for the fabrication of weldments by metal-arc welding processes, which weldments are constructed of homogeneous rolled and cast armor and the steel attachments to this armor. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

1.2 Classification. The welding methods may be classified as follows:

Method 1 - Shielded metal-arc welding with austenitic electrodes.
Method 2 - Shielded metal-arc welding with ferritic electrodes.
Method 3 - Gas metal-arc welding with solid or cored ferritic electrodes.
Method 4 - Gas metal-arc welding with solid or cored austenitic electrodes.
Method 5 - Submerged-arc welding. Electrode type optional.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 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 latest issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-A-11356	- Armor, Steel, Cast, Homogeneous, Combat-Vehicle Type (1/4 to 8 Inches, Inclusive)
MIL-A-12560	- Armor Plate, Steel, Wrought, Homogeneous (For Use In Combat-Vehicles And For Ammunition Testing)
MIL-A-46100	- Armor, Plate, Steel, Wrought, High-Hardness
MIL-A-46177	- Armor, Steel Plate and Sheet, Wrought, Homogeneous (1/8 to Less Than 1/4 Inch Thick)
MIL-DTL-31000	- Technical Data Packages
MIL-E-0022200/1	- Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium and High Tensile Steel, As Welded or Stress-Relieved Weld Application
MIL-E-13080	- Electrodes, Welding, Covered: Austenitic Steel (19-9 Modified) for Armor Applications
MIL-E-22200/10	- Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium, High Tensile And Higher-Strength Low Alloy Steels
MIL-E-23765/2	- Electrodes and Rods - Welding, Bare, Solid, Or Alloy Cored; And Fluxes, Low Alloy Steel

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-1894 - Radiographic Reference Standards And Radiographic Procedures For Partial-Penetration Steel Welds
DOD-STD-00100 - Engineering Drawing Practices

HANDBOOKS

DEPARTMENT OF DEFENSE

MIL-HDBK-21 - Welded Joint Designs, Armored-Tank Type
MIL-HDBK-1264 - Radiographic Inspection For Soundness Of Welds In Steel By Comparison To Graded ASTM E390 Reference Radiographs

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Defense Automated Printing Service (DAPS), 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following document(s) 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 latest issue of the DoDISS, and supplement thereto.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E340 - Standard Test Method for Macroetching Metals and Alloys (DoD adopted)
ASTM E390 - Standard Reference Radiographs for Steel Fusion Welds (DoD adopted)
ASTM E1417 - Standard Practice for Liquid Penetrant Examination (DoD adopted)
ASTM E1444 - Standard Practice for Magnetic Particle Examination (DoD adopted)
ASTM E1742 - Standard Practice for Radiographic Examination (DoD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

AMERICAN WELDING SOCIETY (AWS)

AWS A2.4 - Standard Symbols for Welding, Brazing and Nondestructive Examination (DoD adopted)
AWS A3.0 - Standard Welding Terms and Definitions (DoD adopted)
AWS A5.17 - Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding (DoD adopted)

(Application for copies should be addressed to the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.)

2.4 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. DEFINITIONS

3.1 Contractor and manufacturer. The term "contractor" is defined as the organization having a direct contract with the procuring activity. The term "manufacturer" is defined as the organization actually performing the operations covered by this handbook. The contractor may or may not be the manufacturer.

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

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

3.4 Routine positions. Routine positions are those established in areas where welding defects are most likely to occur and are to be radiographed on each weldment selected for examination.

3.5 Random positions. Random positions are those other than routine as defined in section 3.4 that are selected at the discretion of the Government.

4. GENERAL REQUIREMENTS

4.1 Weldments. The steel armor and steel for attachments to be used in the fabrication of weldments should conform to the requirements of the applicable drawing, contract or order. Deviations in specified compositional requirements for materials should not be permitted unless specifically approved by the procuring activity.

4.2 Armor. Unless otherwise specified in the procurement document, steel armor should be welded in the fully heat-treated condition.

4.3 Preparation of welding procedures and drawings. Prior to the production fabrication of any weldment, the contractor or manufacturer should prepare in accordance with DOD-STD-00100 and MIL-DTL-31000 an isometric, perspective, or other suitable drawing of the structure showing the location of each joint and should establish a recorded joint welding procedure(s) to cover all welding (including a general outline for the repair of base metal and repair of welded joints) to be performed under this handbook.

4.4 Welders or welding operator. The contractor should be responsible for determining the qualification of the welders or the welding operators to perform welding satisfactorily, as prescribed in the contractor's or the manufacturer's welding procedure. As a minimum for determining qualification, the welders should perform the tests given in appendix B.

4.5 Number of radiographs. The number of radiographs of production weldments specified for routine spot-checking of a particular vehicle should not exceed the number that can be taken reasonably during an 8-hour day. The frequency of spot-checking and selection of the standard or handbook should be based on the

importance of the particular joint in the vehicle and on the production schedule in the contractor's plant.

4.6 Metric units. When metric dimensions are required, units for inch may be converted to the metric equivalent by multiplying by the following conversion factor:

English	Multiply by	Equals	Metric SI units
inch	25.40	=	Millimeters (mm)

5. DETAILED REQUIREMENTS

5.1 Recorded joint-welding procedure. Before the production fabrication of any weldment; specified in MIL-A-11356, MIL-A-12560, MIL-A-46100, and MIL-A-46177, the contractor should prepare, or have the manufacturer prepare, an isometric or perspective drawing showing the location of each joint and prepare a description of the joint-welding procedure that covers all welding, including the repair of base metal and welded joints. Each joint-welding procedure should contain a reference to the location of the joint as shown in the isometric or perspective drawing, a detailed cross-sectional sketch of the joint, and should include the factors listed in table B-II (page 36). This information should be prepared in duplicate on a form approved by the procuring activity. The cover sheet should be signed by the manufacturer and the contractor and should be submitted to the procuring activity for review and approval. Appendix A shows the form and content of an approved form.

5.2 Types of electrodes used in conjunction with the various welding methods.

5.2.1 Method 1. The electrodes used for filler metal should conform to the requirements of MIL-E-13080, except that any austenitic-type electrode may be used if such use is recorded in the contractor's recorded joint-welding procedure.

5.2.2 Method 2. The electrodes used for filler metal should conform to MIL-E-0022200/1 or MIL-E-22200/10, except that any low hydrogen ferritic or iron-powder type of electrode having a yield point in excess of 80,000 psi (5.52×10^8 Pa) may be used if such use is recorded in the contractor's recorded joint-welding procedure. Maximum moisture content of the coating should be 0.2 percent by weight.

5.2.3 Method 3. The electrodes used for filler metal should conform to MIL-E-23765/2, except that other ferritic electrodes having a yield point in excess of 80,000 psi (5.52×10^8 Pa) may be used if such use is recorded in the contractor's recorded joint-welding procedure.

5.2.4 Method 4. The electrodes used for filler metal should be austenitic, having a minimum ultimate tensile strength of 85,000 psi (5.86×10^8 Pa) and a minimum elongation in 2 in. (50.8 mm) (transverse section) of 7 percent. Such use should be recorded in the contractor's joint-welding procedure.

5.2.5 Method 5. The electrodes used for filler metal and the fluxes should conform to AWS A5.17. The electrode selection should be recorded in the contractor's joint-welding procedure.

5.3 Shielding gas.

5.3.1 Composition. The composition of the shielding gas mixtures should not be detrimental to the quality of the welded armor joint. The composition should be recorded in the contractor's joint-welding procedure.

5.3.2 Dew point. The dew point of the shielding gas for armor welding should not exceed -57°C (-70°F). The dew point should be recorded in the contractor's joint-welding procedure.

5.3.3 Volume. The volume of the shielding gas should be recorded in the contractor's joint-welding procedure.

5.4 Heating of Weldments.

5.4.1 Preheating. Welding should not be performed when the ambient temperature of the weldment is below 60°F (15.6°C). When the contractor's recorded joint-welding procedure states that the entire weldment or any specified area including the joint is to be preheated, the preheating should be performed in accordance with the conditions described in the recorded joint-welding procedure. Unless otherwise approved by the procuring activity, general or local preheating should not be performed above 500°F (260°C). However, material specified in accordance with MIL-A-46100 should not be preheated above 300°F (149°C).

5.4.2 Postheating. General or local postheating to a maximum of 500°F (260°C) will be permitted. Higher temperatures should not be used unless authorized by the procuring activity. However, general or local postheating will be permitted only to a maximum of 300°F (149°C) for material specified in accordance with MIL-A-46100.

5.4.3 Interpass temperature. The maximum interpass temperature should not exceed 500°F (260°C) regardless of the welding process used. However, for material specified in accordance with MIL-A-46100, the maximum interpass temperature should not exceed 300°F (149°C).

5.5 Repair welding procedures. Repair welding procedures should be prepared, signed, and submitted in accordance with section 5.1. The procedure should include Factors 5, 6, 7, 8, 9, 12 and 13 of table B-II (page 36) and the additional factors listed in footnote 1, table B-II.

5.6 Welded attachment procedures. A tabulation should be prepared grouping attachments and parts which require the same size of fillet weld for all attachments in the fighting compartments of military combat vehicles, and for attachments on other parts of such vehicles when failure of the attachment may affect the mechanical operation of the vehicles. For each group the tabulation should show all factors of table B-II shown in appendix B.

5.7 Qualification for radiographic and joint-welding procedures.

5.7.1 Test samples and workmanship specimens. The contractor should fabricate test samples and specimens that meet the ballistic test and workmanship requirements in order to be qualified for production.

5.7.1.1 Fabrication of ballistic test samples and workmanship specimens. Before production and approval of the recorded joint-welding procedure, the contractor or manufacturer should fabricate ballistic test samples described in section 5.8, and workmanship specimens described in section 5.9 at each plant where production welding is to be performed using the recorded joint-welding procedure. Workmanship specimens should be identified with the name of the contractor or the manufacturer and the date of manufacture.

5.7.2 Sample production weldment. When specified by the procuring activity and at the expense of the government, a sample production weldment may be required to be fabricated in accordance with the approved recorded joint-welding procedure for visual inspection, radiographic inspection and ballistic testing.

5.8 Ballistic testing requirements.

5.8.1 Test samples.

5.8.1.1 Dimensions. The test sample should be constructed to the form and dimensions shown in figure B-16 (page 42). The thickness of the ballistic test plate relative to the joint thickness of the plate should be as shown in table B-III (page 40).

5.8.1.2 Number of test samples.

5.8.1.2.1 Joint types. When joint types 1, 2, 3, 4, 5, 6, or 7 of the designs specified in MIL-HDBK-21 or when partial penetration groove welds are included in the recorded joint-welding procedure, one ballistic test plate of the maximum "T" thickness and one test plate of the minimum "T" thickness involved in any one of these joint types should be prepared. For joint types 8 or 9, ballistic test plates should not be required.

5.8.1.2.2 Different armors. A separate ballistic test plate should be prepared for each type of armor used. All armor manufactured to a single military document should be considered one type.

5.8.1.3 Fabrication of test samples.

5.8.1.3.1 For joint types 1, 2, 4, or 5. The test samples should conform to the design for type 1, with the minimum included angle, minimum root opening, and maximum root face specified in the dimensional requirements for joint types 1, 2, 4, and 5 in the recorded joint-welding procedure. When welding with the gas metal-arc process, the size of the root opening may be changed to accommodate the requirements of the welding process.

5.8.1.3.2 For joint types 3, 6, or 7. The test samples should conform to the design for type 3, with the minimum included angle, minimum root opening, and maximum root face specified in the dimensional requirements for joint types 3, 6, and 7 in the recorded joint-welding procedure. When welding with the gas metal-arc process, the size of the root opening may be changed to accommodate the requirements of the welding process.

5.8.2 Preparation of the ballistic test plate. Each ballistic test plate should be welded in accordance with the contractor's joint-welding procedure. Only one joint-welding procedure should be used on a single test plate. A

ballistic test plate should be made for every welding position described in the procedure. The weld joints may be full penetration or partial penetration depending on the recorded joint-welding procedure. The ballistic test plate, shown in figure B-16 (page 42), should be prepared by welding sections ab and cd completely on both sides before welding crossbar ef. Each section and the crossbar should be started at the same preheat or ambient temperature, $\pm$ 5^{o}F ($\pm$ 3^{o}C). Welding in the crossbar prior to completion of the legs should not extend for more than 2 in. (51 mm) in either direction and should be feathered to leave at least 8 in. (203 mm) of continuous, open groove before starting to weld the crossbar. For all welding, the interpass temperature of the plate should not exceed the maximum allowable interpass temperature as stated in section 5.4.3. The interpass temperature of the base metal should be measured immediately before deposition of each bead at a point lying approximately at the intersection of a line 3 in. (76 mm) from, and parallel to, the center of each joint and a line perpendicular to and through the midpoint of the length of each joint.

5.8.3 Identification marking of test plates. Each ballistic test plate should be marked clearly for easy identification on the front surface of the plate. Marking should be in letters not less than 1 in. (25 mm) high and should include the number of the plate, the manufacturer's name, the contractor's name, and a designation showing the front of the plate. The number of the plate and the contractor's name should also be stamped into the metal or painted in the upper right corner. All marking should be fully legible. Painted markings should not be obliterated in normal handling. The front of the ballistic plate should be determined as follows:

a. For double groove joints. The front of the ballistic test plate is considered to be the surface on which welding (excluding tacking) is begun on each leg and on the crossbar.

b. For single groove joints. The front of the ballistic test plate is considered to be the outside or ballistically exposed surface containing the wide side of the groove.

5.8.3.1 Marking of retest plates. When two ballistic test plates are submitted for retest, both should be marked with the number of the original rejected plate as well as the new numbers with the suffix "R" indicating retest.

5.8.4 Ballistic test requirements. A properly executed check list for armor data, as shown in the applicable military document, should be submitted with each ballistic test plate.

5.8.4.1 Ballistic testing. Unless otherwise specified, it is recommended that inquires about testing ballistic plates be directed to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TM-O, Aberdeen Proving Ground, MD 21005. Technical questions regarding testing may be directed to U.S. Army Aberdeen Test Center, ATTN: STEAC-LI, Aberdeen Proving Ground, MD 21005.

5.8.4.2 Allowable cracking. The ballistic test plates should meet the weld cracking requirements of table B-IV (page 41) after being subjected to ballistic shock in accordance with table B-IV.

5.8.4.3 Magnetic particle or dye penetrant test. In borderline cases, where crack length as measured by visual observation, is close to the maximum

allowable, the area in the vicinity of the crack ends should be inspected with magnetic particles in accordance with ASTM E1444 or with liquid dye penetrant in accordance with ASTM E1417, to assure an accurate determination of the crack length.

5.8.5 Test method. The ballistic test plates should be supported solidly on each of the two sides normal to the line of fire and parallel to the longest welds, with these welds upright and subjected to ballistic shock in accordance with table B-IV (page 41). Plates of thickness not covered by table B-III (page 40) should be tested as directed by the procuring activity.

5.8.5.1 Test decision on additional impacts. When a test plate is declared "no test", as defined in 5.8.5.3.3, after being shocked by the impact of the first projectile, but the condition of the plate will permit additional impacts, the plate should be evaluated on the results of the first additional impact meeting the requirements for velocity and location in accordance with the following criteria:

a. When cracking exceeds that allowed by the specification, the qualification decision should be "no test".
b. When cracking does not exceed that allowed by the specification, the qualification decision should be "satisfactory".

5.8.5.2 Location of impact.

5.8.5.2.1 Direct impact. The direct impact of the 75-mm PP M1002 or the 57-mm PP M1001 should contact a part of the weld to be considered as conforming to the requirements of the ballistic test. Contact of the weld by any part of the projectile that spreads after impact will not satisfy the test requirements.

5.8.5.2.2 Point of impact. The point of impact of the 37 mm HE projectile M54 should be within 1.75 in. (44 mm) of the weld, as measured from the center of the point of impact to the center of the weld, to be considered as conforming to the requirements of the ballistic test.

5.8.5.2.3 Unacceptable and acceptable impacts. Impacts less than 6 in. (152 mm) from the top or bottom edge of the plate that cause excessive weld or plate cracking should be considered as failing to meet the requirements of the test. If, however, the cracking is not excessive and the requirements of 5.8.5.2.1 and 5.8.5.2.2 are met, the impact should be considered as acceptable.

5.8.5.3 Evaluation of test results. The plates should meet the requirements for maximum weld cracking specified in table B-IV (page 41) subject to the interpretations in 5.8.5.3.1 and 5.8.5.3.3.

5.8.5.3.1 Parallel cracks. Cracks in the armor parallel to the weld and within 0.125 in. (3 mm) of the edge of the weld should be considered as part of the total weld cracking area.

5.8.5.3.2 Cracks outside the acceptable limits for impacts. Any length of weld cracking revealed as a result of an impact which does not conform with 5.8.5.2.1 or 5.8.5.2.2, whichever is applicable, but which is otherwise acceptable per 5.8.5.2.3 should be cause for rejection of the welding procedure.

5.8.5.3.3 Conditions for a "no test" decision. When test conditions are such that the level of performance of the welding procedure represented by the plate cannot be determined, a "no test" decision should be rendered. The conditions for this decision are as follows:

a. The point of impact of the projectile is not located within the distance limits specified in 5.8.5.2.1 or 5.8.5.2.2 and cracking in excess of specified limits does not occur.

b. The striking velocity of the projectile is above the maximum allowed and excessive cracking occurs.

c. The striking velocity of the projectile is below the minimum allowed and excessive cracking does not occur.

d. The location of the center of impact of the projectile is less than 6 in. (152 mm) from the top or bottom edge of the plate and excessive cracking occurs.

e. Excessive cracking occurs from an impact subsequent to the first impact when more than one is required.

f. Cracks in the plate occur which are greater than 6 in. (152 mm) and do not pass through the center of impact.

g. Cracking of the plate occurs outside a circle of 6 in. (152 mm) radius, the center of which is the center of impact, and excessive weld cracking has not occurred. In this event the cracked plate should be subjected to a ballistic limit test in accordance with the applicable material specification. If the plate passes the ballistic limit requirements, the weld procedure is acceptable; otherwise (ballistic limit failure) a "no test" decision should be rendered.

5.8.6 Visual examination of test plates. All welds in the ballistic test plate should be examined visually before shipment to the designated proving ground. Welds should be equal to, or better, than those of the workmanship specimen (see 5.9).

5.8.7 Radiographic inspection of the test plate. Prior to the ballistic shock test, the welded joints in each test plate should be inspected radiographically by an authorized representative of the Government. Full penetration welds should be inspected for conformance with grade II of MIL-HDBK-1264, with the direction of radiation parallel to the weld interface, then normal to the weld face, and finally parallel to the opposite weld interface. Partial penetration welds should be inspected for conformance to MIL-STD-1894. Radiographs should be subject to review by the Government proving ground, and its decision as to acceptability should be final. The Government proving ground may make additional radiographic inspections at its option. Should the test plate fail to pass the radiographic inspection, the ballistic shock test should not be performed until after the defective weld area(s) has (have) been repaired by the fabricator.

5.8.8 Repair of test plate. Weld repair on a test plate should not exceed a total length of 8 in. (203 mm). The same area should not be repaired more than once. The reason(s) for, extent of, and location of repairs should be reported on a separate sheet of paper and attached to the check list for armor data, as shown in the applicable military document.

5.8.9 Rejection of ballistic test plate. Failure of any ballistic test plate to pass either the ballistic test or the radiographic inspection at the Government proving ground should be cause for rejection of the recorded joint-welding procedure.

5.8.9.1 Retests. Retests may be made upon the request of the contractor. Two additional test plates should be made using the recorded joint-welding procedure and marked in accordance with 5.8.3.1 and submitted to the proving ground for retest. Failure of either or both of these plates should be cause for rejection of the welding procedure represented.

5.9 Workmanship.

5.9.1 Test specimens.

5.9.1.1 Number. One workmanship specimen should be fabricated for each type of joint included in the recorded joint-welding procedure. Separate specimens will not be required for different compositions of armor or for different ambient or preheating temperatures, provided that all other factors in the procedures remain unchanged. Mild steel may be used for the specimen.

5.9.1.2 Dimensions. The size of the workmanship specimen should be in accordance with table B-V (page 41).

5.9.1.3 Preparation of specimens. Each specimen should be welded as shown in figures B-18, B-19, or B-20 of appendix B using the recorded joint-welding procedure. Each layer of weld metal should have a minimum of 1.5 in. (38 mm) of exposed surface.

5.9.1.3.1 Full penetration weld specimens.

5.9.1.3.1.1 Joint types 1, 2, 3, 4, 5, 6, and 7. Joint types should be in accordance with MIL-HDBK-21. Both plates used in making the specimen should be prepared with the minimum included angle, the minimum root opening, and maximum root face, as detailed in the recorded joint-welding procedure for the particular joint type (see figures B-18 and B-19 of appendix B).

5.9.1.3.1.2 Joint types 8 and 9. Joint types should be in accordance with MIL-HDBK-21. Both plates used in making the specimen should be of the maximum "T" thickness, with the maximum fillet size specified in design requirements for each joint type. The joints should be prepared using the minimum angle between the plates and the maximum plate separation specified for the particular joint type in the recorded joint-welding procedure (see figure B-20 of appendix B).

5.9.1.3.2 Partial penetration weld specimens. Joint types and other details should be as required by specification or drawings and as recorded in the contractor's joint-welding procedure.

5.9.1.4 Test method. The test specimen should be cross-sectioned as shown in figures B-18, B-19, and B-20 of appendix B and macro-etched in accordance with ASTM E 340. Both parts of the specimen should be made available to the Government for examination.

5.9.1.5 Visual examination. Workmanship specimens should be examined visually and should be free of the following defects:

a. Undercut.
b. Overlap.
c. Surface cavities.
d. Surface cracks in the weld metal or in the heat-affected zone of the base metal.

5.10 Radiographic procedure.

5.10.1 Radiographic drawings. A radiographic drawing and a welding assembly drawing should be submitted to the cognizant procuring activity for review in establishment of radiographic standards and "Routine Position" (see 3.4). The radiographic drawing should be prepared by the design agency containing the following:

a. An isometric or plan view (or both) of the weldment.
b. Identification, by letter or number, of the joint(s) to be radiographed as identified on the assembly drawing. These joints are limited to types 1 through 7 of MIL-HDBK-21.
c. Identification of positions by letter or number.
d. Cross section of the joint(s) showing the identification and type of the joint(s), either by symbol or by number as assigned in MIL-HDBK-21, and the thickness of the mating pieces.
e. A table entitled "Routine Positions" (see 3.4) containing three columns entitled "Position, left side", "Position, right side", and "Film size".
f. A table entitled "Random positions" (see 3.5) 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 5.11.2".
(2) "All radiographs to conform to grade II of MIL-HDBK-1264 or MIL-STD-1894."
(3) "Radiography to be performed in accordance with ASTM E1742."
(4) "On consecutive exposures and weldments, when feasible, the direction of radiation should be alternated from parallel to the weld interface, to normal to the weld face, and to parallel to the opposite weld interface. The cycle should be repeated for all positions radiographed on the weldment".
(5) " '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 5.11.2.1 through 5.11.2.6".

5.10.2 Pilot vehicles. Radiographic examination should be performed on all pilot vehicles on all joints identified on the radiographic drawing and should comply with the designated standards.

5.10.3 Initial weldments. Each initial weldment in joints subject to direct ballistic attack should be completely radiographed in accordance with the requirements of ASTM E1742 and conform to grade II of MIL-HDBK-1264.

5.10.3.1 Film and position chart. The films for the initial weldment should be submitted to the procuring activity with the radiographic position chart (see 5.10.1) to which the following information has been added:

a. Location of film.
b. Direction of radiation.
c. Stage of assembly.
d. Equipment used.
e. Type of film.
f. Size and location of filter.
g. Focal-film distance.
h. Processing procedure for film.
i. Applicable radiographic standard(s).

5.10.3.2 Radiographic procedure. With the additions shown in 5.10.3.1, 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.

5.11 Inspection of production weldments.

5.11.1 Visual.

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

5.11.1.2 Welds. All welds should be subject to visual inspection. Welds should be equal to, or better than, the workmanship specimens.

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

5.11.1.3 Inspection of weldments subjected to straightening. All weldments subject to straightening should have welded joints in the straightened area inspected by a penetrant or magnetic particle inspection method. 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.

5.11.2 Radiographic.

5.11.2.1 Spot checking. Joints subject to direct ballistic attack should be spot checked by radiography in accordance with 5.11.2.2 through 5.11.2.6 and with supplementary requirements to be determined by the designing agency after examination of the radiographs. The supplementary requirements concern the number of exposures, radiographic position, and radiographic standards. Information about such requirements should be submitted in accordance with 5.10.3 and 5.10.3.1.

5.11.2.2 Daily exposure requirements. The number of radiographs required during a given day should not be below the minimum specified as required by drawings or Supplementary Quality Assurance Provisions (SQAP) or Quality Assurance Requirements (QAR).

5.11.2.3 Selection of joints for radiography. Usually, radiography should be required on any specific joint, with a frequency to be determined by the drawings or SQAP or QAR in accordance to MIL-STD-1894 or MIL-HDBK-1264 according to the relative importance of the joint in the weldment. Thus, spot checking will not require radiographing of all joints in a single weldment.

5.11.2.4 Rejectable joints. When the radiographic spot check of a weldment indicates a rejectable defect in a particular joint, the remainder of the joint should be radiographed. All defects then found in the joint should be repaired and these repaired areas subsequently radiographed. The repaired areas should conform to the radiographic standard established for the joint.

5.11.2.5 Corresponding joints. On the next weldment designated for spot checking, the joint found rejectable in 5.11.2.4 will require spot checking in addition to the other joints selected for radiography. Should a rejectable defect be found, the remainder of the joint should be radiographed. All rejectable defects then found in the joint should be repaired, and the repaired areas subsequently radiographed. The repaired areas should conform to the radiographic standard established for the particular joint.

5.11.2.6 Checking of consecutive weldments. When the radiographs required by section 5.11.2.5 indicate a rejectable defect, the corresponding joint on the next weldment should be completely radiographed. If no rejectable defects are found, spot checking should be resumed. If rejectable defects are found, the corresponding joint on the weldment immediately following (in production) should be completely radiographed. Complete radiography of the corresponding joint should be continued with each consecutive weldment produced until a joint with no rejectable defects is obtained. All defects in each rejectable joint should be repaired. Radiographs of the repaired areas should conform to the radiographic standard established for the particular joint.

5.11.3 Quality control. It should be the full responsibility of the contractor to maintain the quality control procedures and inspection standards necessary to assure that the part, the assembly, the sub-assembly or the end product meets the requirements of the drawings and the contract.

6. NOTES

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

6.1 Intended use. This handbook is to be used as a guide to define the requirements for the fabrication of weldments by metal-arc welding processes, which weldments are constructed of homogeneous rolled and cast armor and the steel attachments to this armor.

6.2 Subject term (key word) listing.

Ballistic testing
Electrodes
Joints
Magnetic particles
Radiographs

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

APPENDIX A

FORMS, WORKMANSHIP SPECIMENS AND TEST PLATES FOR THE JOINT-WELDING PROCEDURE

A.1 SCOPE

A.1.1 Scope. This appendix covers the preparation of forms and associated requirements for workmanship specimens and test plates for use in the joint-welding procedure.

A.2 APPLICABLE DOCUMENTS

The applicable documents referenced in section 2 of this handbook apply to this appendix.

A.3 DEFINITIONS

The definitions in section 3 of this handbook apply to this appendix.

A.4 FORMS

A.4.1 Type. The forms illustrated in this appendix may be used for submittal of the joint-welding procedure. Other forms may be used if all pertinent information is included and if the forms are approved by the procuring activity.

A.4.2 Number. The completed forms should be submitted in duplicate to the procuring activity for review.

A.4.3 Cover sheet. The cover sheet should include a description of the vehicle weldment, the book number, the Government document number, and the date submitted. The cover sheet should be signed by the contractor and the manufacturer, if other than the contractor.

A.5 DESCRIPTIONS OF FORMS AND FIGURES

A.5.1 Form A-1. Cover sheet which should be signed in accordance with A.4.3.

A.5.2 Form A-2. Table of contents for the welding procedure.

A.5.3 Figure A-3. Perspective drawing of a complete hull. An isometric drawing would be equally acceptable. For some types of structures, it may be preferable to show subassemblies, as well.

A.5.4 Form A-4. A summary of this type, although not required by the specification, provides in one place a complete picture of the different joints involved, the types of armor in each joint, and the exact status of procedure qualification. The summary illustrated serves the following purposes:

a. Indicates, for each joint in the structure, the joint type as defined in MIL-HDBK-21 and change notices to the latest revision thereto.

b. Indicates the welding method employed: Shielded metal-arc or gas metal-arc welding.

c. Provides an index to the recorded joint-welding procedure for each joint.

d. Indicates the kind of armor in each joint.

e. Simplifies the problem of determining the minimum number of ballistic test plates and workmanship specimens required to qualify all welding in the structure.

f. Provides space for recording results of tests.

g. Indicates whether or not a given procedure has been qualified, whether it has been qualified in more than one welding position, and provides supporting evidence by recording the test plates which passed the required test.

A.5.4.1 Joint A-A. Requires two ballistic test plates, one of the maximum plate thickness and one of the minimum plate thickness involved in joints of types 3, 6 and 7 as defined by MIL-HDBK-21 and change notices to the latest revision thereto (see 5.8.1.2.1). Workmanship specimens are required for joint types 1 and 3 (see 5.9.1.3.1).

A.5.4.2 Joint B-B. This joint, involving two types of armor, requires separate ballistic test plates for each type.

A.5.4.3 Joint C-C. Although separate ballistic test plates are required to represent each kind of armor, one workmanship specimen made with either kind of armor is sufficient to represent both (see 5.9.1.1).

A.5.4.4 Joint D-D. One ballistic test plate is required for armor I; two are required for armor II. Armor I is used for only one joint of types 1, 2, 4 or 5 and one test plate represents both the maximum and the minimum thickness involved.

A.5.4.5 Joint H-H. A separate workmanship specimen is required for each welding position. This is because a change in welding position means a change in the recorded joint-welding procedure, which requires resubmittal of the procedure (see table B-II).

A.5.5 Form A-5. Space is provided in the last column for recording the draw temperature employed by the armor manufacturer in heat-treating the armor. It is desirable that this information be available for ready reference, since the specification requires the preheating should not be done above $500^{O}F$ ($260^{O}C$).

A.5.6 Form A-6.

A.5.6.1 Tables A and B. The summary of electrodes for shielded metal-arc welding and gas metal-arc welding has been divided into table A for electrodes conforming to MIL-E-13080 and table B for electrodes that do not conform to this specification. Table A does not include the type of covering of ranges of chemical composition, because these factors are controlled by the designations for type and class.

APPENDIX A

A.5.6.2 Table C. This table sets forth the ranges of currents and voltages to be used with each size of electrode. The tabulation simplifies the recorded joint procedure (see form A-7, for example) by making it possible to refer to each table rather than state the current and voltage range for each pass (see factor 8 of table B-II).

A.5.7 Form A-7. This form represents an attempt to devise the simplest possible form for recording a complete joint-welding procedure. Note that all of the factors listed in table B-I have been included.

A.5.8 Form A-8. This recorded joint welding procedure designates only electrodes B and C, whereas electrode F is also of the same type and class, and could, under the provisions of this document, be employed without resubmittal of the procedure. This illustrates that a contractor may wish to subject a given procedure to limitations greater than those prescribed.

A.5.9 Form A-9. The sketch of the joint designates the kind of armor used in each part. This should be done whenever a joint involves more than one kind of armor. This is also illustrated on form A-8.

A.5.10 Figure A-10. It is unnecessary to show in detail the recorded joint-welding procedures for these joints because they are prepared by completing forms similar to those on forms A-7, A-8, and A-9. The contractor should prepare a complete joint welding procedure for each joint. The joint designs are shown in order to provide a basis for illustrating this method of qualifying a group of welding procedures (see form A-4).

A.5.11 Forms A-11 and A-12. When a joint is welded in two or more positions, different procedures may be designated by literal suffixes such as 8a, 8b, 8c, etcetera, as illustrated here.

A.5.11.1 Orientation. When recorded joint welding procedures relate to the same joint, but differ with respect to the position of welding, it is desirable to orient the sketch under "Location and sequence of passes" in such a way as to convey the idea of welding position. Forms A-11 and A-12 cover the flat and horizontal positions, respectively. Similar treatment will readily identify the overhead position, and a different orientation can be selected as a conventional way to represent the vertical position.

A.5.12 Ballistic test plate forms. Unless otherwise specified, it is recommended that inquires about forwarding the three forms listed below be directed to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TM-O, Aberdeen Proving Ground, MD 21005:

a) Form A-13 Armor Welding Data Sheet No. 1.
b) Form A-14 Armor Welding Data Sheet No. 2.
c) Form A-15 Armor Welding Data Sheet No. 3.

APPENDIX A

RECORDED JOINT-WELDING PROCEDURE

For

MEDIUM TANK, MI (VEHICLE)

WELDED TANK (WELDMENT)

Book 10

DATE OF SUBMITTAL: 10 May 1977

MANUFACTURED BY

Mars Manufacturing Company

Detroit, Michigan

Contract No. _____

Signed for Manufacturer:

_____
(Signature)
(Name, Typed)

Title: _____

Date Signed: _____

Manufactured Under
Military Specification
_____

Signed for Contractor:

_____
(Signature)
(Name, Typed)

Title: _____

Date Signed: _____

FORM A-1. Cover sheet.

APPENDIX A

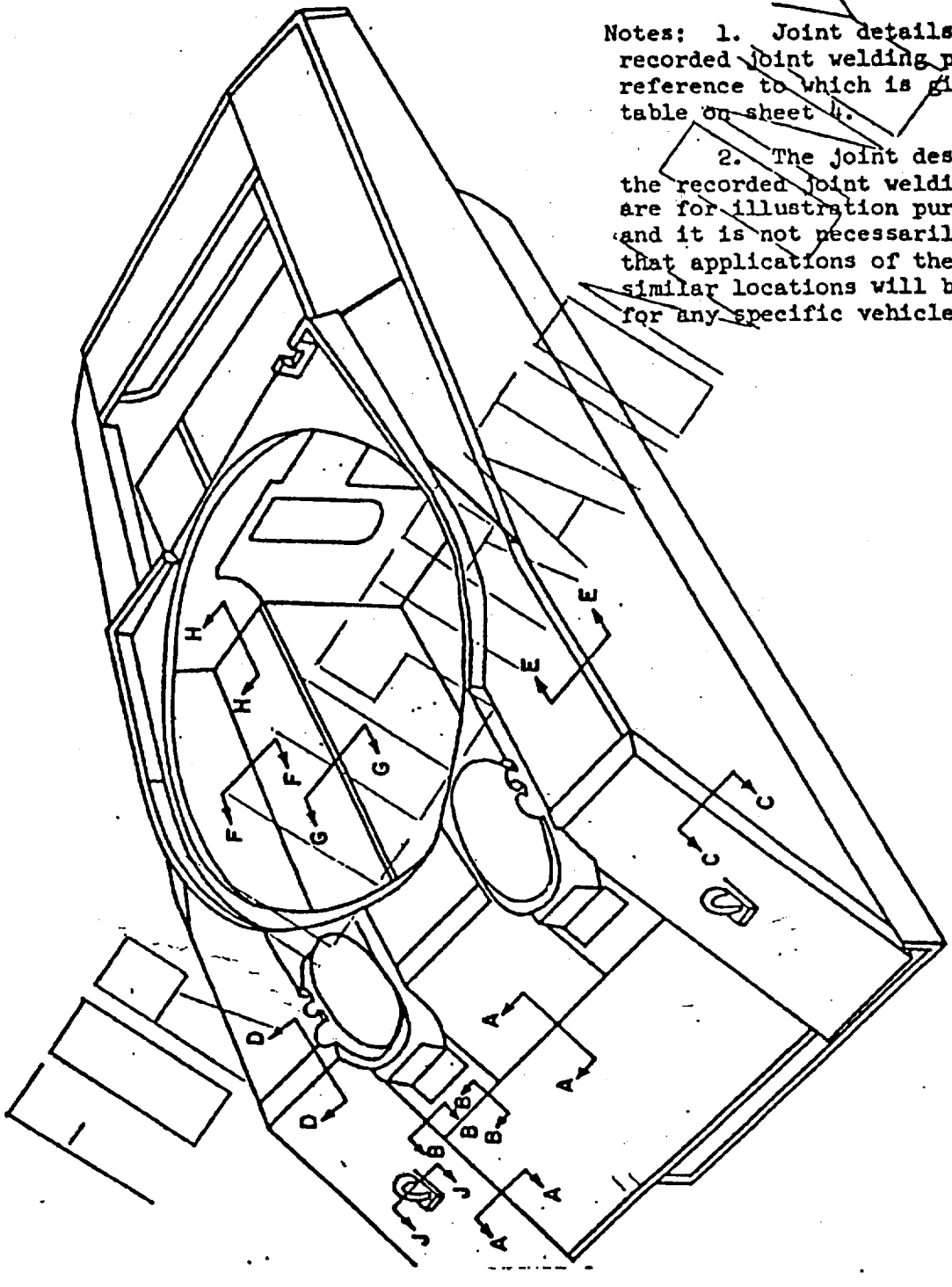
Recorded Joint Welding Procedures for a Welded Hull

Contents:

Miscellaneous Information:

FORM A-2. Table of contents for the welding procedure.

APPENDIX A

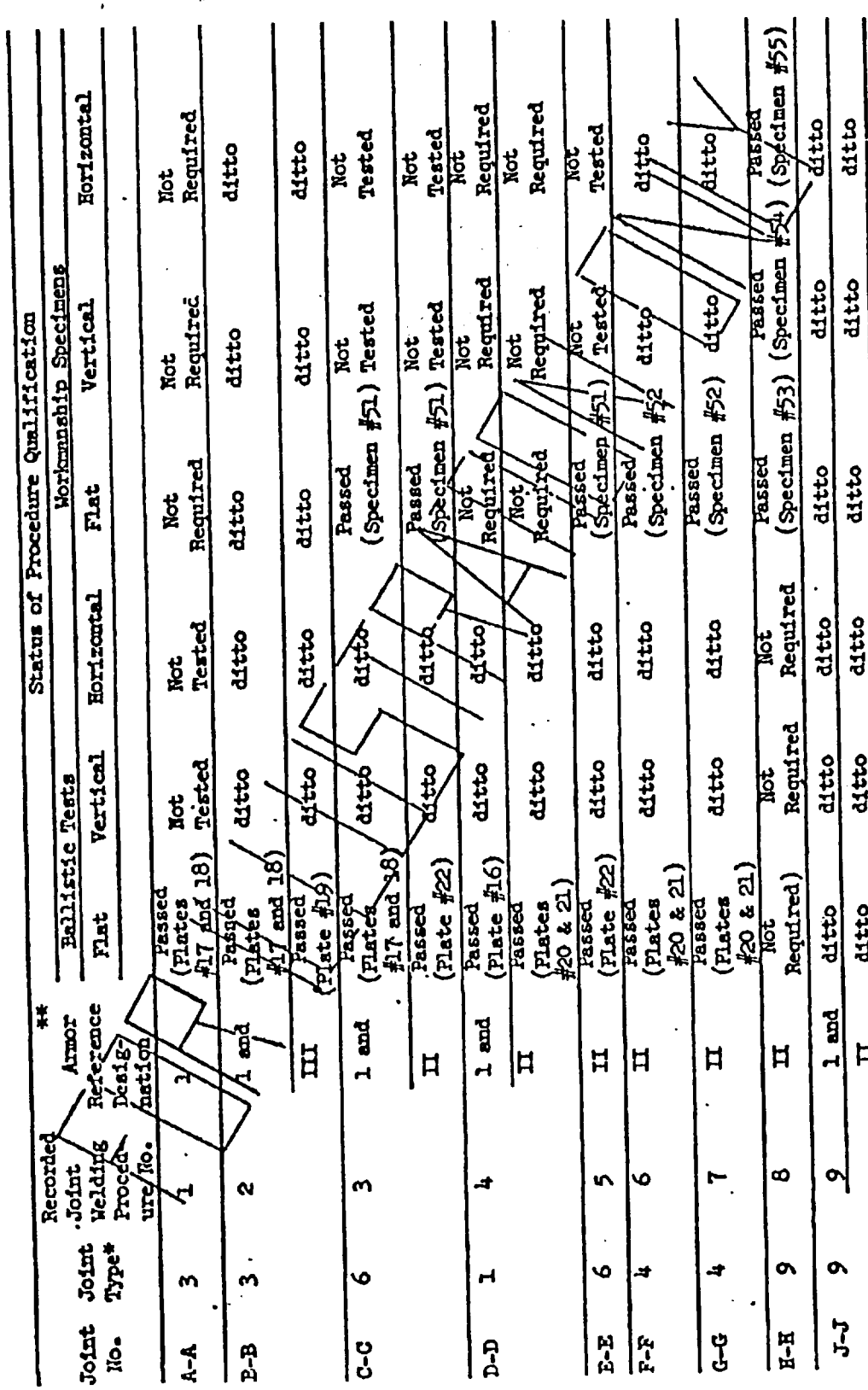


Notes: 1. Joint details are shown in recorded joint welding procedures, reference to which is given in table on sheet 4.

2. The joint designs shown in the recorded joint welding procedures are for illustration purposes only, and it is not necessarily indicated that applications of these joints in similar locations will be approved for any specific vehicle.

FIGURE A-3. Perspective drawing of a complete hull.

APPENDIX A



Form A-4. Summary of qualification tests for recorded joint welding procedure.

Armor Reference Designation	Type	Specification No.	Manufacturer	Chemical Composition Range (%)											Draw Temperature*
				C	Mn	Si	S	P	Cr	Ni	Mo	V	Cu	Zr	
I	Rolled Homogeneous	MIL-A-12560	"X"	.26 .30	.95 1.15	.60 .90	.035 Max.	.035 Max.	.60 .70		.20 .25			.07 .11	800
II	Rolled Homogeneous	MIL-A-12560	"Y"	.23 .30	.85 1.00	.20 .30	.04 Max	.03 Max	.75 .90	.90 1.10	.30 .35		.07 .16		600
III	Cast Homogeneous	MIL-A-11356	"Z"	.21 .31	1.30 1.80	.25 .75	.05 Max.	.05 Max.	.20 .70		.25 .45				1100

* Draw temperature employed by the armor manufacturer in heat-treating the armor.

FORM A-5. Summary of armor types and compositions.

APPENDIX A

Table A. Electrodes Conforming With Specification No. XXX

Electrode Reference Designation	Manufacturer	Brand Name	Type	Class
A	"X"	Bestweld	V	WD-EL-307-10
B	"X"	Superweld	VI	WD-ET-308-10
C	"Y"	Bestalloy	VI	WD-ET-308-10
D	"Y"	Superloy	VI	WD-ET-308-10
E	"Z"	Reflare	V	WD-ET-307-10
F	"Z"	Superare	VI	WD-ET-308-10

Table B. Electrodes Not Conforming With Specification No. XXX

Electrode Reference Designation	Manufacturer	Brand Name	Type of Covering	Chemical Composition Range (%)									
					C	Mn	Si	S	P	Cr	Ni	Mo	V	Others
G	"Q"	Excelweld	Lime	Core Wire	.15 Max.	3.50 4.50	.25 .60	.03 Max.	.04 Max.	19.5 21.5	9.0 10.5			
				Deposited Weld Metal	.17 Max.	4.50 5.00	.80 Max.			18.0 20.5		.50 1.00		
H	"R"	Wooderweld	Titania	Core Wire	.15 Max.	1.50 2.00	.25 .60	.03 Max.	.04 Max.	19.5 21.5	9.0 10.5			
				Deposited Weld Metal	.17 Max.	1.25 2.00	.80 Max.			18.0 20.5		1.80 2.25		

Table C. Ranges of Current* and Voltage To Be Used With Each Size of Electrode

Diameter of Electrode	Current Range (Amperes)			Voltage Range		
	Flat Position	Vertical Position	Horizontal Position	Flat Position	Vertical Position	Horizontal Position
5/32	85-115	75-100	80-105	21-28	20-26	20-26
3/16	150-185	135-165	145-175	23-29	22-27	22-27
1/4	200-245	--	190-230	24-30	23-28	23-28
5/16	310-340	--	--	25-32	24-30	24-30

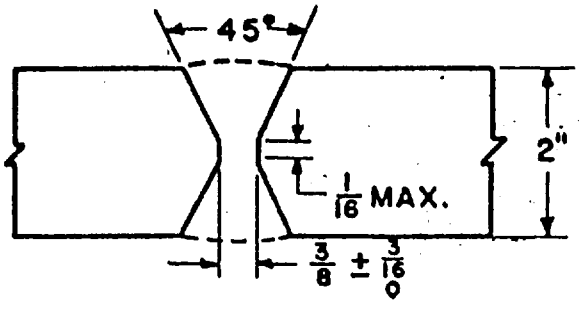
* Current values. Welding current may be measured with a tong-type tester. Current variations for all types and sizes of electrodes shall be limited to approximately ± 15 percent.

FORM A-6. Summary of electrodes with welding currents and voltages.

APPENDIX A

Recorded Joint Welding Procedure No. 1

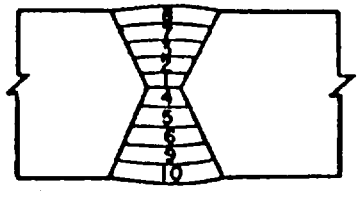
Joint A-A



Joint Welding Procedure: General Information

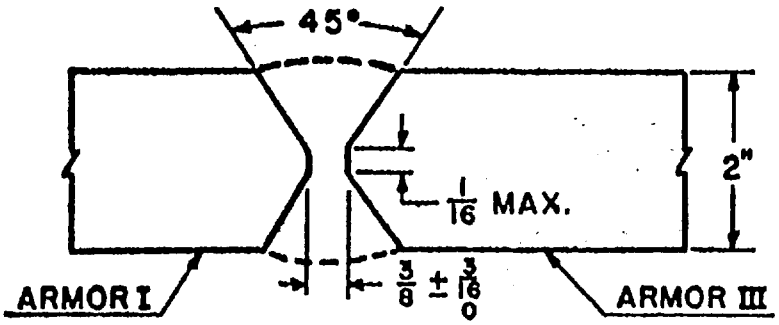
Armor (reference designation)	I
Electrode (reference designation)	B, C, or F
Power Source (AC-DC) and Polarity if DC	DC, Reverse
Welding Current & Arc Voltage Range	As Specified in Table C, Figure 6
Use of Spatter Compound on Scarfed Edges	None
Backing	Copper
Preheating	None
Position of Welding	Flat

Joint Welding Procedure: Details of

Pass	Electrode	Type of Pass	Location & Sequence of Passes
1	3/16	Stringer	
2,3	1/4	Weave	
4	3/16	Stringer	
5,6	1/4	Weave	
7 to 10	5/16	Full Weave	
			Note: Root of weld shall be ground to sound metal before depositing pass No. 4

FORM A-7. Recorded joint welding procedure no.1 joint A-A.

APPENDIX A



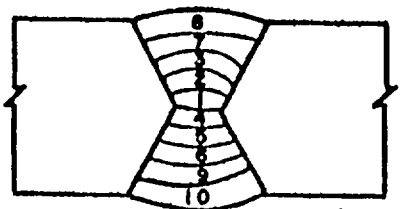
Recorded Joint Welding Procedure No. 2

Joint B-B

Joint Welding Procedure: General Information

Armor (reference designation)	I and III
Electrode (reference designation)	B or C
Power Source (AC or DC) and Polarity if DC	DC, Reverse
Welding Current & Arc Voltage Range	As Specified in Table C, FORM A-6
Use of Spatter Compound on Scarfed Edges	None
Backing	Copper
Preheating	None
Position of Welding	Flat

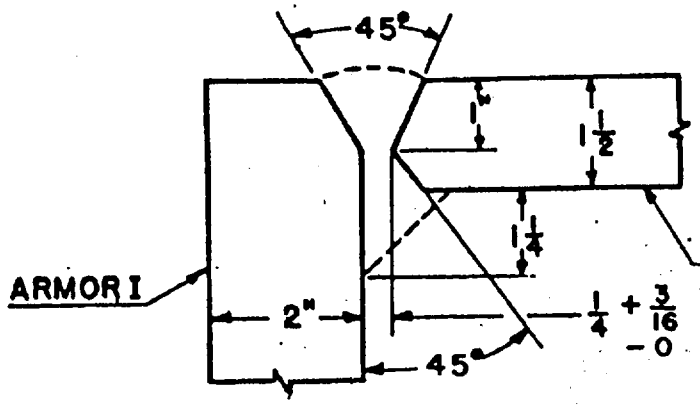
Joint Welding Procedure: Details of

Pass No.	Electrode Size	Type of Pass	Location & Sequence of Passes
1	3/16	Stringer	
2,3	1/4	Weave	
4	3/16	Stringer	
5,6	1/4	Weave	
7 to 10	5/16	Full Weave	

Note: Root of Weld shall be ground to sound metal before depositing pass No. 4.

FORM A-8. Recorded joint welding procedure no.2 joint B-B.

APPENDIX A



Recorded Joint Welding Procedure No. 3

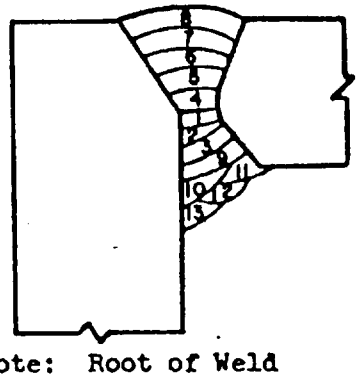
Joint C-C

Joint Welding Procedure: General Information

Armor (reference designation)	I and II
Electrode (reference designation)	B.C. or F
Power Source (AC or DC) and Polarity if DC	D. C. Reverse
Welding Current & Arc Voltage Range	As Specified in Table C, FORM A-6
Use of Spatter Compound on Scarfed Edges	None
Backing	Copper
Preheating	None
Position of Welding	Flat

Joint Welding Procedure: Details of

Pass No.	Electrode Size	Type of Pass	Location & Sequence of Passes
1	3/16	Stringer	
2,3	1/4	Weave	
4	3/16	Stringer	
5,6	1/4	Weave	
7 to 9	5/16	Full Weave	
10 to 13	5/16	Weave	



Note: Root of Weld shall be ground to sound metal before depositing pass No. 4

FORM A-9. Recorded joint welding procedure no.3 joint C-C.

APPENDIX A

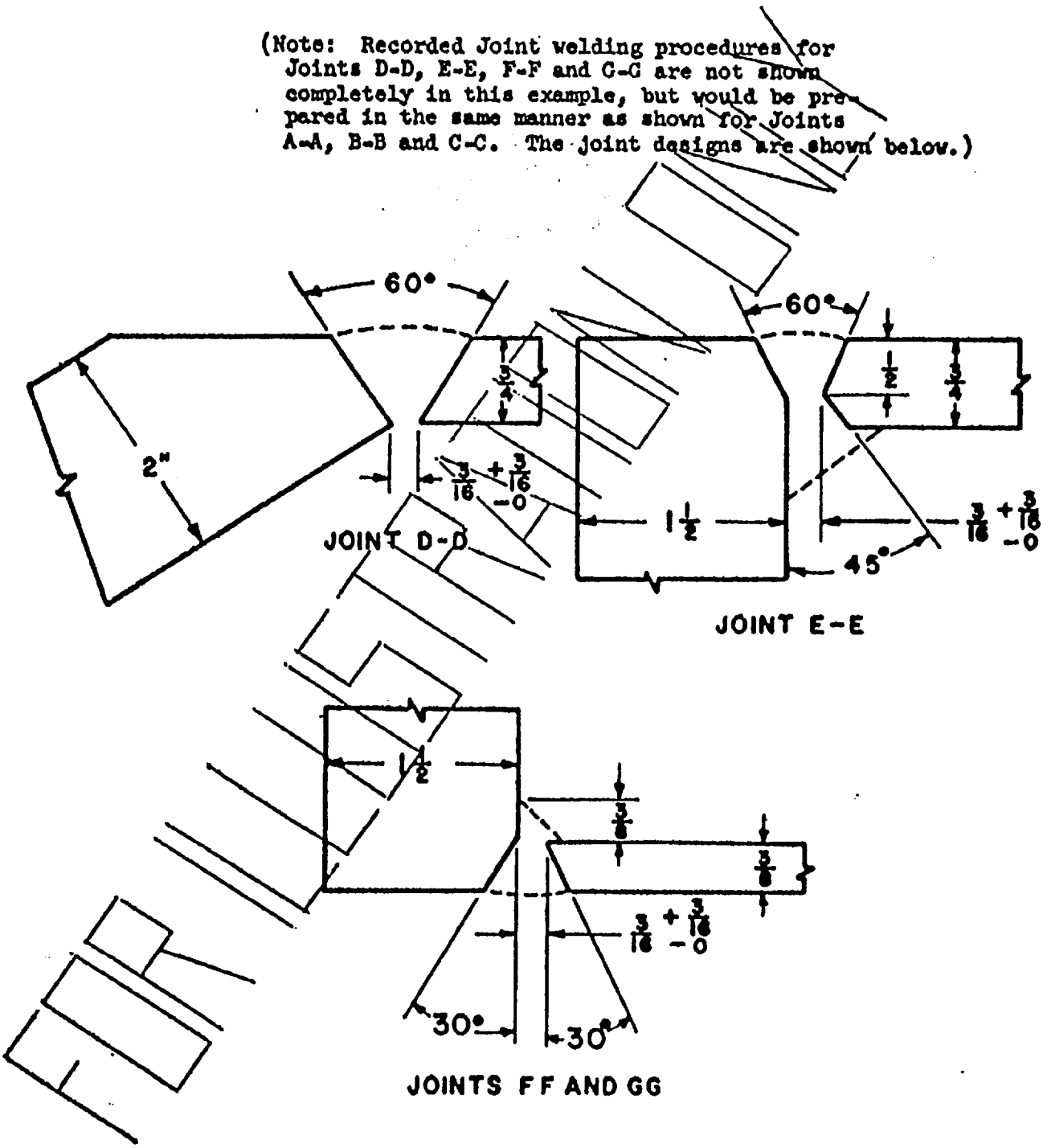
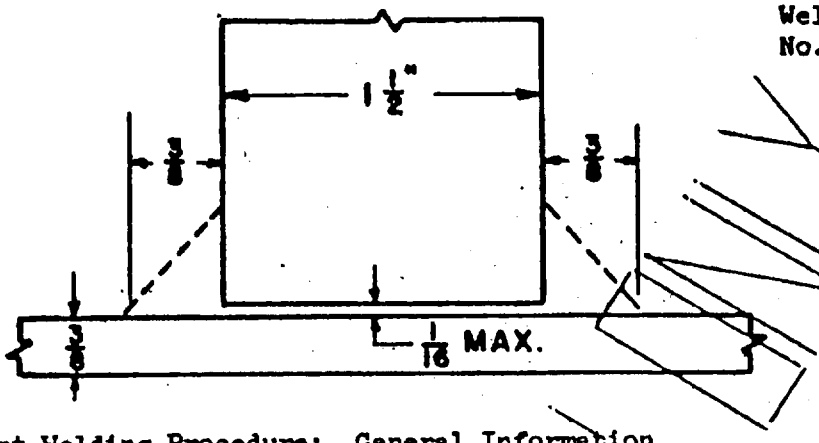


FIGURE A-10. Recorded joint welding procedure for joints D-D, E-E, F-F and G-G.

APPENDIX A

Recorded Joint Welding Procedure No. 8 a

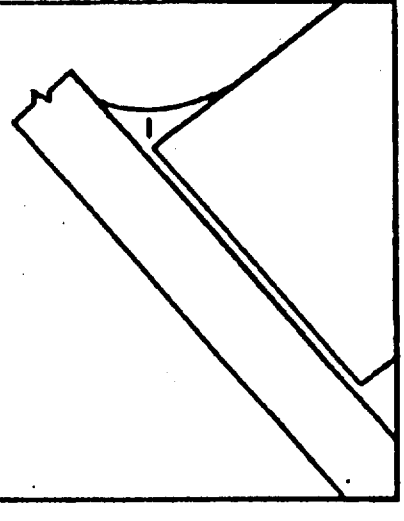
Joint H-H



Joint Welding Procedure: General Information

Armor (reference designation)	II
Electrode (reference designation)	A or E
Power Source (AC or DC) and Polarity if DC	DC, Reverse
Welding Current & Arc Voltage Range	As Specified in Table C, FORM A-4
Use of Spatter Compound on Scarfed Edges	None
Backing	----
Preheating	None
Position of Welding	Flat

Joint Welding Procedure: Details of

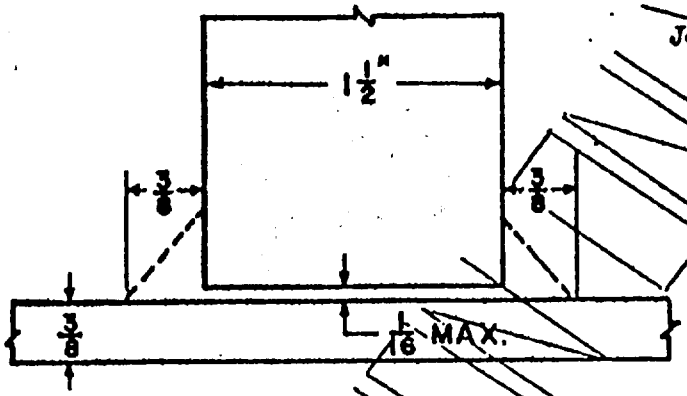
Pass No.	Electrode Size	Type of Pass	Location & Sequence of Passes
1	1/4	Weave	

FORM A-11. Recorded joint welding procedure no. 8a joint H-H.

APPENDIX A

Recorded Joint Welding Procedure No. 8 B

Joint H-H



Joint Welding Procedures: General Information

Armor (reference designation)	II
Electrode (reference designation)	A or E
Power Source (AC or DC) and Polarity if DC	DC, Reverse
Welding Current & Arc Voltage Range	As Specified in Table C, FORM A-6
Use of Spatter Compound on Scarfed Edges	None
Backing	----
Preheating	None
Position of Welding	Horizontal

Joint Welding Procedure: Details of

Pass No.	Electrode Size	Type of Pass	Location & Sequence of passes
1	3/16	Stringer	
2	3/16	Weave	

(Note: Recorded Joint Welding Procedures are not shown for Joint H-H in the vertical position and Joint J-J in the flat, horizontal and vertical positions; but would be prepared in the same manner as illustrated for Joint H-H in the flat and horizontal positions.)

FORM A-12. Recorded joint welding procedure no. 8b joint H-H.

APPENDIX A

THIS FORM MAY BE REPRODUCED FOR USAGE

ARMOR WELDING DATA SHEET #1	REPORT No.
	SHEET No. of

WELDED ARMOR DATA

Plate No.	SUBMITTED BY
DATE	
TYPE	ADDRESS
THICKNESS	
SPECIFICATION	CONTRACT NO.
ORDNANCE MATERIAL CONCERNED	
WELDED BY	
OBJECT	

On a dimension sketch of the groove and weldment, indicate: (1) the included angles (2) the root opening; (3) the root face; (4) the bead sequence; (5) additional sketch of spacer strip on back-up, if any; (6) width of marking, if any on edges of cast plate; (7) average height of weld reinforcement

Weld reinforcement (has) (has not) been removed.

WELDING DATA

PLATE PREPARATION - Flame cutting - Flame softening - Grinding - Machining

POSITION OF WELDING: Flat - Horizontal - Vertical - Overhead

WELDING: Automatic - Hand - POLARITY: - Str - Rev - AC -DC

PREHEAT POSTHEAT

PEENING BUTTERING

PASS	ELEC SIZE	TYPE PASS	AMPS	VOLTS	CRACKING	CHIP OR GRIND	SPEED IN/MN.	INTERPASS.TEMP.(F) A-B	C-D	E-F-G
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

B - BEADING PASS W- WEAVING PASS

FORM A-13. Armor welding data sheet no. 1.

APPENDIX A

THIS FORM MAY BE REPRODUCED FOR USAGE

ARMOR WELDING DATA SHEET # 2

REPORT No.

SHEET No. of

ARMOR PLATE DATA

TEST PLATE No.	PLATE "A"	PLATE "B"
MANUFACTURER		
TYPE		
THICKNESS		
HEAT		
LOT		
PROCESS	O;H; ELEC ACID BASIC	O;H; ELEC ACID BASIC

CHEMICAL COMPOSITION

	C	Mn	Si	P	S	Cr	Ni	Mo	Zr	V	FACE	BACK
PLATE "A"												
PLATE "B"												

HEAT TREATMENT DATA

HEAT TREATED BY

TABLE 1 ELECTRODE OR FILLER METAL DATA

SIZE	Manufacturer	Trade Name	Type	Class

TABLE 2

MANUFACTURER TRADE NAME AND SIZE		CHEMICAL ANALYSIS C	Mn	Si	S	P	Cr	Ni	Mo	COATING
	CORE WIRE									
	WELD METAL									
	CORE WIRE									
	WELD METAL									
	CORE WIRE									
	WELD METAL									
	CORE WIRE									
	WELD METAL									

TABLE 3 (AUTOMATIC WELDING)

MANUFACTURER	TRADE NAME	SIZE	FLUX

RADIOGRAPHED BY

RADIOGRAPH SERIAL No.

REMARKS: The procedure used in fabricating the crossbar weld (is) (is not) the same as the procedure used in fabricating the leg welds.

FABRICATOR REPRESENTATIVE	RESIDENCE INSPECTOR OF ORDNANCE

FORM A-14. Armor welding data sheet no. 2.

APPENDIX A

FORM MAY BE REPRODUCED FOR USAGE

ARMOR WELDING DATA SHEET # 3	(1) REPORT No. SHEET No. of
(2) X-RAY SERIAL NO.	
WELD RADIOGRAPHIC REPORT	
(3) PLATE SUBMITTED BY	(4) Plate No. / (5) SPEC
(6) RADIOGRAPH BY	(7) DATE
(8) PLATE THICKNESS / (9) KV / (10) MA / (11) TIME	
(12) FOCAL DIST. / (13) TYPE OF FILM / (14) SCREEN OR FILTERS	

SHOCK TEST PLATE

Showing Locations of Radiographs and Results of Tests

(15) CRACK / INCOMPELTE FUSION / INCOMPLETE PENETRATION
POROSITY AND SLAG INCLUSIONS / UNDERCUTTING

(16) RESULTS

(17) NEGATIVES READ BY

FORM A-15. Armor welding data sheet no. 3.

APPENDIX B

EVALUATION OF WELDER CAPABILITY

B.1 SCOPE

B.1.1 Scope. This appendix covers the minimum requirements for evaluation by the contractor or manufacturer of the capability of welders to perform under the requirements of this handbook.

B.2 APPLICABLE DOCUMENTS

The applicable documents referenced in section 2 of this handbook apply to this appendix.

B.3 DEFINITIONS

The definitions in section 3 of this handbook apply to this appendix.

B.4 REQUIREMENTS

B.4.1 Weld type. Each welder should demonstrate his capability to weld groove or fillet welds or both by fabricating the specimens shown in figures B-20, B-21 and B-22, as applicable.

B.4.2 Position of weld. Each welder should demonstrate his capability in the position in which he will weld in production by welding the test specimens in the positions prescribed in B.4.2.1.1 through B.4.2.1.4. Welders found acceptable in one or more positions will be considered acceptable in other positions under the conditions specified in table B-I.

TABLE B-I. Welder evaluation with the "K" qualification plate.[1/]

"K" plate position	Qualified in groove welds in the following positions				Qualified for fillet welds in the following positions[2/]			
	Flat	Horiz	Vert	OH	Flat	Horiz	Vert	OH
Flat	Yes	No	No	No	Yes	Yes	No	No
Horizontal	Yes	Yes	No	No	Yes	Yes	No	No
Vertical	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Overhead	Yes	Yes	No	Yes	Yes	Yes	No	Yes

[1/] See figure B-21.

[2/] For fillet welds only, "K" joint qualification is not required (see B.4.2.2).

B.4.2.1 Groove welds.

B.4.2.1.1 Flat position. The plates should be placed in an approximately horizontal plane, and the weld metal deposited from the upper side.

B.4.2.1.2 Horizontal position. The plates should be placed in an approximately vertical plane with the welding groove in an approximately horizontal position.

B.4.2.1.3 Vertical position. The plates should be placed in an approximately vertical plane with the welding groove in an approximately vertical position, approximately 90^{o} to the horizontal plane.

B.4.2.1.4 Overhead position. The plates should be placed in an approximately horizontal plane, and the weld metal deposited from the underside.

B.4.2.2 Fillet welds only. The welder for fillet welds only should fabricate a specimen in accordance with figure B-23. The arrangement of the test plates for the various positions refers only to the making of the fillet weld. The closing weld (cross hatched in figure B-23) between fillet welds may be made in any position as follows:

a. The welding of plates so placed that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical will determine the capability of welders for flat fillet welds.
b. The welding of plates so placed that each weld is deposited on the upper side of the horizontal surface and against the vertical surface will determine the capability of welders for flat and horizontal fillet welds.
c. The welding of plates so placed that each weld is made vertically will determine the capability of welders for flat, horizontal and vertical fillet welds.
d. The welding of plates so placed that each weld is deposited on the under side of the horizontal surface and against the vertical surface will determine the capability of welders for flat, horizontal, and overhead fillet welds.

B.4.2.3 Radiography of welds. The completed weld should be radiographed and should comply with the following standards:

a. Grade II of MIL-HDBK-1264 with the direction of radiation parallel to the weld interface, then normal to the weld face, and finally parallel to the opposite weld interface for full penetration welds.
b. MIL-STD-1894 for partial penetration welds.

In either case defects within 1 in. (25.4 mm) of either end of the weld should not be regarded as cause for rejection. Radiographic negatives should be suitably identified and returned for Government inspection, when requested.

B.4.2.4 Materials. Specimens may be made of either mild steel or armor.

B.4.2.5 Electrodes. The electrodes for groove or fillet welds should conform to the type of electrode for method 1, 2, 3 or 4 of this handbook (see 1.2) as applicable. The diameter of electrode used for any layer of a groove weld should be the maximum diameter that will be used for that width in the recorded joint-welding procedure.

B.4.2.6 Workmanship. Welds should be equal to, or better than, the workmanship specimens prepared for the recorded joint-welding procedures.

B.5 INSPECTION

B.5.1 Test specimens.

B.5.1.1 Groove welds. Groove welds should be fabricated to the form and dimensions shown in figure B-21 or B-22, as applicable, using the same welding current values for the electrodes that would be used in the recorded joint-welding procedures. When the thickness of the plates in the structure does not exceed 1/2 in. (12.7 mm), the specimen should be as shown in figure B-21 and the two plates should be 3/8 by 4 by 12 in. (9.5 by 102 by 305 mm) with the butt weld made on the 12 in. (305 mm) dimension. When the thickness of the plates to be welded exceeds 1/2 in. (12.7 mm) the specimen should be as shown in figure B-22 and the two plates should be 1 by 4 by 12 in. (25.4 by 102 by 305 mm). All dimensions should be considered minimum. Welders capable of welding the 1 in. (25.4 mm) plates do not have to weld the 3/8 in. (9.5 mm) plates.

B.5.1.2 Fillet welds. The specimen should be of the form and dimensions shown in figure B-23.

B.5.2 Inspection procedures.

B.5.2.1 Visual. Visual examination of the weld should be made for compliance with the workmanship requirement (see B.4.2.6).

B.5.2.2 Radiographic. Welds should be radiographed in accordance with ASTM E1742.

B.6 FACTORS IN THE JOINT-WELDING PROCEDURE

B.6.1 Factors to be included in the joint-welding procedure and changes requiring resubmittal of the procedure and requalification of welders. Factors to be included in the joint-welding procedure and changes requiring resubmittal of the procedure and requalification of welders should be as specified in table B-II.

APPENDIX B

TABLE B-II. Requirements for the joint-welding procedure.[1/]

Factors to be included in joint-welding procedure	When factor is changed, joint-welding procedure to be revised and procedure requalified, as indicated	When factor is changed, welder to be requalified, as indicated
1. Composition of armor.	Yes - When a change in composition outside the steel producer's declared chemical range is made, unless a specific waiver is granted by the procuring activity.	No.
2. Thickness of armor for each joint type.	Yes - When the maximum or minimum thickness for the joint type represented by the procedure qualification plates tested for representation of the joint type is exceeded (see table B-III).	Yes (see B.5.1.1).
3. Dimensions of root opening, root face and included angle for each joint type. Each dimension should have a specified tolerance.[2/]	Yes - When established limits are increased or decreased, i.e., basic dimensions plus tolerances.	No.
4. Backing or spacer strip, if used.	Yes - When backing or spacer strip is added or removed, or when basic type of material of backing or spacer strip is changed.	Yes - When backing or spacer strip is removed.
5. Position in which welding will be performed.	Yes.	Yes (see B.4.2.1).

TABLE B-II. Requirements for the joint-welding procedure - Continued.

Factors to be included in joint-welding procedure	When factor is changed, joint-welding procedure to be revised and procedure requalified, as indicated	When factor is changed, welder to be requalified, as indicated
6. Electrode type and class if not qualified under MIL-E-13080, MIL-E-0022200/1, MIL-E-22200/6, or MIL-E-23765/2. Electrodes should be designated as SMAW or GMAW, as appropriate.	Yes - when the brand used for procedure qualification has been recorded but does not meet the requirements of MIL-E-13080, MIL-E-0022200/1, MIL-E-22200/10, or MIL-E-23765/2; substitution of any other brand will require requalification of procedure. However, when the brand used for procedure qualification has met the requirements of MIL-E-13080, MIL-E-22200/1, MIL-E-22200/10, or MIL-E-23765/2 for a specific type and class, and provided that all other factors remain the same, any other brand that has met the requirements of the foregoing specifications for the same type and class and may be substituted without qualification of procedure.	No.
7. Electrode sizes[3/] for all passes.	Yes - when (for groove welds) the actual width of groove, at which any given size of electrode is used, is decreased; or (for fillet welds) when the diameter used at any given distance from the root of the weld is increased.	Yes - when (for groove welds) the actual width of groove, at which any given size of electrode is used, is decreased; or (for fillet welds) when the diameter used at any given distance from the root of the weld is increased.

TABLE B-II. Requirements for the joint-welding procedure - Continued.

Factors to be included in joint-welding procedure	When factor is changed, joint-welding procedure to be revised and procedure requalified, as indicated	When factor is changed, welder to be requalified, as indicated
8. Welding current[4/] and arc-voltage range for all passes (see B.7.4).	Yes - When outside the limits established in the recorded joint-welding procedure (either above or below).	Yes - When outside the limits established in the recorded joint-welding procedure (either above or below)
9. Preheat and interpass temperature range (see 5.4.1 & 5.4.3).	Yes - When the range is changed.	No.
10. Location, type and approximate number of passes.	Yes - In case of change from beading to weaving, or vice versa.	No.
11. Method of preparing root of joint before welding second side.	Yes.	No.
12. Source of power, AC or DC, and polarity if DC is used.	Yes.	No.
13. Spatter compound.	Yes - When spatter compound is used on any area where weld metal is to be deposited.	No.
14. Temperature of plate at time welding is started and method of attaining temperature.	Yes - When ambient or preheat temperature is more than 20°F (11.2°C) below that of the test plate. No - When method of attaining temperature is changed.	No.
15. Shielding medium type.	Yes - when changing to another medium.	Yes.
16. Composition, volume, and dew point of the shielding gas.	Yes.	No.

APPENDIX B

TABLE B-II. Requirements for the joint-welding procedure - Continued.

Factors to be included in joint-welding procedure	When factor is changed, joint-welding procedure to be revised and procedure requalified, as indicated	When factor is changed, welder to be requalified, as indicated
17. Method of joint edge preparation.	No - When method changes from thermal to mechanical (machining or grinding).	No.

1/ Additional factors for repair welding:

a. Method to be used (grinding or other) for removal of the defect.
b. Contour of cavity prior to welding, such as 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, magnetic particle, visual, radiographic, etc.).

2/ Root opening. It should be noted that MIL-HDBK-21 provides for minimum root openings ranging from 3/16 to 1/2 in. (4.8 to 12.7 mm). In all cases, these root openings are known as "design openings". In other words, they are the root openings which would exist after completion of the weld if the root face had not melted away. This type of root-opening dimension is used because it can be shown on assembly drawings and still permit the addition of plate dimensions plus root-opening dimensions to give the correct over-all dimension for the structure. The "design opening" is not ordinarily the root opening which is actually visible before welding, since this opening must include an increase for the amount of contraction across the joint during welding. Thus, this root opening, sometimes known as the "set-up opening", equals the "design opening" plus the shrinkage allowance.

3/ Option on electrode size. The contractor should specify in his recorded joint-welding procedure the diameter of the electrode to be used for deposition of the root pass in each width of root opening from the minimum to the maximum. A contractor may specify that a 1/8 in. (3.2 mm) electrode should be used for the minimum root opening of 3/16 in. (4.8 mm) and that a 3/16 in. (4.8 mm) electrode should be used for a root opening of 1/4 to 1/2 in. (6.4 to 12.7 mm). In the operation of the procedure, the contractor may use a smaller diameter of electrode than that specified for the particular root opening, but he may not use an electrode larger than that specified without requalifying his procedure. The contractor may not use a 3/16 in. electrode for the 3/16 in. minimum root opening when a 1/8 in. (3.2 mm) electrode has been specified in his recorded joint-welding procedure.

4/ Current values. Welding current may be measured with a tong-type tester. Current variations for all types and sizes of electrodes should be limited to approximately $\pm$ 15 percent.

APPENDIX B

B.7 REQUIREMENTS FOR BALLISTIC TEST PLATES, BALLISTIC TESTS AND WORKMANSHIP SPECIMENS

B.7.1 Thickness of ballistic test plates. Thickness of ballistic test plates should be as specified in table B-III.

TABLE B-III. Thickness of ballistic test plates.

Maximum or minimum "T" thickness of plate in joint: in. (mm)	Thickness of ballistic test plate: in. (mm) 1/,2/,4/
1/8 to 3/4 (3.2 to 19.0)	1/2 (12.7)3/
3/4 to 1-1/8 (19.1 to 28.6)	1 (25.4)
Greater than 1-1/8 (28.6)	1-1/2 (38.1)

1/ For cast and rolled armor, thickness tolerances should not exceed plus or minus 0.030 in. (0.76 mm).

2/ Before welding, cast or rolled plates 18 by 40 in. (46 by 102 cm), or smaller, should have a maximum out-of-flatness tolerance of 1/16 in. (1.6 mm) in any direction. Plates 36 by 36 in. (91.4 by 91.4 cm) should have a maximum out-of-flatness tolerance of 1/8 in. (3.2 mm) in any direction.

3/ For cast armor 1 in. (25.4 mm) plate should be used.

4/ Ballistic test plate thickness may equal the armor thickness for production use provided it is no less than 1/2 in. (12.7 mm) nor more than 2 in. (50.8 mm). Striking velocities should be adjusted in accordance with Footnotes 1(a) and 1(b) of table B-IV. A 1/2-in. (12.7 mm) thick plate should be submitted for production plates thinner than the 1/2 in. (12.7 mm) nominal size, and a 1-1/2 in. (38.1 mm) should be submitted for production plates thicker than the 2-in. (50.8 mm) nominal size.

APPENDIX B

B.7.2 Requirements for ballistic tests. Requirements for ballistic tests should be as specified in table B-IV.

TABLE B-IV. Requirements for ballistic tests.

Thickness of plate, in. (mm)	Type of homogeneous armor	Projectile	Striking velocity f/s ± 25 f/s (m/s + 7.6 m/s)[1/]	Maximum allowable weld cracking, in. (mm)[2/]
1-1/2 (38.1)	Rolled	75 mm PP M1002	1200 (365.8)	15 (381)
1-1/2 (38.1)	Cast	75 mm PP M1002	1050 (320)	10 (254)
1 (25.4)	Rolled	57 mm PP M1001	1050 (320)	9 (228.6)
1 (25.4)	Cast	57 mm PP M1001	975 (297)	6 (152.4)
1/2 (12.7)	Rolled	37 mm HE M54	2525 (770)	15 (381)

1/ If the actual plate thickness is more than the nominal thickness, the test striking velocity should be increased. If the actual plate thickness is less than the nominal thickness, the test striking velocity should be decreased.

a. For cast armor only the correction factor should be 6 f/s (1.83 m/s) of velocity for each 0.01 in. (0.25 mm) deviation in plate thickness.
b. For rolled armor only the correction factor should be 7 f/s (2.13 m/s) velocity for each 0.01 in. (0.25 mm) deviation in plate thickness.

2/ Typical crack situations are illustrated in figure B-17.

B.7.3 Size of workmanship specimen. Workmanship specimen sizes should be as specified in table B-V.

TABLE B-V. Workmanship specimen sizes.

Plate thickness, in. (mm)	Minimum plate size, in. (mm)
1/8 to 1-1/4 (3.2 to 31.8) incl	4 by 12 (102 by 305)
greater than 1-1/4 (31.8)	4 by 16 (102 by 406)

B.7.4 Welder requalification requirements.

a. If the welder has not welded for the period of 1 month (20 working days or 30 calendar days) or longer, the welder must requalify in the position the welding is to be performed in.
b. If the welder has three consecutive rejected welds or weld repairs, the welder must requalify.

APPENDIX B

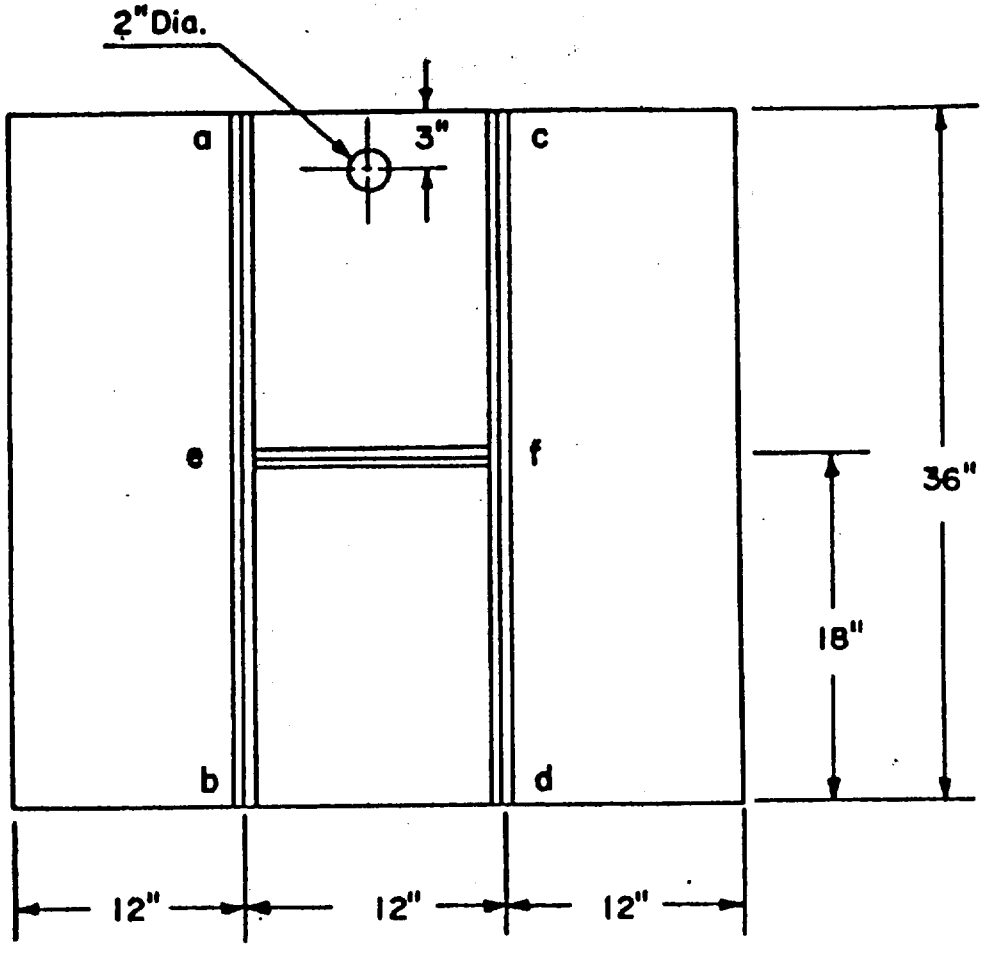


FIGURE B-16. Ballistic test plate.

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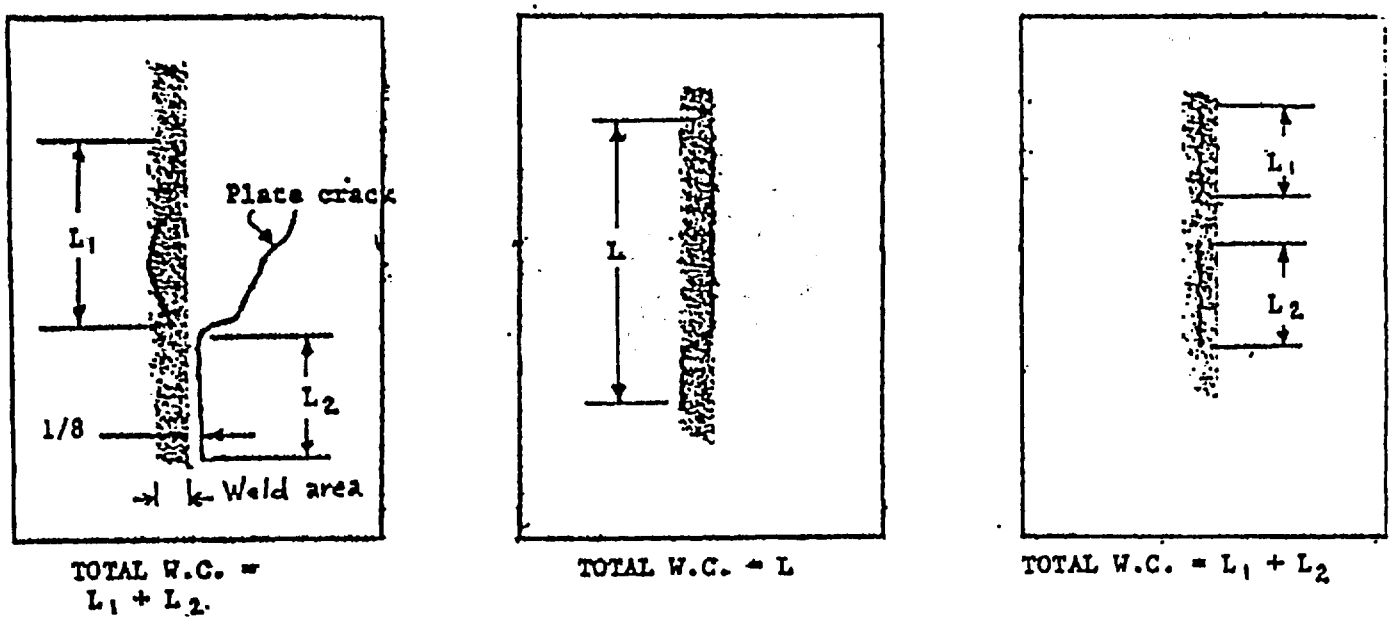

FIGURE B-17 Some weld cracks (W.C.) which could occur from projectile impact, and measurement of total weld cracks for acceptance purposes (see table IV).

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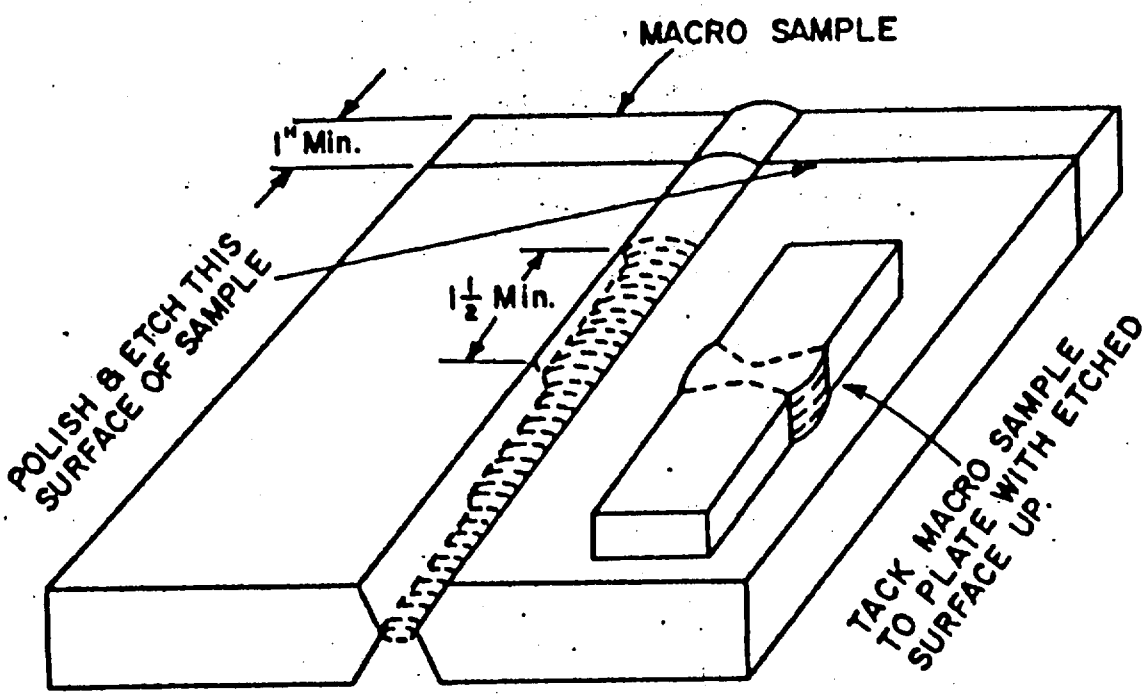

Note: Joint type No. 3 is illustrated. However, groove details of actual specimens should conform to details of contractor's recorded joint welding procedure for each type of joint involved.

FIGURE B-18. General form of workmanship specimen for joint types 1, 2 and 3.

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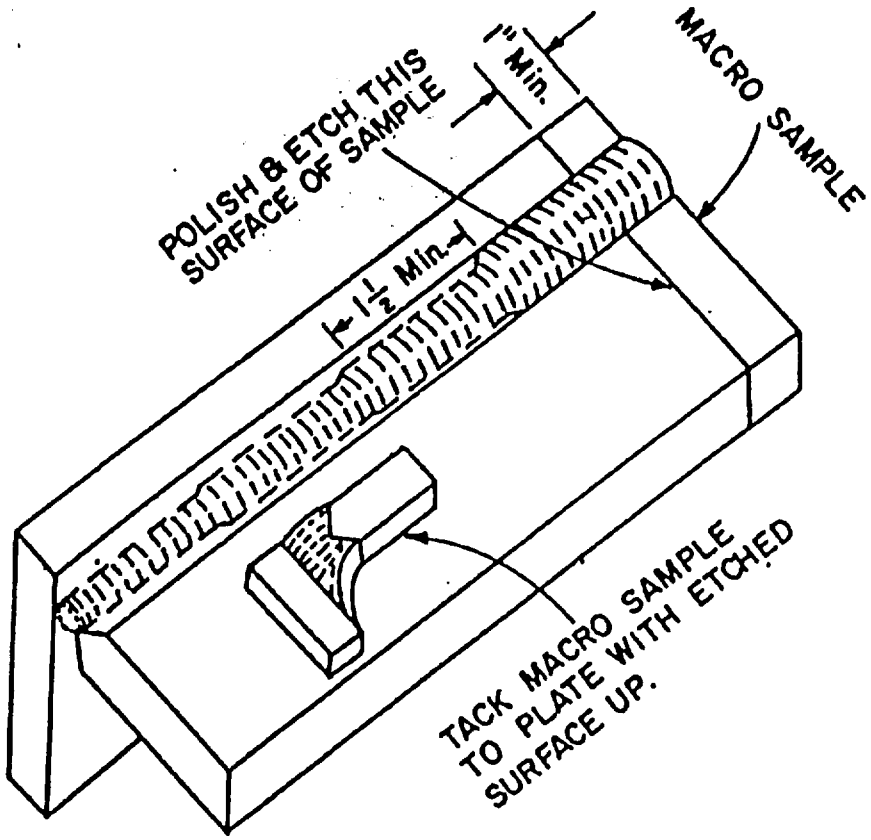

Note: Joint type No. 5 is illustrated. However, groove details of actual specimens should conform to details of contractor's recorded joint welding procedure for each type of joint involved.

FIGURE B-19. General form of workmanship specimen for joint types 4, 5, 6 and 7.

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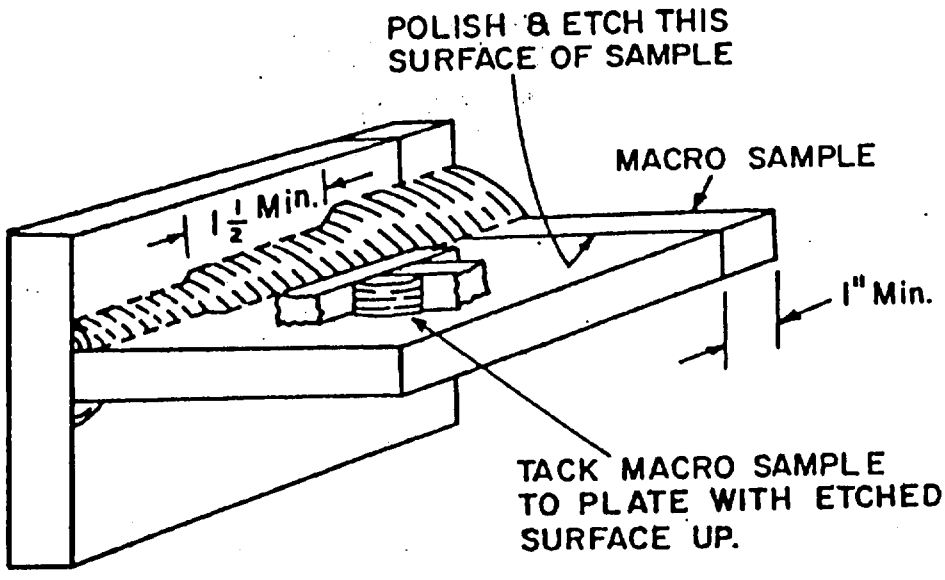

Note: Type 9 is illustrated. However, groove details of actual specimens should conform to details of contractor's recorded joint welding procedure for each type of joint involved.

FIGURE B-20. General form of workmanship specimen for joint types 8 and 9.

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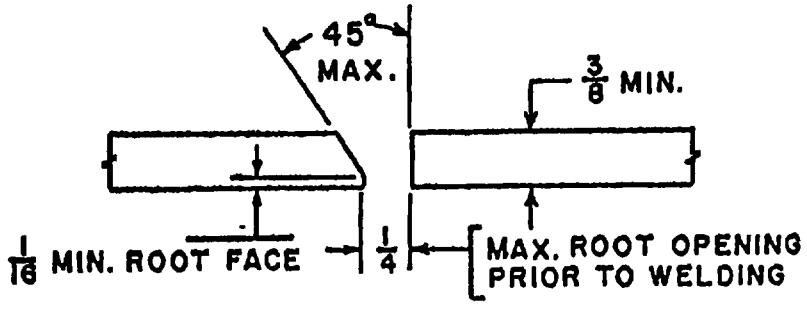

FIGURE B-21. Groove weld test specimen for qualifications of welders or welding operators for plate thickness of 0.5 in. (12.7 mm) or less.

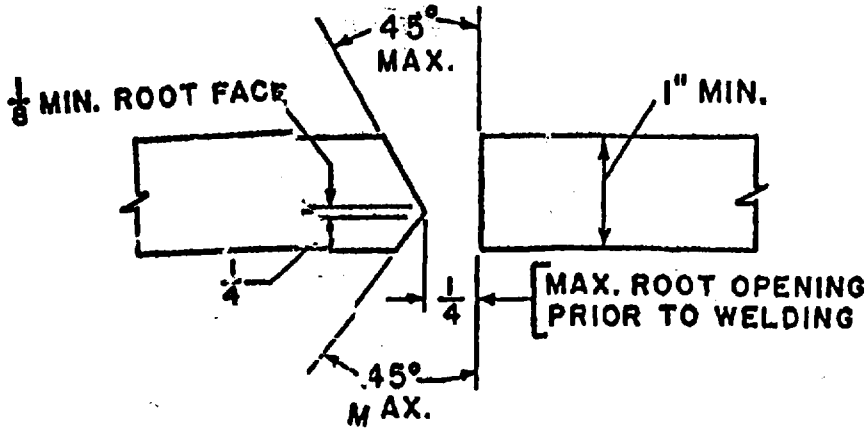

FIGURE B-22. Groove weld test specimen for qualification of welders or welding operators for plate thickness of more than 0.5 in. (12.7 mm).

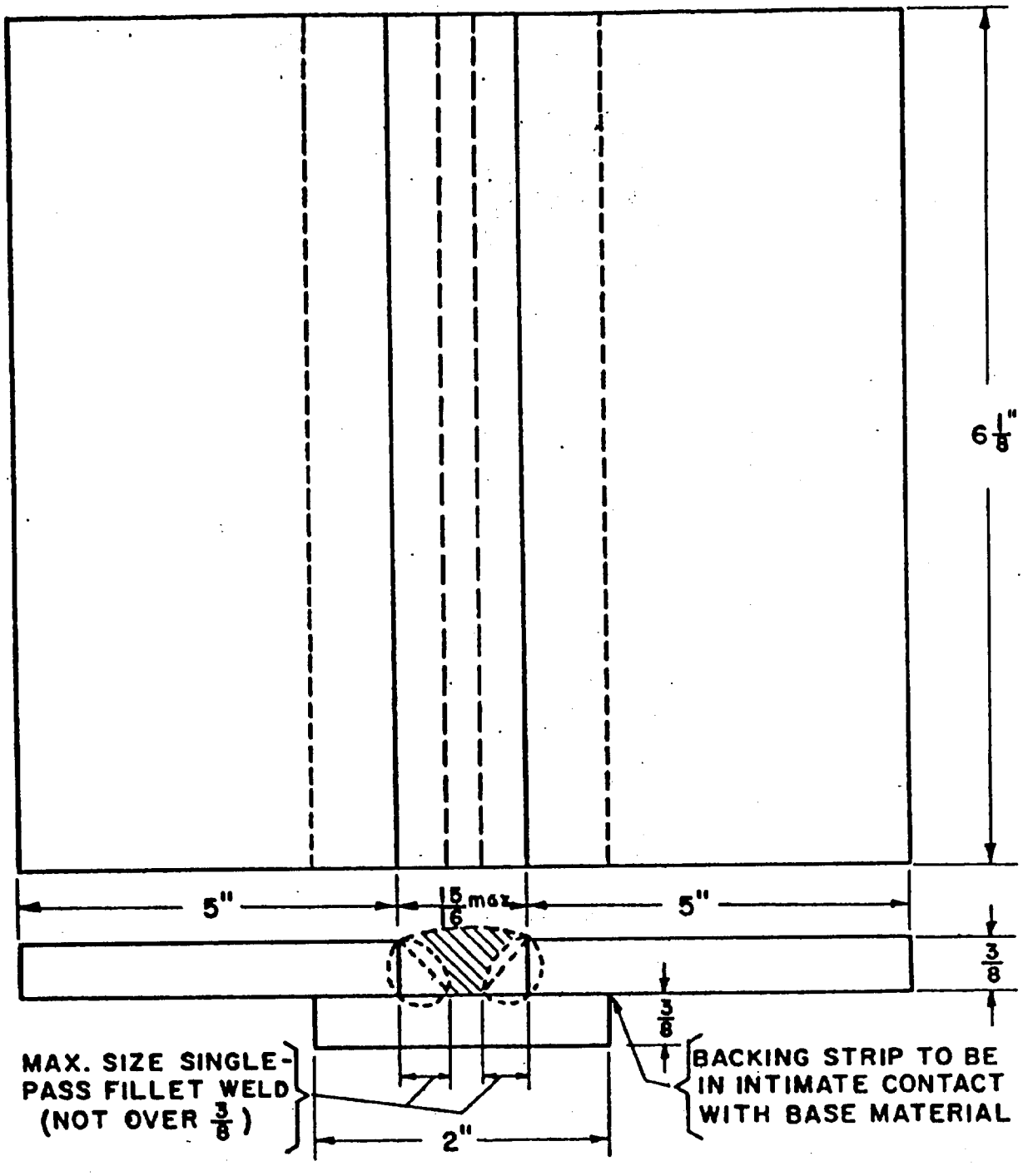

FIGURE B-23. Fillet weld test specimen for qualification of welders or welding operators.

CONCLUDING MATERIAL

Custodians:
Army - MR
Navy - AS
Air Force - 11

Review activities:
Army - AV, MI
Navy - EC, NP, SH
Air Force - 13
DLA - DH(DCMC-OF, DLSC-LEQ)

Preparing activity:
Army - MR

(Project THJM-0403)

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.

I RECOMMEND A CHANGE:	**1. DOCUMENT NUMBER** MIL-HDBK-1941	**2. DOCUMENT DATE (YYMMDD)** 980916

DOCUMENT TITLE METAL-ARC WELDING OF HOMOGENEOUS ARMOR

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 US ARMY RESEARCH LABORATORY	b. TELEPHONE *Include Area Code)* (1) Commercial ((410-306-0725 (2) AUTOVON 458-0725
c. ADDRESS *(Include Zip Code)Commander* Weapons & Material Research Directorate Attn: AMSRL-WM-M Aberdeen Proving Ground, MD 21005-5069	**IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:** DEFENSE QUALITY AND STANDARDIZATION OFFICE 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22401-3466 Telephone (703) 756-2340 AUTOVON 289-2340