NOTE: MIL-STD-2149 has been redesignated as a Test Method Standard. The cover page has been changed for Administrative reasons. There are no other changes to this Document.

INCH-POUND

MIL-STD-2149A(SH)
2 February 1990
SUPERSEDING
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14 November 1983
(See 10.6)

DEPARTMENT OF DEFENSE
TEST METHOD STANDARD

STANDARD PROCEDURES FOR EXPLOSION TESTING FERROUS AND NON-FERROUS METALLIC MATERIALS AND WELDMENTS

AMSC N/A AREA THJM

FOREWORD

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

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this standard should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. The explosion crack starter and explosion bulge tests were developed in 1949 to 1950 and have been used extensively to investigate the factors which determine the performance of weldments, particularly in submarine structure and other large welded structures. These tests were demonstrated to be simple and reliable methods for determining the performance characteristics of service type weldments and represent the only feasible testing procedures by which the base metal, heat-affected zone (HAZ) and fusion zone of weldments and the performance of weld metal can be fully evaluated as a complete unit. The explosion tear test was developed by Naval research personnel as a modification of the explosion bulge test. The test was originally utilized to evaluate base material resistance to fracture and fracture extension under rapid loading conditions. Subsequently the test has also been utilized to evaluate weldments (the composite of weld metal, base metal weld heat-affected zone, and base metal) under conditions of controlled rapid loading. The test design permits weld transverse loading to specific strain levels and is amenable to strain gage instrumentation. This test is utilized with and without a fracture initiating mechanical notch or brittle weld crack starter.

4. This standard provides instructions and guidance for both performance of explosion bulge and explosion tear testing of nominal 1-inch and 2-inch thick materials for the evaluation of metallic plates, castings, forgings, extrusions, welding filler materials and welding procedures as required by applicable purchase specifications or fabrication documents. The test methods described herein may also be implemented as an investigative tool for developmental work or failure analysis purposes.

CONTENTS

CONTENTS - Continued

CONTENTS - Continued

1. SCOPE

1.1 Scope. This standard covers explosion testing used to evaluate ferrous and non-ferrous base materials, welding filler materials and welding procedures when required by applicable specifications, contracts, acquisitioning documents and other authorities.

1.2 Test methods. Three test methods are described herein.

(a) Explosion crack starter testing - filler metals and base plate.
(b) Explosion bulge testing - filler metals and base plate.
(c) Explosion tear testing - primarily titanium.

1.3 Approval authority. Any requirements contained in this standard specifically requiring Naval Sea Systems Command (NAVSEA) approval shall be forwarded to the Naval Sea Systems Command, Assistant Director, Materials Engineering, Washington, DC 20362.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 10.2).

STANDARDS

MILITARY

MIL-STD-271 - Requirements for Nondestructive Testing Methods.
MIL-STD-45662 - Calibration System Requirements.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

0900-LP-003-8000 - Surface Inspection Acceptance Standards for Metals.
0900-LP-003-9000 - Radiographic Standards for Production and Repair Welds.

(Application for copies should be addressed to the Naval Publications and Forms Center (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 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 issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 10.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
E 604 - Standard Test Method for Dynamic Tear Testing of Metallic Materials.

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

AMERICAN WELDING SOCIETY (AWS)
A3.0 - Standard Welding Terms and Definitions. (DoD adopted)
B4.0 - Standard Methods for Mechanical Testing of Welds.

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

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

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

3. DEFINITIONS

3.1 General. Except as noted herein, welding nomenclature and definitions shall be in accordance with AWS A3.0.

3.1.1 All-weld-metal test specimen. An all-weld-metal test specimen is a test specimen wherein the portion being tested is composed totally of deposited weld metal.

3.1.2 Bulge area. Bulge area is an unrestrained area of weldment test specimen subjected to explosive loading.

3.1.3 Compression side. The compression side is that surface of the test specimen facing the explosive.

3.1.4 Crack starter bead. A crack starter bead is the brittle weld metal deposited on the weldment to present a sharp crack front to the weld or HAZ or base-metal for the purpose of assessing the resistance to cracking of the material being tested.

3.1.5 Explosion test. An explosion test is a general term applicable to the explosion crack starter, explosion bulge and explosion tear tests as covered herein.

3.1.6 Explosion bulge test. An explosion bulge test is an explosion test principally used to qualify prospective contractors' products wherein a flat test plate specimen or weldment is explosively loaded into a circular test die.

3.1.7 Explosion crack starter test. An explosion crack starter test is an explosion bulge test plate with a deposited and notched crack starter bead.

3.1.8 Explosion tear test (ETT). An explosion tear test is a slotted explosion test used where preferential transverse loading of the test specimen is specified.

3.1.9 Explosive. An explosive is a material that when detonated generates, by instantaneous burning, rapidly expanding gases producing sufficient force to plastically deform the metallic materials under test.

3.1.10 Explosive stand-off distance. Explosive stand-off distance is the distance measured from the top face of the explosion test die to the bottom surface of the explosive charge.

3.1.11 Finished weld. A finished weld is a weld which has received final inspection and has been accepted.

3.1.12 Heat soak. Heat soak is any application of heat, during or on completion of welding, to a weld joint to promote hydrogen removal.

3.1.13 Hold-down area. The hold-down area is that portion of the weldment resting on the die.

3.1.14 Prolongation. Prolongation is an explosion test specimen or weldment extension intended for mechanical testing. Prolongation length will depend on the number of mechanical tests planned.

3.1.15 Reduction in thickness (percent). Reduction in thickness is the percent plate thickness reduction affected by explosive loadings. It shall be calculated from measurements taken at a standardized location (see 9.3.5).

3.1.16 Tension side. The tension side is that surface of the weldment located away from the explosive charge.

4. GENERAL REQUIREMENTS

4.1 Material qualification. When explosion testing is required to be conducted by Military specifications for base metal or filler metal, contractors shall prepare data for the material on which qualification is proposed by the instructions of the applicable material specification. Prior to fabricating the test weldments, all filler metal lots to be used when base metal is being evaluated or all base metal to be used when weld metal is being evaluated shall be receipt inspected in accordance with the applicable specification.

5. DETAILED REQUIREMENTS

5.1 Mechanical test samples. Mechanical test specimens (prolongations to explosion test specimens see figures 1, 2, and 3) shall be prepared and tested by the authorized Government laboratory performing the explosion testing. Quantities and test specimen details shall be in accordance with sections 6 and 7. Mechanical properties of the base metal or weld metal shall be evaluated in accordance with the applicable specification. The feasibility of a successful explosion test shall be determined by the authorized Government laboratory on the basis of the material's mechanical properties. The mechanical test prolongations shall be prepared integral with the explosion test specimens and shall be severed by flame or saw cutting. Mechanical test specimens shall be machined from the prolongations in accordance with figures 2 and 3.

5.2 Explosion crack starter samples. Explosion crack starter specimens shall be prepared by the Government laboratory performing the explosion testing. Quantities and explosion test specimen details shall be in accordance with sections 6 and 7. The explosion crack starter test and the explosion bulge test are used in the evaluation of base metals, weld metals, heat-affected zones, weld fusion zones, and welding procedures. Normally, when the explosion crack starter test results are unsatisfactory, the explosion bulge test is not conducted. However, when requested in advance of testing by the prospective contractor, and agreed to by the Government laboratory conducting the explosion testing, the explosion bulge samples may be tested to support the failure and provide additional information or data on the cause of failure.

5.3 Explosion bulge specimens. Explosion bulge test specimens shall be prepared by the Government laboratory performing the explosion testing. Explosion test specimens may be prepared by the vendor or fabricating activity when required, if adequate, approved welding procedures are in place. Quantities and test specimen details shall be in accordance with sections 6 and 7 (see figures 1 and 4).

5.4 Explosion tear test. Explosion tear test specimens shall be prepared (see section 8) and tested by a Government laboratory to determine the performance of transversely loaded test specimens with respect to high strain rate loading (see figure 5).

6. QUALIFICATION CONDITION OF MATERIAL

6.1 Base metal product forms. When seeking approval to produce one of the below listed product forms requiring explosion bulge testing, the contractor shall furnish material in accordance with 6.1.1 through 6.1.4, unless otherwise specified by the authorized Government laboratory.

6.1.1 Rolled plate. Contractor shall provide sufficient rolled plate to produce a minimum of two 2 by 50 by 30 inch explosion/mechanical prolongation weldments and four 2 by 30 by 30 inch explosion weldments. The plate surfaces shall be in the as-rolled condition. Figure 1 defines the required orientation of the major rolling direction. Crack starter candidates shall be selected from the test specimens by the authorized Government laboratory.

6.1.2 Castings. Contractor shall provide sufficient cast plate to produce a minimum of two 2 by 50 by 30 inch explosion/mechanical prolongation weldments and four 2 by 30 by 30 inch explosion weldments. The cast plate surfaces (both sides) shall be submitted machined to a 250 micro-inch finish or better to provide a uniform 2-inch thickness. Crack starter candidates shall be selected from the test specimens by the authorized Government laboratory.

6.1.3 Forgings and shapes. Contractor shall provide sufficient forged shaped plate to produce a minimum of two 2 by 50 by 30 inch explosion/mechanical prolongation weldments and four 2 by 30 by 30 inch explosion weldments. The forged or shaped plate surfaces (both sides) shall be submitted machined to a 250 micro-inch finish or better to provide a uniform 2 inch thickness. Crack starter candidates shall be selected from the test specimens by the authorized Government laboratory.

6.1.4 Maximum 1 inch thickness material. Where the maximum material thickness to be produced is 1 inch or less and explosion bulge testing is specified, the above applies except plate sizes shall be 20 inches wide by 60 inches long for explosion/mechanical prolongation weldments and 20 by 20 inches for explosion weldments.

6.2 Filler metals. When seeking approval to produce filler metals that require testing, the contractor, when not specifically directed by the Military specification, shall furnish sufficient filler metal to produce a minimum of two 2 by 50 by 30 inch explosion/mechanical prolongation weldments. If explosion bulge testing is to be performed, additional 2 by 30 by 30 inch explosion weldments may be required as specified by the authorized Government laboratory.

6.3 Welding procedure. When seeking approval for a welding process or procedure, the activity shall furnish sufficient rolled, forged or cast plate to produce two 2 by 50 by 30 inch explosion/mechanical prolongation weldments. If explosion bulge testing is to be performed, additional 2 by 30 by 30 inch explosion weldments may be required as specified by the authorized Government laboratory. The plates and filler metal shall be in accordance with the applicable Military specifications.

7. PREPARATION AND WELDING OF EXPLOSION TEST WELDMENTS WITH AND WITHOUT MECHANICAL PROLONGATION

7.1 Preparation of base metal for welding. Rolled plate material may be used in the as-rolled "mill finish" condition. Cast, forged, extruded material forms shall be machined or ground, both sides, to provide a uniform plate thickness. Unless otherwise specified, weld joints and approved double-V bevels shall be prepared in accordance with figure 6. Double-V groove bevels shall be applied by machining or oxy-fuel cutting provided the flame cutting operation produces a smooth uniform bevel. Bevel preparation residue (cutting oils or flame cutting scale remnant from the weld bevel preparation operation) shall be removed prior to welding. For wrought materials, the weld bevel shall be oriented parallel to the primary rolling or working direction of the base materials.

7.2 Welding of samples. Welding of samples shall be in accordance with 7.2.1 and 7.2.2.

7.2.1 Base metal. For base metal qualification, all samples shall be welded in accordance with an approved welding procedure incorporating the required applicable material or fabrication document requirements or both.

7.2.2 Electrodes and welding procedures. For testing electrodes and qualifying welding processes and procedures, the welding parameters shall be established by the prospective contractor or qualifying activity.

7.3 Nondestructive evaluation of test weldments. When 48 hours have elapsed after completion of welding, the following nondestructive tests in accordance with 7.3.1 through 7.3.3 shall be conducted with the weld reinforcement in place except for the hold-down areas.

7.3.1 Visual inspection. Weldments shall be evaluated in accordance with MIL-STD-271 and meet visual inspection acceptance criteria in accordance with NAVSEA 0900-LP-003-8000, class 1. Additionally, the weldments shall be checked for flatness. Base plate rotation due to weld metal shrinkage shall not exceed 5 degrees. Maximum joint offset due to fit-up shall not exceed 1/8 inch.

7.3.2 Radiographic inspection (RT). Weldments shall be radiographed in accordance with MIL-STD-271 and meet the acceptance criteria of NAVSEA 0900-LP-003-9000, class 1.

7.3.3 Magnetic particle inspection (MT). Weldments shall be inspected in accordance with MIL-STD-271 and meet the acceptance criteria of NAVSEA 0900-LP-003-8000, class 1.

8. PREPARATION OF TEST ASSEMBLIES FOR EXPLOSION TESTING

8.1 Crack starter specimen preparation. The explosion crack starter test assembly is a modified explosion test specimen on which brittle Murex Hardex N or equivalent crack starter beads have been placed. The deposits may be oriented one of two ways depending on the intent of the test; base metal evaluation (see 8.1.1); or weld metal or weld procedure evaluation (see 8.1.2 and figure 7).

8.1.1 Base metal evaluations. For base metal evaluations incorporating a weld joint, the Hardex N or equivalent weld deposits shall be placed directly on the weld joint parallel to the axis of the weld as specified on figure 7A (plan view). The number of crack starter beads per test specimen used for this orientation will be dependent on weld joint width. Weld joint widths less than 3/4-inch will have one bead deposited, while those in excess of 3/4-inch will require two beads. When applying two beads, the beads shall be an equal distance from the weld centerline and shall be no closer than 1/16-inch from the edge of the weld fusion lines. The Hardex beads shall be 2 to 3 inches long and shall be placed midway between the extremities of the weld joint.

8.1.1.1 Base metal fusion line evaluations. On one test specimen, one crack starter bead shall be placed on the weld joint transverse to the weld axis. The center line of the bead shall be the center line of the plate. The bead shall be 2 to 3 inches long and extend a minimum of 1/4 inch beyond both weld fusion lines (see figure 7C (plan view)). If the weld joint is wider than 2-1/2 inches,

allowance shall be made to increase the bead length to achieve the minimum 1/4-inch extension beyond the weld fusion lines. For 1-inch thick weldments, in which the gauge marks for measuring thickness reduction are specified as 2 inches apart (see figure 4), the crack starter bead shall be 1 to 2 inches long.

8.1.1.2 Base metal evaluations without weld joints. For base metal evaluations using test plates without weld joints, a single Hardex N or equivalent crack starter 2 to 3 inches long shall be placed transverse to the plate or forging primary worked direction at the center of the test specimen (see figure 7B). Cast plate test specimens shall be considered to have no primary working direction.

8.1.2 Weld metal and weld procedure evaluations. For crack starter evaluation of weld metal or weld procedures, including weld metal, weld fusion zone and base metal heat-affected zone. A single Hardex N or equivalent weld deposit shall be placed directly on the weld joint transverse to the axis of the weld at the plate centerline intersection as specified on figure 7C (plan view). The Hardex bead shall be 2 to 3 inches long and extend 1/4 inch beyond both weld fusion lines. Where the weld joint is wider than 2-1/2 inches, allowance shall be made to increase the bead length to achieve the minimum 1/4-inch extension beyond the weld fusion lines. This will require increasing the distance from the weld centerline to the reduction of thickness point of measurement. This distance is normally standardized at 1-1/2 inches from the weld centerline for 2-inch thick weldments and 1 inch from the weld centerline for 1-inch thick weldments.

8.1.3 Crack starter bead application. The Government laboratory authorized to perform the testing shall be responsible for the crack starter bead application. The required welding parameters are as follows:

(a)	Process:	Shielded metal arc, direct current, reverse polarity (DCRP)
(b)	Electrode:	3/16-inch diameter
(c)	Position:	Flat, down hand
(d)	Welding current and voltage:	180-190 amps; 22-23 volts
(e)	Travel speed:	4.5 - 5.0 inches per minute

Welding shall be performed using a stringer bead technique. Bead width shall not exceed 5/8 inch. Welding progression shall be as specified on figure 7. Before breaking the arc, back-fill the crater to assure adequate weld metal for grinding of the crack starter notch.

8.1.4 Notching the Hardex N or equivalent weld bead. Final preparation of the "standard" Hardex N or equivalent bead shall consist of notching the bead as specified on figure 7. Notch mid-length of crack starter (CS) weld for CS bead parallel to butt welds or for base metal CS test. For weld metal and welding procedure evaluations with CS bead placement transverse to butt weld, notch the CS bead in three locations; that is, over each butt weld fusion line and at the center. For base metal evaluations incorporating a transverse CS bead in a welded joint, only notches over the welded fusion lines shall be made. Notching may be accomplished with a thin 1-inch diameter abrasive disc on a flexible shaft machine. Notches (see figure 7) shall be cut normal to the surface of the

specimen and across the full width of the CS bead to a depth such that 0.070 to 0.100 inch remains between the bottom of the notch and the surface of the underlying weldment or plate to be tested. The notch shall not be cut into either the underlying weld joint or base plate.

8.2 Explosion bulge preparation. Explosion bulge test assemblies shall be prepared in accordance with figure 4 and the fabrication and inspection parameters outlined in section 7.

8.3 Explosion tear test specimen. Explosion tear test assemblies shall be prepared in accordance with figure 5 employing the fabrication and inspection parameters outlined in section 7. To date, principally 1-inch thick tear test weldments have been tested. For this reason the dimensions for a 1-inch test assembly are illustrated.

8.4 Grinding for die fit and drilling thermocouple holes. Test assembly types listed above shall be prepared for die fit. Because of weld reinforcement, or possible unusual test specimen irregularities, preparation of the test assembly shall consist of grinding the weld reinforcement flush for approximately 6 inches in from the assembly edges (see figure 4). Explosion tear test assemblies shall be ground from the test assembly edges to the slots. Additionally, to facilitate temperature monitoring of the explosion test specimen, both while normalizing in the cooling medium and when setting on the explosion test die, thermocouple holes shall be drilled in the edges of each explosion test specimen. The holes shall be approximately 1/8 inch in diameter by 1 inch deep located at the specimen edge, that is, thickness centerline, a minimum of 1 inch away from any corner of the plate.

9. MECHANICAL AND EXPLOSION TESTING

9.1 Mechanical test assembly requirements. The requirements for obtaining the mechanical specimens, as specified on figure 2, from the prolongations to the explosion crack starter weldments shall be in accordance with 9.1.1 through 9.1.4. Specimens shall be taken for conformance testing to the requirements of the Military specification that initiated the explosion testing.

9.1.1 Tensile test specimens. Weld metal tensile specimens shall be the 0.505 inch diameter size when permitted by the weld joint configuration and base material thickness; otherwise, they shall be the maximum size possible. Two-inch thick test weldments will have both base material and weld metal thickness to permit the removal of two type R-1, 0.505-inch diameter tensile specimens. Tensile specimens shall be prepared and tested in accordance with AWS B4.0

9.1.2 Charpy V-notch specimens. Charpy V-notch (CVN) specimens shall be taken so that the surface of the specimen nearest the surface of the test assembly is 3/16 to 5/16 inch from the test assembly surface. The specimens shall be notched as specified on figure 2. For the weld metal specimens, light chemical etching of the specimen is recommended to locate the notch within the weld metal. The CVN specimens shall be machined and tested in accordance with AWS B4.0.

9.1.3 Dynamic tear test specimens. Standard 5/8 inch dynamic tear (DT) specimens shall be machined and tested in accordance with ASTM E 604. Specimens shall be taken so that the surface of the specimen nearest the surface of the test assembly is 3/16 to 5/16 inch from the test assembly surface. The DT specimens shall be notched as specified on figure 2. For the weld metal specimens, light chemical etching of the specimen is recommended to locate the notch within the weld metal.

9.1.4 Bend specimens. Transverse full section side bends, when required, shall be removed from weldments and shall be prepared and tested in accordance with AWS B4.0.

9.2 Explosion test assembly requirements. The type of explosion test and number of test specimens shall be as specified in the applicable material specification. The acceptance criteria for the explosion tear test shall be as specified in the applicable material specification. The acceptance criteria for the explosion crack starter and bulge tests shall be as specified in table I and the applicable material specification.

9.2.1 Explosion crack starter testing. The crack starter specimens are tested prior to the explosion bulge specimens. Two explosive loadings (shots) shall be detonated, unless the specimen fails to meet the requirements of table I on the first shot.

9.2.2 Explosion bulge testing. The explosion bulge specimens require the application of repeated explosive loadings to assess the critical regions of the weldment under high strain rate loading. The explosion bulge test specimens shall be tested by repeated explosive shots until failure occurs or until the minimum reduction in thickness required by the material specification is met. The reduction in thickness shall be measured at the locations specified on figure 4 by the methods shown on figure 8.

TABLE I. Explosion test acceptance criteria.

	Crack starter test		Bulge test		
	First shot	Second shot	First shot	Second shot	Additional shots
Crack-starter bead shall crack	x	1/	N/A	N/A	N/A
No piece shall be thrown out of material being tested	x	x	x	x	x
No through thickness cracks shall be present	x	N/R	x	x	N/R

TABLE I. Explosion test acceptance criteria - Continued.

	Crack starter test		Bulge test		
	First shot	Second shot	First shot	Second shot	Additional shots
No cracks shall extend into the hold-down area	x	x	x	x	x
Percent reduction in thickness	2/	2/	2/	2/	3/

Conditions required for each shot are marked with an "x".
N/R = not required.

1/ In the event the crack-starter bead does not crack on the first shot, the first shot shall be repeated.
2/ The percent reduction in thickness shall be recorded for information only.
3/ The required percent reduction in thickness shall be as specified in the applicable material specification. Shots shall be discontinued when the metal fails to meet the above conditions, or when the reduction in thickness requirements are met.

9.2.2.1 No tests. When testing plate properties, failures confined to the weld metal shall be considered no test. When testing weld metal properties, failures through the plate shall be considered no test. In both cases retest may be required on additional specimens dependent on the results of an engineering analysis of the failure, or failure mode, or both.

9.3 Explosion test procedure. Explosion test specimens shall be subjected to the following as specified in 9.3.1 through 9.3.6.

9.3.1 Refrigeration of test specimens. The test specimens shall be cooled (refrigerated) to a temperature below the required test temperature so that any heat gain during handling will not cause the test temperature to be exceeded. Any refrigeration equipment attaining and maintaining the test temperature in the samples is acceptable. Experience has shown the use of a liquid nitrogen or dry ice cooled alcohol medium to be a relatively inexpensive and extremely efficient method of cooling test specimens. An advantage to this type of cooling system is that there is no need for electrical power. Where circulated air cooling medium cold boxes are employed, a mechanical refrigeration cold box with a propeller type air circulator is superior to the dry ice type equipped with a squirrel cage centrifugal type circulator.

9.3.1.1 Establishment of test assembly cooling requirements. When employing refrigeration to cool test specimens, it will normally be necessary to refrigerate to a level below the testing temperature to compensate for heat gain during handling. Rate of heat gain is a function of plate thickness, ambient

temperature, and the time lapse between removal from the cooling medium and detonating the explosive. The degree of undercooling employed shall be determined by making use of "control" plates to develop supporting test data that establish the required amount of undercooling. Supporting test data shall include continuous strip chart temperature recordings showing explosion test assembly temperature rise as a function of time from removal from cooling medium through placement on the test die, and reaching final test temperature. Temperature data shall be obtained from at least three thermocouples, one of which is located in mid-thickness at the center of the test assembly.

9.3.1.2 Cooling procedure. Test specimens in the cooling medium shall be allowed to normalize in temperature through thickness. The time required shall be based on specimen thickness. The minimum time shall be 1 hour per inch of thickness. Deviation from this procedure to shorten the test specimen conditioning time shall be supported by data which shall be approved by NAVSEA. Plate temperature monitoring, while in the cooling medium, shall be by thermocouples imbedded in the plate edges. Preliminary testing shall be used to establish the correlation between plate edge temperature and plate center mid-thickness temperature. To further ensure proper thermal control from cooling medium to explosive loading, the test plate shall incorporate thermocouple monitoring.

9.3.2 Setting the explosion test specimen and detonation of explosive charge. On completion of test specimen thermal conditioning, the specimen shall be placed on the die (see figure 9) with the ground hold-down surfaces contacting the die. The explosive charge shall be centered over the specimen with the proper standoff distance (see figure 9). The standoff distances for explosion bulge type tests for all materials, except HY-130, shall be 15 (minus 0, plus 1) inches. The standoff distance for HY-130 shall be 17 (plus or minus 1/2) inches. The blasting cap may be placed on or in the explosive charge using the following method:

Placed no deeper than 3/4 inch into a predrilled or precast 0.300-inch diameter hole located in the top center of the explosive charge.

9.3.3 Explosive types. Historically, composition C3 and C4 explosive was replaced by 50 and 50 pentolite. Fifty and 50 pentolite explosive is a combination of 50 percent PETN and 50 percent TNT. Now that pentolite, once readily available and inexpensive, is becoming increasingly difficult to acquire, other explosives may be utilized. Before their use the following conditions shall be met:

(a) Develop or cite data that shows that the candidate substitute is similar in burning rate and explosive force.
(b) Demonstrate through comparative testing that the candidate explosive produces similar results when used in explosion testing equivalent test plate blanks, and
(c) Submit to NAVSEA for approval and retain the supporting data on file in an engineering technical report form.

9.3.4 Explosive charge weight selection. For explosion bulge testing, charge weights and standoff distances shall be selected to achieve an approximate 3 percent reduction in test specimen thickness (near the center, see 9.2.2) for each shot. The following pentolite charge sizes shall be used for the following materials and thicknesses:

Material	Nominal thickness (inches)	Nominal charge size (inches)	Nominal pentolite charge weight (pounds)
HY-130	2	10 diameter by 10 height	42
HY-100	2	10 diameter by 7.3 height	30
HY-80	2	10 diameter by 6 height	24
HY-80	1	7 diameter by 3.5 height	7

Other testing shall have either the type and charge weight, or the expected surface strain, rate, and reduction in thickness specified for each shot. When charge size and weight is not specified, test work will be conducted to establish required explosion charge size and standoff distance to achieve the required surface strain and reduction in thickness for each explosive loading (shot). For explosion tear testing, where the specimen over the explosion die cavity is required to be uniformly loaded, flat sheet explosive such as DETA sheet has been found to be an effective explosive.

9.3.5 Crack description. After each shot the test specimen shall be examined, and the location, length and direction of all cracks recorded both by a written and sketch description (see figure 10). The Explosion Testing Record Form shown on figure 11 shall be completed following each explosion test. Depending on the type of test being conducted, either reduction in thickness measurements or surface strain measurements shall also be recorded. Unless otherwise specified, measurements of plate thickness reductions shall be taken at the locations identified for measurements (see 10.3 and figures 4 and 8).

9.3.5.1 Reduction in thickness measuring devices. Figure 8 shows two methods of measuring the reduction in thickness of the test specimen. The deep throat caliper shall be maintained in accordance with MIL-STD-45662. The ultrasonic gauging equipment shall meet the qualification requirements of MIL-STD-271. The ultrasonic gauging equipment shall be calibrated with two blocks (minimum) of known thickness (plus or minus 0.001 inch) and of the same nominal composition and condition as the plate to be gauged. One block shall be above the maximum thickness to be measured and one shall be below the minimum thickness to be measured. The minimum precision of the ultrasonic readings shall be 0.005 inch. Regardless of the method used by the authorized Government laboratory, the basis for selection shall be justified by demonstrating its accuracy over the full range of expected test assembly configuration (measurements on actual bulged test specimens). This information shall be documented and made available to NAVSEA on request (see 10.3).

accordance with MIL-STD-271 and meet the acceptance criteria of NAVSEA

9.3.6 Successive explosive loadings. Before each successive shot, the test specimen shall be returned to the cooling medium long enough to thermally recondition the test specimen to obtain the required temperature and equilibrate as specified in 9.3.1.2. Succeeding shots shall be fired using the same sequence described above and the results recorded. The number of shots required shall be that necessary to obtain the required surface strain minimum or percent reduction in thickness minimum (based on average of both measuring locations) specified in the applicable material specification. If failure occurs as specified in table I before obtaining the required reduction in thickness, testing shall be terminated on the involved test specimen.

10. NOTES

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

10.1 Intended use. This standard covers explosion testing used to evaluate ferrous and nonferrous base materials, plates, castings, forgings, welding filler materials and welding procedures as required by applicable purchase specifications or fabrication documents.

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

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

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
9.3.5, 9.3.5.1, and appendix A	DI-MISC-80653	Test reports	-----

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

10.4 Other crack starter geometries. Other crack starter geometries have been successfully employed besides the Hardex N type detailed herein. Some examples are:

(a) Electron beam welded crack starter beads embrittled by introducing aluminum in titanium explosion tear test specimens.

(b) Hardex N or equivalent deposited weld metal in a test specimen groove and mechanically notched lengthwise with respect to the embrittled deposit, and
(c) Fatigue cracks introduced into test specimens.

The above methods are considered special applications and, if required to be used for crack initiation, the details of the type will be provided by NAVSEA.

10.5 Subject term (key word) listing.

Bead, crack starter
Prolongation
Test, bulge
Test, tear

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

Preparing activity:
Navy - SH
(Project THJM-N267)

APPENDIX

TEST REPORT TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers the technical requirements that should be included in test reports when required by the contract or order. This appendix is mandatory only when data item description DI-MISC-80653 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. TEST REPORTS

30.1 Test reports. When required by the contract or order, test reports shall contain the results of the mechanical and explosion tests in an engineering technical report format and shall include an analysis of the test results. Where test failures occur, the report analysis shall address the cause for failure. The report text shall be supplemented by photographs, sketches, and other illustrations to assist in defining clearly the tests conducted, and the results obtained (see 10.3).

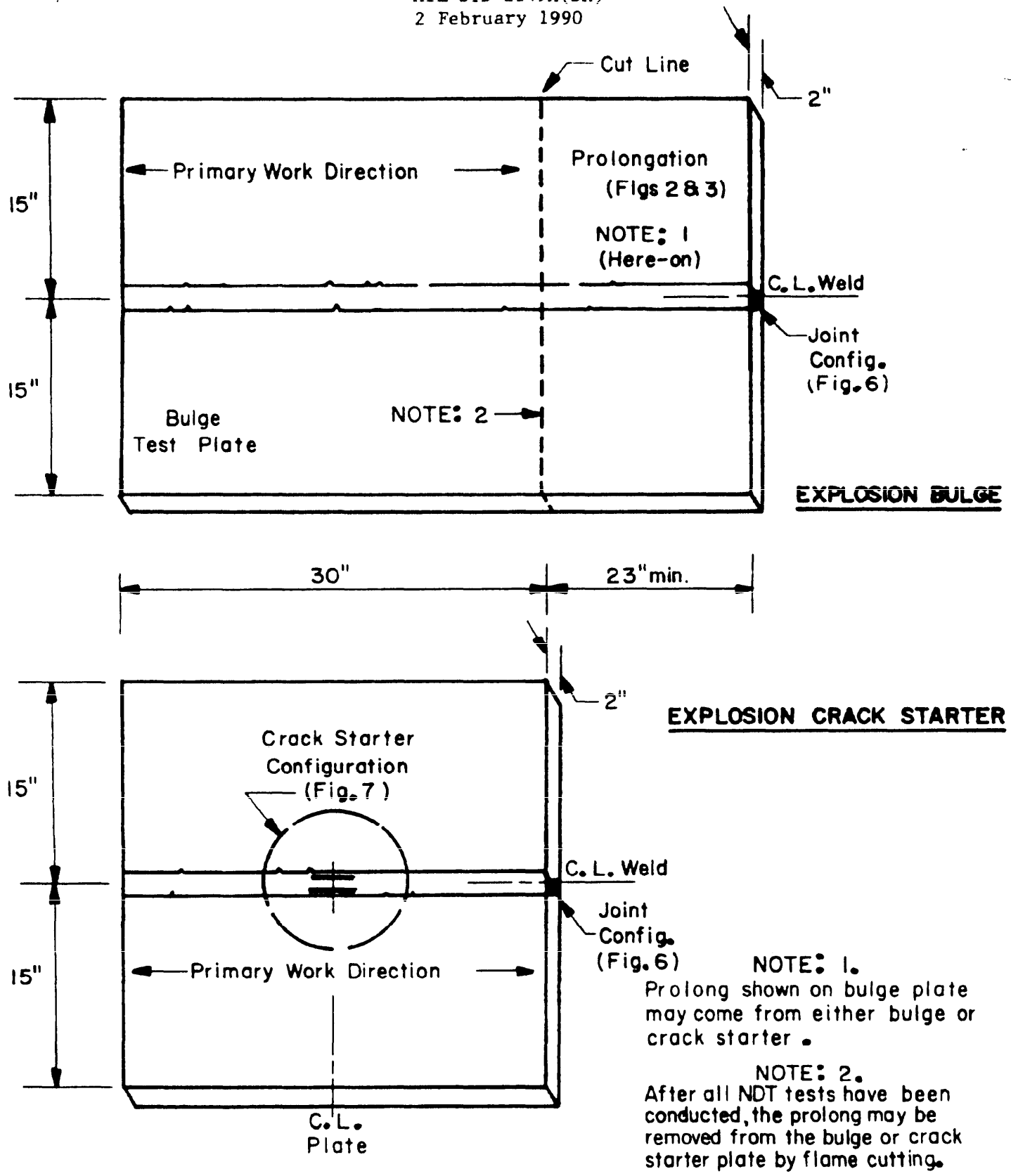
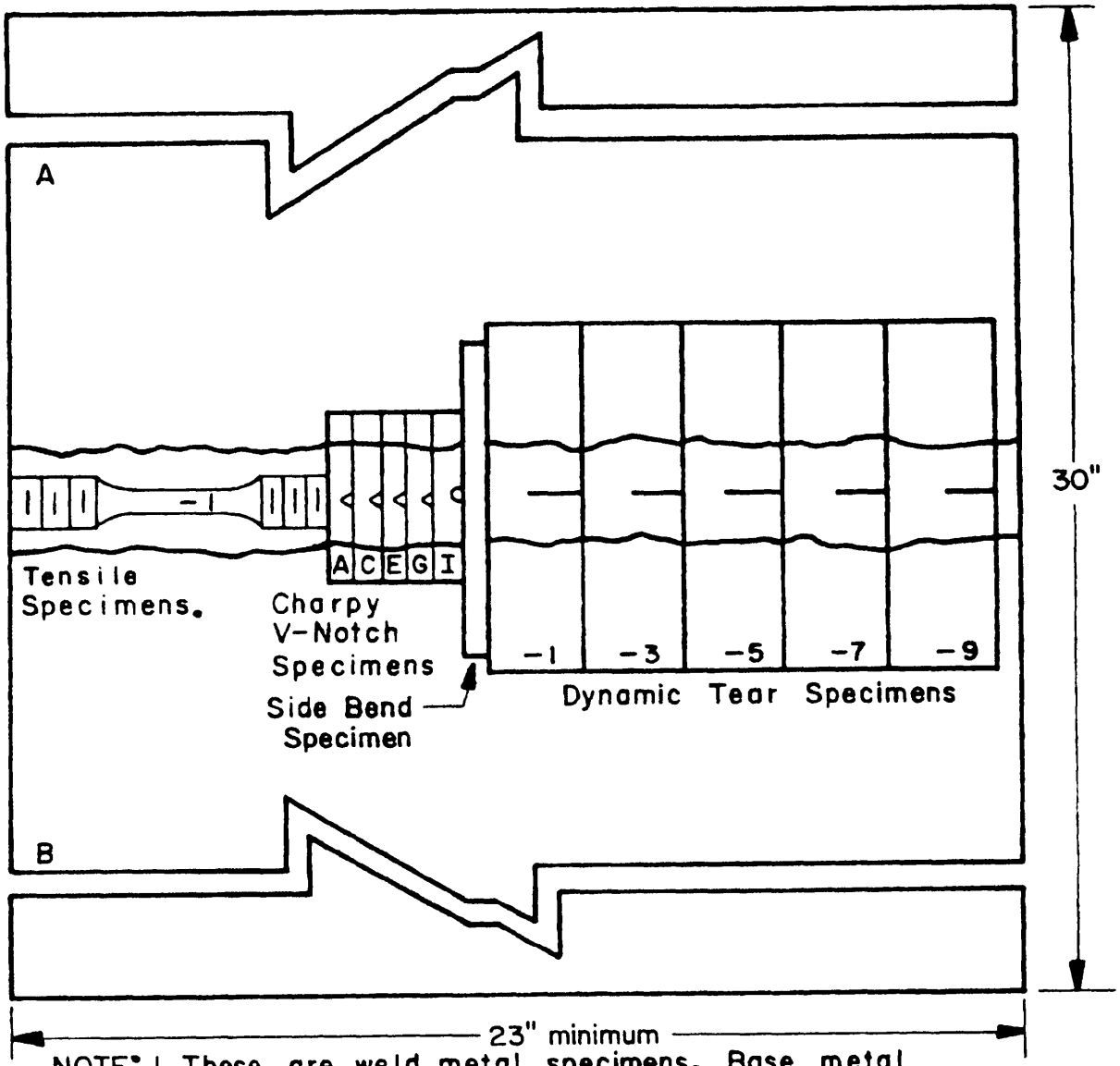
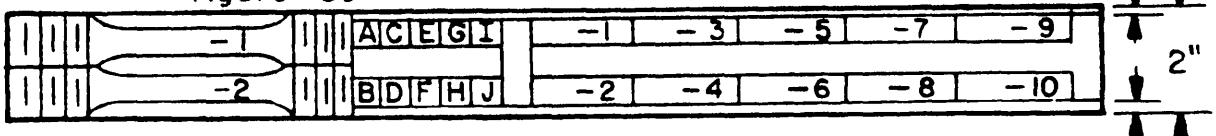


FIGURE 1. Explosion test specimen configuration.

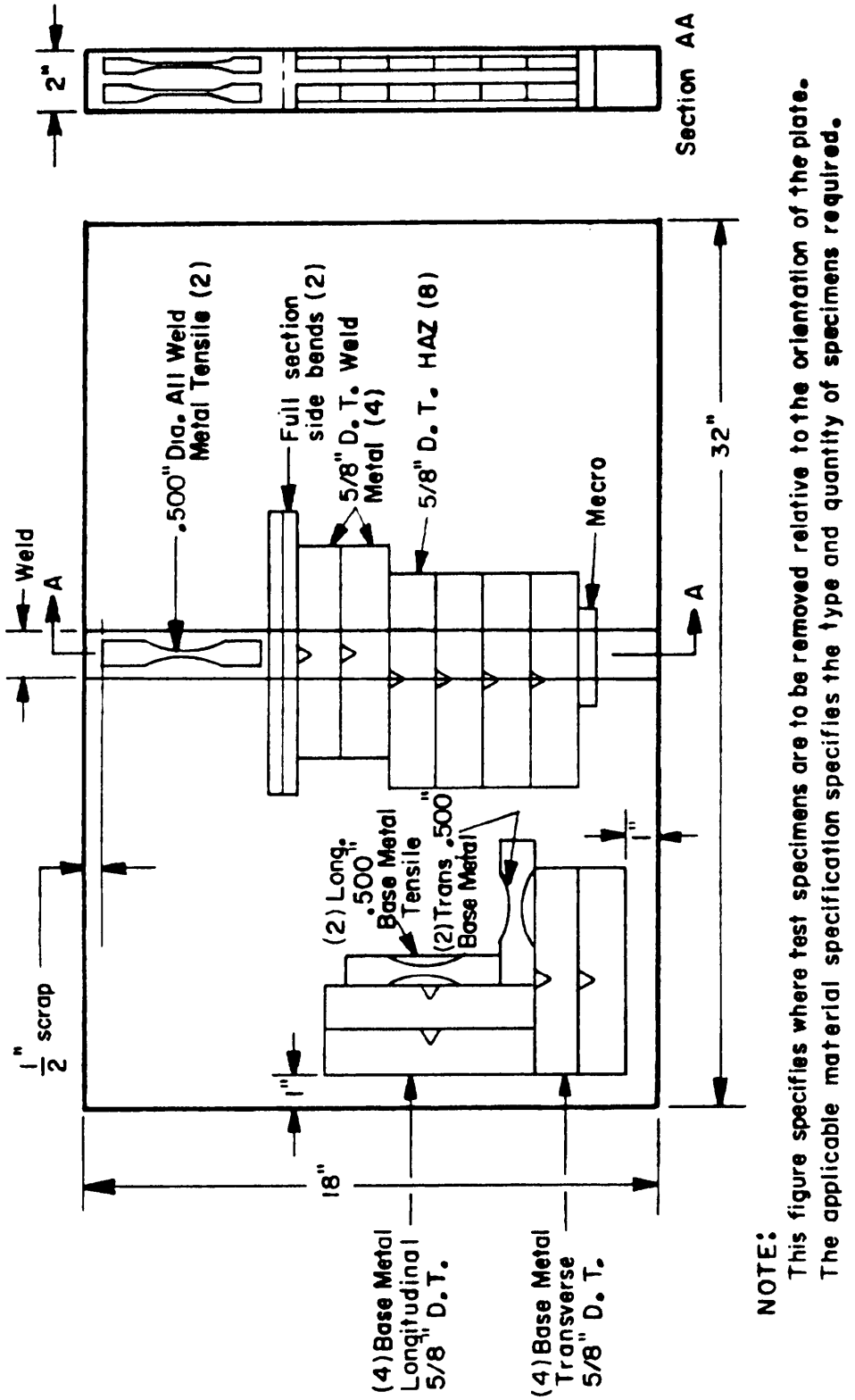


NOTE: 1. These are weld metal specimens. Base metal specimens are taken in accordance with the base metal specification that initiated explosion testing or figure 3.



NOTE: 2. Flame cutting may be used along the ends of the specimens but no closer than 1/2" to the weld metal along the side of the tensile specimen. The test specimens shall be separated by sawing and finished by sawing or machining.

FIGURE 2. Diagram of a typical mechanical specimen removal orientation.



NOTE:
This figure specifies where test specimens are to be removed relative to the orientation of the plate.
The applicable material specification specifies the type and quantity of specimens required.

FIGURE 3. Prolongation mechanical property specimen layout for preproduction qualification testing.

Dimensions (inches)

Plate thickness	Weldment size C	Grind flush D	Bulge region E	Punch marks F
1	20	5	15	1
2	30	6	25	1 1/2

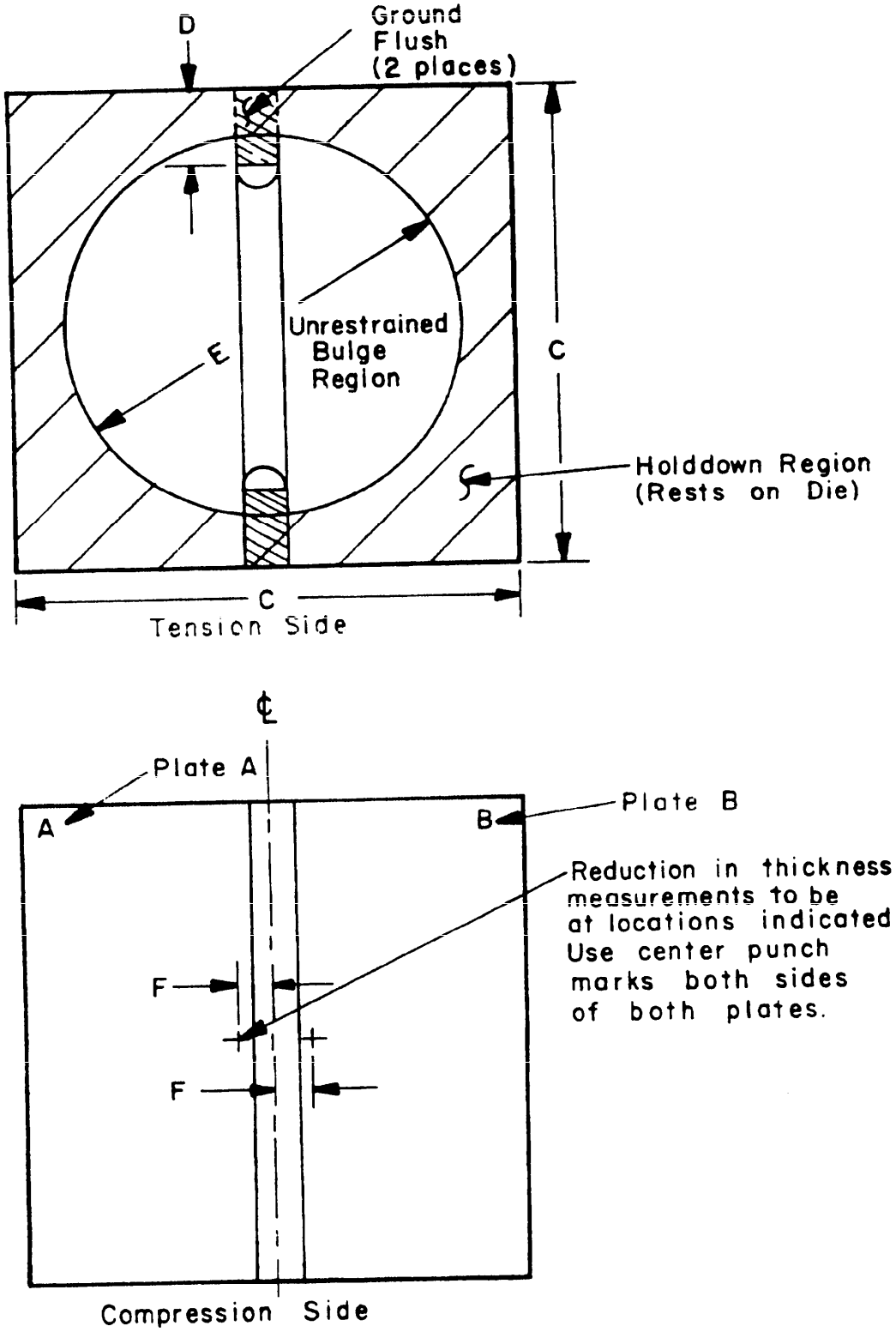


FIGURE 4. Explosion test plate preparation.

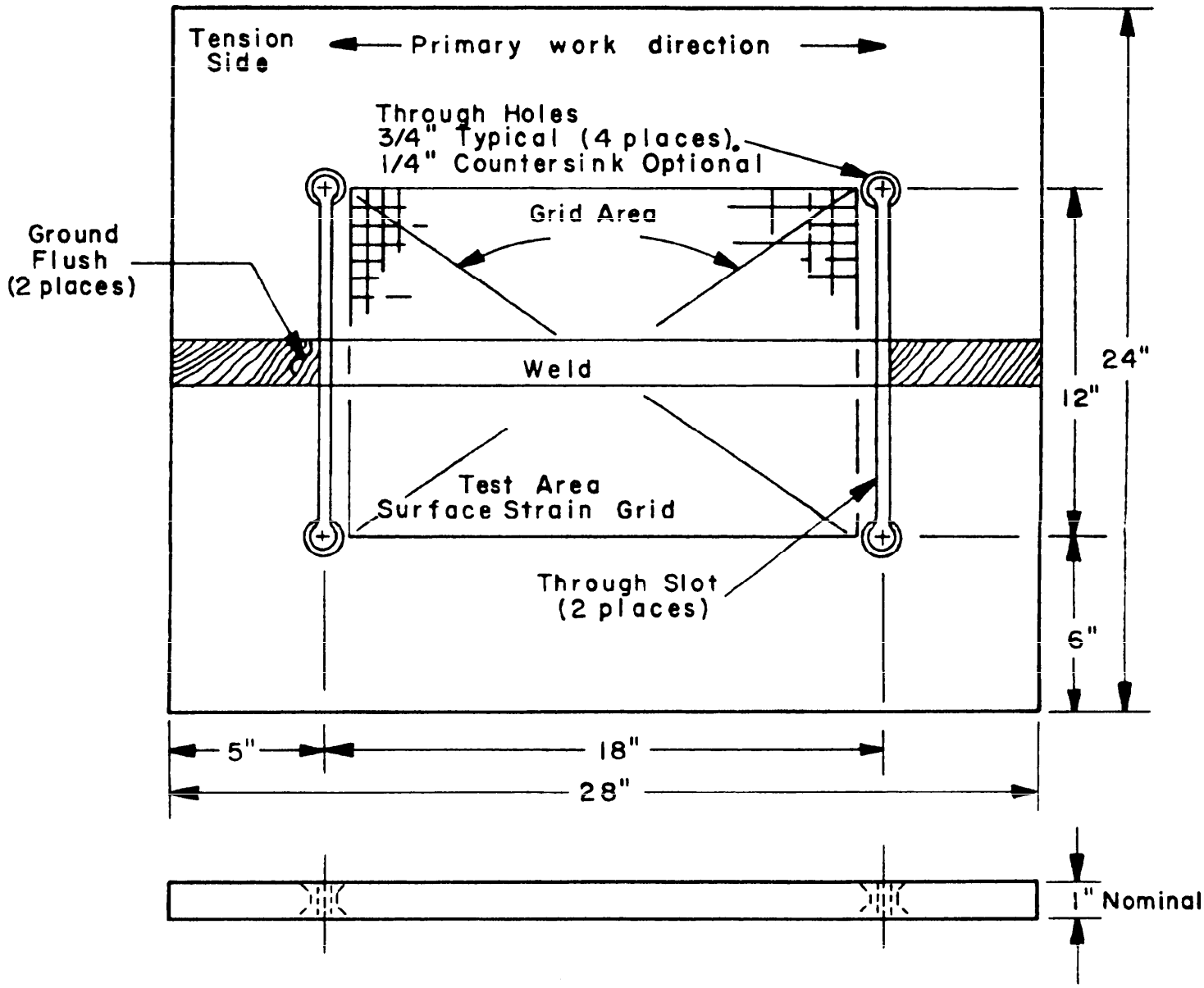


FIGURE 5. Explosion tear test weldment.

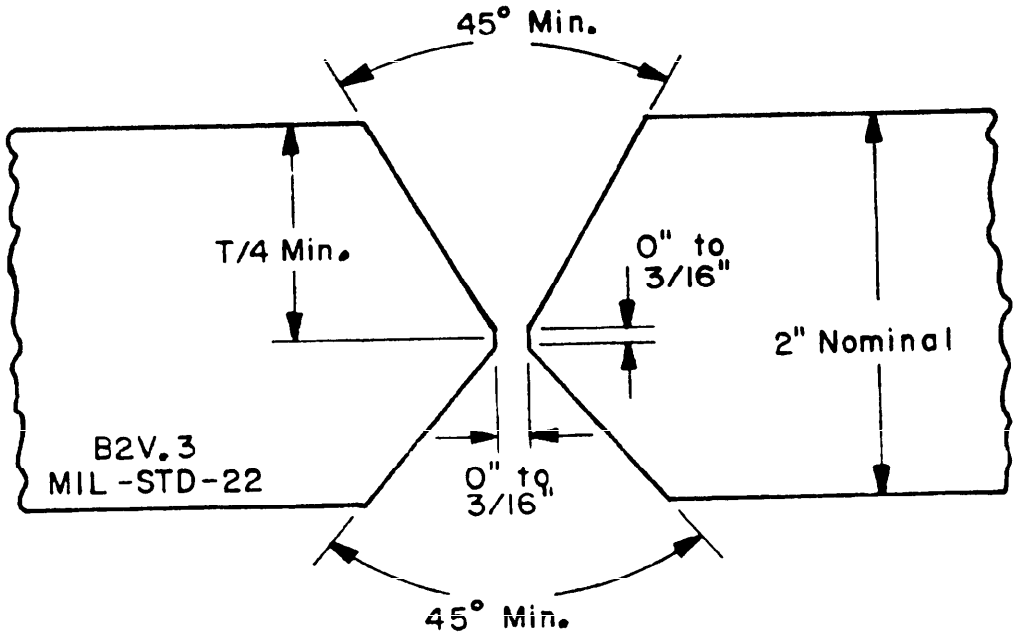


FIGURE 6. Typical joint configurations for explosion test weldments.

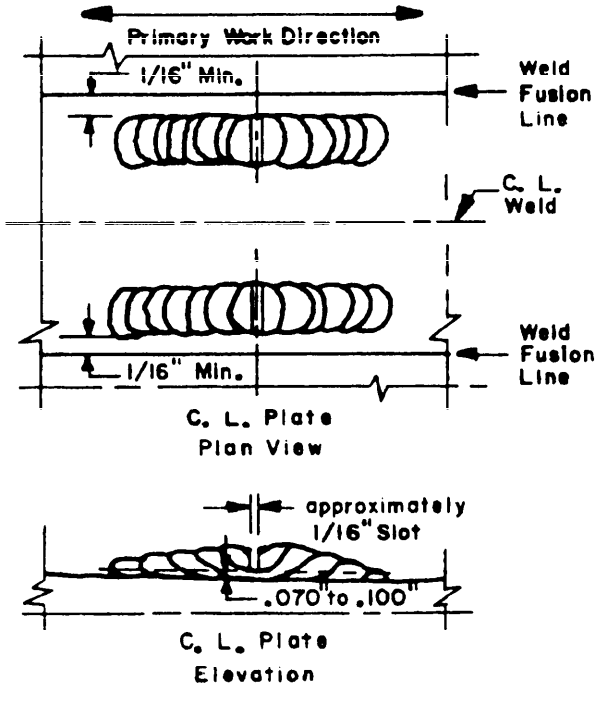


FIG. 7A Base Metal Evaluation.

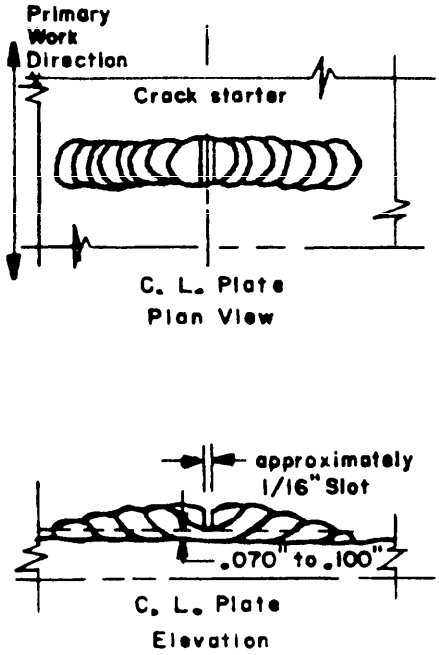
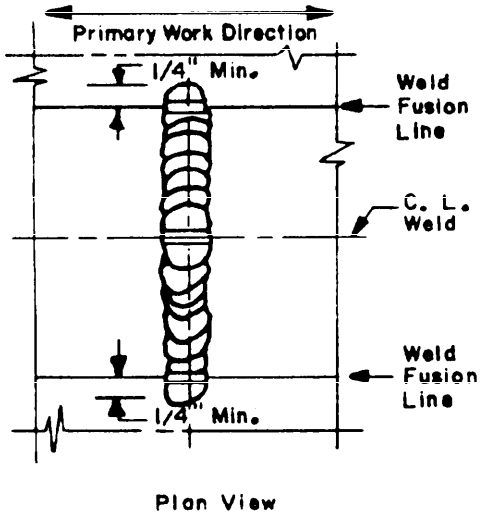
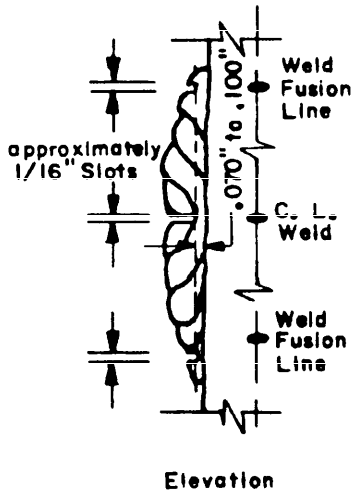


FIG. 7B Base Metal Evaluation Without a Weld Joint.





NOTE: The mid-length notch is not required for base metal fusion line evaluations.

FIG. 7C Weld Metal and Weld Procedure Evaluation; and Base Metal Fusion Line Evaluation # (see note).

FIGURE 7. Crack starter bead configurations.

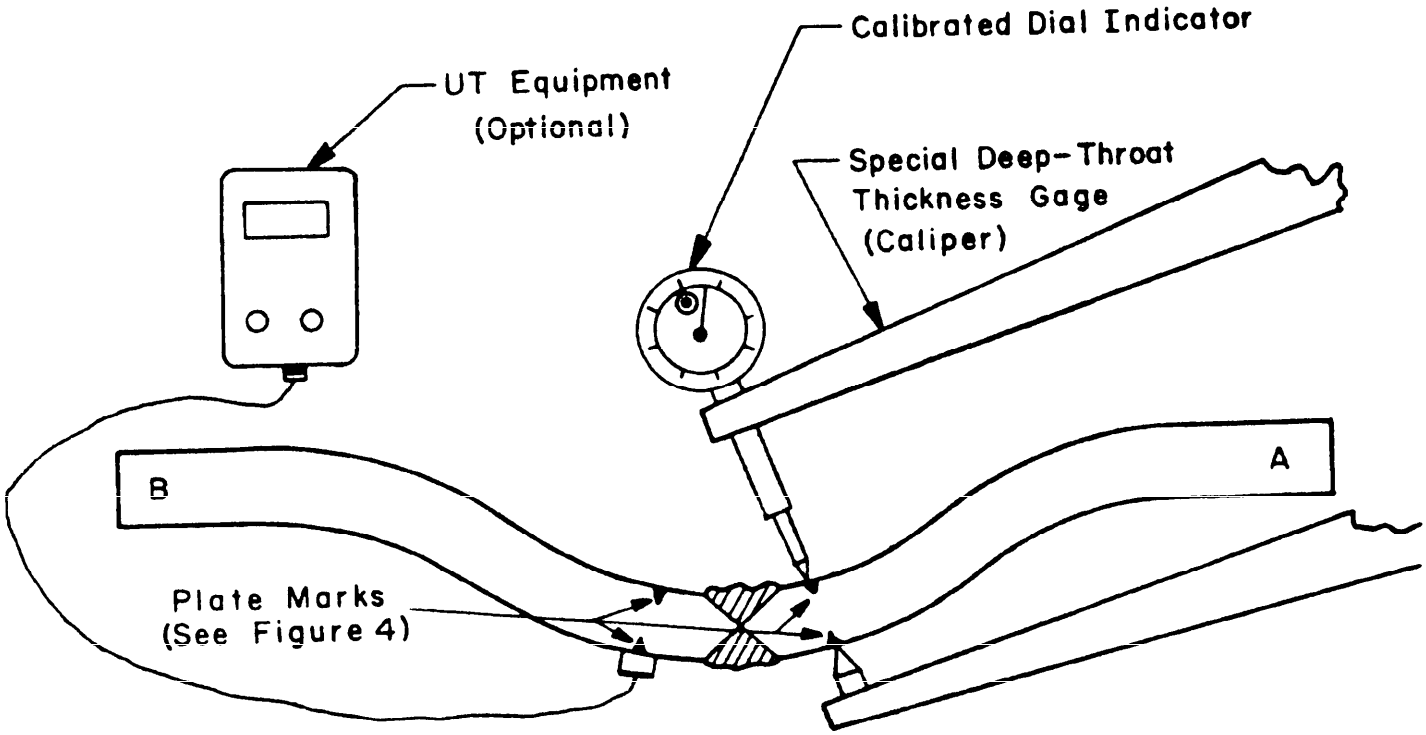


FIGURE 8. Explosion test measurements.

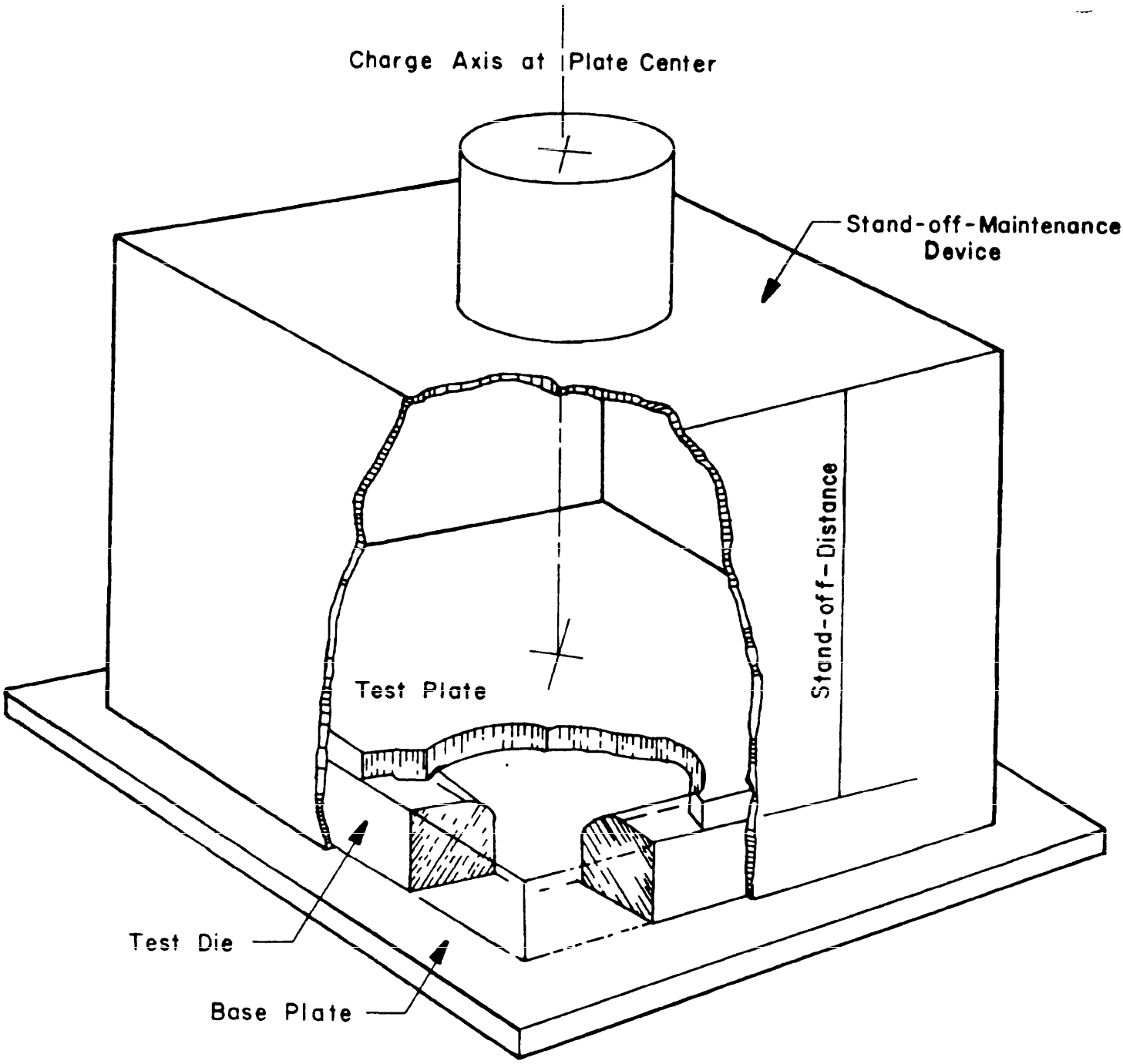


FIGURE 9. Explosion test configuration.

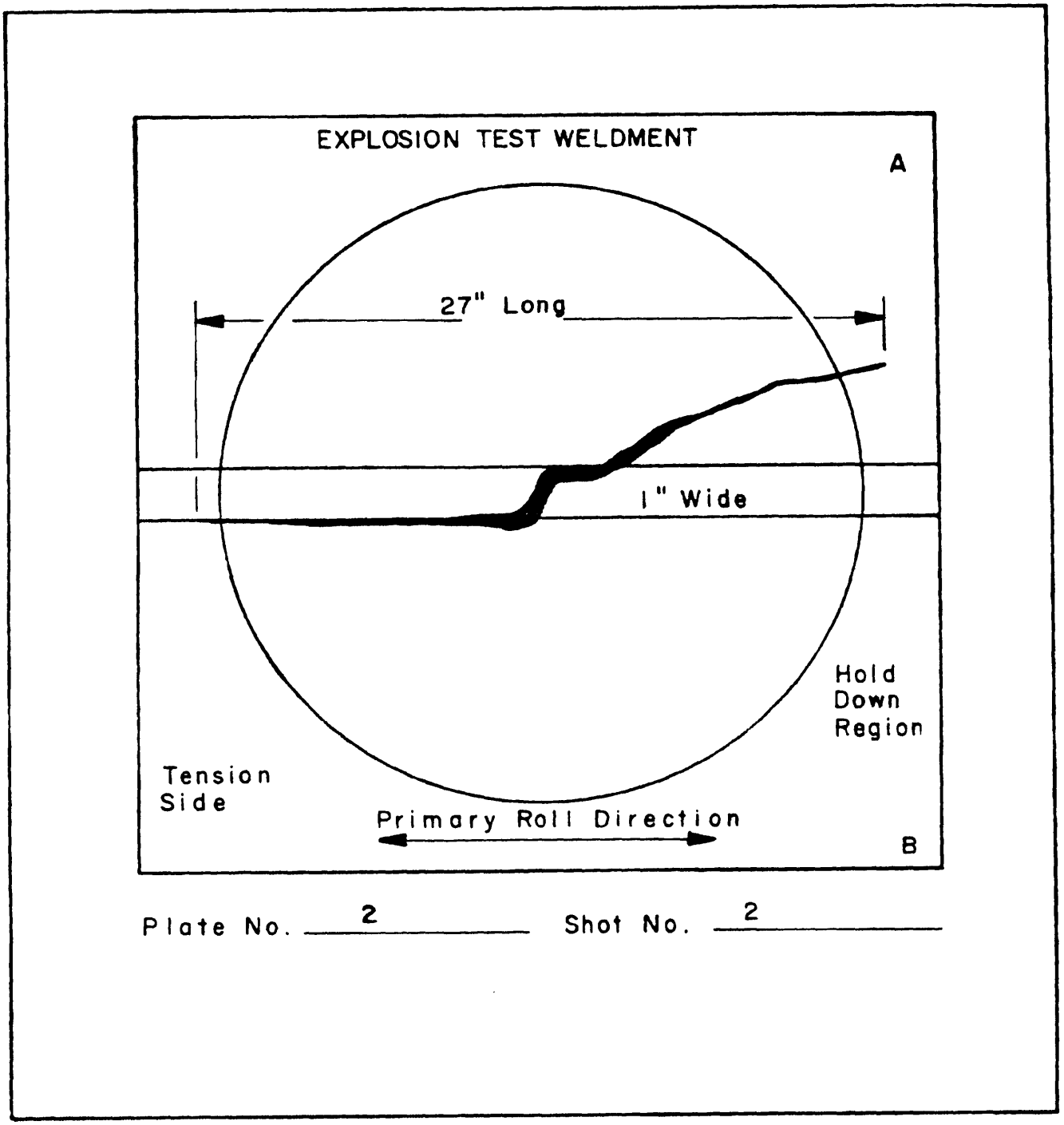


FIGURE 10. Typical fracture sketch of explosion test weldment.

EXPLOSION TESTING RECORD

DATE:

PLATE IDENTIFICATION NO. :	PROCESS:	ELECTRODE TYPE AND SIZE:	☐ CRACK STARTER ☐ EXPLOSION BULGE
STAND-OFF DISTANCE:	COOLING MEDIUM:	TEST TEMPERATURE AND % REDUCTION SPECIFIED:	
PLATE SIDE IN TENSION:	PLATE THICKNESS PRIOR TO SHOT: "A" _____ "B" _____		

SHOT NO.	DATE	NORMALIZING			EXPLOSIVE CHARGE TYPE, SIZE, AND WEIGHT	BATH TO SHOT				THICKNESS		% OF REDUCTION		REMARKS
		START TIME	EXIT TIME	TOTAL TIME		AMB TEMP	EXIT TEMP	SHOT TEMP	TOTAL TIME	A	B	A	B	
1														
2														
3														
4														
5														
6														
7														
8														

NOTES:

FIGURE 11. Sample explosion testing record.

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-STD-2149A(SH)	STANDARD PROCEDURES FOR EXPLOSION TESTING FERROUS AND NON-FERROUS METALLIC MATERIALS AND WELDMENTS

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR
b. ADDRESS *(Street, City, State, ZIP Code)*	☐ USER
	☐ MANUFACTURER
	☐ 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	8. DATE OF SUBMISSION *(YYMMDD)*

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