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Welding of Ferrous Materials

Canadian Coast Guard Standards

Canada

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#	Date	Subject	Initials
1	June 12, 2002	Third Edition: Revision of Organization's names, Authorities and references. (Note: Changes have been identified with paragraph side bars).	

Foreword

This Standard is issued by the Director General Integrated Technical Support, CCG's National Authority under delegation from the Deputy Minister Fisheries and Oceans and the Commissioner of the Canadian Coast Guard

This Standard has been prepared by the Technical Services, Integrated Technical Support (ITS), Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.

The purpose of this Standard is stated in Chapter 1.0, Scope.

When, this Standard is used other than as stated in the Scope, it ***shall*** remain the responsibility of the user to judge its suitability for their particular purpose.

All inquiries regarding this Standard, including suggestions for revision and requests for interpretation ***shall*** be addressed to the Director, Technical Services, Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada, 200 Kent Street, Ottawa, Ontario, K1A 0E6.

All requests ***should***:

- define the problem;
- reference the specific chapter, clause, figure or table;
- include a sketch if considered necessary;
- provide a detailed explanation surrounding the actual work conditions;
- be phrased, where possible, to permit a specific "yes" or "no" answer.

Table Of Contents

CHAPTER 1 SCOPE

This Standard states the requirements of the Technical Services, Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.

This Standard shall be followed whenever required by contract for new construction, modernization, alteration and repair welding steel vessels.

This Standard details the requirements for welding and nondestructive inspection of welds for ferrous materials.

This Standard is intended as an Owner's Requirement. In addition to this standard, the contractor ***shall*** meet all regulations and rules required by Transport Canada Marine Safety and the governing Classification Society. When the above mentioned rules exceed the requirements specified herein, the more stringent requirement ***shall*** take precedence.

This Standard includes provisions for Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Flux Cored Arc Welding (FCAW), Submerged Arc Welding (SAW), Electroslag Welding (ESW), and Electrogas Welding (EGW).

This Standard includes provisions for manual, semi-automatic and automatic (machine) welding.

CHAPTER 2 DEFINITIONS & ABREVIATIONS

The following definitions and abbreviations apply in this Standard:

Approved (approval) means reviewed and accepted by the Technical Authority, unless otherwise specified.

Backing Bar (non-metallic) means a non-metallic substance attached to the root side of a joint for the purpose of containing molten weld metal and it is not fused as part of the final joint (e.g. ceramic tape).

Backing Bar (permanent) means a metallic strip attached to the root side of a joint for the purpose of containing molten weld metal that will remain as part of the completed weld.

Backing Bar (temporary) means a metallic or non-metallic strip attached to the root side of a joint for the purpose of containing molten weld metal that will be removed and not remain as part of the completed weld.

Basic Electrode (formerly low hydrogen) means an electrode that deposits weld metal having a controlled amount of diffusible hydrogen. The maximum permissible amount of hydrogen is set in the pertinent electrode standard.

Canadian Welding Bureau (CWB) means the Certification Division of CWB Group – Industry Services 1998. The organization mandated by the Canadian Standards Association (CSA) to provide certification services for organizations, fabricators and individuals desiring compliance to the applicable CSA Standards for Welding and Weld Inspection.

Cellulose means the principle ingredient used for deep penetrating electrode coatings. The coatings are formulated to have 5-7% moisture content.

"CH" means a filler material that deposits weld metal having a controlled amount of diffusible hydrogen. The maximum permissible amount of hydrogen is set in the pertinent electrode standard (e.g. "CH" flux cored wires in accordance with CSA Standard W48.5-M).

Consumable Insert	means a metallic backing material of the same composition as the joint which is shaped to fit into the root of the joint and, when fused, becomes an integral part of the completed weld.
Contractor	means a supplier of services or work for the construction, modernization, repair or alteration to steel vessels and/or shipboard equipment constructed of ferrous materials by welding.
Defect	means a discontinuity or discontinuities which by nature or accumulated effect render a part or product unable to meet the minimum requirements of an acceptable criteria (e.g. Chapter 10.0).
Delegated Representative	means an officer appointed by the Director, Technical Services, Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada to carry out responsibilities on behalf of the Technical Authority.
Discontinuity	means an interpretation of the typical structure of a weldment, such as a lack of homogeneity in the mechanical, metallurgical or physical characteristics of the material or weldment. A discontinuity is not necessarily a defect.
Essential Variables	means the parameters, conditions or specific details of the enactment of welding that, if changed beyond the specified tolerances, may adversely affect weld quality.
Hull Structure, Primary	means that part of the vessel hull structure which makes up the primary hull girder, including structure to resist ice loadings. It consists of strength decks, platforms and shell plating and their supporting framing, tank top, vertical keel, longitudinal and main transverse bulkheads. In addition to the primary hull girder, water, oil and gas tight bulkheads shall be considered part of the primary hull structure.
Hull Structure, Secondary	means all of the vessel hull structure which is not included in the definition for primary hull structure.
Holding Oven	A thermostatically controlled oven designed for storage of coated electrodes.
Inspection Authority	means the individual department, or agency appointed by the Technical Authority to act for and on behalf of the Technical Authority on all inspection and quality matters within the scope of the contract documents.

Non-Hygroscopic Material	means a material or substance that will not readily retain moisture or humidity.
Pressure Piping	means any piping used to convey a fluid at a pressure above atmospheric pressure unless otherwise stated.
Technical Authority	means the Director, Technical Services, Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.
Temporary Weld	means a weld made to attach a piece or pieces for temporary use in handling, alignment, shipping or working of the weldment.
Welder	means one who performs a manual or semi-automatic welding operation.
Welding Operator	means one who operates a machine or automatic welding equipment.
Wet Electrode	means an electrode or electrode coating that has come in direct contact with liquid.
Welding Requirement Symbol	means a symbol used on design drawings providing adequate information for the development of a detail drawing.
Welding Symbol	means a symbol used on shop drawings that provides information about welding in accordance with the requirements of AWS A2.4.

Note: Additional welding terms and definitions are defined in the American Welding Society (AWS) Publication A3.0, latest edition.

List of Abreviations:

EGW	= Electrogas Welding
ESW	= Electroslag Welding
FCAW	= Flux Cored Arc Welding
GMAW	= Gas Metal Arc Welding
HAZ	= Heat Affected Zone
SAW	= Submerged Arc Welding
SCE	= Standard Calomel Electrode
SMAW	= Shielded Metal Arc Welding

CHAPTER 3 APPLICABLE DOCUMENTS

The Contractor or Sub-contractor performing welding or inspection of welds shall be familiar with the applicable codes, standards, rules and publications referred to within this Standard (see Annex A).

Use of the above-mentioned references shall be the **LATEST EDITION** approved by the organization issuing the publication specified at the time of contract award unless to the otherwise mutually agreed to between the Contractor and the Technical Authority.

When the requirements of other standards appear to be in conflict with the requirements specified herein, the Technical Authority shall be requested to establish precedence.

CHAPTER 4 ADMINISTRATION

This Standard shall be administered by the Director, Technical Services, Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.

For the purpose of administration, the Technical Authority shall delegate representatives responsible for the measurement of the Contractor's performance and ability to meet the requirements specified herein.

This Standard requires the Contractor to conform to various CSA Standards. The administrative organization for certification to CSA Standards shall be the Canadian Welding Bureau (CWB), Certification Division.

The Contractor shall allow the Technical, Inspection and Regulatory Authorities' delegate(s) access to the facilities, files and records relative to the requirements of this Standard for the duration of the contract and warranty period.

Review of documentation shall include, but not be limited to, personnel qualification, welding procedures, certification records and nondestructive inspection results.

CHAPTER 5 DRAWING AND WELD DETAILS

Adequate information about welds will appear on design drawings by the use of weld requirement symbols in order that shop drawings may be produced.

All weld requirement symbols for groove welds *shall* be considered full penetration unless otherwise stated on the reference line of the symbol. (See Figure 5.1).

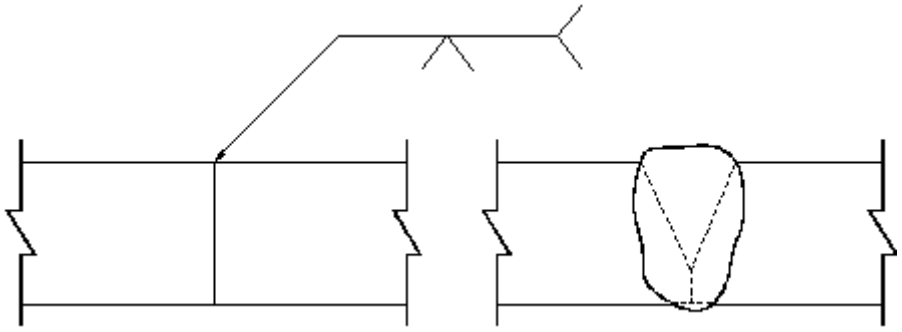


Figure 5.1 Full Penetration Groove Welds

Weld requirement symbols for partial penetration groove welds ***shall*** display the applicable effective throat dimensions on the reference line and the words partial penetration ***shall*** appear in the tail portion of the symbol. (See Figure 5.2).

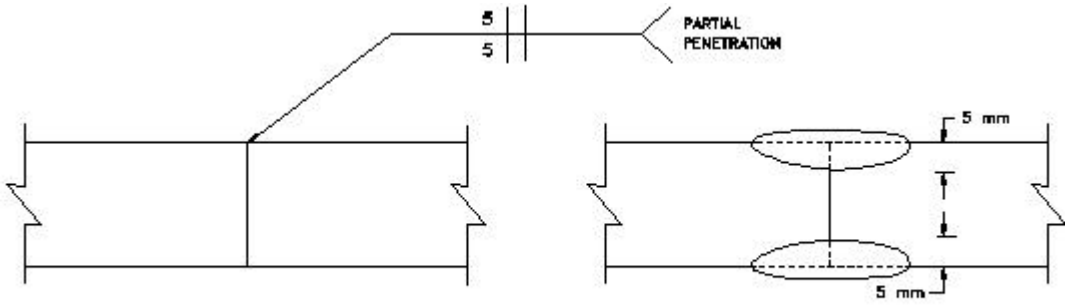


Figure 5.2 Partial Penetration Groove Welds

The weld requirement symbol for fillet welds ***shall*** display the disposition of the weld, but will not necessarily indicate the leg length or effective throat size. The disposition of the weld ***shall*** offer continuous versus double continuous and intermittent versus staggered intermittent, etc. (See Figure 5.3.)

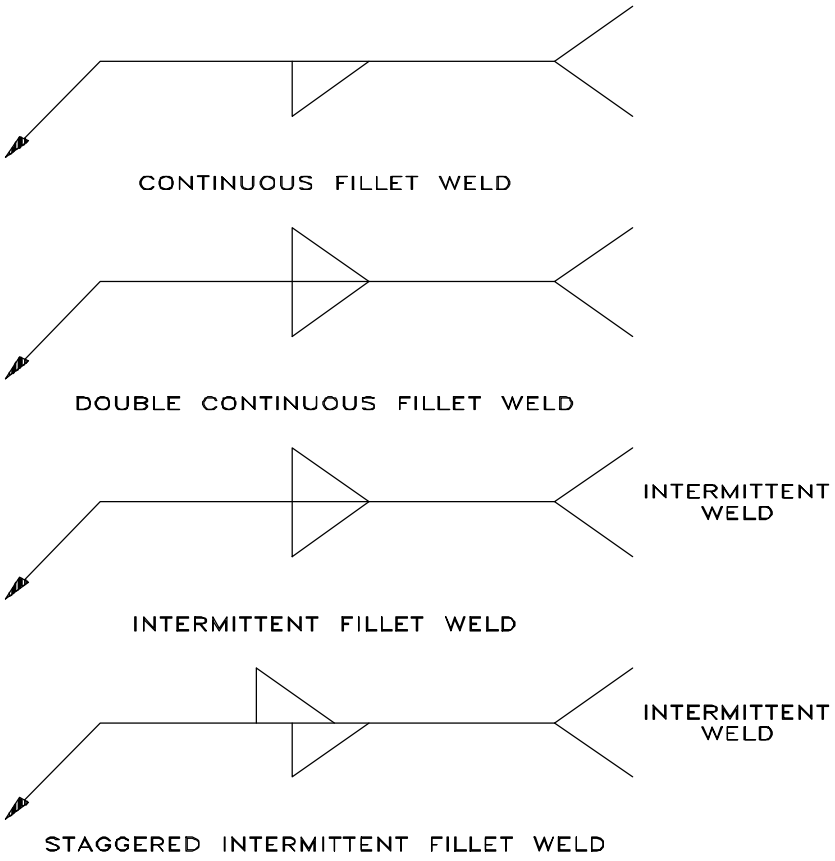


Figure 5.3 Fillet Welds

Shop drawings ***shall*** display adequate information about the location, type, size, and disposition of the welds they are locating.

The contractor ***shall*** use a weld symbol system that complies with the requirements of AWS A.2.4, latest edition.

The Contractor will use a system capable of transmitting information similar to that of AWS Publication A.2.4.

Prior to submitting drawings for review, the Contractor will provide to the Technical, Inspection and Regulatory Authorities adequate information about the system used for weld symbols to ensure that misinterpretation of the welding details that appear on drawings does not occur.

CHAPTER 6 WELDING ELECTRODES AND CONSUMABLES

6.1 GENERAL

This chapter states the requirements for welding electrodes and consumables used for new construction, mid-life modernization and repair welding of steel vessels.

The electrode, electrode-flux, electrode-gas or grade of deposited weld metal ***shall*** meet the requirements specified herein.

All welding electrodes and consumables ***shall*** be certified by CWB in accordance with the applicable CSA W48 Series Standard or ***shall*** conform to the applicable AWS Specification. (See Annex A.) Electrodes and consumables ***shall*** be matched to the base metals being welded following the requirements outlined in this chapter.

This chapter specifies the minimum requirements for storage, handling and conditioning of welding electrodes and consumables. When the minimum requirements specified herein are considered in conflict with manufacturer's recommendations, the more stringent requirement ***shall*** apply.

6.2 STORAGE AND HANDLING

6.2.1 General

Welding electrodes and consumables received in their originally sealed packaging ***shall*** be stored in a dry atmosphere at uniform temperatures. All welding electrodes and consumables ***shall*** be carefully handled to prevent damage to sealed packaging and electrode coating. Packaging ***shall*** be carefully inspected and ***shall*** not be opened until required for welding or distribution to the shop floor. Inventory ***shall*** be rotated in such a manner as to prevent an accumulation of aged materials. When damaged packaging is discovered, the conditions of Clause 6.2.2 ***shall*** apply.

Welding electrodes and consumables ***shall*** be kept free of oil, grease, moisture and other deleterious matter once removed from their original packaging. Electrodes that are or have been "wet" ***shall*** be discarded, (see Chapter 2.0 for definition of wet electrodes).

Electrodes classified as EXXX10 or EXXX11, cellulose coating, ***shall not*** be conditioned or stored in holding ovens at temperatures above 40 °C.

Storage and conditioning ***shall*** comply with the requirements of Table 6.1.

6.2.2 Basic Electrodes

Basic electrodes ***shall*** be supplied by the manufacturer in airtight packaging. Packaging ***shall*** be carefully inspected upon receipt from the manufacturer. Basic electrodes with damaged packaging ***shall*** be discarded or returned to the manufacturer. When basic electrode packaging is damaged during handling by the contractor, electrodes ***shall*** be used within the exposure limit permitted by this standard or immediately placed in holding ovens.

Basic electrodes ***should*** be immediately stored in holding ovens, (see Chapter 2.0), once the air tight packaging is opened. Electrodes from opened packaging that are not immediately stored in holding ovens ***shall*** be used within the exposure limit permitted by this Standard.

Holding ovens ***shall*** maintain a constant dry atmosphere at a temperature not less than 120°C.

Holding ovens ***shall not*** contain articles that produce moisture.

Electrodes removed from holding ovens ***shall*** be placed in a container made of non-hygroscopic material (see Chapter 2.0) to provide adequate protection against moisture pick-up. Maximum exposure to the atmosphere ***shall not*** exceed 4 hours for E 480XX electrodes and 2 hours for basic electrodes of a greater ultimate tensile strength.

When exposure to the atmosphere exceeds the time allotted but is less than 24 hours, electrodes ***shall*** be discarded or ***conditioned*** for a minimum period of one hour at 400°C to 450°C.

Basic electrodes ***shall not*** be ***conditioned*** more than ***once***.

Basic electrodes that are wet shall be discarded

Table 6.1 Filler Material Storage & Conditioning

Filler Material Category	Storage		(1) Re-conditioning	
	°C	°F	°C	°F
Basic Covered Electrodes	100 - 150	200 - 300	400 - 450	700 - 800
Rutile and Other Electrodes	25 - 40	75 - 100	120 - 150	250 - 300
Nickel Covered electrodes	40	100	(1)	(1)
Cellulose Covered Electrodes	25 - 40	75 - 100	(2)	(2)
Basic Flux Cored Electrodes	20 - 40	70 - 100	(1)	(1)
Solid Wires/Other	20 - 40	70 - 100	(3)	(3)
Basic Flux for Submerged Arc Welding	100 - 150 (1)	200 - 300 (1)	400 - 450 (1)	750 - 850 (1)

Note (1) Consult Manufacturer;
(2) Not Recommended;
(3) Not Required.

6.3 IDENTIFICATION

Welding electrodes and consumables ***shall*** be clearly identified in accordance with the governing CSA Standard or AWS Specification (See Annex A).

Welding personnel ***shall*** be knowledgeable in the welding electrode and consumable identification systems employed by the governing standards, specifications and manufacturers (proprietary trade names).

6.4 MATCHING ELECTRODES AND CONSUMABLES TO BASE METALS

Electrodes and consumables for all welding processes ***shall*** be selected on the basis of retained hydrogen, mechanical properties (UTS, YS, elongation and toughness) and resistance to corrosion in sea water.

Generally the requirements of Tables 6.2- 6.7 inclusive ***shall*** apply for most new construction, modernization and repair applications involving the use of normal and higher strength steels having a yield stress below 360 MPa (N/mm²) and Charpy V-notch toughness requirements at test temperatures above -45°C.

For welding higher strength steel, notably grades FH-XX and XX-40 through XX-69 inclusive, welding electrodes and consumables ***shall*** be approved on the basis of successful completion of the tests outlined in Clause 6.12 of this chapter.

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships ***shall*** be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13.

For base metals having a manganese content of less than 1.25 wt%, corrosion resistant weld metals may be selected from the tables herein, where offered.

When corrosion resistant weld zones are not a consideration and two different grades of material of the same tensile strength properties are being joined by welding, electrodes and consumables for the lower grade is generally acceptable. Similarly, when joining materials with differing tensile strength properties, electrodes and consumables are to be suitable for the tensile strength of the component on which the weld size (e.g. fillet weld) has been determined.

For other materials, welding electrodes and consumables ***shall*** be selected in accordance with the requirements of the following clauses:

- Clause 6.11 for atmospheric corrosion resistant steels;
- Clause 6.14 for stainless steels;
- Clause 6.15 for other ferrous materials; and,
- Clause 6.16 for pipe welding.

6.5 BASIC OR CONTROLLED HYDROGEN ELECTRODE REQUIREMENTS

In addition to other factors that must be considered for matching weld metal deposits to the various grades of base materials used for ship construction, modernization and repair, welding processes and their respective welding electrodes and consumables produce varying amounts of hydrogen gas which may be retained in the deposited weld metal. Although the amount of retained hydrogen may be reduced by increasing preheat temperatures, basic and controlled hydrogen electrodes and consumables ***shall*** be required in accordance with Table 6.2.

Table 6.2 Selection of Basic or Controlled Hydrogen Electrodes

Mandatory Use of Basic and Controlled Hydrogen Electrodes					**Other than Basic Electrodes (1)**	
CSA G.40.21					**CSA G.40.21**	Material Thickness (t) ≤ 20 mm
		38W 44W	38WT 44Wt	Material Thickness (t) ≥ 20 mm	38W 38WT	
50W 50A 70W	50WT 50AT 70WT	60W 60A 100Q	60WT 60AT 100QT	All Thicknesses	44W 44WT	
ASTM					**ASTM**	
A36 A516	A53 A529	A500 A570	A501 A572	Material Thickness (t) ≥ 20 mm	A36 A53 Gr. B	
A441 A588 A633	A514 A606 A131	A515 A607	A517 A618	All Thicknesses	A500 Gr. B A501 A516 Gr. 55, 60	
Gr. A	Gr. B	Gr. D	Gr. DS	Material Thickness (t) ≥ 20 mm	A131 Gr. A	
	Gr. CS Gr. AH	Gr. E Gr. DH	Gr. EH	All Thicknesses	Gr. B Gr. D	
ABS / Lloyds					**ABS / Lloyd's**	
		Gr. A Gr. B Gr. D Gr. DS Gr. AH 32, 34 Gr. DH 32, 34		Material Thickness (t) ≥ 20 mm	Gr. A Gr. B Gr. D Gr. DS Gr. AH 32, 34 Gr. DH 32, 34	
		Gr. CS Gr. E Gr. AH 36 Gr. DH 36 Gr. EH 32, 34,36 Gr. FH 32, 36,40 Gr. FH 42 - 69		All Thicknesses		
Where (t) is the thickest member					**Where (t) is the thickest member**	

Note: (1) Independent of the material grade specified, when the carbon equivalent (CE.) of the material exceeds 0.40 where the carbon equivalent is calculated from the ladle analysis as follows:

$$(CE. = \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15})$$

Basic or controlled hydrogen electrodes are required.

When the grades of base metals requiring basic or controlled hydrogen electrodes and consumables are produced using thermomechanical controlled rolling practice, the contractor may apply for exemption from the mandatory requirements listed in Table 6.2. Exemption will only be granted by the Technical Authority after due consideration of susceptibility to hydrogen assisted or induced cold cracking.

6.6 SHIELDED METAL ARC WELDING

Welding electrodes for shielded metal arc welding normal and higher strength shipbuilding grade steels ***shall*** be selected following the requirements of Table 6.3.

Table 6.3 Selection of Welding Electrodes for Shielded Metal Arc Welding

	CSA Standards	AWS Specifications
ABS / Lloyd's	CSA W48.1-M	AWS A5.1
Grade A	E41000,10,11,13,27(2) E48015,16,18,28,48(1) E48014,24(2) CLA E48018-RCR (5) (6) (7)	E6010,11,13,27(2) E7015,16,18,28,48(1) E7014,24(2) ESAB 73:08 (5) (6) (7)
Grades B, D, DS	E41000,10,11,27(2) E48015,16,18,28,48(1) CLA E48018-RCR (5) (6) (7)	E6010,11,27(2) E7015,16,18,28,48(1) ESAB 73:08 (5) (6) (7)
Grades E, CS	E48015,16,18(1) CLA E48018-RCR (5) (6) (7)	E7015,16,18(1) ESAB 73:08 (5) (6) (7)
Grades AH32, 34 DH32, 34	E48015,16,18,28,48(1) CLA E48018-RCR (5) (6) (7)	E7015,16,18,28,48(1) ESAB 73:08 (5) (6) (7)
Grades AH36 DH36	E48015,16,18,28,48(1) CLA E48018-RCR (5) (6) (7)	E7015,16,18,28,48(1) ESAB 73:08 (5) (6) (7)
Grades EH32 EH34 EH36	E48018-1(3) CLA E48018-RCR (5) (6) (7)	E7018(4) ESAB 73:08 (5) (6) (7)
Grades EH40 FH-XX XX-40-69	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13

NOTES:

(1) As required in Table 6.2;

(2) Restricted use as required in Table 6.2;

(3) Charpy V Notch specimens are taken at -45°C;

(4) Only if Charpy V Notch specimens have been taken at -45°C;

(5) For finishing layers or repair of corroded welds located in base plates having Mn ≤ 1.25 %;

(6) E48018-G, E48018-W and E55018-C1, C2 or C3 electrodes may be suitable after proven adequate in accordance with the requirements of Clause 6.13.

(7) When the manganese content of the base plate is below 1.25 wt%, E55018-C1, C2 or C3 may be substituted for those corrosion resistant electrodes listed.

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships shall be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13. These requirements also apply to weld repair of scars in shell plating caused by removal of temporary attachments.

6.7 SUBMERGED ARC WELDING

Wire electrode-flux combinations for submerged arc welding normal and higher strength shipbuilding grade steels ***shall*** be selected following the requirements of Table 6.4.

The submerged arc welding process ***shall*** be considered a process that deposits weld metal designated as Controlled Hydrogen (CH) providing storage, handling and conditioning of wire electrode and flux are in accordance with the manufacturer's recommendations and the requirements specified herein.

Wire electrodes for submerged arc welding ***shall*** be dry and free from rust, contamination or deleterious materials.

Fluxes used for submerged arc welding ***shall*** be dry and free from contamination or deleterious materials.

Flux packaging ***shall*** be so designed to ensure that storage will not have an adverse effect on welding characteristics and/or deposited weld metal properties.

Flux from damaged packaging ***shall*** be discarded or conditioned in an oven for a minimum period of 1 hour at 250°C. Flux ***shall*** be dried in layers not exceeding 50mm in depth.

Unfused deposited basic fluxes exposed to the atmosphere for periods of 4 hours or more ***shall*** be conditioned in accordance with this Clause prior to re-use.

Unfused deposited flux picked up from the weld zone ***shall*** be filtered prior to re-use. Filtering methods ***shall*** ensure all contaminants are removed.

Fused deposited flux ***shall not*** be ground for re-use without approval from the Technical Authority.

Table 6.4 Selection of Welding Electrodes and Consumables for Submerged Arc Welding

Base Material	CSA Standards W48.6-M		AWS Specifications A5.17	
ABS / Lloyds	**Flux**	**Electrodes**	**Flux**	**Electrodes**
Grade A	F4102-XXXX (1) F4802-XXXX (1)	XXXX-EL12 XXXX-EM12K	F60-XXXX (1) F70-XXXX (1)	XXX-EL12 XXX-EM12K
Grades B,D,DS	F4102-XXXX (1) F4802-XXXX (1)	XXXX-EL12 XXXX-EM12K	F60-XXXX (1) F70-XXXX (1)	XXX-EL12 XXX-EM12K
Grades E,CS	F4804-XXXX (1) F4805-XXXX (1)	XXXX-EM12K XXXX-EM13K	F74-XXXX (1) F76-XXXX (1)	XXX-EM12K XXX-EM13K
Grades AH32,34 DH32,34	F4802-XXXX (1) F4803-XXXX (1)	XXXX-EM12K XXXX-EM13K	F70-XXXX (1) F72-XXXX (1)	XXX-EM12K XXX-EM13K
Grades AH36 DH36	F4802-XXXX (1) F4803-XXXX (1)	XXXX-EM12K XXXX-EM13K	F70-XXXX (1) F72-XXXX (1)	XXX-EM12K XXX-EM13K
Grades EH32,34 EH36	F4804-XXXX (1) F4805-XXXX (1)	XXXX-EM12K XXXX-EM13K	F74-XXXX (1) F76-XXXX (1)	XXX-EM12K XXX-EM13K
Grades EH40 FH-XX XX-40-69	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13

Note: (1) Neutral flux only for shell plate groove welds.

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships ***shall*** be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13.

There are no pre-approved corrosion resistant wire electrodes for submerged arc welding.

6.8 FLUX CORED ARC WELDING

Wire electrodes for flux cored arc welding normal and higher strength shipbuilding grade steels ***shall*** be selected following the requirements of Table 6.5. Shielding gas type ***shall*** be in accordance with the approved weld procedure data sheets for the wire electrode selected.

Flux cored arc welding wire electrodes ***shall*** be dry, clean, free of surface rust and deleterious materials.

When required, as specified in Table 6.2 of this chapter, flux cored arc welding wire electrodes ***shall*** be of the Controlled Hydrogen (CH) type.

Flux cored arc welding wire electrodes ***shall*** only be used in the position of welding they are approved for.

Shielding gas ***shall*** be welding grade having a dew point of -40°C or lower.

Shielding gas cylinders ***shall*** clearly display their contents. Welding personnel ***shall*** be familiar with the identification system employed by the manufacturer.

Table 6.5 Selection of Welding Electrodes for Flux Cored Arc Welding

Base Materials ABS/Lloyds	CSA Standards CSA W48.5-M		AWS Specifications AWS A5.20	
Grade A	E410X -T -1 E480X -5 -6 -8 -9	E410X -T -G(1) E480X -GS(1)(2) -2(1) -3(1) -4(1) -7(1) -10(1) -11(1)	EX6 -T -1 E7X -5 -6 -8	E6X -T -G(1) E7X -GS(1)(2) -2(1) -3(1) -4(1) -7(1) -10(1) -11(1)
Grades B,D,DS	E480X -T -1 -6 -8	E480X -T -9 -G1 (1) -G2 (1)	E7X -T -5 -6 -8	E7X -T -1
Grades E	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13
Grades AH32,34 DH32,34	E480X -T -1 -6 -8 -G1(1)	E480X -T -9 -G2(1)	E7X -T -5 -6 -8	E7X -T -1
Grades AH36 DH36	E480X -T -9 -G2(1)		E7X -T -5 -6 -8	
Grades EH32,34 EH36	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13
Grades EH40 FH-XX XX-40-69	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13

NOTE: (1) Submit to the Technical Authority for approval;
(2) For single pass welds only;

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships ***shall*** be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13. These requirements also apply to weld repair of scars in shell plating caused by removal of temporary attachments.

There are no pre-approved corrosion resistant wire electrodes for flux cored arc welding.

6.9 GAS METAL ARC WELDING

Wire electrodes for gas metal arc welding normal and higher strength shipbuilding grade steels ***shall*** be selected following the requirements of Table 6.6. Shielding gas type ***shall*** be in accordance with the approved weld procedure data sheets for the wire electrode selected.

The gas metal arc welding process ***shall*** be considered a process that deposits weld metal designated as Controlled Hydrogen (CH) providing storage, handling and conditioning of wire electrodes are in accordance with the manufacturer's recommendations and the requirements specified herein.

Gas metal arc welding wire electrodes ***shall*** be dry, clean, free of surface rust and deleterious materials.

Shielding gas ***shall*** be welding grade having a dew point of -40°C or lower.

Shielding gas cylinders ***shall*** clearly display their contents. Welding personnel ***shall*** be familiar with the identification system employed by the manufacturer.

Table 6.6 Selection of Welding Electrodes for Gas Metal Arc Welding

Base Materials ABS/Lloyds	CSA Standards CSA W48.4-M	AWS Specifications AWS A5.18
Grade A	ER480S-2 -6 -7, ER480S-3, ER480S-G(1) -4(1) -5(1)	ER70S-2 -6 -7, ER70S-3, ER70S-G(1) -4(1) -5(1)
Grades B,D,DS	ER480S-2 -6 -7, ER480S-3, ER480S-G(1)	ER70S-2 -6 -7, ER70S-3, ER70S-G(1))
Grades E,CS	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13
Grades AH32,34 DH32,34	ER480S-2 -6 -7, ER480S-3, ER480S-G(1) -4(1) -5(1)	ER70S-2 -6 -7, ER70S-3, ER70S-G(1)
Grades AH36 DH36	ER480S-2 -6 -7, ER480S-G(1)	ER70S-2 -6 -7, ER70S-G(1)
Grades EH32,34 EH36	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13
Grades EH40 FH-XX XX-40-69	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13

Note: (1) Submit to the Technical Authority for approval;

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships **shall** be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13. These requirements also apply to weld repair of scars in shell plating caused by removal of temporary attachments.

There are no pre-approved corrosion resistant wire electrodes for gas metal arc welding.

6.10 ALL METAL CORED WIRE ELECTRODES

Wire electrodes for gas shielded all metal cored arc welding normal and higher strength shipbuilding grade steels ***shall*** be selected following the requirements of Table 6.7 herein. Shielding gas type ***shall*** be in accordance with the approved weld procedure data sheets for the wire electrode selected.

When required, as specified in Table 6.2 of this chapter, all metal cored wire electrodes ***shall*** be of the Controlled Hydrogen (CH) type.

All metal cored wire electrodes ***shall*** only be used in the position they are approved for.

All metal cored wire electrodes ***shall*** be dry, clean, free of surface rust and deleterious materials.

Shielding gas ***shall*** be welding grade having a dew point of -40°C or lower.

Shielding gas cylinders ***shall*** clearly display their contents. Welding personnel ***shall*** be familiar with the identification system employed by the manufacturer.

Table 6.7 Selection of Welding Electrodes for All Metal Cored Wire Welding

Base Materials ABS/Lloyds	CSA Standards CSA W48.5-M	AWS Specifications AWS A5.18
Grade A	E480XC-3 E480XC-6 E480XC-G (1) E480XC-GS (1)	E70C-3 (2) E70C-6 (2) E70C-G (1) (2) E70C-GS (1) (2)
Grades B,D,DS	E480XC-3 E480XC-6 E480XC-G (1) E480XC-GS (1)	E70C-3 (2) E70C-6 (2) E70C-G (1) (2) E70C-GS (1) (2)
Grades E,CS	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13
Grades AH32,34 DH32,34	E480XC-3 E480XC-6 E480XC-G (1) E480XC-GS (1)	E70C-3 (2) E70C-6 (2) E70C-G (1) (2) E70C-GS (1) (2)
Grades AH36 DH36	E480XC-3 E480XC-6 E480XC-G (1) E480XC-GS (1)	See Clause 6.12 See Clause 6.13
Grades EH32,34 EH36	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13
Grades EH40 FH-XX XX-40-69	See Clause 6.12 See Clause 6.13	See Clause 6.12 See Clause 6.13

NOTES: (1) Submit to the Technical Authority for approval;

(2) Tests required to meet controlled hydrogen (CH) requirements.

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships ***shall*** be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13. These requirements also apply to weld repair of scars in shell plating caused by removal of temporary attachments.

There are no pre-approved corrosion resistant all metal cored wire electrodes.

6.11 ELECTROSLAG AND ELECTROGAS WELDING

Electroslag and electrogas welding electrodes and consumables ***shall*** be approved by weld procedure qualification tests for all material grades.

Tests that have already been performed in accordance with a recognized standard (e.g. Lloyds, ABS or DnV) ***shall*** be approved by the Technical Authority on an individual case basis.

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships ***shall*** be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13.

There are no pre-approved corrosion resistant weld metal deposits for electroslag and electrogas welding processes.

6.12 ELECTRODES FOR ATMOSPHERIC CORROSION RESISTANT STEELS

Electrodes for shielded metal arc welding atmospheric corrosion resistant steels ***shall*** be selected following the requirements of Table 6.8.

Table 6.8 Welding Electrodes & Consumables for Improved Atmospheric Corrosion Resistant Steel

Base Materials	Shielded Metal Arc Welding	Gas Metal Arc Welding	Flux Cored Arc Welding	Submerged Arc Welding
CSA G40.21	**CSA W48.3(M)**	**AWS A5.28**	**AWS A5.29**	**AWS A5.23**
50A 50AT 60A 60AT ASTM A242 A588	E48015 (E8015) E48016 (E8016) E48018 (E8018) -G -B1 -B2 -B2L -C1 -C2 -C3	ER80S -G -B2 -BL -Ni1 -Ni2 -Ni3	E8XTX -B1 -B2 -B2L -Ni1 -Ni2 -Ni3	F7-EXXX F8-EXXX -W -B1 -B2 -Ni1 -Ni2 -Ni3 -Ni4
	▪ Minimum impact properties required 27J at -18°C (20 ft.-lb at 0°F). ▪ EXXXXX-G Electrodes require submission of typical deposited composition for review.	▪ Minimum impact properties required 27J at -18°C (20 ft.-lb at 0°F). ▪ ER80S-G Electrodes require submission of typical deposited composition for review.	▪ "CH" classification only ▪ Minimum impact properties required 27J at -18°C (20 ft.-lb at 0°F). ▪ CSA EXXXT-G-CH Electrodes require submission of typical deposited composition for review.	▪ Minimum impact properties required 27J at -18°C (20 ft.-lb at 0°F). ▪ FX-EXXX-W Electrodes require submission of deposited composition for review.

The finishing layers of shell butts and seams located on the sea water side of ice-transiting ships ***shall*** be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13. These requirements also apply to weld repair of scars in shell plating caused by removal of temporary attachments.

There are no pre-approved corrosion resistant weld metal deposits for atmospheric corrosion resistant steels for any welding process.

6.13 ELECTRODES FOR HIGHER STRENGTH NOTCH TOUGH STEELS

Welding electrodes and consumables for joining normal and high strength shipbuilding grade steels that have been manufactured using the thermomechanical controlled rolling practice method ***shall*** be approved by a series of weld procedure qualification tests.

Welding electrodes and consumables for joining shipbuilding steel grades FH-XX and XX-40 through XX-69 inclusive ***shall*** also be approved by a series of weld procedure qualification tests.

As a minimum, welding electrodes and consumables ***shall*** match the base metal strength (UTS, YS and elongation) and notch toughness properties at the base metal test temperature. If weld deposits are intended to be located on the sea water side of the shell envelope, they are to be proven resistant from weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Clause 6.13.

There are no pre-approved corrosion resistant welding electrodes and consumables for the grades of steels referred to in this Clause. These requirements also apply to weld repair of scars in shell plating caused by removal of temporary attachments.

To qualify welding electrodes and consumables, a series of weld procedure qualification tests ***shall*** be performed in each position of welding using joint configurations typical of that intended for production. For each of the test conditions, two welds ***shall*** be made; one test each at the minimum and maximum anticipated heat inputs (kj/mm) planned for production welding.

Assemblages, type of tests and specimens ***shall*** be in accordance with CSA Standard W47.1. Each procedure qualification test ***shall*** be supplemented with 15 Charpy V notch specimens; 5 specimens with the "V" notch located at the centre of the joint, 5 specimens with the "V" notch intersecting the line of fusion and 5 specimens with the "V" notch located 5mm from the fusion line (HAZ). Charpy V notch specimens ***shall*** be tested in accordance with the requirements of CSA Standard W47.1 at test temperatures equivalent to that of the base metal classification (i.e. E & EH @ -40°C, FH @ -60°C, etc.).

The minimum acceptance requirements for each test method, ***shall*** be those requirements of the test standard under which the base metal was qualified.

When corrosion resistant weld zones are not a consideration and two different grades of material of the same tensile strength properties are being joined by welding, electrodes and consumables for the lower grade is generally acceptable. Similarly, when joining materials with differing tensile strength properties, electrodes and consumables are to be suitable for the tensile strength of the component on which the weld size (e.g. fillet weld) has been determined.

6.14 ELECTRODES AND CONSUMABLES FOR RESISTING CORROSION IN SEA WATER

Weld deposits required to exhibit resistance to corrosion in sea water ***shall*** meet all of the requirements of this Clause. Two test methods ***shall*** be used to determine corrosion resistance; the anodic dissolution test and the synthetic sea water tank test.

Once the contractor has matched a welding electrode and consumable to the minimum base plate mechanical property requirements of this Standard, test specimens ***shall*** be prepared, welded and tested for corrosion resistance in sea water by conducting anodic dissolution tests as outlined in Annex C of this Standard. Two weld specimens ***shall*** be made for each weld metal/base metal combination; one test each at the anticipated minimum and maximum heat inputs (kj/mm) planned for production welding.

The target acceptance criterion sought is near equivalent loss of the base plate, heat affected zone and weld metal deposit. Since this may not always be accomplished for all grades of base metal, slight loss of weld metal is desired over any loss in the heat affected zone. Anodic dissolution test results ***shall*** be tabulated and submitted to the Technical Authority for consultation prior to synthetic sea water tank testing.

Once optimum corrosion resisting weld zones have be identified, the contractor ***shall*** prepare trapezoidal specimens for synthetic sea water tank testing following the requirements of Annex C of this Standard to validate anodic dissolution test results. The Technical Authority may choose to waive tank tests if sufficient previous research data is present to safely predict corrosion life and behavior.

Welding bead sequence for these tests must employ a stringer temper bead technique as illustrated in Annex C of this Standard. All finishing layers of shell butts and seams located on the sea water side of ice-transiting ships ***shall*** be welded by the stringer temper bead technique. No weaving is permitted.

6.15 STAINLESS STEELS

Welding electrodes and consumables for joining stainless steels ***shall*** be selected following the requirements of Table 6.9.

Table 6.9 Electrodes and Consumables for Stainless Steels

Base Materials	Shielded Metal Arc Welding CSA W48.2-M,. AWS A5.4		Gas Metal Arc Welding AWS 5.9		Gas Tungsten Arc Welding AWS 5.9	
302	E308-15 E308-16		ER 308		ER 308	
304	E308-15 E308-16	E308L-15 E308L-16	ER 308 ER 308L	ER 308L Hi Sil	ER 308 ER 308L	ER 308L Hi Sil
304 ELC	E308L-15 E308L-16	E347-15 E347-16	ER 308L ER 308L Hi Sil		ER 308L ER 308L Hi Sil	
308	E308-15 E308-16	E309-15 E309-16	ER 308 ER 309		ER 308 ER 309	
310	E310-15 E310-16		ER 310		ER 310	
316	E316-15 E316-16	E316L-15 E316L-16	ER 316 ER 316L		ER 316 ER 316L	
316 ELC	E316L-15 E316L-16	E309MoL-15 E309MoL-16	ER 316L		ER 316L	
317	E317-15 E317-16	E309MoL-15 E309MoL-16	ER 317		ER 317	

Base Materials	Shielded Metal Arc Welding CSA W48.2-M,. AWS A5.4	Gas Metal Arc Welding AWS 5.9	Gas Tungsten Arc Welding AWS 5.9
321	E347-15 E347-16	ER 347	ER 347
347	E347-15 E347-16	ER 347	ER 347
348	E347-15 E347-16	ER 347	ER 347
431	E308-15 E308-16 E309-15 E309-16	ER 308 ER 309	ER 308 ER 309

Welding electrodes and consumables for other grades of stainless steel ***shall*** be selected in accordance with the requirements of ASME Section IX.

Repairs to corroded steel/stainless steel connections (e.g. Kort Nozzles) ***shall*** be performed following the requirements of Annex I of this Standard.

6.16 OTHER MATERIALS

Welding electrodes and consumables for joining other materials common to ship construction, modernization and repair ***shall*** be selected following the requirements of Table 6.10.

Table 6.10 Electrodes and Consumables for Other Materials

Base Materials	Shielded Metal Arc Welding AWS A5.6, A5.11, A5.15	Gas Metal Arc and Gas Tungsten Arc Welding AWS A5.7, A5.14
Monel 404 R-405	E Ni Cu-7	ER Ni Cu-7
Monel K-500 502	E Ni Cu-7	ER Ni Cu-7
Inconel 625	(1) MIL-E22200/3 Type MIL-1N12	ER Ni Cr Mo-3
Incoloy 801 802	(1) MIL-E22200/3 Type MIL-1N12	ER Ni Cr Mo-3
Copper Nickel 90/10 80/20 70/30	E Cu Ni	ER Cu Ni
Cast Iron - Gray - Ductile - Malleable	(2) E Ni CI E Ni Fe-CI	(3)
Monel to Steel	E Ni Cu-7	ER Ni-3
Copper Nickel to Steel	E Ni Cu-7	ER Ni-3
Cast Iron to Steel	E Ni Fe-CI	(3)
Nickel to Steel	E Ni-1	ER Ni-3

Note (1) U.S. Military Standard;
(2) Improved machineability of weld deposits;
(3) Flux Cored Wire with the appropriate composition (minimum 55% Ni).

Welding electrodes and consumables for other materials not listed in Table 6.9 shall be selected in accordance with the requirements of ASME Section IX.

6.17 PIPE WELDING

Welding electrodes and consumables for joining materials forming pressure vessels, piping and components forming part of pressure containment systems ***shall*** be selected in accordance with the requirements of ASME Section IX.

CHAPTER 7 QUALIFICATIONS OF CONTRACTORS FOR FUSION WELDING

7.1 GENERAL

This chapter states the qualification requirements of contractors for fusion welding ferrous materials for new construction, modernization, alteration and repair welding of Coast Guard vessels.

This chapter requires all contractors to be currently certified by CWB in accordance with CSA Standard W47.1, Latest Edition "Certification of Companies for Fusion Welding of Steel Structures".

7.2 WELDING

All primary contractors ***shall*** be currently certified by CWB in accordance with CSA Standard W47.1, Latest Edition, Division 1, 2.1 or 2.2.

All personnel performing work ***shall*** be approved by the Canadian Welding Bureau. Typical personnel ***shall*** include:

- Welding Engineer (Staff or Retained)
- Welding Supervisor(s);
- Welder(s);
- Welding Operator(s);
- Tack Welder(s).

All sub-contractors shall be currently certified by CWB in accordance with CSA Standard W47.1, Latest Edition, Division 1, 2.1., 2.2 or 3. When a sub-contractor is certified to Division 3 requirements, then the primary Contractor shall have a certified Quality Assurance Program in place that introduces and maintains proper control of the sub-contractor's performance.

7.3 TESTS

All tests for welding personnel qualification ***shall*** be administered and witnessed by CWB. The Technical, Inspection or Regulatory Authorities may choose to witness tests administered by CWB.

7.4 QUALIFICATION TO OTHER CODES AND STANDARDS

Welders, welding operators and tack welders who are currently qualified to codes, standards or classifications, other than those outlined within this chapter, may be accepted providing CWB issues certificates of compliance to the qualification categories of CSA Standard W47.1.

7.5 QUALIFICATION OF WELDERS AND WELDING OPERATORS FOR THIN MATERIALS

In addition to the tests required in CSA Standard W47.1, for materials 4 mm or less the following ***shall*** apply:

- For groove welds the welder or welding operator ***shall*** qualify using the joint type to be used in practice. Apart from thickness, the dimensions of the test plate ***shall*** be per CSA W47.1.

- A stop/start ***shall*** be made in the first pass of the weld which ***shall***, thus, be defined as the root. A total of two (2) root and two (2) face bends ***shall*** be taken as per CSA W47.1 except that one (1) root bend ***shall*** be through the start /stop position. The acceptance criterion of CSA W47.1 ***shall*** apply except that the maximum flaw size after bending ***shall*** be 2 mm.

- For fillet welds the test ***shall*** be made using the test plate length and stop/start as per CSA W47.1, except that the fillet leg length and material thickness ***shall*** be as per that used in practice. A total of three (3) macro sections ***shall*** be taken, two (2) as per CSA W47.1 and the third macro ***shall*** be taken through the stop/start. The acceptance criterion of CSA W47.1 ***shall*** apply.

- Fracture tests for materials of this thickness are not required.

7.6 QUALIFICATION OF WELDERS AND WELDING OPERATORS FOR TEMPORARY NON METALLIC BACKING MATERIALS

Welders and welding operators intended to weld joints containing temporary non metallic backing materials ***shall*** be qualified in accordance with CSA Standard W47.1 to "T" classification for the process, electrode, base metal and positions of welding intended to be used for production.

Welders and welding operators currently qualified to "S" classification may retest to "T" classification or be subjected to separate qualification tests per the special conditions requirements of CSA W47.1.

CHAPTER 8 QUALIFICATION OF WELD PROCEDURES

8.1 GENERAL

This chapter states the qualification requirements of weld procedures used for fusion welding of ferrous materials for new construction, modernization, alteration and repair of steel vessels.

This chapter requires all contractors to document the appropriate information on Weld Procedure Data sheets in accordance with CSA Standard W47.1 for general structural applications and ASME Code Section IX for pipe and pipe connections.

All Contractors shall submit their confidential file of Welding Specifications and Welding Procedure Data Sheets to the Technical Authority for approval prior to commencing welding work.

8.2 APPROVED WELD PROCEDURES

Welding shall only occur with procedures that are approved by the Technical Authority. All submissions for approval shall display CWB's stamp of compliance.

8.3 WITNESSING OF TESTS

Unless otherwise agreed to by the Technical Authority, all tests for structural plate applications ***shall*** be witnessed by CWB. Similarly, unless otherwise agreed to by the Technical Authority, all tests for pressure vessels, piping and components of pressure containing systems ***shall*** be witnessed by either the Provincial Pressure Vessel Authority or the CWB.

The Technical, Inspection or Regulatory Authorities may choose to witness tests administered by CWB.

8.4 PROCEDURE QUALIFICATION OF THIN MATERIALS

For qualification of procedures for materials 4 mm or less in thickness, the contractor ***shall*** agree to perform tests using the joint geometry and parameters to be used in production. The following ***shall*** apply:

- For groove welds, apart from thickness, the dimensions of the test plate ***shall*** be per CSA W47.1.

- No reduced section tension test is required, but all other tests ***shall*** be as required in CSA W47.1. The acceptance criterion of CSA W47.1 ***shall*** apply except that the maximum flaw size after bending ***shall*** be 2 mm.

- For fillet welds the test ***shall*** be made using the test plate length and stop/start as per CSA W47.1, except that the fillet leg length and material thickness ***shall*** be as per that used in practice. A total of three (3) macro sections ***shall*** be taken, two (2) as per CSA W47.1 and the third macro ***shall*** be taken through the centre of the weld. The acceptance criterion of CSA W47.1 ***shall*** apply.

8.5 PROCEDURE QUALIFICATION FOR TEMPORARY NON METALLIC BACKING MATERIALS

Separate qualification tests are required for joints welded using temporary non metallic backing materials as specified herein. For the purposes of this Standard, non metallic backing materials ***shall*** be classed as flux or ceramic type.

For joints welded using granular flux backing materials, weld procedure qualification testing to the requirements of CSA Standard W47.1 is required. All procedure testing must be witnessed by the Canadian Welding Bureau. Weld procedure data sheets, displaying CWB's stamp, and weld procedure qualification test records ***shall*** be submitted to the Technical Authority for approval.

Ceramic backing materials may be fitted to joints that are intended to be welded using previously approved procedures without further qualification subject to the following conditions:

- The joint is welded from both sides employing gouge to sound metal techniques.

- A new data sheet, indicating the use of ceramics is produced and submitted to the Technical Authority displaying CWB's stamp of compliance. For each proposed ceramic material, the supplier's technical data sheet must be attached thereto.

- The as-fitted condition of joints for ceramic attachment are in conformance with the workmanship tolerances of Clause 9.5, Table 9.1 "Groove Weld Tolerances", of this Standard.

For all other joint geometry and welding technique conditions, qualification by testing to the requirements of CSA Standard W47.1 and this Standard is required. Each data sheet ***shall*** indicate workmanship tolerances for preparation, alignment and fit-up.

CHAPTER 9 WORKMANSHIP

9.1 ENVIRONMENT

The work being welded ***shall*** be adequately protected against the direct effects of wind, rain and snow throughout the welding operation. Welding ***shall not*** be carried out when the ambient temperature is below -17°C. The ambient temperature will be considered the temperature surrounding the work being welded. The minimum temperature of the material being welded ***shall*** be as specified in Clause 9.10 of this Standard unless otherwise approved on the weld procedure data sheet.

Welding with processes that utilize externally supplied shielding gas ***shall not*** be performed in a draught or wind unless the weld zone is protected from loss of shielding gas. Protective shelters ***shall*** be designed and erected to reduce draught or wind velocity in the vicinity of the weld zone to a value below 2.25 m/second (8 km/hour).

9.2 PREPARATION OF MATERIALS

Surfaces and edges of plates ***shall*** be clean, smooth, uniform and free of discontinuities that will affect the structure or strength of the weld connection and completed weld.

Surfaces to be welded ***shall*** be free of deleterious materials that may adversely affect the quality of the weld. Typical deleterious materials would include:

- Paint (except weldable primers)
- Oil
- Grease
- Moisture
- Rust
- Heavy mill scale, etc.

Prior to welding, plate surfaces ***shall*** be cleaned of paint and other deleterious materials to a minimum distance of 50 mm from each weld toe. When high preheat temperatures are used and plate surfaces are painted, an increase in the minimum distance is required.

Welding over pre-construction primer ***shall*** only be permitted when the welding and pre-construction primer conditions have been approved by the Technical Authority based on the results of the tests outlined in Annex B of this Standard.

Plate edges and weld preparation surfaces ***shall*** be examined for the presence of nicks, gouges and irregularities. Occasional notches less than 3 mm in depth on otherwise satisfactory surfaces ***shall*** be repaired by grinding or machining. Occasional notches greater than 3 mm and less than 8 mm in depth on flame cut surfaces of plate less than 75 mm in thickness may be repair welded. All repair welds ***shall*** be examined and accepted prior to fit-up. When an irregularity is removed and does not require repair welding, it ***shall*** be prepared with at least a slope of 1 in 10 in the longitudinal direction.

All repair welds ***shall*** use approved weld procedures. When a discontinuity is removed and does not require welding, it ***shall*** be prepared with at least a slope of 1 in 10 in the longitudinal direction.

Plate edges and weld preparation surfaces ***shall*** be visually examined prior to fabrication for the presence of discontinuities lying parallel to the plate surface (planar discontinuities).

If planar discontinuities are discovered, they ***shall*** be immediately reported to the Inspection Authority. Repair of planar discontinuities is only permitted when welding and inspection procedures have been approved by the Technical Authority. Contractor submissions requesting approval should follow the guidelines of Clause 5 of CSA Standard W59. When the accumulated length of all discontinuities located on a single plate edge is equal to or greater than 10% of the single plate edge length, no action ***shall*** be taken without approval of the Technical Authority. The plate in question ***shall*** be examined by ultrasonic methods to the extent required by the Inspection Authority.

All contractors ***shall*** have a "Workmanship Standard" in place to control cutting line accuracy. Tolerances ***shall*** include, but not be limited to, the following:

- Machine Plasma Cutting ± 2 mm from required dimension
  ± 2.5° from required dimension
- Machine Oxy/Fuel Cutting ± 3 mm from required dimension
  ± 3.5° from required dimension
- Manual Oxy/Fuel Cutting ± 4 mm from required dimension
  ± 5° from required dimension

9.3 HEAT LINE BENDING

Heat line bending by the application of oxy-fuel gas torches for creating curvatures in plates is permitted for certain shipbuilding grade steels, providing the requirements of this Clause are complied with.

9.3.1 Personnel

Personnel performing heat line bending ***shall*** be trained to a high standard and qualified prior to forming plates for production or repair of distortion. A list of qualified personnel ***shall*** be submitted to the Inspection Authority prior to any heat line bending operations.

9.3.2 Materials

Heat line bending is permitted on shipbuilding grade materials "A"-"EH36" providing the material has not been produced by the thermo-mechanical controlled rolling practice method. All other grades of steel including "FH-XX" and "XX-40 through XX-69" inclusive, ***shall*** require special consideration and approval by the Technical Authority. Heat line bending ***shall not*** be permitted on quench and tempered steels.

9.3.3 Procedures

For those pre-approved shipbuilding grades of steel listed in Clause 9.3.2 herein, heat line bending procedures and techniques ***shall*** be limited to the following:

Steel Grade	Maximum Allowable Temperature	Maximum Water Quenching Temperature	Technique
All Grades (except EH)	900°C	550°C	Air and Water Cooling
EH	650°C	550°C	Air and Water Cooling

For those materials not pre-approved, heat line bending procedures ***shall*** be submitted to the Technical Authority for approval. The submission ***shall*** contain results of metallurgical, physical and corrosion tests.

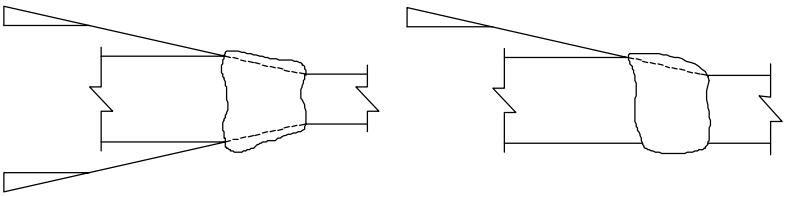
9.3.4 Controls

During plate forming, controls ***shall*** be in place to check maximum plate and water or air quenching temperatures. On material grades having notch toughness properties, direct supervision and monitoring is required.

9.4 DISSIMILAR PLATE THICKNESS

Plates of different thicknesses that are groove welded require a transition in accordance with the requirements of this Clause.

When the difference in thickness is less than or equal to 5 mm, the transition may be created by welding as illustrated in Figure 9.1.

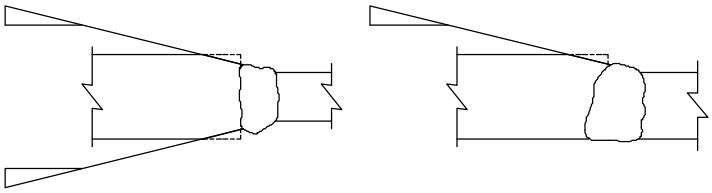


TRANSITION BY SLOPING WELD SURFACE

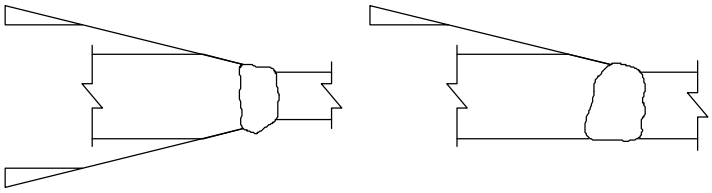
1 in 4 for Shell Plating of Ice-Transiting Ships
1 in 3 for Others

Figure 9.1 Sloping Weld

When the difference in thickness exceeds 5 mm, the transition may be achieved by chamfering or a combination of chamfering and welding as illustrated in Figure 9.2.



TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING AFTER WELDING



TRANSITION BY CHAMFERING THICKER PART PRIOR TO WELDING

1 in 4 for Shell Plating of Ice-Transiting Ships
1 in 3 for Others

Figure 9.2 Chamfering

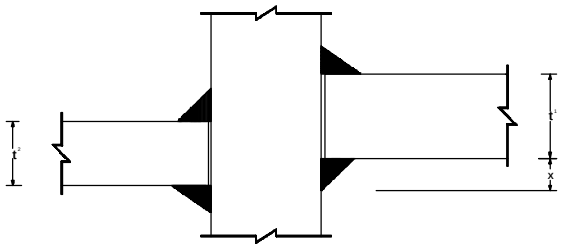
9.5 WORKMANSHIP TOLERANCES

9.5.1 General

Joints fitted for welding ***shall*** meet the dimensional tolerances detailed herein, unless otherwise approved on construction or repair drawings.

9.5.2 Intercostals

Alignment of intercostals ***shall not*** exceed the limitations illustrated in Figure 9.3.



(X) = misalignment

For Strength Members:	- When $t^1/3 \leq (X) < t^1/2$	Increase Fillet Leg Size Equal to Offset
	- When $(X) > t^1/2$	Release and Re-Align
For Other Members:	- When $(X) > t^1/2$	Release and Re-Align

Figure 9.3 Intercostals

9.5.3 Lap Joints

Alignment of lapping structure ***shall not*** exceed the limitations illustrated in Figure 9.4

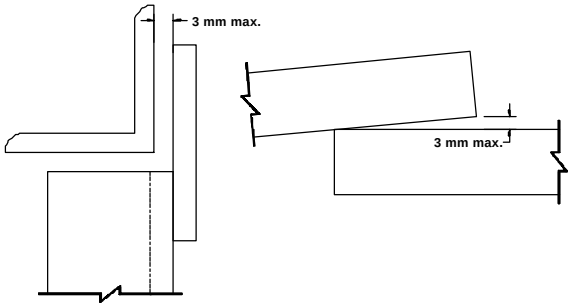
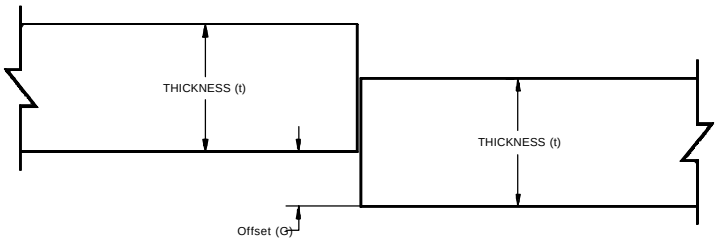


Figure 9.4 Lapping Structure

The members ***shall*** be fitted to have a lapped faying surface of 3 (t), 25 mm minimum. When a gap is present between members, the fillet weld ***shall*** be increased in size equal to the gap (i.e., 5 mm + 3 mm, new size 8 mm).

9.5.4 Butt Joints

Alignment of plates to be groove welded ***shall not*** exceed the limitations illustrated in Figure 9.5.



OFFSET (G) = 0.10 (t), 3 mm maximum
Where (t) is the thinnest member

Figure 9.5 Plating Alignment

When fitted with an acceptable misalignment, the weld ***shall*** be built-up by welding to offer a transition equivalent to that specified in Clause 9.4 of this Standard.

9.5.5 Fitted Tolerances for Groove Welds

Edge preparations for groove welds utilizing all welding processes except electrogas and electroslag welding ***shall*** require joint geometry dimensions as shown on the approved Weld Procedure Data Sheet. Variations in groove dimensions, fit up and assembly, ***shall not*** exceed the tolerances listed in Table 9.1

Table 9.1 Tolerances for Groove Welds

	Not Removed to Sound Metal	Removed to Sound Metal
Included Angle (1)	+ 10° - 5°	+ 10° - 5°
Root Face	+ 3mm - 2mm	.5 (t)
Root Opening with Backing Bar	+ 3mm - 2mm	N/A N/A
Root Opening without Backing Bar	+ 2mm - 1mm	+ 2mm - 2mm

Note: ***(1)*** *When the groove angle is the minimum permitted by Clause 10 of CSA Standard W59, a minus tolerance from that which has been approved on the data sheet, is not permitted.*

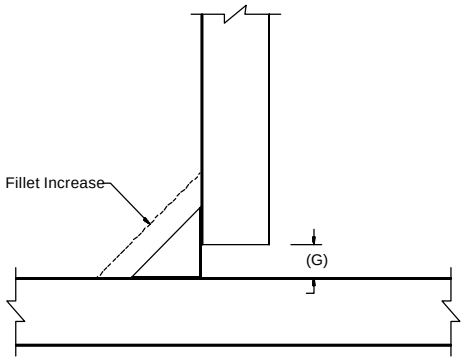
Root openings in excess of the allowable tolerances in Table 9.1 may be repair welded by buttering techniques, providing the following conditions are complied with:

- The build-up procedure is documented on the appropriate data form;
- The build-up procedure is approved by the Technical Authority;
- The Inspection Authority accepts the build-up procedure for the location in question;
- The completed repair is subjected to non-destructive inspection to the extent required by the Inspection Authority prior to and after welding the final connection.

- For strength members, the build-up ***shall not*** exceed 0.5 (t) where (t) is the plate thickness;
- For other members, the build-up ***shall not*** exceed 1.0 (t) where (t) is the plate thickness.

9.5.6 Tee Joints to be Fillet Welded

Tee joints attached by fillet welds ***shall*** be brought into as close contact as is practicable. The separation between faying surfaces ***shall not*** exceed the limitations illustrated in Figure 9.6. The fillet weld leg length ***shall*** be increased in size equal to the gap.



(G) = 3mm Maximum

Figure 9.6 Fillet Welds

9.6 WELDING PROCESSES

All Submerged Arc Welding, Electroslag Welding, Electrogas Welding and Stud Welding ***shall*** meet the workmanship and pre-qualified joint requirements of CSA Standard W59 Clause 5 and Clause 10 respectively.

9.7 ACCESS AND POSITIONING

Whenever possible, welds ***shall*** be made in the flat position.

When designing joints or establishing erection plans, access for the welder ***shall*** be considered. Special attention and planning ***shall*** be given to joints requiring full penetration welds. Production and inspection schedules ***shall*** be such to permit welding, inspection and corrections in an accessible condition.

Additional consideration ***shall*** be given to the size of welding equipment (e.g. GMAW vs. SMAW) and the restriction it places on welding access.

9.8 DISTORTION AND RESIDUAL STRESS

9.8.1 General

Welding of structures, sub-assemblies and parts ***shall*** progress symmetrically to minimize distortion. Members ***should*** remain unrestrained during welding to minimize stresses. Welds ***shall*** be deposited in a sequence that will balance the heat applied throughout the welding process. Welds ***shall*** progress from points where the parts are relatively fixed in position towards points where they have relatively greater freedom of movement.

Weld sizes ***shall*** be kept to a minimum. Excessive weld cross sections and over welding ***shall*** be avoided. Joints anticipated to cause significant shrinkage ***shall*** be welded first.

9.8.2 Submission of Welding Sequence

All contractors ***shall*** submit a welding sequence prior to performing any work.

Welding sequences ***shall*** be developed for the method of construction (unit or frame and plate) and for insert plates.

For unit construction, a sequence for assembling units, blocks and erecting and welding units to each other at the berth is required.

For frame and plate construction, a sequence for shell butts and seams, frames and bulkheads to shell plating, tank top to inner bottom framing and "A" frames and stern tubes and other critical components is required.

9.8.3 Restrained Joints

When welding joints that are restrained and/or where significant shrinkage is anticipated, welding ***shall*** be carried out continuously or to a point that will ensure freedom from cracking after the joint has cooled below the interpass temperature. Root passes ***shall*** be of adequate size to withstand shrinkage stress. Block welding or cascade welding techniques ***should*** be used wherever practicable. Back step techniques are desired when welding joints containing permanent backing bars.

9.8.4 Jigs and Fixtures

Jig's, fixtures, clamping and strong backs ***shall*** be used in such a manner as to avoid restraint during welding. Strong backs welded on one side of the joint and wedged on the other are preferred. When removing strong backs, care ***shall*** be taken not to scar the material to which they are welded. Repair of scars to base plates ***shall*** be in accordance with the requirements of Clause 9.13.3 of this Standard.

9.8.5 Progression

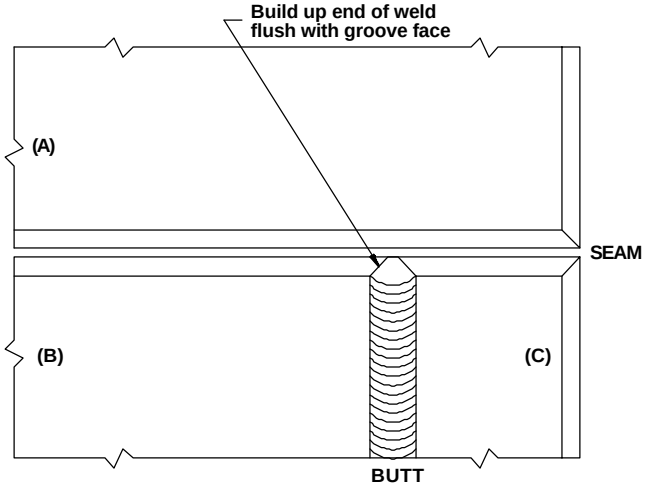
Frames, stiffeners or intercostals ***should*** be welded to each other before they are welded to the plating. When joining sub-assemblies to each other, joints connecting plating ***should*** be welded prior to welding the butt joints of the sub-assembly framing.

Welding ***should*** be started in the centre of the ship and progress outward, forward and aft. Sub-assemblies ***should*** be welded in the same manner starting in the centre, progressing outward. The back step or skip technique ***shall*** be employed where necessary to control distortion (see Annex D).

Transverse butts in plating ***should*** be welded prior to longitudinal seams

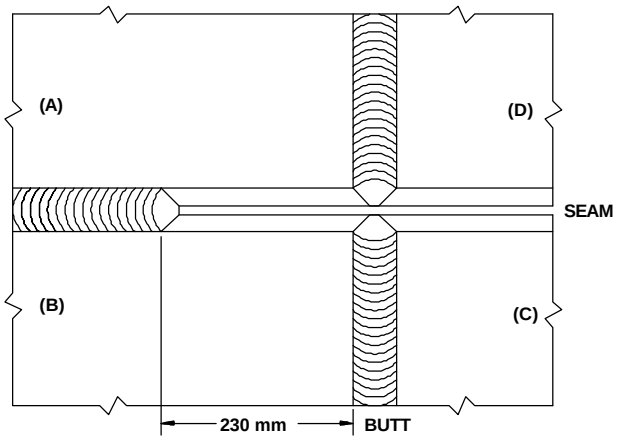
9.8.6 Intersections and Release Distance

Care ***shall*** be taken when welding intersecting butts and seams. The techniques illustrated in Figure 9.7 ***shall*** be followed.



1) Weld butt between (B) and (C).

2) Weld seam between (A) and (B).



1) Weld seam between (A) and (B) to within 230 mm of butt joint.
2) Weld butt between (B) and (C).
3) Weld butt between (A) and (D).
4) Complete welding seam between (AD) and (BC).

Figure 9.7 Intersecting Butts and Seams

Fillet welds traversing butts and seams ***shall not*** be welded a minimum of 230 mm each side of the joint until the groove weld is completed.

9.8.7 Bead Width to Depth Ratio

To assist in eliminating centre line cracking, the depth to width ratio of individual weld passes ***shall*** be controlled for all welding processes except electroslag and electrogas welding.

Neither the depth nor the maximum width in the cross-section of weld metal deposited in each weld pass ***shall*** exceed the width at the face of the weld pass.

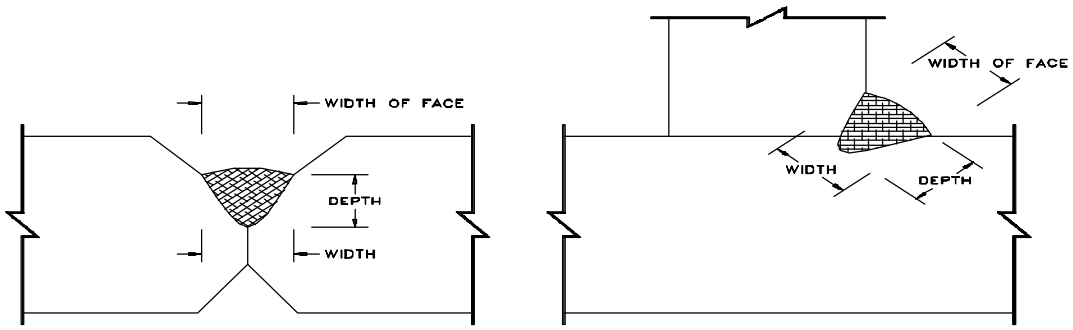


Figure 9.8 Bead Width to Depth Ratio

9.8.8 Peening

Peening ***shall not*** be used without approval from the Technical Authority. When approved, peening ***shall not*** be used on root passes or the final face of the weld. When permitted for inter-

weld layers, extreme caution ***shall*** be exercised to prevent flaking, overlapping, cracking and excessive cold working of the material.

9.9 REPAIR OF DISTORTION

Where preventative measures are inadequate to prevent unacceptable distortion and fairness of plating, straightening will be required when requested by the Inspection Authority.

When flame shrinking is proposed, the requirements of Clause 9.3 ***shall*** apply.

Locations that have been subjected to flame shrinking will be visually examined for defects after straightening is completed.

9.10 PREHEAT AND INTERPASS TEMPERATURE

The minimum preheat and interpass temperatures for welding shipbuilding grades "A" through "EH36" ***shall*** be in accordance with the requirements of Table 9.2.

Table 9.2 Minimum Preheat and Interpass Temperatures

	Base Materials Being Welded					
Filler Material	**CSA G40.21**	**ASTM**		**Lloyds ABS DnV**	**Material Thickness (mm)**	**Preheat/ Interpass**
Non-basic or Non "CH" Designation	38W & WT 44W & WT	A36 A53 Gr B	A570 All Grades A572 Gr 42, 50, 60	Gr A B D E EH	(t) ≤ 19 19 < (t) ≤ 38 38 < (t) ≤ 65 (t) > 65	None 70°C 110°C 150°C
SMAW - Basic Electrodes FCAW - "CH" Designation GMAW - SAW -	38W & WT 44W & WT 50W & WT 50A & AT 55W & WT 60A & AT	A500 Gr B A501 A516 Gr 55,60 A529	A529 A570 All Grades A572 Gr 42, 50 A588 A606 A607 All Grades A618 A633 Gr A, B, D	Gr A B D E EH	(t) ≤ 19 19 < (t) ≤ 38 38 < (t) ≤ 65 (t) > 65	None 10°C 70°C 110°C
SMAW - Basic Electrodes FCAW - "CH" Designation GMAW - SAW -	60W & WT 70W & WT	A515 Gr 65, 70 A572 Gr 60, 65 A633 Gr E	A515 Gr 65, 70 A572 Gr 60, 65 A633 Gr E		(t) ≤ 19 19 < (t) ≤ 38 38 < (t) ≤ 65 (t) > 65	10°C 70°C 110°C 150°C

When the base material temperature is equal to or below 0°C, the minimum preheat temperature ***shall*** be 10°C.

The minimum preheat and interpass temperatures for welding shipbuilding grades "A" through "EH36" produced by the thermo-mechanical controlled rolling practice method, "FH-XX" and "XX-40 through "XX-69" inclusive ***shall*** be determined by the hydrogen control method in accordance with the requirements of CSA Standard W59, Appendix "P" and the steel manufacturer's recommendations.

The contractor ***shall*** provide suitable means for measuring preheat and interpass temperatures through the use of thermal melting crayons (tempil sticks) or other approved thermal measuring devices.

When preheat or minimum interpass temperatures are required, the base material ***shall*** be heated in such a manner so that the surfaces of the parts being joined by welding are at or above the specified minimum temperature, both laterally and in advance of the welding arc, for a distance equal to the thickness of the material being welded but not less than 75 mm.

Preheat and interpass temperatures above the minimum requirements of Table 9.2 may be required for:

- high strength weld metal;
- highly restrained weldments;
- certain combinations of energy input conditions, material composition and material thickness;
- conditions where transfer of tensile stress is in the through thickness direction of the material.

A reduction in preheat temperature from the minimum requirements of Table 9.2 may be permitted in accordance with the requirements of Clause 5 of CSA Standard W59.

9.11 INTERPASS PROFILES

Interbead profiles ***shall*** be such as to ensure that adequate fusion with the adjacent base material and previously deposited weld metal occurs.

Prior to depositing additional passes and layers, the joint ***shall*** be thoroughly cleaned of slag deposits and dressed by grinding to remove overlap, excessive undercut, tightly adhering slag in undercut, spatter, deposits from air carbon arc electrodes and other conditions that may obstruct fusion.

When employing remove to sound metal techniques, a "U" groove contour ***shall*** be required unless otherwise approved by the Technical Authority. The "U" groove contour ***shall*** have a minimum radius of 5 mm and a groove angle greater or equal to 20° independent of groove depth.

9.12 BACKING MATERIALS

When permitted by the Technical Authority, permanent backing bars ***shall*** be of a material grade similar to that of the base metal being welded. Backing bars ***shall*** be continuous for the entire length of the joint.

When composed of individual lengths, backing bars ***shall*** be of the same material grade, width and thickness. Backing bars that are to be spliced ***shall*** be carefully aligned with each other. Abutting ends of backing bar splices ***shall*** be prepared for welding, in order that full penetration is achieved. Splices in backing bars ***shall*** be welded prior to starting the joint they are attached to. Completed groove welds in backing bar splices, ***shall*** be inspected and accepted prior to welding the joint it forms part of.

The separation between faying surfaces of joints employing backing bars ***shall*** be 1.5 mm maximum. Where and whenever practicable, backing bars ***shall*** have a tight contacting fit. Tack welding of backing bars ***shall*** be adequate to ensure separation of the faying surfaces does not exceed 1.5 mm during the welding operation.

The use of any type of filler piece or spacer bar that is intended to form part of the completed joint is prohibited unless otherwise approved by the Technical Authority.

Unless otherwise approved by the Technical Authority, permanent backing bars ***shall*** be sealed all around by fillet welds to prevent crevices for preferential corrosion.

Fillet weld size ***shall*** be as small as possible. Seal welds ***shall not*** be performed until the primary joint has been examined and accepted by the Inspection Authority. Permanent backing bars ***shall not*** be permitted within the boundaries of fuel storage tanks and compartments.

When metallic backing bars are used, they ***shall*** be clean and free of rust, mill scale, oxides, moisture and deleterious materials.

Temporary metallic backing bars or nonmetallic backing materials (e.g. ceramics) ***shall*** be detailed within the weld procedure data sheets and approved by the Technical Authority prior to their use. Methods for removal of temporary metallic backing bars ***shall*** be detailed within the approved weld procedure data sheets. Temporary metallic backing bars ***shall*** be fitted in such a manner as to ensure that arcing does not occur between the faying surfaces. All arc spots ***shall*** be repaired with approved procedures as required by the Inspection Authority.

9.13 TACK WELDS, TEMPORARY WELDS AND LUG REMOVAL

9.13.1 Tack Welds

Tack welds that are incorporated into the final weld ***shall*** meet the same requirements as the final welds.

Preheat is not mandatory for single pass tack welds when it can be proven to the Technical Authority that the tack weld is totally re-melted and incorporated into the final weld. Defects such as undercut, unfilled craters and porosity need not be removed provided the quality of the final weld is acceptable.

Tack welds that are incorporated into the final weld ***shall*** be made with filler metal matched to the base metal grouping following the requirements of Chapter 6.0 of this Standard.

Multi-pass tack welds ***shall*** have cascaded ends (see Annex D).

Tack welds ***shall*** be of a size not to obscure penetration and fusion. Tack welds ***shall*** be of a size or reduced in size to not create objectionable changes in the appearance of welds at the surface.

Tack welds that are not incorporated into the completed weld ***shall*** be removed.

9.13.2 Temporary Welds

Temporary welds ***shall*** be made using approved weld procedures.

Temporary welds ***shall not*** be located on a welded butts or seams.

When temporary welds are removed, the surface ***shall*** be made flush with the original surface. Scars in plate surfaces ***shall*** be repaired by welding with approved procedures. Welding electrodes for repairing scars in exterior shell plating ***shall*** be corrosion resistant in sea water in accordance with the requirements of Chapter 6.0 of this Standard. Completed repairs ***shall*** meet the same requirements as the final welds.

9.13.3 Lug and Temporary Attachment Removal

For the hull exterior, exposed bulkheads, decks, panels, superstructure, walkways, bulwarks, fairleads, bollards, and any other zone deemed necessary by the Inspection Authority to avoid operational hazards and provide a good cosmetic appearance to the vessel, all lugs, temporary fairing aids, studs, etc., ***shall*** be removed by flame cutting, chipping and grinding to render a flush and smooth surface. Hammering or other mechanical means that will result in scars to the base material ***shall*** be avoided.

For all other zones, temporary attachments ***shall*** be flame cut or chipped slightly proud and smooth bead welded unless approved otherwise by the Technical Authority.

Scars to base metal surfaces ***shall*** be repair welded and dressed flush and smooth. Welding electrodes for repairing scars on the shell plate exterior, ***shall*** be corrosion resistant in sea water in accordance with the requirements of Chapter 6.0 of this Standard. These requirements also apply to shell plating of atmospheric corrosion resistant steels.

The contractor ***shall*** submit a detailed "Plate Work Finishing Standard" for approval to the Technical Authority.

9.14 RUN ON AND RUN OFF TABS

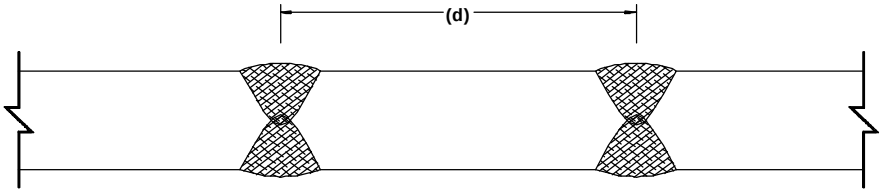
Run on and Run off tabs or extension bars ***shall*** be made of a material similar to that of the base metal they are being attached to. Tabs ***shall*** be of sufficient size and thickness to ensure effectiveness. Tabs ***shall*** be removed by flame cutting, chipping and grinding being careful not to scar the base metal. Nicks, gouges, irregularities and discontinuities ***shall*** be repaired by welding with approved procedures and finished flush and smooth over the cross section of the base plates.

9.15 WELD SIZE DIMENSIONS

The size and length of welds ***shall not*** be less than, nor ***shall*** they be substantially in excess of, those specified by the design requirement.

9.16 ADJACENT WELD SPACING

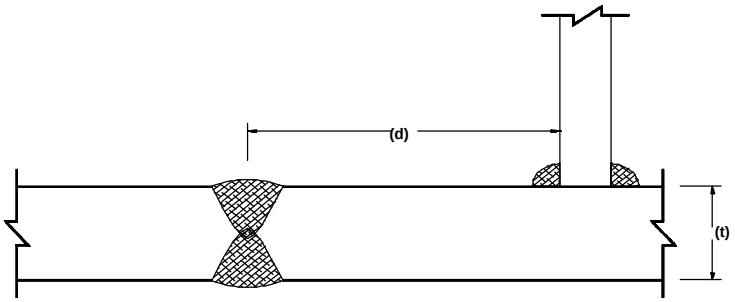
The dimension between adjacent groove welds that are not approved by the Technical Authority on construction or repair drawings ***shall*** meet the requirements illustrated in Figure 9.9.



(d) = 300 mm Minimum
Note: Not Applicable For Shell Plating.

Figure 9.9 Adjacent Groove Welds

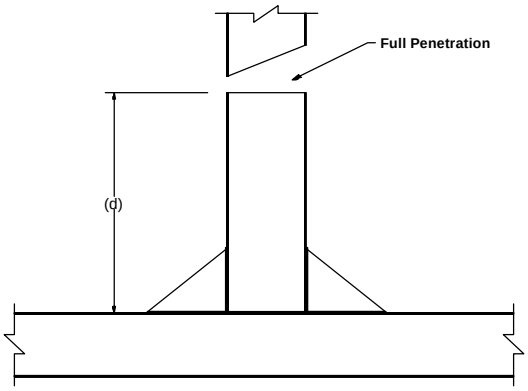
The dimension between a groove weld in a table member to fillet welds that are not approved by the Technical Authority on construction or repair drawings ***shall*** meet the requirements illustrated in Figure 9.10.



(d) = 30 mm

Figure 9.10 Adjacent Fillet/Groove Weld Table Member

The minimum dimension between fillet welds to a groove weld in an abutting members that are not approved by the Technical Authority on construction or repair drawings ***shall*** meet the requirements illustrated in Figure 9.11.



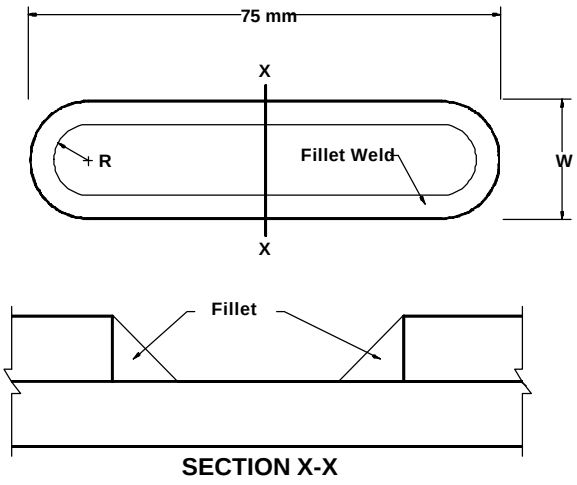
(d) = 150 mm Minimum

Figure 9.11 Adjacent Fillet/Groove Weld Abutting Member

9.17 SLOT AND PLUG WELDS

For the connection of plating to internal webs, etc., where access for welding does not permit construction by conventional fillet and groove weld design, closing plates ***shall*** be attached by a combination of groove welds with permanent backing bars and fillet welds in slots. Plug welds ***shall not*** be permitted.

Slot dimension ***shall*** meet the minimum requirements illustrated in Figure 9.12.



NOTES:

1. Minimum Length = 75 mm.
2. Minimum Distance Between Slots = 150mm
3. Slot Width (W) = 2(t)
4. Radius (R) = 0.5 x Slot Width (W)

Figure 9.12 Slot Weld Dimensions

Slots ***shall not*** be filled flush with weld metal. Fillet welds ***shall*** be continuous around the perimeter of the slot.

The minimum width of the slot weld ***shall*** be increased to a maximum of 2.5(t) when the size of equipment requires additional space to achieve adequate root penetration and side wall fusion.

All slot weld configurations and the various welding conditions ***shall*** be qualified by weld procedure qualification tests. A sample test plate ***shall*** be welded and one macro examination specimen taken at the centre of each end of the slot.

9.18 SNIPES AND SCALLOPS

Where snipes and scallops are permitted in the design requirements and they are intended to provide access for welding, the radius of snipes andscallops ***shall*** be adequate to allow for proper electrode angles. The size of snipes and scallops ***shall*** be adjusted by taking into consideration the welding equipment used for production and the limitations its size places on achieving correct electrode angles to obtain acceptable weld profiles and fusion (i.e., scallop for SMAW = 20 mm, scallop for FCAW = 30 mm).

9.19 WELDING AND FASTENERS

When welding and rigid fastening (e.g. Rivets) is combined within the same structure, all welding ***shall*** be completed first.

9.20 STRAY ARC STRIKES

Arc strikes outside the area of a weld ***shall*** be avoided.

The surface of plates containing stray arc strikes ***shall*** be repair welded, ground flush and visually examined. Welding electrodes for repair of stray arc strikes on the exterior hull, ***shall*** be corrosion resistant in sea water in accordance with the requirements of Chapter 6.0 of this Standard.

9.21 REJECTED WELD OR PART

When an ***entire*** weld, base material, ***entire*** part or ***entire*** section contains unacceptable discontinuities as specified in Chapter 10.0 of this Standard, no corrective action ***shall*** be taken prior to approval of the repair procedure by the Inspector and Technical Authorities.

When a ***portion of a weld*** contains unacceptable discontinuities as specified in Chapter 10.0 of this Standard, corrective action may be taken if the Inspection Authority has reviewed the extent of unacceptable discontinuities and agrees to the proposed repair procedure.

When a weld has been rejected in accordance with the acceptance criterion specified in Chapter 10.0 of this Standard, the unacceptable discontinuities ***shall*** be corrected as follows:

- cracks in the base metal and/or weld zone ***shall*** be removed and repair welded.

- unacceptable porosity, slag inclusions, metallic inclusions, incomplete penetration and non-fusion ***shall*** be removed and repair welded.

- unacceptable reinforcement, convexity and overlap ***shall*** be repaired by removal of excess weld metal.

- unacceptable concavity, insufficient reinforcement, inadequate leg, inadequate throat and undercut ***shall*** be repaired by additional welding. Extreme care ***shall*** be taken not to over weld causing unacceptable excessive weld reinforcement. Repair welds to compensate for deficiency in size or undercut ***should*** be made with an electrode of smaller diameter than that used for depositing the original weld.

In the event that faulty welding, or its removal for re-welding, so damages the base metal that its retention is not in accordance with the intent of the design, plans and specifications, the contractor ***shall*** remove and replace the damaged material or ***shall*** otherwise rectify the deficiency to the satisfaction of the Technical Authority.

When work has been performed subsequent to the making of a deficient weld and has rendered the deficient weld inaccessible for repair, the original conditions ***shall*** be restored by removal of plates or members allowing for access to enable effective repair. If the original condition cannot be restored, compensation by performing additional work ***shall*** be provided to the satisfaction of the Technical Authority.

CHAPTER 10 NONDESTRUCTIVE INSPECTION OF WELDS

10.1 GENERAL

This chapter states the requirements for nondestructive inspection of welds for new construction, mid-life modernization and repair of Coast Guard vessels.

For new construction, the quantity and methods of nondestructive inspection to be taken as the Technical Authority's minimum requirement shall be as specified in Annex F of this standard.

For modernization or major alterations, the quantity and methods of nondestructive inspection to be taken as the Technical Authority's minimum requirement shall be specified in the Vessel Specifications and Annex F shall not apply.

For minor alterations or repair, the quantity and methods of nondestructive inspection to be taken as the Technical Authority's minimum requirement shall be as specified in Annex J of this standard.

All nondestructive inspections taken as the Technical Authority's minimum requirement ***shall*** be considered separate of the requirements of the applicable Classification Society and Regulatory Bodies.

The method and location of inspections ***shall*** be determined by the Inspection and Technical Authorities.

10.2 SELECTION OF NONDESTRUCTIVE INSPECTION METHODS

The method of inspection ***shall*** be appropriate to depict discontinuities dependent on:

- material type;
- joint type;
- weld type;
- orientation of typical discontinuities;
- accessibility.

Each nondestructive inspection method is limited due to the nature and orientation of discontinuities and the sensitivity of the inspection method. Typical limitations are as follows:

- Visual Inspection: Coarse surface discontinuities or weld profiles.

- Magnetic Particle Inspection: Surface or near-surface discontinuities in ferromagnetic materials.
- Penetrant Inspection: Discontinuities extending to the surface.
- Radiographic Inspection: Coarse discontinuities within the weld cross section.
- Ultrasonic Inspection: Most planar discontinuities within the weld cross section.

All welds ***shall*** be visually examined prior to inspection by other methods.

Full penetration welds ***shall*** be selectively sampled. Radiographic inspection ***shall*** be used for full penetration groove welds in butt joints. Ultrasonic inspection ***shall*** be used for full penetration groove welds in tee joints. When groove welds in butt joints are inaccessible for radiographic inspection, ultrasonic inspection ***shall*** be used.

Fillet welds ***shall*** be selectively sampled. Magnetic particle inspection or liquid penetrant inspection ***shall*** be used.

10.3 NONDESTRUCTIVE INSPECTION PROCEDURES

When visual inspection is required the methods set forth in ASME Code Section V ***shall*** be implemented. The weld acceptance criteria ***shall*** be in accordance with Clause 10.11.2 of this Standard.

When penetrant inspection is required the methods set forth in ASTM Standard E165 ***shall*** be implemented. The weld acceptance criteria ***shall*** be in accordance with Clause 10.12.2 of this Standard.

When magnetic particle inspection is required the methods set forth in ASTM Standard E709 ***shall*** be implemented. The weld acceptance criteria ***shall*** be in accordance with Clause 10.13.2 of this Standard.

When radiographic inspection is required the methods set forth in ASTM Standard E142 ***shall*** be implemented. The weld acceptance criteria ***shall*** be in accordance with Clause 10.14.16 of this Standard.

When ultrasonic inspection is required the methods set forth in ASTM Standard E164 ***shall*** be implemented. The weld acceptance criteria ***shall*** be in accordance with Clause 10.15.2 of this Standard.

All inspection reports ***shall*** display a reference to the inspection procedure and technique used for that inspection. Inspection procedures and techniques ***shall*** be submitted to the Technical Authority for approval prior to performing any inspections.

When circumstances are such that there is inadequate time to attain prior approval from the Technical Authority, the inspection procedure and technique sheet ***shall*** be attached to the interpretation report. If it is considered unacceptable by the Technical Authority, the inspection ***shall*** be retaken with an approved inspection procedure and technique.

All nondestructive inspection is subject to audit. Audit may occur prior to, during or after completion of the actual inspection.

10.4 LOCATIONS SUBJECTED TO INSPECTION

Welds subjected to nondestructive inspection ***shall*** include, but will not necessarily be limited to, the following:

- Strength members;
  - Flat and vertical keel,
  - Tank margin plates,
  - Sheer strake,
  - Bilge strake,
  - Deck stringer plates.
- Shell plating;
  - Intersection of butts and seams,
  - Transverse butts,
  - Longitudinal seams.
- Other;
  - Inserts and closure plates,
  - Cruciform welds,
  - Terminal welds.

Locations selected by the Inspection and Technical Authorities shall be considered separate from the minimum requirements of the applicable classification society or regulatory body.

The exact position of inspections shall be determined by the Inspection and Technical Authorities. The length of each individual inspection shall be as follows:

- Visual Method: Entire weld length
- Penetrant Method: 1000 mm

- Magnetic Particle Method: 1000 mm.
- Radiographic Method,

  Intersection: 300 X 300 mm (1)

  Others: 440 mm.
- Ultrasonic Method: 1000 mm.

Note: ***(1)*** *When access disallows the use of 300 mm by 300 mm film size at intersecting butts and seams, a series of films* **shall** *be positioned to offer examination of 150 mm of weld in all directions.*

Welds that have been rejected by penetrant, magnetic particle, radiographic and ultrasonic inspection methods ***shall not*** be repaired until the Inspection and Technical Authorities have full knowledge of the type and extent of defects including the contractor's planned method of repair.

Inspection test results ***shall*** be returned to the Inspection Authority within the agreed time frame.

No radiograph or interpretation report ***shall*** be destroyed or discarded.

10.5 SURFACE PREPARATION PRIOR TO INSPECTION

For visual Inspection, the surfaces of welds and adjacent base material ***shall*** be cleaned adequately to provide accurate interpretation of the area of interest (weld zone). Examination over paint or pre-construction primer ***shall not*** be permitted.

For penetrant, magnetic particle and radiographic inspections the surfaces of welds and adjacent base material ***shall*** be free from scale, loose paint, weld spatter and other foreign matter. Weld profiles and contours ***shall*** be sufficiently smooth to ensure that geometric conditions do not cause false indications.

For ultrasonic inspection the surfaces of welds and adjacent base material ***shall*** be free from scale, paint, weld spatter and other foreign matter to enable accurate interpretation of the area of interest (weld zone). The contact surfaces ***shall*** be smooth to the extent that the finish does not interfere with the inspection. Tests performed on rough surfaces ***shall*** require special calibration procedures.

10.6 DELAYED INSPECTION

When testing welds subject to high restraint and/or when the steel yield strength is greater than 360 MPa, tests ***shall*** be delayed at least 48 hours after weld completion.

10.7 ADJACENT OVERLAPPING INSPECTION

When an unacceptable discontinuity extends to either or both ends of a location being inspected, additional overlapping inspection ***shall*** be required. The adjacent overlapping inspection ***shall*** show a portion of the defects originally rejected at the location end(s).

When an adjacent overlapping inspection displays unacceptable discontinuities to both ends, the entire weld length ***shall*** be considered unacceptable unless proven otherwise by the contractor. Under this condition, welds ***shall*** be repaired to the extent required by the Inspection and Technical Authorities.

All adjacent overlapping inspections ***shall*** be taken prior to repair of the originally rejected location. If repair has occurred prior to adjacent overlapping inspections and the entire weld length has not been repaired, the adjacent overlapping inspections ***shall*** be placed to overlap the start and finish of the repair.

The contractor ***shall*** be responsible for all costs associated with performing adjacent overlapping inspections.

10.8 REJECTED LOCATIONS

When a location is rejected in accordance with the acceptance criteria specified in this section, it ***shall*** be corrected and re-inspected by at least the same nondestructive inspection method used for the original inspection. Care ***shall*** be taken to ensure that the re-inspection is accurately located so that it measures the original location that was rejected.

For each failed location, one new location ***shall*** be examined. All new locations ***shall*** be selected by the Inspection and Technical Authorities. Each new location selected ***shall*** be considered in addition to the requirements of Clause 10.7 of this Standard.

All costs associated with performing the additional inspections required by this Clause ***shall*** be at the contractor's expense.

10.9 INSPECTION REPORTS

When a portion of a weld is to be inspected by penetrant, magnetic particle, radiographic or ultrasonic methods, the location ***shall*** be subjected to visual inspection in advance of the other inspection methods and a visual inspection interpretation report is required.

When a portion of weld is inspected by penetrant, magnetic particle, radiographic or ultrasonic methods, an interpretation report is required for each location inspected.

When 100% visual inspection is required and unit construction methods are not used, the qualified Inspector ***shall*** provide a verification report for each fabricated compartment (e.g. between two adjacent bulkheads/engine room compartment).

The verification report ***shall*** be a statement signed off by a qualified inspector which states that all welds have been inspected and that they conform to the requirements of Clause 10.11.2 of this Standard. Verification reports ***shall*** be presented to the Inspection Authority prior to the Inspector's planned audit schedule of the unit or compartment (e.g., scheduled dry survey).

10.10 INSPECTION PERSONNEL CERTIFICATES

For each inspection method, a copy of the examining individual's current year qualification certificate ***shall*** be attached to the initial interpretation or verification report supplied to the Inspection and Technical Authorities. If a new validation year is entered or if a different individual is used, new qualification certificates ***shall*** be supplied with any subsequent interpretation report being submitted.

Sample qualification certificates are illustrated in Annex G of this Standard.

10.11 VISUAL INSPECTION

10.11.1 Personnel Qualification

Individuals performing and interpreting visual Inspection ***shall*** be currently certified by the Canadian Welding Bureau in accordance with CSA Standard W178.2, Certification of Welding Inspectors. The individual ***shall*** maintain Level II or III in the following code categories:

- Ships and Marine Structures;
- Buildings and Industrial Structures.

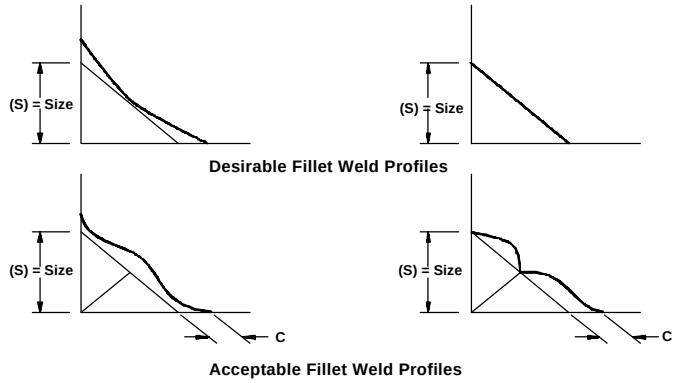
10.11.2 Acceptance Criterion

A weld subjected to visual inspection ***shall*** be acceptable if inspection shows:

- that weld profiles are in accordance with this Clause;
- that groove welds have no visible porosity;
- that fillet welds located within and forming tank boundaries have no visible porosity;
- that the sum of diameters of visible porosity in fillet welds outside the above noted boundaries does not exceed 10 mm in any 25 mm length of weld, and does not exceed 20 mm in any 300 mm length of weld providing no single pore exceeds 3 mm in diameter;
- that there ***shall*** be no visible fusion type defect;
- that there ***shall*** be no visible overlap;
- that there ***shall*** be no craters or crater defects;

- that there ***shall*** be no visible cracks.

The faces of fillet welds may be slightly convex, flat or slightly concave. Acceptable profiles are specified in Figure 10.1. Unacceptable profiles are specified in Figure 10.2.



Convexity "C" *shall not* exceed 0.10S + 1.5mm

Figure 10.1 Acceptable Fillet Weld Profiles

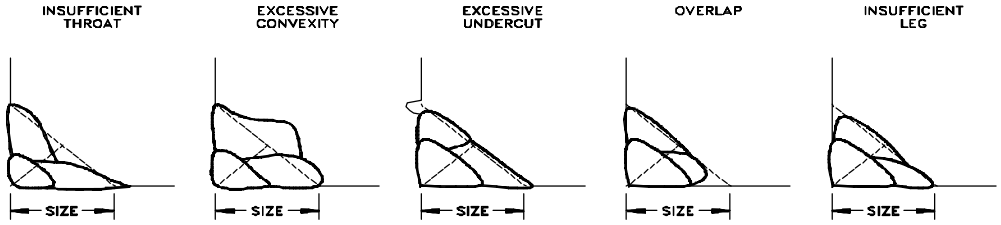
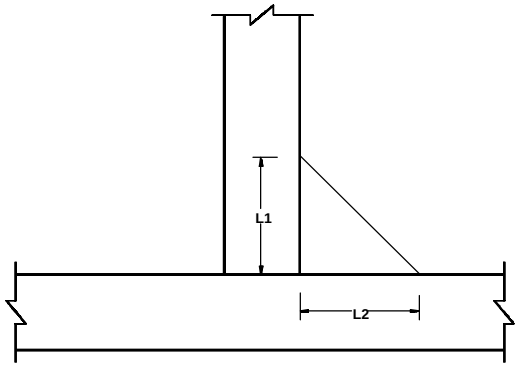


Figure 10.2 Defective Fillet Weld Profiles

Unless otherwise specified on construction or repair drawings, for strength members fillet welds ***shall*** have equal leg lengths within the tolerance permitted in Figure 10.3.

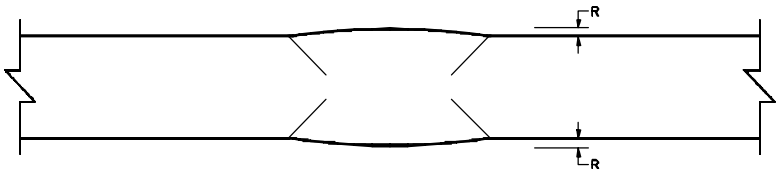


L1 and L2 *shall* be equal in size within 3mm, but *shall not* be undersized.

Figure 10.3 Leg Length Tolerance

Undercut ***shall not*** exceed 1 mm in depth for welds located in primary structure, nor ***shall*** it exceed 1.5 mm in depth for welds located in secondary structure.

The finishing passes of all butts, seams and corner joints ***shall*** provide a reinforcement at the center of the weld, not exceeding 3 mm. Acceptable profiles are illustrated in Figure 10.4. Unacceptable profiles are illustrated in Figure 10.5.



Reinforcement "R" *shall not* exceed 3mm

Figure 10.4 Acceptable Butt Weld Profile

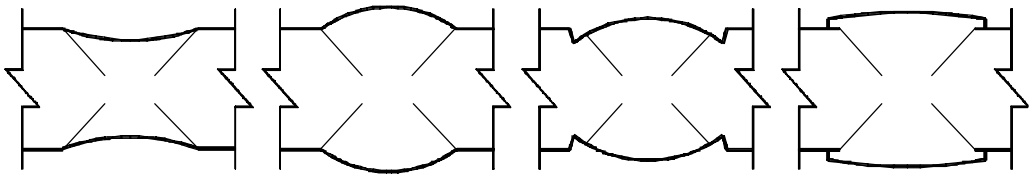


Figure 10.5 Defective Butt Weld Profiles

There ***shall*** be no excessive valley or groove along the edge or at the center of the weld and weld metal ***shall*** blend smoothly into the base metal at each weld toe. The deposited metal ***shall*** be smooth and uniform in cross section. The ends of joints ***shall*** be of sound metal, finished smoothly and conforming to the cross section of the welded joint.

Undercut ***shall not*** exceed 0.5 mm in depth for welds located in primary structure, nor ***shall*** it exceed 1 mm in depth for welds located in secondary structure.

10.11.3 Flush Tolerance

Surfaces of butt joints required to be flush ***shall*** be finished so as not to reduce the cross section as specified in Table 10.1. The surface finish ***shall*** be as approved on construction and repair drawings. (See Table 10.2.)

Table 10.1 Flush Tolerance

Maximum Reinforcement	Maximum Concavity
5% (t) Maximum 1 mm	5% (t) Maximum 1 mm

Table 10.2 Roughness

Maximum Roughness	Finish Parallel to Primary Stress	Finish in any Direction
250 - CSA B95	125 - CSA B95 250 - CSA B95	125 - CSA B95

10.11.4 Smooth Tolerance

Surfaces of groove welds required to be smooth ***shall*** be finished so as to ensure that the weld reinforcement does not exceed 2 mm; that there are no valleys or grooves between individual weld beads; and, that each weld toe blends smoothly into the base metal without undercut or overlap.

10.12 PENETRANT INSPECTION

10.12.1 Personnel Qualifications

Individuals performing and interpreting penetrant inspection ***shall*** be currently qualified to CGSB Standard 48.9712 Level II or III.

10.12.2 Acceptance Criterion

A weld subjected to penetrant inspection ***shall*** be evaluated on the basis of the requirements for visual inspection as specified in Clause 10.11.2 of this Standard.

10.13 MAGNETIC PARTICLE INSPECTION

10.13.1 Personnel Qualifications

Individuals performing and interpreting magnetic particle inspection ***shall*** be currently qualified to CGSB Standard 48.9712 Level II or III.

10.13.2 Acceptance Criterion

A weld subjected to magnetic particle inspection ***shall*** be evaluated on the basis of the requirements for radiographic inspection as specified in Clause 10.14.16 of this Standard.

10.14 RADIOGRAPHIC INSPECTION

10.14.1 Personnel Qualifications

Individuals performing radiographic inspection ***shall*** be currently qualified to CGSB Standard 48.9712 Level I, II or III.

Individuals interpreting radiographic inspection ***shall*** be currently qualified to CGSB Standard 48.9712 Level II or III.

A person that is performing radiographic inspection and is qualified to Level I ***shall*** be directly supervised by a Level II or III individual at the work site.

10.14.2 Source of Radiation

Radiographs ***shall*** be made either by X-Ray or Gamma Ray as follows:

- X-Ray ***shall*** be used for material less than 6 mm in thickness.
- the minimum material thickness inspected by Gamma Ray ***shall*** be 6 mm.
- the maximum material thickness inspected by Gamma Ray ***shall*** be 50 mm. Material thicknesses greater than 50 mm ***shall*** be examined by ultrasonic methods.
- for Gamma Ray applications, the source of radiation ***shall*** be Iridium 192.

10.14.3 Radiographic Film

The class of film is dependent on material thickness, source of radiation and required sensitivity. The following ***shall*** apply:

- for X-ray on material thickness less than 6 mm, Class II Film may be used providing the 2-2(t) hole is clearly visible on the radiograph. Otherwise, Class I Film must be used;
- when the material thickness is greater than or equal to 6 mm and less than 12 mm, Class I Film and Iridium 192 Gamma Radiation must be used;
- when the material thickness is greater than or equal to 12 mm, Class I or Class II Film and Iridium 192 Gamma Radiation must be used.

10.14.4 Film Processing

Film processing techniques ***shall*** be adequate to develop the latent image of the radiograph into a visual image with adequate clarity and resolution.

Film processing and chemical control procedures ***shall*** be displayed in the developing facility for review by the Inspection and Technical Authorities. Developed films that are received displaying water stains, blotches, streaks, fingerprints, sharp lines, milky zones, brownish tones and fog ***shall*** be rejected and retaken if these conditions interfere with the interpretation of the area of interest (weld zone).

10.14.5 Double Loaded Film Requirement

All radiographic inspection ***shall*** be taken with a double loaded film technique so that two film negatives are obtained for each inspection. One film negative ***shall*** be sent to the Technical Authority, Ottawa, and the other film negative ***shall*** remain at the work site in the possession of the Inspection Authority. At contract completion, the film negatives stored at the work site ***shall*** be turned over to the Technical Authority, Ottawa.

10.14.6 Film Viewer

The contractor ***shall*** make available at the work site a high intensity film viewer capable of penetrating film densities of 1.8 minimum to 4.5 for the duration of the contract and warranty period.

10.14.7 Area of Interest

The exposed radiographs ***shall*** depict all portions of the welded joint including the weld, heat affected zone and adjacent base material.

Interpretation of the area of interest ***shall not*** be inhibited in any way by the presence of Image Quality Indicators (IQI), flash or lead identification and location markers.

All radiographs ***shall*** be free of mechanical, chemical and/or other blemishes to the extent that they do not mask or inhibit interpretation of the area of interest (weld zone) or IQI's.

10.14.8 Essential Holes

The exposed radiograph ***shall*** show the outline of the image quality indicator, shims, image quality indicator identification number, essential hole, radiograph identification number, location markers, the date it was taken, reference to the contract number or vessel identification and the radiographer's initials.

- When X-Ray is used, the image of the 2-2(t) hole ***shall*** appear clearly on the radiograph.
- When Iridium 192 Gamma Radiation is used on material thicknesses requiring Class 1 Film, the image of the 2-2(t) hole ***shall*** appear clearly on the radiograph.
- When Iridium 192 Gamma Radiation is used on material thicknesses greater than or equal to 12 mm and less than or equal to 30 mm, the image of the 2-4(t) hole ***shall*** appear clearly on the radiograph.
- When Iridium 192 Gamma Radiation is used on material thicknesses greater than 30 mm, the image of the 2-2(t) hole ***shall*** appear clearly on the radiograph.

10.14.9 Film Density and Sensitivity

The radiographic technique ***shall*** be of sufficient sensitivity to display the IQI's image and the essential hole, both of which are indications of image quality of the radiograph. If the density of the radiographs through the area of interest (weld zone) varies by more than -15% or +30% from the density through the body of the IQI within the minimum/maximum allowable density range specified, an additional IQI ***shall*** be used for each exceptional area or areas and the radiograph retaken. The transmitted film density through the radiographic image of the body of the appropriate IQI and the adjacent area of interest ***shall*** be 2.0 - 3.5.

10.14.10 Geometric Unsharpness

Geometric unsharpness ***shall not*** exceed the values specified in Table 10.3.

Table 10.3 Geometric Unsharpness

Material Thickness		Geometric Unsharpness	
Metric	**Imperial**	**Metric**	**Imperial**
Up to 25 mm	Up to 1"	0.125 mm	0.005"
25 to 50 mm	1 to 2"	0.250 mm	0.010"
50 to 75 mm	2 to 3"	0.375 mm	0.015"

10.14.11 Intensification Screens

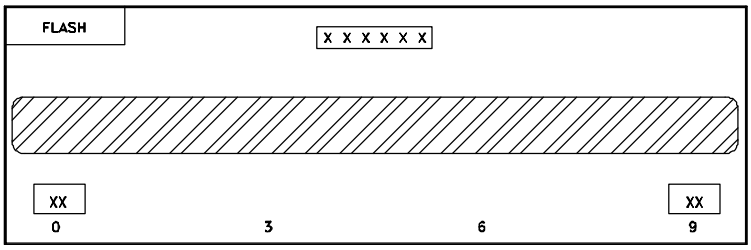
Intensification screens ***shall not*** be used unless it can be proven that radiographic sensitivity may be enhanced. If adequate contrast cannot be achieved with a single film when examining unequal thicknesses, a dual exposure technique ***shall*** be used.

10.14.12 Back Scatter Radiation

As a check for back scattered radiation, a lead symbol "B" having a minimum dimension of 12.5 mm in height and 1.5 mm in thickness ***shall*** be attached to the back of each film cassette. If the image of the "B" appears on the radiographs, protection from back scatter is insufficient and the radiograph ***shall*** be retaken.

10.14.13 Film Identification

The permanent identification to appear on radiographic films ***shall*** utilize a system of flash and lead markers in accordance with Figure 10.6.



Flash Identification

- Date
- Contract Number
- Owner
- Vessel Identification
- Radiographers Initials

Lead Markers

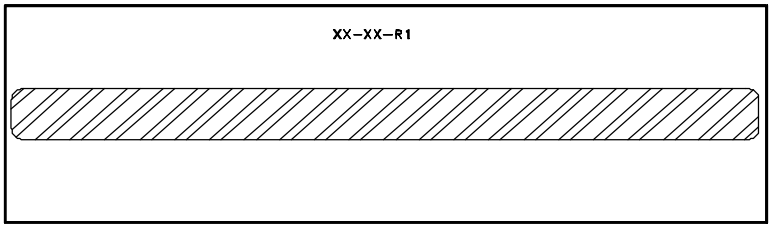
- Weld Identification
- Location Numbers
- Deltas (if used)

Figure 10.6 Film Identification

Lead markers ***shall*** be placed on the source side of the part being examined.

A system of weld identification ***shall*** be developed, submitted and approved by the Technical Authority prior to the start of the inspection.

The letter "R" and the initial film number ***shall*** appear when it is a repair as illustrated in Figure 10.7.



Note: R1 = 1st Repair Attempt.

R2 = 2nd Repair Attempt.

Films not having the correct identification *shall* be retaken.

Figure 10.7 Repair Identification

10.14.14 Image Quality Indicators

Image quality indicators (IQI) ***shall*** be certified to ASTM or ASME Standards.

IQI's ***shall*** be made of a material having radiographic behavior similar to the base material under examination.

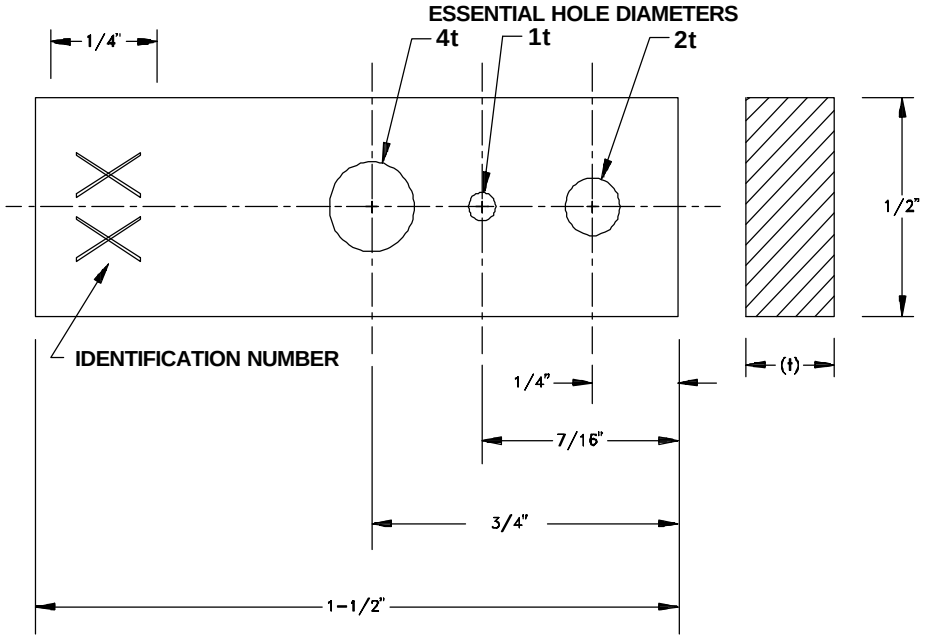
IQI thickness, identification and essential hole dimensions ***shall*** be in accordance with Table 10.4 of this Standard.

IQI's ***shall*** be placed on the source side of the part being examined.

Table 10.4 IQI Essential Holes

Material Thickness Range (inches)	Image Quality Indicators		Essential Hole	
	Thickness (inches)	N °	2 - 2 (t)	2 - 4 (t)
Up to ½	0.0100	10	0.020	0.040
Over ½ to 5/8	0.0125	12	0.025	0.050
5/8 to ¾	0.0150	15	0.030	0.060
¾ to 7/8	0.0175	17	0.035	0.070
7/8 to 1	0.0200	20	0.040	0.080
1 to 1¼	0.0250	25	0.050	0.100
1¼ to 1½	0.0300	30	0.060	
1½ to 2	0.0350	35	0.070	

Image quality indicator design ***shall*** be in accordance with Figure 10.8.



IQI (t) ≤ 0.050 inches

Figure 10.8 IQI Design

For materials of equal thicknesses, one IQI ***shall*** appear at each film end as shown in Figure 10.9.

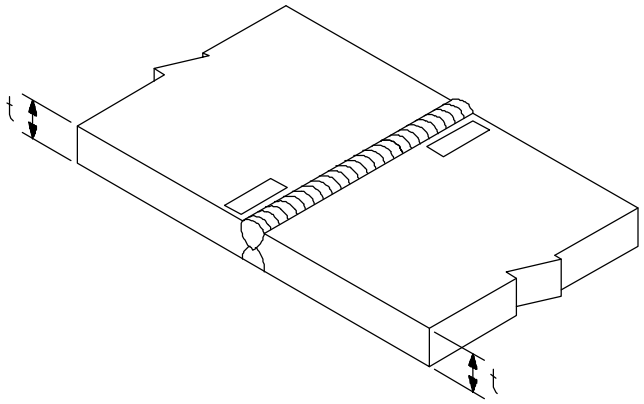


Figure 10.9 IQI Placement for Materials of Equal Thickness

For materials of unequal thickness, three IQI's ***shall*** be used and their placement ***shall*** be in accordance with Figure 10.10.

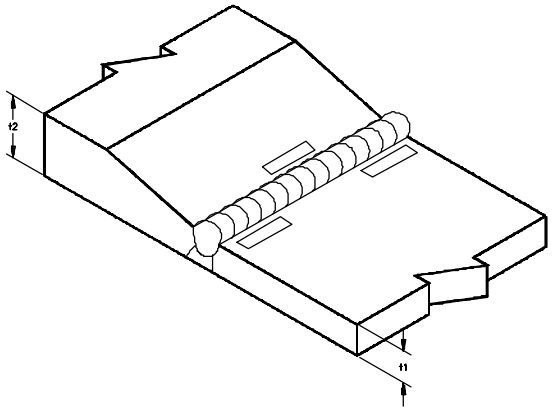


Figure 10.10 IQI Placement for Materials of Unequal Thickness

10.14.15 Shims

Shims ***shall*** be made of a material having radiographic behavior similar to the base material under examination.

When there is weld reinforcement, a shim equal to the reinforcement ***shall*** be placed under each IQI. Shim dimensions ***shall*** be in accordance with Figure 10.11.

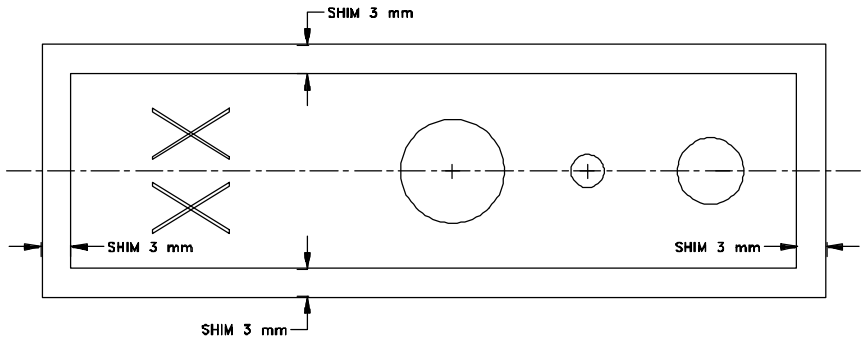


Figure 10.11 Shim Dimensions

10.14.16 Acceptance Criterion

A weld subjected to radiographic inspection ***shall*** be evaluated in accordance with ABS Rules for Nondestructive Inspection of Hull Welds. Welds in ice-transiting ships ***shall*** be evaluated by following the requirements of ABS Class 'A' acceptance criterion and other ships ***shall*** be evaluated following the requirements of ABS Class 'B' acceptance criterion.

10.14.17 Interpretation Reports

Interpretation reports ***shall*** reference:

- Radiographic procedure;
- IQI design and identification number;
- Source of radiation
- Source to film distance;
- Angle of incident radiation;
- Film type;
- Intensification screen design;
- Material type, thickness, joint type and geometry.

Interpretation reports ***shall*** record:

- Date the radiograph was taken;
- Builder/contractor's name;
- Vessel type and hull number;

- Owner's name;
- Inspection organizations name;
- Radiographic procedure number;
- Interpretation report number;
- Film identification number;
- Location;
- All discontinuities including single and accumulated indications;
- Weld acceptance criteria;
- Location of discontinuities;
- Radiographer's:
  - name,
  - CGSB level,
  - signature;
- Radiographic Interpreter's:
  - name,
  - CGSB level,
  - signature;

10.15 ULTRASONIC INSPECTION

10.15.1 Personnel Qualifications

Individuals performing and interpreting ultrasonic inspection ***shall*** be currently qualified to CGSB Standard 48.9712 Level II or III.

Individuals developing and documenting ultrasonic inspection procedures ***shall*** be currently qualified to CGSB Standard 48.9712 Level III.

10.15.2 Acceptance Criterion

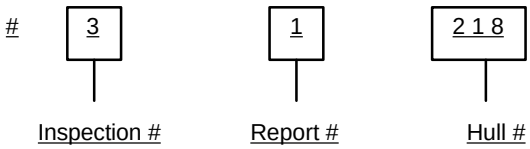
A weld subjected to ultrasonic inspection ***shall*** be evaluated in accordance with ABS Rules for Nondestructive Inspection of Hull Welds, Latest Edition. Welds in ice-transiting ships ***shall*** be evaluated by following the requirements of ABS Class 'A' acceptance criterion and other ships ***shall*** be evaluated following the requirements of ABS Class 'B' acceptance criterion.

10.16 REPORTING AND DOCUMENTATION OF RESULTS

Each interpretation report ***shall*** contain a report number. The report number ***shall*** include the contractor's hull number (i.e. #1-218, etc.). Each location listed on the report ***shall*** be identified with an Inspection number (i.e., location #50 port is Inspection #3).

For radiographs, each film and its duplicate ***shall*** be submitted in a paper protective folder.

The identification to appear on each folder ***shall*** be Inspection #, Report # and Hull # as illustrated below.



Each repaired location ***shall*** reference the original report of the rejected location:

i.e., Location # 50 Port R1 See # 3-1-218

The contractor ***shall*** prepare an adequate number of nondestructive inspection arrangement drawings and sketches so that the location of the inspections are accurately documented for present and future reference by the Inspection and Technical Authorities.

The inspection method, weld identification number and abbreviations for each inspection ***shall*** be accurately recorded on a progressive basis (e.g. UT #75-R1, RT # 150 - adjacent - aft, etc.). A legend detailing the identification symbols used by the contractor ***shall*** appear on each nondestructive inspection arrangement drawing required by this Clause.

The contractor ***shall*** supply updated drawings to the Inspection and Technical Authorities on a regular basis throughout the contract period.

Three copies of the final drawings ***shall*** be supplied to the Technical Authority at contract completion.

ANNEX A REFERENCED CODES, PUBLICATIONS AND STANDARDS

A.1 REFERENCED CODES, PUBLICATIONS AND STANDARDS

ASME		• Boiler and Pressure Vessel Code
		• Section V Nondestructive Examination
		• Section IX Welding and Brazing Qualifications
ASTM	E165	• Penetrant Inspection Method
	E709	• Magnetic Particle Inspection Method
	E142	• Radiographic Inspection Method
	E164	• Ultrasonic Inspection Method
AWS	A.2.4	• Symbols for Welding and Nondestructive Testing
	A.3.0	• Welding Terms and Definitions
CGSB	48.9712	• Qualification and Certification of Non-Destructive Testing Personnel
CSA	W47.1	• Certification of Companies for Fusion Welding of Steel Structures
	W59.1	• Welded Steel Construction
	178.2	• Certification of Welding Inspectors
ABS		• Rules for Non-Destructive Inspection of Hull Welds

A.2 LIST OF APPLICABLE FILLER MATERIAL STANDARDS

CANADIAN STANDARDS ASSOCIATION – CSA STANDARD

W48.1-M	• Mild Steel Covered Electrodes.
W48.2-M	• Corrosion-Resisting Chromium And Chromium-Nickel Steel Covered Electrodes.
W48.3-M	• Low Alloy Steel Covered Arc Welding Electrodes.
W48.4-M	• Solid Mild Steel Filler Metals For Gas Shielded Arc Welding.
W48.5-M	• Mild Steel Electrodes For Flux Cored Arc Welding.
W48.6-M	• Bare Mild Steel Electrodes And Fluxes For Submerged Arc Welding.
W48.7-M	• Diffusible Hydrogen In Mild Steel And Low Alloy Steel Weld Metals; Test Methods

AMERICAN WELDING SOCIETY – AWS SPECIFICATION

A5.4	• Specification For Covered Corrosion-Resisting Chromium And Chromium-Nickel Steel Welding Electrodes
A5.5	• Specification For Low Alloy Steel Covered Arc Welding Electrodes
A5.9	• Specification For Corrosion-Resisting Chromium And Chromium-Nickel Steel Bare And Composite Metal Cored And Stranded Welding Electrodes And Welding Rods
A5.11	• Specification For Nickel And Nickel Alloy Covered Welding Electrodes
A5.14	• Specification For Nickel And Nickel Alloy Bare Welding Rods And Electrodes
A5.15	• Specification For Welding Rods And Covered Electrodes For Cast Iron
A5.17	• Specification For Carbon Steel Electrodes And Fluxes For Submerged Arc Welding
A5.18	• Specification For Carbon Steel Filler Metals For Gas Shielded Arc Welding
A5.20	• Specification For Carbon Steel Electrodes For Flux Cored Arc Welding
A5.23	• Specification For Low Alloy Steel Electrodes And Fluxes For Submerged Arc Welding
A5.28	• Specification For Low Alloy Steel Filler Metals For Gas Shielded Arc Welding
A5.29	• Specification For Low Alloy Steel Electrodes For Flux Cored Arc Welding

UNITED STATES MILITARY STANDARD

MIL E22200/3	• Nickel based covered electrodes

ANNEX B TEST FOR QUALIFYING WELDABLE PRE-CONSTRUCTION PRIMERS

B.1 SCOPE

This Annex outlines the requirements for qualifying welding over pre-construction primer as required by Chapter 9.0 of this Standard. Qualification only applies to the blast finish, pre-construction primer and welding conditions tested.

To qualify specific welding conditions with a pre-construction primer the contractor ***shall***:

- Prepare a test joint assembly.
- Produce test welds using the primer and welding conditions to be qualified.
- Determine the amount of primer induced porosity in the test weld.

The qualification test detailed in this Annex is intended to predict the performance of primed steel plates and shapes prepared for initial assembly and cannot be considered reliable for situations where primer accumulation can occur in unwelded or partially welded joints. The Technical Authority ***shall*** require additional qualification tests if deemed necessary to cover such situations.

B.2 TEST CONDITIONS

Successful qualification ***shall*** only apply to the blast finish, pre-construction primer and welding conditions tested.

B.2.1 Essential Variables

Essential variables of this Annex are:

a) Manual, semi-automatic, or automatic welding

b) Current and polarity

c) Electrode diameter

d) Electrode coating

e) Wire electrode type

f) Gas type

g) Flux type

h) Position

i) Technique

B.2.2 Joint Design

Acceptance of the fillet weld test outlined herein ***shall*** qualify welding butt joints, providing production practice disallows the application of pre-construction primer to the faying surfaces of square butt joints and/or the prepared edge of groove welded butt joints.

B.2.3 Weld Size

For each combination of primer and welding conditions to be qualified, the contractor ***shall*** perform a test for the minimum and maximum single pass fillet weld sizes detailed in Table B1.

Table B1 Single Pass Fillet Size

Process	Minimum	Maximum
SMAW	5 mm	9.5 mm flat, 8 mm horizontal or overhead, 12.5 mm vertical
FCAW	5 mm	12.5 mm flat, 9.5 mm horizontal, 8 mm vertical and overhead
GMAW	5 mm	8 mm
SAW	5 mm	11 mm flat, 8 mm horizontal

B.2.4 Electrodes and Consumables

Welding electrodes and consumables requiring test are detailed in Table B2.

Table B2 Test Electrodes and Consumables

Welding Process	Test Consumables	Qualified Consumables
SMAW	EXXX-24	EXXX-00, 10, 11, 12, 13, 14, 24
	EXXX-27	EXXX-27
	EXXX-48	EXXX-18, 28, 48
	EXXX-28	EXXX-18, 28
	EXXX-18	EXXX-18
FCAW GMAW	Each Wire/Gas Combination	That Tested
SAW	Each Wire/Flux Combination	That Tested

B.2.5 Electrode Size

The smallest and largest electrode sizes to be used in production ***shall*** be tested.

B.2.6 Test Material

The test material may be any grade of plain carbon steel. The surfaces to be welded ***shall*** be free of deleterious materials that may adversely affect the quality of the weld. Typical deleterious materials include:

- paint (except weldable primer)
- oil
- rust
- grease
- moisture
- heavy mill scale

To ensure a clean fracture of the test weld, plate thicknesses ***shall*** be as detailed in Table B3.

Table B3 Minimum Plate Thickness

FILLET SIZE (Leg Length)	TEST PLATE (Thickness)
5 mm 8 mm 9.5 mm	12.5 mm
11 mm 12.5 mm	16 mm

When a clean fracture is not possible due to depth of penetration or suitable plate thickness, a notch ***shall*** be placed in the centre of the fillet weld for its entire length to a depth not exceeding 25% of the throat thickness of the fillet weld.

B.3 TEST ASSEMBLY

B.3.1 General

The test assembly ***shall*** be prepared following the requirements in Figure B1.

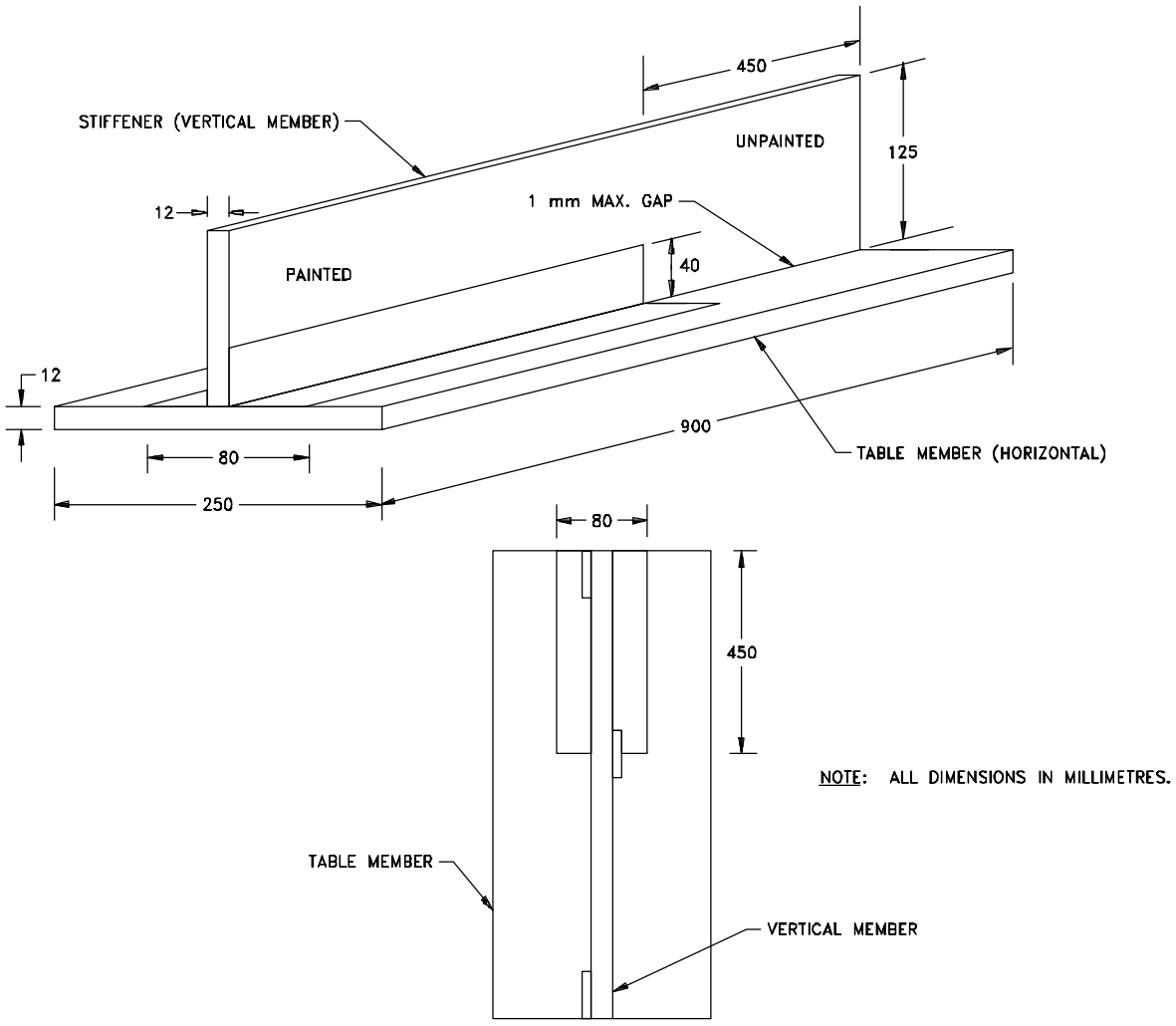


Figure B1 Prefabrication Primer Test Assembly

The assembly sequence to maintain root gap and stiffener alignment ***shall*** be as required in Clause B3.4 of this Annex.

B.3.2 Surface Finish

B.3.2.1 Stiffener (Vertical Member)

The mating surface of the vertical member ***shall*** be prepared using the practices intended for production (sheared, flame cut, primed, etc.).

B.3.2.2 Surface Preparation Before Priming

Before applying the pre-construction primer, the plate surfaces ***shall*** be cleaned to a condition which represents production practice. The surface ***shall*** be prepared to the maximum roughness allowed in production and ***shall*** be measured using profile tape or a depth gauge micrometer.

B.3.3 Priming

B.3.3.1 Location

Before assembly, pre-construction primer ***shall*** be applied for half the test joint length. The primer need only be applied in strips to the dimensions illustrated in Figure B1. The stiffener need only be primed on the test weld side. The mating surface of the stiffener ***shall*** be primed if this represents production practice.

B.3.3.2 Thickness of Pre-construction Primer

The pre-construction primer ***shall*** be applied to the maximum thickness allowed in production. Consideration ***should*** be given to overlapping regions where peak thicknesses will occur. The thickness applied ***shall*** be measured to Steel Structures Painting Council SSPC-PA2 (Standard for Measuring Dry Film Thickness With Magnetic Gauges).

B.3.3.3 Age of Pre-construction Primer

The primer applied to the test material must be aged under normal ambient conditions for a minimum period of seven (7) days prior to welding.

B.3.4 Tack and Sealing Pass Welds

Tack and sealing pass welds ***shall*** be made using 3.2 mm diameter E48024 shielded metal arc welding electrodes as illustrated in Figure B2.

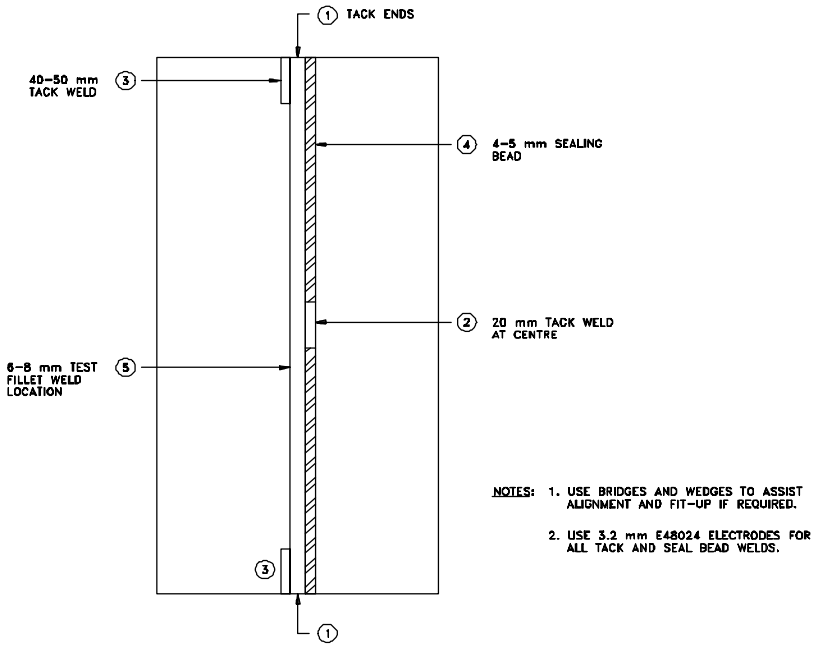


Figure B2 Tack and Sealing Pass Welds

B.3.5 Root Gap

The root gap ***shall not*** exceed 1 mm. The root gap ***shall*** be measured just prior to applying the test weld, after the sealing pass has been completed.

B.3.6 Identification

All test assemblies ***shall*** be stamped in the primed section for subsequent identification.

B.4 TESTING

B.4.1 Welding

The test weld ***shall*** be performed once the test assembly has been prepared and the primer has aged a minimum of seven (7) days. The weld ***shall*** begin in the primed section of the test assembly and proceed into the unprimed section. Whenever possible, the entire length of the test assembly ***shall*** be welded without interruption by stops and starts in the fillet weld.

B.4.2 Examination

After welding, the seal weld ***shall*** be removed by grinding so that the test weld may be fractured. On removal of the seal weld, a force ***shall*** be applied to the test specimen so that a clean fracture occurs through the throat of the fillet weld. Specimens ***shall*** be fixed in a test jig similar to that illustrated in Figure B3.

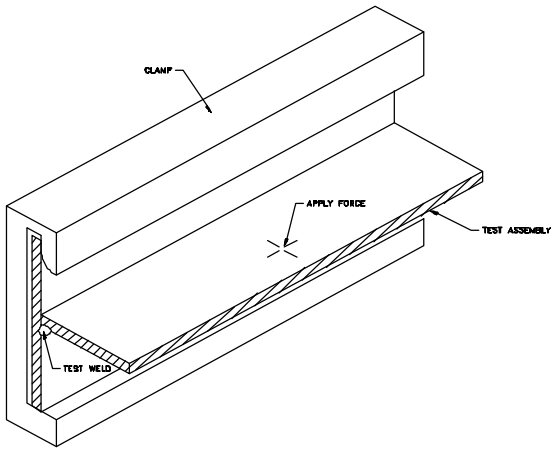


Figure B3 Fillet Fracture Test Jig

Photographs ***shall*** be taken normal to the fracture face, and reproduced at X5 magnification and included with the test result records for presentation to the Technical Authority.

Porosity ***shall*** be reported as a percentage of the total longitudinal cross sectional area of the weld throat (fracture face). The amount of porosity ***shall*** be determined for both the primed and unprimed section using the following method:

1) Total throat cross sectional area for each fillet size ***shall*** be determined.

2) Pore diameters and quantity ***shall*** be measured and recorded.

3) Area of pores and total accumulated area of porosity ***shall*** be calculated as a percentage of the throat cross sectional area.

4) Wormholes, blowholes, and piping porosity ***shall*** be included in the total area of porosity.

B.5 ACCEPTANCE CRITERION

Acceptance ***shall*** be based on the total percentage area of porosity measured across the throat cross section of the primed area. Qualification ***shall*** be awarded if the total area of porosity does not exceed 2% of the total cross sectional area of the primed portion of the test piece. The percentage of porosity ***shall*** also be measured in the unprimed area.

Additional testing ***shall*** be done at the request of the Technical Authority to ensure repeatability of initial results. The Technical Authority may request additional testing at any time prior to or during production.

B.6 RE-TESTS

If the results of individual tests do not meet the acceptance criterion of Clause B5.0 herein, the fabricator may apply for re-test. For each failure, one additional test ***shall*** be required (i.e., first failure, two re-test plates, etc.).

B.7 WITNESS AND DOCUMENTATION

B.7.1 Witness

The following steps ***shall*** be witnessed by the Technical Authority:

1) Blast Finishing

2) Surface Roughness Measurement

3) Priming

4) Stamping of Primed Area

5) Film Thickness Measurement

6) Production of Test Weld

7) Fracturing of Test Specimen

B.7.2 Documentation

All results ***shall*** be recorded and supported by Welding Procedure Qualification Records (WPQR). The original and two copies of the WPQR ***shall*** be transmitted to the Technical Authority for approval.

ANNEX C TESTS FOR RATING CORROSION RESISTANCE OF CARBON STEEL WELD METALS IN SEA WATER

C.1 SCOPE

When required by Clause 6.0 of this Standard, weld metals ***shall*** be tested for corrosion resistance in sea water following the procedures detailed herein.

This Annex specifies the requirements for welding and testing plate assemblages. Organizations performing machining, mechanical testing of welds and corrosion tests ***shall*** be approved by the Technical Authority in advance of any tests.

Welding of test assemblies ***shall*** be witnessed by the Technical Authority.

C.2 TEST ASSEMBLY

When anodic dissolution testing is required to determine ***target*** corrosion resistant weld metals, test assemblies ***shall*** be made in accordance with the requirements of Figure C1 herein.

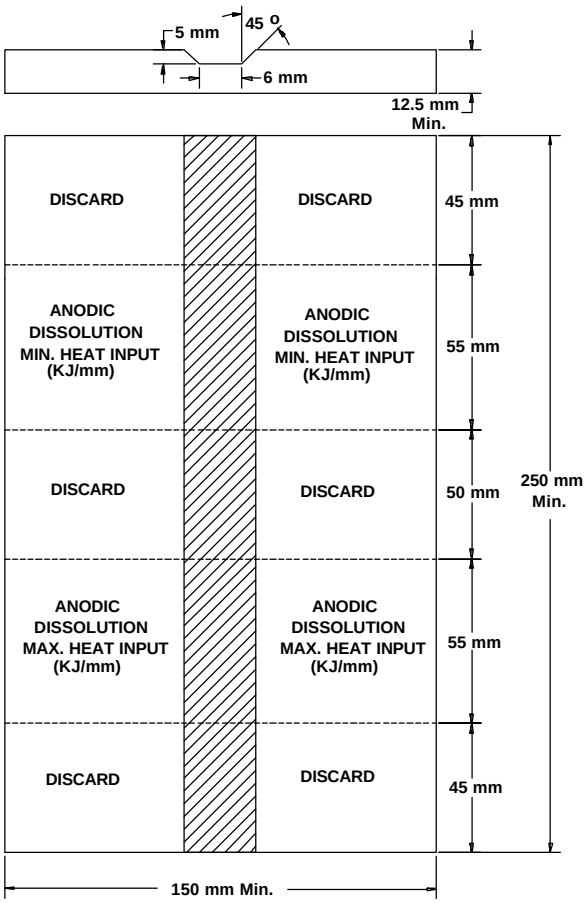


Figure C1 Anodic Dissolution Test Plate Assembly

Welds ***shall*** be deposited following a stringer temper bead sequence at the lowest and highest heat input (kj/mm) planned for production as illustrated in Figure C2 herein. The centre 50 mm discard portion of the test assembly ***shall*** be used as a transition between low and high heat input welds (stop/starts).

For automatic welding using the submerged arc welding process, two test assemblies may be used; one for high heat input and the other for low heat input welds. Bead and layer sequences ***shall*** be adjusted to offer split layer finish to the weld.

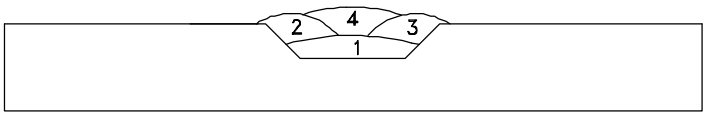


Figure C2 Bead Sequence

When synthetic sea water tank testing is required to validate anodic dissolution test results, test assemblies ***shall*** be made in accordance with the requirements of Figure C3 herein.

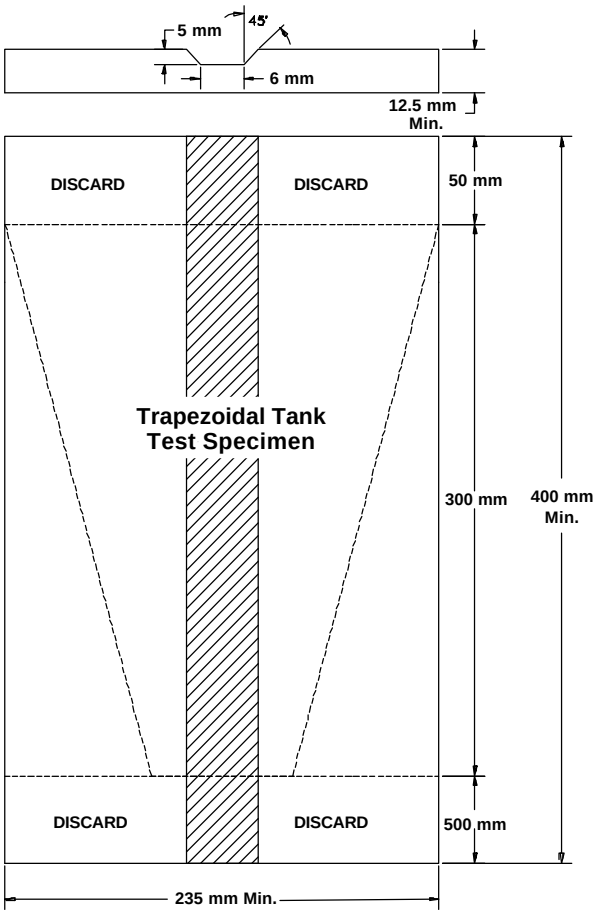


Figure C3 Tank Test Plate Assembly

Welds ***shall*** be deposited following a stringer temper bead sequence as illustrated in Figure C2. For each weld metal deposit two trapezoids ***shall*** be made; one at the lowest and highest heat input planned for production.

For automatic welding using the submerged arc welding process, bead and layer sequences ***shall*** be adjusted to offer a split layer finish to the weld.

C.3 ANODIC DISSOLUTION TESTING

Specimens removed from the test assemblages detailed in Clause C2.0 of this Annex ***shall*** be prepared by machining as illustrated in Figure C4 herein.

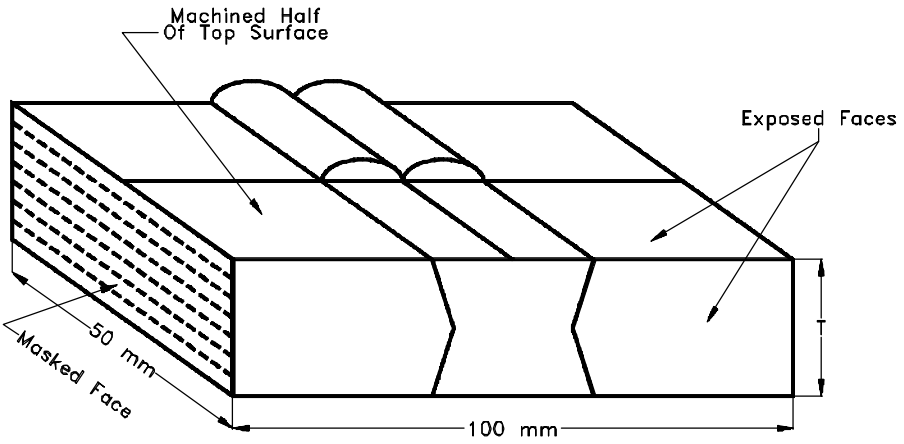


Figure C4 Anodic Dissolution Test Specimen

Each of the specimens ***shall*** be corroded at room temperature at a nominal current density of 0.88 mA/cm² for a period of 15 days. The test solution ***shall*** be 3.5% NaCl. Intermixing of the anolyte and catholyte ***shall*** be prevented by placing a membrane over the opening to the cathode compartment. The test system ***shall*** be as illustrated in Figure C5 herein.

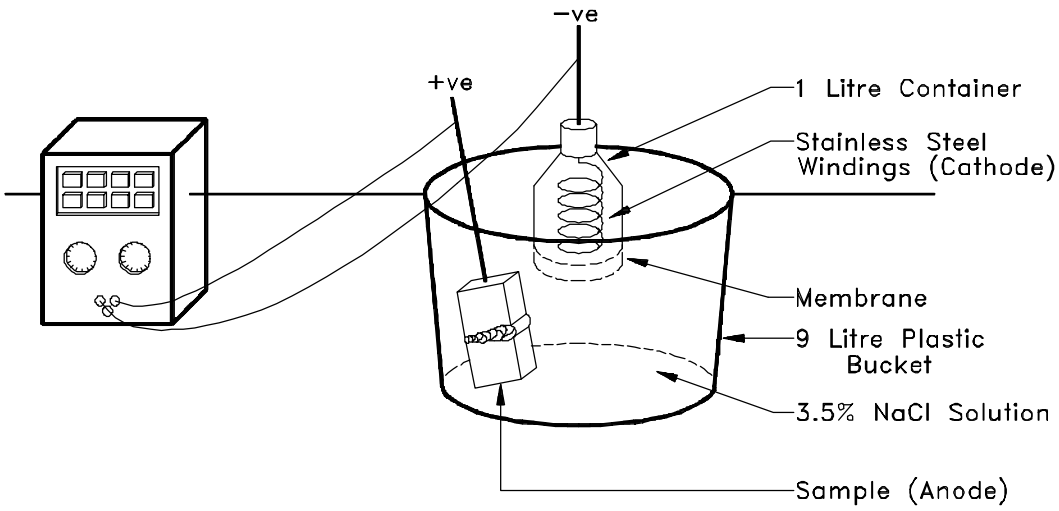


Figure C5 Anodic Dissolution Test System

Anolyte and catholyte pH ***shall*** be monitored daily to ensure the membrane is not leaking. Anolyte pH ***should*** be in the range of 6 to 8.5 units and anode potentials ***should*** be in the range of -600 to -560 mV vs SCE which are potentials typical of unprotected steel in sea water. When the potential is > -600 mV vs SCE, daily stirring ***shall*** occur to avoid pH stratification of the anolyte.

C.4 SYNTHETIC SEA WATER TANK TESTING

Specimens removed from the test assemblies detailed in Clause C2.0 of this Annex ***shall*** be prepared by machining as illustrated in Figure C6 herein.

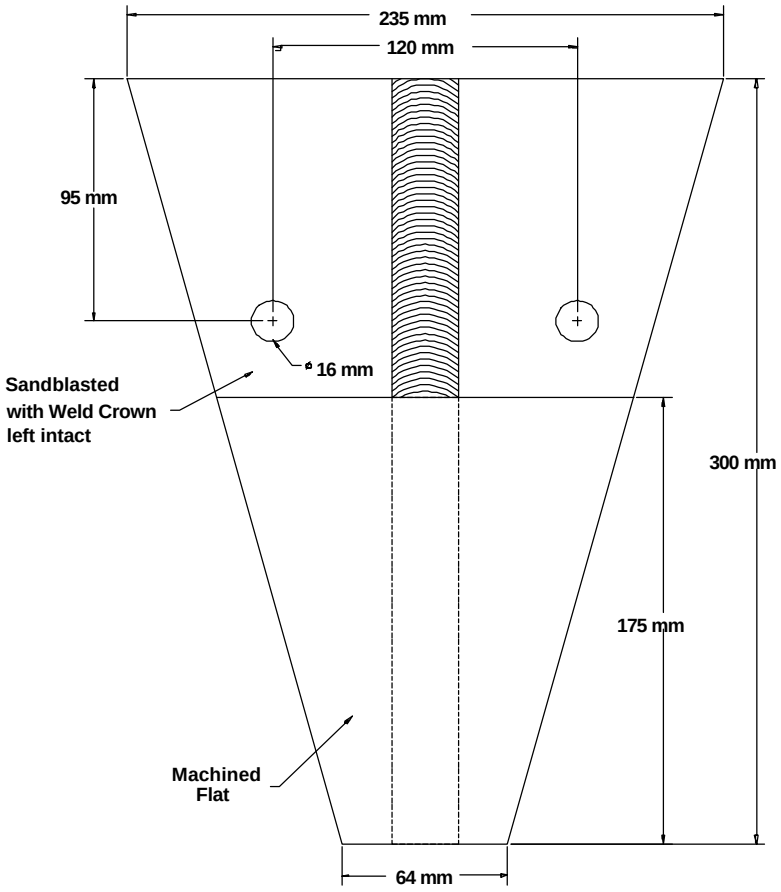


Figure C6 Trapezoidal Specimen

Each of the specimens ***shall*** be subjected to a 180 day free corrosion exposure test. The trapezoidal steel plates containing sample weldments ***shall*** be fixed with carbon steel bolts to a 1.12 m diameter wheel that is turned at 80 rpm giving a linear velocity of 9 m/s at the outer edge and 6.5 m/s at the inner edge of the plates. If stainless steel bolts are used they shall be electrically isolated from the trapezoidal specimens by nylon sleeves and washers. The wheel ***shall*** be housed in a tank that is half filled with a 3.5% NaCl solution held at 1-2° C. The 3.5% NaCl solution ***shall*** be aerated by continuosly blowing air into the tank at a pressure ≈ 35 kPa and a flow rate ≈ 25 L/min. A monolayer of polyethylene chips cut from ≈ 12 mm rod ***shall*** be added for mild abrasion. The test system ***shall*** be as illustrated in Figure C7 herein.

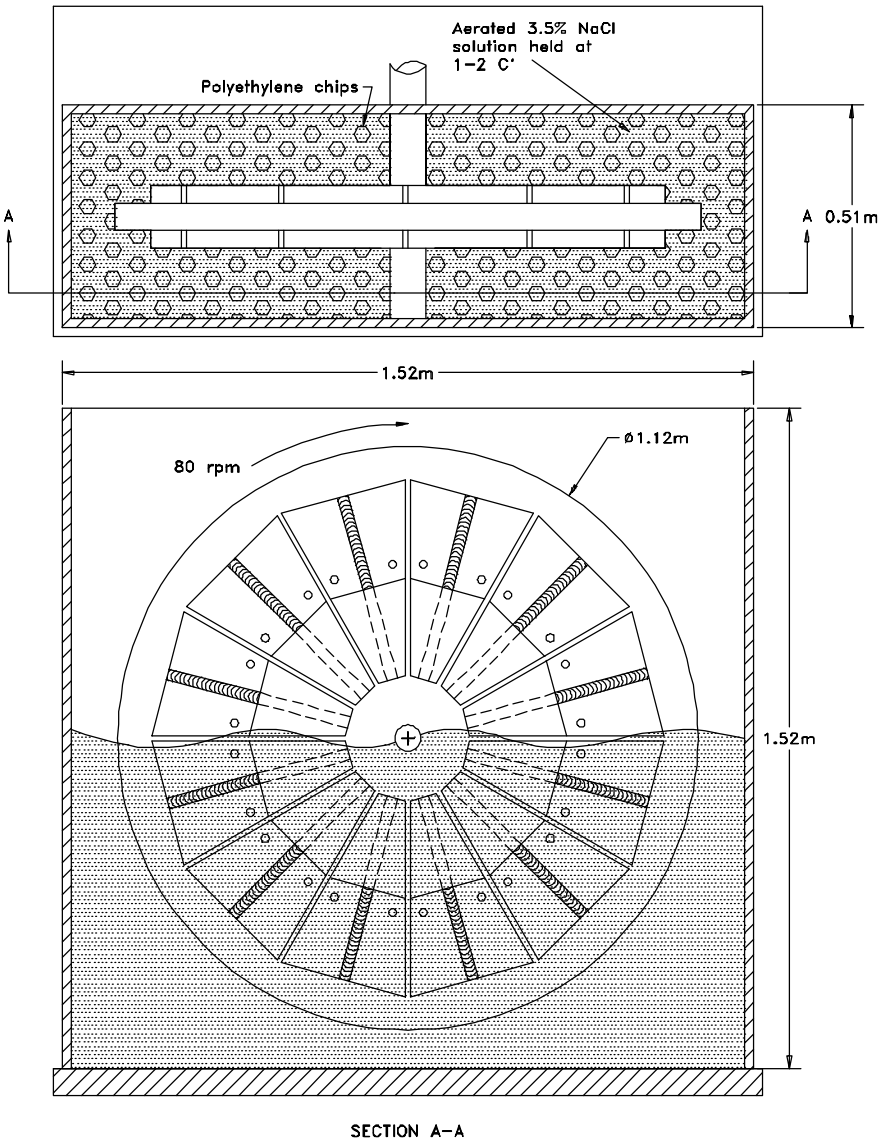


Figure C7 180 Day Free Exposure Corrosion Test

After each 60 day exposure period, the plates **shall** be removed from the test tank, cleaned by wire or nylon brushing, photographed and examined. The degree of attack **shall** be quantified by measuring depth profiles between fiducial markers consisting of nylon screws which **shall** be countersunk in the plates prior to first exposure. Depth profiles **shall** be measured using a profilometer system having resolution in the "Z" direction of ± 0.0125 mm.

C.5 REPORTING TEST RESULTS

Mechanical test results, base plate and weld metal chemistries ***shall*** be recorded on weld procedure qualification record forms.

Corrosion test results ***shall*** be accurately documented and supported by colour photographs and black and white macro examination photo records at 5X magnification.

Corrosion loss for both anodic dissolution and tank test specimens ***shall*** be quantified by taking a series of profile measurements across the weld zone using a profilometer system having resolution in the "Z" direction of ± 0.0125 mm. The depth of attack ***shall*** be well documented for each area of interest in the weld zone; unaffected base plate, heat affected zone and weld metal.

Three copies of the test result reports ***shall*** be provided to the Technical Authority for review and approval of the optimum corrosion resistant weld metal.

ANNEX D WELD TECHNIQUES

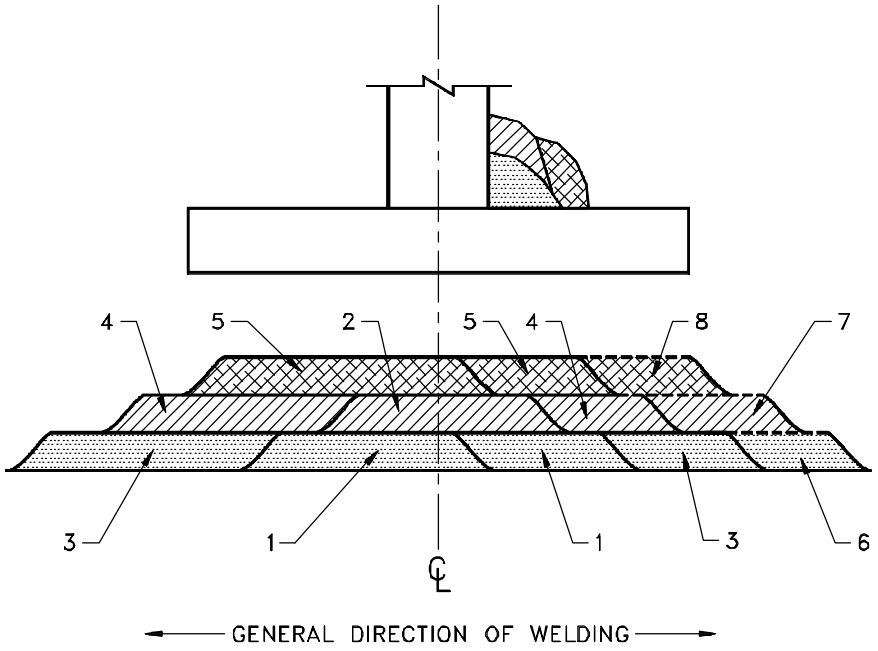


Figure D1 Fillet Weld - Skip Technique

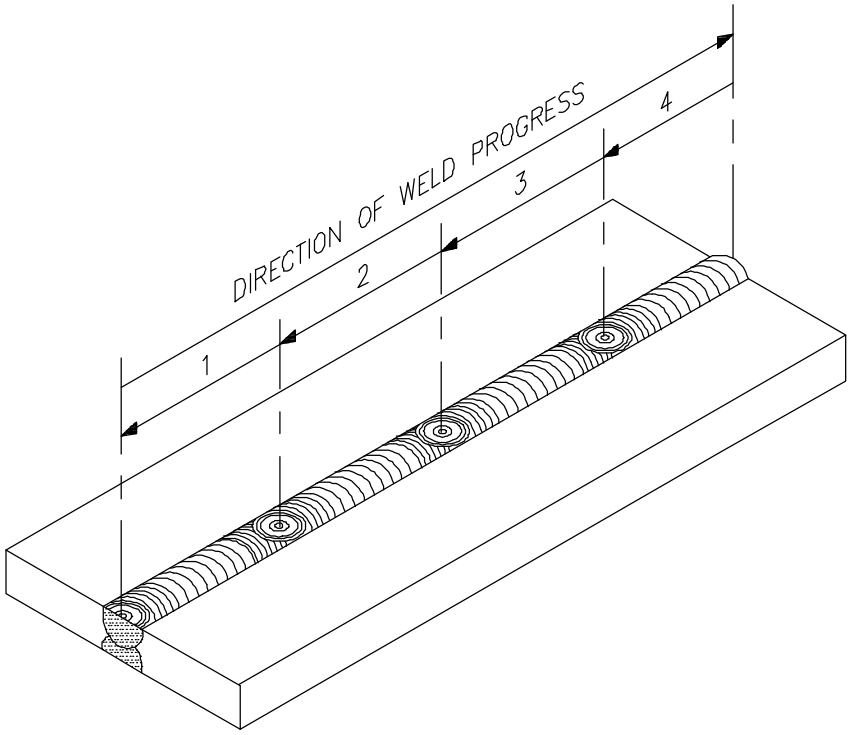


Figure D2 Groove Weld - Back Step Technique

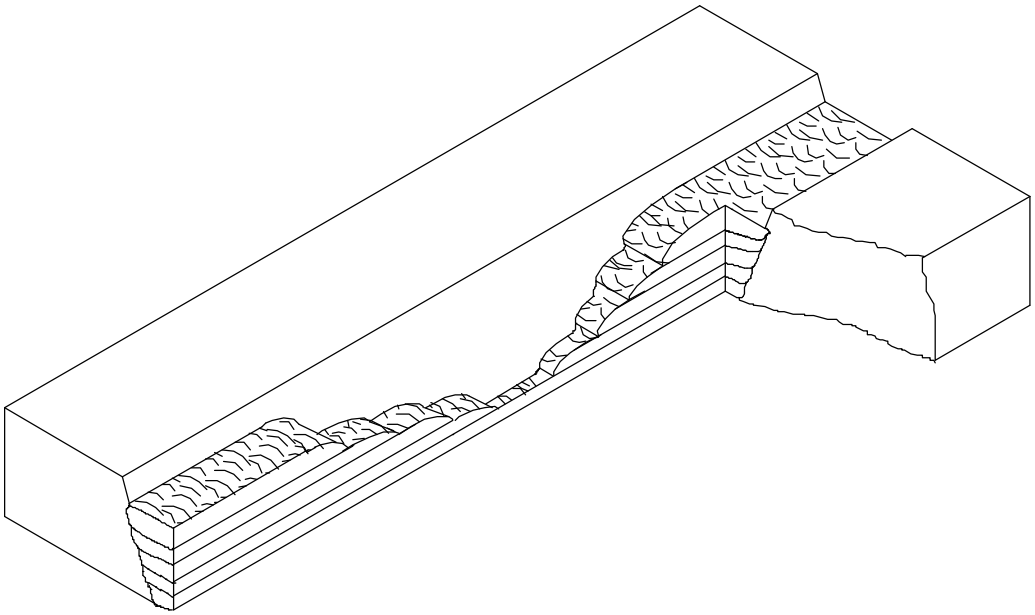


Figure D3 Groove Weld - Block Technique

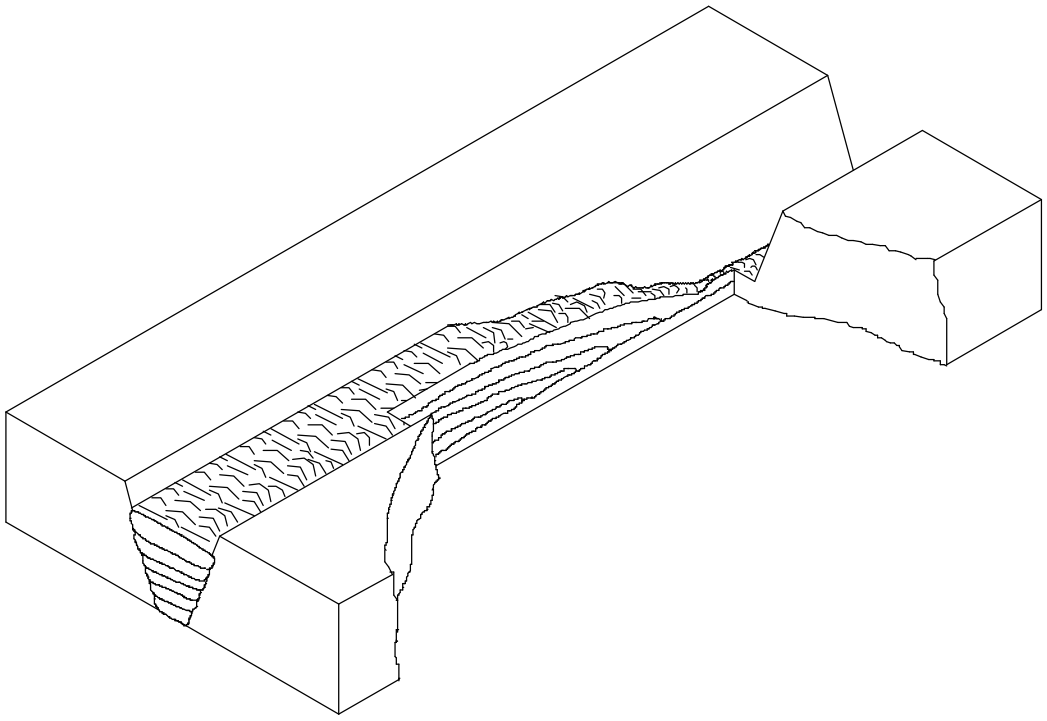


Figure D4 Groove Weld - Cascade Technique

ANNEX E PIPE WELDING

E.1 SCOPE

The requirements of this Annex ***shall*** apply to welding and inspection of all pressure piping and pressure containment systems.

E.2 DESIGN AND DRAWINGS

Weld design for pressure piping and containment systems ***shall*** be in accordance with ASME B31.1. A weld design schedule for pressure piping and pressure containment systems ***shall*** be submitted in drawing form for approval by the Technical Authority prior to commencing any work.

E.3 WELDING ELECRODES AND CONSUMABLES

All welding electrodes and consumables ***shall*** comply with ASME IX and ASME B31.1. Electrodes and consumables not covered by ASME Section IX may be used provided a weld procedure qualification test is successfully completed prior to performing any work. Tests ***shall*** reflect the requirements of ASME Section IX as approved by the Technical Authority.

E.4 PERSONNEL QUALIFICATIONS

Qualification of welders and welding operators ***shall*** comply with the requirements of ASME Section IX and ASME B31.1. Testing and approval ***shall*** be administered by the local Provincial Authorities. Personnel qualification records ***shall*** be forwarded to the Inspection Authority prior to welding.

E.5 QUALIFICATION OF WELD PROCEDURES

Welding procedures ***shall*** be qualified in accordance with ASME Section IX and ASME B31.1. Testing and approval ***shall*** be administered by the local Provincial Authorities. Weld procedure qualification records ***shall*** be forwarded to the Technical Authority for approval prior to welding.

E.6 WORKMANSHIP

All workmanship ***shall*** be in accordance with the requirements of ASME B31.1.

E.7 INSPECTION

E.7.1 General

All examination and inspection of pressure piping and pressure containment systems ***shall*** comply with the requirements of ASME B31.1.

E.7.2 Personnel

All inspection personnel ***shall*** meet the requirements of Chapter 10.0 of this Standard.

E.7.3 Inspections

All welds in pressure piping and pressure containment systems ***shall*** be visually examined along 100% of their length for correct size, profile and the presence of visible defects. Unacceptable conditions or defects ***shall*** be repaired to the satisfaction of the Inspection Authority.

Full penetration groove welds ***shall*** be sampled by spot radiography at a frequency of one in every five welds produced by each welder. Welders ***shall*** be assigned a unique identification number that ***shall*** be stamped on each full penetration connection welded. If a radiograph reveals gross defects, one additional joint ***shall*** be inspected by radiography. If the new radiograph reveals gross defects, the remaining three welds ***shall*** be radiographed

Repair of defects ***shall*** be performed following procedures approved by the Technical Authority. Second repair attempts ***shall not*** be permitted without due consideration of the conditions and approval by the Technical Authority.

E.7.4 Acceptance Criterion

For all inspection methods, welds ***shall*** be evaluated in accordance with the acceptance standards of ASME B31.1.

ANNEX F MINIMUM NONDESTRUCTIVE INSPECTION REQUIREMENTS FOR STEEL VESSELS

F.1 MINIMUM NONDESTRUCTIVE INSPECTION REQUIREMENTS FOR STEEL VESSELS

For new construction, the quantity and methods of nondestructive inspection to be taken as the Technical Authority's minimum requirement shall be as specified herein.

For modernization or major alterations, the quantity and methods of nondestructive inspection to be taken as the Technical Authority's minimum requirement shall be specified in the Vessel Repair Specification and this Annex does not apply.

For minor alterations or repair, the quantity and methods of nondestructive inspection to be taken as the Technical Authority's minimum requirement shall be as specified in Annex J of this Standard.

The length of inspections are specified in Chapter 10.0.

For new construction all welds shall be visually inspected for 100% of their length.

For all other nondestructive inspection methods the following minimum number of inspections apply.

This will depend on vessel overall dimensions in meters.

Legend:	PI	= Penetrant Inspections
	MT	= Magnetic Particle
	RT	= Radiographic Inspections
	UT	= Ultrasonic Inspections
	L	= Overall Length in meters
	B	= Greatest Moulded Breadth in meters
	D	= Moulded Depth at Side, in meters, measured at L/2

UT Inspections	= 0.50 x (L+B+D)
MT or PT Inspections	= 1.00 x (L+B+D)
RT Inspections	= 2.00 x (L+B+D)

For example: An Arctic Class IV Icebreaker 100 meters in length having a moulded breadth of 20 meters and a moulded depth of 8 meters will require:

	Number	**Length**
UT Inspections	= 64	1000 mm
MT or PT Inspections	= 128	1000 mm
RT Inspections	= 256	440 mm or 300 mm x 300 mm

ANNEX G SAMPLE NONDESTRUCTIVE INSPECTION PERSONNEL CERTIFICATES

G.1 GENERAL

This Annex provides sample copies of Nondestructive Inspection Personnel Qualification Certificates. Copies of Nondestructive Inspection Personnel Certificates ***shall*** be filed with the Technical Authority as required in Chapter 10.0 of this Standard.

The administrative organization for CSA Standard W178.2 is the Canadian Welding Bureau and the administrative organization for CGSB Standard, 48.9712 is Certifying Agency, Natural Resources Canada.

G.2 CSA STANDARD W178.2 CERTIFICATE SPECIMEN

(Front) **(Back)**

G.3 CGSB STANDARD CERTIFICATES SPECIMEN

(Front) **(Back)**

ANNEX H REPAIR OF TRIPPING DAMAGE WITHOUT PREHEAT

H.1 SCOPE

This Annex provides guidance for repairing tripping damage to stiffeners attached to the shell plating of ice-transiting ships.

This Annex applies to all fillet welds connecting stiffeners to shell plating for repairs above and below the waterline without preheat when the ambient temperature is above -20°C.

H.2 LIMITATIONS OF USE

The provisions of this Annex do not apply when ambient temperatures are less than -20°C.

The provisions of this Annex apply to steel shell plate thicknesses equal to or greater than 12.5 mm.

The ship's shell and replacement steel plate chemistries ***shall*** be known. This Annex does not apply to ship's shell plates having a carbon equivalent greater than 0.50 (see Table H1), quench and tempered steels or steels manufacured by the thermomechanical controlled process (TMCP).

Table H1 Carbon Equivalent.

$$\text{Carbon Equivalent (CE)} = \frac{(Mn + Si)}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

This Annex does not apply to groove welding shell plates.

All welding and tacking ***shall*** be performed using the Shielded Metal Arc Welding (SMAW) process and only those electrodes approved in Clause H4 of this Annex.

H.3 PERSONNEL REQUIREMENTS

All welders ***shall*** be currently certified by the Canadian Welding Bureau to the requirements of CSA Standard W47.1 for Shielded Metal Arc Welding with F4 electrodes in all welding positions. In addition, the individual ***shall*** demonstrate to the satisfaction of the Technical Authority, that they are capable of depositing acceptable single pass fillet welds in the positions of welding listed in Table H2.

Table H2 Single Pass Fillet Size

Position	Fillet Size (mm)
horizontal	8
vertical	8
overhead	6

Welder qualification test assembly dimensions, requirements and acceptance criterion are as described in Figure H1. Welding electrodes ***shall*** be only those listed in Clause H4 of this Annex.

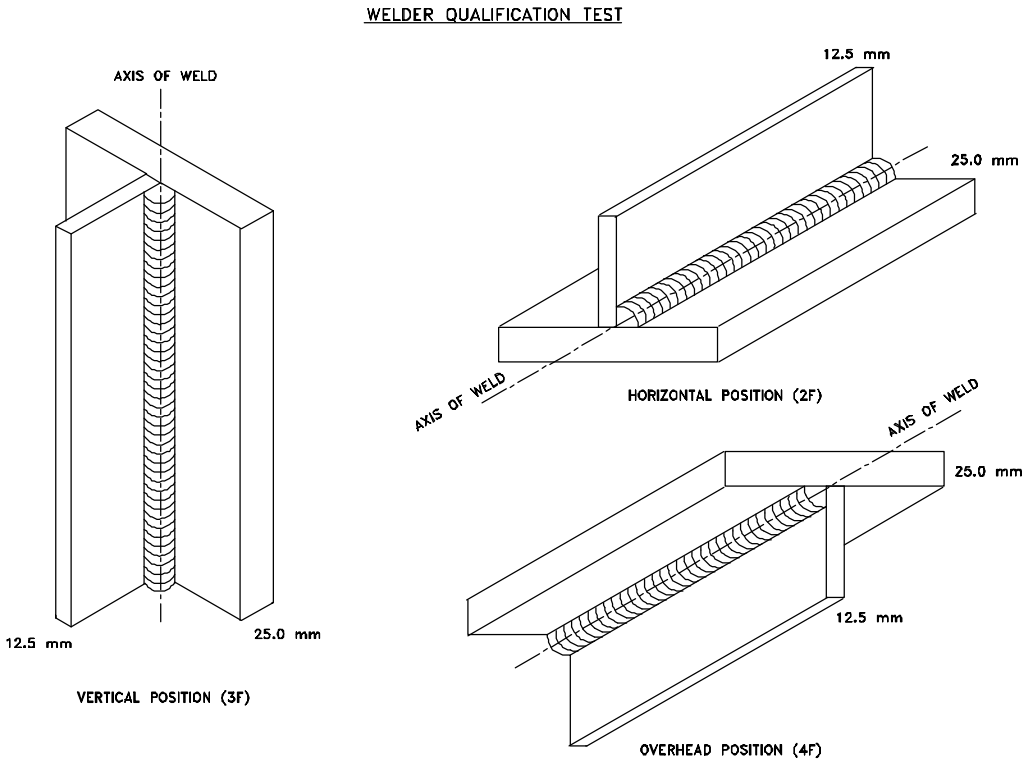


Figure H1 Qualification Test Positions of Welding.

WELDER QUALIFICATION TEST REQUIREMENTS

Test Conditions

1) All test welds ***shall*** be deposited using a 4 mm diameter electrode.

2) The type of electrode shall be approved (refer to Table H3).

3) The test weld length shall be 500 mm.

4) Test welds produced in each position shall incorporate 1 stop and restart location.

5) The minimum test weld size shall be 6 mm for the 4F position and 8 mm for the 2F and 3F positions.

6) The power source output characteristics shall be similar to that intended for actual repairs.

Acceptance Criterion

1) Weld leg lengths ***shall*** be the minimum as defined for the position with a tolerance of + 2 mm only.

2) The weld profiles shall meet the requirements of Chapter 10.0 of this Standard.

3) The maximum depth of undercut permitted is 0.5 mm.

4) Welds including stop and restart locations, shall be free from visible porosity.

5) Two macro sections shall be taken in areas selected by the Technical Authority. The macro sections shall show full fusion to the root and meet the requirements of Chapter 10.0 of this Standard.

H.4 EQUIPMENT AND MATERIALS

This Annex does not apply to ship's shell plates having a carbon equivalent greater than 0.50 (see Table H1), quench and tempered steels or steels manufacured by the thermomechanical controlled process.

The carbon equivalent of replacement plates ***shall not*** exceed 0.40.

The chemistry of all plates being welded ***shall*** be known. A chemical analysis of replacement steel and ship's shell plates ***shall*** be made available to the Technical Authority.

Air Heaters

Forced air heaters ***shall*** be used to raise the ambient air temperature of the compartment to 10°C minimum.

Welding Electrodes

Only approved shielded metal arc welding electrodes ***shall*** be used for all welding including tack welding. The minimum diameter ***shall*** be 4.0 mm. Approved electrodes are specified in Table H3.

Table H3 Approved Shielded Metal Arc Consumables.

Electrode Manufacturer	Trade Name	Classified	Minimum Diameter

Metrode	Ultramild	E42018 (AWS E6018)	4.00 mm

Electrode Storage Oven

All electrodes ***shall*** be stored in close proximity to the repair in electric ovens.

Portable electrode holders ***shall*** be used to transport electrodes from the electric oven to the repair location.

Temperature Indicator

The temperature of steels to be welded ***shall*** be continuously monitored by a suitable surface temperature probe recording temperatures below -20°C and to an accuracy of ± 2°C.

Flame Heating Torch (for moisture removal)

Although this Annex does not include the use of preheat before welding, a heating torch using a rosette pre-heating tip is necessary to remove all moisture, grease and other sources of hydrogen from steel surfaces. Tips designed for cutting ***shall not*** be used for pre-heating.

H.5 WORKMANSHIP AND PROCEDURES

H.5.1 Removing Damaged Material

All damaged material requiring replacement ***shall*** be removed by oxy-fuel cutting and grinding. Special care ***shall*** be taken to not scar or damage shell plates. Air carbon arc gouging ***shall not*** be used without approval of the Technical Authority.

H.5.2 Preparing Edges for Welding

All surfaces to be welded ***shall*** be cleaned thoroughly to remove any foreign matter for a distance of at least 50 mm each side of the weld toe.

Paint film must be completely removed from areas to be welded.

Edges that are to be welded must be ground smooth to remove all notches and surface oxides.

H.5.3 Storage and Conditioning of Electrodes

Electrodes ***shall*** be supplied in the manufacturer's approved containers. If the container shows evidence of damage, all electrodes from the container ***shall*** be discarded.

Electrodes ***shall*** be stored in an electric oven set at a minimum temperature of 125°C. The oven ***shall*** be preheated for a minimum of 30 minutes before receiving electrodes from the manufacturer's containers.

Electrodes ***shall*** be placed in the electric oven immediately after breaking the electrode container's seal.

When transferring electrodes from the oven to portable containers, electrodes ***shall*** be handled so that the coating is not contaminated by oil, dirt, grease, moisture or any other substance. Storing the electrodes with the bare end at the oven/holder opening will help ensure contamination from soiled gloves does not occur. The electrode end must not be handled with soiled or wet gloves.

Electrodes ***shall*** be removed from portable holders, one at a time, closing the lid each time.

H.5.4 Fit-up and Assembly

Parts to be welded ***shall*** be brought into alignment and held in position for welding so that the maximum gap does not exceed 2 mm.

Members ***should*** be brought into alignment and held for welding using bolts, clamps, wedges, struts or other approved devices.

Stiffeners brought into alignment with force ***shall not*** have alignment devices removed until all repairs are completed and the welded area has cooled to ambient conditions.

If attachments or temporary welds are made on the ship's hull, these welds must be applied in accordance with all of the requirements of this Annex.

Temporary welds made on the shell plates ***shall*** be ground smooth after removal and inspected by the magnetic particle methods. Any repairs ***shall*** be made in accordance with all of the requirements of this Annex.

H.5.5 Minimum Fillet Weld Size

All fillet weld beads ***shall*** be applied at a minimum leg size of 6 mm. For horizontal and vertical welding, a minimum single pass fillet weld size of 8.0 mm is preferred and ***should*** be stipulated in the weld procedure.

Weaving and other means of arc manipulation is permitted, however, the maximum single pass fillet weld size ***shall not*** exceed 10 mm.

For large multipass fillet welding, the final passes of the last layer ***shall*** progress from the shell plate to the stiffener following a temper bead sequence.

H.5.6 Welding Parameters

All welding parameters ***should*** be as per those used in the Welder Qualification Test (see Clause H3). These parameters ***shall*** be documented on a Welding Data Sheet (WDS) and approved by the Technical Authority. The Welding Data Sheet ***shall*** be available on site for reference.

The objective during welding is to apply a defined amount of energy into the joint by depositing large fillet weld beads in order that the weld cooling rate is controlled. The amperage and electrode size must, therefore, be at a maximum while permitting the deposition of fillet weld free of notches, undercut or undesirable profiles. The minimum heat input for all welding ***shall*** be 2.0 kJ/mm.

H.6 INSPECTION

H.6.1 Visual Inspection

All fillet welds ***shall*** be 100% visually inspected in accordance with the methods set forth in ASME Section V, Article 9.

H.6.2 Magnetic Particle Inspection

All permanent fillet welds and temporary weld locations ***shall*** be completely inspected for cracks using magnetic particle inspection methods not less than 72 hours after the completion of repairs. Magnetic particle inspection procedures and techniques ***shall*** be in accordance with the methods set forth in ASTM Standard E709.

H.7 ACCEPTANCE CRITERION

Personnel qualifications and acceptance criterion for visual and magnetic particle inspection methods ***shall*** be in accordance with Chapter 10.0 of this Standard.

H.8 CORRECTIONS AND REPAIRS

All undercut or undesirable weld profiles ***shall*** be corrected using small hand-held grinders. Corrections ***shall*** be strictly controlled. Areas showing linear indications such as cracks and incomplete fusion ***shall*** be carefully repaired with repair welding procedures approved by the Technical Authority.

ANNEX I REPAIR OF CORRODED CARBON / STAINLESS STEEL CONNECTIONS IN KORT NOZZLES

I.1 SCOPE

This Annex only applies to connections attaching carbon-manganese steels that are in compliance with Lloyds, ABS or DnV Grade A, D, E, DH36 and EH36 attached to 316 stainless steels (SS). Independent of steel grade, this Annex **"does not apply"** to base plates having a manganese content **"greater than 1.25 wt %"**.

Welds in need of repair located in the plain carbon steel portion of the kort nozzle structure ***shall*** be repaired in accordance with the requirements of Chapter 6.0 of this Standard.

This Annex ***shall*** be complied with when referenced by a given repair or refit specification.

I.2 WELDING ELECTRODES AND CONSUMABLES

Welding electrodes for repair build-up ***shall*** be Canadian Liquid Air (CLA) E48018 RCR or ESAB 73:08 approved to Lloyds 3,3Y,H and E309-16 SS. No substitutes are permitted.

I.3 WELD PROCEDURE QUALIFICATION TESTS

Weld repair build-up ***shall*** only be performed using qualified procedures. Weld procedures ***shall*** be qualified in accordance with the requirements of this Clause.

A test ***shall*** be required in the flat (1G), vertical (3G) and overhead (4G) positions. Vertical-down progression is not permitted. Tests ***shall*** be made with the largest diameter electrode intended for repair at a representative heat input (kJ/mm).

Base plates ***shall*** be Grade A and 316 SS having an as-fitted dimension of at least 500 mm in length and 250 mm in width.

Test plate assemblies ***shall*** be as illustrated in Figure **I**1.

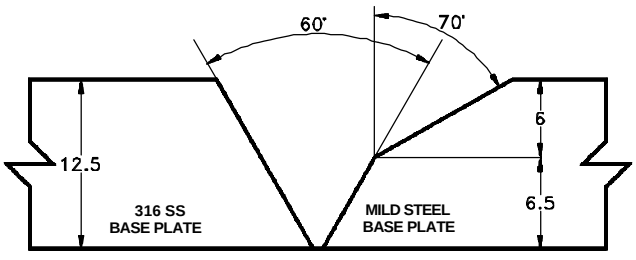


Figure I1 Preparation for Weld Procedure Test

The groove ***shall*** be welded following the technique illustrated in Figure I2. The exact bead sequence ***shall*** be followed.

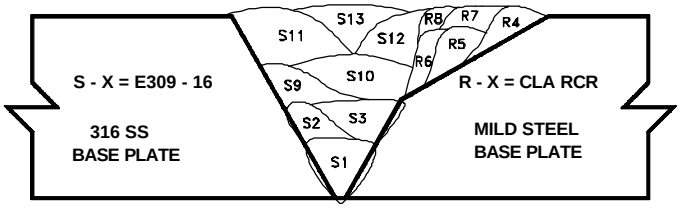


Figure I2 Bead Sequence for Weld Procedure Test

Contractor may adjust number of layers and passes to suit conditions.

The completed weld ***shall*** be subjected to visual and radiographic inspection. The acceptance standard for weld procedure qualification tests ***shall*** be in accordance with the requirements of Chapter 10.0 of this Standard.

A welder that has successfully completed a weld procedure qualification test ***shall*** be considered qualified to the requirements of Clause I4.0 of this Annex for the position(s) the test was completed in.

I.4 WELDER QUALIFICATION TESTS

Weld repair build-up ***shall*** only be performed using qualified welders.

Each welder ***shall*** be tested using a combination of CLA E48018 RCR and E309-16 SS weld metals as stipulated in the qualified weld procedures. Tests ***shall*** be conducted in the positions necessary for actual repair conditions.

Completed welds ***shall*** be examined by visual and radiographic inspection. The acceptance standard ***shall*** be as required in Chapter 10.0 of this Standard.

I.5 REMOVAL OF PROTECTIVE COATINGS

Protective coatings ***shall*** be removed exposing the steel and stainless steel substrate to a width of 150 mm across the corroded weld. The technique employed for removal of protective coatings, especially epoxy based low friction types, must not cause grooving or damage the metallurgical structure of either base metal.

I.6 PREPARATION FOR WELDING

All corrosion product, grooves and valleys ***shall*** be washed to a smooth profile by the carbon arc air gouging method and finished by grinding. The finished profile ***shall*** offer a transition from carbon steel to stainless steel weld metal as illustrated in Figure I3.

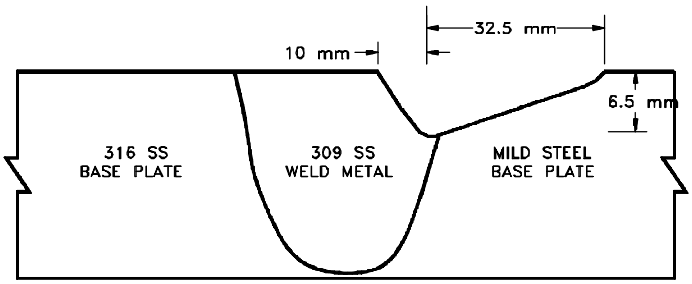


Figure I3 Required Preparation Geometry

I.7 TECHNIQUE

The maximum size of electrode ***shall*** be 4 mm. No single pass ***shall*** be weaved more than 1.5 times the electrode diameter. No individual layer ***shall*** exceed 5 mm in thickness.

For buttering layers with CLA E48018 RCR, the bead sequence illustrated in Figure I4 ***shall*** be employed in all positions of welding to reduce the risk of heat affected zone corrosion at the weld toe transition to carbon steel.

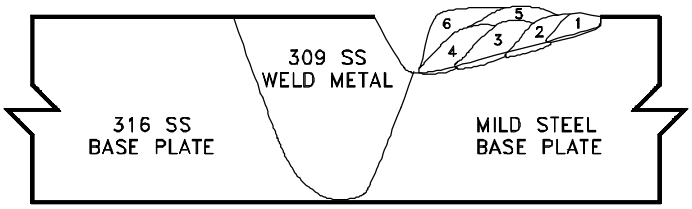


Figure I4 Weld Sequence for Buttering Layer

Once the buttering layers of CLA E48018 RCR are in place the joint ***shall*** be prepared by grinding to a profile equivalent to that illustrated in Figure I5.

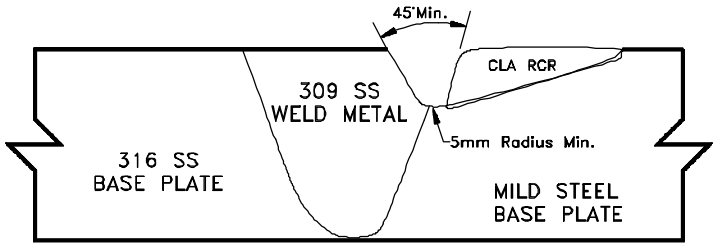


Figure I5 Required Preparation for Stainless Steel Weld Metal

Welding ***shall*** proceed using E309-16 SS electrodes following the bead sequence detailed in Figure I6.

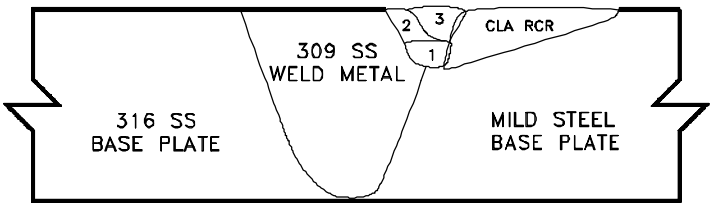


Figure I6 Bead Sequence for Stainless Steel Weld Metal

Completed welds ***shall*** be ground flush.

I.8 INSPECTION REQUIREMENTS

All welds ***shall*** be visually examined along their entire length for undercut, profile and discontinuities open to the surface. Acceptance standards ***shall*** be in accordance with the requirements of Chapter 10.0 of this Standard.

Undercut having a dimension not exceeding 1.0 mm in depth, ***shall*** be carefully repaired by grinding to a profile suitable for fatigue enhancement that blends the area smoothly into the surrounding material without interruption.

Undercut exceeding 1.0 mm in depth and other unacceptable conditions ***shall*** be repaired by welding. After repair welding, temper bead(s) ***shall*** be reapplied and the resulting profile ground flush.

Any zones repaired by welding ***shall*** be inspected by visual and penetrant inspection their entire length.

ANNEX J WELDING STANDARD FOR MINOR ALTERATIONS AND REPAIR OF STEEL

J.1 SCOPE

This Standard states the requirements of Technical Services, Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa for welding steel. This Standard shall be used whenever required as specified by a contract issued on behalf of the Technical Authority, Canadian Coast Guard, Fisheries and Oceans Canada. This Standard is intended only for minor alterations or repair. In addition to this Standard, the contractor shall meet all regulations and standards required Transport Canada Marine Safety and the Applicable Classification Society.

When the above mentioned rules exceed the requirements specified herein, the more stringent requirement shall take precedence.

J.2 DEFINITIONS

The following definitions apply in this Standard:

Approved (Approval)	means reviewed and accepted by the Technical Authority, unless otherwise specified.
Backing Bar (permanent)	means a metallic strip attached to the root side of a joint that will remain as part of the completed weld.
Canadian Welding Bureau (CWB)	means the Certification Division of CWB Group – Industry Services 1998.
Contractor	means a supplier of services or work for the alteration to, or the repair of, steel vessels.
Hull Structure, Primary	means that part of the vessel hull structure which makes up the primary hull girder. It consists of strength decks, platforms and shell plating and their supporting framing, tank top, vertical keel, longitudinal and main transverse bulkheads including water, oil and gas tight bulkheads.
Hull Structure, Secondary	means all of the vessel hull structure which is not included in the definition for primary hull structure.

Inspection Authority	means the individual department, or agency appointed by the Technical Authority to act for and on behalf of the Technical Authority on all inspection and quality matters within the scope of the contract documents.
Technical Authority	means the Director, Technical Services, Integrated Technical Support (ITS), Canadian Coast Guard, Fisheries and Oceans Canada.
Regulatory Authority	means the Transport Canada Marine Safety.
Temporary Weld	means a weld made to attach a piece or pieces for temporary use in handling, alignment, shipping or working of the weldment.
Welder	means one who performs a manual or semi-automatic welding operation.

Where reference in this standard is made to the abbreviation **(t)**, it shall mean the thickness of thinnest member of the connection to be welded.

Additional welding terms are defined in the American Welding Society (AWS) Publication A3.0.

J.3 APPLICABLE DOCUMENTS

The Contractor performing welding or inspection of welds shall be familiar with the following documents:

CSA	W47.1	• Certification Of Companies For Fusion Welding Of Steel Structures
	W48.1	• Carbon Steel Covered Electrodes For Shielded Metal Arc Welding
	W178.2	• Certification Of Welding Inspectors
CGSB	48.9712	• Qualification And Certification Of Non-Destructive Testing Personnel
ABS		• Rules for Nondestructive Inspection of Hull Welds
AWS	A3.0	• Guide For Steel Hull Welding
	D3.5	• Standard Welding Terms And Definitions

J.4 DESIGN, DRAWINGS, WELD DETAILS & SEQUENCE

Unless otherwise approved by the Technical Authority:

1) all groove welds in butt joints shall be full penetration, welded from both sides of the joint employing remove to sound metal techniques. Vee or double Vee preparations having an included angle of at least 60°shall be used.

2) all fillet welds shall be double continuous having a minimum leg length equal to the thickness of the thinner member but never less than 5mm.

3) all corner joints shall be full penetration combined with a single continuous fillet weld.

When required by the Technical Authority, the contractor shall supply drawings and or sketches detailing weld design, dimensioning of materials, fitted tolerances and welding sequence.

J.5 MATERIALS, WELDING PROCESS, CONSUMABLES AND PREHEAT

Materials fitted into the structure shall be marine grade steel alloys and preferably of the same alloy group of the material that was originally fitted. Plates normally are Grade “A”, Grade “D”, Grade “E”, or Grade “EH36”. Ideally, they should be qualified by either Lloyd’s Register of Shipping (LR), American Bureau of Shipping (ABS) or Det Norske Veritas (DnV).

Since ultimate and yield strength and test temperature for notch toughness are significantly altered between Grades, substitutes should be carefully examined. Grade “A” materials should be less than 19 mm in thickness. They are not grain refined which results in poor notch toughness and low through thickness ductility. Grade “D” and Grade “E” have the same ultimate and yield strength as Grade “A”, however Grade “D” has improved notch toughness and Grade “E” is grain refined and has good notch toughness at low temperatures. Grade “EH 36” has higher ultimate and yield strength than does Grade “E”, however notch toughness is similar to Grade “E”.

In most North American Standards, steel 5 mm in thickness or thinner, are classified as sheet. Sheet is available in two grades: utility and structural. When needed, ensure a structural grade is used that is classed weldable, having equivalent ultimate and yield strength, elongation and notch toughness as does the marine grade being substituted.

Shielded Metal Arc Welding is the most conservative welding method for steel repair. Other methods may be used, however matching of consumables and attaining desired levels of quality in a ship repair environment is more challenging.

E48018 electrodes are suitable for all Grade “A” and Grade “D” steel repair welding. E48018-1 is needed for welding the notch tough steels; Grade “E” or Grade “EH36”.

For finishing layers of welds in the shell envelope of ice breaking ships, to reduce or repair corrosion, E48018-RCR or ESAB OK73:08 or E55018-C3 can be used for Grade “A”, Grade “D” and Grade “E” steels having a manganese content less than 1.25% wt. For Grade “EH36” or other steels having a manganese content greater than 1.25% wt, E55018-C3 should be used. Gas Metal Arc Welding should never be used because of the high silicon content of their weld metal deposits. Silicon increases corrosion rate of weld metal significantly.

For those vessels having been fitted with atmospheric corrosion resistant steel or often termed weathering steel as the shell plating (typical trade name "Corten Steel"), electrodes shall be carefully selected to match the copper and nickel content of the base metal in addition to the ultimate and yield strength, elongation and toughness properties desired.

All electrodes should be certified by CWB in accordance with CSA Standard W48.1.

Welding electrodes should be stored in the original package in a dry, clean, heated place adequately protected from the weather or environmental hazards until actually needed at the welding site. The storage area temperature shall be uniformly maintained.

Welding electrodes, rods and consumables shall be kept free of oil, grease, moisture and other deleterious materials once they have been removed from their original packaging. All electrodes of the EXXX18 designation must be stored in a holding oven at a temperature of at least 120°C and never exposed to ambient temperatures for more than 4 hours. Electrodes that become wet must be discarded.

J.6 QUALIFICATIONS OF WELDERS

Welders shall be qualified to CSA Standard W47.1 for the process, filler and base metal grouping, position of welding and type of joint to be welded.

Welders currently qualified to other codes, standards or classifications, may be accepted after review of appropriate documentation by the Technical Authority.

If time does not permit third party approval of welders, the contractor shall perform tests following the requirements of CSA Standard W47.1 to the satisfaction of the Technical Authority.

J.7 QUALIFICATION OF WELD PROCEDURES

Welding should occur with procedures approved by the Canadian Welding Bureau as being compliant with CSA Standard W47.1. The procedure should be for the same joint, position of welding, material and process planned on being used.

In joining steel, torch manipulation techniques such as weaving and whipping are not desired. Stringer beads are the only accepted practice unless otherwise proven by weld procedure qualification tests. For finishing layers of welds located on the seawater side of the shell envelope of icebreakers, a temper bead approach should be employed as illustrated in Figure J1.

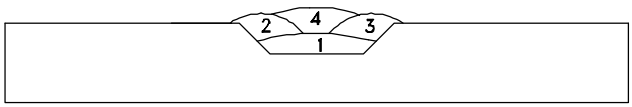


Figure J1 Temper Bead Approach for Finishing Layers in Shell Plating

Each data sheet should indicate workmanship tolerances for preparation, alignment and fit-up.

Procedures approved by the local pressure vessel branch or Classification Societies such as LR, ABS or DnV may be approved for use after review of the appropriate documentation by the Technical Authority.

If time does not permit third party approval of procedures, the contractor shall perform tests following the requirements of CSA Standard W47.1 to the satisfaction of the Technical Authority.

J.8 WORKMANSHIP

The work being welded shall be adequately protected against the direct effects of wind, rain and snow throughout the welding operation. Welding shall not be carried out when the work surfaces are damp and when the ambient temperature is below -17°C except when approved by the Technical Authority. The work zone shall be adequately protected against the direct effects of winds and drafts and for most applications the base metal should be preheated to 10°C prior to welding for material thickness up to 38 mm, 70°C for material thickness up to 65 mm and 110°C for material thickness greater than 65 mm. Plate temperature should be verified prior to welding and during welding by the use of thermal melting sticks.

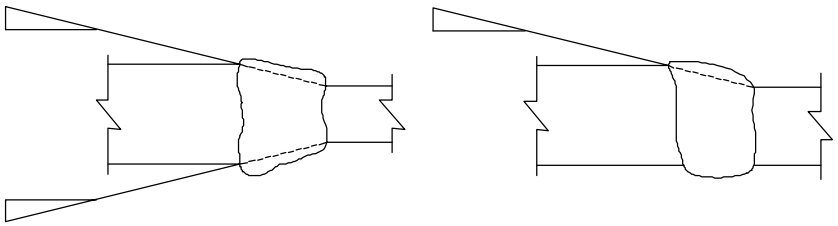
Surfaces and edges of plates shall be clean, smooth, uniform and free of discontinuities that will affect the structure, strength of the weld connection and the completed weld. The minimum surface area to be cleaned prior to welding shall be 50 mm from the anticipated location of each weld toe.

Plate edges and weld preparation surfaces shall be examined for the presence of nicks, gouges and irregularities.

The surface roughness of the cut surfaces shall be no greater than 25 µm. Occasional notches or gouges up to 3 mm deep, on otherwise satisfactory surfaces, shall be flared into the cut surface by machining or grinding to a slope of at least 1 in 10. Occasional notches or gouges greater than 3 mm deep, on otherwise satisfactory surfaces, shall be flared, welded and ground smooth prior to fit up.

The contractor will use accepted cutting practices for steel and steel alloys. Guidance may be found in AWS D.3.5 Guide for Steel Hull Welding.

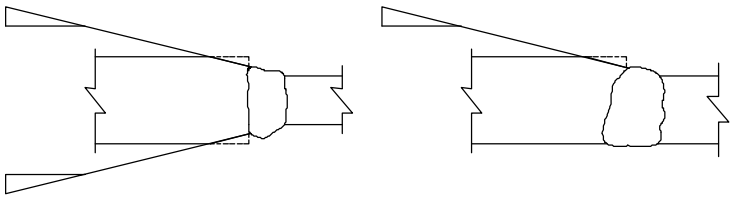
When groove welds are used to join plating of different thickness and the difference in thickness is less than or equal to 5 mm, then the weld may be built-up to the thickness of the plate by welding to a slope of at least: 1 in 4 for shell plating in ice transiting ships or 1 in 3 for other structure or vessels as illustrated in Figure J2.



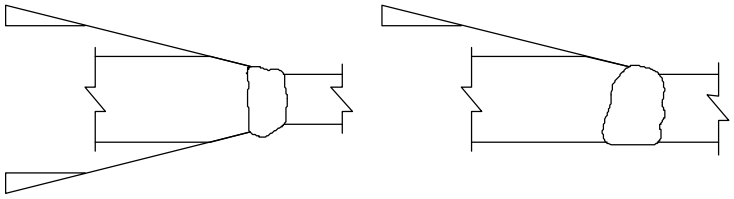
TRANSITION BY SLOPING WELD SURFACE

Figure J2 Slope by Welding

When the difference in thickness exceeds 5 mm, then the transition should be achieved by chamfering to the desired slope as illustrated in Figure J3.



TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING AFTER WELDIN



TRANSITION BY CHAMFERING THICKER PART PRIOR TO WELDING

Figure J3 Slope by Chamfering

Plates to be groove welded shall not be misaligned by an offset more than 10% of the thinnest plate's thickness to a maximum of 3mm as illustrated in Figure J4.

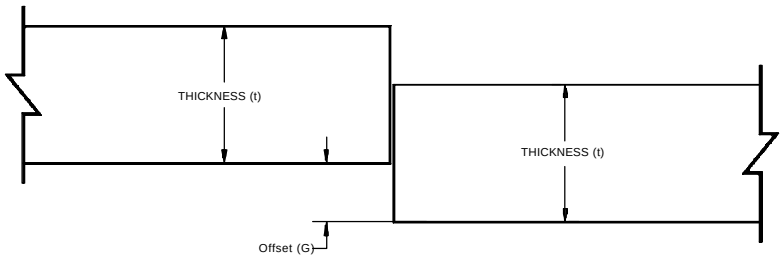


Figure J4 Maximum Offset for Butt Joints

Parts to be joined by fillet welds shall be brought into as close contact as is practicable. The separation between faying surfaces of Tee joints shall not exceed 3 mm. The fillet weld leg length shall be increased in size by an amount equal to the gap as illustrated in Figure J5.

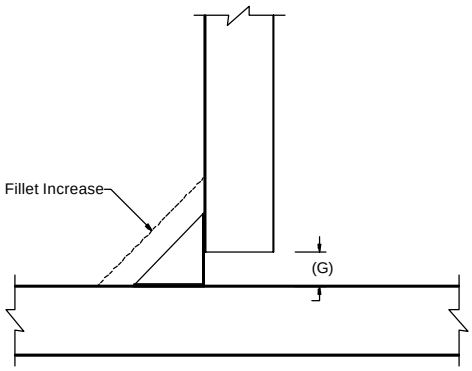
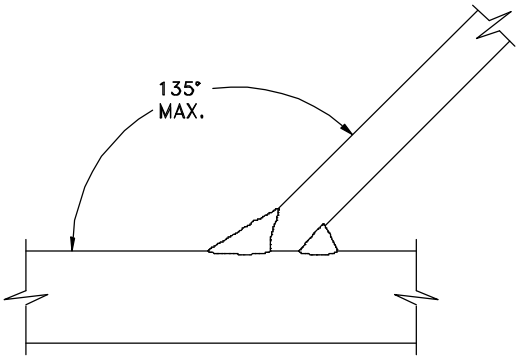


Figure J5 Tee Joints

For Tee joints in the skewed condition (see Figure J6), the deposited leg length of fillet welds shall



be adjusted based on the fitted angle and gap as provided in Table J1.

Figure J6 Skewed Tee Joints

Table J1 Adjustment to Fillet Size for Skewed Joints

Dihedral Angle in Degrees	60	65	70	75	80	85	90	95
Factor to Multiply by	0.71	0.76	0.81	0.86	0.91	0.96	1.00	1.03
Dihedral Angle in Degrees	100	105	110	115	120	125	130	135
Factor to Multiply by	1.08	1.12	1.16	1.19	1.23	1.25	1.28	1.31

Example: Slab longitudinal in the skewed condition fitted to be 135° . Desired fillet weld in the non skewed condition (90°) is 5 mm. Leg length required (5 mm x 1.31). If there is a gap when fitted, add the dimension of the gap to the calculated value. Gaps should not exceed 3 mm (e.g. 5 mm x 1.31 + 3 mm). Round the value up to the nearest fillet gauge size.

The dihedral angle shall not exceed 135°.

The separation between faying surfaces of lapping structure shall not exceed 3 mm. The fillet weld leg length shall be increased in size by an amount equal to the gap. Plates should have an overlap of 75 mm or more as illustrated in Figure J7.

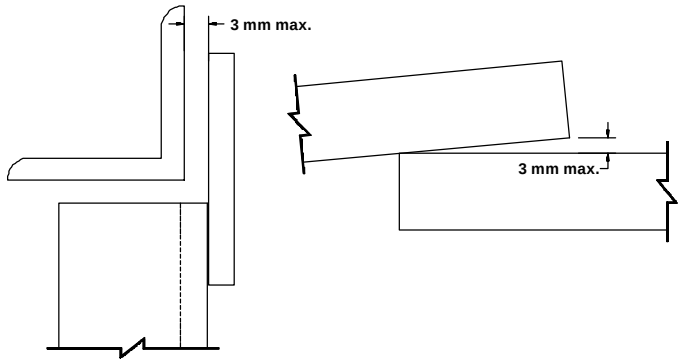


Figure J7 Lapping Structure

When fitting plating for corner joints, the plate shall be edge prepared for a full penetration groove weld. The inside corner shall be continuous fillet welded whenever practicable. Dependent on type of structure and location, the fillet weld leg size may be reduced in size, however shall never be less than 5 mm as illustrated in Figure J8.

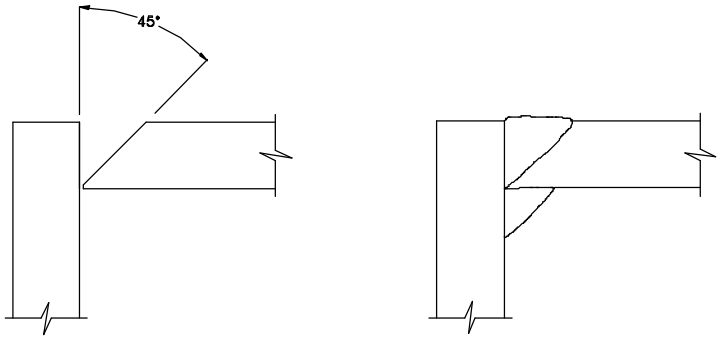
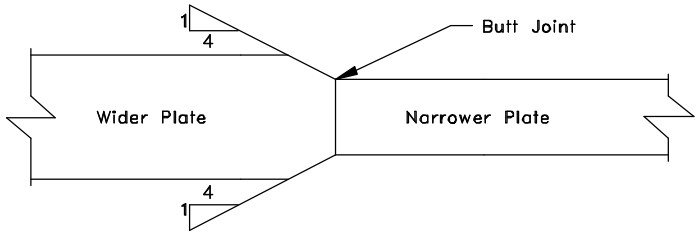


Figure J8 Corner Joints

For differences in flange plate width, the web shall be aligned and the wider flange will have a transition by sniping off both sides to a slope of at least 1 in 4 as illustrated in Figure J9.

Figure J9 Transition for Flange Width



Where a local increase in plate thickness is required, insert plates shall be used instead of doubler plates. Insert plates should be as large as is practicable and preferably tied into existing weld butts and seams. For shell plating, inserts should be at least 1000 mm in dimension. The minimum corner radius used for all insert locations shall be 8 (t) 75 mm minimum as illustrated in Figure J10.

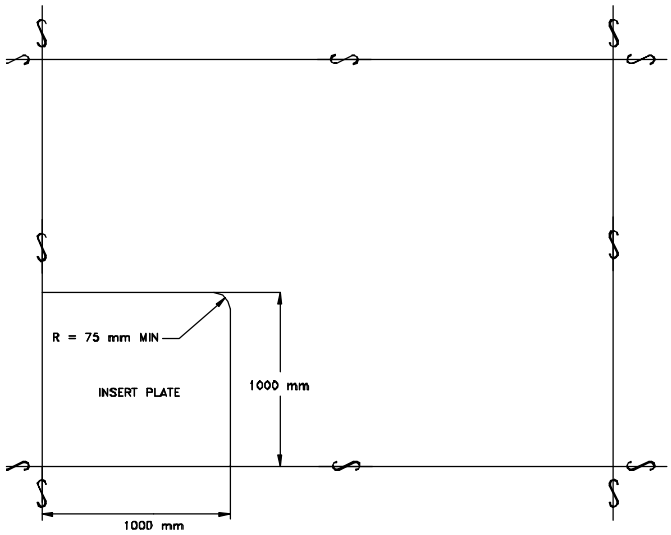


Figure J10 Insert Plates

The dimension between adjacent groove welds in fabricated plating shall be not less than 300mm as illustrated in Figure J11.

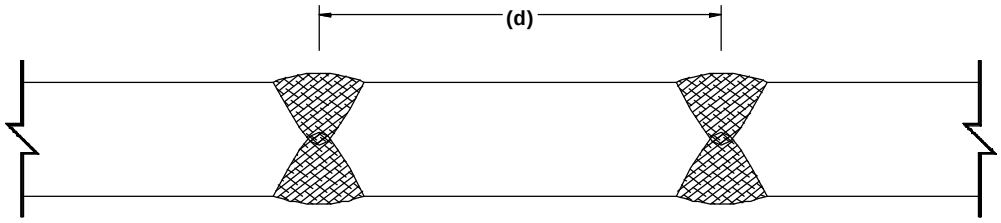


Figure J11 Distance Between Groove Welds

The dimension between a groove weld in plating to a fillet weld attaching a stiffener to the plating shall be at least 30mm as illustrated in Figure J12.

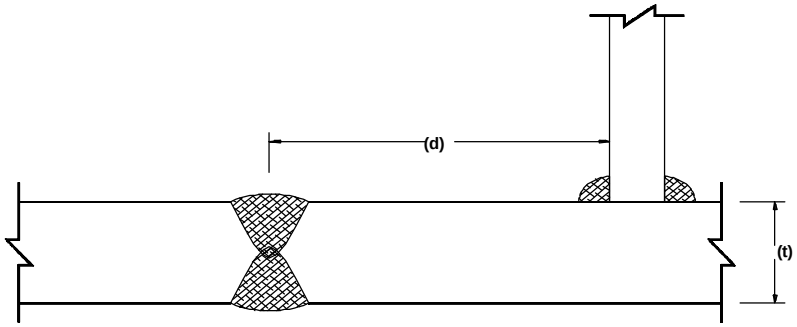


Figure J12 Distance Between Groove and Fillet

The dimension between a groove weld in the web of a stiffener to a fillet weld attaching a stiffener to the plating shall be at least 150mm as illustrated in Figure J13.

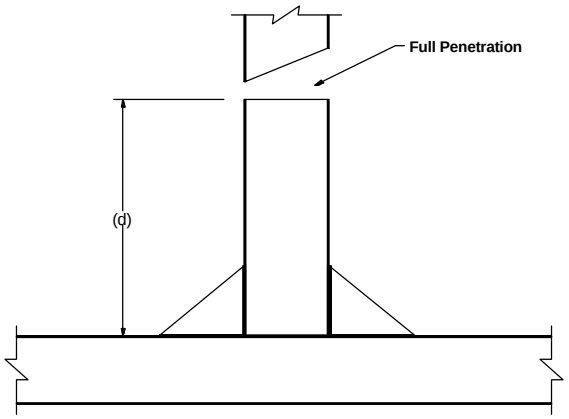
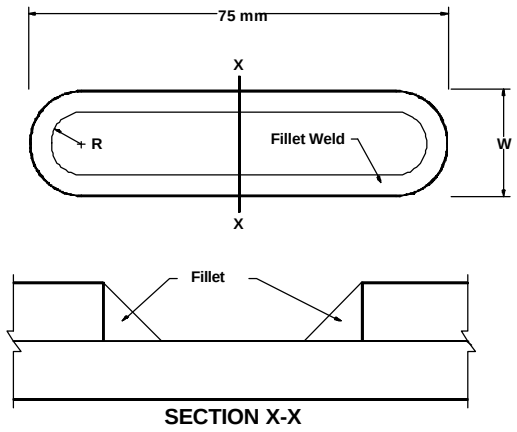


Figure J13 Distance Between Groove and Fillet

For the connection of plating to internal webs, etc., where access is not practicable, the closing plating is to be attached by continuous fillet welds or slots to backing bars fitted to webs. The minimum dimensions of slots shall be as illustrated in Figure J14.



Length	75 mm (minimum)
Width	2.5 (t) (t) = slotted plate thickness
slot spacing	150 mm (maximum)

Figure J14 Slot Welds

Slots shall not be filled with weld metal after completion of the fillet welds. Plug welds are not recommended.

Edge preparations for groove welds shall require joint geometry dimensions as shown on the approved weld procedure data sheet.

The contractor should use fabrication methods that allow welds to be performed in the flat position as much as possible.

When designing weld joints or establishing plans, accessibility for the welder should be considered. When scallops are permitted to provide access for welding, the dimensions shall be adequate to allow for proper electrode angles. Wherever possible, scallops of 20 – 25 mm radius should be used for shielded metal arc welding. Compensation plates may be needed as required by the Technical Authority.

Interbead profiles shall be such as to ensure that adequate fusion with the adjacent base material and previously deposited weld metal occurs. Interbeads shall be cleaned prior to depositing the next weld bead.

When fitting backing bars for groove welds and tee joints the backing bars shall be of the same alloy group number as the base material being welded. Backing bars shall be continuous for the entire length of the joint. Individual bars shall be of the same width and thickness. Abutting ends of backing bars shall be welded prior to initiating the welding of the primary joint it is attached to. Backing bars shall be a tight contacting fit. When and wherever practicable backing bars shall be fillet welded all around. Fillet welds shall be as small as practicable to reduce shrinkage stresses. The primary groove weld must be fully complete prior to depositing fillet welds. The use of any type of filler or spacer bar is prohibited.

Tack welds shall be of a size as to ensure that the finished weld profile is acceptable.

Temporary welds shall not be located on a welded butt or seam.

Temporary welded attachments shall not be removed by mechanical force such as hammering. Insufficient material shall be repaired by welding. Any reinforcement remaining or caused by repair welding shall be removed flush with the base metal. Corrosion resistant welding rods shall be used on the external shell plating (see J5.0 herein)

Materials used for run on / run off tabs, starting tabs or extension bars are to be of the same alloy group as the base material being welded.

Arc strikes outside the area of welds shall be repaired by welding and ground flush with the base metal and examined. Corrosion resistant welding electrodes should be used on the seawater side of shell plating for ice transiting ships (see J.5 herein).

Welding of all structures, sub-assemblies and parts shall progress following a systematic plan that reduces distortion and residual stresses. Guidance can be found in AWS D3.5 Guide for Steel Hull Welding.

Members to be welded should remain unrestrained during welding as much as possible. Insofar as practicable, all welds shall be deposited in a sequence that will balance the heat applied throughout the welding process. The direction of weld progression should be from points where the parts are relatively fixed in position towards points where they have relatively greater freedom of movement.

When welding under high restraint, back step or block welding techniques should be used wherever practicable as illustrated in Figure J15 and Figure J16.

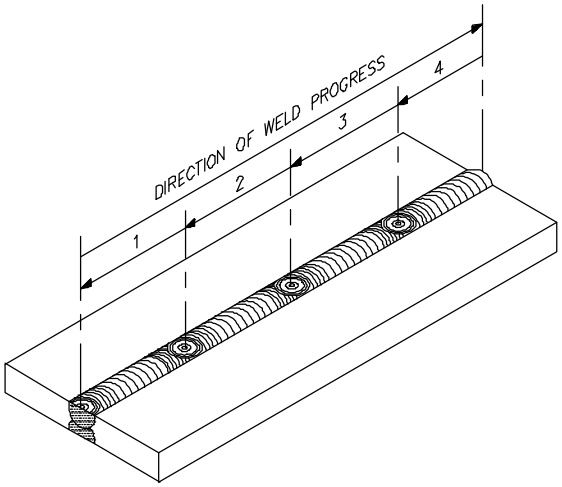


Figure J15 Back Step Technique

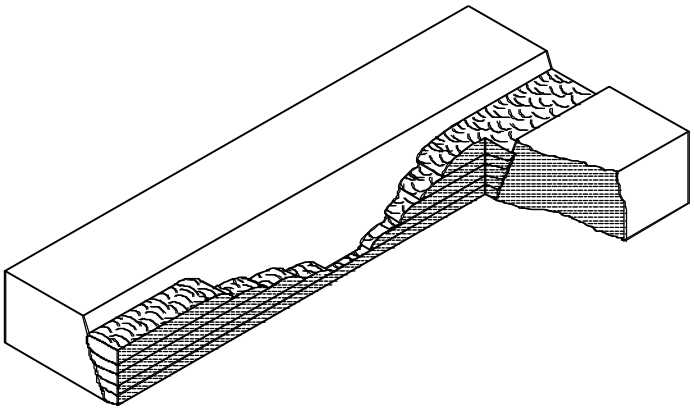


Figure J16 Block Technique

Jigs, fixtures, clamping devices and strong backs should only be used in such a manner as to avoid restraint during welding after tack welds are in place. Strong backs welded on one side of the joint and wedged on the other are preferred. For individual panels consisting of a number of plates, butts shall be welded before seams as illustrated in Figure J17.

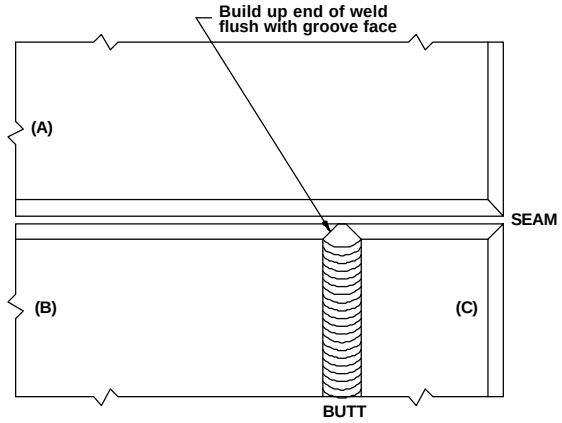


Figure J17 Weld Butt before Seam

For four way intersections of butts and seams, the seam can be welded up to a distance of 230 mm from the unwelded butts. Once the butts have been fully welded, then the seam can be welded as illustrated in Figure J18.

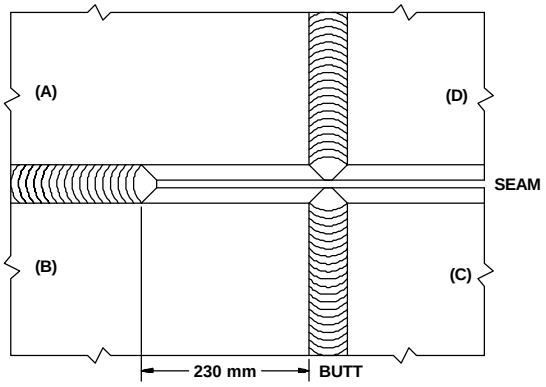


Figure J18 Release Distance for Seams

Stiffeners fillet welded to plating shall remain unwelded at edges of plating for a distance of at least 230 mm until the butts or seams they traverse have been fully welded.

Members distorted by welding shall be straightened at ambient temperature by mechanical means or by carefully supervised application of a controlled amount of localized heat in conjunction with mechanical means. Guidance can be found in AWS D3.5 Guide for Steel Hull Welding.

If localized heating is to be applied in any straightening operation, the complete procedure shall be approved by the Technical Authority. This procedure shall adhere to the maximum temperature values listed in Table J2.

Table J2 Maximum Temperatures for Air and Water Cooling

Steel Grade	Maximum Allowable Temperature	Maximum Water Quenching Temperature	Technique
All Grades (except EH)	900°C	550°C	Air and Water Cooling
EH	650°C	550°C	Air and Water Cooling

Locations that have been subjected to heat straightening will be visually examined for defects after straightening is completed.

When a weld has been rejected in accordance with the applicable acceptance criteria, it shall be corrected and made right at the contractor's expense.

When a portion of a weld contains unacceptable discontinuities, corrective action may be taken providing the Inspection Authority has reviewed the extent of unacceptable discontinuities and the repair procedures are agreed to by the Inspection Authority.

When an entire weld, base material, entire part or entire section contains unacceptable discontinuities, no corrective action shall be taken without the Technical and Inspection Authorities' approval of the repair procedure.

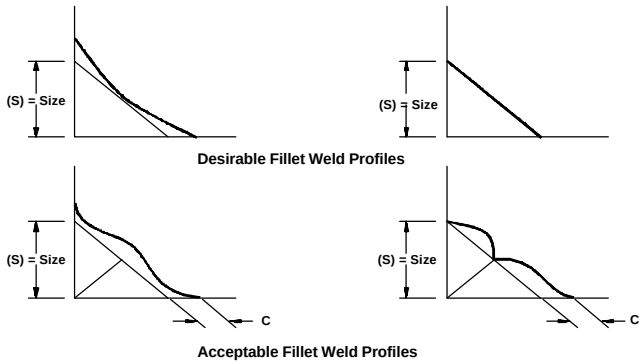
In the event that faulty welding, or its removal for re-welding, so damages the base metal that its retention is not in accordance with the intent of the plans and specifications, the contractor shall remove and replace the damaged material or shall otherwise rectify the deficiency.

When work has been performed subsequent to the making of a deficient weld and has rendered the deficient weld inaccessible for repair, the original conditions shall be restored by removal of plates or members allowing for access to enable effective repair. If the original condition cannot be restored, additional work shall be performed to the satisfaction of the Technical Authority.

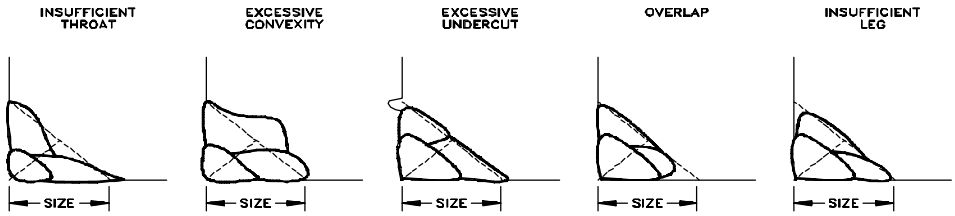
J.9 INSPECTION

All welds shall be visually inspected. All completed welds shall be free of undercut, overlap, visible porosity, fusion faults, cracks or craters.

Fillet welds shall be of the required leg size free of concavity or objectionable convexity. Reinforcement shall be smooth without grooves or valleys along the length of the weld. Toes of welds shall blend smoothly into the base metal. Desirable and undesirable profiles are illustrated in Figure J19.



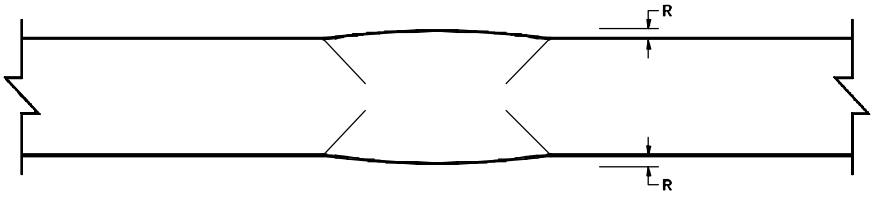
"C"- Convexity shall not exceed 10% leg length plus 1.5 mm



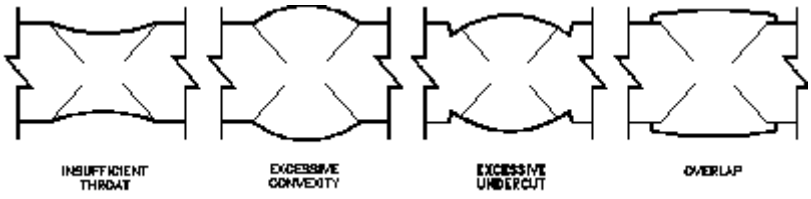
Undesirable Profiles

Figure J19 Fillet Weld Profiles

Groove welds in butt joints shall fill the groove completely not having a reinforcement greater than 3 mm. Reinforcement shall be smooth without grooves or valleys along the length of the weld. Toes of welds shall blend smoothly into the base metal. Desirable and undesirable profiles are illustrated in Figure J20.



Desirable Profile



Undesirable Profiles

Figure J20 Groove Weld Profiles

Personnel inspecting welds visually, shall be qualified to a recognized standard, preferably CSA Standard W178.2 Level II and shall use adequate lighting and staging when performing inspections. Neither paint, primer nor fillers shall be applied to welds until they have been inspected, repaired if necessary, and accepted by the Inspection Authority. Unacceptable discontinuities shall be repaired to the extent required by the Inspection Authority.

Groove welds in the primary hull girder shall be inspected visually and sampled by radiography. Personnel performing radiography and interpreting results shall be currently qualified by the Certifying Agency of Natural Resources Canada to Level II or Level III of CGSB 48.9712. Class II film and X-Ray shall be used for material thickness less than 6 mm. Class I film and gamma ray (Iridium 192 only) shall be used for all other thickness. Film density shall be between 2.0 and 3.5 and film sensitivity shall be at least 2-2t.

Appropriate Image Quality Indicator's (IQI's) shall be placed at each end of the film on the source side of the part only as provided in Table J3 and as illustrated in Figures J21, J22 and J23. IQI's shall be certifiable to ASTM or ASME Standards.

Table J3 Image Quality Indicators

Material Thickness Range (inches)		Image Quality Indicators		Essential Hole	
		Thickness (inches)	N °	2 - 2 (t)	2 - 4 (t)
Up to	½	0.0100	10	0.020	0.040
Over	½ to 5/8	0.0125	12	0.025	0.050
	5/8 to ¾	0.0150	15	0.030	0.060
	¾ to 7/8	0.0175	17	0.035	0.070
	7/8 to 1	0.0200	20	0.040	0.080
	1 to 1¼	0.0250	25	0.050	0.100
	1¼ to 1½	0.0300	30	0.060	
	1½ to 2	0.0350	35	0.070	

NOTE: ASTM and ASME IQI's are not available in metric.

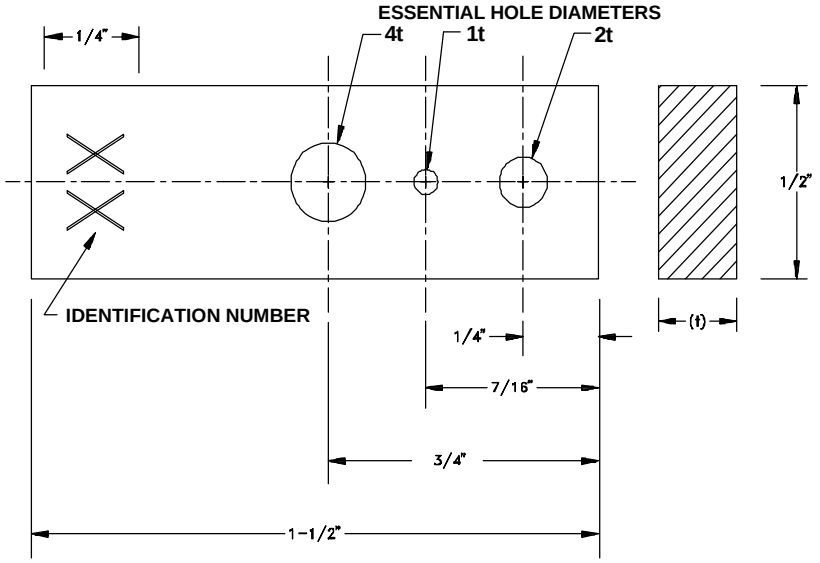


Figure J21 Image Quality Indicator

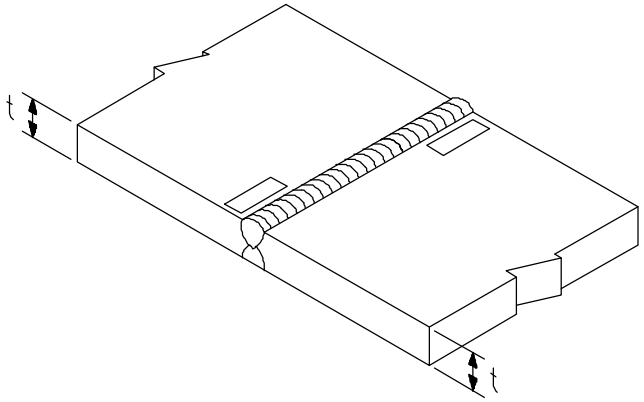


Figure J22 IQI Placement for Same Plate Thickness

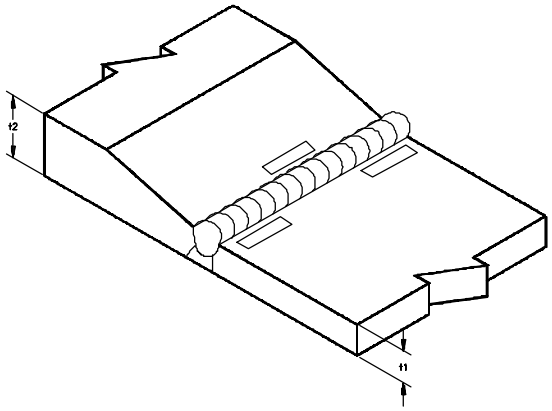


Figure J23 IQI Placement for Differing Plate Thickness

Intensification screens shall not be used. A lead symbol "B" shall be placed on the back side of the film as an indicator of insufficient protection from back scatter radiation. Films displaying the symbol "B" shall be retaken. Film length should be 440 mm.

Shims of a thickness equal to weld reinforcement shall be placed under IQI's as illustrated in Figure J24.

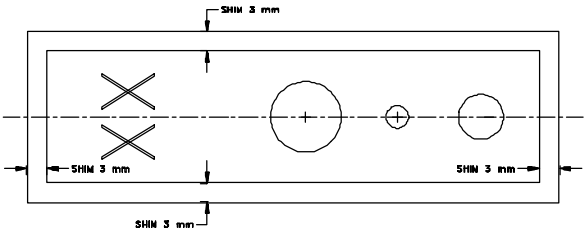


Figure J24 Shims for IQI's

Film processing techniques shall be adequate to develop the latent image of the radiograph into a visual image with adequate clarity and resolution.

Film processing and chemical control procedures shall be displayed in the developing facility for review by the Inspection and Technical Authorities. Developed films that are received displaying water stains, blotches, streaks, fingerprints, sharp lines, milky zones, brownish tones and fog shall be rejected and retaken if these conditions interfere with the interpretation of the area of interest (weld zone).

The exposed radiographs shall depict all portions of the welded joint including the weld, heat affected zone and adjacent base material. Interpretation of the area of interest shall not be inhibited in any way by the presence of Image Quality Indicators (IQI), flash or lead identification and location markers.

All radiographs shall be free of mechanical, chemical and/or other blemishes to the extent that they do not mask or inhibit interpretation of the area of interest (weld zone) or IQI's.

The radiographic technique ***shall*** be of sufficient sensitivity to display the IQI's image and the essential hole, both of which are indications of image quality of the radiograph. If the density of the radiographs through the area of interest (weld zone) varies by more than -15% or +30% from the density through the body of the IQI within the minimum/maximum allowable density range specified, an additional IQI ***shall*** be used for each exceptional area or areas and the radiograph retaken.

Procedures shall follow the requirements of ABS Rules for Nondestructive Inspection of Hull Welds. Interpretation shall be to Class A requirements of ABS Rules for ice transiting ships and Class B for other ship types.

Unless otherwise specified in the contract documents, 10% of the length of each groove weld shall be sampled by radiography. Welds found to not meet the standards shall be made right by welding and repairs checked by re-examination using the same inspection method used for the original examination.

If discontinuities are found at either film end, overlapping films shall be taken at the Contractor's expense.

For each failed location, one new location shall be examined at the Contractor's expense.

Ultrasonic inspection may be used in lieu of radiography if the person performing the inspection is currently qualified by the Certifying Agency to Level III requirements of CGSB 48.9712.

A detailed procedure and technique sheet must be supplied with each interpretation report.

The contractor shall make available to the Technical and Inspection Authorities an authentic radiographic film viewer for the entire duration of the contract and warranty period.

The contractor shall supply to the Technical Authority inspection records in the form of weld inspection procedures and interpretation reports including NDE arrangement drawings in three copies.