財團法人驗船中心
CR CLASSIFICATION SOCIETY

GUIDELINES FOR APPROVAL OF CRHS-56/70 HIGH STRENGTH LOW ALLOY STEEL FOR CRITICAL APPLICATION

CR CLASSIFICATION SOCIETY

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The Society may revise the Guidelines as necessary to reflect technological developments.

GUIDELINES FOR APPROVAL OF CRHS-56/70 HIGH STRENGTH LOW ALLOY STEEL FOR CRITICAL APPLICATION

CONTENTS

CHAPTER 1 GENERAL

1.1 Scope

1.1.1 The Guidelines for Approval of CRHS-56/70 Low Alloy Steel for Critical Application (hereinafter referred to as the Guidelines) published by CR Classification Society (hereinafter referred to as the Society) include the requirements of CRHS-56 and CRHS-70 (high yield strength, age-hardening alloy steel plate, sheet, and coil) specified in Chapter 2, the requirements of bare welding electrodes and fluxes, covered welding electrodes, and flux-cored welding electrodes for CRHS steels applications specified in Chapter 3, the requirements of welding procedure for CRHS steels applications specified in Chapter 4, and the explosion testing used to evaluate base materials, welding materials and welding procedures specified in Appendix 1.

1.1.2 For high strength low alloy steels for critical application having characteristics or specifications differing from the requirements in the Guidelines, special consideration may be given by the Society.

1.2 Works Approval

1.2.1 CRHS steels or welding materials for CRHS steels shall be made at works which have been approved by the Society. In order that works can be considered for approval, the Manufacturer is required to demonstrate to the satisfaction of the Society that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

1.2.2 A specified procedure of approval of works generally consists of document review, on-site audit and approval test. In addition to the reqirements in applicable chapter of the Guidelines, the works shall also comply with "Guidelines for Survey of Products for Marine Use" of the Society for works approval when specified.

CHAPTER 2 CRHS-56/70 STEEL PLATE, SHEET, OR COIL

2.1 General

2.1.1 Scope

This chapter covers CRHS-56 and CRHS-70 high yield strength, age-hardening alloy steel plate, sheet, and coil intended primarily for approved uses in critical structural applications where notch-tough, high-strength materials are required. The requirements of this chapter apply to CRHS-56 up to and including 56 mm thick and CRHS-70 up to 152 mm thick.

2.1.2 Access to works

The CRHS steel manufacturer (hereinafter referred to as the Manufacturer) is to allow the surveyor of the Society (hereinafter referred to as the Surveyor) access to all relevant parts of the works and are to afford the Surveyor all necessary facilities and information to enable him to verify the approved procedure of manufacturing and selection of test samples, the witnessing of mechanical tests and the examinations of materials as required in this chapter .

2.1.3 Material information

Prior to the submission of materials for inspection and acceptance, the Manufacturer is to provide the surveyor with details of the order (eg., purchase order), specification and any special conditions additional to the requirements of this chapter. The tests and the examinations are to be carried out before the materials are dispatched from the Manufacturer's works. The results of the tests and the examnations are to comply with this chapter, and all materials are to be to the satisfaction of the surveyor before final acceptance.

2.1.4 In the event of any material proven unsatisfactory in the process of being worked, machined or fabricated subsequently, such material is to be rejected or retested notwithstanding any previous certification.

2.2 Definitions

2.2.1 Works approval

Works approval is required to the Manufacturer by the Society to assure the quality of the product which is manufactured by means of batch production in a continuous process, especially when the product quality is completely based on production technology and process.

2.2.2 Process control plan

Process control plan shall document the manufacturing process control procedures/documents used in the production of the first article product. All processing on material offered for acceptance in conformance with this chapter shall be the same as that performed on material submitted for works approval testing as documented in the process control plan with any amendments/revisions as specifically allowed as specified herein.

2.2.3 Change control plan

Change control plan specifies the criteria and plan to verify the acceptability of any change in the critical processing procedures as listed in the Process Control Plan

2.2.4 Production lot verification

Production lot verification means the process to verify the conformance of production lots to the requirements of this chapter.

2.2.5 A lot

In production lot verification of production lots , a lot is defined as follows:

(a) For chemical analysis
  (i) ingot cast, each heat;
  (ii) continuous cast, each ladle;
  (iii) VAR or ESR (vacuum arc or electroslag remelt), each remelted ingot; and
  (iv) AOD (argon-oxygen decarburization), each vessel charge.

  Note: Unless multiple ladle continuous casting was qualified by works approval testing, continuous casting shall cease after one ladle of steel is completely cast.

(b) For tension tests
  Each plate, sheet, or coil as-heat-treated shall constitute a lot.

(c) For impact tests
  Each plate, sheet, or coil as-heat-treated shall constitute a lot.

(d) For examination
  For purposes of visual and dimensional examination and for nondestructive inspection, each plate, sheet, or coil prepared for final inspection shall constitute a lot.

2.2.6 Heat treatment

Any of the following processes: homogenization/normalization, austenitization, quenching (in any medium), tempering, precipitation hardening, stress relief, and hydrogen soak.

2.2.7 As rolled condition

As rolled condition means that the material is not heat treated after rolling.

2.2.8 Purchase order

A purchase order herein means a document issued by a buyer (e.g., a shipyard) to a seller (e.g., the Manufacturer) indicating product type, grade, and other details of specification or requirements. It is used to control the purchasing of products which shall meet the needs and specification from a seller.

2.2.9 Final rolling direction

For plate, sheet, or coil, final rolling direction is the direction of rolling in which the greatest reduction ratio was achieved.

2.3 Works Approval

2.3.1 General

CRHS steels are to be made at works which have been approved by the Society. In order that works can be considered for approval, the Manufacturer is required to demonstrate to the satisfaction of the Society that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. When the Manufacturer has more than one work or foundry, the approval is only valid for the individual work or foundry for which the assessment procedure has been carried out.

2.3.2 Steel producer

When steel is not produced at the works at which it is rolled, a certificate is to be supplied to the Surveyor by the Manufacturer stating the name of the steel producer, the process of manufacture, the cast number and the chemical composition of ladle samples, and the steel producer is also to have works approval issued by the Society.

2.3.3 Works approval requirements

A specified procedure of approval of CRHS steels works generally consists of document review, on-site audit and approval test. In addition to the reqirements in this chapter, the works shall also comply with "Guidelines for Survey of Products for Marine Use" of the Society for works approval as specified in Table 2-1.

Table 2-1
Works Approval Requirements

Works Approval Requirement	Guidelines for Survey of Products for Marine Use	Guidelines for Approval of CRHS-56/70 Low Alloy Steel for Critical Application
Document Review	X	X
On-Site Audit	X	-
Approval Test	-	X

Note: Required items for works apprvoal of CRHS steels are marked with an "X".

2.3.4 Document review

(a) Submittal

In addition to the documets specified in "Guidelines for Survey of Products for Marine Use" of the Society for works approval, the Manufacturer shall submit a detailed qualification plan to the Society for approval outlining the manufacturing processes and testing proposed to meet the requirements herein. Documented quality system (the latest edition of ISO 9001), process control plan associated with the CRHS steels and a listing of referenced process documents which become part of the process control plan are also to be submitted to the Society for document review before on-site audit and approval test.

(b) Process control plan

(i) The Manufacturer must demonstrate during works approval that it has an adequate process to ensure the specified composition and mechanical properties are met throughout the product. The process control plan shall contain at least the following critical processing procedures:

(1) Melting facility.

(2) Melting method, including refining and degassing procedures.

(3) Cropping practices to ensure all finished material will meet specification requirements.

(4) Casting procedures (as applicable), including molding materials.

(5) Ingot, plate, and casting soaking treatments (as applicable).

(6) Minimum rolling reduction ratios (as applicable).

(7) Heat treatment parameters (temperature, time, cooling method, and atmosphere for intermediate (in process) and final heat treatment).

(8) Heat treatment facilities (which facilities were used, etc.).

(9) Any lubricating, de-scaling, cleaning, or pickling operations used during manufacture.

(10) All processes that could negatively impact the final surface and near surface chemical composition of the delivered product.

(11) A specific change control plan which specifies the criteria and plan to verify the acceptability of any change in the critical processing procedures as listed in the Process Control Plan.

(12) Procedures and processes for removing, machining, preparing, and testing of tensile specimens from first articles, prolongations, and/or test blocks with specific consideration for minimizing hydrogen loss from specimens between removal and testing.

(13) Additional requirements as deemed necessary by the Society.

(ii) Cold cracking susceptibility (P_{cm}) and carbon equivalent (C_{eq})

In addition, as part of the process control plan, the Manufacturer shall identify the maximum P_{cm} and the minimum C_{eq} values that will be used during production to provide enhanced resistance to hydrogen-assisted heat affected zone cracking and reasonable assurance of meeting minimum yield strength, respectively. These values shall be based upon available laboratory and production data and shall be reflected in the material submitted for works approval testing. The formulas for determining P_{cm} and C_{eq} are as follows:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn+Cu+Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B \ (\%)$$

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15} \ (\%)$$

(iii) Record

All previous revisions must be kept on file for audit, and the version of the process control plan used during manufacture of procured products must be recorded for each delivered lot. The revision record of the Process Control Plan must also indicate any problems that have been identified by the Manufacturer, the Navy, or the Society with their product which required a process control plan revision, including receipt inspection, fabrication, or in service and how these problems were adequately resolved and the necessary changes made in the manufacturing procedures to ensure that these problems will not occur in the future.

(iv) Employees

The Manufacturer shall ensure that employees responsible for manufacturing and testing the approved product(s) understand the appropriate procedures (e.g., molding, heat treatment, nondestructive inspection, mechanical property testing) in the plan. Any amendments/revisions to this plan which could negatively affect the properties of the product must be supported by data and submitted to the Society for review for acceptability. The employee training methods shall be available for auditors when requested. The Manufacturer shall ensure that an up-to-date copy of the Process Control Plan, including any amendments/revisions, is readily available in the work for use by auditors when evaluating compliance with procedures approved by works approval testing and by employees.

2.3.5 On-site audit

(a) When the documents submitted to the Society for the document review are deemed satisfactory, the Surveyor of the Society is to carry out an on-site audit at the work.

(b) The work is to be assessed to ascertain that it is duly organised and managed in accordance with the requirements specified in "Guidelines for Survey of Products for Marine Use" of the Society and submitted documents as specified in 2.3.4 which includes its quality system.

2.3.6 Approval tests

(a) Approval tests consist of several tests and examinations as specified in Table 2-2.

Table 2-2
Examinations and Tests of Approval Tests

Tests and Examination	Requirement	Test Method	Approval Tests
Chemical analysis	2.6	2.9.1	X
Microstructure analysis	2.9.2		X
Weldability test	2.9.4		X
Explosion test	2.9.8	Appendix 1	X
Mechanical Properties			
Tensile properties	2.8.1	2.9.3(a)	X
Charpy V-notch	2.8.1	2.9.3(b)	X
Drop weight nil-ductility	2.8.2	2.9.3(b)	X
CTOD test	2.8.3	2.9.3(c)	X
Examinations			
Surface quality	2.9.5		X
Dimensional tolerance	2.9.6		X
Internal soundness	2.9.7		X

Note: Required examinations and tests for approval tests are marked with an "X".

(b) The manufacture of the first article (e.g., rolling of plate or slabs) for works approval, the laying out of test specimens, and the testing shall be witnessed by the Suveyor.

2.3.7 Renewal audit of works approval

(a) General

For all materials covered in this chapter, renewal audit of the works approval is required every 3 years to verify that the Manufacturer's facilities, processes and manufacturing methods associated with works approval are being maintained.

(b) Request and submittal

Each approved Manufacturer is required to request this renewal audit from the Society to maintain its works approval qualification. The Manufacturer's request shall be submitted to the Society directly with a copy to all procuring activities associated with approved materials where deemed necessary by the Society. This request should be submitted at least 3 months prior to the need for renewal audit. The Manufacturer's renewal audit submittal shall include the following:

(i) A summary of the production lot verification test results (including maximum thickness of product, mechanical properties, re-test results, and chemical composition) on qualified products produced since qualification or the previous renewal audit including production product non-conformances and the associated cause(s) and corrective action(s).

(ii) All production related facility changes on facilities used to produce the qualified product over the past 3 years.

(iii) All process control plan changes over the past 3 years which could affect the quality or performance of the product.

(iv) The change control plan used to adjudicate changes to the process control plan and required related submittals for approval to the Society by the Manufacturer.

(c) Additional requirements

The renewal audit process shall include a review of the Manufacturer's submittal. This may include a request for additional information or data and/or an audit of the facility to review current procedures and equipment, if deemed necessary by the Society. Based on the findings of these reviews, additional works approval testing may be required for approval of renewal audit.

(d) Where the renewal audit is not completed before the expiry date of the certificate, the certificate will be invalidated and the CR Lists of Approved Marine Products will be revised accordingly.

2.4 Production Lot Verification

2.4.1 Production lot verification consists of several examinations and tests as specified in Table 2-3.

Table 2-3
Examinations and Tests of Production Lot verification

Tests and Examination	Requirement	Test Method	Production lot verification
Chemical analysis	2.6	2.9.1	X
Microstructure analysis	-		-
Weldability test	-		-
Explosion test	-		-
Mechanical Properties			
Tensile properties	2.8.1	2.9.3(a)	X
Charpy V-notch	2.8.1	2.9.3(b)	X
Drop weight nil-ductility	-	-	-
CTOD test	-	-	-
Examinations			
Surface quality	2.9.5		X
Dimensional tolerance	2.9.6		X
Internal soundness	2.9.7		X

Note: Required examinations and tests for production lot verification are marked with an "X".

2.4.2 Certification of conformance of production lot verification

(a) A certificate of conformance shall be prepared for each lot of material offered for acceptance. The certificate shall include:

(i) actual data of specified chemical and mechanical tests;

(ii) a record of the final heat treatment (if applicable); and

(iii) qualitative results of nondestructive tests and other inspections or tests.

(b) In addition, the certificate shall state that

(i) each lot has been sampled, tested, and inspected in accordance with the requirements of this chapter and that the Manufacturer has maintained adequate manufacturing procedures demonstrated in works approval testing as listed and maintained as specified in process control plan and quality assurance practices to produce a product that meets the chemical and mechanical property requirements specified throughout the product; and

(ii) each lot meets all requirements of this chapter and shall be signed by a responsible representative of the Manufacturer.

Where test certificates issued by the Manufacturer contain the above data requirements, a separate certificate of conformance will not be required. The certificate shall include the revision of the process control plan used and the date of most recent first article approval or recertification.

2.5 Manufacture

2.5.1 Classification

Steel plate, sheet, or coil covered in this chapter shall be of the following types and grades as specified.

Type I	-	Plate, sheet, or coil for which ultrasonic testing for soundness and thickness is not performed.
Type II	-	Plate over 13 mm in thickness for which ultrasonic testing for soundness and thickness is performed. Unless otherwise specified in purchase order, each plate over 13 mm (see 2.9.7) in thickness shall be classified as Type II.
Grade CRHS-56	-	552 MPa tensile yield strength, minimum.
Grade CRHS-70	-	690 MPa tensile yield strength, minimum for plate less than or equal to 102 mm thick; or
	-	655 MPa tensile yield strength, minimum for plate greater than 102 mm thick.

CRHS-56 and CRHS-70 are further categorized into Grade A and Grade B in accordance with 1.1.2(b) of Appendix 1, with the designation CRHS-56A, CRHS-56B, CRHS-70A or CRHS-70B.

If requested by the applicant, the specific tests which are not specified by the steel grade and/or in the Guidelines can be carried out in accordance with specified requirements provided by the applicant and to the satisfaction of the attending Surveyor. When the specific tests were completed successfully, the identification mark "**S**" will be affixed to the steel grade, such as CRHS-56S, CRHS-56AS, etc.

2.5.2 All materials covered by this chapter shall be made by the same process as that used for the production of the works approval test items with any amendments/revisions as specifically allowed as specified herein. As a minimum, the steel shall be fully killed and produced to fine grain practice. Melting practice may include argon-oxygen decarburization (AOD), other refining processes, or remelting by the vacuum arc (VAR) or electroslag remelt (ESR) processes.

2.5.3 The steel shall be vacuum degassed except for thicknesses of 9.5 mm or less, and very low sulfur, calcium treatment, or other melt practices approved by the Society shall be used for sulfide inclusion shape control.

2.5.4 The steel may be cast by conventional methods or, for plate, sheet, and coil, may be continuous cast. When continuous cast slab is used, the ratio of reduction in cross-sectional area from the slab to the plate or bar shall be a minimum of 3:1. When specified, virgin material shall be used. Other production practices, if approved by the Society, may be used to produce this steel.

2.5.5 Recycled, recovered, or environmentally preferable materials

Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

2.5.6 Ingot discard

Sufficient discard shall be taken from each ingot to ensure freedom from piping and to prevent undue segregation. The extent of ingot cropping shall be in accordance with the most recent revision of the process control plan.

2.6 Chemical Composition

2.6.1 For works approval and production lot verification, the chemical composition shall be as specified in Table 2-4.

Table 2-4
Chemical Composition (Weight Percent)(1)

Element	Grade CRHS-56		Grade CRHS-70		
	≤ 32 mm	≤ 56 mm	≤ 25 mm (Comp. 1)	≤ 41 mm (Comp. 2)	All Thickness (Comp. 3)
Carbon	0.06(2)				
Manganese	0.40 ~ 0.70		0.75 ~ 1.15	0.75 ~ 1.15	0.75 ~ 1.15
Phosphorus	0.020				
Sulfur	0.004(3)				
Silicon	0.40				
Nickel	0.70 ~ 1.00	0.70 ~ 2.20	1.50 ~ 2.00	2.45 ~ 3.00	3.35 ~ 3.65
Chromium	0.60 ~ 0.90		0.45 ~ 0.75	0.45 ~ 0.75	0.45 ~ 0.75
Molybdenum	0.15 ~ 0.25		0.30 ~ 0.55	0.45 – 0.60	0.55 ~ 0.65
Copper	1.00 ~ 1.30		1.00 ~ 1.30	1.00 ~ 1.30	1.15 ~ 1.75
Niobium (Columbium)	0.02 ~ 0.06				
Aluminum	(4)				
Titanium	0.02				
Arsenic(6)	0.025				
Antimony(6)	0.025				
Vanadium	0.030				
Tin(6)	0.030				
Nitrogen	(5)				

Notes:

(1) Single values are maximum percentages. Except for carbon and sulfur, the chemical analysis tolerances as specified in ASTM A6 are to be applied to product (check) analysis. For elements not listed in ASTM A6, the product analysis shall not exceed the specified maximum.

(2) For CRHS-56 thickness 19 mm and under, a maximum of 0.07 percent shall be permitted in heat analysis.

(3) The product analysis tolerance shall be 0.002 percent over the specified maximum.

(4) Minimum acid-soluble aluminum content of 0.010 percent or minimum total aluminum content of 0.015 percent for each ladle of each heat.

(5) For information only.

(6) Elements shall not be added intentionally.

2.7 Heat Treatment

2.7.1 Heat treatment shall be in accordance with the requirements in SAE AMS-H-6875 and as specified below, unless otherwise determined to be acceptable by the Society and documented in the process control plan as specified in 2.3.4(b).

2.7.2 Heat treatment equipment and controls

Continuous or automatic heat treating equipment may be employed provided such equipment produces heat treated material that meets the requirements specified herein. The furnaces and temperature recording equipment shall be shown to correlate with the actual temperature of the material and shall be maintained and calibrated on a regular scheduled basis in accordance with the requirements in SAE AMS-H-6875 or as permitted in 2.7.1. The temperature of the material shall be recorded during the heating. After the charge reaches the selected temperature control setting, the furnace shall maintain the temperature of the material at any point in the working zone within ±14 °C.

2.7.3 Heat treatment record

(a) Record of each product and batch-type furnace

The Manufacturer shall maintain a complete record of the heat treatments given each product, and shall prepare a record of the heat treatment as part of the certification specified in 2.4.2. For batch-type furnaces, the heat treatment record shall include all the information presented on Fig. 2-1 and Fig. 2-2 and a verification of inspection record.

(b) Digital photographs and sketches

In addition to the requirements above for batch-type furnaces, the heat treatment record shall also include digital photographs and sketches providing sufficient accuracy to recreate positions and orientations of the plates in the furnace at future dates. The sketches shall identify every part in the load uniquely according to the Manufacturer's internal tracking methodology. The sketches and photographs in the heat treatment record shall be of the furnace car plate-load immediately prior to entering the furnace for the precipitation heat treating cycle(s).

(c) Manufacturer standard practices

Manufacturer standard practices shall be established, which shall include placement of plates, plate support structure (i.e., pylons, saw horses, racks, etc.) on the furnace car, placement of the burners in the furnace, and the distances and orientations of the plates and support structure with respect to the burners. The verification of inspection record shall validate that the plate was loaded in accordance with the sketches and photographs in the heat treatment record and the Manufacturer standard practices.

2.7.4 Working zone temperature survey

Working zone temperature surveys shall be in accordance with SAE AMS-H-6875 or as permitted in 2.7.1. However, when specified in purchase order, furnace working zone temperature surveys of batch-type furnaces shall be conducted with a typical, nominal, or simulated production load in the furnace.

2.7.5 Load distribution

During heat treatment, the items shall be distributed and, when necessary, properly supported by fixtures to permit complete and uniform heat treatment, to minimize distortion, and to allow free circulation of protective atmosphere (when used) to each item. Prior to heat treatment, fixtures shall be visually inspected for foreign material. Foreign material shall be removed prior to heat treatment unless it is positively identified as a material that does not contain detrimental material. All fixture surfaces in contact with heat treated items shall be manufactured from the material that is not detrimental. To meet these requirements, the following (a) through (e) shall apply:

(a) Items shall be placed only within the working zone dimensions that are determined as part of the 2.7.4 temperature survey.

(b) Items in the load shall contact only supporting fixtures, other furnace load items, or attached thermocouples.

(c) Through holes and blind holes shall not be blocked in a manner that would prevent entry of protective atmosphere (when used).

(d) Thermal expansion and distribution of the load shall be considered so that distortion of items is minimized.

(e) In gas or oil-fired furnaces, items shall be distributed to avoid localized heating by flame impingement.

2.7.6 Quenchant temperature

When quenching is required, the water temperature at the initiation of the quenching operation shall not exceed 27 °C.

2.7.7 Contact thermocouples

Unless specially approved by the Society based on data presented at works approval, for batch type furnaces a minimum of three thermocouples shall be attached to the furnace load. The hot junctions (or the caps of sheathed thermocouples) shall be in contact with the items.

2.7.8 Unless otherwise specified in purchase order, the Manufacturer shall determine the detailed procedure to produce products meeting the mechanical property requirements of this chapter with the following restrictions:

(a) The heat treatment shall be as specified in purchase order for treatment of Class 1 or Class 3 as follows:

(i) Class 1 - Controlled rolled and precipitation heat treated

This class is permissible only for CRHS-56 plate, sheet, or coil up to and including 13 mm in thickness, unless otherwise specifically approved by the Society.

(ii) Class 3 - Solution treated, quenched, and precipitation heat treated

(b) The plate shall not be stress relieved.

(c) Support of plate

For all heat treatment operations, plates shall be positioned and supported in such a manner to prevent shifting or falling from their initial set positions during the heat treatment process. In addition, during precipitation heat treatment, plates shall be positioned in the furnace so that in a direct-fired furnace burner flames and hot gases from these flames cannot impinge upon plate surfaces and result in heating the plates above the maximum allowable precipitation heat treatment temperature. As a minimum, the plates shall be supported in the furnace in a manner that ensures that the plates cannot fall or shift outside of the furnace working zone and be exposed to burner flames or hot gases. Attention shall be given to ensure that the structure supporting the plate in the furnace, such as pylons, sawhorses, and racks, will not deflect flames and hot gases onto plate surfaces. The entire furnace load from the precipitation heat treatment for batch-type furnaces shall be taken from the furnace and quenched at the same time. Multiple quenching operations from the precipitation heat treatment batch-type furnace are strictly prohibited.

(d) Quench tank

The quench tank facility used to accomplish the solution heat treatment shall be of a sufficient capacity and design to provide multi-directional (from at least three directions or other effective design based on results of works approval testing) water flow for effective quenching of the largest plates to be heat treated. The effectiveness of the quench tank facility in terms of capacity and water flow shall be demonstrated during works approval testing. The maximum quench tank water temperature at the initiation of the quenching operation shall not exceed 26.7 °C. The mill shall put a process in place to maintain the effectiveness (e.g., flow rate and water capacity) of the quench tank similar to that used during the first article qualification.

(e) Thermal survey

As an alternate to the thermal survey requirements of SAE AMS-H-6875, all furnaces that are used to heat-treat plates over 6.4 mm gage may be thermally surveyed as follows:

(i) The initial survey is done once using the thickest gage plate; the following surveys may use any gage.

(ii) Furnaces must be surveyed every 6 months after the initial survey.

(iii) Thermal surveys are conducted as follows:

(1) Three contact thermocouples must be used, one at each edge and one in the middle across the width of the plate.

(2) A calibrated recording device and thermocouples must be used.

(3) The test plate is run through the furnace using standard hold times.

(4) Trial starts when plate exits heat-up zones, and ends when plate exits furnace.

(5) Maximum temperature variability when plate is in soaking zones is ±14 °C.

(f) Thermal hydrogen soak after hot rolling

All plates greater than 76 mm thick shall receive a post hot rolling soak using a procedure demonstrated to the requirements in 2.10.1, unless otherwise approved by the Society.

A. Procedure No._____ Revision _____ Date _____

B. Heat treatment facility _____

C. Item material specification _____ Revision _____Amend. _____ Interim Change _____

D. Material Composition _____Type _____ Condition _____ Grade _____ Class _____

E. Time and temperature:

Heat Treatment	Aim Temperature	Tolerance	Holding Time
Preheating			
Annealing			
Solution Treating			
Precipitation Hardening			
Austenitizing			
Tempering			
Stress Relieving			

* Includes temperature tolerance of the tolerance is other than ±14 °C)

F. Will items be quenched? Yes _____ No _____ If yes, identify:
1. Quenching method (e.g., immersion, spray, etc.) _____
2. Quenching medium (include additives, if any) _____

G.
1. If not quenched, how are the items cooled? _____
2. Cooling rate (if specified by the contract document) _____

H. Working zone atmosphere:
1. Type of atmosphere: _____
2. Dew point (maximum): _____°C
3. Temperature above the dew point must be controlled if other than 316 °C _____
4. Flow rate: _____ cubic feet per hour
5. Vacuum - Maximum pressure: _____ torr (mm Hg) or _____microns Hg
6. Type of inert gas backfill (if used): _____ Backfill dew point (maximum) _____°C

Fig. 2-1
Heat Treatment Procedure Information

A. Heat treatment facility _____

B. Items heat treated _____

C. Lot numbers or serial numbers _____

D. Heat treatment procedure used (including revision and date of revision) _____

E. Date of heat treatment _____

F. Time/temperature data (the original temperature chart or the original manually recorded data). Include a standard time interval, such as one hour, or the starting time and chart speed marked on the chart.

G. Specific furnace(s) used: _____

H. Method of thermocouple attachment (batch furnace only): _____

I. Quenching Information

1. Was the item quenched in accordance with the heat treatment requirements of the applicable appendix?

   Yes_____ No_____

   (If items were quenched, answer 2 through 14 below. If items are not quenched, answer 15 below)

2. Quenching method: immersion _____ spray _____ other (specify) _____

*3 Quenching medium: _____

Additives (generic type & amount) _____

4. Approximate quench tank capacity: _____liters
5. Approximate rate of flow to quench tank: _____liters/minute
6. Type, number and locations of agitation devices in quench tank: _____

_____

7. Approximate flow rate of quench sprays: _____liters/minute
8. Maximum time interval between removal from the furnace and the start of quenching: _____minutes
9. Is the item quenched individually: Yes _____ No _____
10. If items are not quenched individually, how many items are quenched simultaneously? _____
11. Minimum time in quenchant: Hours _____ Minutes _____
12. Quenchant temperature: _____°C at start, _____°C at completion
13. Surface temperature of thickest section when removed from quenchant (not requires for items of uniform thickness quenched in water provided the minimum time in the quenchant is at least four minutes per inch of thickness): _____°C
14. Forgings over 2500 pounds: Fixtured during quenching: Yes ____ No ____

Orientation in quenching medium (a sketch or reference to a standard practice is acceptable). _____

15. If not quenched, how are the items cooled? _____

Fig. 2-2
Information to be Documented on the Heat Treatment Record

J. Furnace Information:
1. Furnace type(s):

Batch furnace _____ Salt bath _____ Type of salt _____

Vacuum furnace _____ Integral quench: Yes _____ No _____

Continuous furnace _____ Furnace fuel: _____

2. Method of preventing flame impingement: _____

K. Temperature measurement and control information:
1. Thermocouple information:

(a) How many thermocouples were used? Contact _____ Noncontact _____

(b) Describe the location of each thermocouple (may provide a sketch)

_____

2. How was working zone temperature recorded?

Automatically _____ Manually _____ (Monitoring interval) _____

3. How was working zone temperature controlled?

Automatically _____ Manually _____ (Monitoring interval) _____

4. If manual temperature control was used, how was the temperature adjusted (may reference a written standard practice): _____

5. If thermocouples were not used, briefly describe the type, number, and location of the temperature measuring devices used to indicate, record, and control temperature:

_____

6. Distance between the thermocouples and the load in an oscillating furnace: _____inches

L. Furnace loading information:
1. General description of item distribution in the load (not required when a thermocouple is attached to eash item in the load).

_____

(a) Approximate weight or size of batch furnace load:

Pounds (Kilograms) _____ or no. of pieces _____ and size _____

(b) Approximate continuous furnace production rate: _____pounds/hour

2. General description of the supporting method used.

_____

M. Location of test coupons (when used) in relation to items and attached thermocouples (when used).

_____

N. Furnace survey information:
1. Was this heat treatment used in conjunction with a temperature survey? Yes _____ No _____

Fig. 2-2 (Continued)
Information to be Documented on the Heat Treatment Record

2.8 Mechanical Properties

2.8.1 Tensile test and impact test

For works approval and production lot verification, the materials shall meet the tensile property requirements and impact property requirements as specified in Table 2-5 and Table 2-6 respectively after all heat treatments.

2.8.2 Drop weight nil-ductility test

For works approval, the test specimen shall be tested in accordance with ASTM E208.

2.8.3 Crack tip opening displacement (CTOD) test

For works approval, the CTOD test is deemed to be valid and acceptable provided that post-test-data analysis meets all validity criteria of BS 7448 Parts 1 & 2, or ASTM E1820, or any other recognized standard, and is approved by the Society.

Table 2-5
Tensile Property Requirements

Tensile Properties	Grade CRHS-56		Grade CRHS-70	
	< 6.4 mm	≥ 6.4 mm	≤ 25 mm	> 25 mm
Ultimate tensile strength	(1)			
Yield strength, 0.2% offset (MPa)	552 – 758(2)	552 – 690(2)	690 – 828	690 – 828(3)
Elongation in 51 mm, minimum (percent)	14	20	17(4)	18
Reduction in area, minimum, round specimen (percent)	(5)	50(5)	(5)	45(6)

Notes:

(1) To be recorded for information only.

(2) For CRHS-56 materials equal to or less than 13 mm in thickness, maximum yield strength shall be 759 MPa.

(3) For CRHS-70 plate greater than 102 mm and less than or equal to 152 mm thick, the minimum yield strength shall be 655 MPa.

(4) For CRHS-70 material less than 6 mm in thickness, elongation shall be 12 percent, minimum.

(5) A minimum percent reduction in area is not required for plate thicknesses equal to or less than 19 mm.

(6) Through-thickness tensile testing is required for plate ≥ 76 mm thick (see 1.10.1 and 1.10.2(c)). The only requirement is for reduction of area to be a minimum of 20 percent. There are no requirements for yield strength or elongation.

Table 2-6
Impact Requirements, Charpy V-Notch, Transverse

Test (Coolant) Temperature	Minimum Average Energy, joules(1)			Minimum Shear Fracture, percent (2)	
	Grade CRHS-56		Grade CRHS-70	Grade CRHS-56	Grade CRHS-70
	9.5 ≤ t ≤ 32 mm(3)	32 < t ≤ 56 mm	t ≥ 9.5 mm	9.5 ≤ t ≤ 56 mm(3)	t ≥ 9.5 mm
- 84±2 °C	142	-(4)	81	50	50(2)
- 18±2 °C	Not Required		109	Not Required	90

Notes:

(1) Minimum average energy is average value of three specimens. No single value shall be below the minimum average required by more than 7 J, or equivalent fraction as designated by the appropriate standard sub-sized

specimen, for the Charpy V-notch test. For works approval testing, more specimens for Charpy V-notch transition curves are required as specified in 2.9.3(b)(i).

(2) Measurement required on each Charpy V-notch specimen. No individual result shall be lower than the minimum. For CRHS-70 plate greater than 102 mm thick, the minimum percent shear fracture shall be 40 percent.

(3) For material thicknesses below 11 mm, sub-sized Charpy V-notch test specimens shall be as specified in ASTM A673. Equivalent absorbed energy requirements for sub-sized specimens shall be as specified in purchase order or in equivalent standard accepted by the Society.

(4) Both test temperature and minimum average energy for the Charpy V-notch test are to be as specified by the purchase order of the owner or the manufacturer.

2.9 Tests and Examinations

Examinations of surface quality, dimensions and internal soundness are the responsibility of the steel the Manufacturer. The acceptance by the Surveyor of the Society is not to absolve the steel the Manufacturer from this responsibility.

2.9.1 Chemical composition

(a) Specimens shall be analyzed in accordance with a standard ASTM method or a method that will ensure equally accurate results for conformance to the chemical composition requirements. The method(s) shall be correlated with National Institute of Standards and Technology standard reference materials, when available, to ensure the validity of the test method that is used as a control in chemical analysis or for calibration in instrumental methods of analysis. Additionally, the range over which the chemical analysis test methods can be shown to be accurate for the particular element reported shall be provided. The accuracy and precision of the chemical analysis method(s) used for each element being analyzed shall be provided.

(b) If the samples from the inspected plate, sheet, or coil fail to meet the requirements, all material from the lot in question shall be rejected. Samples from rejected lots of plates, sheets, or coils may be analyzed individually provided the samples are taken from each in the specified locations, and only those plates, sheets, or coils which conform to chemical composition requirements will be accepted.

2.9.2 Microstructure analysis

(a) Prior Austenite grain size

For works approval, the average prior austenite grain size shall be determined in accordance with the planimetric procedure of ASTM E112 for the product in the final heat treated condition.

(b) Microstructure

The microstructure at the centerline of the thickest plate to be qualified shall be reported in the form of photomicrographs showing the relative quantities and morphologies of the phases present.

2.9.3 Mechanical tests

(a) Tensile test

Tensile test specimens shall be tested in accordance with ASTM A370 and, for through-thickness testing of plate when required, ASTM A770. If a product is to be aged or otherwise heat treated to reduce hydrogen, then the tensile test specimen(s) shall be removed from the plate, prolongation, or keel block after the hydrogen reduction heat treatment. Tensile specimens or specimen blanks shall not be aged or otherwise heat treated to reduce hydrogen.

(b) Impact toughness

(i) Charpy V-notch impact test

Production lot verification test specimens shall be tested in accordance with ASTM A370 with coolant temperatures as specified in Table 2-6. For works approval testing, Charpy V-notch transition curves (transverse to rolling direction) with data points at each temperature of minus 84 °C, minus 68 °C, minus 51 °C, minus 34 °C, minus 18 °C, and room temperature shall be provided. At least three specimens for each point are required and individual values shall be recorded.

(ii) Drop weight nil-ductility test

For works approval, the test specimen shall be tested in accordance with ASTM E208. The specimen shall exhibit "no break" condition at minus 68±2 °C for CRHS-56 and at the temperature specified in purchase order for CRHS-70.

(iii) Marking of Test Specimens

The test specimens shall be marked to ensure positive identification of the lot being tested.

(c) CTOD test

(i) The crack tip opening displacement (CTOD) tests for metallic materials and weldments shall be carried out according to BS 7448 Parts 1 & 2, or ASTM E1820, or any other recognized standard.

(ii) The CTOD test specimens are to be tested in three point bending. Specimen dimension shall be in accordance with BS 7448 Parts 1 & 2, or ASTM E1820, or any other recognized standard.

(iii) The CTOD test is to use a testing machine with controllable loading rate and displacement-load synchronous recording device, and the data of test process are to be recorded automatically. The test equipment is to be calibrated annually.

(iv) The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

2.9.4 Weldability tests

(a) General

Weldability tests are required for plates and are to be carried out on samples of the thickest plate.

(b) Preparation and welding of the test assemblies

The welding procedure should be as far as possible in accordance with the normal welding practice used at the yards for the type of steel in question.

The welding parameters including consumables designation and diameter, pre-heating temperatures, interpass temperatures, heat input, number of passes, etc. are to be reported.

(c) Type of tests

From the test assemblies the following test specimens are to be taken:

(i) Tensile test

(ii) Charpy V-notch impact test.

The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.

(iii) Hardness tests HV 5 across the weldment.

The indentations are to be made along a 1 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:

- Fusion line

- HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

The maximum hardness value should not be higher than 350 HV.

A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations should be attached to the test report together with photomacrographs of the weld cross section.

2.9.5 Surface quality

(a) Visual examination

Each plate shall be examined visually and shall meet the requirements of surface quality. With respect to coating applications, the number of plates subject to paint film thickness measurements should be held to the minimum necessary to assure continued satisfactory performance.

(i) Procedures of coating

The material, as prepared for coating, shall be in the descaled condition and free from visible rust. Plates, sheets, or coils shall be cleaned by either abrasive blast cleaning or acid pickling. One coat of primer shall be applied to a dry film thickness of approximately 0.025 mm. The drying time of the coating at 23 °C shall be a maximum of 6 hours. The thickness of the dry film shall be not less than 0.018 mm at any point. The Manufacturer shall choose a coating compatible with the intended application and duration of protection.

(ii) Descale

(1) Abrasive blast cleaning
Abrasive blast cleaning shall result in a clean metal surface for painting, with mill scale, rust, and other surface contaminants completely removed.

(2) Acid pickling
The acid pickling process shall be as follows:

- Plates, sheets, or coils shall be handled on edge throughout the various steps of the procedures. They shall not be laid flat in the solutions.
- Rust preventatives, oils, greases, oil paints, and other foreign matter shall be removed from the plates prior to immersion in the acid pickling bath. Where alkaline solutions are used for this purpose, the plates shall be thoroughly rinsed with water prior to pickling.
- The pickling bath shall consist of a sulphuric acid solution to which has been added pickling inhibitor and 1.5% of sodium chloride. In making the solution initially, 19 liters of concentrated sulphuric acid are used for each 378.5 liters of solution. The acid concentration shall not be allowed to drop below 3.5% by volume. The inhibitor shall be used at the concentration recommended by the Manufacturer. The bath temperature shall be maintained at 71 to 82 °C. When the concentration of iron in the solution reaches 5% by weight, the entire bath shall be discarded.
- The water rinse shall consist of fresh circulating water maintained at a temperature of 49 to 82 °C. The flow of fresh water shall be maintained so that a complete change of water occurs every 24 hours. The combined concentrations of sulphuric acid and iron sulfates in the bath, calculated from the acid concentration and the ferrous iron concentration, shall not exceed 5.3 grams per 10 liters. This determination shall be made at least once each week.

(iii) Measurement of coating
The paint film shall cover surface roughness peaks. Two random dry film thickness measurements per 9 m^2 of painted surface, made with a calibrated suitable thickness gauge, shall be sufficient for determining conformity of any one plate to the specified coating thicknesses. Other methods of measurement may be used for paint film thickness, subject to the approval of the Society. Organic coatings containing lead, chromium, asbestos, arsenic, or mercury shall not be used.

(b) The depth of rolled-in scale, pits, or other defects shall not exceed 0.38 mm and shall not result in an under gauge (less than minimum thickness) condition. Isolated, individual pits not over 0.76 mm deep or within 152 mm of each other will be acceptable, provided plate, sheet, or coil thickness is not reduced to an under gauge condition. Surface imperfections may be removed by grinding, provided the thickness is not reduced to an under gauge condition and the ground area is smoothly faired into surrounding metal.

(i) Weld repair of mill defects after heat treatment

Unless otherwise specified in purchase order, weld repair after final heat treatment shall be permitted. Mill imperfections may be repair-welded by the Manufacturer or referred to the contracting activity for acceptance with subsequent repair welding to be performed by the contracting activity. Areas of the plate, sheet, and coil found to have less than the minimum specified thickness may have the thickness restored by welding the depressed area. The following limitations shall apply to all weld repairs:

(1) The total area to be repaired shall not exceed 1% of the surface of one side of the plate, sheet, or coil.

(2) The depth of any area to be repaired shall not exceed one-half the minimum plate or coil thickness specified or 13 mm, whichever is less. The depth of the area to be repaired shall be a minimum of 1.6 mm.

(3) Areas within 51 mm of each other which require weld repair shall be combined to form a single repair.

(4) Areas to be welded shall be ground to assure that the welds are made on clean, sound metal.

(5) After preparation for repair and prior to welding, the depressed area shall be magnetic particle inspected in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271, and shall be free of relevant linear indications.

(6) Weld repairs shall be made in accordance with NAVSEA Technical Publication T9074-AD-GIB-010/1688, MIL-STD-1689, or the applicable fabrication document. Procedures and personnel shall be qualified in accordance with NAVSEA Technical Publication S9074-AQ-GIB-010/248.

(7) The final repaired surface shall be ground smooth and shall be essentially flush with the adjacent surface and free of undercut in excess of 0.5 mm. No point of the finished weld surface shall be below the adjacent plate surface.

(8) Surface weld repairs shall be magnetic particle inspected after final grinding (or subsequent heat treatment, if applicable) in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271. Welds and 13 mm of adjacent base material shall be free of relevant linear indications greater than 3.2 mm in length.

(9) Repaired areas shall be marked. The markings shall remain legible and shall not be removed prior to performing all inspections specified herein.

(10) Notation of such repaired areas and the type of welding material used to make the weld repair(s) shall be made on the plate inspection form as part of the records.

(11) If a non-heat treatable electrode is used, reheat treatment of the plate, sheet, or coil is prohibited.

(12) MIL-120S-1 and MIL-12018-M2 or equivalent strength welding consumables shall not be used for any welding including repair welding and weld build-up.

(13) MIL-11018-M electrodes shall not be used for any welding including repair welding and weld build-up. Weld repair and weld build-up shall be accomplished using MIL-10718-M or MIL-100S electrodes.

(ii) Weld repairs of mill defects prior to heat treatment

Weld repairs of mill imperfections may be accomplished prior to heat treatment within the limitations as specified in 2.9.5(b)(i), except such weld repairs shall be made using a heat treatable electrode approved by the Society.

(iii) Edge defects

Visual laminar edge defects less than 6.4 mm long shall be acceptable. Laminar edge defects 6.4 mm long and over shall be explored by ultrasonic inspection on the surface adjacent to the affected area. Edge defects that extend into the material that will result in rejectable defects according to the ultrasonic

acceptance standards specified in 2.9.2 shall be cause for rejection. Laminar edge defect weld repairs shall be made using a weld procedure approved by the Society.

2.9.6 Dimensional tolerances

Tolerances shall be as specified in (a) through (f):

(a) Tolerances for material less than 4.8 mm in thickness

For material less than 4.8 mm in thickness, the tolerances of ASTM A505 shall apply.

(b) Alternate dimensional tolerances

Due to extensive past applications of CRHS-56/70 plate to the tolerances of ASTM A6, when specified in purchase order, CRHS-56/70 plate shall be ordered to the tolerances specified in ASTM A6. When plate is ordered to the dimensional tolerances in ASTM A6 and ordered by weight, the allowable under gauge at the edge of plates shall be as specified in Table 2-7.

(c) Thickness, weight, and gauge

For plate ordered to decimal thickness over 4.8 mm and not ordered to ASTM A6, the maximum allowable variations in thickness measurements shall be as specified in Table 2-8 and Table 2-9. For plate ordered to a specific weight basis and not ordered to ASTM A6, the maximum allowable variations in weight and gauge shall be as specified in Table 2-7.

(d) Flatness

Plates over 4.8 mm thick not ordered to ASTM A6 shall be flat within the tolerance limits specified in Table 2-10. The flatness, as specified in Table 2-10, shall be an overall flatness factor. This factor shall not apply to "kinks" or "waviness". The waviness or kinking permitted shall be judged by laying a 1-meter straightedge across the affected edges. The maximum permissible deviation from the straightedge shall be 6.4 mm. When specified purchase order, tighter requirements may be required.

(e) Camber

Camber of the plates over 4.8 mm thick not ordered to ASTM A6 shall not exceed the tolerance limits specified in Table 2-11.

(f) Size tolerances

The width and length of the plates over 4.8 mm thick not ordered to ASTM A6 shall not vary in excess of the tolerances specified in Table 2-12 and Table 2-13.

2.9.7 Internal soundness and thickness

Plates over 13 mm thick, unless otherwise specified in purchase order, shall be ultrasonically inspected for internal soundness in accordance with 2.9.7(a)(i) and ultrasonically measured for decimal thickness in accordance with 2.9.7(a)(ii). Each Type II plate, and, when specified in purchase order, all plates, shall be ultrasonically inspected for internal soundness and ultrasonically measured for decimal thickness. Plates over 13 mm thick not ultrasonically inspected or ultrasonically measured for decimal thickness shall be classified as Type I in accordance with 2.5.1.

(a) Ultrasonic examination

The requirements of NAVSEA Technical Publication T9074-AS-GIB-010/271 shall apply for the qualification of ultrasonic testing personnel, qualification and calibration of equipment, qualification of procedures, and reporting of test results. The scanning surface of the plate may have one coat each of pretreatment and primer.

(i) Ultrasonic soundness

Examinations shall be performed in accordance with ASTM A435, including the Supplementary Requirements of S1, and shall meet the acceptance standards stated therein.

(ii) Ultrasonic thickness

Examinations shall be performed and meet the requirements of Table 2-8 and Table 2-9 herein. When plate is specified on a lb/ft^2 basis, ultrasonic inspection for thickness is not required.

(b) Documentation

(i) Records of thickness measurements and soundness specified in 2.9.6(b)(ii) shall be prepared and transmitted with the material

(ii) When internal soundness inspection is performed, results shall be prepared in accordance with the format shown on Fig. 2-7.

2.9.8 Explosion test

For works approval, the explosion crack starter test and explosion bulge test shall be conducted in accordance with Appendix 1.

2.9.9 Rejection and retests

(a) When a test specimen representing a lot of material fails to meet specification requirements, the lot shall be rejected. The Manufacturer may rework or retest the lot as provided herein. The Manufacturer shall identify and separate rejected lots from acceptable lots until the rejected lots are withdrawn by the Manufacturer, or are demonstrated as meeting specification requirements.

(b) Only one (1) retest of a nonconforming original test is permitted, and the retest specimens shall be taken in the vicinity of the initial location of the failed specimen(s). If any retest specimen fails, the lot shall be rejected with no further testing permitted, except in cases where a lot consists of more than one item.

When a lot with a rejected test specimen consists of more than one item and there are no other instructions specified in this chapter, at the option of the Manufacturer, each item in the rejected lot may be tested for the failed test and each item that fails to meet the requirements shall be rejected.

All test results, including failures, shall be reported, unless otherwise approved by the Society in works approval to accommodate automated data reporting systems. In all cases, all test results, including failures, shall be available for review upon request.

(i) Reheat treatment

The Manufacturer shall be permitted to reheat-treat material along with the representative prolongations or test blocks which fail to meet the tensile or impact requirements. Required tests at the same required test location as originally performed on the failed material shall be repeated when the material is re-inspected, except for the chemical analysis. On any additional heat treatment given, including austenitizing/quench and temper/quench, re-tempering/quench or hydrogen soak, all the new mechanical test specimens from the material, prolongation, or test block shall be taken from locations that meet the criteria from as quenched surfaces of the reheat treatment as specified in this chapter.

(ii) Tensile retest

If the results of an original tensile specimen fails to meet the requirements, but are within 6.9 MPa of the required yield strength, or within 2 percent of the required elongation, or within 2 percent of the required reduction-in-area, a retest on two additional specimens (selected from the same approximate location) shall be permitted.

- Gauge Length Retest

If the percentage of elongation or reduction in area of an individual tensile specimen is less than that prescribed in this chapter, and any part of the fracture is outside the gauge length, or within the gauge

length and less than 25 percent of the gauge length from either datum point, another specimen from the same approximate location may be selected in its place.

(iii) Charpy V-notch retest

In the event that initial Charpy V-notch test results at a specified temperature do not meet the requirements, a retest of two additional sets of specimens (i.e., six specimens) from the same approximate location and at the same temperature shall be permitted on the same material. If the retest specimens do not meet the requirements (average and individual values), the lot represented by the specimens shall be rejected.

(d) Defective specimen/replacement of test specimens

A test specimen shall be discarded and a replacement specimen selected from the same lot of the material under the following conditions:

(i) When the specimen is incorrectly machined.

(ii) When the test procedure is incorrect.

(iii) When there is a malfunction of the testing equipment.

(iv) When a flaw that is not indicative of an inferior or defective lot of material is revealed during the test. However, internal flaws such as cracks, ruptures, and porosity are not reasons for the selection of a replacement test specimen.

2.10 Sampling

Test specimens shall be stamped or otherwise marked for identification. Any applied marks shall remain on the test specimens until they are tested and necessary records are made. The test specimens shall not receive any treatment, working, straightening, or other processing, except for machining, that may result in changing the properties to be evaluated by the testing, except as provided in the specific test methods.

2.10.1 Sampling for works approval

(a) Specimen locations

Specimens for works approval testing shall be located and tested as specified on Fig. 2-3 and Fig. 2-4, unless otherwise specified in purchse order.

(b) Specimens for CTOD test

For base metal, 3 specimens in both two directions which are parallel and prependicular to the final rolling direction respectively are required. For weldment, 3 specimens are to be taken.

(c) Specimens for weldability test

(i) The following test assembly is in general required:

1 butt weld test assembly welded with a heat input in accordance with the thickness of base metal as follows:

Base metal thickness (mm)	Max. heat input (kJ/cm)
t < 12.7	17.7
t ≥ 12.7	21.7

Notes:

(1) Max. heat input means the averages for each weld pass.

(2) For base metal thickness of 25 mm and above, 1 additional butt weld test assembly welded with a heat input approximately 39 kJ/cm is required. Where the manufacturer specifies a heat input value for the welds other than 39 kJ/cm, special consideration may be given to.

(3) The heat input for each weld pass is to be within 10% of the specified value.

(4) For the root layers, they may be deposited with a heat input other than that specified notwithstanding the requirement in note (3) above.

The butt weld test assemblies are to be prepared with the weld seam transverse to the plate rolling direction, so that impact specimens will result in the longitudinal direction. The bevel preparation should be preferably 1/2V or K.

(ii) From the test assemblies the following test specimens are to be taken:

(1) 1 cross weld tensile test specimen

(2) a set of 3 Charpy V-notch impact specimens transverse to the weld with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line.The fusion boundary is to be identified by etching the specimens with a suitable reagent.

(3) Hardness tests HV 5 across the weldment. The indentations are to be made along a 1 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:

- Fusion line
- HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

(d) As a minimum, for CRHS-56 plate of the thickness of 25 mm or 51 mm, plus the thickest and the thinnest gauge to be produced are required to be produced and tested. As a minimum, for CRHS-70 plate thicknesses of 25 mm, 41 mm, or 51 mm, and the thickest gauge to be produced at the mill shall be produced and tested depending on the chemical composition being qualified. Each individual chemical composition type of CRHS-56 and CRHS-70 shall be tested separately.

2.10.2 Sampling for production verification

(a) Location of test specimens in plate, sheet, or coil

The test samples shall be taken as shown on Fig. 2-5 and Fig. 2-6. Fig. 2-5 shall be used when the final direction of rolling is parallel to the longitudinal axis of the ingot. Fig. 2-6 shall be used when the final rolling direction is parallel to the transverse axis of the ingot.

(b) Sampling for chemical or spectrographic analysis

Solid samples for chemical or spectrographic analysis shall be taken from mid-thickness at the top center position of the top plate from each ingot in each lot, as shown on Fig. 2-5 and Fig. 2-6. For continuous cast slabs, samples shall be taken from either the Charpy V-notch or drop weight nil-ductility at mid-thickness from one location in one plate in each lot.

(c) Sampling for tensile test

After final heat treatment of the lot, a transverse tensile test sample shall be taken from each end of the plate, sheet, or coil. The tensile test sample shall be taken as shown on Fig. 2-5 and Fig. 2-6 and one surface of the sample shall be at a depth as near as practicable to T/2 below the surface, where T is the as-heat-treated thickness of the plate, and not less than three times the plate thickness or 102 mm, whichever is less, from the as-heat-treated edge and not more than 305 mm from the ends of the plate, sheet, or coil. In addition, for plate thickness of 76 mm or greater, a through-thickness tensile test sample (see note 6 to Table 2-5) shall be taken from the same location as the sample for chemical analysis.

(d) Sampling for impact test

After final heat treatment of the lot, the test samples shall be taken as shown on Fig. 2-5 and Fig. 2-6 and be not less than three times the plate thickness or 102 mm, whichever is less, from the as-heat-treated edge and not more than 305 mm from the ends of the plate, sheet, or coil.

- Sampling for charpy V-notch impact test

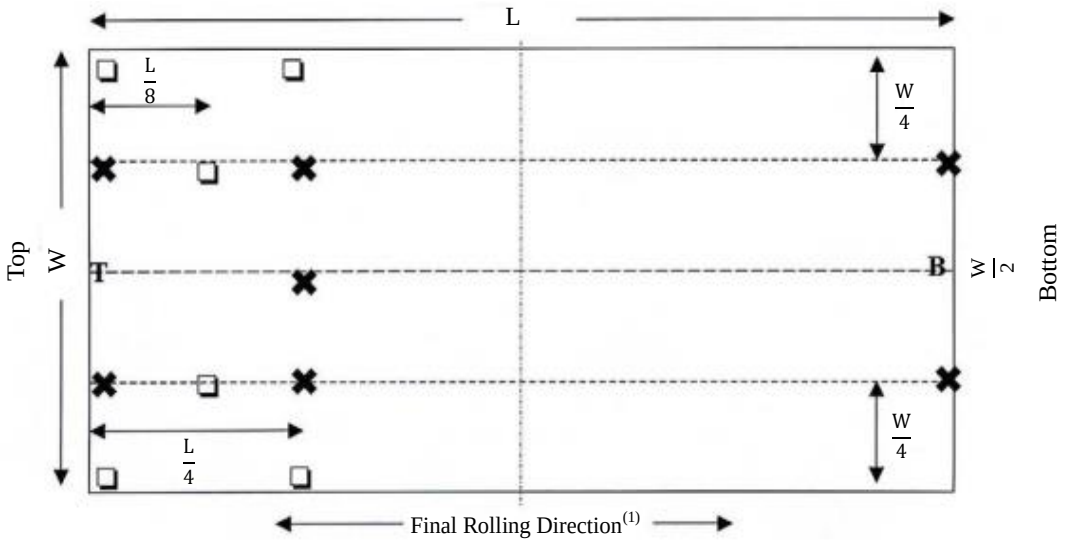
Specimens for works approval and production lot verification tests shall be taken from the thickness of the plate that, for 3 mm to 22 mm thick, the plate surface (after light machining) shall be one face of the specimen, and for plates 22 mm thick and upwards, the centerline of the plate shall be one face of the specimen. The notch shall be perpendicular to the plate surface.

(e) Thermal buffer pad requirements

Where the crop is insufficient to obtain test specimens, thermal buffer pads in accordance with ASTM A20 shall be used to maintain the proper distance from the heat treated edge of the plate.

(f) Sampling for thickness testing

Each plate, sheet, or coil shall be measured with a calibrated micrometer at three evenly distributed points along each longitudinal edge and at two evenly distributed points along each transverse edge.



Test	Location Symbol	Comments
Tensile (longitudinal)(2)	✖	Surface and mid-tickness depth (1 test at room temperature at each location)
Tensile (transverse)(3)	✖	Surface and mid-tickness depth (1 test at room temperature at each location)
Chemical Composition	✖	Full chemistry from all broken transverse tensiles
Chemical Composition(4)	❑	Full chemistry from surface and mid-thickness location
CVN (transverse)(2)	✖	See 2.10.2(d) for specimen depth
CVN Transition Curve(5)	▲	See 2.10.2(d) for specimen depth and 2.9.3(b)(i) for test temperature
Drop weight Nil-Ductility Test(3)	✷	Surface specimen test in accordance with 2.9.3(b)(ii)
Macrostructure / Microstructure	✖	In accordance with 2.9.2
Multiple Tests	**T**	Conduct the following test at this location: ✖, ❑, ✷, ▲
Multiple Tests	**B**	Conduct the following test at this location: ✖, ❑, ✷

Notes:

(1) The final rolling direction is the direction of rolling in which the greatest reduction ratio is achieved. For example, if 25 percent reduction of the initial slab or ingot thickness is achieved by rolling in direction A, and 75 percent reduction of the initial thickness is achieved by rolling in direction B, then direction B is the final rolling direction.

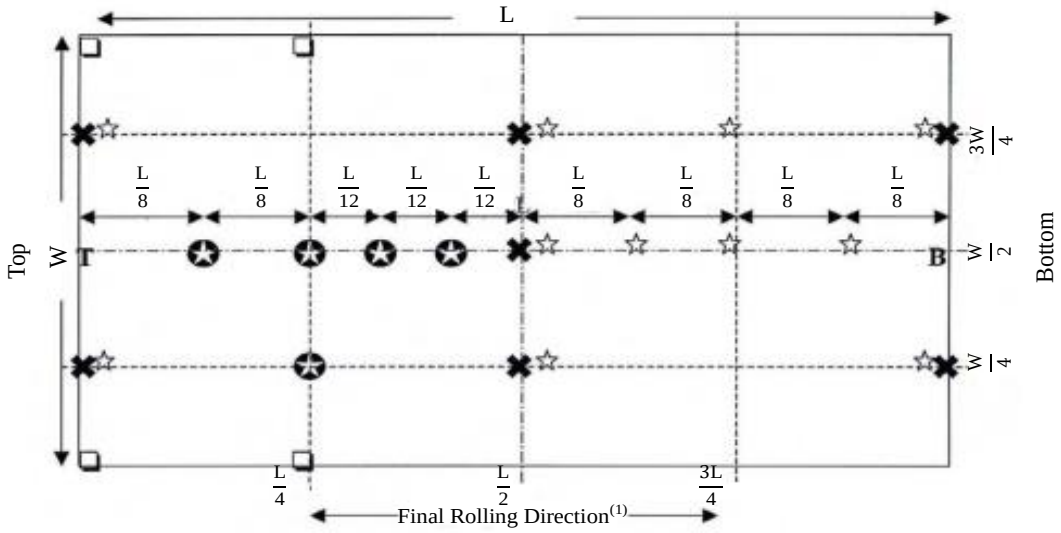
(2) CVN specimens and longitudinal tensile, from the top and bottom locations, shall be removed from material up to 305 mm from the as-cut edge of the plate, but not closer than 102 mm from the as-heat-treated edge of the plate.

(3) Transverse tensile specimens from top and bottom locations shall be removed from the as-cut edge of the plate, but not closer than 102 mm from the as-heat-treated edge of the plate.

(4) Specimens shall be removed from as-cut edge(s) of the plate, but not closer than 102 mm from as-heat-treated edge of the plate.

(5) Specimens shall be removed from material up to 305 mm from the as-heat-treated edge of the plate.

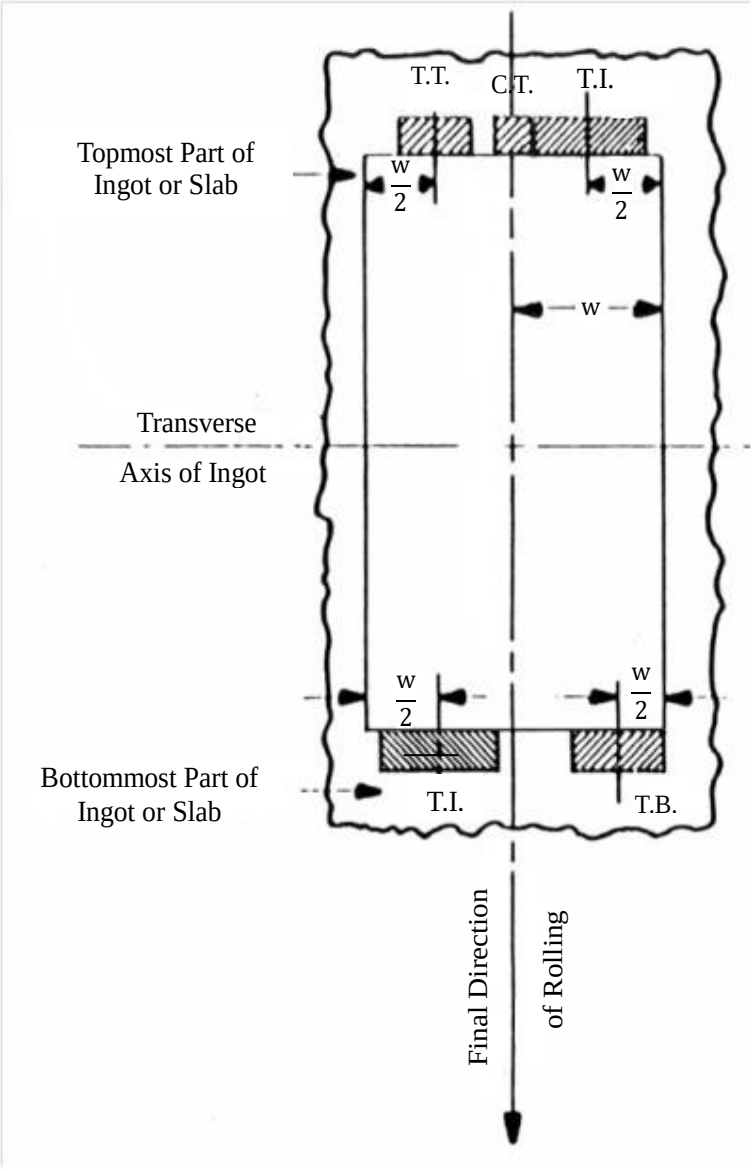
Fig. 2-3
Works Approval Testing (Plate < 76 mm Thick)



Test	Location Symbol	Comments
Tensile (longitudinal)(2)	✖	Surface and mid-tickness depth (1 test at room temperature at each location)
Tensile (transverse)(3)	✖	Surface and mid-tickness depth (1 test at room temperature at each location)
Tensile (through thickness)(2)	☆	Mid-length of specimen at mid-thickness depth (2 test at each location)
Chemical Composition	✖	Full chemistry from all broken transverse tensiles
Chemical Composition and through Thickness Tensile	✪	Full chemistry from gauge length of one broken through thickness tensile
Chemical Composition(4)	❑	Full chemistry from surface and mid-thickness location
CVN (transverse)(2)	✖	See 2.10.2(d) for specimen depth
CVN Transition Curve(5)	▲	See 2.10.2(d) for specimen depth and test temperature
Drop weight Nil-Ductility Test(3)	✷	Surface specimen test in accordance with 2.9.3(b)(ii)
Macrostructure / Microstructure	✖	In accordance with 2.9.2
Multiple Tests	**T**	Conduct the following test at this location: ✖, ☆, ❑, ✷, ▲
Multiple Tests	**B**	Conduct the following test at this location: ✖, ☆, ❑, ✷

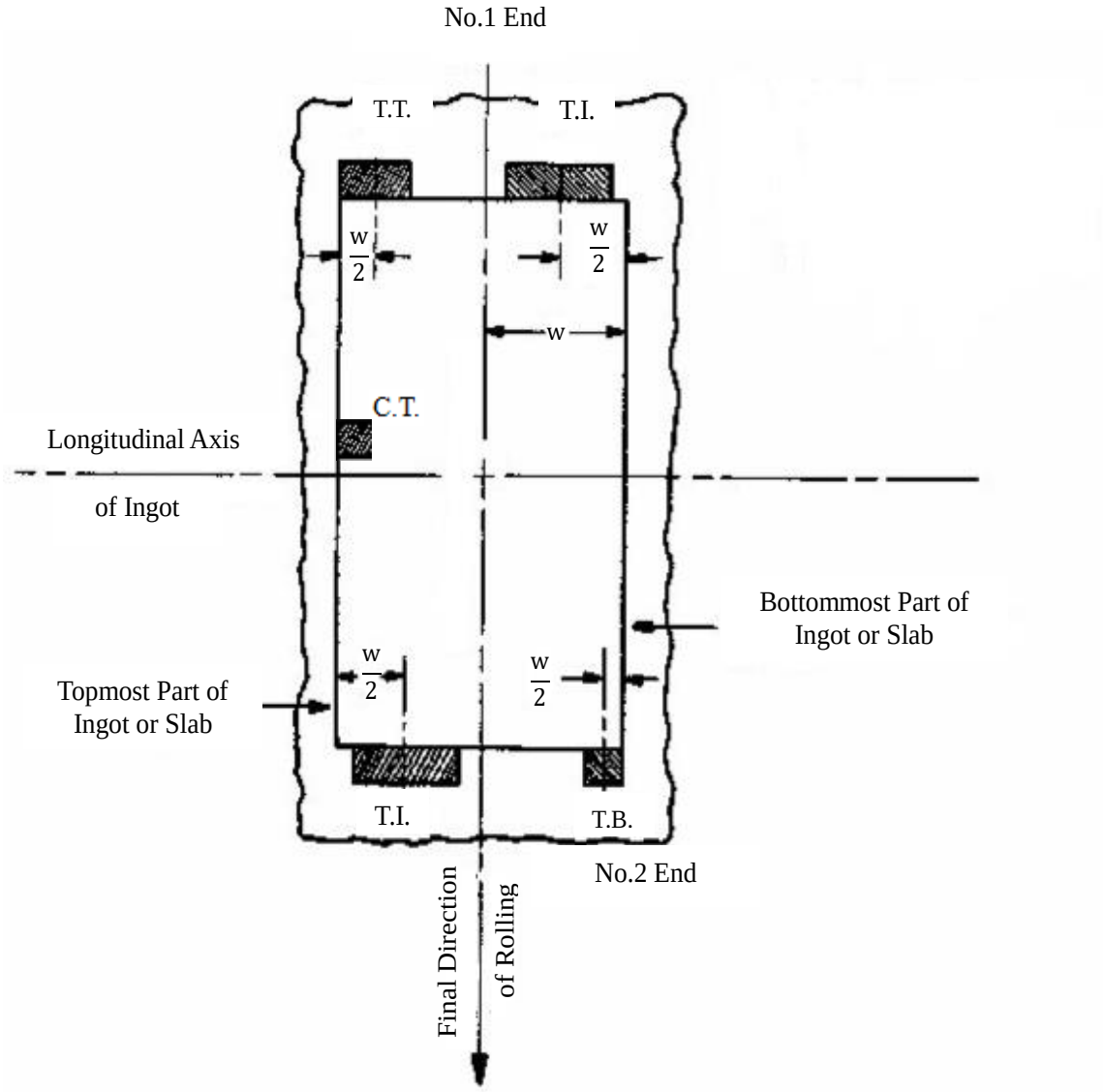
Notes:
1. The final rolling direction is the direction of rolling in which the greatest reduction ratio is achieved. For example, if 25 percent reduction of the initial slab or ingot thickness is achieved by rolling in direction A, and 75 percent reduction of the initial thickness is achieved by rolling in direction B, then direction B is the final rolling direction.
2. Longitudinal tensile, through thickness tensile and CVN specimens, from the top and bottom locations, shall be removed from material up to 305 mm from the as-cut edge of the plate, but not closer than 102 mm from the as-heat-treated edge of the plate.
3. Transverse tensile specimens from top and bottom locations shall be removed from the as-cut edge of the plate, but not closer than 102 mm from the as-heat-treated edge of the plate.
4. Specimens shall be removed from as-cut edge(s) of the plate, but not closer than 102 mm from as-heat-treated edge of the plate.
5. Specimens shall be removed from material up to 305 mm from the as-heat-treated edge of the plate.

Fig. 2-4
Works Approval Testing (Plate ≥ 76 mm Thick)



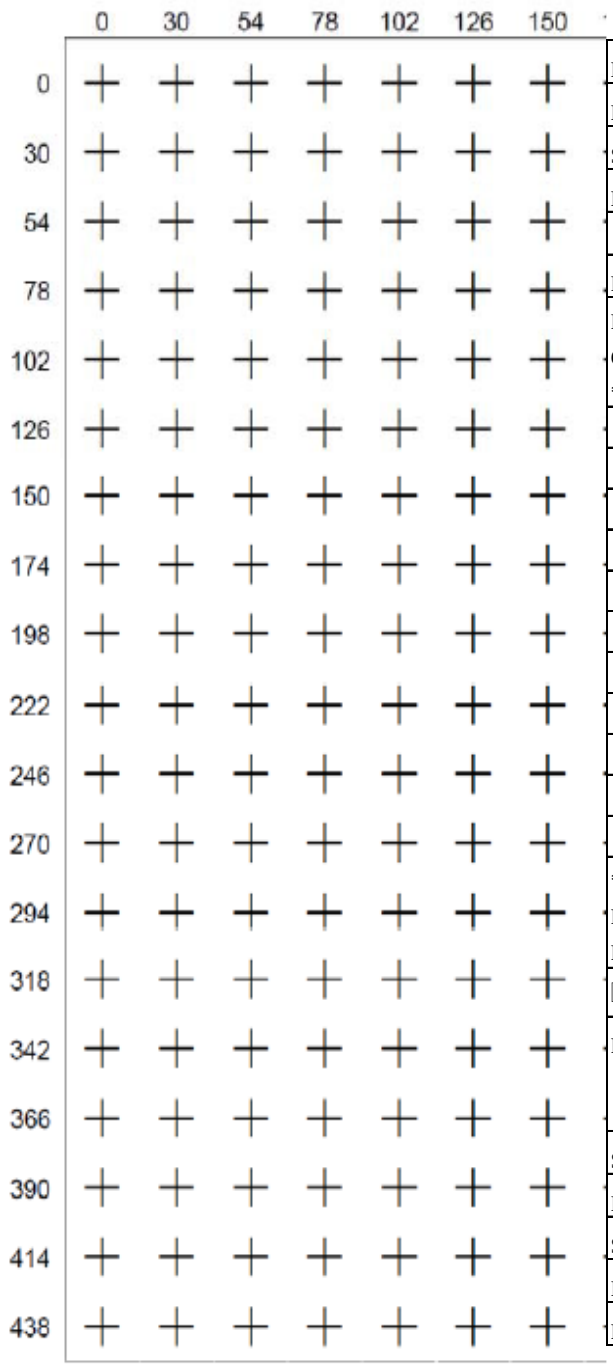
CT	=	Mid-thickness chemical analysis at top center (see 2.10.2(b))
T.I.	=	Transverse impact tests (Charpy)
T.T.	=	Transverse tensile test (top)
T.B.	=	Transverse tensile test (bottom)
W.	=	Distance from centerline to edge

Fig. 2-5
Method of Locating Test Samples for Production Verification of Plates as Rolled from Ingots or Slabs with the Final Direction of Rolling Parallel to the Longitudinal Axis of the Ingot



CT	=	Mid-thickness chemical analysis at top center (see 2.10.2(b))
T.I.	=	Transverse impact tests (Charpy)
T.T.	=	Transverse tensile test (top)
T.B.	=	Transverse tensile test (bottom)
W.	=	Distance from centerline to edge

Fig. 2-6
Method of Locating Test Specimens for Production Verification of Plates as Rolled from Ingots or Slabs with the Final Direction of Rolling Parallel to the Transverse Axis of the Ingot



Mill Mark No.			
Heat/Melt No.			
Slab/Plate No.			
Material	Length	Width	Gauge

Recordable Soundness Discontinuities

Flaw Class *	Dimension To. Top End	Dimension To. Left Side	Flaw Class *	Dimension To. Top End	Dimension To. Left Side

*KEY
REC-ACCEPTABLE DISCONTINUITY
REJ-REJECTABLE DISCONTINUITY

☐ Soundness Satisfactory ☐ Refer Evaluation

Remarks

Specification/Procedure

Inspector/Cert. Level Model No.

Search Unit: Size Frequency

Inspector(S): Date

Reviewed By: Date

Fig. 2-7
Sample Plate Ultrasonic Soundness Report

Table 2-7
Allowable Variation in Weight and Gauge for Plates Specified on a Weight Basis (Applicable to Single Plates)

Allowable under gauge at edge for widths given, w (mm)									
Specified weight and thickness t (mm) , W (kg/m^2)	w ≤ 1676	1676 < w ≤ 2032	2032 < w ≤ 2286	2286 < w ≤ 2540	2540 < w ≤ 2921	2921 < w ≤ 3429	3429 < w ≤ 3810	3810 < w ≤ 4267	w > 4267
	%	%	%	%	%	%	%	%	%
W < 100, t < 13	6	6	8	8	8	8	8	8	8
100 ≤ W < 125, 13≤ t < 16	3.5	4	4.5	5	5.5	6.5	6.5	6.5	6.5
125 ≤ W < 149, 16≤ t < 19	3.5	4	4.5	5	5.5	6	6	6	6
149 ≤ W < 199, 19≤ t < 25	3	3	3.5	4	4	4.5	5	5.5	6
W ≥ 199, t ≥ 25	3	3	3	3	3	3.5	4	4.5	5

Allowable weight tolerance for widths given, w (mm)						
Specified weight and thickness t (mm) , W (kg/m^2)	w ≤ 3810		3810 < w ≤ 4267		w > 4267	
	%		%		%	
	Over	Under	Over	Under	Over	Under
W < 100, t < 13	8	10	-	-	-	-
100 ≤ W < 125, 13≤ t < 16	2	4	-	-	-	-
125 ≤ W < 149, 16≤ t < 19	2	4	-	-	-	-
149 ≤ W < 199, 19≤ t < 25	2	3.5	3	4	3	4
W ≥ 199, t ≥ 25	2	3	2	3	3	4

Table 2-8
Thickness Tolerances in mm (average) Over Ordered Thickness for Single Plate 51 mm and Under in Thickness[(1)]

Specified thickness (mm)	Tolerance over ordered thickness for widths given, w (mm)											
	w < 1219	1219 ≤ w < 1524	1524 ≤ w < 1829	1829 ≤ w < 2133	2133 ≤ w < 2348	2348 ≤ w < 2743	2743 ≤ w < 3048	3048 ≤ w < 3353	3353 ≤ w < 3658	3658 ≤ w < 4267	4267 ≤ w < 4623	4623 ≤ w
6.4 ≤ t ≤ 7.2	0.4	0.4	0.5	0.5	0.7	0.7	0.9	-	-	-	-	-
7.2 < t ≤ 8.7	0.4	0.4	0.5	0.7	0.7	0.7	0.9	1.1	-	-	-	-
8.7 < t ≤ 10.3	0.4	0.4	0.5	0.7	0.7	0.9	0.9	1.1	-	-	-	-
10.3 < t ≤ 11.9	0.4	0.4	0.5	0.7	0.7	0.9	1.1	1.1	1.3	-	-	-
11.9 < t ≤ 13.5	0.5	0.5	0.5	0.7	0.7	0.9	1.1	1.1	1.3	1.6	-	-
13.5 < t ≤ 15.1	0.5	0.5	0.7	0.7	0.7	0.9	1.1	1.3	1.3	1.6	-	-
15.1 < t ≤ 16.7	0.7	0.7	0.7	0.7	0.7	0.9	1.1	1.3	1.3	1.6	1.8	1.9
16.7 < t ≤ 18.3	0.7	0.7	0.7	0.7	0.7	0.9	1.1	1.3	1.3	1.6	1.8	1.9
18.3 < t ≤ 19.9	0.7	0.7	0.7	0.7	0.9	0.9	1.1	1.3	1.7	1.9	2	2.2
19.9 < t ≤ 21.4	0.7	0.9	0.9	0.9	0.9	1.1	1.3	1.3	1.7	1.9	2.2	2.4
21.4 < t ≤ 23.0	0.9	0.9	0.9	0.9	1.1	1.1	1.3	1.6	1.7	1.9	2.2	2.4
23.0 < t ≤ 24.6	0.9	0.9	0.9	0.9	1.1	1.1	1.3	1.6	1.9	2.2	2.4	2.7
24.6 < t ≤ 26.2	0.9	0.9	1.1	1.1	1.1	1.1	1.3	1.6	1.9	2.2	2.4	2.7
26.2 < t ≤ 27.8	0.9	0.9	1.1	1.1	1.1	1.3	1.3	1.6	1.9	2.2	2.4	2.7
27.8 < t ≤ 29.4	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.7	1.9	2.2	2.4	2.7
29.4 < t ≤ 31.0	1.1	1.1	1.3	1.3	1.3	1.3	1.6	1.9	2.2	2.4	2.6	3
31.0 < t ≤ 32.6	1.1	1.1	1.3	1.3	1.3	1.6	1.6	1.9	2.2	2.4	2.7	3
32.6 < t ≤ 34.1	1.1	1.1	1.3	1.3	1.3	1.6	1.6	1.9	2.4	2.7	2.9	3.2
34.1 < t ≤ 35.7	1.2	1.3	1.3	1.3	1.3	1.6	1.7	2.2	2.4	2.7	2.9	3.2
35.7 < t ≤ 37.3	1.2	1.3	1.6	1.6	1.6	1.6	1.9	2.2	2.7	2.9	3.2	3.4
37.3 < t ≤ 38.9	1.3	1.3	1.6	1.6	1.6	1.7	1.9	2.2	2.7	2.9	3.2	3.4
38.9 < t ≤ 40.5	1.3	1.3	1.6	1.6	1.6	1.7	1.9	2.4	2.7	3.3	3.7	4.1
40.5 < t ≤ 42.1	1.6	1.6	1.6	1.6	1.6	1.9	2.2	2.4	2.9	3.3	3.7	4.1
42.1 < t ≤ 43.7	1.6	1.6	1.7	1.7	1.7	1.9	2.2	2.7	2.9	3.3	3.7	4.1
43.7 < t ≤ 45.3	1.6	1.6	1.7	1.7	1.7	1.9	2.2	2.7	3.2	3.7	4.2	4.7
45.3 < t ≤ 46.8	1.6	1.6	1.9	1.9	1.9	2.2	2.4	2.7	3.2	3.7	4.2	4.7
46.8 < t ≤ 48.4	1.6	1.6	1.9	1.9	1.9	2.2	2.4	2.9	3.2	3.7	4.2	4.7
48.4 < t ≤ 51	1.7	1.7	1.9	1.9	1.9	2.2	2.4	2.9	3.6	4	4.4	4.8

Note:

(1) Tolerance under specified thickness, 0.3 mm.

Table 2-9

Thickness Tolerances in mm (average) Over Ordered Thickness for Single Plate Over 51 mm in Thickness(1)

Specified thickness t (mm)	Tolerances over specified thickness for widths given, w (mm)					
	w < 914	914 ≤ w < 1524	1524 ≤ w < 2134	2134 ≤ w < 3048	3048 ≤ w < 3353	w ≥ 3353
51 < t < 76	1.6	2.4	2.8	3.2	3.2	3.6
76 ≤ t < 102	2.0	2.4	2.8	3.2	3.2	3.6
102 ≤ t < 152	2.4	3.2	3.6	4.0	4.0	4.4
t =152	2.8	3.2	4.0	4.4	4.4	-

Note:

(1) Tolerance under specified thickness, 0.3 mm.

Table 2-10
Flatness Tolerances for Plates Ordered on a kg/m^2 or mm Basis[(1)(2)(3)]

Specified thickness t (mm)	Specified weight W (kg/m^2)	Flatness tolerance for specified widths, w (mm)										
		w < 914.4	914.4 ≤ w < 1219.2	1219.2 ≤ w < 1524	1524 ≤ w < 1828.8	1828.8 ≤ w < 133.6	2133.6 ≤ w < 438.4	2438.4 ≤ w < 2743.2	2743.2 ≤ w < 3048	3048 ≤ w < 3657.6	3657.6 ≤ w < 4267	w ≥ 4267
t < 6.4	W < 49.8	21	29	35	48	51	57	60	67	70	-	-
6.4 ≤ t < 9.5	49.8 ≤ W < 74.7	19	24	29	35	45	48	51	57	60	-	-
9.5 ≤ t < 13	74.7 ≤ W < 99.6	19	22	24	24	29	33	38	41	48	70	79
13 ≤ t < 19	99.6 ≤ W < 149.4	16	19	21	22	25	29	32	35	41	57	76
19 ≤ t < 25	149.4 ≤ W < 199.2	16	19	22	22	24	25	29	33	38	51	67
25 ≤ t < 51	199.2 ≤ W < 398.4	14	16	19	21	22	24	25	25	25	41	57
51 ≤ t < 102	398.4 ≤ W < 797	13	14	18	19	19	19	19	22	25	32	41
102 ≤ t < 152	797 ≤ W < 1195	14	18	19	19	22	22	24	29	32	32	38
t = 152	W = 1195	16	19	19	24	25	29	32	33	38	38	38

Notes:

(1) Flatness tolerances for length and width. The longer dimension specified is considered the length. Variation from a flat surface along the length shall not exceed the tabular amount for the specified width in any 4 meters of length.

(2) When the longer dimension is under 1 meter, the variation in flatness shall not exceed 6.4 mm.

(3) The above table and notes also cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

Table 2-11
Camber Tolerances for Plates Ordered on a kg/m^2 or mm Basis

Specified weight, W (kg/m^2)	Specified thickness t (mm)	Width w (mm)	Camber tolerance for thickness and width given
W ≤ 398	t ≤ 51	All	3.2 mm × 1.524 (length) m
-	51 < t ≤152	w ≤ 762	4.8 mm × 1.524 (length) m
-	51 < t ≤152	762 < w ≤ 1524	6.4 mm × 1.524 (length) m

Table 2-12
Width and Length Tolerances for Sheared Plates 25 mm Thick or Less(1)

Specified dimensions (mm)		Maximum permissible variations over specific width and length for weight or thickness given					
Width, w	Length, *l*	t < 9.5 (mm)		9.5 ≤ t < 16 (mm)		16 ≤ t < 25 (mm)	
		W < 74.7 (kg/m$^{2)}$		74.7 ≤ W < 124.6 (kg/m$^{2)}$		124.6 ≤ W < 199.4 (kg/m$^{2)}$	
		Width, (mm)	Length, (mm)	Width, (mm)	Length, (mm)	Width, (mm)	Length, (mm)
w < 1524	*l* < 3048	9.5	13	11.1	16	13	19
1524 ≤ w < 2134		11.1	16	13	18	16	22
2134 ≤ w < 2743		13	19	16	22	19	25
w ≥ 2743		16	22	19	25	22	29
w < 1524	3048 ≤ *l* < 6096	9.5	19	13	22	16	25
1524 ≤ w < 2134		13	19	16	22	19	25
2134 ≤ w < 2743		14	22	18	24	21	29
w ≥ 2743		16	25	19	30	22	32
w < 1524	6096 ≤ *l* < 9144	9.5	27	13	30	16	33
1524 ≤ w < 2134		13	27	16	30	19	33
2134 ≤ w < 2743		14	27	18	30	22	37
w ≥ 2743		18	30	22	33	25	37
w < 1524	9144 ≤ *l* < 12192	11.1	30	13	33	16	37
1524 ≤ w < 2134		13	33	16	37	19	40
2134 ≤ w < 2743		14	33	19	37	22	40
w ≥ 2743		19	37	22	40	25	43
w < 1524	12192 ≤ *l* < 15240	11.1	35	13	41	16	45
1524 ≤ w < 2134		13	38	16	41	19	45
2134 ≤ w < 2743		16	38	19	41	22	45
w ≥ 2743		19	41	22	45	25	48
w < 1524	15240 ≤ *l* < 18288	13	48	16	51	19	51
1524 ≤ w < 2134		16	48	19	51	22	51
2134 ≤ w < 2743		16	48	19	51	22	51
w ≥ 2743		22	48	25	54	29	60
w < 1524	*l* ≥ 18288	14	54	19	57	22	60
1524 ≤ w < 2134		19	54	22	57	25	60
2134 ≤ w < 2743		19	54	22	57	25	60
w ≥ 2743		25	54	29	64	32	67

Note:
(1) Maximum permissible variation under specified width and length, 6.4 mm

Table 2-13
Width and Length Tolerances for Gas-Cut Rectangular Plates(1)

Specified thickness t (mm)	Tolerance over for all specified widths or lengths (mm)
t < 51	19
51 ≤ t < 102	25
102 ≤ t < 152	29
t = 152	33

Note: Maximum permissible variation under specified width and length, 6.4 mm.

2.11 Marking

Each plate, sheet, or coil shall be indentation stamped with heat number, plate number, type number, class number, grade, and the designation CRHS-56 A/B or CRHS-70 A/B. The primary (final) rolling direction of the plate with respect to the hot top of the ingot shall be identified. Where the plate, sheet, or coil number provides positive identification of any required numbers, the numbers may be omitted from the markings. When the plates, sheets, or coils are cut into smaller sizes for delivery, each piece shall be marked with the required data. The marking may be painted or stenciled in lieu of die stamped on material 6.4 mm and less. Indentation stamping shall be done with a round-nosed die.

2.12 Packaging

2.12.1 Preparation for packaging and packing

Preparation for packaging and packing shall be as follows:

(a) Product(s) shall be clean and free of dirt, chips, or any other foreign matter.

(b) Contact preservative shall not be used.

(c) Product(s) shall be segregated as to heat number, composition, finish, and size.

2.12.2 Packaging, packing, and marking for shipment

Unless additional requirements are specified by the purchaser in purchase order, material shall be prepared for shipment in accordance with commercial practice to ensure delivery of product in full compliance with this chapter. The level of packaging and marking for shipment shall meet the requirements of carrier rules and regulations applicable to the mode of transportation.

2.13 Notes

2.13.1 Responsibility for performance of inspection

The performance of the inspections or tests set forth in this chapter does not relieve the Manufacturer of his responsibility to provide a product that meets all requirements of this chapter.

2.13.2 Responsibility for compliance

All items must meet all requirements in this chapter. The inspections set forth in this chapter shall become a part of the Manufacturer's overall inspection system or quality program. The absence of any inspection requirements in this chapter, shall not relieve the Manufacturer of the responsibility of assuring that all products or supplies submitted for acceptance comply with all requirements of the purchase order.

CHAPTER 3 WELDING MATERIALS FOR CRHS-56/70 STEEL

3.1 General

3.1.1 Scope

This chapter covers the general requirements, quality control provisions, test procedures, and instructions for packaging for bare welding electrodes and fluxes, covered welding electrodes, and flux-cored welding electrodes for CRHS-56/70 steel applications.

Note: Welding materials for other low-alloy steel applications, such as HY-80 and HY-100, are to be specially considered in accordance with Navsea Technical Publication T9074-BC-GIB-010/0200.

3.1.2 Manufacturing and approval

(a) The plant manufacturing welding materials submitted for approval is to be inspected by the Surveyor to satisfy himself that the facilities, methods of production and quality control procedures in that plant are to be such as to ensure reasonable uniformity in manufacture. Where a plant manufacturing welding materials were approved by the Society to submit a new welding material for approval, plant inspection may be required for the facilities, methods of production and quality control procedures for the new product. The requirements of work approval is to refer to "Guidelines for Survey of Products for Marine Use" of the Society.

(b) Welding materials intended to be approved by the Society are to be subjected to a satisfactory approval test specified in the chapter. Data in connection with characteristics of the welding materials are to be submitted.

(c) Welding materials are to have approval at each manufacturer's plant for each brand. Where approval welding materials are intended to be produced at plants other than those of the manufacturers or at plants of their licenses of the said welding materials, approval tests may be dispensed with partially by the Society.

(d) Approval tests and quality conformance tests for welding materials which are not covered by the requirements specified in this Chapter are to be carried out in accordance with the test specification approved by the Society.

(e) The Society may require, in any particular case, such additional tests or requirements as may be necessary. The Society is also to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval.

(f) In the following cases, the approval of welding materials by the Society is to be revoked, after notice is given to the manufacturer:

(i) Where the Society has recognized that the quality of welding materials is remarkably worse than that when the approval test was carried out.

(ii) For the major changes to approved products, the manufacturer is not to inform the Society and receive the Society assessment thereof.

(g) Certification and renewal audit of work approval

(i) Where the welding material produced by the manufacturer is complying with all the requirements of this chatper, the works approval will be granted and a Product Works Approval Certificate will be issued by the Society . The Product Works Approval Certificate is valid for not more than 3 years.

(ii) Renewal of the Product Works Approval Certificate is necessary at its expiry. Renewal audit is to be carried out in compliance with section 2.7 of "Guidelines for Survey of Products for Marine Use" of the Society. In addition, the approval test items required by renewal audit are to be in accordance with the requirements of Schedule A tests as specified respectively in 3.2, 3.3 or 3.4, whichever is applicable. Samples of welding materials, such as eletrodes, rods and fluxes , etc., are to be selected by the Surveyor.

3.1.3 Classification

Welding electrodes, wires or fluxes and other welding materials are to be furnished in the types, classes, and sizes as specified in 3.2, 3.3 or 3.4, if applicable.

3.1.4 Requirements for approval tests

A approval test plan for welding material is to be submitted to the Society in accordance with the requirements of this chapter. The individual item requirements are to be as specified herein and in 3.2, 3.3 or 3.4. Manufacturers have to successfully complete approval test prior to being entered into CR Lists of Approved Marine Products. A approval test report is to be prepared in accordance with the requirements of this chapter.

(a) Samples for approval test

Samples shall be selected at one time in the presence of the Surveyor and so indicated. The manufacturer shall indicate on the sample whether the electrodes and packages were produced on a laboratory or experimental scale, or on a production scale.

(b) Materials

All elements of the electrodes covered by this Guidelines (including base material, fluxes, and/or coatings) shall be produced from materials which ensure the deposited weld metal or the bare wire will conform to the requirements of 3.2, 3.3 or 3.4, if applicable. When coatings are used, the composition of the deposited weld metal and procedure for moisture control between baking and packaging shall form a part of the approval, and any subsequent major change that may modify the design or performance of the product may require re-approval or additional tests, and shall be subject to the approval of the Society. The electrodes shall be asbestos free, and a statement of compliance shall be submitted to the contracting activity when required in purchase order. When specified, manufacturers shall demonstrate that plastic spools, if used, do not burn or stop burning when tested in accordance with procedures of ASTM D 635.

(c) Chemical composition

The bare electrode or the deposited weld metal, as applicable, shall meet the alloy identity requirements for coils in AWS A5.01 and the limits on chemical composition specified in 3.2, 3.3 or 3.4, if applicable.

(i) Chemical analysis

(1) Chemical range limits

The chemical compositions specified in 3.2, 3.3 or 3.4 are minimum and maximum limits. However, these specifications do not imply and it should not be inferred that each of the possible chemistry compositions defined by these limits will meet the full requirements of this chapter (for example, mechanical properties). Once a formulation is developed and approved, and the aim values for each element have been established, changes to the formulation or aim values shall be verified not to alter the design criteria and be supported by test data. This information shall be reported to the Society, who will determine if re-approval is required in cases where the changes are found to adversely affect design criteria or performance.

At the time of approval, the aim values and maximum and minimum limits for each major alloying element (C, Si, Mn, Cr, Cu, Ni, Mo, V) and boron and related maximum and minimum carbon equivalent values shall be established or developed when data is available for acceptance

of this product. These values (maximum and minimum limits for each major alloying element and boron, and the maximum and minimum carbon equivalent values) shall be reported to the Society when available. The values for both major alloying elements and carbon equivalent limits shall represent statistically determined variations due to manufacturing tolerances. The carbon equivalent shall be determined using the formula specified in (3) below. The maximum and minimum chemical range limits and related carbon equivalents shall be supported by data to demonstrate that mechanical properties can be achieved with the range established. It is not intended that data be provided to support the maximum and minimum limit for each element. The data must demonstrate that material with high and low carbon equivalent due to the elements promoting hardenability at the high limits or low limits of the composition range for the formulation will meet the mechanical properties requirements.

(2) Uniformity of composition plan
The manufacturer shall have a test plan to verify uniformity of chemical composition in each lot and submit the test plan to the Society for review. The plan shall include testing of intermediate and final products other than chemical analysis of deposited weld metal and shall for solid wire include testing of each individual coil of rod stock received from the mill or supplier. The test plan must exhibit 95 percent confidence level, based on statistical analysis of actual test data that not less than 95 percent of the unwelded electrode and rods for GMAW and GTAW and the deposited weld metal for all other electrode forms and processes from each lot will be within the chemistry range specified for each element in accordance with the chemistry limits of the formulation. In the case of a new product or a product where sufficient data has not been developed, the 95/95 tolerance limits shall be provided as soon as possible after data is developed. The plan shall identify how any material found to fall outside the 95 percent confidence limits established during approval shall be discarded or subjected to additional conformance testing to confirm that mechanical properties are acceptable.

(3) Carbon equivalent control
The manufacturer shall verify the chemical uniformity of each lot using the plan in above (2), when developed, and shall verify that the high and low carbon equivalent (C.E.) limits established in above (1) are met, based on actual chemical analyses using the following formula:

$$\text{C.E.} = \%\text{C} + \frac{\%\text{Si}}{30} + \frac{(\%\text{Mn} + \%\text{Cr} + \%\text{Cu})}{20} + \frac{\%\text{Ni}}{60} + \frac{\%\text{Mo}}{15} + \frac{\%\text{V}}{10} + 5(\%\text{B})$$

Where:

%	is	percent
C	is	carbon
Si	is	silicon
Mn	is	manganese
Cr	is	chromium
Cu	is	copper
Ni	is	nickel
Mo	is	molybdenum
V	is	vanadium
B	is	born

When specified, the maximum C.E. shall not exceed limits in 3.2, 3.3 or 3.4 for the specific product.

(4) Sample for chemical analysis
The sample from the broken tension test specimen or from a corresponding location or any location above it in the weld metal is selected.

(d) Mechanical properties

The deposited weld metal shall exhibit the mechanical properties specified in 3.2, 3.3 or 3.4, as applicable. Tensile specimens should be kept cool (i.e., shall not be warm to the touch) during machining using appropriate methods and shall not be heated above room temperature at any time prior to testing.

(e) Diffusible hydrogen

The deposited weld metal shall meet the requirements for limits on diffusible hydrogen specified in 3.2, 3.3 or 3.4, as applicable.

(i) Diffusible hydrogen control plan

The manufacturer shall have a test plan to verify uniformity of diffusible hydrogen in each lot and submit the test plan to the Society for review. The diffusible hydrogen tests shall be conducted according with 3.2, 3.3 or 3.4, as applicable. The 95/95 confidence limit shall be determined using the average values from the diffusible hydrogen tests performed in accordance with AWS A4.3. The test plan shall exhibit a 95 percent confidence level, based on statistical analysis of actual test data (i.e., average values), that not less than 95 percent of the electrodes from each lot will meet the diffusible hydrogen limits specified in 3.2, 3.3 or 3.4. Any lot that is rejected because of high hydrogen content may be reprocessed or may be retested as specified in 3.1.8. If the supplier chooses reprocessing, the rejected lot shall not be reprocessed more than two times. Failure to meet the requirements for diffusible hydrogen after the second reprocessing shall cause final permanent rejection of the lot. In addition to diffusible hydrogen, all other tests (i.e., chemical and mechanical property) shall be performed using electrodes sampled after the last reprocessing operation.

(f) Nondestructive testing (NDT)

The length of test weld that shall meet the nondestructive testing requirements specified herein shall be the length of weld that contains all required chemical and mechanical property test specimens. The minimum lengths of weld that shall be subjected to required nondestructive testing is to be 635 mm for approval test. The minimum lengths of weld that shall be subjected to required nondestructive testing shall be 432 mm for quality conformance test.

(i) Radiography testing (RT)

Radiographs of welds deposited with all types of electrodes or rods shall meet the class 1 acceptance criteria as specified in MIL-STD-2035A, except that high cooling rate welds shall meet the class 2 acceptance criteria as specified in MIL-STD-2035A. Any linear indication transverse to the weld length in the high cooling rate welds or the low cooling rate submerged arc welds shall be cause for rejection of the weld.

Radiography testing shall be performed by qualified operators with level II qualification or above using the standard 2-2T quality level.

(ii) Magnetic particle testing (MT)

Magnetic particle inspection of welds, when required, shall meet the class 1 acceptance criteria for non-linear indications and the acceptance criteria for linear indications specified in MIL-STD-2035A.

Magnetic particle inspection shall be performed by qualified operators with level II qualification or above.

(iii) Ultrasonic testing (UT) and visual inspection of CR-E7418-M (MIL-10718-M) welds

Ultrasonic testing is required for approval test only of high cooling rate CR-E7418-M (MIL-10718-M) welds. Results of UT inspection performed in accordance with the transverse discontinuities (special case) requirements of NAVSEA Technical Publication T9074-AS-GIB-010/271, section 6.6.4.3.5 shall not exhibit suspected transverse cracks. Visual inspection is required for both approval and quality conformance testing of all CR-E7418-M (MIL-10718-M) welds. Visual inspection results shall conform to Class 2 acceptance criteria as specified in MIL-STD-2035A.

(g) Alloy identity

The alloy identity requirements of AWS A5.01 are considered mandatory.

When specified in purchase order, each spool, coil and container of electrode or rod shall be tested for alloy identity after final marking. Identification of each spool, coil, or container of electrodes tested after final marking and meeting the acceptance criteria shall include the words "Alloy tested".

(h) In-process excavation

Grinding, burring, machining, or other excavation during welding of a test plate shall be limited to weld starts and stops, correction of operator errors including use of the incorrect heat input and, as necessary, contouring in way of the bead to be subsequently deposited to avoid a welding defect or allow deposition without adjusting the target heat input. Excavation to avoid a defect or allow deposition at the target heat input shall only be performed against a previously deposited bead and not against the base metal. The amount, location, and method of excavation employed shall be recorded by the welder on the test plate work sheet. Under no circumstances shall grinding or other excavation be performed for the purpose of altering the bead position in an attempt to alter weld metal mechanical properties.

(i) Rounding procedure

For purposes of determining conformance with this chapter, an observed or calculated value shall be rounded to the nearest 1 MPa for tensile and yield strength, to the nearest 1°C for temperature and to "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding method specified in ASTM E 29.

(j) Lot identification requirements

For both approval and quality conformance testing of electrodes and fluxes in this chapter, lot identification shall be accomplished by marking each unit and shipping container with a unique manufacturer's control number.

3.1.5 Quality conformance tests

Each lot of welding electrodes, rods and fluxes shall be inspected in accordance with requirements of 3.2, 3.3 or 3.4, as applicable. Lots shall be as defined in the applicable sections.

(a) Sampling for visual inspection of bare wire, rods and flux-cored electrodes

Sample rods and electrodes shall be selected either from the production line immediately prior to packaging or from filled unit packages. If selected from the production line, the total sample shall be in accordance with Table 3-1 and the electrodes or rods shall be selected throughout the run so that all parts of the run are represented. If selection is made after the packaging operation, the total sample shall be in accordance with Table 3-1 and approximately the same number of electrodes or rods shall be selected from each of the sample unit packages (five cut-lengths (rods) of each package) and sufficient electrode to form one complete circle shall be taken from each sample spool, coil and drum.

Table 3-1
Sampling for Visual and Dimensional Inspections (Bare Wire, Rods, and Flux-cored Electrodes)

Lot size, number of spools, coils or drums of electrodes or boxes of rods in lot	Sample size, number of spools, coils, drums or boxes selected at random for inspection	Acceptance number, maximum number spools, coils, drums or boxes containing defective electrodes or rods for acceptance of the lot
2 ~ 8	2	0
9 ~ 15	2	0
16 ~ 25	3	0
26 ~ 50	3	0
51 ~ 90	5	0
91 ~ 150	5	0
151 ~ 280	8	1
281 ~ 500	8	1
501 ~ 1200	13	2
1201 ~ 3200	13	2
3201 ~ 10000	20	3
10001 ~ 35000	20	3

Any sample coil, spool, drum, box or other container that contains any nonconforming material shall be counted as defective. If in any sample the number of coils, spools, drums or boxes that do not conform to this chpater exceeds the acceptance number specified in Table 3-1, then this shall be cause for rejection of the lot.

(b) Sampling for visual inspection of covered electrodes

Sample electrodes shall be selected either from filled unit packages or from the production line after the baking operation. If sample electrodes are selected from filled unit packages or cans, the total sample shall be in accordance with Schedule A of Table 3-2 for electrode sizes 3.2 mm and larger and Schedule B for electrode sizes 2.4 mm and smaller for single sampling, and approximately the same number of electrodes shall be selected from each of the unit packages or groups of cans (6 cans per group). Lot size shall be expressed in kg. Sample size shall be the number of electrodes to be examined. A minimum number of unit packages shall be selected to permit sampling of ten electrodes maximum from each 22.5 kg package or from each 4.5 kg package. If the sample electrodes are selected from the production line, the total sample shall be equivalent to the above and the electrodes shall be selected through the production period so that all parts of the lot are represented. The electrodes selected shall be identified as to type, wet batch, lot, size, and other available information such as contract or order number being filled. When a lot is found to be acceptable, any electrodes in the lot found to be defective shall be replaced with nondefective electrodes prior to delivery. In no case shall known defective material be delivered.

Table 3-2
Sampling for Visual and Dimensional Inspection (Covered Electrodes)

Lot Size (weight of electrodes) (kg)	Sample Size (number of electrodes to be examined)		Acceptance number, maximum number of defective electrodes for acceptance of the lot	
	Schedule A	Schedule B	Schedule A	Schedule B
Weight ≤ 7	2	2	0	0
7 < weight ≤ 11.5	3	3	0	0
11.5 < weight ≤ 41	5	5	0	0
41 < weight ≤ 68	8	8	0	1
68 < weight ≤ 227	13	13	1	2
227 < weight ≤ 545	20	20	2	3
545 < weight ≤ 4536	32	32	3	5
4536 < weight ≤ 15786	50	50	5	7

(c) Requirements for NDT are in accordance with 3.1.4(f).

3.1.6 Preparation of test assemblies

Preparation of test assemblies are to be in accordance with the the requirements of 3.2, 3.3 or 3.4, as applicable, in this chapter.

(a) Preheat and interpass temperature

Preheat and interpass temperatures shall be controlled within the ranges specified using temperature indicating crayons or other suitable means. Preheat shall be applied evenly along the length of the test assemblies. For SMAW electrodes preheat shall be applied using electric resistance contact strip heaters or other suitable devices (e.g. electric resistance ceramic pad heaters). The preheat and interpass temperatures for each test assembly shall be monitored at a distance of 25 mm to 38 mm from the bevel edge on both plates being joined at a minimum of three locations along the length (at each end and the middle on the side opposite from the heater strips). The heat shall be applied in a way to ensure that it is through thickness with heater strips (for SMAW) on the bottom of each assembly (opposite from the side being welded).

(b) Thermal cycling

Welding should be continuous except for interpass cooling. Any heating devices used for controlling preheat and interpass temperatures shall be removed (or, if the device is part of the fixture, turned off) immediately on completion of the last weld pass. If welding of any test assembly is to be stopped for more than two hours, the test assembly shall be allowed to cool in still air, then re-heated to preheat temperature when required. Time delays per pass beyond that necessary for interpass cooling shall be reported on the approval and quality conformance test record. Under no circumstances shall a plate be heated to a temperature greater than 13.9° C in excess of the maximum interpass temperature specified for that plate. Immediately after the final bead is deposited, the test assembly shall be allowed to cool in still air. No post-weld soaking or other heat treatment is allowed.

(c) Instrumentation

For shielded metal arc or gas tungsten arc welding, voltage shall be measured between the test plate and a point as near as possible to the electrode holder/torch or the electrode holder/torch cable. For submerged arc, gas metal arc, and flux cored arc welding, voltage shall be measured between the wire feeder drive rolls and the work piece. Welding current and arc voltage measurements shall be made using digital or analog meters. Digital meters may be RMS-type devices provided the digital RMS meters are only used for DC and non-pulsed arc welding; RMS meters shall not be used where AC or pulsed arc welding is performed. Tong meters shall not be used. Only calibrated instruments shall be used.

(d) Root passes

If required for ease of welding, the root layers may be deposited with a heat input other than that specified. For single-V joints, this is restricted to a single layer (i.e., one bead in thickness). For double-V joints, an alternate heat input may be used for no more than two layers on each side welded. The root layers for the first side welded of double-V joints may be deposited in the flat position. Otherwise, root layers will be deposited in the same welding position required for the fill passes. Additionally, for gas metal arc or submerged arc tests in 51 mm thick double-V joints, up to two layers of shielded metal arc weld metal (CR-E7418-M (MIL-10718-M) for MIL-100S welds or CR-E8318-M2 (MIL-12018-M2) for MIL-120S welds) may be used for the root passes. These layers do not require removal prior to second side welding with the gas metal arc or submerged arc processes.

(e) Weld sequencing

Weld beads shall be located within the joint such that the target heat input may be used while maintaining acceptable weld quality. The direction of welding shall be the same for all beads in a weldment, including both sides of a two-sided weldment. In addition, bead placement in a layer shall be from one side wall to the other, with the "start" side wall being the same for all layers in a weldment. The use of a "split bead" or

"temper bead" placement technique is not allowed. Minor adjustments to individual bead locations may be made to ensure adequate fusion and weld quality when properly documented, but in no case to intentionally influence weld metal mechanical properties. Each weld pass shall be completed prior to commencing any other weld pass. For double-V joints, each side of the joint shall be independently welded from start to finish. This means that side 1 welding shall be complete before side 2 is started.

(f) Restraint

Welded test assemblies for evaluation of SMAW electrodes shall be thermally insulated or separated from the workbench. To minimize the angular and longitudinal distortion of the completed test weld, test assemblies shall be fully restrained during heating, welding, and cooling by appropriate fixturing or strongbacks unless otherwise specified by the purchaser. Restraining fixtures and strongbacks shall not interfere with the placement of strip heaters or heating pads on the backside of the assembly. Contact points between the fixture and the test plates shall be minimized to minimize the heat sink effect of the fixturing and strongbacks. Base plates on either side of the weld joint shall not be back set (reverse distorted) before welding to compensate for weld shrinkage, as an alternative to the required fixturing (or strongbacks).

(g) Welding heat input

Heat input (kJ/mm) shall be calculated using the following formula:

$$\text{Heat input (kJ/mm)} = \frac{\text{Volts} \times \text{Amperes} \times 0.06}{\text{Travel Speed (mm/min)}}$$

The root pass(es) shall be excluded from all heat input calculations. Specified heat inputs reflect minimum acceptable ranges and approval testing or quality conformance testing at values beyond the specified range shall be accepted.

(i) Operational heat input calculation

(1) To determine the travel speed for each complete weld pass, divide the total length of the complete weld pass by the total arc time for the pass. Total length of the complete weld pass and total arc time for the pass shall be calculated as in (2) and (3) below, respectively.

(2) To determine the total length of the complete weld pass, measure each weld bead individually and add the bead lengths. Measure each bead from the apparent trailing edge of the bead to the apparent trailing edge of the stop crater. Do not use the length of the test assembly as the pass length.

(3) To determine the total arc time of the complete weld pass, measure the arc time for each weld bead in the pass and add the individual bead arc times together. An electronic arc timer or equivalent automated system that measures the total arc time for the pass may also be used.

(4) Measure the arc voltage and welding amperage for each weld bead in the pass. Average the voltage and amperage to derive the average voltage and amperage values for the weld pass.

(5) Insert the average travel speed, arc voltage and amperage for each complete pass into the heat input equation of 3.1.6(g) to calculate the heat input for the weld pass.

(ii) Average heat input

The average heat input shall be the average of the operational heat input of all passes in the test assembly and shall fall within the range (and tolerances) specified in 3.2, 3.3 or 3.4, as applicable.

(h) Additional requirements

(i) All test variables such as amps, volts, bead placement and travel speed shall be recorded and reported.

(ii) The edge preparation if flame cut shall be ground to remove slag and surface irregularities.

(iii) The as-welded weld reinforcement shall not be greater than 4.8 mm.

(iv) Carbon arc or other thermal gouging operations shall not be performed on completed welds. This does not apply to plate preparations for the original joint. Thermal cutting may be performed on completed welds provided cutting is not within 13 mm of the weld face.

(v) After completion of the weld (and, for CR-E7418-M (MIL-10718-M), completion of visual inspection), the weld reinforcement and backing strap shall be removed flush with the base plate on both surfaces before performing required nondestructive testing. Grinding shall be performed to the extent necessary to provide for nondestructive testing of welds and to repair defects in accordance with MIL-STD-2035A.

(vi) Weld pick-up (i.e., welding performed prior to formal nondestructive testing to correct minor visual surface irregularities, such as low areas in the weld reinforcement, weld bead roll and a start-stop area) and minor repair may be accomplished on the weld face (before or after flush grinding) and on the backside after backing bar removal provided that the same electrode being tested is used in conjunction with the same welding conditions, welding position, and other controls used in the original welding of the test assembly.

(vii) No base metal shall be removed within 13 mm of the edges of the face of the weld by flame cutting. Only sawing or machining shall be used for removal of test specimen coupons.

(viii) For each test assembly, a record of actual weld bead placement, actual root opening and weld bead sequence shall be kept. The total number of weld passes, the actual root opening, and the actual bead placement shall be recorded and reported with a schematic sketch or the use of written format for bead placement, such as 1 full, 2 split, 3 triple and 5 quad layers.

3.1.7 Test items and test procedures

(a) Mechanical tests

The deposited weld metal is to exhibit the mechanical tests specified in 3.2, 3.3 or 3.4 with the result complying with the required mechanical properties. The test items may include the followings (but not limited when specified).

(i) Tension tests

(ii) Impact tests (Charpy V-notch, hereinafter called CVN)

(iii) Transverse side bend

(iv) Explosion test series (such as explosion crack starter test)

The test procedures of tension test, impact test and transverse side bend are to comply with the requirements of AWS B4.0. The test procedure of explosion test series is in accordance with Appendix 1.

(b) Other tests

(i) Chemical analysis

(ii) Alloy identity

Test procedure for alloy identity is to follow AWS A5.01.

(iii) Diffusible hydrogen

Test procedure for the deposited weld metal of specific electrode is to follow AWS A4.3.

(iv) Moisture testing

Test procedure for moisture testing is to follow AWS A4.4.

(v) Visual and dimensional inspection

(vi) Nondestructive testing

3.1.8 Retest

This paragraph consists of retest requirements under three different conditions as follows:

- Condition 1: Failure due to testing and/or specimen preparation error

For both approval test and quality comformance test, if the test failed due to one (or more) of the conditions listed in 3.1.8(a)(i) below, then the retest shall be carried out according to the requirements in3.1.8(a)(ii) below.

- Condition 2: Failure to meet test requirements

  For both approval test and quality comformance test, if the test failed due to conditions other than those listed in 3.1.8(a)(i) below, then the retest shall be carried out according to the requirements in 3.1.8(b) below.

- Condition 3: Receipt inspection by the purchaser

  As part of receipt inspection, the purchaser may check mechanical testing tolerances and chemical composition tolerances to determine acceptability of the product by repeating the quality conformance tests.

Note that all the specimens in a single test, whether the test involves a single specimen (such as for RT) or multiple specimens (such as for CVN tests), shall be considered a "set".

(a) Condition 1: Failure due to testing and/or specimen preparation error

(i) Testing and/or specimen preparation error includes:

(1) Improperly fabricated test welds. This applies to test welds that have not been fabricated in accordance with the applicable requirements or the published welding operating ranges for the product under test.

(2) Improperly prepared specimens. This applies to test specimens that are not in compliance with applicable standards.

(3) Test equipment malfunction in the process of conducting a test.

(4) Flaws in test specimens that are not indicative of inferior or defective product. Flaws at weld starts and stops at the ends of the test assembly, lack of fusion and slag due to operator technique are normal weld artifacts and do not count as flaws indicative of inferior or defective products. Cracks, clustered porosity, flakes, and ruptures are flaws that may be indicative of inferior or defective products and shall not qualify a lot for a testing/specimen preparation error retest.

(ii) Retests for conditions listed above shall be as follows:

(1) For each original test that failed due to one (or more) of the conditions in (a), only one testing or preparation error retest is permitted.

(2) A testing and/or preparation error retest shall consist of one replacement specimen for each specimen that failed due to the conditions in (i). Note for VT, MT and RT, the specimen is the entire weld. If the testing error is due to a malfunction of MT and/or RT equipment or to a flaw not indicative of inferior or defective products (see 3.1.8(a)(i)(4)) removed by grinding or other suitable methods within 1.6 mm of the top surface, the original test assembly may be retested.

(3) Results of all retests and reasons for all retests shall be reported on the report of quality conformance test.

(4) Retests of weld metal (e.g., mechanical properties) shall be from the same weld used for the original test, if feasible. If replacement test welds are needed, they shall be fabricated using consumables from the original sampling, if feasible. If sufficient material is not available from the original sampling or storage of an opened package is expected to influence results, another sample may be taken from the same lot and/or production run.

(5) Retests of product (e.g., diffusible hydrogen and moisture) shall be from the same sampling as the original test, if feasible. If sufficient material is not available from the original sampling or storage of an opened package is expected to influence results, another sample may be taken from the same lot and/or production run.

(6) If the results of the testing/preparation error retest do not satisfy the applicable requirements, then a retest shall be performed per (b) as below.

(b) Condition 2: Failure to meet test requirements

Retests for failure to meet test requirements shall be as follows:

(i) For each original test that failed due to conditions other than those listed in 3.1.8(a)(i), only one retest is permitted.

(ii) A retest shall consist of repeating the test that failed two times (i.e., two-for-one). Note that a mechanical property test such as tensile or impact toughness involves a set of test specimens and therefore two full sets of specimens for each test that failed are required under this two-for-one rule.

(iii) Results of all retests and reasons for all retests shall be reported on the test report.

(iv) Retests of weld metal shall be from the same weld used for the original test, if feasible. If replacement test welds are needed, they shall be fabricated using consumables from the original sampling, if feasible. If sufficient material is not available from the original sampling or storage of an opened package is expected to influence results, another sample may be taken from the same lot and/or production run.

(v) Retests of product shall be from the same sampling as the original test, if feasible. If sufficient material is not available from the original sampling or storage of an opened package is expected to influence results, another sample may be taken from the same lot and/or production run.

(vi) Unless the welding procedure was determined to be the root cause of the original test failure, any replacement test weld shall employ the same welding procedure as the original test weld. If a new procedure is used to correct the root cause of the original test failure, the retest shall include all tests conducted for the original weld. Two-for-one is only required for the test that failed. All future lots of the material must use the new procedure. The reason for changing procedure shall be justified to the Society and included on the Marine Products Certificate of the conformance test.

(vii) If the results of any conformance retest do not satisfy the applicable requirements, then the lot shall be rejected.

(c) Condition 3: Receipt inspection by the purchaser

(i) Mechanical testing tolerances

Repeating the mechanical property conformance tests as part of receipt inspection by the purchaser may employ the following check mechanical testing tolerances to determine acceptability of the product to the requirements in 3.2, 3.3 or 3.4, as applicable. The use of these values by the purchaser is at the purchaser's option and, if any or all of these tolerances are to be used, their use shall be indicated in purchaser's order. Mechanical property tolerances are as follows:

(1) Yield strength test results may be higher or lower than the specified requirement by 3% (rounded off to nearest 1 MPa).

(2) Ultimate tensile strength (when required) test results may be lower than the specified requirement by 3% (rounded off to nearest 1 MPa).

(3) Elongation test results shall not be lower than 93% of the minimum requirement.

(4) Impact test (CVN) results may be lower than the minimum requirements by 10%. This applies to both minimum individual values and to minimum average values.

(ii) Chemical composition tolerance

Repeating chemical composition conformance tests as part of receipt inspection by the purchaser may employ the following check chemical composition tolerances to determine the acceptability of CR-E69S-1, CR-E69S-2 and CR-E691TM (MIL-100S-1, MIL-100S-2 and MIL-101TM) electrodes to the requirements in 3.2, 3.3 or 3.4, as applicable. The use of these values by the purchaser is at the purchaser's option and, if any or all of these tolerances are to be used, their use shall be indicated in purchase order.

Table 3-3
Chemical Composition Tolerances of E69S-1, E69S-2 and E691TM (100S-1, 100S-2 and 101TM)

Element	Tolerance (1)
Manganese	0.07
Silicon	0.03
Phosphorus	0.003
Sulfur	0.003
Nickel	0.06
Molybdenum	0.03
Chromium	0.03
Vanadium	0.02
Aluminum	0.003
Titanium	0.02
Zirconium	0.003

Note:
(1) Weight percent Applies to values higher than maximum and lower than minimum requirement, as applicable.

3.1.9 Packaging

(a) Standard packaging

Electrodes and fluxes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

Flux, in its original unopened container, shall withstand storage under normal conditions for at least 6 months without damage to its welding characteristics or the properties of the weld. Heating of the flux to assure dryness may be necessary when the very best properties (of which the materials are capable) are required. For specific recommendations, consult the manufacturer.

(b) Loose-fill packaging

The use of all types of loose-fill materials for packaging and packing applications such as cushioning, filler, or dunnage is prohibited for materials destined for shipboard installation or storage. If cushioning is required, specify the use of cellulosic material, bound fiber, fiberboard, or transparent flexible cellular material.

3.2 Approval Requirements for Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3.2.1 Scope

This section covers the requirements for low-alloy steel flux cored welding electrodes designed for use with the flux cored arc welding process with or without gas shielding, specifically for the fabrication of CRHS-56 and CRHS-70 steel weldments for as-welded applications. This section is based on NAVSEA Technical Publication T9074-BC-GIB-010/0200 and AWS A5.29.

3.2.2 Classification

Electrodes shall be of the types specified in 3.2.3(a) and shall be of the forms and sizes in accordance with AWS A5.29.

3.2.3 Requirements for approval test

Electrodes covered by this section and intended to be approved by the Society are to be subjected to a satisfactory approval test. The requirements of approval test are as follows:

(a) Chemical composition

The types and chemical composition of the deposited weld metal shall be in accordance with the approved formulation, which is bracketed by the maximum and minimum values in Table 3-4. The carbon equivalent calculated as indicated in 3.1.4(c)(i)(3) shall not exceed 0.20.

(b) Mechanical properties

The mechanical properties of deposited weld metal shall be as specified in Table 3-5.

(c) Hydrogen content

The diffusible hydrogen levels in milliliters (mL) per 100 grams of deposited weld metal shall not exceed 4.0 mL per 100 grams maximum average value nor 4.8 mL per 100 grams maximum single value. Electrodes with a LH suffix added to the designation shall not exceed 2.6 mL per 100 grams maximum average value nor 3.2 mL per 100 grams maximum single value. A diffusible hydrogen control plan in accordance with 3.1.4(e)(i) is required.

(d) Hydrogen content after moisture exposure.

At approval the manufacturer shall provide data to benchmark the hydrogen content after moisture exposure of the product being approved. Diffusible hydrogen measurements in accordance with AWS A4.3 shall be made on electrode from the same spool using electrode from the outer layer or layers of the spool, both before and after exposure in a suitably controlled environmental chamber for 9 hours minimum at 27°C (-0 to +2.8°C) and 80% relative humidity (-0% to +5%). Results of these tests shall be provided to the Society as part of the approval test report. These benchmark test results shall be used to assess changes to manufacturing procedures that may affect hydrogen content after moisture exposure. The results of these tests shall be made available upon request to all purchasers of this product referencing this document.

(e) Visual and dimensional inspections

Electrode size and tolerances, electrode finish and uniformity, electrode winding and electrode identification shall be in accordance with AWS A 5.29.

(f) Magnetic particle and radiographic testing

Welds shall be inspected in accordance with requirements in 3.1.4(f), 3.1.4(f)(i) and 3.1.4(f)(ii).

Table 3-4
Type Designation and Chemical Composition of Deposited Weld Metal

Type[1]	Chemical composition (weight percent)[2],[3]									
	Carbon	Manganese	Silicon	Phosphorus	Sulfur	Nickel	Chromium	Molybdenum	Vanadium	Copper
CR-E69XTY (MIL-101TC) (MIL-101TM)	0.07	0.5 ~ 1.50	0.6	0.015	0.015	1.30 ~ 3.75	0.20	0.50	0.05	0.06

Notes:
(1) CR-EXXXTY the first latter E designates an electrode. The first two numbers in the CR-type designation classify tensile strength in MPa divided by 10 (i.e., 69 = 690 MPa). CR-EXXXTY the third number indicates what positions the electrodes should be used in.
0 is for electrodes used in the flat and horizontal welding position and tested in the flat position.
1 is for electrodes designed primarily for all welding positions. Sizes 2 mm and smaller electrodes are used in all positions and are tested in the vertical position (3G) position (including explosion crack starter tests; see Appendix 1). Sizes greater than 2 mm are used primarily for flat position welding and for horizontal fillet welds and are tested in the flat position (including explosion crack starter tests; see Appendix 1).
CR-EXXXTY The first letter (T) indicates that these are flux-cored electrodes.
CR-EXXXTY The last letter describes the shielding gas (C for carbon dioxide, M for 75% argon, 25% carbon dioxide shielding mixture).
For example, CR-E691TC is a 690 MPa tensile strength (69) electrode that can be welded in all positions (1) with a flux core (T) and carbon dioxide shielding gas (C).
CR-E691TM is the same, except that it is to be used with 75% argon, 25% carbon dioxide shielding gas mixture (M).
(2) Single values are maximum percentages.
(3) Boron shall be analyzed to the parts per million (ppm) level and reported for information and for use in calculating the carbon equivalent.

Table 3-5
As-Welded Mechanical Properties[1]

CR-type	E691TC (101TC) E691TM (101TM)
Yield strength[2] (MPa)	565 to 758
Elongation in gauge length (at least 51 mm) (%)	18
Transverse side bend	[3]
CVN Energy Joules minimum average at Temperature (degrees centigrade) (°C)[4]	47 Joules at (-51°C) 81 Joules at (-18°C)
Explosion crack starter test	[5]

Notes:
(1) The ultimate tensile strength and percentage reduction of area shall be recorded for information only.
(2) The yield strength shall be the average of duplicate specimens measured at 0.2 percent offset yield. When specified by the purchaser, a 607 MPa minimum yield strength shall be required, e.g., for joining CRHS-70.
(3) The bend radius shall be 2t and the convex surface of the specimen after bending shall have no visual cracks exceeding 3.2 mm. The corners of the specimen shall have no visual cracks exceeding 3.2 mm.
(4) For each testing temperature, the average value shall be determined based on five tests. Only one test specimen may have a value below the minimum average specified; such a test specimen may have a value no more than 14 Joules below the minimum average specified.
(5) Acceptance criteria shall be in accordance with Appendix 1.

3.2.4 Test assemblies for approval tests

Electrodes selected for approval shall be used for tests specified in Table 3-6. Schedule A tests shall be conducted by the manufacturer, and upon successful completion of these tests, schedule B tests will be conducted at recognized test facilities accepted by the Society. Both Schedule A and Schedule B tests are to be carried out in the presence of the Surveyor.

The electrode selected for testing shall be one spool, one drum, or one coil of each size of each type for which the manufacturer desires to qualify. However, for electrode sizes less than or equal to 2 mm diameter if the manufacturer's formulation is the same for the range of sizes of that type, only the largest size of that range of sizes shall be tested to qualify all sizes represented.

(a) Samples for approval test

Two test assemblies are to be prepared, one at a high cooling rate and one at a low cooling rate. Each test assembly is to consist of 2 tensile specimens with 12.5 mm diameter and 10 CVN specimens. The dimensions of the test assembly and the location of the tensile and CVN specimens shall be as shown in Fig. 3-1. Tensile specimens shall be all weld metal (longitudinal axis of the specimen shall be parallel to the welding direction) and shall be centered at T/2 (9.5 mm below the surface) of the test plate. No specimens shall be removed from within 20 mm of the ends of the welded test assembly. The test assmebiles shall be welded, machined, and tested as outlined below. Tests conducted shall be in accordance with Table 3-6.

Type of tests	Test Assemblies	
	High cooling rate	Low cooling rate
Tensile specimens	2	2
CVN specimens	5 at -51°C 5 at -18°C	5 at -51°C 5 at -18°C
Transverse side bend	2	2

(i) The base-plate material shall be CRHS-56 steel. The base plates shall be in accordance with Chapter 2 in which case the base plates may be in the as-rolled condition and need only conform to the chemical requirements of Chapter 2.

(ii) The type of shielding shall be in accordance with the classification requirements (see notes to Table 3-4).

(iii) Direct current shall be used with the polarity recommended by the electrode manufacturer. The welding current shall be within plus or minus 10 percent of the value as specified in Table 3-7.

(iv) Testing shall be of the as-welded condition.

(v) The high cooling rate sample shall be prepared in the flat position using a heat input of 1.2 ± 0.2 kJ/mm with minimum preheat and maximum interpass temperatures of 16°C and 52°C, respectively, for steel conforming to Chapter 2 (CRHS-56/70). See Table 3-7 for welding current.

(vi) The low cooling rate sample for electrode 2 mm and smaller in diameter shall be prepared in the vertical up position using a heat input of 2.2 ± 0.2 kJ/mm and minimum preheat and maximum interpass temperatures of 107°C and 135°C, respectively. See Table 3-7 for welding current. The low cooling rate sample for electrode larger than 2mm diameter shall be welded in the flat position, using minimum preheat and maximum interpass temperatures of 107°C and 135°C, respectively, a heat input of 2.2 ± 0.2 kJ/mm and welding electrical parameters that produce a sound weld.

(vii) Peening of weld beads shall not be permitted.

(vii) The test weld shall be prepared by using welding sequence and techniques recommended by the electrode manufacturer.

(ix) When 48 hours have elapsed after completion of the welding, the weldment shall have the reinforcement and backing strap removed flush with the base plate on both surfaces.

(x) See Table 3-5 for mechanical property testing requirements.

(xi) See 3.1.6 for additional welding requirements.

Table 3-6
Summary of Weld Metal Tests Required for Approval Test(1)

Test	Schedule		Test procedures	Requirements
	A	B(2)		
Chemical analysis	X	---	AWS A5.29 and 3.1.4(c)(i)	Table 3-4
Alloy identity	X	---	AWS A5.01	AWS A5.01
Diffusible hydrogen(5)	X	---	AWS A4.3	3.2.3(c) and 3.2.3(d)
Welded test assembly	X	X	AWS A5.29 and 3.2.4(a)	AWS A5.29
Nondestructive testing	X	X	3.1.4(f)(i) and 3.1.4(f)(ii)	3.1.4(f)(i) and 3.1.4(f)(ii)
Visual and dimensional inspection	X	X	3.1.5(a)	AWS A5.29
Tension	X	X	AWS B4.0	Table 3-5
Transverse side bend	X	X	AWS B4.0	Table 3-5
CVN(3)	X	X	AWS B4.0	Table 3-5
Explosion test series(4)	---	X	3.2.4(b)	Table 3-5

Notes:

(1) Test assemblies shall be made in the welding position and with the type of shielding specified in the classification requirements (see notes to Table 3-4).

(2) When a single electrode formulation is being approval for use with both shielding gases CR-E691TC and CR-E691TM (MIL-101TC and MIL-101TM), the schedule A tests shall be conducted for each shielding gas using one sample of the electrode. Schedule B tests shall be conducted using the same sample of the electrode and only the shielding gas that produced the lower average of CVN tests results.

(3) The CVN tests shall be conducted to determine conformance to the impact requirements of Table 3-5.

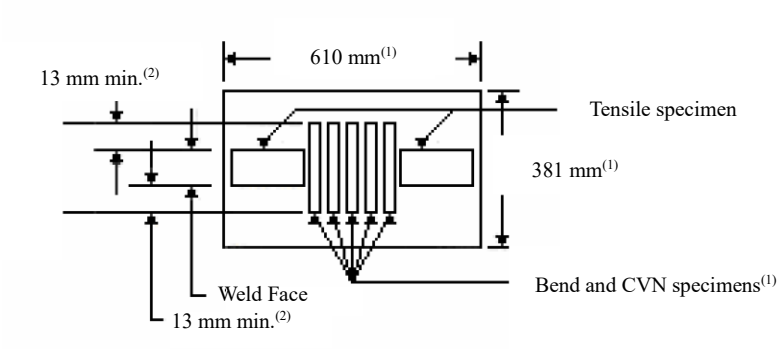
(4) If the results of the mechanical tests of Chapter 2 indicate that the weld metal properties on an electrode from the same welding position are equivalent to those of a larger size electrode of the same classification and formulation previously qualified, the crack starter test may be eliminated.

(5) Samples of CR-E691TM and CR-E691TC (MIL-101TM and MIL-101TC) electrodes shall be evaluated for diffusible hydrogen measurements by welding in the flat position and the following welding parameters.

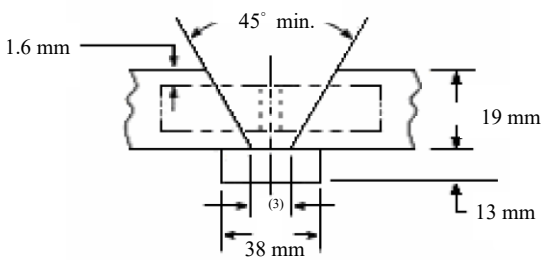
1.2 mm dia. electrode:
Amperage = 220 – 230
Electrode stick out = 16 ±1.6 mm

1.6 mm dia. electrode:
Amperage = 255 – 265
Electrode stick out = 16 ± 1.6 mm

Voltage shall be as specified by the manufacturer. Similar parameters, appropriately adjusted by the manufacturer, shall be used with other sizes.



(A) Plan view of test specimen layout



(B) Groove preparation of test plate showing orientation of CVN specimens

Notes:
(1) Base plate size shall be increased to provide additional CVN test specimens as required. Note that no specimens shall be removed from within 19 mm of the ends of the welded test assembly.
(2) No base metal shall be removed within 13 mm of the edges of the face of the weld by flame cutting.
(3) Root opening shall be 6.4 mm as minimum.
(4) See 3.2.4(a) for additional specimen number, location and orientation details.

Fig. 3-1
Welded Joint for Tension and Impact Tests(4)

Table 3-7
Electrode Size and Welding Current for 1.2 kJ/mm and 2.2 kJ/mm Test Assemblies

Electrode diameter (mm)	Welding current (amperes)(1)	
	CR-E691TC (MIL-101TC) CR-E691TM (MIL-101TM)	
	1.2 kJ/mm	2.2 kJ/mm
0.9	200	180
1.2	250	190
1.4	275	200
1.6	300	220
2.0	330	230
2.4	---	---
2.8	---	---
3.2	---	---
4.0	---	---

Notes:
(1) Welding current shall be within plus and minus 10 percent (±10%) of the value specified. If no value is specified, values appropriate for producing a sound weldment at the required heat input and welding position shall be used.

(b) Explosion crack starter

Two crack starter tests shall be conducted and two prolongation assemblies shall be prepared for determination of mechanical properties.

(i) Welding parameters

Fabrication of the explosion crack-starter and mechanical property prolongation assemblies shall be as follows:

(1) The base plate shall be CRHS-56 steel in accordance with Chapter 2.

(2) Dimensions of the test assemblies shall be in accordance with Appendix 1.

(3) The welding position and type of shielding shall be in accordance with the classification requirements (see notes to Table 3-4).

(4) Direct current shall be used with the polarity recommended by the electrode manufacturer. The welding current shall be plus or minus 10 percent of the values specified in Table 3-7.

(5) The preheat and interpass temperature shall be 121 ± 13.9°C.

(6) The welding-heat input shall be 2.2 plus or minus 0.2 kJ/mm. (See Table 3-7 for welding current).

(7) Peening of weld beads shall not be permitted.

(8) The test assembly shall be prepared by using the welding sequence and techniques recommended by the electrode manufacturer, which shall be reported.

(9) The joint surfaces shall not be clad or buttered.

(10) The tests shall be conducted at -18°C in accordance with Appendix 1.

(ii) Prolongation assembly

The prolongation assembly shall be tested in accordance with schedule B of Table 3-6.

(c) Special instructions

When applying for approval test or during approval test, the manufacturer shall furnish the information specified in (i) or (ii) below. This information, together with test results, shall form a part of the approval test.

(i) Single heat lot

For lots conforming to AWS A5.01 classification T3, the manufacturer shall furnish the following information:

(1) Type and size range (each size manufactured shall be specified) for approval.

(2) Composition of tube, or strip, and flux ingredients in terms of nominal percentages for each constituent (See Note (1)).

(3) Composition of deposited weld metal.

(4) Recommended amperage for each weld test and size of electrode to be tested during approval tests.

(5) Residual drawing lubricant and/or feeding lubricant left on the wire and its effect on diffusible hydrogen and moisture pickup on exposure. (See Note (1))

(6) Brand name.

Note (1) Information shall be maintained at the manufacturer's plant for audit purposes; need not be submitted.

(ii) Chemical control lot

For lots conforming to AWS A5.01 classification T4, the manufacturer shall furnish the following information:

(1) The type and size range (each size manufactured shall be specified) for approval.

(2) Chemical composition-control limits for mill coil. (See Note (1))

(3) Method of determining chemical-composition of the mill coil.

(4) Production line quality control methods used in producing electrodes from chemically controlled mill coil. (See Note (1))

(5) Percent allowable variation (disclosed) from standard (not disclosed) for each formulated chemical element in the mix of chemically controlled flux material for each MIL-type electrode. (See Note (1))

(6) Method of determining chemical composition of the mix of chemically controlled flux material. (See Note (1))

(7) Production line quality control methods used in producing electrodes from chemically controlled flux material. (See Note (1))

(8) Recommended amperage for each weld test, and size of electrode to be tested during approval tests.

(9) Residual drawing lubricant and/or feeding lubricant left on the wire and its effect on diffusible hydrogen and moisture pickup on exposure. (See Note (1))

(10) Brand name.

Note (1) Information shall be maintained at the manufacturer's plant for audit purposes; need not be submitted.

(iii) Change Control Procedure

The manufacturer shall document the criteria and procedure for verifying the acceptability of any changes, which may be made in key processes after approval of the product that may affect the design or performance of the product. The change control procedure shall be maintained at the manufacturer's plant for the Society audit purposes and need not be submitted. Any changes, which are determined necessary to a process that negatively affect the acceptable performance of the product shall be submitted to the Society for concurrence with the supporting data to show acceptability.

3.2.5 Quality conformance tests

For quality conformance test, electrodes shall be selected in accordance with the lot definition as follow. Electrodes selected shall be used for tests specified in Table 3-8. Quality conformance tests shall be conducted by the manufacturer in the presence of the Surveyor.

(a) Lot definition

(i) One AWS A5.01 Class T3 lot, not to exceed 11340 kg of electrodes

(ii) One AWS A5.01 Class T4 lot

(b) Visual and dimensional inspections

Sampling for visual and dimensional inspection shall be as specified in 3.1.5(a).

(c) Preparation of test assemblies for quality conformance tests

Quality conformance testing shall require two 12.5mm diameter tension specimens and ten CVN specimens (five (5) at each test temperature) from both the high and low cooling rate test welds. The dimensions of the test welds and the location of the tensile and impact specimens shall be as shown in Fig. 3-1.

The welding parameters for samples of quality conformance test are to the same as the approval test.

Type of tests	Test Assemblies	
	High cooling rate	Low cooling rate
Tensile specimen	2	2
Impact test specimens (CVN)	5 at -51°C 5 at -18°C	5 at -51°C 5 at -18°C

Where the lot of electrodes are found to comply with the requirements of approval test at the quality conformance test, the attending Surveyor authorized by the Society is to issue the Marine Product Certificate. However, where the quality of the lot of electrodes is found not complying with the properties specified in approval tests, the retests specified in 3.1.8 may be carried out. If retest also failures to meet the requirements, the lot of electrodes is to be rejected.

Table 3-8
Summary of Tests Required for Quality Conformance Tests

Test items	Test procedures	Requirements
Chemical analysis(1)	AWS A5.29 and 3.1.4(c)(i)	AWS A5.01
Alloy identity	AWS A5.01	AWS A5.01
Diffusible hydrogen(2)	AWS A4.3	3.2.3(c)
Nondestructive testing	3.1.4(f)	3.1.4(f)
Visual and Dimensional inspection	3.1.5(a)	AWS A5.29
Tension	AWS B4.0	Table 3-5
CVN	AWS B4.0	Table 3-5

Notes:
(1) Carbon equivalent 95/95 tolerance limits shall be reported (see 3.1.4(c)(i)(3)).
(2) See Table 3-6 for welding parameters.

3.3 Approval Requirements for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding and Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

3.3.1 Scope

This section covers low-alloy steel solid bare welding electrodes for use with the gas metal arc welding (GMAW) process and the submerged arc welding (SAW) process employing a neutral granular flux, low-alloy steel alloy-cored bare welding electrodes for use with the GMAW process and the SAW process employing a neutral granular flux, and low-alloy steel solid bare electrodes and cut length rods for use with the gas tungsten arc welding (GTAW) process. This section is based on AWS A5.23 and A5.28 and NAVSEA Technical Publication T9074-BC-GIB-010/0200.

3.3.2 Classification

(a) Electrode and rod types, forms and sizes, E69S and E83S (100S and 120S) material

Electrodes and rods shall be of the types specified (see 3.3.3(a)) and shall be of the forms and sizes in accordance with AWS A5.28. For coils and spools, in addition to the standard sizes listed in AWS A5.28, electrode diameters of 4 mm, 4.8 mm, 5.6 mm and 6.4 mm are acceptable and shall be in accordance with the sizes and tolerances in AWS A5.23. For welding rods, in addition to the standard sizes listed in AWS A5.28, electrode diameters of 0.8 mm, 0.9 mm, 1.4 mm, 5.6 mm and 6.4 mm are acceptable.

(b) Neutral granular flux types

Neutral granular flux for as-welded SAW applications shall be provided in the types qualified (see 3.3.3(a)(i)(3)).

3.3.3 Requirements for approval test

Electrodes and rods provided under this section shall be in accordance with AWS A5.23 or A5.28, as appropriate, and as specified herein. Neutral granular flux provided under this section shall be in accordance with AWS A5.23 and as specified herein.

(a) Types

(i) E69S and E83S (100S and 120S) types

(1) Finish

Electrodes and rods shall have either a clean bright finish or a uniform, continuous, well-bonded, smoothly-drawn copper coating on a clean surface. Diameters 2.4 mm and smaller may be coated with other types of rust preventatives or arc enhancers or feeding aids provided such coatings do not impair usability of the electrodes and rods or the quality or soundness of weld metal deposits. When alternative rust preventative, arc enhancer or feeding aid coatings are used for electrode diameters 2.4 mm and smaller, the manufacturer shall provide data and other evidence to verify that the coating prevents rust, enhances arc stability or aids in feeding and does not impair usability of the electrode or the quality and soundness of the weld deposit.

(2) Special type with suffix RC
Special electrodes and rods designated by the suffix RC shall not be copper coated but may have either a bright finish or a rust preventative or arc enhancer or feeding aid coating provided the coating does not impair usability of the electrodes or rods or the quality and soundness of the weld metal deposits.

(3) Type with suffix F
For as-welded applications, the designation of a qualified flux consists of the designation of the electrode it was qualified with, plus the suffix F (for example, MIL-100S-1F).

(4) Special CR-E83 (MIL-120) types with suffix X
CR-E83 (MIL-120) electrodes, rods or alloy-cored electrodes qualified using alternating current (AC) shall be designated by the suffix X.

(5) Types with suffix C
CR-E69 and CR-E83 (MIL-100 and MIL-120) alloy-cored electrodes shall be designated by suffix C.

(6) Types with suffix SA
CR-E69S and CR-E83S (MIL-100S and MIL-120S) electrodes with higher carbon content intended only for SAW shall be designated with suffix SA.

(b) Chemical composition

Chemical composition of unwelded electrodes and rods or deposited weld metal shall be in accordance with the approved formulation which is bracketed by the maximum and minimum values in Table 3-9.

For solid electrodes and rods, chemical analysis shall be made on the solid electrode or rod in accordance with AWS A5.28. In addition, a chemical analysis shall be performed on each individual coil of rod stock received from the mill or supplier.

For alloy-cored electrodes used for GMAW, the chemical analysis shall be made in accordance with AWS A5.28.

For alloy-cored electrodes used for SAW (see 3.3.4(a)(vi)), chemical analysis shall be made in accordance with AWS A5.23.

The maximum and minimum carbon equivalent for CR-E69S and CR-E83S (MIL-100S and MIL-120S) must be established in accordance with 3.1.4(c)(i)(3). If the product is to be copper-coated, then the maximum carbon equivalent of the rod stock shall be decreased appropriately to account for effect of the copper coating on the carbon equivalent of the deposited weld metal. Data demonstrating that acceptable CR-E69S (MIL-100S) properties for GMAW and SAW are achieved from fast cooling rate tests at the maximum carbon equivalent value in accordance with 3.1.4(c)(i)(3) shall be submitted to the Society for specific approval. In general, the maximum carbon equivalent for CR-E69S (MIL-100S) shall not exceed 0.23.

(c) Mechanical properties

The mechanical properties of weld metal in the as-welded condition shall be in accordance with Table 3-10.

(d) Magnetic particle and radiographic testing

Welds shall be inspected in accordance with requirements in 3.1.4(f), 3.1.4(f)(i) and 3.1.4(f)(ii).

(e) Cut-length rods (100S and 120S material only)

(i) Length

For 914 mm long rods, the length tolerance is plus 0, minus 13 mm. In addition to that length tolerance, for 914 mm long rods up to 10 percent of the rods in any container may be shorter than 901 mm, but not shorter than 610 mm. When specified in purchase's order, rods may be supplied in lengths of 305 or 457 mm, which also have length tolerances of plus 0, minus 13 mm.

(ii) Marking

In addition to the requirements of AWS A5.28, cut-length rods shall be identified by positive and legible methods such as imprinting or indenting the applicable type designation number at one or more locations on the rod surface approximately 25 mm from the rod end, or shall be identified by pressure-sensitive adhesive, plastic-coated tape imprinted with the applicable type number at one or more locations and attached to the rod approximately 25 mm from its end. Imprints on rods or on tape shall be with fade-proof ink and shall be resistant to oils, solvents, all atmospheric conditions, and to normal wear and tear encountered in shipping and handling.

(f) Diffusible hydrogen

The diffusible hydrogen levels in milliliters per 100 grams (mL/100 grams) of deposited weld metal shall be not greater than the values specified in Table 3-11. A diffusible hydrogen control plan in accordance with 3.1.4(e)(i) is required.

(i) Hydrogen content after moisture exposure

At approval test, the manufacturer shall provide data to benchmark the hydrogen content after moisture exposure of the product being approved. Diffusible hydrogen measurements in accordance with AWS A4.3 shall be made on electrode from the same spool using electrode from the outer layer or layers of the spool, both before and after exposure in a suitably controlled environmental chamber for 9 hours minimum at 27°C (-0 to +2.8°C) and 80% relative humidity (-0 to +5%). Results of these tests shall be provided to the Society as part of the approval test report. These benchmark test results shall be used to assess changes to manufacturing procedures that may affect hydrogen content after moisture exposure. The results of these tests shall be made available upon request to all purchasers of this product referencing this guidelines.

(g) Moisture content of CR-E69 and CR-E83 (MIL-100 and MIL-120) type fluxes

The total moisture content of CR-E69S-1F, CR-E69S-2F, CR-E83S-1F or CR-E83S-2F (MIL-100S-1F, MIL-100S-2F, MIL-120S-1F or MIL-120S-2F) flux shall not be greater than 0.10 percent by weight when the infrared method identified in AWS A4.4 is used.

For CR-E69S-1F, CR-E69S-2F, CR-E83S-1F and CR-E83S-2F (MIL-100S-1F, MIL-100S-2F, MIL-120S-1F and MIL-120S-2F), flux lots exhibiting moisture contents between 0.10 and 0.14 percent by weight when the infrared method identified in AWS A4.4 is used shall be accepted provided diffusible hydrogen testing confirms that the lot meets the requirements of Table 3-11. When other moisture content testing methods are used the total moisture content shall not exceed 0.05 percent by weight.

For CR-E69S-1F, CR-E69S-2F, CR-E83S-1F and CR-E83S-2F (MIL-100S-1F, MIL-100S-2F, MIL-120S-1F and MIL-120S-2F), when other moisture content testing methods are used flux lots exhibiting moisture contents between 0.05 and 0.10 percent by weight shall be accepted provided diffusible hydrogen testing confirms that the lot meets the requirements of Table 3-11.

(h) Visual and dimensional inspections

Electrode size and tolerances, electrode finish and uniformity, electrode winding and electrode identification shall be in accordance with AWS A5.28 and 3.3.2(a).

Table 3-9
Electrode and Rod Type Designation and Chemical Composition

Welding process	ALL	GMAW SAW	ALL	GMAW SAW
Type[2]	E69S-1 (100S-1) E69S-2 (100S-2)	E69S-1C (100S-1C) E69S-2C (100S-2C)	E83S-1 (120S-1) E83S-2 (120S-2)	E83S-1C (120S-1C) E83S-2C (120S-2C)
Chemical composition (weight percent)[1]				
Carbon	0.07[3]	0.07[3]	0.07[3],[4]	0.07[3],[4]
Manganese	1.25 ~ 1.8	1.25 ~ 2.5	0.90 ~ 2.35	1.4 ~ 3.8
Silicon	0.20 ~ 0.55	0.20 ~ 0.55	0.60	0.20 ~ 0.55
Phosphorus	0.012	0.012	0.012	0.012
Sulfur	0.008	0.010	0.008	0.010
Nickel	1.4 ~ 2.10	1.4 ~ 2.10	1.00 ~ 3.0	1.00 ~ 3.5
Molybdenum	0.25 ~ 0.55	0.25 ~ 0.55	0.30 ~ 1.00	0.30 ~ 1.00
Chromium	0.30	0.30	0.80	0.60
Vanadium	0.05	0.04	0.03	0.04
Aluminum	0.10	0.05	0.10	0.05
Titanium	0.10	0.10	0.10	0.10
Zirconium	0.10	0.10	0.10	0.10
Copper	[5],[6],[7]	[5],[6],[7]	[5],[6],[7]	[5],[6],[7]
Boron	[7]	[7]	[7]	[7]

Notes:
(1) Wherever single values are shown, they are maximum values. Values apply to bare electrode, rod, or weld deposit as specified in 3.3.3(b).
(2) Including applicable suffixes (see 3.3.3(a)(i)).
(3) Addition of the suffix SA to CR-E69S and CR-E83S (MIL-100S and MIL-120S) designation, for example CR-E83S-1SA (MIL-120S-1SA), indicates a special type electrode intended for SAW only. Other requirements of this Guidelines which apply to a basic type shall also apply to the special counterpart with higher carbon content, except the maximum carbon content for CR-E69S-1SA and CR-E69S-1SA (MIL-100S-1SA and MIL-100S-2SA) shall be 0.08 percent; for CR-E83-1SA, CR-E83S-2SA and CR-E83S-2CSA (MIL-120-1SA, MIL-120S-2SA and MIL-120S-1CSA) shall be 0.084 percent; and for CR-E83S-2CSA (MIL-120S-2CSA) shall be 0.090 percent.
(4) Check analysis after purchase must be not greater than 0.003 weight percent higher.
(5) When the basic type electrode or rod has a copper coating in accordance with 3.3.3(a)(i)(1), the maximum weight percent of copper in the electrode or rod due to the coating and the residual copper content in the steel shall be 0.30 percent maximum. When more than one production line is being used to deposit copper coating on a single lot of electrodes or rods, a sampling plan must be in place to incorporate material from all production lines in the chemical analysis
(6) Addition of the suffix RC to any basic designation, for example, CR-E69S-1RC (MIL-100S-1RC), indicates a special type of electrode or rod, which is not copper coated and for which the copper shall be 0.10 percent maximum. Other requirements of this Guidelines, which apply to a basic type shall also apply to the special counterpart with the restricted copper content.
(7) Copper (except for copper coated and suffix RC electrodes) shall be reported for information only. Boron shall be analyzed to the parts per million (ppm) level, reported for information and for use in calculating the carbon equivalent.
(8) When specified by the purchaser, a 0.05% maximum chromium content in the bare electrode or rod (not weld deposit) may be required for control of hexavalent chromium in fumes.

Table 3-10
Mechanical Properties for As-welded SAW, GMAW and GTAW Welds[1],[9]

Type[2]	E69S-1 / E69S-1F (100S-1/100S-1F) E69S-2 / E69S-2F (100S-2/100S-2F)	E83S-1 / E83S-1F (120S-1 / 120S-1F) E83S-2 / E83S-2F (120S-2 / 120S-2F)
Yield Strength (MPa)	565 ~ 827[3],[9]	703 ~ 848[3],[4],[9]
Elongation in gauge length (at least 51 mm) min. (percent)	16	15
Transverse side bend	[5]	[5]
CVN Energy Joules minimum average at Temperature (degrees centigrade) (˚C)	47 Joules at (-51˚C)[6] 81 Joules at (-18˚C)[6]	61 Joules at (-51˚C)[6] 81 Joules at (-18˚C)[6]
Explosion test series	[8]	[8]

Notes:
(1) The ultimate tensile strength and percentage reduction of area shall be recorded for information only.
(2) Including applicable suffixes (see 3.3.3(a)).
(3) These values are minimum and maximum averages determined by testing all specimens required from each qualification and conformance test weld.
(4) Maximum yield strength shall be 862 MPa when specified in purchase order. Single values shall be not less than 690 MPa or greater than 862 MPa, or, when specified in purchase order, 896 MPa.
(5) The convex surface of the specimen shall have no cracks or other indications exceeding 3.2 mm. Tears less than 3.2 mm on the corners of the bend specimen are acceptable.
(6) For each testing temperature, the average value shall be determined based on five tests. Only one test specimen may have a value below the minimum average specified; such a test specimen may have a value no more than 14 Joules below the minimum average specified.
(7) For high cooling rate tests of CR-E83S (MIL-120S) types, the average CVN toughness at -51°C shall be not less than 54 Joules.
(8) Acceptance criteria shall be in accordance with Appendix 1.
(9) The check tolerance for receipt inspection (see 3.1.8(d) and 3.1.8(e)) cannot be used on the maximum yield strength requirement for CR-E69S or CR-E83S (MIL-100S or MIL-120S type) welding materials.

Table 3-11
Diffusible Hydrogen Values[1]

Type[2]	Welding process	Maximum Average	Maximum single Value[3]
E69S-1 (100S-1)	GMAW	4.0	4.8
E69S-1 / E69S-1F (100S-1/100S-1F)	SAW	5.5	6.7
E69S-2 (100S-2)	GMAW	2.6	3.4
E69S-2 /E69S-2F (100S-2/100S-2F)	SAW	3.0	3.8
E83S-1 (120S-1)	GMAW	4.0	4.8
E83S-1 / E83S-1F (120S-1 / 120S-1F)	SAW	5.5	6.7
E83S-2 (120S-2)	GMAW	2.6	3.4
E83S-2 / E83S-2F (120S-2 / 120S-2F)	SAW	3.0	3.8

Notes:
(1) Diffusible hydrogen control plan see 3.1.4(e)(i).
(2) Including applicable suffixes (see 3.3.3(a)).
(3) Refers to the highest single value determined in a set of 4 tests per AWS A4.3.

3.3.4 Test assemblies for approval test

Electrodes selected for approval tests shall be used for tests specified in Table 3-12. For each lot of material, sufficient samples shall be selected to perform the tests listed. Test assemblies shall be prepared in accordance with Table 3-13, 3-14, 3-15, 3-16, and 3-17, as applicable. Schedule A tests shall be conducted by the manufacturer, and upon successful completion of these tests, schedule B testing will be conducted at a recognized test facilities accepted by the Society. Both Schedule A and Schedule B tests are to be carried out in the presence of the Surveyor.

Table 3-12
Summary of Test Required for Approval Test(1),(2),(3)

Test	Schedule		Test procedures	Requirements
	A	B(9)		
Cast(4)	X	---	AWS A5.28(7)	AWS A5.28(7)
Helix(4)	X	---	AWS A5.28(7)	AWS A5.28(7)
Chemical analysis	X	---	AWS A5.28, 3.3.3(b) and 3.1.4(c)(i)(8)	Table 3-9
Alloy identity	X	---	AWS A5.01	AWS A5.01
Diffusible hydrogen	X	---	AWS A4.3(6)	3.3.3(f) and Table 3-11
Moisture testing	X	X(10)	AWS A4.4 and 3.3.4(a)(ii)	3.3.3(g)
Welded test assembly	X	X	3.3.4	Fig. 3-2 or Both Fig. 3-2 and 3-3
Nondestructive testing	X	X	3.1.4(f)(i) and 3.1.4(f)(ii)	3.1.4(f), 3.1.4(f)(i) and 3.1.4(f)(ii)
Visual and dimensional examination	X	X	3.3.3(h)	3.3.3(h)
Tension	X	X	AWS B4.0	Table 3-10
Transverse side bend	X	X	AWS B4.0	Table 3-10
CVN(5)	X	X	AWS B4.0	Table 3-10
Explosion test series	---	X	3.3.4(b)	Table 3-10

Notes:

(1) The brand name of flux used in Schedule A and B testing shall be specified in the approval test reports.

(2) Applicable to all electrode types (see 3.3.3(a))

(3) Use SAW with a qualified electrode to qualify neutral granular fluxes for the as-welded condition.

(4) Not applicable to straight-cut rod electrodes.

(5) See Fig. 3-2 and 3-3 and their associated tables for requirements on CVN testing.

(6) For electrodes to be approved for use with the GMAW process, diffusible hydrogen specimens shall be prepared in the flat position using the spray transfer mode, C-5 (5% CO2 / 95% Ar) shielding gas, 13 mm gas cup inner diameter, 35cfh gas flow, using mechanized or automatic welding methods. The power supply shall be constant potential with no oscillation. Torch angle shall be perpendicular to the test specimen. Instrumentation shall be an in-line ammeter and a voltmeter sensing voltage between the wire feeder drives rolls and the test assembly fixture (see 3.1.6(c)).

Wire feed speeds shall be as specified below. The voltage shall be adjusted to produce a short arc length without electrode stubbing or excessive spatter. In general, the proper arc can be obtained by bringing the voltage to the point where stubbing begins, then gradually increasing the voltage to the point where no stubbing occurs and the arc has a "crackling" sound.

The following welding parameters shall be used. If the voltage or current varies significantly (i.e. 1 volt or 10 amps) from the ranges shown, the actual parameters and the justification for the deviation shall be submitted to the Society for approval. Travel speed shall be adjusted to obtain a nominal bead width of 16 mm ± 1.6 mm.

1.2 mm dia. Electrode

Voltage at wire feeder	=	25.5 to ~26.5 V
Current - bare wire	=	240 to ~260 A
Current - copper plated	=	260 to ~280 A
Electrode stick out	=	16 ± 1.6 mm
Wire feed speed	=	80.4 ~ 84.7 mm/sec

1.6 mm dia. Electrode

Voltage at wire feeder	=	25.5 to ~26.5 V
Current - bare wire	=	315 to ~325 A
Current - copper plated	=	335 to ~345 A
Electrode stick out	=	16 mm ± 1.6 mm
Wire feed speed	=	125.3 ~ 129.5 mm/sec

Similar parameters, appropriately adjusted by the manufacturer, shall be used with other sizes.

(7) AWS A5.28 applies to electrodes used for all welding processes, except use AWS A5.23 for 2.4 mm and larger electrodes.
(8) See AWS A5.23 in the case of alloy cored electrodes used with SAW.
(9) Feedability will be evaluated based on standard shipyard practices during schedule B testing.
(10) If the manufacturer's testing laboratory or facility with proper quality control procedures (such as ISO 9000 series qualification) accepted by the Society, the moisture testing could only be conducted in Schedule A.

(a) Samples for approval tests

(i) Electrode samples

(1) E69S and E83S (100S and 120S) materials

For each type electrode to be approved, one spool (300 mm or larger), multiple spools less than 300 mm, or one coil (29.5 kg and under), of the appropriate electrode size(s) specified in Table 3-13 shall be tested. The spool(s) (or coil) and the electrode size(s) tested shall be representative of the cleaning method used for all forms and for the range of sizes to be approved (see Table 3-13). If more than one cleaning method is used for the sizes to be approved, all details for cleaning methods shall be submitted to the Society. When an electrode is to be approval tested for the SAW process, the manufacturer shall furnish a sample of the flux. All samples shall be selected in the presence of the Surveyor.

- Bare solid electrode sample

  Approval obtained for the electrode size(s) tested qualifies the same type electrode for the size range indicated in Table 3-13.

- Alloy-cored electrode sample

  When tested using the GMAW process, approval obtained for the 1.6 mm size electrode qualifies all sizes smaller than 2.4 mm of the same type. Unlike GMAW, 1.6 mm alloy-cored electrode is not normally used for SAW. Therefore, when tested using the SAW process, approval obtained for the 3.2 mm size electrode qualifies all sizes 3.2 mm and larger for the same type that are made to the same formulation.

(ii) SAW flux sample

The flux sample selected for approval test (see Table 3-12 and Table 3-18) shall be at least 45.5 kg supplied in sealed containers. When both schedule A and schedule B tests are to be conducted, at least 91 kg of flux in at least two sealed containers shall be selected at the same time. Half of the flux shall be used for the schedule A tests while the remainder shall be used for the schedule B tests. The container or containers of flux shall remain unopened until the start of welding. The sample for moisture content testing shall be removed from the top of a previously unopened container.

(iii) Electrodes for as-welded applications

For electrodes and rods for as-welded applications, the welding parameters, welding position, welding process and test assembies shall be in accordance with Fig. 3-2 and Fig. 3-3, Table 3-13, Table 3-16 and Table 3-17.

(iv) Fluxes

For approval, CR-E69S-1F, CR-E69S-2F, CR-E83S-1F, and CR-E83S-2F (MIL-100S-1F, MIL-100S-2F, MIL-120S-1F, and MIL-120S-2F) flux types shall be used in combination with a corresponding type electrode to deposit weld metal by the SAW process, and the weldments tested in the as-welded condition. Welding parameters, welding position, and welding process shall be in accordance with Fig. 3-2 and Fig. 3-3 and Table 3-13.

(v) Alloy-cored electrode

Test assemblies shall be made in accordance with 3.3.4(a)(iii), as applicable. When alloy-cored electrodes are tested using the SAW process, the same brand name flux that was used in qualification shall be used.

(vi) Electrode and flux combinations

For approval testing of CR-E83S (MIL-120S) type electrodes for the SAW process, each specific brand name electrode and flux combination shall be tested and listed as a unique combination on CR Lists of Approved Marine Products.

(vii) Base metal

Unless otherwise specified, the base metal steel used for the tests required herein shall be in accordance with Table 3-14.

(b) Explosion crack starter

Two crack starter tests shall be conducted and two prolongation assemblies shall be prepared for determination of mechanical properties.

(i) CR-E69S and CR-E83S (MIL-100S and MIL-120S) material

(1) The base plate shall be in accordance with Table 3-14.

(2) Dimensions of the test assemblies shall be as specified in Appendix 1.

(3) The preheat and interpass temperature shall be 121 ±13.9°C.

(4) The welding heat input shall be 4.4 kJ/mm minimum for CR-E69S (MIL-100S) and 2 ~ 2.4 kJ/mm for CR-E83S (MIL-120S).

(5) Peening of weld beads shall not be permitted.

(6) The test assembly shall be prepared by using welding sequence and techniques recommended by the manufacturer which shall be reported.

(7) The joint surface shall not be clad or buttered.

(8) The joint surface shall not be clad or buttered.

(9) The weldments shall be fabricated using the welding position and electrode diameter specified in Table 3-15.

(10) The tests shall be conducted at -18°C in accordance with Appendix 1.

(ii) Prolongation assembly

The prolongation assembly shall be tested in accordance with Appendix 1.

(c) Special instructions

When applying for approval test or durring approval test, the manufacturer shall furnish the following information. This information, together with test results obtained from the sample, shall form a part of the approval test.

(i) Bare solid electrode, single heat lot

For bare solid electrode, conforming to AWS A5.01 classification S3 (without the requirement that the electrodes be from one production cycle), the following information shall apply:

(1) Type and size under which approval is desired.

(2) Composition of wire in terms of nominal percentages for each constituent. (See Note (1))

(3) Composition of the deposited weld metal.

(4) Shielding gas composition.

(5) Recommended amperages for each weld test.

(6) Brand name of electrode and, when applicable, brand name of flux.

(7) Residual drawing lubricant and/or arc enhancer or feeding lubricant left on the wire and its effect on diffusible hydrogen and moisture pickup on exposure. (See Note (1))

(8) Cleaning method. (See Note (1) and 3.3.4(a)(i)(1))

Note (1) Information shall be maintained at the manufacturer's plant for audit purposes; need not be submitted.

(ii) Bare solid electrode, chemical control lot

For bare solid electrode, conforming to AWS A5.01 classification S4 in addition to the information in 2.3.4(c)(i), the following shall be furnishe:

(1) Chemical composition control limits in wire of each type electrode. (See Note (1))

(2) Production line methods used to produce electrodes from chemically controlled core wire. (See Note (1))

(3) Method of determining wire chemistry.

Note (1) Information shall be maintained at the manufacturer's plant for audit purposes; need not be submitted.

(iii) Alloy-cored electrode, batch control lot

For alloy-cored electrode, conforming to AWS A5.01 classification T3, the following information shall be furnished:

(1) The type and size range (each size manufactured shall be specified) for which approval is desired.

(2) Composition of tube, or strip, and flux ingredients in terms of nominal percentages for each constituent. (See Note (1))

(3) Composition of deposited weld metal.

(4) Recommended amperage for each weld test and size of electrode to be approval tested.

(5) Brand name.

(6) Residual drawing lubricant and/or arc enhancer or feeding lubricant left on the wire and its effect on diffusible hydrogen and moisture pickup on exposure. (See Note (1))

Note (1) Information shall be maintained at the manufacturer's plant for audit purposes; need not be submitted.

(iv) Alloy-cored electrode, chemical control lot

For alloy-cored electrode, conforming to AWS A5.01 classification T4, the following information shall be furnished:

(1) The type and size range (each size manufactured shall be specified) for which approval is desired.

(2) Chemical composition control limits for mill coil. (See Note (1))

(3) Method of determining chemical composition of the mill coil.

(4) Production line quality control methods used in producing electrodes from chemically controlled mill coil. (See Note (1))

(5) Percent allowable variation (disclosed) from standard (not disclosed) for each formulated chemical element in the mix of chemically controlled welding material for each type electrode.

(6) Method of determining chemical composition of the mix of the chemically controlled welding material.

(7) Production line quality control methods used in producing electrodes from chemically controlled flux material. (See Note (1))

(8) Recommended amperage for each weld test, and size of electrode to be approval tested.

(9) Brand name.

(10) Residual drawing lubricant and/or arc enhancer or feeding lubricant left on the wire and its effect on diffusible hydrogen and moisture pickup on exposure. (See Note (1))

Note (1) Information shall be maintained at the manufacturer's plant for audit purposes; need not be submitted.

(v) SAW flux

For SAW granular neutral flux, conforming to AWS A5.01 classification F2, the following information shall be provided:

(1) The type of flux for which approval is desired.

(2) Percentage allowable variation (disclosed) from standard (not disclosed) for each formulated chemical element in the chemically controlled flux for each type.

(3) Method of determining chemical composition of the chemically controlled flux. (See Note (1))

(4) Production line quality control methods used in producing the chemically controlled flux. (See Note (1))

(5) Brand name.

Note (1) Information shall be maintained at the manufacturer's plant for audit purposes; need not be submitted.

(vi) Change control procedure

The manufacturer shall document the criteria and procedure for verifying the acceptability of any changes, which may be made in key processes after approval of the product that may affect the design or performance of the product. The change control procedure shall be maintained at the manufacturer's plant for the Society audit purposes and need not be submitted. Any changes, which are determined necessary to a process that negatively affect the acceptable performance of the product shall be submitted to the Society for concurrence with the supporting data to show acceptability.

Table 3-13
Welding Parameters for As-welded Application[1],[2],[3],[10],[11],[13],[14]

Welding Parameters for Approval Tests								
Type	E69S-1, E69S-2 (100S-1, 100S-2)				E69S-1, E69S-1F, E69S-2, E69S-2F (100S-1, 100S-1F, 100S-2, 100S-2F)			
Electrode size tested (mm)	1.2[5]		1.6[5]		1.6[8]		2.4 or 3.2[5]	
Size range qualified (mm)	0.5 ~ 1.2		1.4 ~ 2.0		1.6		2.4 ~ 6.4	
Welding process	Pulsed arc GMAW		Spray GMAW		SAW		SAW	
Position	Vertical up		Flat		Flat		Flat	
Cooling rate[6]	High	Low	High	Low	High	Low	High	Low
Heat input (kJ/mm)[7]	1.4	4.4	1.2	4.4	1.6	4.4	1.6	4.4
Preheat and interpass temperature (°C)	52 ~ 66	107 ~ 135	52 ~ 66	107 ~ 135	52 ~ 66	107 ~ 135	52 ~ 66	107 ~ 135

Type[4]	E83S-1, E83S-2 (120S-1, 120S-2)						E83S-1, E83S-1F, E83S-2, E83S-2F (120S-1, 120S-1F, 120S-2, 120S-2F)			
Electrode size tested (mm) [5]	1.2				1.6		1.6		2.4	
Size range qualified (mm)	0.5 ~ 1.2				1.4 ~ 2.0		1.4 ~ 2.0		2.4 ~ 6.4	
Welding process	Pulsed arc GMAW		Spray GMAW		Spray GMAW		SAW		SAW	
Position	Vert. up	Flat	Flat		Flat		Flat		Flat	
Cooling rate[6]	High	Low	High	Low	High	Low	High	Low	High	Low
Heat input (kJ/mm)[7]	1.36	1.8	1.24	1.92	1.24	1.92	1.6	2.0	1.6	2.0
Preheat and interpass temperature (°C)	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163

Welding Parameters for Quality Conformance Tests												
Type	E69S-1 (100S-1) E69S-2 (100S-2)				E69S-1 (100S-1) E69S-1F (100S-1F) E69S-2 (100S-2) E69S-2F (100S-2F)		E83S-1 (120S-1) E83S-2 (120S-2)				E83S-1 (120S-1)[4] E83S-1F (120S-1F) E83S-2 (120S-2)[4] E83S-2F (120S-2F)	
Electrode size tested (mm) [5]	Each size 1.2 and smaller[12]		Each size 1.4 and larger		Each size		Each size 1.2 and smaller		Each size 1.4 and larger		Each size	
Size range certified (mm)	Size tested		Size tested		Size tested		Size tested		Size tested		Size tested	
Welding process	Spray GMAW	Pulsed arc GMAW	Spray GMAW		SAW		Spray GMAW	Pulsed arc GMAW	Spray GMAW		SAW	
Position	Flat	Vert. up	Flat		Flat		Flat	Vert. up	Flat		Flat	
Cooling rate[6]	High	Low	High	Low	High	Low	High[9]	Low	High	Low	High	Low
Heat input (kJ/mm)[7]	1.2	4.4	1.2	4.4	1.6	4.4	1.12	1.8	1.24	1.92	1.6	2.0
Preheat and interpass temperature (°C)	52 ~ 66	107 ~ 135	52~ 66	107 ~ 135	52 ~ 66	107 ~ 135	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163

Notes:
(1) Weldments shall be tested in the as-welded condition without any heat soaking for hydrogen removal.
(2) Alternate welding parameters may be used for approval or quality conformance testing when approved by the Society.
(3) Including applicable suffixes 3.3.3(a).

(4) For approval tests and quality conformance tests of CR-E83S (MIL-120S) types, electrodes or rods representing the highest carbon equivalent (see 3.1.4(c)(i)) in the heat shall be used for high cooling rate tests and electrodes representing the lowest carbon equivalent shall be used for low cooling rate tests. Test weld assemblies shall be fabricated using electrodes representing the extremes of measured carbon equivalent.

(5) Qualification of the approved size will qualify all of the electrodes in the size range specified.

(6) For CR-E69S (MIL-100S) types, test plates shall be in accordance with Fig. 3-2 for both low cooling rate tests and high cooling rate tests.
For CR-E83S (MIL-120S) types, test plates shall be in accordance with Fig. 3-2 for the low cooling rate test and in accordance with Fig. 3-3 for high cooling rate tests.
For high cooling rate CR-E83S (MIL-120S) test assemblies, results from each side shall be reported separately, with side 1 depicting results from the first side welded.
Failure of either side shall constitute failure of the entire test assembly. Alternatively, high cooling rate quality conformance testing of type CR-E83S (MIL-120S) may be performed using test assemblies in accordance with Fig. 3-2 when approved by the Society, provided these conditions are observed:
  (a) Test data from both Fig. 3-2 and Fig. 3-3 test plates demonstrate comparability with respect to cooling rate and performance.
  (b) Written test quality conformance test procedures submitted for approval establish welding parameter controls and comparative differences in acceptance criteria for Fig. 3-2 test plates.
  (c) When both test plates are tested, results from the Fig. 3-3 test plates shall be the authoritative results.

(7) See 3.1.6(g). Average heat input shall fall within 0.08 kJ/mm of the heat input specified. Further, the operational heat input of at least 80% of all individual passes shall be within 0.08 kJ/mm of the specified heat input. No pass shall have an operational heat input more than 0.28 kJ/mm from the specified heat input. A weld pass shall be defined as one bead extending from the beginning to the end of the test assembly.

(8) The 1.6 mm diameter electrode is intended for twin arc SAW.

(9) This test shall be conducted in accordance with the requirements of Fig. 3-2 on 25.4 mm thick plate at the high cooling rate.

(10) The weld sample shall be allowed to sit undisturbed for 48 hours before any cutting or testing of any kind is performed.

(11) When steel conforming to Chapter 2 is specified the high cooling rate weld shall be prepared using a 16°C minimum preheat temperature and a 52°C maximum interpass temperature.

(12) Electrode sizes 0.9 mm and smaller shall be tested at a minimum heat input of 2.2 kJ/mm for the low cooling rate condition, unless otherwise specified by the purchaser.

(13) Purchasers of products for the GTAW process shall define required testing parameters in the purchase order.

(14) See 3.1.6 for additional welding requirements.

Table 3-14
Base Metal Requirements

Types(1)	Base metal
E69S-1 (100S-1) E69S-1F (100S-1F) E69S-2 (100S-2) E69S-2F (100S-2F)	CRHS-56 or CRHS-70 in accordance with Chapter 2.
E83S-1 (120S-1) E83S-1F (120S-1F) E83S-2 (120S-2) E83S-2F (120S-2F)	CRHS-70 in accordance with Chapter 2.

Notes:
(1) Including applicable suffixes (see 3.3.3(a)).

Table 3-15
Welding Parameters for Explosion Crack Starter Tests(1)

Qualification electrode size (mm)	Welding process	Position	Size range qualified
			E69S – E83S (100S-120S)
1.2	Pulsed-arc GMAW	Vertical up	0.5 ~ 1.2 mm
1.6	Spray-arc GMAW	Flat	1.4 ~ 2.0 mm
3.2	SAW	Flat	2.4 ~ 6.4 mm

Notes:
(1) For alloy-cored electrodes, the qualification electrode size and size range qualified refer to 3.3.4(a)(i)(1).

Table 3-16
Welded Test Assembly for CR-E69S (MIL-100S) Low and High Cooling Rate Test and for CR-E83S (MIL-120S) Low Cooling Rate Test(6)

Type	E69S (100S)		E83S (120S)	
Purpose	Approval test	Quality conformance test	Approval test	Quality conformance test
Welding process	All	All	All	All
Stress relief	(1)	(1)	(1)	(1)
Base material	Table 3-14	Table 3-14	Table 3-14	Table 3-14
Welding parameters	(2)	(2)	(2)	(2)
Shielding gas	(3)	(3)	(3)	(3)
Cooling rate	High and low	High and low	Low	Low
Joint configuration	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2
Thickness (T) (mm)	25	25	19	19
Width (W) (mm)	381 min.	381 min.	381 min.	381 min.
Length (L) (mm)(5)	762 min.	610 min.	762 min.	610 min.
Root opening (R) (mm)	13 min.	13 min.	13 min.	13 min.
Root face (F) (mm)	0 ~ 1.6	0 ~ 1.6	0 ~ 1.6	0 ~ 1.6
Included angle (θ) (degree)	45	45	45	45
Backing strap size (B) (mm)	13 x 38	13 x 38	13 x 38	13 x 38
Test specimens (number/type)	From each weld: 2 tension, 2 bend, 10 CVN(4)	From each weld: 2 tension, 10 CVN(4)	From each weld: 2 tension, 2 bend, 10 CVN(4)	From each weld: 2 tension, 10 CVN(4)

Notes:
(1) Welded test assemblies shall not be stress relieved. Heat soaking for hydrogen removal is prohibited.
(2) The welding-heat input shall be as specified in Table 3-13. The preheat and interpass temperature shall be in accordance with Table 3-13. When CR-E69S (MIL-100S) tests are conducted with Chapter 2 or ASTM A710 steel the minimum preheat and maximum interpass temperatures for the high cooling rate test shall be 16 and 52°C, respectively.
(3) Shielding gas shall be argon for GTAW and argon plus 2 percent oxygen for GMAW welding electrodes. Argon plus 5 percent CO_2 may also be used for GMAW welding electrodes. For MIL-120S, shielding gas for GMAW shall be either argon plus 2 percent oxygen or argon plus 5 percent CO_2, as specified. The neutral granular flux for the SAW process shall be in accordance with 3.3.4(a)(iv), whichever is consistent with the type electrodes being tested.
(4) Tensile specimens shall be all weld metal (longitudinal axis of the specimen shall be parallel to the welding direction) and shall be centered in the weld metal at 9.5 mm below the surface of the test plate. CVN specimens shall have the notch perpendicular to the welded assembly top surface, shall be centered in weld metal, and the top surface of each specimen shall be 1.6 mm below the top surface of the welded test assembly. No specimens shall be removed from within 19 mm of the ends of the welded test assembly. See Fig. 3-4 for more specimen location information.

(5) For retests, when tensile and impact properties do not both need to be retested, the length of the plate may be decreased below the minimum length, but shall not be less than 610 mm.
(6) See 3.1.6 for additional welding requirements.

Table 3-17
Welded Test Assembly for CR-E83S (MIL-120S) High Cooling Rate Tests(6)

Type	E83S (120S)	
Purpose	Approval test	Quality conformance test
Welding process	All	All
Stress relief	(1)	(1)
Base material	Table 3-14	Table 3-14
Welding parameters	(2)	(2)
Shielding gas	(3)	(3)
Cooling rate	High	High
Joint configuration	Fig. 3-3	Fig. 3-3
Thickness (T) (mm)	51	51
Width (W) (mm)	381 minimum	381 minimum
Length (L) (mm)(5)	762 minimum	610 minimum
Root opening (R) (mm)	0 ~ 4.8	0 ~ 4.8
Root face (F) (mm)	0 ~ 1.6	0 ~ 1.6
Included angle (θ) (degrees)	45	45
Backing strap dimensions	N.A.	N.A.
Test specimens (number/type)	From each side: 2 tension, 2 bend, 10 CVN(4)	From each side: 2 tension, 10 CVN(4)

Notes:
(1) Welded test assemblies shall not be stress relieved. Heat soaking for hydrogen removal is prohibited.
(2) The welding heat input shall be as specified in Table 3-13.
(3) Shielding gas shall be argon for GTAW, and argon plus 2 percent oxygen for GMAW welding electrodes. Argon plus 5 percent CO_2 may also be used for GMAW welding electrodes. For MIL-120S, shielding gas for GMAW shall be either argon plus 2 percent oxygen or argon plus 5 percent CO_2, as specified. The neutral granular flux for the SAW process shall be in accordance with 3.3.4(a)(iv), whichever is consistent with type electrodes being tested.
(4) Tensile specimens from each side shall be all weld metal (longitudinal axis of the specimen shall be parallel to the welding direction) and shall be centered in the weld metal at 9.5 mm below the surface of side represented by the specimen. CVN specimens from each side shall have the notch perpendicular to the welded assembly top surface, shall be centered in weld metal, and the top surface of each specimen shall be 1.6 mm below the surface of the side of the welded test assembly represented by the specimen. No specimens shall be removed from within 19 mm of the ends of the welded test assembly. Specimen location from each side shall be as illustrated in Fig. 3-4(A).
(5) For retests, when tensile and impact properties do not both need to be retested, the length of the plate may be decreased below the minimum length, but shall not be less than 610 mm.
(6) See 3.1.6 for additional welding requirements.

3.3.5 Quality conformance tests

Quality conformance tests shall be performed in accordance with Table 3-18. For each lot of material, sufficient samples shall be selected to perform the tests listed. Test assemblies shall be prepared in accordance with Tables 3-13, 3-14, 3-16 and 3-17, as applicable. Quality conformance tests shall be conducted by the manufacturer in the presence of the Surveyor.

(a) Lot definition

(i) Bare solid electrodes

For the purposes of quality conformance test, a lot of electrodes shall be the quantity of one type alloy produced as specified in 3.3.4(c)(i) or 3.3.4(c)(ii). In addition, for chemical composition control lots,

mill coils conforming to established wire chemistry control for a specific type of electrode shall be appropriately identified and segregated to avoid mix-ups.

(ii) Alloy-cored electrodes

For the purposes of quality conformance tests, a lot of electrodes shall be the quantity of one type alloy produced as specified by either Class T3 (core batch control) not exceeding 11340 kg of electrodes or Class T4 (core composition control) of AWS A5.01 not exceeding 45000 kg of electrodes.

(iii) Submerged arc flux

For the purposes of quality conformance inspection, a lot shall consist of all flux of one type and as specified by Class F2 of AWS A5.01.

(b) Test assemblies for quality conformance tests

(i) Fluxes

For quality conformance test, test assemblies shall be made in combination with a corresponding type electrode in accordance with 3.3.4(a)(iii), as applicable.

(ii) Electrode and flux combinations

For conformance testing of CR-E83S (MIL-120S) type electrodes with the SAW process, the specific brand name electrode and flux combination(s) specified shall be used for conformance testing.

(c) Sampling electrodes for visual and dimensional inspections shall be as specified in 3.1.5(a).

Where the lot of electrodes are found to comply with the requirements of approval test at the quality conformance test, the attending Surveyor authorized by the Society is to issue the Marine Product Certificate. However, where the quality of the lot of electrodes is found not complying with the properties specified in approval tests, the retests specified in 3.1.8 may be carried out. If retest also failures to meet the requirements, the lot of electrodes is to be rejected.

Table 3-18
Summary of Tests Required for Quality Conformance Tests[(1),(2),(3)]

Test	Test procedures	Requirements
Cast[(4),(6)]	AWS A5.28	AWS A5.28
Helix[(4),(6)]	AWS A5.28	AWS A5.28
Chemical analysis	AWS A5.28 and 3.1.4(c)(i)	Table 3-9
Alloy identity	AWS A5.01	AWS A5.01
Diffusible hydrogen[(5)]	AWS A4.3	3.3.3(f) and Table 3-11
Moisture content	AWS A4.4 and 3.3.4(a)(ii)	3.3.3(g)
Welded test assembly	3.3.4	Fig. 3-2 or both Fig. 3-2 and 3-3
NDT	3.1.4(f)(i) and 3.1.4(f)(ii)	3.1.4(f), 3.1.4(f)(i) and 3.1.4(f)(ii)
Visual and dimensional inspections	3.1.5(a)	3.3.3(h)
Tension	AWS B4.0	Table 3-10
Impact test (CVN)	AWS B4.0	Table 3-10

Notes:
(1) When a heat of metal is processed into electrodes and rods, weld metal tests are required only with electrodes.
(2) Applicable to all electrode types (see 3.3.3(a)).
(3) When using SAW process with a qualified electrode for quality conformance test of a lot of qualified neutral granular flux E69S-1F, E69S-2F, E83S-1F, E83S-2F (100S-1F, 100S-2F, 120S-1F, 120S-2F). A lot of electrodes and a lot of qualified granular flux can be quality conformance tested by the same set of tests.
(4) Not applicable to rods.
(5) The diffusible hydrogen test for the GMAW process shall be conducted using the spray transfer mode and the parameters presented in Note (6) to Table 3-12, or using parameters as otherwise indicated in Note (6) of Table 3-12 for other diameter electrodes.
(6) AWS A5.28 applies to all electrodes, except use AWS A5.23 for 2.4 mm and larger electrodes.

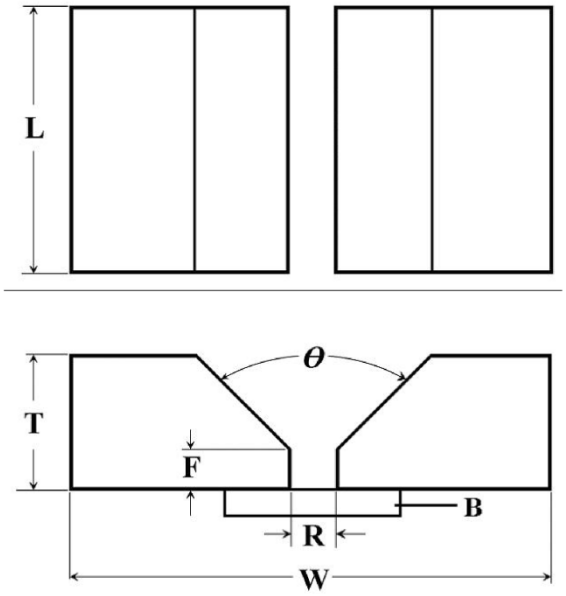


Fig. 3-2
Single-V Style Weld Joint Configuration

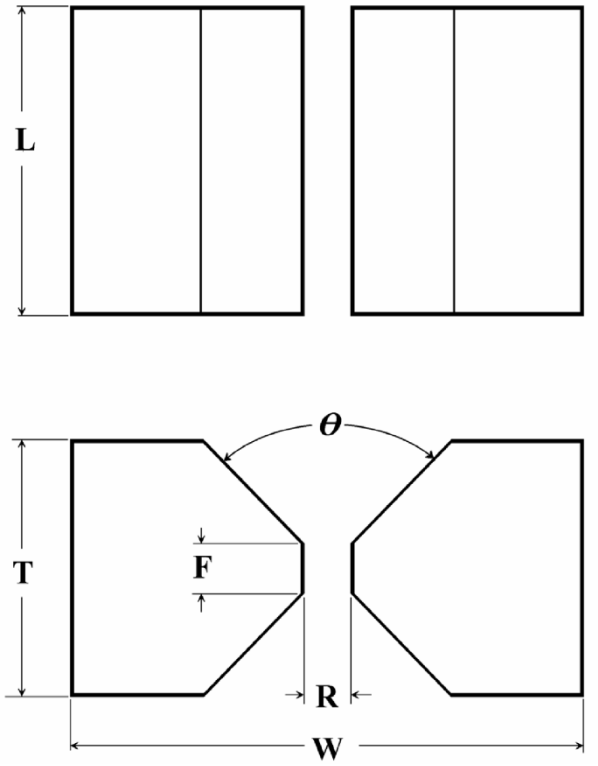
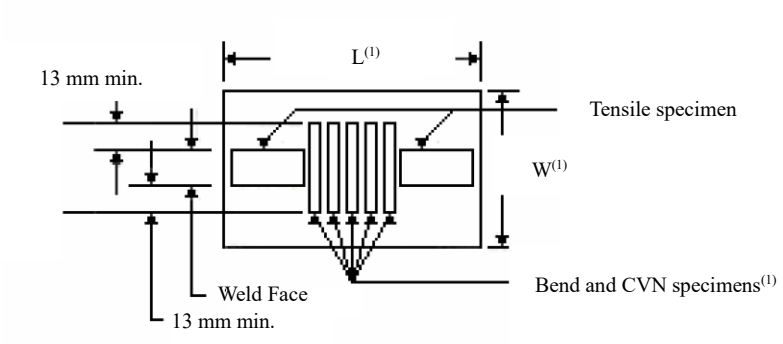
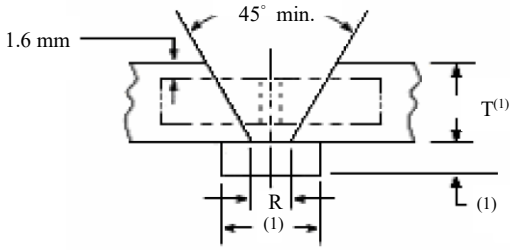


Fig. 3-3
Double-V Style Weld Joint Configuration



(A) Plan view of test specimen layout for single-V and each side of double-V test plates



(B) Groove preparation of single-V test plan showing orientation of CVN specimens

Notes:

(1) See Table 3-16 and 3-17 as appropriate. Note that no specimens shall be removed from within 19 mm of the ends of the welded test assembly.

Fig. 3-4
Welded Joint for Tensile and Impact Tests

3.4 Approval Requirements for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

3.4.1 Scope

This section covers iron-powder, low-hydrogen types of covered electrodes for the fabrication and repair welding of CRHS-56 and CRHS-70 steels for as welded applications. This section is based on AWS A5.5 and NAVSEA Technical Publication T9074-BC-GIB-010/0200.

3.4.2 Classification

Electrodes shall be of the types specified (see 3.4.3(a)), and shall be of the sizes and lengths specified in AWS A5.5.

3.4.3 Requirements for approval test

Electrodes provided under this section shall be in accordance with AWS A5.5 and as specified herein.

(a) Chemical composition

Chemical composition of deposited weld metal shall be in accordance with Table 3-19 and the approved formulation, which is bracketed by the maximum and minimum values in Table 3-19.

(b) Mechanical properties of deposited weld metal

The mechanical properties of deposited weld metal shall be as specified in Table 3-20.

(c) Coverings of electrodes

(i) Composition

The chemical composition of the electrode covering, except as specified in (ii) and (iii) below is optional with the manufacturer.

(ii) Total iron content

The total iron content of the covering, including any combined iron in addition to metallic iron powder, shall be not less than 15 percent.

(iii) Moisture content

The absorbed moisture of the covering shall be not greater than 0.10 weight percent when removed from the manufacturer's sealed container. After exposure to elevated temperature and humidity conditions as specified in AWS A5.5, the absorbed moisture of the covering shall be not greater than 0.20 weight percent. If the infrared detection method identified in AWS A4.4 is used for determining moisture content, the maximum absorbed moisture when removed from the manufacturer's sealed container shall be 0.15 weight percent and after exposure to elevated temperature and humidity as specified in AWS A5.5, the maximum absorbed moisture shall be 0.2 weight percent.

(iv) Diffusible hydrogen

The diffusible hydrogen levels in milliliters per one hundred grams (mL/100 g) of deposited weld metal shall be not greater than the following values for welds deposited with electrodes removed from sealed manufacturer's containers:

(1) Electrodes 3.2 mm size and smaller, maximum average value of 3.2 mL/100 g and maximum single value of 4.0 mL/100g.

(2) Electrodes 4.0 mm size and larger, maximum average value of 3.5 mL/100 g and maximum single value of 4.3 mL/100 g.

A diffusible hydrogen control plan in accordance with 3.1.4(e)(i) is required.

(v) Flaking and cracking of covering

The sum of the surface area of the core wire exposed by flaking and cracking of the covering shall not exceed that permitted for arc ends in accordance with AWS A5.5.

(vi) Slag characteristics

The slags deposited by the coverings shall be removable by hand tools (i.e., slag removal shall not require power tools, though power tools may be used) from the weld deposits. Slag characteristics shall be such that grinding during test plate preparation shall not be required for slag removal.

(vii) Dielectric strength

The coverings of electrodes at room temperature and in the dry condition, that is, as removed from freshly opened containers, shall have a dielectric strength that shall insulate against a difference potential of 110 volts (V), 60 hertz (Hz), alternating current (AC), unless otherwise specified by the purchaser.

(d) Electrode identification

The grade shall be indicated on each electrode. When specified, each electrode shall also be marked (in addition to the requirements of AWS A5.5) with the heat, lot, or other controlled marking code.

(e) Visual and dimensional inspections

Identification shall be in accordance with 3.4.3(d). Electrode sizes, lengths and tolerances, electrode core wire and covering quality and concentricity, electrode grip end and arc end requirements shall be in accordance with AWS A5.5.

Table 3-19
Chemical Composition (Weight Percent) of Deposited Weld Metal(1)

Element	CR-E6918-M1 (MIL-10018-M1)	CR-E7418-M (MIL-10718-M)	CR-E8318-M2 (MIL-12018-M2)
Carbon	0.06	0.07	0.07
Manganese	0.80 ~ 1.85	0.80 ~ 1.85	0.80 ~ 1.85
Silicon	0.65	0.60	0.65
Phosphorus	0.025	0.025	0.025
Sulfur	0.017	0.017	0.012
Chromium	0.40(4)	0.40(4)	0.65
Nickel	1.25 ~ 3.00	1.25 ~ 2.50	1.50 ~ 4.00
Molybdenum	0.50	0.25 ~ 0.50	0.90
Vanadium	0.05	0.05	0.05
Copper	(2)	(2) & (3)	(2) & (3)
Boron	-	(3)	(3)

Notes:
(1) Single values are maximums.
(2) When specified, use of the suffix RC with CR-E6918-M1, CR-E7418-M or CR-E8318-M2 (MIL-10018-M1, MIL-10718-M, or MIL-12018-M2), for example CR-E6918-M1-RC (MIL-10018-M1-RC), indicates that the maximum copper content of the deposited weld metal shall be 0.15 percent. The remaining basic compositional requirements remain unchanged for the specific type.
(3) Copper (except for suffix RC electrodes) shall be reported for information only. Boron shall be analyzed to the parts per million (ppm) level, reported for information and for use in calculating the carbon equivalent.
(4) When specified by the purchaser, a 0.20% maximum chromium content may be required for control of hexavalent chromium in fumes.

Table 3-20
Mechanical Properties(1),(11)

Property	Condition	CR-E6918-M1 (MIL-10018-M1)	CR-E7418-M (MIL-10718-M)	CR-E8318-M2 (MIL-12018-M2)
Yield strength (MPa)	As-welded	565 ~ 758(2)	607 ~ 841(2),(10)	703 ~ 848(2),(3)
Ultimate tensile strength (MPa)		(4)	(4)	(4)
Elongation in gauge length (at least 51mm) (%)	As-welded	20(5)	20(5)	18(5)
Transverse side bend		(6)	(6)	(6)
CVN(7) Energy Joules average at Temperature (°C)	As-welded	47 at -51°C 81 at -18°C	47 at -51°C 81 at -18°C	61 at -51°C(8) 81 at -18°C
Explosion test series		(9)	(9)	(9)

Note:
(1) Single values are minimum unless otherwise noted.
(2) Yield strength shall be the average of two test specimens with no individual value more than 14 MPa below the minimum specified value. For CR-E7418-M and CR-E8318-M2 (MIL-10718-M and MIL-12018-M2), no value shall be more than 14 MPa above the maximum specified value.
(3) When specified, the maximum yield strength may be 862 MPa and the maximum individual value may be 896 MPa.
(4) The ultimate tensile strength and reduction of area shall be recorded for information only.
(5) For high cooling rate tests, the minimum elongation for CR-E6918-M1 and CR-E7418-M (MIL-10018-M1 and MIL-10718-M) is 18 percent; for CR-E8318-M2 (MIL-12018-M2) it is 15 percent.
(6) Transverse side bend specimens after bending shall have no cracks or other indications greater than 3.2 mm in any direction on a convex surface. Tears less than 3.2 mm on the corners of the bend specimen are acceptable.
(7) The average of the five values (Three values for MIL-10718-M after discarding the high and low) shall equal or exceed the minimum average specified; one of the five (three) values may be up to 14 Joules (7 Joules for CR-

E7418-M (MIL-10718-M)) lower than the minimum average value. The remaining values must meet or exceed the minimum average specified.

(8) For high cooling rate tests of type CR-E8318-M2 (MIL-12018-M2), the minimum average CVN toughness shall be 54 Joules at -51°C.

(9) Acceptance criteria shall be in accordance with Appendix 1.

(10) A higher maximum yield strength may be approved for specific sizes of CR-E7418-M (MIL-10718-M) electrodes provided all other mechanical properties are as specified in Table 3-20 and when approved by the Society.

(11) Only yield strength check mechanical tolerance (see 3.1.8(d)) is allowed on CR-E7418-M (MIL-10718-M) electrode.

3.4.4 Test assemblies for approval test

Electrodes selected for approval shall be used for tests specified in Table 3-21. Type CR-E6918-M1 (MIL-10018-M1) shall be tested in as-welded condition. Schedule A tests shall be conducted by the manufacturer, and upon successful completion of these tests, schedule B testing will be conducted at a recognized test facilities accepted by the Society. Both Schedule A and Schedule B tests are to be carried out in the presence of the Surveyor.

(a) Samples for approval test

(i) CR-E6918-M1 (MIL-10018-M1) electrode

The test assembly shall be welded, machined, and tested as specified in Table 3-22 and Table 3-27. Heat input requirements are as follows:

(1) As specified in 3.1.6(g) and Table 3-20 and 3-27.

(2) The operational heat input of at least 80% of all individual passes shall be within the specified heat input range. No pass shall have an operational heat input more than 0.2 kJ/mm outside the specified range.

(3) Average heat input shall fall within the heat input range specified.

(ii) CR-E7418-M (MIL-10718-M) electrode

The test assembly shall be welded, machined, and tested as specified in Table 3-23 and Table 3-28. Heat input requirements are as follows:

(1) As specified in 3.1.6(g) and Tables 3-23 and 3-28.

(2) The operational heat input of at least 90% of all individual passes shall be within the specified heat input range.

(3) No pass shall have an operational heat input more than 0.2 kJ/mm outside the specified range.

(4) Average heat input shall fall within the heat input range specified.

(iii) CR-E8318-M2 (MIL-12018-M2) electrode

The test assembly shall be welded, machined, and tested as specified in Table 3-24, Table 3-29 and Table 3-30. Heat input requirements are as specified in 3.1.6(g), 3.4.4(a)(i), and Tables 3-24, 3-29 and 3-30.

(b) Explosion crack starter tests

(i) Welding parameters

Fabrication of the explosion test assemblies and mechanical property prolongation assemblies shall be in accordance with Table 3-25.

(ii) Test requirements

Two crack starter tests shall be conducted in accordance with Appendix 1. These tests shall be conducted at -18°C, unless otherwise specified. The mechanical property prolongations shall be tested in accordance with Appendix 1.

(c) Chemical analysis

Welding of chemical analysis test pads for the electrodes in (i) and (ii) below shall be as specified in AWS A5.5. In event of variances with composition requirements or conflicting results by testing activities, analysis shall be verified by procedures specified in AWS A5.5.

(i) Chemical analysis of CR-E6918-M1 (MIL-10018-M1)

For CR-E6918-M1 (MIL-10018-M1) electrodes, if chemical analysis is not determined using chemical analysis test pads welded as specified in AWS A5.5, chemical analysis shall be determined from a milling sample taken from the centerline of the broken tensile specimens or drillings, or by optical emission spectroscopy on any sample that is taken and analyzed at the depth of the tensile specimen centerline.

(ii) Chemical analysis of CR-E7418-M and CR-E8318-M2 (MIL-10718-M and MIL-12018-M2)

For each diameter of CR-E7418-M and CR-E8318-M2 (MIL-10718-M and MIL-12018-M2) electrodes, two chemistry pads per lot shall be prepared. One pad shall use electrode from the beginning of the lot and one pad shall use electrode from the end of the lot. Test results for both chemistry pads shall be reported, the values averaged, and the average shall be reported. Averaged chemical analysis values from the chemistry pads shall meet the requirements for CR-E7418-M or CR-E8318-M2 (MIL-10718-M or MIL-12018-M2), as appropriate, specified in Table 3-19 and shall determine acceptability of the lot.

In addition for each diameter of CR-E7418-M and CR-E8318-M2 (MIL-10718-M and MIL-12018-M2) electrode, electrodes from the beginning and end of each lot shall be used to prepare test welds (see Fig. 3-2 and Fig. 3-3 as appropriate). Electrodes from the beginning of the lot shall be used for the low cooling rate weld and electrodes from the end of the lot shall be used for the high cooling rate weld. The chemical analyses shall be performed on a milling sample taken from the centerline of the broken tensile specimen(s) or by optical emission spectroscopy on any weld metal sample that is taken and analyzed at the depth of the tensile specimen(s) centerline. Results of chemical analysis from the high and low cooling rate test welds (see Tables 3-23 and 3-24) shall be averaged and used to determine the carbon equivalent for the lot (see 3.1.4(c)(i)(3)). When specified, CR-E7418-M and CR-E8318-M2 (MIL-10718-M and MIL-12018-M2) electrodes representing the highest and lowest carbon equivalent lots in the order shall be identified for receipt inspection by the user.

(d) Total iron in covering

The total iron content of the covering shall be determined by wet chemical or spectrographic methods. In the case of dispute, the referee method shall be ASTM E 316.

(e) Flaking and cracking of covering

Six electrodes shall be tested for flaking and cracking tendency in accordance with (i) and (ii) below. Welding current shall be as specified in Table 3-22, 3-23 and 3-24 as appropriate. The welding shall consist of depositing a weld bead on a plate surface.

(i) Flaking and cracking during welding

Three electrodes shall be tested. The electrode shall be consumed to a stub not exceeding 51 mm in length. If flaking or cracking is observed during welding, the welding shall be stopped immediately and the arc end of the electrode examined for conformance to the requirements of 3.4.3(c)(v). If no flaking or cracking is observed during welding, the 51 mm stub length of electrode, which is normally discarded, shall not be examined.

(ii) Flaking and cracking during retest

Three electrodes shall be tested. The covering shall be grooved to the core wire completely around the electrode at the midpoint of the length. The groove shall be prepared by grinding with the edge of a grindstone (intersection of the flat side of the grindstone with its periphery). The core wire shall be uncovered at the root of the groove to form a land 1.6 mm minimum in width measured along the length of the electrode. The core wire shall not be undercut. The electrode shall be consumed to the root of the groove in the covering, at which time welding shall be stopped without fusing the coating beyond the groove. The half-length electrode shall be removed immediately from the electrode holder and placed

on a flat steel plate to cool until it can be held comfortably in the bare hand. After cooling, the electrode shall be inserted in the electrode holder and welding resumed. After the restart, the half-length electrode shall be consumed for 25 mm of its length. Welding shall then be stopped, and the arc end of the electrode examined for conformance to the requirements of 3.4.3(c)(v).

(f) Dielectric strength

Dielectric strength of coverings shall be determined by the method shown on Fig. 3-6 . Methods other than the one shown in Fig. 3-6 , yielding the required results, may be used as alternates if such methods are acceptable to the Society.

(g) Nondestructive testing

Radiographic inspection is not required for CR-E8318-M2 (MIL-12018-M2) weldments made at high cooling rates.

(h) Special instruction

When applying for approval test or during approval test, the manufacturer shall furnish the following information, as appropriate. This information, together with test results obtained with the electrode sample, shall form a part of the approval test.

(i) For covered electrode lots conforming to AWS A5.01 classification C4

(1) The lengths of the electrodes and diameters of coating and core wire.

(2) Type under which approval is desired.

(3) Composition of core wire and covering(s) in terms of nominal percentages for each constituent. (See Note (1))

(4) Composition of the deposited weld metal.

(5) Recommended amperages for each weld test. (See Note (1))

(6) Brand name.

Note (1) Information shall be maintained at the manufacturer's plant for the Society audit purposes; need not be submitted.

(ii) For covered electrode lots conforming to AWS A5.01 classification C3, in addition to the information in (i) above, the following shall be furnished for approval by the Society.

(1) Chemical composition control limits in core wire of each type electrode. (See Note (1))

(2) Method of determining core wire chemistry.

(3) Production line methods used to produce electrodes from chemically controlled core wire. (See Note (1))

(4) Procedure for control of moisture content between baking and packaging.

(5) Percent allowable variation from standard for each chemical element in the covering mixture of each type electrode. (See Note (1))

(6) Method of determining covering mixture chemistry.

(7) Production line methods used to produce electrodes from chemically controlled covering mixture. (See Note (1))

Note:

(1) Information shall be maintained at the manufacturer's plant for Government audit purposes; need not be submitted.

(iii) Change control procedure

The manufacturer shall document the criteria and procedure for verifying the acceptability of any changes, which may be made in key processes after approval of the product, that may affect the design or performance of the product. The change control procedure shall be maintained at the manufacturer's plant for the Society audit purposes and need not be submitted. Any changes, which are determined

necessary to a process that negatively affect the acceptable performance of the product shall be submitted to the Society for concurrence with the supporting data to show acceptability.

Table 3-21
Summary of Tests Required for Approval Test

Test	Schedule		Test procedures	Requirements
	A	B		
Chemical analysis	X	-	AWS A5.5, 3.1.4(c)(i) and 3.4.4(c)	Table 3-19
Total iron in covering	X	-	3.4.4(d)	3.4.3(c)(ii)
Covering flaking and cracking	X	-	3.4.4(e)	3.4.3(c)(v)
Dielectric strength	X	-	3.4.4(f)	3.4.3(c)(vii)
Alloy identity	X	X	AWS A5.01	AWS A5.01
Covering moisture	X	X(4)	AWS A4.4	3.4.3(c)(iii)
Diffusible hydrogen	X	X(4)	AWS A4.3	3.4.3(c)(iv)
Welded test assembly	X	X	3.4.4	Fig. 3-2 and Fig. 3-3
NDT of CR-E7418-M (MIL-10718-M)	X	X	3.1.4(f)	3.1.4(f)
NDT of CR-E6918-M1 and CR-E8318-M2 (MIL-10018-M1 and MIL-12018-M2)	X	X	3.1.4(f)(i) and 3.4.4(g)	3.1.4(f)(i)
Visual and dimensional inspection	X	X	3.4.3(e)	3.4.3(e)
Tension(1)	X	X	AWS B4.0	Table 3-20
Transverse side bend	X	X	AWS B4.0	Table 3-20
Impact test (CVN)(1),(2)	X	X	AWS B4.0	Table 3-20
Explosion test series(3)	-	X	3.4.4(b)	Table 3-20

Notes:
(1) Tests shall be conducted for the as-welded condition for all electrodes.
(2) See Fig. 3-2 and Fig. 3-3 and their associated tables for requirements on impact (CVN) tests. Table 3-27, 3-28, 3-29 and 3-30 specify when impact test (CVN) is required.
(3) When explosion testing is required, all sizes shall be approval tested in accordance with Appendix 1. However, when qualifying a smaller size electrode of a type previously qualified, if the Society determines the results of the mechanical property tests indicate that the weld metal properties are equivalent to the larger size electrode previously qualified, the explosion crack starter test shall be omitted.
(4) If the manufacturer's testing laboratory or facility with proper quality control procedures (such as ISO 9000 series qualification) accepted by the Society, the covering moisture and diffusible hydrogen testing could only be conducted in Schedule A.

Table 3-22
Welding Parameters for CR-E6918-M1 (MIL-10018-M1) Weld Metal Test Assemblies[1],[2]

Type	E6918-M1 (10018-M1)													
Base metal	CRHS-56 steel in accordance with Chapter 2													
Electrode size tested (mm)	2.4		3.2		4.0		4.8		5.6		6.4		8.0	
Welding processes	SMAW		SMAW		SMAW		SMAW		SMAW		SMAW		SMAW	
Position	Vert. up	Flat	Vert. up	Flat	Vert. up	Flat	Flat		Flat		Flat		Flat	
Welding current (± 5%) (A) [3]	95	95	[4]	140	[4]	170	[4]	225	[4]	300	[4]	350	[4]	430
Plate thickness (T) (mm)	25	19	25	19	25	19	25	19	25	19	25	19	25	19
Cooling rate	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Joint configuration[6]	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2
Heat input (kJ/mm)[5]	1.0 ~1.4	1.4 ~1.6	1.2 ~1.6	1.76 ~2.0	1.2 ~1.6	2.0 ~2.4	1.2 ~1.6	2.0 ~2.4	1.2 ~1.6	2.0 ~2.4	1.2 ~1.6	2.0 ~2.4	1.2 ~1.6	2.0 ~2.4
Preheat and interpass temp. (°C)	52~ 66	135~ 149	52~ 66	135~ 149	52~ 66	135~ 149	52~ 66	135~ 149	52~ 66	135~ 149	52~ 66	135~ 149	52~ 66	135~ 149

Notes:
(1) Peening of weld beads shall not be permitted.
(2) See 3.1.6 for additional welding requirements.
(3) Welding current shall be direct current, electrode positive (DCEP) (d.c. reverse polarity).
(4) Welding current shall be selected by the manufacturer consistent with the other specified parameters.
(5) The difference in average heat input between the high and low cooling rate tests shall be not less than 0.8 kJ/mm (except for the 2.4 mm and 3.2 mm diameter electrodes, where it shall not be less than 0.2 kJ/mm and 0.4 kJ/mm, respectively). An alternate heat input range may be specified by the purchasing activity to reflect the minimum and maximum cooling rate the purchasing activity will use with agreement from the manufacturer.
(6) The split-weave technique (the practice of depositing only two wide-weave beads per layer) shall be limited to the first 1/2T of weld joint thickness. Each weld layer beyond the first 1/2T of weld joint thickness shall contain three or more beads which are deposited in sequence across the weld joint.

Table 3-23
Welding Parameters for CR-E7418-M (MIL-10718-M) Weld Metal Test Sample(1),(2),(5)

Type	E7418-M (10718-M) (6)											
Base Metal	CRHS-70 steel in accordance with Chapter 2											
Electrode size (mm)	2.4		3.2		4.0		4.8		5.6		6.4	
Welding process	SMAW		SMAW		SMAW		SMAW		SMAW		SMAW	
Position	Vert. up	Flat	Vert. up	Flat	Vert. up	Flat	Flat	Flat	Flat	Flat	Flat	Flat
Welding current (± 5%) (A)(3)	95	(4)	125	140	(4)	180	(4)	235	(4)	300	(4)	350
Plate thickness (T) (mm)	25	19	25	19	25	19	25	19	25	19	25	19
Cooling rate	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Joint configuration	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2	Fig. 3-2
Heat input (kJ/mm)	1.12 ~1.28	1.48 ~1.68	1.12 ~1.36	2.04 ~2.28	1.48 ~1.72	2.08 ~2.32	1.6 ~1.84	2.08 ~2.32	1.6 ~1.84	2.08 ~2.32	1.6 ~1.84	2.08 ~2.32
Preheat and interpass temp. (°C)	38 ~52	135 ~149	38 ~52	135 ~149	38 ~52	135 ~149	38 ~52	135 ~149	38 ~52	135 ~149	38 ~52	135 ~149

Notes:
(1) Peening of weld beads shall not be permitted.
(2) See 3.1.6 for additional welding information.
(3) Welding current shall be direct current, electrode positive (DCEP) (d.c. reverse polarity).
(4) Welding current shall be selected by the manufacturer consistent with other specified parameters.
(5) The split-weave technique (the practice of depositing only two wide-weave beads per layer) shall be limited to the first 1/2T of weld joint thickness. Each weld layer beyond the first 1/2T of weld joint thickness shall contain three or more beads which are deposited in sequence across the weld joint.
(6) Electrodes from the beginning of the lot shall be used for the low cooling rate weld and electrodes from the end of the lot shall be used for the high cooling rate weld.

Table 3-24
Welding Parameters for CR-E8318-M2 (MIL-12018-M2) Weld Metal Test Sample[(1),(2)]

Type	E8318-M2 (12018-M2)[(8)]							
Base Metal	CRHS-70 steel in accordance with Chapter 2							
Electrode size tested (mm)	2.4		3.2		4.0		4.8	
Welding process	SMAW		SMAW		SMAW		SMAW	
Position	Vert. up	Flat	Vert. up	Flat	Horizontal	Flat	Flat	Flat
Welding current (± 5%) (A)[(3)]	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)
Plate thickness (mm)	51[(5)]	19	51[(5)]	19	51[(5)]	19	51[(5)]	19
Cooling rate	High	Low	High	Low	High	Low	High	Low
Joint configuration[(6)]	Fig. 3-3	Fig. 3-2	Fig. 3-3	Fig. 3-2	Fig. 3-3	Fig. 3-2	Fig. 3-3	Fig. 3-2
Heat input (kJ/mm)[(7)]	(4)	(4)	1.48 ~ 1.72[(4)]	1.88 ~ 2.12[(4)]	1.08 ~ 1.32[(4)]	1.68 ~ 1.92[(4)]	(4)	(4)
Preheat and interpass temperature[(7)] (°C)	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163	93 ~ 107	149 ~ 163

Notes:
(1) Peening of weld beads shall not be permitted.
(2) See 3.1.6 for additional welding information.
(3) Welding current shall be direct current, electrode positive (DCEP) (d.c. reverse polarity).
(4) For 2.4 mm and 4.8 mm electrodes, a heat input range shall be specified by the purchasing activity (with the agreement of the manufacturer) to reflect the minimum and maximum cooling rate the purchasing activity will use. Heat input ranges for 3.2 mm and 4.0 mm electrodes shall be as specified unless otherwise specified by the purchasing activity (with the agreement of the manufacturer) to reflect the minimum and maximum cooling rate the purchasing activity will use.
(5) For these test plates, results from each side shall be reported separately, with side 1 depicting results from the first side welded. Failure of either side shall constitute failure of the entire test assembly.
(6) The direction of welding shall be the same for all beads in a weldment. The split-weave technique shall be limited to the first 1/2T of weld joint thickness. Each weld layer beyond the first 1/2T of weld joint thickness shall contain three or more beads, which are deposited in sequence across the weld joint.
(7) Welding parameters shall be selected by the manufacturer consistent with the specified heat input (see Note (5)).
(8) Electrodes from the beginning of the lot shall be used for the low cooling rate weld and electrodes from the end of the lot shall be used for the high cooling rate weld.

Table 3-25
Explosion Test Sample Welding Parameters[1],[5],[6]

Type	CR-E6918-M1 (MIL-10018-M1)		CR-E7418-M (MIL-10718-M)		CR-E8318-M2 (MIL-12018-M2)	
Base metal	CRHS-56		CRHS-70		CRHS-70	
Welding polarity	DCEP		DCEP		DCEP	
Test assembly requirements[2]	Appendix 1					
Electrode size (mm)[6]	4.0 and smaller	4.8 and larger	4.0 and smaller	4.8 and larger	4.0 and smaller	4.8 and larger
Welding position	Vertical up	Flat	Vertical up	Flat	Vertical up	Flat
Preheat and interpass temp. (°C)	121 (+13.9 / -0°C)					
Heat input[3]	[4]					

Notes:
(1) Peening of weld beads shall not be permitted.
(2) The joint surfaces shall not be clad or buttered.
(3) Welding amperage shall be in accordance with the manufacturer's recommendations and the actual values used shall be recorded and reported.
(4) The heat input shall be 2 to 2.4 kJ/mm for the 3.2 mm or 4.0 mm size and larger electrodes and 1.2 to 1.6 kJ/mm for 2.4 mm size electrodes (see Note (6) and 3.1.6(g)).
(5) See 3.1.6 for additional welding requirements.
(6) Explosion testing shall be conducted on 3.2 mm or 4.0 mm electrode sizes. Explosion testing of other electrode sizes (from the same manufacturer) are not required provided the same basic formulation and design as used in the qualified electrode size (3.2 mm or 4.0 mm) is used in the other sizes of electrode, modified as required for the differences in core size, coating thickness and position requirements of these different size electrodes.

3.4.5 Quality conformance tests

Quality conformance inspection tests shall be performed in accordance with Table 3-26. The test assemblies shall be prepared in accordance with Table 3-22, 3-23, 3-24, 3-27, 3-28, 3-29, 3-30, as applicable. For each lot of material, sufficient samples shall be selected to perform the tests listed. Quality conformance tests shall be conducted by the manufacturer in the presence of the Surveyor.

(a) Lot definition

(i) CR-E6918-M1 and CR-E7418-M (MIL-10018-M1 and MIL-10718-M) electrodes.

For CR-E6918-M1 and CR-E7418-M (MIL-10018-M1 and MIL-10718-M electrodes, a lot shall be defined as a Class C3 lot as described in AWS A5.01.

(ii) CR-E8318-M2 (MIL-12018-M2) electrodes.

For CR-E8318-M2 (MIL-12018-M2) electrodes, a lot shall be defined as a Class C4 lot as described in AWS A5.01. When agreed by the Society, a lot may be defined as the amount produced in a continuous 8 hour period of a Class C3 lot as described in AWS A5.01. Under this definition, should any lot fail due to unacceptable toughness or yield strength, the lot definition shall revert back to Class C4 until five consecutive lots are successfully tested, and the test results are accpeted by the Society.

When the modified 8 hour Class C3 lot definition is in use, and a series of 50 consecutive lots have been successfully tested, the lot definition may be changed to a Class C3 lot, subject to the Society approval. The failure of any lot due to unacceptable toughness or yield strength shall result in the lot definition reverting back to Class C4.

(b) Sampling for visual and dimensional inspection shall be as specified in 3.1.5(b).

Where the lot of electrodes are found to comply with the requirements of approval test at the quality conformance test, the attending Surveyor authorized by the Society is to issue the Marine Product Certificate. However, where the quality of the lot of electrodes is found not complying with the properties specified in approval tests, the retests specified in 3.1.8 may be carried out. If retest also failures to meet the requirements, the lot of electrodes is to be rejected.

Table 3-26
Summary of Tests Required for Quality Conformance Tests

Test	Test Procedures	Requirements
Chemical analysis	3.1.4(c)(i), AWS A5.5 and 3.4.4(c)	Table 3-19
Alloy identity	AWS A5.01	AWS A5.01
Covering moisture	AWS A4.4	3.4.3(c)(iii)
Diffusible hydrogen	AWS A4.3	3.4.3(c)(iv)
Welded test assembly	3.4.4	Fig. 3-2 and 3-3
NDT of MIL-10718-M	3.1.4(f)	3.1.4(f)
NDT of MIL-10018-M1 and MIL-12018-M2	3.1.4(f)(i) and 3.4.4(g)	3.1.4(f)(i)
Visual and dimensional inspection	3.1.5(b)	3.4.3(e)
Tension	AWS B4.0	Table 3-20
Impact test (CVN)(1)	AWS B4.0	Table 3-20

Notes:
(1) See Fig. 3-2 and Fig. 3-3 and their associated tables for the requirements on impact tests (CVN).

Table 3-27
Welded Test Assembly CR-E6918-M1 (MIL-10018-M1) As-welded(6)

Type	CR-E6918-M1 (MIL-10018-M1)	
Purpose	Approval test	Quality conformance test
Stress relief	(1)	(1)
Welding parameters	(2)	(2)
Joint configuration(3)	Fig. 3-2	Fig. 3-2
Width (W) (mm)	381 min.	381 min.
Length (L) (mm)(5)	762 min.	610 min.
Root opening (R) (mm)	6.4 min.	6.4 min.
Root face (F) (mm)	0 ~ 0.8	1 ~ 0.8
Included angle (θ) (degree)	45 min.	45 min.
Backing strip dimensions (B) (thickness x width) (mm)	13 x 38	13 x 38
Test specimens (number/type)(4)	From each weld: 2 Tension 2 Bend 10 CVN	From each weld: 2 Tension 10 CVN

Notes:
(1) Welded test assemblies shall not be stress relieved. Heat soaking for hydrogen removal is prohibited.
(2) Welding parameters shall be in accordance with Table 3-22.
(3) Plate thickness (T) shall be in accordance with Table 3-22.
(4) Tensile specimens shall be all weld metal (longitudinal axis of the specimen shall be parallel to the welding direction) and shall be centered at 9.5 mm below the surface in the weld metal. CVN specimens shall have the notch perpendicular to the welded assembly top surface, shall be centered in the weld metal and the top surface of each specimen shall be 1.6 mm below the top surface of the welded test assembly. No specimens shall be removed from within 19 mm of the ends of the welded test assembly. See Fig. 3-5 for more specimen location information.
(5) For retests, when tensile and impact properties do not both need to be retested, the length of the plate may be decreased below the minimum length, but shall not be less than 457 mm.
(6) See 3.1.6 for additional welding requirements.

Table 3-28
Welded Test Assembly CR-E7418-M (MIL-10718-M) High and Low Cooling Rate(3)

Type	CR-E7418-M (MIL-10718-M)	
Purpose	Approval test	Quality conformance test
Stress relief	(1)	(1)
Welding parameters	(2)	(2)
Joint configuration(4)	Fig. 3-2	Fig. 3-2
Width (W) (mm)	381 min.	318 min.
Length (L) (mm)	762 min.	610 min.
Root opening (R) (mm)	13 ± 1.6	13 ± 1.6
Root face (F) (mm)	0 ~ 0.8	0 ~ 0.8
Included angle (θ) (degree)	45	45
Backing strip dimensions (B) (thickness x width) (mm)	13 x 38	13 x 38
Test specimens (number/type)(5)	From each weld: 2 Tension 2 Bend 10 CVN	From each weld: 2 Tension 10 CNV

Notes:
(1) Welded test assemblies shall not be stress relieved. Heat soaking for hydrogen removal is prohibited.
(2) Welding parameters shall be in accordance with Table 3-23.
(3) See 3.1.6 for additional welding requirements.
(4) Plate thickness (T) shall be in accordance with Table 3-23.
(5) Tensile specimens shall be all weld metal (longitudinal axis of the specimen shall be parallel to the welding direction) and shall be centered at 9.5 mm below the surface in the weld metal. CVN specimens shall have the notch perpendicular to the welded assembly top surface, shall be centered in the weld metal and the top surface of each specimen shall be 1.6 mm below the top surface of the welded test assembly. No specimens shall be removed from within 19 mm of the ends of the welded test assembly. See Fig. 3-5 for more specimen location information.

Table 3-29
Welded Test Assembly CR-E8318-M2 (MIL-12018-M2) Low Cooling Rate(6)

Type	CR-E8318-M2 (MIL-12018-M2)	
Purpose	Approval test	Quality conformance test
Stress relief	(1)	(1)
Welding parameters	(2)	(2)
Joint configuration(3)	Fig. 3-2	Fig. 3-2
Width (W) (mm)	381 min.	381 min.
Length (L) (mm)	762 min.(5)	610 min.
Root opening (R) (mm)	13 min.	13 min.
Root face (F) (mm)	0 ~ 0.8	0 ~ 0.8
Included angle (θ) (degree)	45	45
Backing strip dimensions (B) (thickness x width) (mm)	13 x 38	13 x 38
Test specimens (number/type)(4)	From each weld: 2 Tension 2 Bend 10 CVN	From each weld: 2 Tension 10 CVN

Notes:
(1) Welded test assemblies shall not be stress relieved. Heat soaking for hydrogen removal is prohibited.
(2) Welding parameters shall be in accordance with Table 3-24.
(3) Plate thickness (T) shall be in accordance with Table 3-24.
(4) Tensile specimens shall be all weld metal (longitudinal axis of the specimen shall be parallel to the welding direction) and shall be centered at 9.5 mm below the surface of the weld metal. CVN specimens shall have the notch perpendicular to the welded assembly top surface, shall be centered in the weld metal and the top surface of

each specimen shall be 1.6 mm below the top surface of the welded test assembly. No specimens shall be removed from within 19 mm of the ends of the welded test assembly. See Fig. 3-5 for more specimen location information.

(5) For retests, when tensile and impact properties do not both need to be retested, the length of the plate may be decreased below the minimum length, but shall not be less than 610 mm.

(6) See 3.1.6 for additional welding requirements.

Table 3-30
Welded Test Assembly CR-E8318-M2 (MIL-12018-M2) High Cooling Rate(7)

Type	CR-E8318-M2 (MIL-12018-M2)	
Purpose	Approval test	Quality conformance test
Stress relief	(1)	(1)
Welding parameters	(2)	(2)
Joint configuration(4)	Fig. 3-3	Fig. 3-3(3)
Width (W) (mm)	381 min.	381 min.
Length (L) (mm)	762 min.(6)	610 min.
Root opening (R) (mm)	0 ~ 4.8	0 ~ 4.8
Root face (F) (mm)	0 ~ 1.6	0 ~ 1.6
Included angle (θ) (degree)	45	45
Test specimens (number/type)(5)	From each side: 2 Tension 2 Bend 10 CVN	From each side: 2 Tension 10 CVN

Notes:

(1) Welded test assemblies shall not be stress relieved. Heat soaking for hydrogen removal is prohibited.

(2) Welding parameters shall be in accordance with Table 3-24.

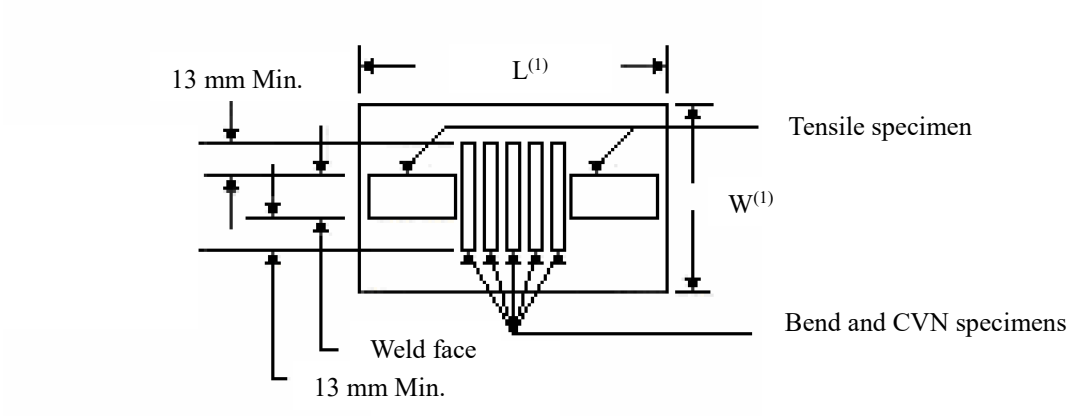
(3) Alternatively, high cooling rate quality conformance testing may be performed in accordance with Fig. 3-2 when approved by the Society provided:
  (a) Test data from both Fig. 3-2 and Fig. 3-3 test plates demonstrate comparability with respect to cooling rate and performance.
  (b) Written quality conformance test procedures submitted for approval establish welding parameter controls and comparative differences in acceptance criteria for Fig. 3-2 test plates.
  (c) When both test plates are tested, results from the Fig. 3-3 test plate shall be the authoritative test.

(4) Plate thickness (T) shall be in accordance with Table 3-24.

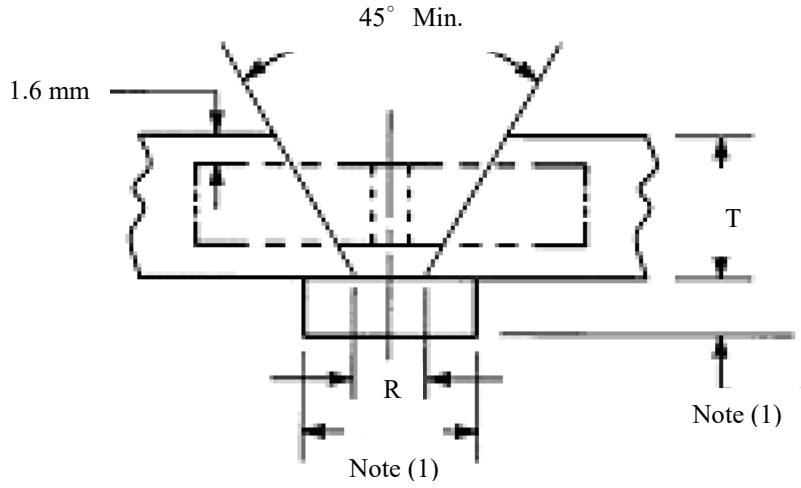
(5) Tensile specimens from each side shall be all weld metal (longitudinal axis of the specimen shall be parallel to the welding direction) and shall be centered at 9.5 mm below the surface of the side represented by the specimen. CVN specimens from each side shall have the notch perpendicular to the welded assembly top surface, shall be centered in the weld metal and the top surface of each specimen shall be 1.6 mm below the surface of the side of the welded test assembly represented by the specimen. No specimens shall be removed from within 19 mm of the ends of the welded test assembly. Specimen location from each side shall be as illustrated in Fig. 3-5(A).

(6) For retests, when tensile and impact properties do not both need to be retested, the length of the plate may be decreased below the minimum length, but shall not be less than 610 mm.

(7) See 3.1.6 for additional welding requirements.



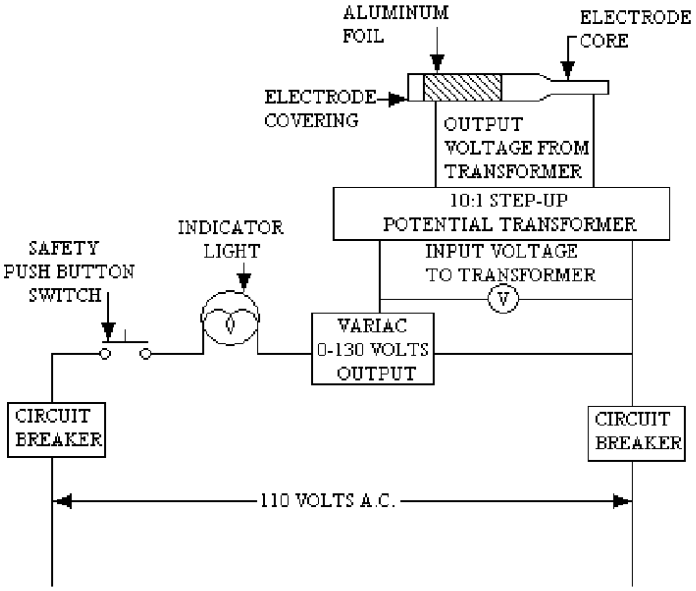
(A) Plan view of test specimen layout for single-V and each side of double-V test plates



(B) Groove preparation of single-V test plate showing orientation of impact test (CVN) specimens

Notes:
(1) See Table 3-27, 3-28, 3-29 and 3-30 as appropriate. Note that no specimens shall be removed from within 19 mm of the ends of the welded test assembly.

Fig. 3-5
Welded Joint Test Specimen Layout



Notes:
(1) Wrap conducting aluminum foil around 152 mm length of electrode.
(2) Place electrode with grip-end on one lug and foil covered section on other.
(3) Close circuit breaker; press safety button and slowly rotate variac control.
(4) Record maximum voltage before breakdown.
(5) Dielectric strength is recorded voltage, multiplied by 10 (transformer ratio).
(6) When dielectric strength is below 300V, connect appropriate voltmeter across electrode terminals.

Fig. 3-6
Circuit for Dielectric Strength Determination

CHAPTER 4 WELDING PROCEDURE FOR CRHS-56/70 STEEL

4.1 General

4.1.1 Approval of welding procedure is to be in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/248.

4.1.2 The requirements of retest are to be in accordance with 3.1.8 of the Guidelines.

APPENDIX 1 STANDARD PROCEDURES FOR EXPLOSION TEST

1.1 General

1.1.1 Scope

This Appendix covers explosion testing used to evaluate base materials, welding materials, and welding procedures when required by the Guidelines.

1.1.2 Material test method and Grade classification

(a) Two test methods are described herein
  (i) Explosion crack starter test
  (ii) Explosion bulge test

(b) Grade classification according to explosion tests
  (i) Materials specified in Chapter 2 are categorized into Grade A or Grade B according to the applied explosion tests, as shown in Table 1 as below.
  (ii) Normally, the crack starter test is to be carried out before the explosion bulge test. When requested by the applicant, the explosion bulge test may be carried out before completion of the explosion crack starter test. In this case, however, if the explosion crack starter test fails, the results of the explosion bulge test are to be deemed invalid accordingly.

Table 1
Requirement of Explosion Tests for Two Grades

Test / Grades	Explosion Crack Starter Test	Explosion Bulge Test
Grade A	X	not required
Grade B	X	X

Note: Tests required for each grade are marked with an "X".

1.2 Definitions

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

1.2.1 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.

1.2.2 Bulge area

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

1.2.3 Compression side

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

1.2.4 Tension side

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

1.2.5 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 heat affected zone (HAZ) or base metal for the purpose of assessing the resistance to cracking of the material being tested.

1.2.6 Explosion test

An explosion test is a general term applicable to the explosion crack starter and explosion bulge as covered herein.

(a) Explosion crack starter test

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

(b) Explosion bulge test

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

1.2.7 As Rolled

As rolled condition means that the material is not heat treated after rolling.

1.2.8 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.

1.2.9 Explosive stand-off distance

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

1.2.10 Finished weld

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

1.2.11 Heat soak

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

1.2.12 Hold-down area

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

1.2.13 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.

1.2.14 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.

1.3 Preparation: Material Verification and General Specimen Requirements

1.3.1 Material verification

When explosion testing is required to be conducted for base metal or welding material, manufacturers 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 welding material 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 inspected to verify their conformance in accordance with the applicable requirements (e.g., chemical composition and mechanical properties).

1.3.2 Specimen preparation

(a) Specimen sizes and quantities

(i) Base metal product forms

When seeking approval to produce product forms, the Manufacturer shall furnish material as follows, unless otherwise specified by the authorized laboratory.

(1) Quantity and dimension

- The Manufacturer shall at least provide base metal products as follows:

Grade A		
Type	Quantity	Dimension (mm)
Explosion crack starter test without a weld joint	2	762 (l) × 762 (w)
Explosion crack starter test incorporating a weld joint(1)	2	762 (l) × 762 (w)
Grade B		
Explosion crack starter test without a weld joint	2	762 (l) × 762 (w)
Explosion crack starter test incorporating a weld joint(1)(2)	2	762 (l) × 762 (w)
Explosion bulge test(1) (2)	4	762 (l) × 762 (w)

Notes:

(1) Two prolongations for mechanical tests specified in 1.4 in this Appendix are to be provided together with the plates. For the plates prepared for both mechanical tests and explosion test, length of prolongation shall be at least 398 mm as shown in Fig.1, Fig. 2 and Fig. 3 in this Appendix.

(2) Prolongations for mechanical tests specified in 1.4 may come from either bulge or crack starter plate.

- The plate surfaces shall be in the as-rolled condition. The material shall be from plate taken from the topmost portion of the ingot or slab. See Fig. 1 in this Appendix for explosion test specimen configuration. Fig. 1 in this Appendix defines the required orientation of the major rolling direction.

(2) Thickness

The thickness of the specimens shall be 25 mm, or 51 mm for CRHS-56 as applicable, and 25 mm for CRHS-70 Composition 1 plate, 41 mm for CRHS-70 Composition 2 plate, or 51 mm for CRHS-70 Composition 3 plate depending on grade and chemical composition type for CRHS-70 being qualified. The required composition types for CRHS-70 are specified in Table 2-4 in Chapter 2.

(3) Less than 51 mm thickness material
Where the maximum material thickness to be produced less than 51 mm, the above applies except plate sizes shall be 1310 mm (*l*) × 508 mm (w) for explosion/mechanical prolongation weldments, and 508 mm (*l*) × 508 mm (w) for explosion weldments.
Note: The length of the prolongation of the materials less than 51 mm in thickness shall be in accordance with the need of the specimens as required, but is not to be less than 802 mm without approval of the Society.

(ii) Welding materials

When seeking approval to produce welding materials that require testing, the Manufacturer, shall furnish sufficient welding material to produce a minimum of two 51 mm (t) × 1160 mm (*l*) × 762 mm (w) explosion/mechanical prolongation weldments. If explosion bulge testing is to be performed, additional 51 mm (t) × 762 mm (*l*) × 762 mm (w) explosion weldments may be required as specified by the authorized laboratory. If the thickness of the weldments are less than 51 mm, dimensions specified in 1.3.2(a)(i)(3) above are to be applied.

(iii) Welding procedure

When seeking approval for a welding process or procedure, the activity shall furnish sufficient rolled plate to produce two 51 mm (t) × 1160 mm (*l*) × 762 mm (w) explosion/mechanical prolongation weldments. Additional 51 mm (t) × 762 mm (*l*) × 762 mm (w) explosion weldments may be required as specified by the authorized laboratory. The plates and welding material shall be in accordance with the applicable Military specifications. If the thickness of the weldments are less than 51 mm, dimensions specified in 1.3.2(a)(i)(3) above are to be applied.

(b) Preparation and welding of explosion test weldments with and without mechanical prolongation

(i) Preparation of base metal for welding

Rolled plate material may be used in the as-rolled "mill finish" condition. Unless otherwise specified, weld joints and approved double-V bevels shall be prepared in accordance with Fig. 6 in this Appendix. 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.

(ii) Welding of Samples

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

(2) Electrodes and welding procedures
For testing electrodes and qualifying welding processes and procedures, the welding parameters shall be established by the prospective Manufacturer or qualifying activity.

(iii) Nondestructive evaluation of test weldments

When 48 hours have elapsed after completion of welding, the following nondestructive tests shall be conducted with the weld reinforcement in place except for the hold-down areas.

(1) Visual inspection
Weldments shall be evaluated in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271 and meet the criteria of the Class 1 Acceptance Standard of MIL-STD-2035. 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 3.2 mm.

(2) Radiographic testing (RT)
Weldments shall be radiographed in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271 and meet the criteria of the Class 1 Acceptance Standard of MIL-STD-2035.

(3) Magnetic particle testing (MT)
Weldments shall be inspected in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271 and meet the criteria of the Class 1 Acceptance Standard of MIL-STD-2035.

1.4 Mechanical Test

1.4.1 Feasibility assessment of explosion test

(a) The feasibility of a successful explosion test shall be determined by the authorized laboratory on the basis of the material's mechanical properties. Mechanical properties of the base metal or weld metal shall be evaluated in accordance with the applicable specification.

(b) The mechanical test prolongations shall be prepared integral with the explosion test specimens specified in 1.3.2 in this Appendix and shall be severed by flame or saw cutting. Mechanical test specimens shall be machined from the prolongations in accordance with Fig. 2 and Fig. 3 in this Appendix.

1.4.2 Preparation of mechanical test specimens

(a) Responsiblility of preparation

Mechanical test specimens (i.e., prolongations to explosion test specimens, see Fig. 1, Fig. 2, and Fig. 3 in this Appendix) shall be prepared by the manufacturer and tested by the authorized laboratory in the presence of the Surveyor.

(b) Test assembilies

The requirements for obtaining the mechanical specimens, as specified on Fig. 2 in this Appendix, from the prolongations to the explosion crack starter weldments shall be in accordance with (i) through (iv) as below. Specimens shall be taken for production lot verification testing to the requirements of the Guidelines that initiated the explosion testing.

(i) Tensile test specimens

Weld metal tensile specimens shall be the 13 mm diameter size when permitted by the weld joint configuration and base material thickness; otherwise, they shall be the maximum size possible. 51 mm thick test weldments will have both base material and weld metal thickness to permit the removal of two Type R-1, 13 mm diameter tensile specimens. Tensile specimens shall be prepared and tested in accordance with ANSI/AWS B4.0.

(ii) Charpy V-notch impact test specimens

Charpy V-notch (CVN) specimens shall be taken so that the surface of the specimen nearest the surface of the test assembly is 4.8 to 8 mm from the test assembly surface. The specimens shall be to locate the notch within the weld metal. The CVN specimens shall be machined and tested in accordance with ANSI/AWS B4.0.

(iii) Bend specimens

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

(iv) Sub-sized specimens

Where complying with the requirements of specimens above is impracticable, sub-sized specimens in accordance with corresponding standards or national or international standards may be used at the discretion of the Soeiety.

1.5 Explosion Crack Starter Test

1.5.1 General

The explosion crack starter test is used in the evaluation of base metals, weld metals, heat affected zones, weld fusion zones, and welding procedures.

1.5.2 Prepartion of explosion crack starter test specimens

Quantities and specimen details shall be in accordance with 1.3.2 in this Appendix.

1.5.3 Preparations of explosion crack starter test assembilies

The explosion crack starter test assembly is modified explosion test specimen specified in 1.3.2 in this Appendix 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 specified as follows; or weld metal or weld procedure evaluation as follows (see Fig. 7, Fig. 8, and Fig. 9 in this Appendix).

(a) For base metal evaluations

(i) For base metal evaluations without a weld joint, the beads shall be placed transverse to the plate primary working direction (cast plates have no primary working direction) at the center of the test specimen as specified on Fig. 7 in this Appendix. Where two beads are deposited, the beads shall be spaced 15.9 mm from each side of the plate centerline.

(ii) For base metal evaluations incorporating 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 Fig. 8 (plan view) in this Appendix. On 51 mm thick specimens, two beads shall be deposited an equal distance from the weld centerline and 1.6 mm to 2.4 mm from the edge of the weld fusion lines. On 25 mm thick specimens, one bead shall be deposited along the weld centerline. The required beads are to be approximately 51 to 76 mm long and shall be placed midway between the extremities of the weld joint.

(b) For weld metal and weld procedure evaluations

For weld metal and weld procedure evaluations, the Hardex N or equivalent weld deposits shall be placed directly on the weld joint transverse to the axis of the weld as specified on Fig. 9 (plan view) in this Appendix. On 51 mm thick specimens, two beads shall be deposited 16 mm from each side of the plate centerline. On 25 mm thick specimens, one bead shall be deposited on the plate centerline. The required beads are to be approximately 51 to 76 mm long and extend 6.4 mm beyond both weld fusion lines. Where the weld joint is wider than 63.5 mm, allowance shall be made to increase the bead length to achieve the minimum 6.4 extension beyond the weld fusion lines. This may require increasing the distance from the weld centerline to the reduction of thickness point of measurement.

(c) Crack starter bead application

The crack starter bead shall be welded in accordance with the following welding parameters or other equivalent method agreed by the Society.

(i) Process: Shielded metal arc, direct current, electrode positive (DCEP)

(ii) Electrode: approximately 4.8 mm diameter

(iii) Position: Flat, down hand

(iv) Welding current and voltage: 180 – 190 amps: 22 – 23 volts

(v) Travel speed: 114 – 127 mm per minute

Welding shall be performed using a stringer bead technique. Bead width shall not exceed 16 mm. Welding progression shall be as specified on Fig. 7, Fig. 8, and Fig. 9 in this Appendix. Before breaking the arc, back-fill the crater to assure adequate weld metal for grinding of the crack starter notch.

(d) Notching the Hardex N or equivalent weld bead

Final preparation of the crack starter specimen shall consist of notching the crack starter beads as specified on Fig. 7, Fig. 8, and Fig. 9 in this Appendix. For base metal evaluations, the crack starter beads shall be notched mid-length. For weld metal and weld procedure evaluation, the crack starter beads shall be notched at mid-length and over each fusion line. Notching may be accomplished with a thin 25 mm diameter abrasive disk. Notches shall be cut normal to the specimen and across the full width of the bead to a depth such that

1.8 to 2.5 mm 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.

(e) 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 152 mm in from the assembly edges (see Fig. 4 in this Appendix). 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 test die, thermocouple holes shall be drilled in the edges of each explosion test specimen. The holes shall be approximately 3.2 mm in diameter by 25 mm deep located at the specimen edge, that is, thickness centerline, a minimum of 25 mm away from any corner of the plate.

1.5.4 Acceptance criteria of 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 test acceptance criteria of Table 2 on the first shot.

Table 2
Crack Starter Explosion Test Acceptance Criteria (1)(2)

Acceptance Criteria	Crack Starter Explosion Test	
	First Shot	Second Shot
Crack starter bead shall crack	X	(3)
No piece shall be thrown out of material being tested	X	X
No through-thickness shall be present	X	N/R
No cracks shall extend into the hold-down area	X	X
Percent reduction in thickness	(4)	(4)

Notes:
(1) Conditions required for each shot are marked with an "X". The suffix RC added to the MIL type pertains to restriction of the copper content. All requirements, tests and acceptance criteria remain otherwise unchanged.
(2) N/R = not required.
(3) In the event the crack starter bead does not crack on the first shot, the first shot shall be repeated.
(4) The percent reduction in thickness shall be recorded for information only.

1.5.5 Explosion crack starter test procedures

Explosion test specimens shall be subjected to the following as specified in (a) through (g).

(a) Unless otherwise specified in purchase order, the explosion test shall be conducted at minus 18 ± 2°C.

(b) 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.

(i) 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 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.

(ii) 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 25 mm of thickness. Deviation from this procedure to shorten the test specimen conditioning shall be supported by data, which shall be approved by the Society. 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.

(c) Setting of the explosion test specimens and detonation of explosive charge

(i) On completion of thermal conditioning, the specimen shall be placed on test die with the ground hold down surfaces contacting test die. The explosive charge shall be centered over the specimen with the proper stand-off distance. The stand-off distances for explosion tests shall be 381 (minus 0, plus 25) mm. See Fig. 11 in this Appendix for the explosion test configuration. Each part of the configuration shall be checked such that the result of explosion test will not be affected by reasons related to configuration. For example, the height of test die and the way of setting the stand-off-maintenance device shall be appropriate considering the deformation of the plate. Plate deformation may lead to the contact with the base plate which may affect the test result if the height of test die is not enough; plate deformation may also affect setting of the stand-off-maintenance device.

(ii) The blasting cap may be placed on or in the explosive charge using the following method: "Placed no deeper than 19 mm into a predrilled or precast 7.6 mm diameter hole located in the top center of the explosive charge."

(d) 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 as approved by the Society. Before their use the following conditions shall be met:

(i) Develop or cite data that shows that the candidate substitute is similar in burning rate and explosive force.

(ii) Demonstrate through comparative testing that the candidate explosive produces similar results when used in explosion testing equivalent test plate blanks, and

(iii) Submit to the Society for approval and retain the supporting data on file in an engineering technical report form.

(e) Explosive charge weight selection

The explosive charge sizes and charge weight shall be refered to NAVSEA Technical Publication T9074-BD-GIB-010/300.

(f) Crack examination and description

After each shot the test specimen shall be examined, and the location, length, and direction of all cracks recorded by a written and sketch description (see Fig. 12 in this Appendix) and a picture. The explosion testing record form shown on Table 4 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.

(g) 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 1.5.5(b)(ii) in this Appendix. 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) as specified. If failure occurs as specified in Table 2 before obtaining the required reduction in thickness, testing shall be terminated on the involved test specimen.

1.6 Explosion Bulge Test

1.6.1 General

The explosion bulge test is used in the evaluation of base metals, weld metals, heat affected zones, weld fusion zones, and welding procedures.

1.6.2 Preparation of explosion bulge test specimen

Quantities and explosion test specimen details shall be in accordance with 1.3.2 in this Appendix.

1.6.3 Preparation of explosion bulge test assembilies

(a) Explosion bulge test assemblies shall be prepared in accordance with Fig. 4 in this Appendix and the fabrication and inspection parameters outlined in 1.3.2(b) in this Appendix.

(b) Grinding for die fit and drilling thermocouple holes

The requirements of grinding for die fit and drilling thermocouple holes shall be in accordance with 1.5.4(e) in this Appendix.

1.6.4 Acceptance criteria of explosion bulge testing

(a) Acceptance criteria

Bulge test shots shall continue until a minimum reduction in thickness of 16 percent for CRHS-56 or 14 percent for CRHS-70 is obtained on one or both sides.

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 specified in Table 3 in this Appendix occurs or until the minimum reduction in thickness required above is met. The reduction in thickness shall be measured at the locations specified on Fig. 4 in this Appendix by the methods shown on Fig. 10 in this Appendix.

(b) Failure

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 engineering analysis of the failure, or failure mode, or both.

Table 3
Explosion Bulge Test Acceptance Criteria(1)(2)

Acceptance Criteria	Explosion Bulge Test		
	First Shot	Second Shot	Additional Tests
Crack starter bead shall crack	N/A	N/A	N/A
No piece shall be thrown out of material being tested	X	X	X
No through-thickness shall be present	X	X	N/R
No cracks shall extend into the hold-down area	X	X	X
Percent reduction in thickness	(4)	(4)	(5)

Notes:
(1) Conditions required for each shot are marked with an "X". The suffix RC added to the MIL type pertains to restriction of the copper content. All requirements, tests and acceptance criteria remain otherwise unchanged.
(2) In the event the crack starter bead does not crack on the first shot, the first shot shall be repeated.
(3) N/R = not required; N/A = not applicable.
(4) The percent reduction in thickness shall be recorded for information only.
(5) The required percent reduction in thickness shall be as specified in 1.6.4 above. Shots shall be discontinued when the metal fails to meet the above conditions, or when the reductions in thickness requirements are met.

1.6.5 Explosion bulge test procedures

Explosion bulge test procedures shall be as specified in 1.5.5 in this Appendix except the requirements specified herein.

(a) Unless otherwise specified in purchase order, the explosion bulge test shall be conducted at minus 18 ± 2°C.

(b) For explosion bulge testing, charge weights and stand-off distances shall be selected to achieve an approximate 3 percent reduction in test specimen thickness (near the center, see 1.6.4(a) above) for each shot.

(c) Thickness-reduction measurement

(i) Unless otherwise specified, measurements of plate thickness reductions shall be taken at the locations identified for measurements (see 1.6.4(a) and Fig. 4 and Fig. 10 in this Appendix).

(ii) Fig. 10 in this Appendix 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 NAVSEA Technical Publication T9074-AS-GIB-010/271. The ultrasonic gauging equipment shall be calibrated with two blocks (minimum) of known thickness (±0.025 mm) 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 0.1 mm.

(iii) Regardless of the method used by the authorized 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 the Society on request.

1.7 Notes

1.7.1 Other crack starter geometries

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

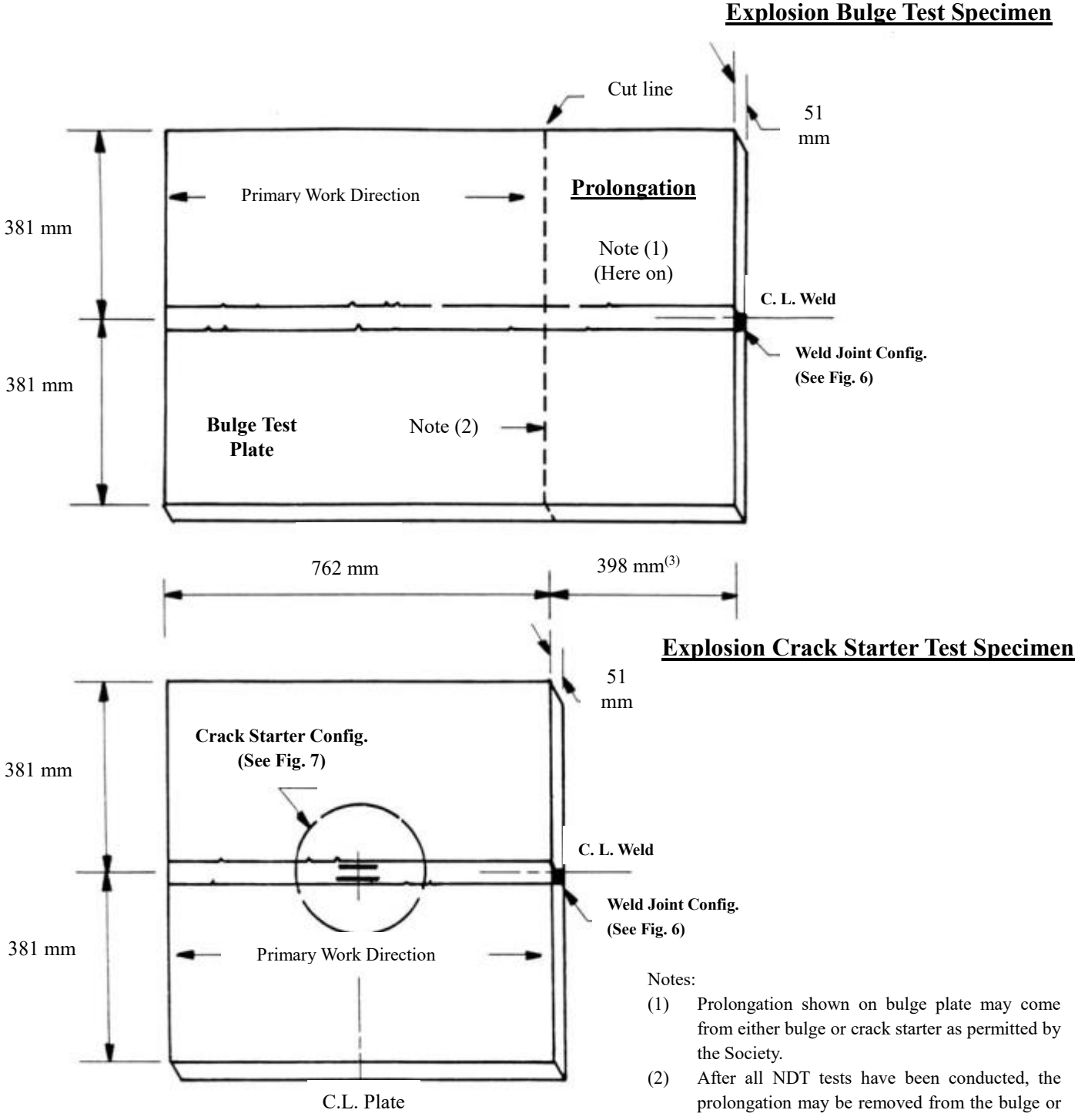
(a) Hardex N or equivalent deposited weld metal in a test specimen groove and mechanically notched lengthwise with respect to the embrittled deposit, and

(b) 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 shall be specially considered by the Society.

1.7.2 Test report

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 supplements by photographs, sketches, and other illustrations to assist in defining clearly the tests conducted, and the results obtained (see 1.7.1 above).



Notes:

(1) Prolongation shown on bulge plate may come from either bulge or crack starter as permitted by the Society.

(2) After all NDT tests have been conducted, the prolongation may be removed from the bulge or crack starter plate by flame cutting.

(3) The length of the prolongation shall be in accordance with the need of the specimens as required, but is not to be less than 398 mm without approval of the Society.

Fig. 1
Explosion Test Specimen Configuration

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

Flame cutting may be used along the ends of the specimens but no closer than 13 mm 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.

Notes:

(1) The length of the prolongation shall be in accordance with the need of the specimens as required, but is not to be less than 398 mm without approval of the Society.

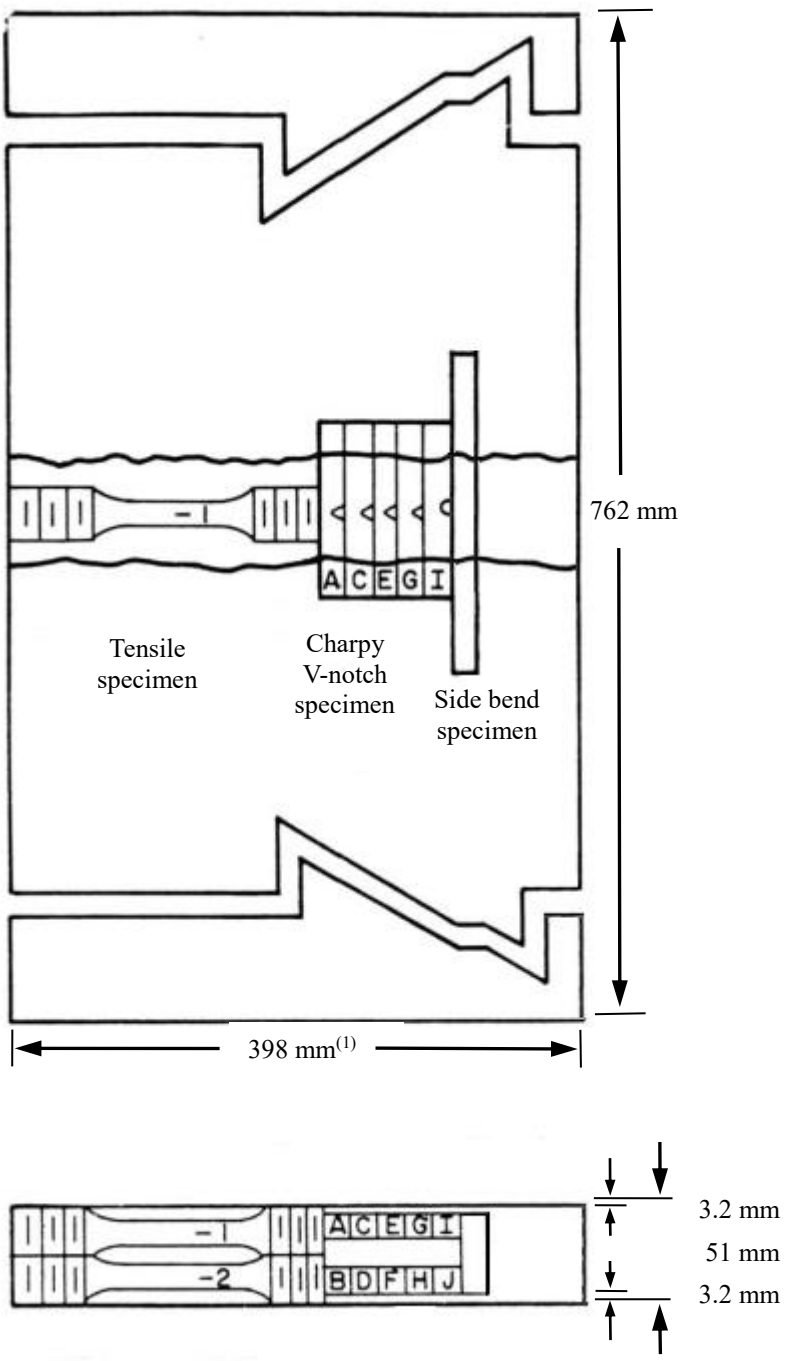
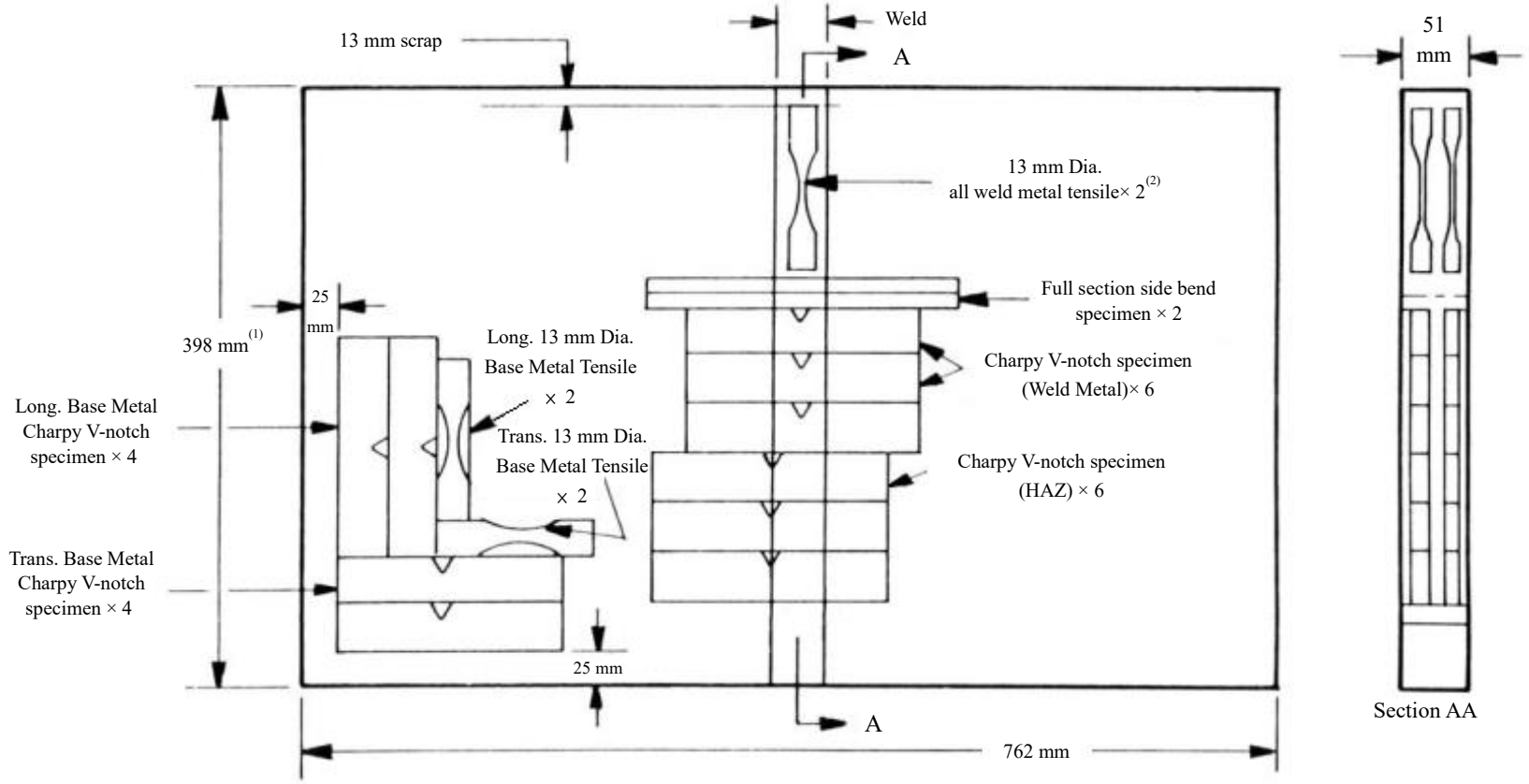


Fig. 2
Diagram of a Typical Mechanical Removal Orientation

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

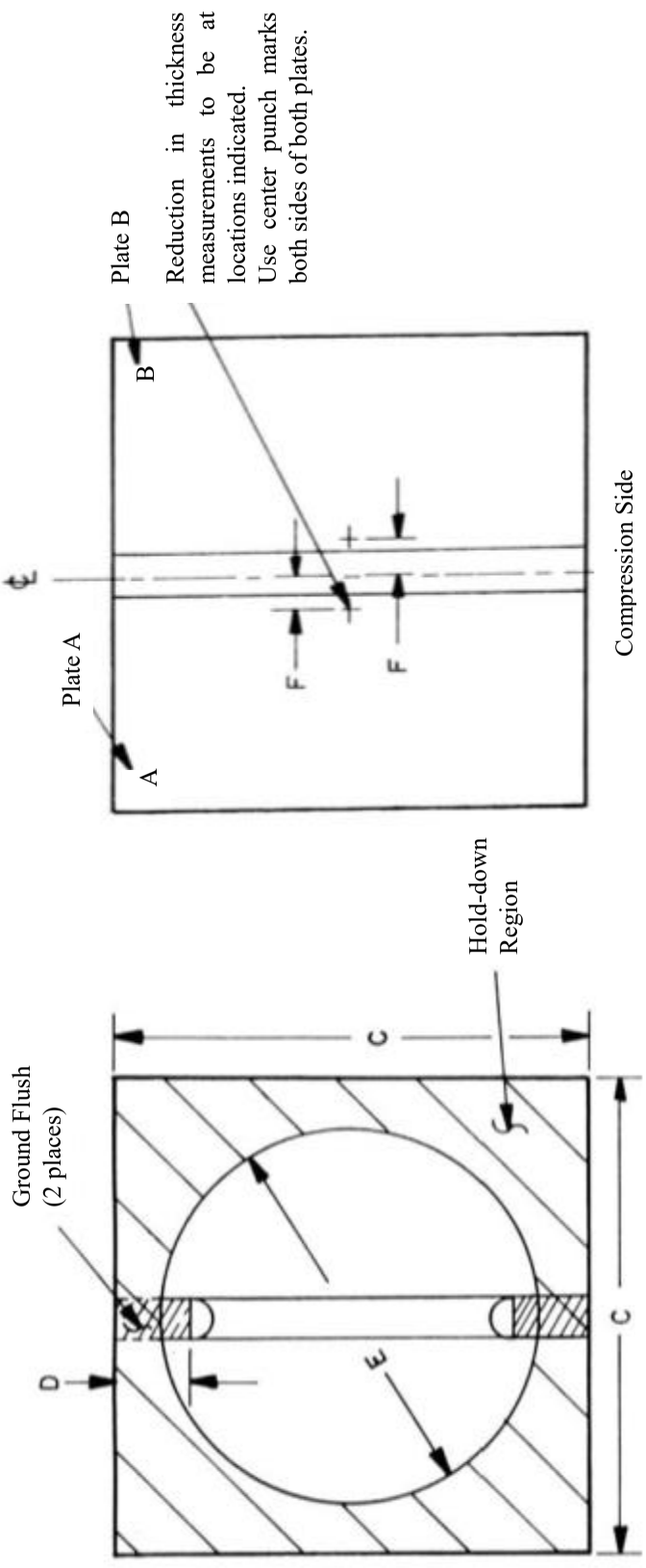


Notes:

(1) The length of the prolongation shall be in accordance with the need of the specimens as required, but is not to be less than 398 mm without approval of the Society.

(2) For tensile test for base metal evaluation, transverse specimens with full section may be accepted as substitutes for all weld metal specimens when agreed by the Society.

Fig. 3
Prolongation Mechanical Property Specimen Layout for Preproduction Qualification Testing



Dimensions (mm)

Plate Thickness	Weldment Size	Grind Flush	Bulge Region	Punch Marks
25	508	127	381	25
51	762	152	635	38

Fig. 4
Explosion Test Plate Preparation

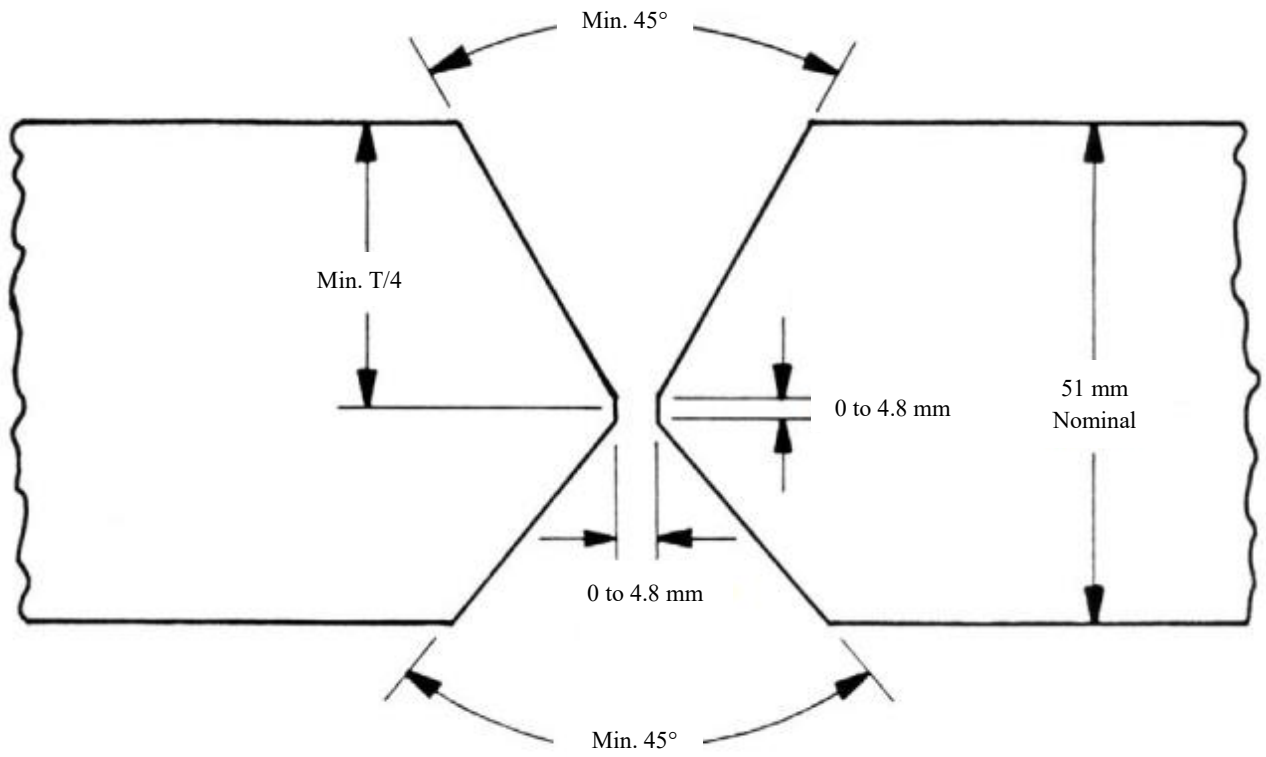
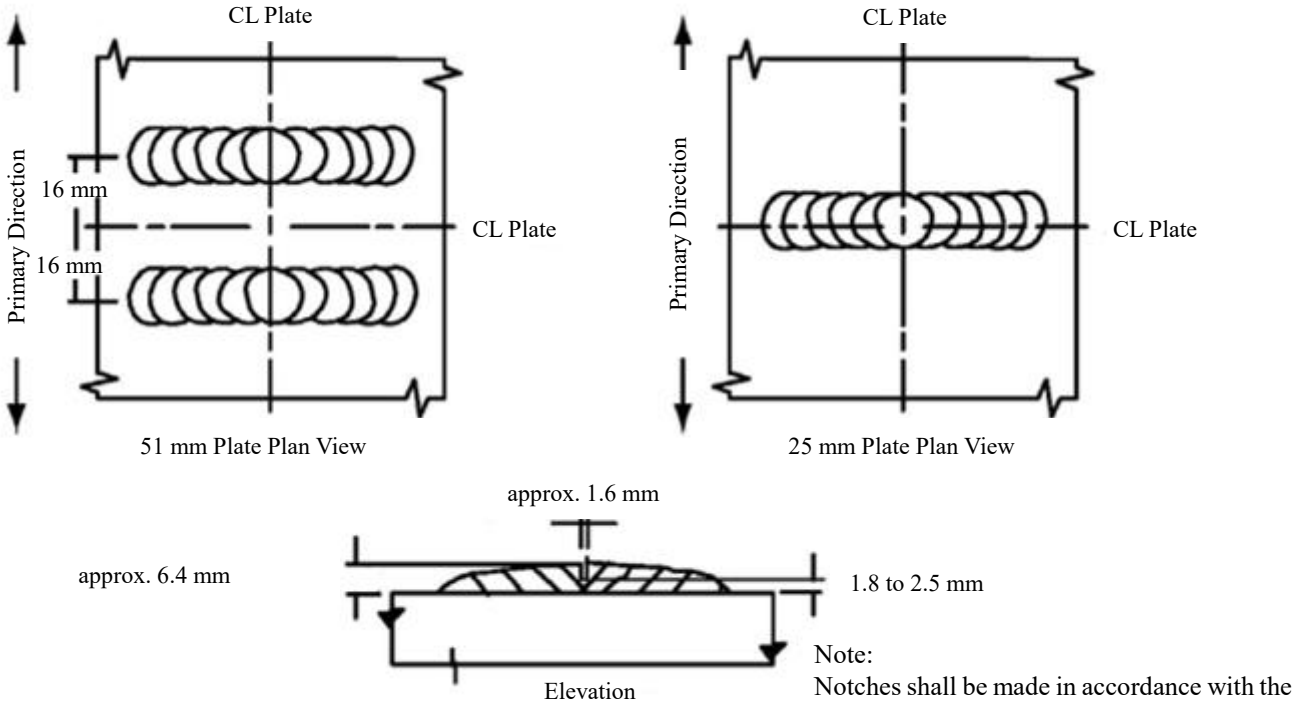
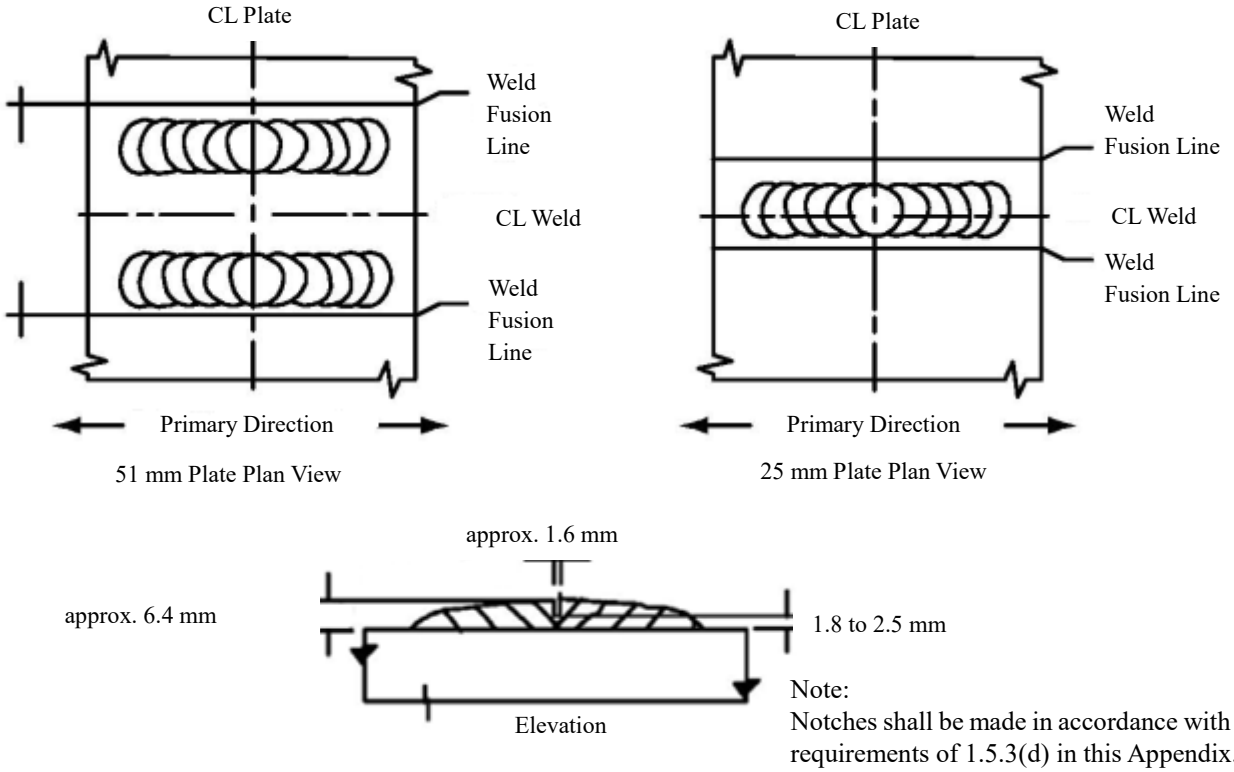


Fig. 6
Typical Configuration for Explosion Test Weldment



Note:
Notches shall be made in accordance with the requirements of 1.5.3(d) in this Appendix.

Fig. 7
Crack Starter Bead Configuration – Base Metal Evaluation Without a Weld Joint



Note:
Notches shall be made in accordance with the requirements of 1.5.3(d) in this Appendix.

Fig. 8
Crack Starter Bead Configuration – Base Metal Evaluation Incorporating a Weld Joint

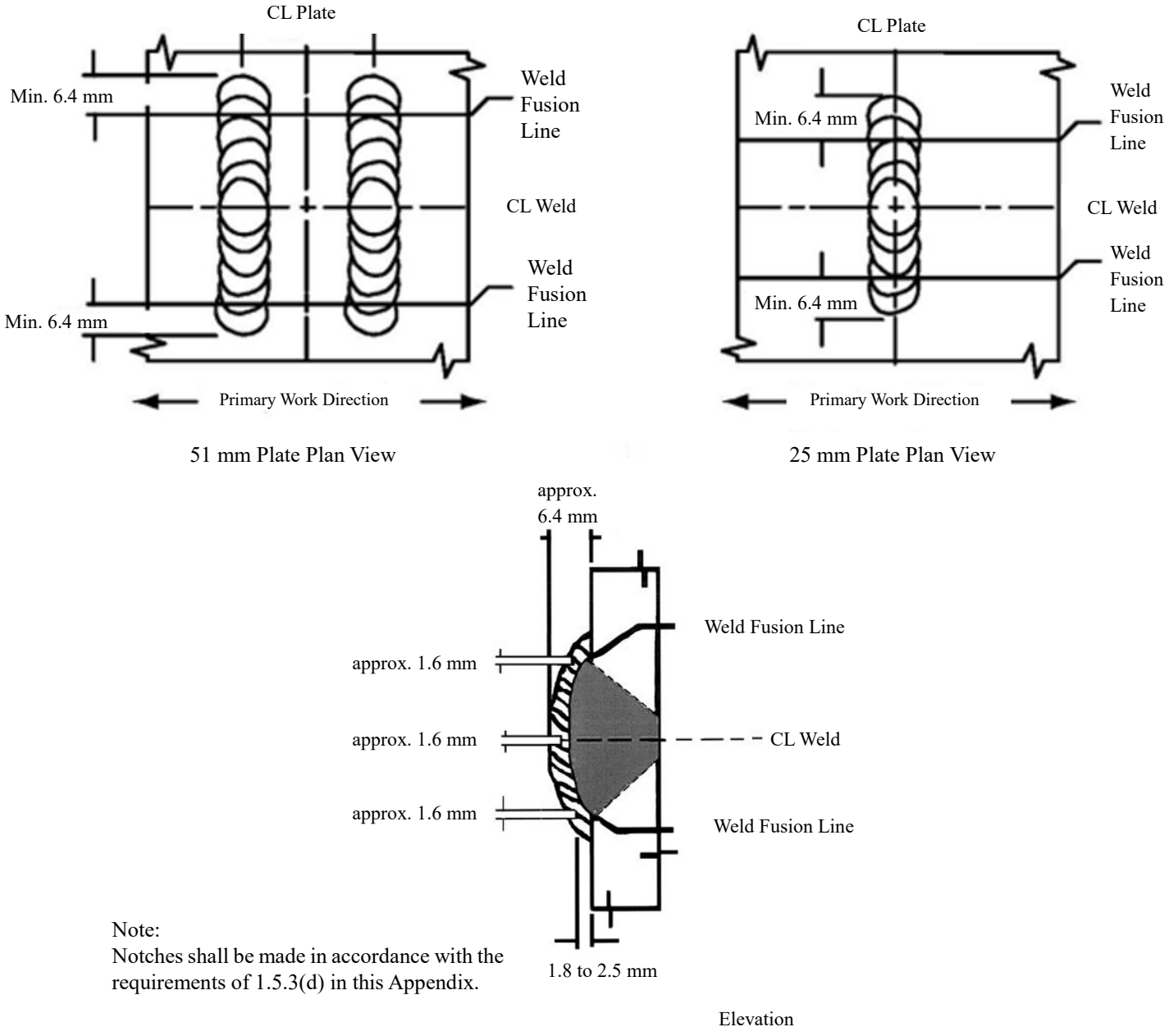


Fig. 9
Crack Starter Bead Configuration – Weld Metal and Weld Procedure Evaluation

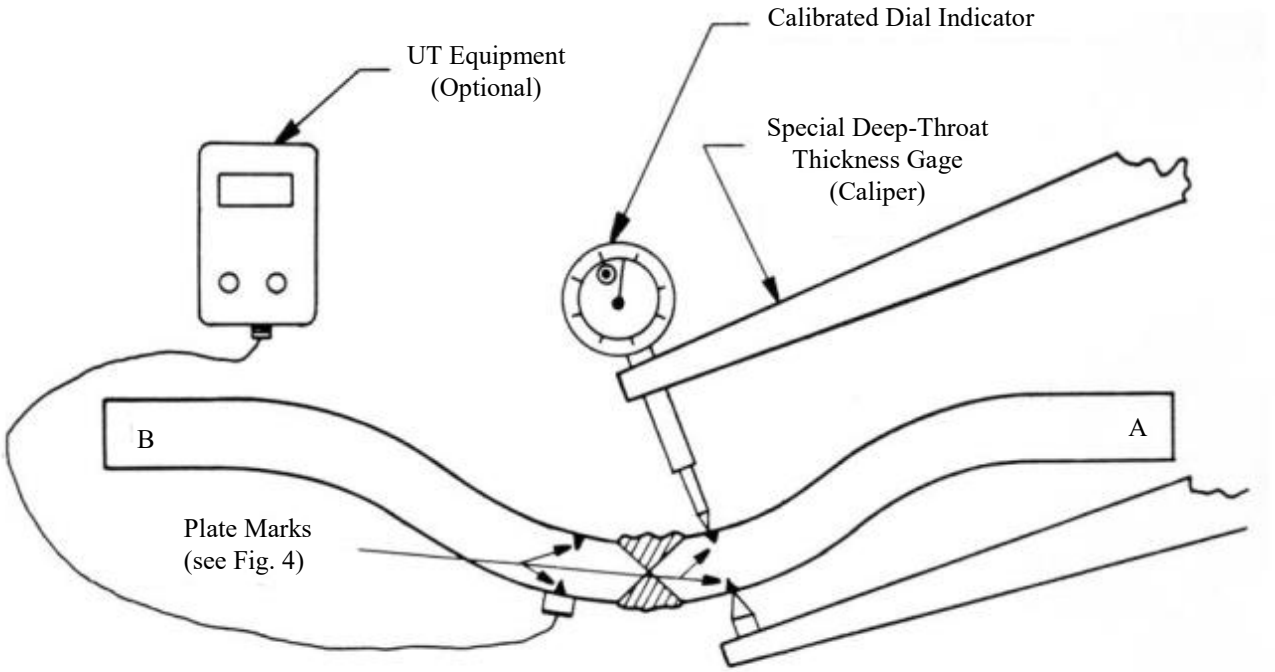


Fig. 10
Explosion Test Measurements

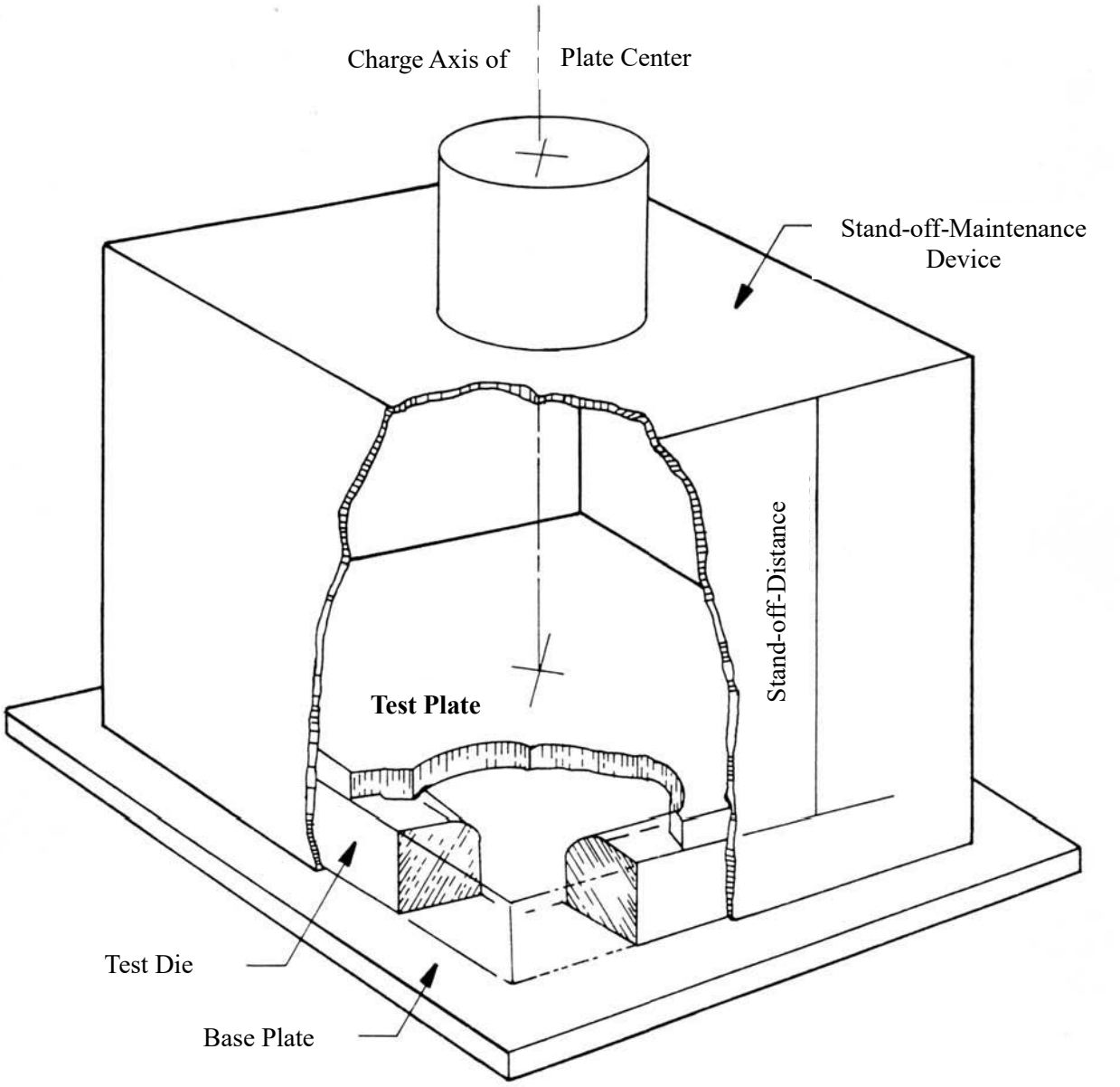


Fig. 11
Explosion Test Configuration

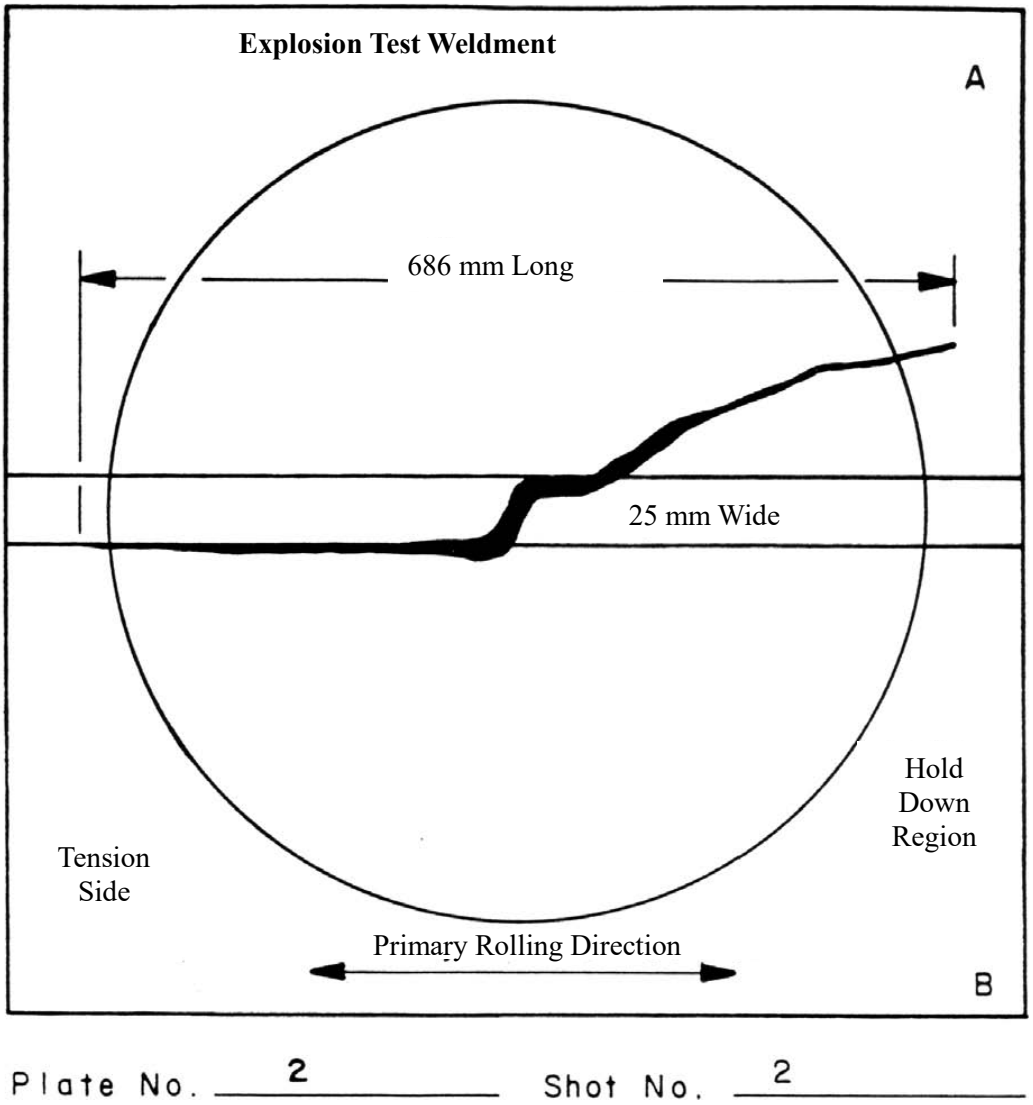


Fig. 12
Typical Fracture Sketch of Explosion Test Weldment

Table 4
Sample Explosion Testing Record

Explosion Testing Record	☐ Explosion Crack Starter Testing ☐ Explosion Bulge Testing		Date:
Plate Identification No.:	Process:	Electrode Type and Size:	
Stand-off Distance:	Cooling Medium:	Specified Test Temperature:	Specified Thickness Reduction (%):
Plate Side in Tension:	Plate Thickness Prior to Shot: "A"____________________ "B"____________________		

Shot No.	Date	Normalizing			Explosive Charge Type, Size, Gnd. Weight	Amb. Temp	Bath to Shot			Thickness		% of Reduction		Remarks
		Start Time	Exit Time	Total Time			Exit Temp	Shot Temp	Total Temp	A	B	A	B	
1														
2														
3														
4														
5														
6														
7														
8														