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WELDING OF ALUMINUM AND ALUMINUM ALLOYS

SALUTI PRIMUM AUXILIO SEMPER

Canadian Coast Guard
Standards

Canada

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1	March 1999	2nd Edition	
2	Feb 2000	2nd Edition / 1st Revision	
3	June 2002	3rd Edition: Change of organizational structure and authorities. *Note: Modifications are identified with paragraph sidebars*	

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 Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.

The intended purpose of this Standard is stated in Chapter 1, 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 (ITS), Canadian Coast Guard, Fisheries and Oceans Canada, 200 Kent Street, Ottawa, Ontario K1A 0E6.

All requests should:

- define the problem;
- reference the specific Chapter, Section, Figure, 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 Integrated Technical Support, Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.

This Standard shall be used whenever required as specified by a contract.

This Standard details the requirements for welding aluminum and aluminum alloys.

This Standard is intended as an Owner's Special Requirement for new construction, modernization, alteration or repair.

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 Gas Metal Arc Welding (G.M.A.W.), Gas Tungsten Arc Welding (G.T.A.W.), and Plasma Arc Welding (P.A.W.). No other welding process is permitted for welding of aluminum and aluminum alloys.

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

CHAPTER 2 DEFINITIONS AND ABREVIATIONS

The following definitions and abreviations 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 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.
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.
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.
Contaminated Electrode	means an electrode that is contaminated with any type of foreign matter.
Contractor	means a supplier of services or work for the construction, repair or alteration to aluminum vessels and/or shipboard equipment constructed of aluminum 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 the established acceptance criterion (e.g. Chapter 10 of this standard).
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 interruption 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.
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.
Regulatory Authority	means the Transport Canada Marine Safety.
Technical Authority	means the Director, Technical Services, Integrated Technical Support (ITS) or delegated representative(s), 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.
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 detail drawings providing information similar to 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 Appendix "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.

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 (ITS), 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 DRAWINGS AND WELD DETAILS

Adequate information about welds will appear on design drawings, by the use of weld requirement symbols, in order that working shop detail 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) Weld requirement symbols, for partial penetration groove welds, will display the applicable effective throat dimensions on the reference line of the symbol used and the words 'partial penetration' shall appear in the tail portion of the symbol. (See Figure 5-2)

Figure 5-1 Full Penetration Groove Welds

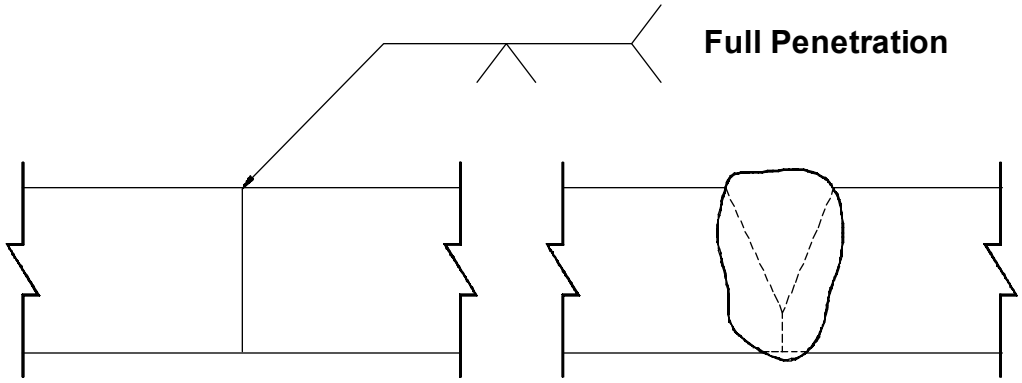
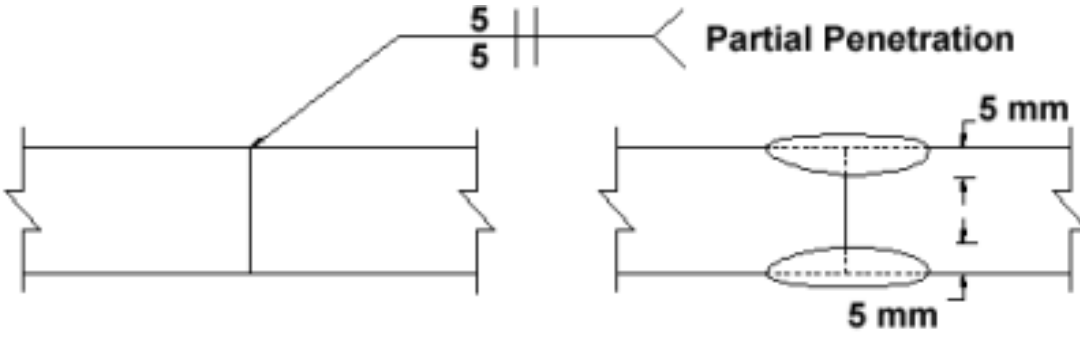
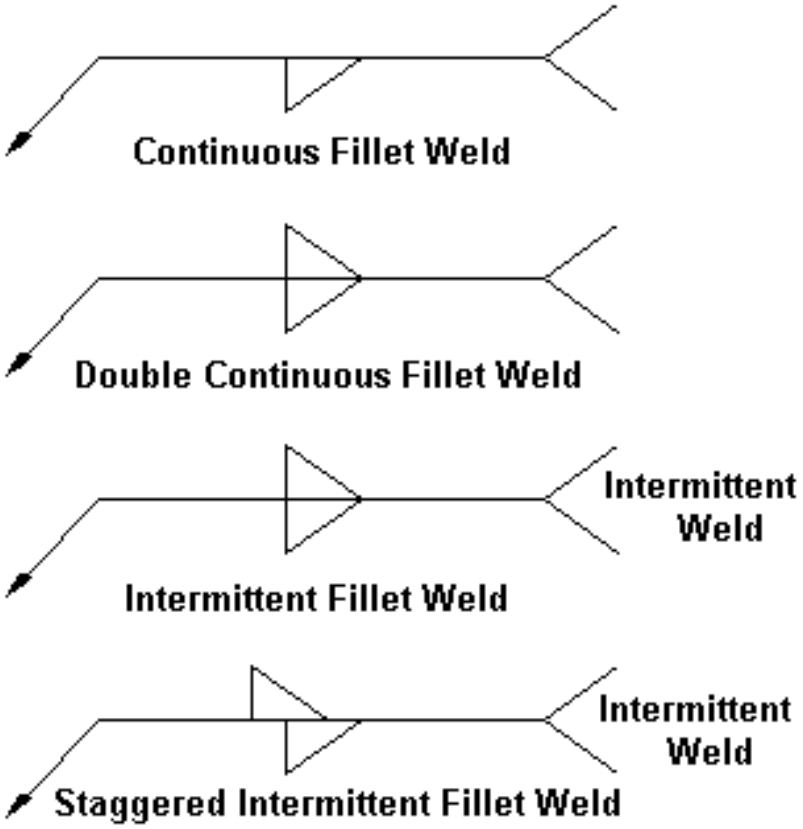


Figure 5-2 Partial Penetration Welds



The weld requirement symbol for fillet welds will display the disposition of the weld but will not necessarily indicate the leg length or effective throat dimension. The disposition of the weld would include continuous versus double continuous and intermittent versus staggered intermittent, etc. (See Figure 5-3)

Figure 5-3 Fillet Welds



Working shop detail drawings will display adequate information about the location, type, size and disposition of the welds.

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, RODS AND CONSUMABLES

6.1 GENERAL

This chapter states the requirements for welding electrodes, rods and consumables used for welding aluminum and aluminum alloys.

The grade of welding electrode, rod, shielding gas or grade of deposited weld metal shall meet the requirements specified herein.

All welding electrodes, rods and consumables shall be certified by CWB as conforming to the requirements of AWS Specification A5.10. Welding electrodes, rods and consumables will be matched to the base metal in accordance with the requirements of Table 6-1 herein.

6.2 IDENTIFICATION

Welding electrodes, rods and consumables shall be clearly identified. The system and type of identification used shall be in accordance with AWS Specification A5.10.

Adequate information detailing welding electrode, rod and consumable identification shall be made readily available to welding personnel for their use.

6.3 STORAGE AND HANDLING

Filler metal shall 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.

All welding electrodes, rods and consumables shall be carefully handled to prevent damage to sealed packaging. Adequate inspection of packaging shall be undertaken and the original sealed packaging should not be opened until required for welding or distribution to the welding site. Inventory of welding electrodes, rods and consumables shall be rotated in such a manner as to prevent an accumulation of aged material.

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.

6.4 CONSUMABLES FOR GAS METAL ARC, GAS TUNGSTEN ARC AND PLASMA ARC WELDING

Welding electrodes, rods and consumables shall be clean, dry, and free from extraneous oxide and deleterious materials. Rods intended for manual Gas Tungsten Arc Welding and Plasma Arc Welding should be degreased with commercial solvents prior to welding and cleaned with stainless steel wool just prior to use.

The shielding gas shall be welding grade argon, helium, or an argon-helium mixture, and shall be limited to those specified on the approved weld procedure data sheets. No additions of other gases shall be acceptable. The welding gases shall have a dew point of -60°C, or lower, at 15,000 KPA.

Shielding gas cylinders shall be clearly identified as to their content and welding personnel shall be familiar with the identification system used.

Table 6-1 Filler Alloy Selection Guide

Base Metal Alloys	520	A356	356	6005, 6061 6063, 6101 6151, 6201 6351, 6951	5456	5454	5254 5652	5154	5086	5083
5083				5356(b)	5356(b)	5356(a)	5654(a)	5356(a)	5356(b)	5356(b)
5086				5356(b)	5356(b)	5356(a)	5654(a)	5356(a)	5356(b)	
5154				5356(a)	5356(a)	5356(a)	5654(a)	5356(a)		
5254, 5652				5654(a)	5654(a)	5654(a)	5654(a)			
5454				5356(a)	5356(a)	5554(a)				
5456				5356(b)	5556(a)					
6006, 6061 6063, 6101 6151, 6201 6351, 6951				4043(b)						
520	5356(a)		4043(a)							
A356		4043								
356		4043	4043							

(a) 5183, 5356, 5554 and 5556 may be used.
In some cases they provide improved colour match after anodizing, higher weld strength, and highest weld ductility. 5554 is suitable for high-temperature service.

(b) 5183, 5356 or 5556 may be used.
In some cases they provide better colour match after anodizing, higher weld strength and highest weld ductility.

General Notes:

Choice of filler alloys may be limited by service conditions such as immersion in fresh or salt water, exposure to certain chemicals, or sustained high temperatures over 65°C (150°F). Filler alloys 5356, 5654, 5183 and 5556 are not recommended for sustained high-temperature service.

CHAPTER 7 QUALIFICATIONS OF CONTRACTORS FOR FUSION WELDING

7.1 GENERAL

This chapter states the qualification requirements of Contractors for welding aluminum and aluminum alloys.

This chapter requires all contractors to be currently certified by CWB in accordance with CSA Standard W47.2 "Certification of Companies for Fusion Welding of Aluminum and Aluminum Alloys".

All Contractors shall submit to the Technical Authority their confidential file of welding and inspection personnel, their qualifications and supporting certificates issued by CWB prior to commencing welding work.

7.2 CERTIFICATION REQUIREMENTS

All primary Contractors shall be currently certified by CWB in accordance with CSA Standard W47.2, Division 1, 2.1 or 2.2.

All personnel performing work shall be approved by CWB. Typical personnel shall include:

- Welding Engineers (Staff or Retained);
- Welding Supervisors;
- Welders;
- Welding Operators;
- Tack Welders.

All Sub-contractors shall be currently certified by CWB in accordance with CSA Standard W47.2, Division 1, 2.1, 2.2 or 3. When the Sub-contractor is certified as a Division 3 Company, 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 WITNESSING TESTS

All welder or welding operator tests shall be 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 and welding operators 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 W47.2.

7.5 QUALIFICATION OF WELDERS AND WELDING OPERATORS FOR THIN MATERIALS

In addition to the tests required in CSA Standard W47.2, for materials 4 mm or less in thickness, 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 as per CSA W47.2.

A stop/start shall be made in the first pass of the weld. A total of two (2) root and two (2) face bends shall be taken as per CSA W47.2 except that one root bend shall be through the stop/start position. Two (2) macro-etch specimens shall be taken as per CSA W47.2. The acceptance criteria of CSA W47.2 shall apply except that the maximum flaw size after bending shall be 2 mm.

Fracture tests for materials of this thickness are not required.

For **fillet welds** the test shall be made using the test plate length and stop/start as per CSA W47.2, except that the fillet leg length and material thickness shall be the same as the part to be repaired or piece to be produced. A total of three (3) macro sections shall be taken, two (2) as per CSA W47.2 and the third macro shall be taken through the stop/start. The acceptance criteria of W47.2 shall apply.

Fracture tests for materials of this thickness are not required.

7.6 QUALIFICATION OF WELDERS AND WELDING OPERATORS FOR TEMPORARY NONMETALLIC BACKING MATERIALS

Welders and welding operators intended to weld joints containing temporary nonmetallic backing materials shall be qualified in accordance with CSA Standard W47.2 - Latest Edition, to Performance Level III requirements for the electrode/base metal grouping and positions of welding intended to be used for production with such materials.

Welders and welding operators currently qualified to Performance Level II requirements, may re-test to Level III or be subjected to separate qualification tests per CSA Standard W47.2.

CHAPTER 8 QUALIFICATION OF WELD PROCEDURES

8.1 GENERAL

This chapter states the qualification requirements of weld procedures used for welding aluminum and aluminum alloys.

This section requires all Contractors to document the appropriate information on Weld Procedure Data Sheets in accordance with CSA Standard W47.2 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.

In joining aluminum, torch manipulation techniques such as weaving and whipping are not permitted. Stringer beads is the only accepted practice unless otherwise proven by weld procedure qualification tests.

8.3 WITNESSING TESTS

All welding procedure tests shall be witnessed by CWB. The Technical, Inspection or Regulatory Authorities may choose to witness tests administered by CWB.

8.4 PROCEDURE QUALIFICATION OF THIN MATERIALS

For the qualification of materials less than 4 mm in thickness, the Contractor shall agree to perform the tests utilizing the joint geometry and the parameters to be used in construction.

For **groove** welds, apart from thickness, the test plate dimensions shall be as per CSA W47.2. No fracture test is required, but all other tests shall be as required in CSA W47.2.

For **fillet** welds, the test piece dimensions, apart from thickness, shall be as per CSA W47.2. No break test is required, but there shall be three (3) macro-sections taken, two (2) as per W47.2 and the third from the center of the test weld.

For both groove and fillets, the acceptable criteria of W47.2 shall apply except that in the bend tests the maximum flaw dimension shall be 2 mm.

8.5 PROCEDURE QUALIFICATION FOR TEMPORARY NONMETALLIC BACKING MATERIALS

Separate qualification tests are required for joints welded using temporary nonmetallic backing materials as specified herein. For the purposes of this standard, only ceramic type may be used.

For joints welded using ceramic type backing materials, weld procedure qualification testing to the requirements of CSA Standard W47.2 - Latest Edition, is required. All procedure testing must be witnessed by CWB. Weld procedure data sheets and weld procedure qualification test records having CWB's stamp of compliance 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 Section 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 W47.2 and this Standard is required. Each data sheet shall indicate workmanship tolerances for preparation, alignment and fit-up.

CHAPTER 9 WORKMANSHIP

9.1 GENERAL

Generally, the size and length of welds (weld design) shall be in accordance with the vessel specification and/or supplied schedule as approved by the applicable Classification Society and Ship Inspection Directorate, Transport Canada. However, upon occasion aluminum structures are of a physical size and weight that does not warrant Classification Society and/or Ship Inspection Directorate approval. In such cases, the minimum weld design requirements shall be in accordance with ABS Rules for Building and Classing Aluminum Vessels, as approved by the Technical Authority.

9.2 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 work surfaces are damp and when the ambient temperature is below 0°C except when approved by the Technical Authority. The ambient temperature will be considered the temperature surrounding the work being welded. The minimum temperature of the material being welded will be as on the approved weld procedure data sheet, additional thermal requirements being defined in Section 9.9.

When gas metal arc, gas tungsten arc and plasma arc welding are used with externally supplied shielding gas, the arc zone will be adequately protected against the direct effects of winds and drafts in such a manner as to ensure the loss of shielding gas does not occur.

9.3 PREPARATION OF MATERIALS

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.

Surfaces to be welded shall be free of deleterious materials that may adversely affect the weld quality.

Typical deleterious materials would include:

- paint;
- oil;
- grease;
- moisture;
- extraneous aluminum oxide;
- cutting fluids;

- anti-spatter compounds;
- water stain;
- general grit and dust;
- any other material that can cause porosity.

The minimum surface area to be cleaned prior to welding shall be 50 mm from the anticipated location of each weld toe. Care shall be taken in selecting correct cleaning methods and techniques (see Appendix "E" of CSA W47.2).

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 greater than 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. In cut edges, occasional notches or gouges > 3 mm deep may be repaired by Gas Tungsten Arc Welding with the approval of the Inspection Authority.

All repair welds shall be examined and accepted prior to fit up.

Prior to fabrication plate edges and weld preparation, surfaces shall be visually examined for the presence of discontinuities lying parallel to the plate surface.

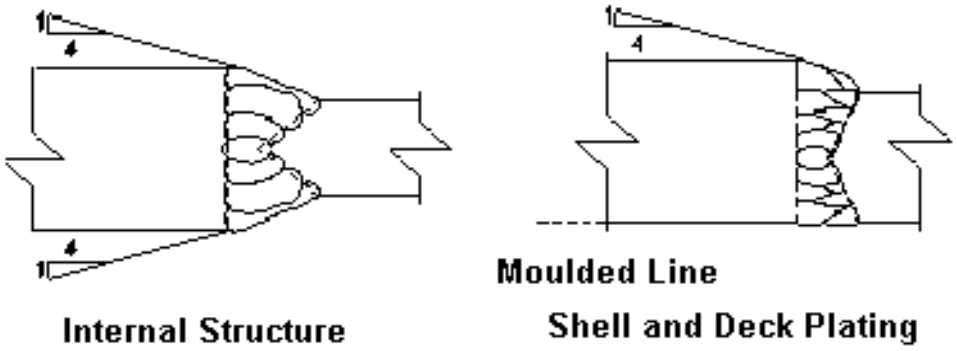
When plate laminations are discovered during inspection, the plate in question shall be examined by ultrasonic methods to the extent required by the Inspection Authority. Repair of laminated plate shall require approval.

The contractor will use accepted cutting practices for aluminum and aluminum alloys using all the precautions required to ensure cleanliness as given in this Standard (see Appendix "E" of CSA W47.2).

9.4 DISSIMILAR PLATE THICKNESS

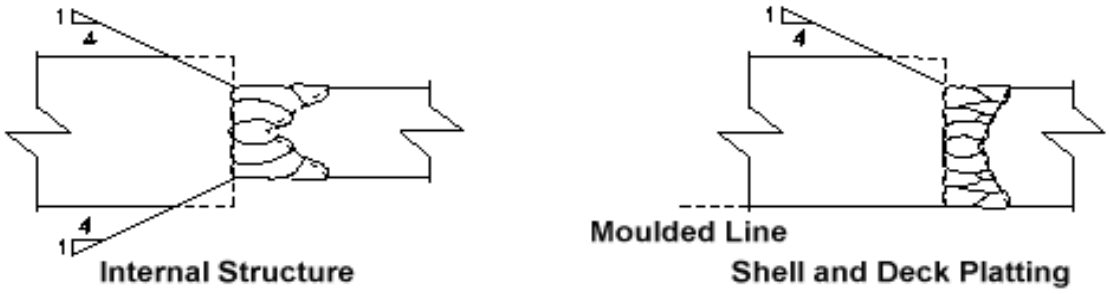
When groove welds are used to join plating of different thicknesses and the difference in thickness is less than or equal to 3 mm, then the weld may be built-up to the thickness of the plate as illustrated in Figure 9-1.

Figure 9-1 Transition by Sloping Weld



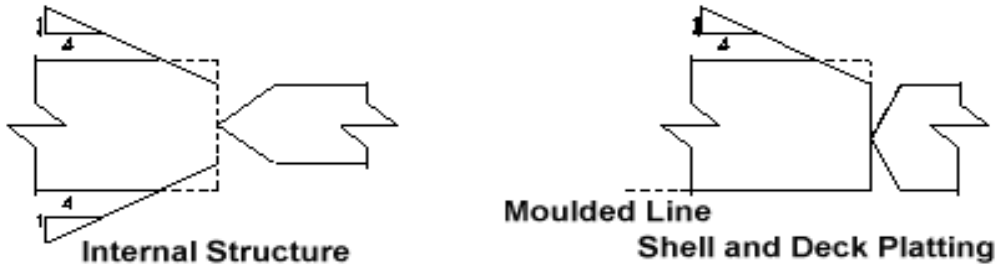
When the difference in thickness exceeds 3 mm, then the transition may be achieved by chamfering or a combination of chamfering and welding as illustrated in Figures 9-2 (a) and 9-2 (b).

Figure 9-2 (a) Chamfering



Transition by Sloping Weld Surface and Chamfering After Welding

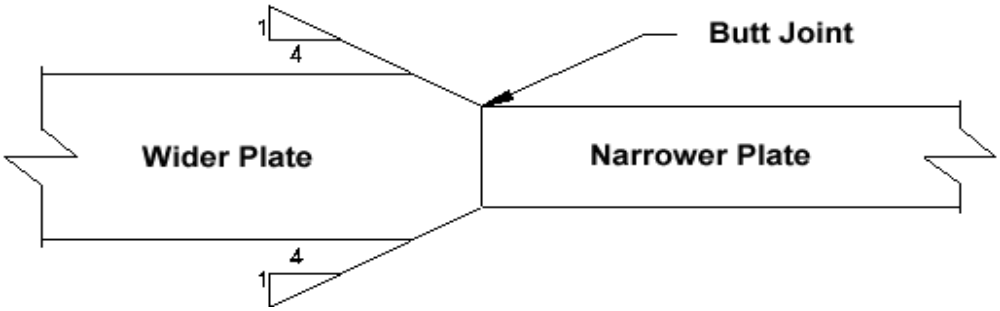
Figure 9-2 (b) Chamfering



Transition by Chamfering Thicker Part Prior to Welding

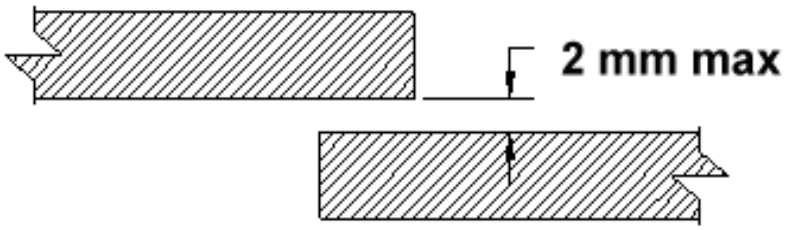
For differences in plate width, the wider member will have a transition as illustrated in Figure 9-3 unless otherwise detailed on an approved drawing.

Figure 9-3 Width Transition



9.5 WORKMANSHIP TOLERANCES

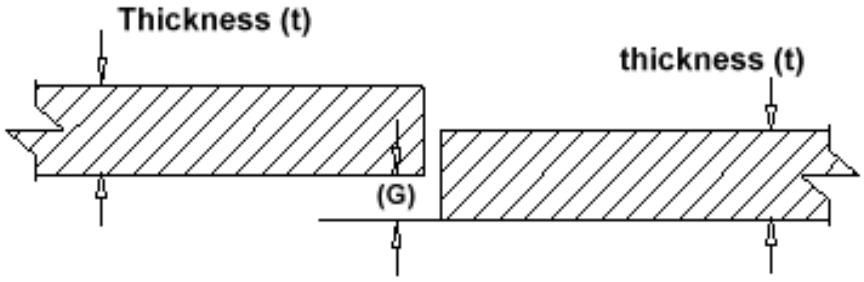
Figure 9-4 Lapping Structure



Alignment of lapping structure shall not exceed the limitations illustrated in Figure 9-4.

NOTE: *Fillet weld leg length shall be increased equal to the gap.*

Figure 9-5 Plating Alignment



Alignment of plates to be groove welded shall not exceed the limitations illustrated in Figure 9-5.

(g) = 0.10 (t^1) 3 mm maximum
Where t^1 is the thinnest member.

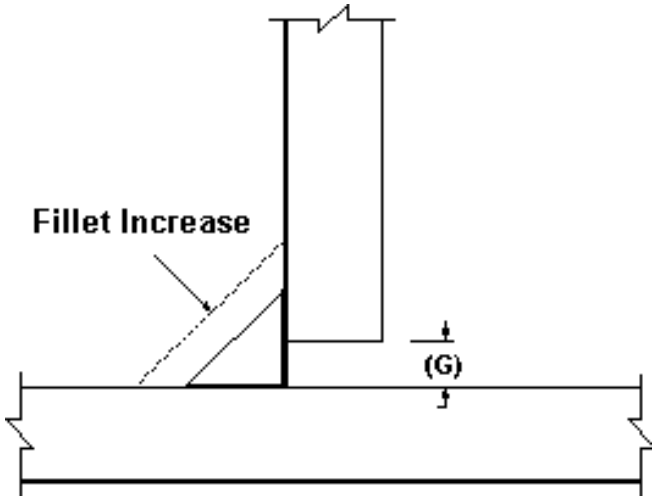
Edge preparations for groove welds shall require joint geometry dimensions as shown on the approved weld procedure data sheet. Variations in preparation, fit up and assembly, from the approved dimensions shall be limited as illustrated in Table 9-1.

Table 9-1 Groove Weld Tolerances

Included Angle	+	10°
Root Face	+	1.5 mm
	-	1.5 mm
Root Opening With Backing Bar	+	4 mm
	-	1.5 mm
Root Opening Without Backing Bar	+	1.5 mm
	-	1.5 mm

Parts to be joined 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.

Figure 9-6 Fillet Welds



(G) = 3 mm maximum

9.6 ACCESS AND POSITIONING

The contractor should use fabrication methods that allow welds to be performed in the flat position as much as possible. Methods including sub-assemblies and positioning shall be used when and wherever practicable.

When designing weld joints or establishing erection plans, accessibility for the welder should be considered. Special consideration and planning should be given to joints requiring full penetration

welds. Schedules should be such that welding, inspection and possible corrections are performed in an accessible condition.

9.7 DISTORTION AND RESIDUAL STRESS

Welding of all structures, sub-assemblies and parts shall progress following a systematic plan that reduces distortion and residual stresses. Prior to fabrication or repair, a welding sequence shall be developed by the contractor and submitted to the Technical Authority for approval.

Planning the optimum welding sequence to minimize distortion and meet specified tolerances varies with the method of construction, the assembly to be welded, the thickness of the materials and jigs or fixtures used.

The thermal expansion coefficient of aluminum is about twice that of steel. The total amount of thermal expansion varies inversely with the speed of welding. As a result, fixtures should be designed so that plate alignment will accommodate twice the dimensional change normally expected for welding a similar steel component.

Unlike steel, restrictions apply to correcting distortions in aluminum caused by welding. In addition, as-deposited weld metal elongation properties are 5 - 7% on average rendering weld deposits prone to cracking under restraint.

For unit construction methods, a sequence for welding individual units shall be produced in addition to an erection sequence for joining units together at the berth. For frame and plate construction methods however, a welding sequence shall be developed for the following:

- Panels such as deck, bulkhead, wheelhouse sides and top plating and stiffeners.
- Butts and seams of the shell plating.
- Frames and bulkheads to shell plating.
- Tank top plating to double bottom framing.
- Insert and doubler plates forming part of the primary hull girder.
- "A" frames and stern tubes and similar critical components.

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.

Fillet weld size and groove weld cross-sections must be kept to a minimum. Excessive joint preparations and over-welding is not permitted. Joints anticipated to cause significant shrinkage should be welded first.

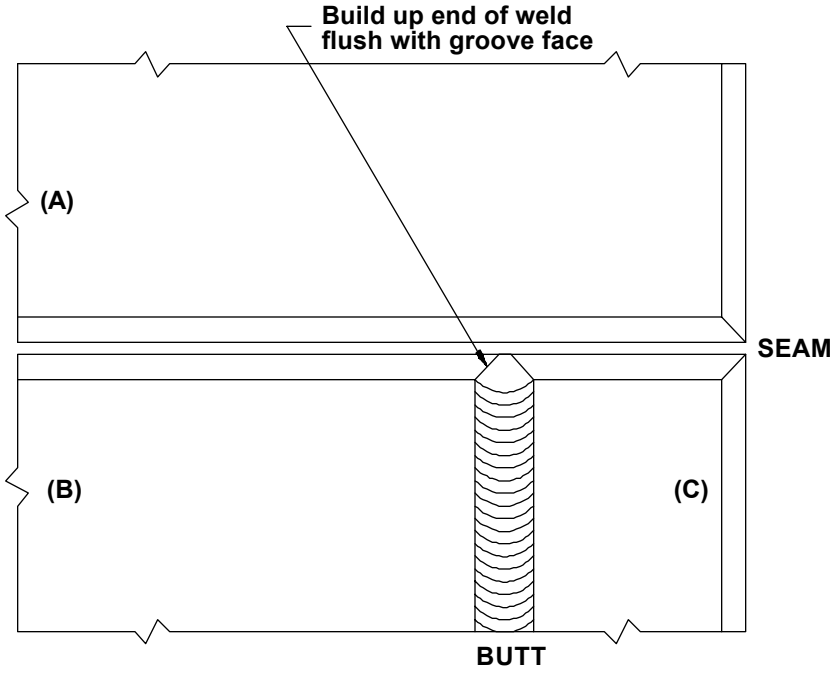
When welding joints that are restrained and/or where significant shrinkage is anticipated, welding shall be carried out continuously or to a point that will ensure freedom from cracking. For thick

sections, root passes shall have adequate effective throat dimensions to withstand shrinkage stress. Back step, block or cascade welding techniques should be used wherever practicable (see Appendix "B").

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 9-7.

Figure 9-7 Weld Butt Before Seam



For four way intersections of butts and seams, the seam can be welded up to a distance of 300 mm from the unwelded butts. Once the butts have been fully welded, then the seam can be welded as illustrated in Figure 9-8.

Welding of panels constructed of multiple plates shall progress from the center toward the outer edges. Starting at the center of a seam and welding outward with a backstep technique is desired. Stiffeners fillet welded to plating shall remain unwelded a minimum distance of 300 mm at edges of plating.

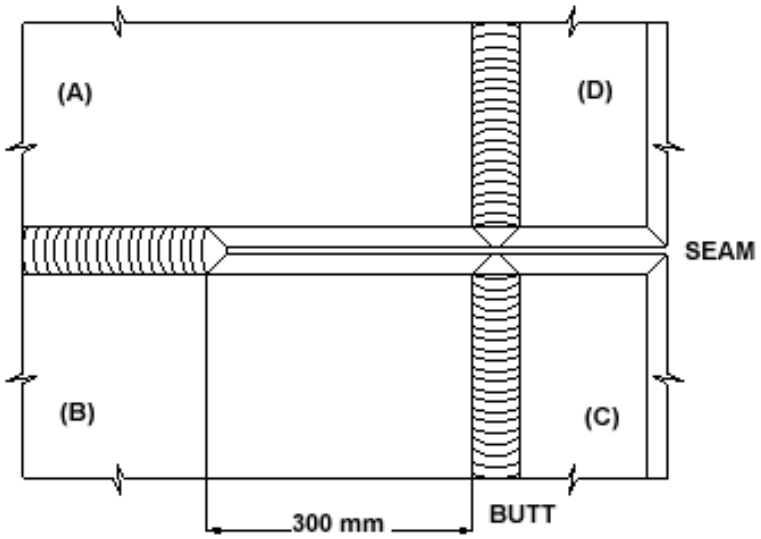
Generally frames, stiffeners or intercostals shall be welded to each other before they are welded to the plating. When joining sub-assemblies to each other, joints connecting plating should be welded prior to welding the butt joints of the sub-assembly framing.

Figure 9-8 Release Distance for Seams

Welding of shell butts and seams should occur prior to fillet welding frames and bulkheads to shell plating. If frames or bulkheads are fillet or tack welded, the member traversing shell butts or seams shall remain unwelded for a minimum distance of 300 mm each side of the joint to be groove welded. Welding shall start in the center of the ship and should progress outward, forward and aft, welding butts and then seams. Seams must remain unwelded a minimum distance of 300 mm each side of unwelded butts.

9.8 REPAIR OF DISTORTION

When distortion of plating is identified as being unacceptable in accordance with the design requirements, straightening will be required as requested by the Inspection Authority and subject to the approval of the Technical Authority.



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.

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 both Appendix "D" of this Standard and AWS D1.2, Section 3.7 and the following:

The part to be heated for straightening shall be substantially free of stress and from external forces.

Maximum holding times for the forming and straightening of aluminum alloys are listed in AWS D1.2 and Appendix "D" of this Standard.

For 5XXX series alloys with magnesium contents greater than 3%, holding with the temperature range from 65 - 230°C must be avoided in order to minimize the possibility of

sensitization to exfoliation and stress corrosion cracking. The length of time at temperature is a critical factor in determining the degree of sensitization. Hot forming techniques must include quick heat up to avoid a loss of mechanical properties. Forming must be completed before the metal cools below 230°C. The metal should then be fan cooled, to drop the metal temperature from 230 to 65°C in the minimum time possible to prevent sensitization.

For 6XXX alloys, distortion removal shall be done at a temperature below 230°C. The time that the structure is held at temperature while removing the weld distortion shall not exceed those times given in AWS D1.2, Section 3.7 or Appendix "D" of this Standard.

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

9.9 THERMAL REQUIREMENTS FOR WELDING

When welding thick aluminum sections, preheating is sometimes used to avoid cold-start defects, to achieve heat balance with dissimilar thickness, or to remove moisture. Care shall be taken to ensure temperature control, particularly when fabricating the heat treatable alloys and the 5XXX series alloys that contain more than 3% magnesium (see Section 9.8). Preheating temperatures for these types of alloys shall not exceed 65°C.

When fabricating heat treatable alloys and 5XXX series alloys containing more than 3% magnesium, interpass temperatures shall fall below 65°C before starting the next pass.

The contractor shall provide adequate methods of measuring temperatures. The base material shall be preheated in such a manner that the surfaces of the parts where weld metal is being deposited are at the specified minimum temperature for a distance equal to the thickness of the material being welded but not less than 75 mm both laterally and in advance of the welding arc.

9.10 INTERPASS PROFILES

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 to remove all deleterious materials prior to depositing the next weld bead.

Weld procedures that utilize removal to sound metal prior to back welding techniques shall use methods to ensure that the second side groove contours are acceptable for welding.

Extreme caution shall be exercised in selecting the proper preparation method for ‘remove to sound metal’ operations. Welders and/or fitters shall be trained and well versed in the use of such methods prior to performing work.

If any preparation method other than bull nosed chipping tools are used, ‘remove to sound metal’ preparation depth shall be controlled by the use of a depth gauge. The minimum and maximum preparation depth shall be determined by weld procedure qualification and proven effective by in-process production monitoring.

Thermal preparation methods, such as plasma arc gouging, are permitted with the approval of the Technical Authority. Operators of plasma arc gouging equipment must be welders qualified to Performance Level II or III of CSA Standard W47.2 having had specific training in the proper use of such equipment. Prior to performing work, each operator must demonstrate proficiency to the extent required by the Inspection Authority.

9.11 BACKING MATERIALS

When utilizing permanent backing bars for groove welds and tee joints the backing bars shall be of aluminum of the same group number as the base material being welded.

Backing bars shall be continuous for the entire length of the joint. Where backing bars are composed of individual lengths, they shall be properly aligned. Individual bars shall be of the same width and thickness. Abutting ends of backing bars shall be prepared for welding, in order that full penetration is achieved. Groove welds attaching abutting backing bars shall be welded, inspected and accepted prior to initiating the welding of the primary joint it is attached to.

The separation between faying surfaces of butt/tee joints utilizing backing bars shall be 1.5 mm maximum. Where and whenever practicable it shall be a tight contacting fit. The use of any type of filler or spacer bar is prohibited unless the weld procedure is approved by the Technical Authority.

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 temporary metallic backing bars shall be detailed within the weld procedure data sheets. When metallic backing bars are used they shall be clean and free of oxides, moisture and any other deleterious materials that directly affect weld quality. Temporary backing bars are to be fitted to ensure that arcing does not occur between the faying surfaces. All arc spots shall be repaired by grinding and Gas Tungsten Arc Welding. Methods used for the removal of temporary backing bars shall be detailed within the approved weld procedure data sheet.

Temporary metallic backing may be of austenitic stainless steel or aluminum of the same group number. Other materials may not be used. Nonmetallic, nonfused backing materials such as ceramic tiles, etc., will require weld procedure qualification to the requirements of Chapter 8 of this Standard. In addition, welders and welding operators must be currently qualified to the requirements of Chapter 7 of this Standard.

Full penetration groove welds made from one side with nonmetallic backing materials shall have the melt-through weld reinforcement dressed smooth for the entire joint's length. Independent of the nondestructive inspection requirements of Appendix "E" of this Standard, the melt-through side of the joint shall be subjected to visual and liquid penetrant inspection for 100% of its length.

9.12 TEMPORARY AND TACK WELDS

Tack welds that are incorporated into the completed weldment shall meet the acceptance requirements of Chapter 10 and the filler material requirements of Chapter 6 of the Standard. Base metals should be cleaned thoroughly before tack welding.

Tack welds shall be of a size as to ensure that the finished weld profile, over the tack weld, meets the weld profile requirements within Chapter 10 of the Standard. Multipass tack welds shall be performed utilizing a "Cascade End Technique" (see Appendix "B").

Tack welds that are not incorporated into the completed weldment shall meet the requirements of Chapter 6 (Consumables). Methods utilized for removal of tack welds shall ensure that no adverse effects to the base material or completed weld occur.

Temporary welds shall be performed utilizing approved weld procedures. Temporary weldments shall not be located on a welded butt or seam.

Removal of temporary welds shall ensure that excessive reinforcement or insufficient material does not occur. Mechanical force such as hammering shall not be used to remove temporary welded attachments. Corrective measures taken shall utilize only approved procedures performed by Gas Tungsten Arc Welding. Completed corrections shall be subject to inspection and to the acceptance criteria requirements within Chapter 10 of this Standard.

The contractor shall submit a detailed "platework finishing standard" that outlines the removal procedures and detailed finish at various locations within the ship structure for approval by the Technical Authority.

9.13 RUN ON / RUN OFF AND STARTING TABS

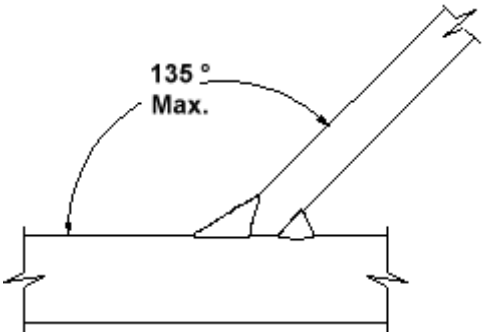
Materials used for run on / run off tabs, starting tabs or extension bars are to be of the same alloy group as the base material being welded. Dimensions and thickness of tabs are to be such as to ensure sufficient arc stability prior to the arc entering the material being welded. Removal of tabs, extension bars and starting lugs shall be in an acceptable manner to ensure a smooth surface at ends of groove welds. Nicks, gouges and discontinuities shall be blended to sound metal. If weld repair is required it shall be by using the Gas Tungsten Arc Welding method.

9.14 WELD SIZE AND 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.

Fillet welds may be used in skewed "TEE" joints having a dihedral angle of not more than 135°.

Figure 9-9 Skewed Tee Joint



The required leg size, S, of a fillet weld to give an effective throat, E, shall be given by:

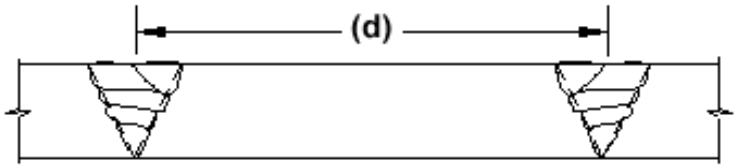
S =2E sin (Ø/2) – G Where G = gap, mm Ø = angle between fusion faces

The gap, G, shall not exceed 3 mm.

9.15 ADJACENT WELD SPACING

The dimension between adjacent groove welds that do not appear on approved drawings shall be limited as illustrated in Figure 9-10.

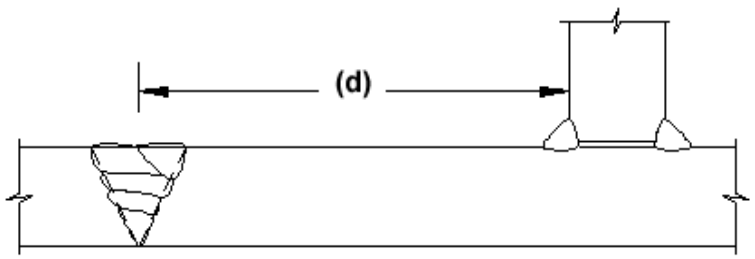
Figure 9-10 Adjacent Groove Welds



d) = 300 mm minimum

NOTE: *Not applicable for shell plating. See Section 9.16.*

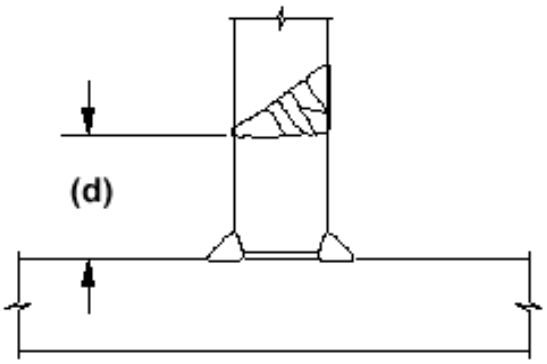
Figure 9-11 Adjacent Fillet/Groove Weld Table Member



The dimension between a groove weld in a table member and to a fillet weld that does not appear on approved drawings shall be limited as illustrated in Figure 9-11.

The minimum dimension between a fillet weld to a groove weld in an abutting member that does not appear on approved drawings shall be limited as illustrated in Figure 9-12.

Figure 9-12 Adjacent Fillet/Groove Weld Abutting Member



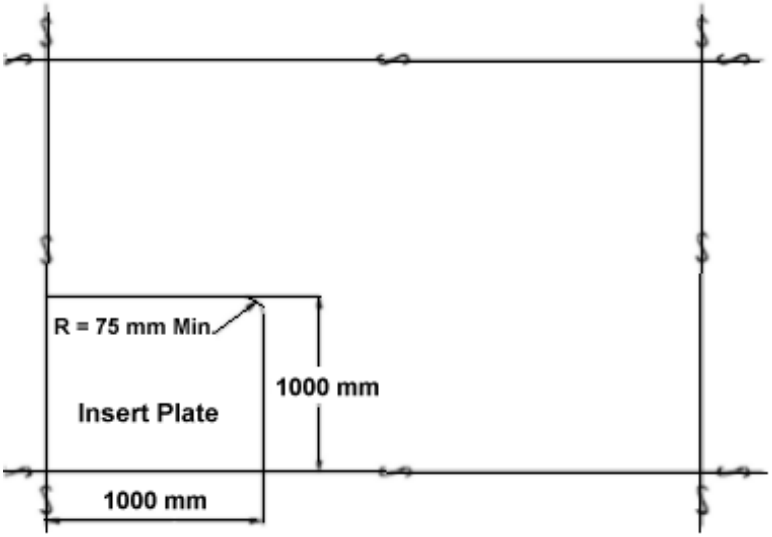
(d) = 300 mm minimum

9.16 INSERTS AND DOUBLERS

Where a local increase in plate thickness is required, insert plates shall be used instead of doubler plates.

When an insert is to be located within the shell envelope the minimum dimension shall be in accordance with Figure 9-13 herein.

Figure 9-13 Minimum Dimensions for Inserts Located in Shell Plating



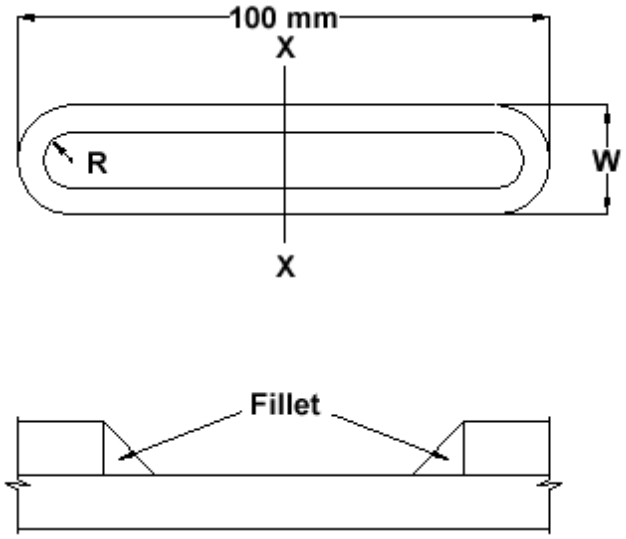
The minimum corner radius used for all insert locations shall be 8(t) 75 mm minimum. Welding sequences shall be carefully developed in order that shrinkage stress is balanced and restraint cracking does not occur (see Section 9.7). Whenever practicable, back step or block welding techniques will be used.

9.17 SLOT AND PLUG WELDS

For the connection of plating to internal webs, etc., where access is not practicable, plug welds shall not be allowed.

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:

Figure 9-14 Slot Welds



length	100 mm (minimum)
width	2.5 (t) (t) = slotted plate thickness
slot spacing	150 mm (maximum)

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

All slot welding procedures shall be submitted to the Technical Authority for approval.

9.18 SNIPES AND SCALLOPS

Where snipes and scallops are permitted in the design requirements and are intended to provide access for welding, the dimensions shall be adequate to allow for proper electrode angles. Wherever possible, snipes and scallops of 38 mm radius or larger should be used, depending upon the depth of the member, as specified below:

Depth of Member	Radius
Less than 150 mm	38 mm
150 mm to 230 mm	50 mm
> 230 mm	75 mm

Members having scallops for welding access may require fitting and welding of compensation pieces to the extent required by the Technical Authority.

9.19 STRAY ARC STRIKES

Arc strikes outside the area of welds should be avoided. Arc strikes shall be ground to a smooth contour, checked for soundness, and repair welded if necessary by the Gas Tungsten Arc Welding method.

When they occur in a location deemed critical by the Inspection Authority, the surface shall be lightly ground and inspected with the appropriate nondestructive inspection methods. If found defective, they shall be repaired to the satisfaction of the Inspection Authority.

9.20 REJECTED WELD OR PART

When an entire weld, base material, entire part or entire section contains unacceptable discontinuities as specified in Chapter 10 of this Standard, no corrective action shall be taken prior to approval of the repair procedure by the Inspection and Technical Authorities.

When a portion of a weld contains unacceptable discontinuities as specified in Chapter 10, corrective action may be taken providing the Inspection Authority has reviewed the extent of unacceptable discontinuities and agrees to the proposed repair procedures.

When the weld has been rejected in accordance with the applicable acceptance criteria specified within Chapter 10 of the Standard, the unacceptable defects shall be corrected as follows:

- Cracks found within the base material, or weld metal zone shall be removed and repaired.
- Unacceptable porosity, metallic inclusions, incomplete penetration and non-fusion shall be removed and repaired.
- 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 require additional welding. Extreme care shall be taken not to deposit unacceptable excessive weld reinforcement.

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 to the satisfaction of the Inspection and Technical Authorities.

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 Inspection and the Technical Authorities.

CHAPTER 10 NONDESTRUCTIVE INSPECTION OF WELDS

10.1 GENERAL

This Chapter states the requirements for nondestructive inspection of welds.

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 Appendix "E" 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 Repair Specification and Appendix "E" shall not apply.

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

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

The method of inspection to be used and the locations to be inspected shall be selected by the Technical and Inspection Authorities.

10.2 SELECTION OF NONDESTRUCTIVE INSPECTION METHODS

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

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

Each nondestructive inspection method is limited due to the orientation and nature of typical discontinuities within the weld.

Typical limitations are as follows:

Visual Inspection: Coarse surface discontinuities or weld profiles.

Liquid Dye 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 if porosity does not interfere with effective sound propagation.

All welds shall be subjected to visual inspection prior to inspection by other nondestructive inspection methods.

Full penetration welds shall be subjected to selective sampling. Radiographic Inspection shall be used for groove welds in butt joints. Ultrasonic Inspection shall be used for full penetrating 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 subjected to selective sampling. Liquid Penetrant Inspection shall be used.

10.3 NONDESTRUCTIVE INSPECTION PROCEDURES

When visual inspection is used, the methods set forth in ASME Code Section V shall be implemented. The weld acceptance criteria shall be in accordance with Section 10.10 herein.

When Liquid Dye Penetrant Inspection is used, the methods set forth in ASTM Standard E165 shall be implemented. The weld acceptance criteria shall be in accordance with Section 10.11 herein.

When Radiographic Inspection is used, the methods set forth in ASTM Standard E142 shall be implemented. The weld acceptance criteria shall be in accordance with Section 10.12 herein.

When Ultrasonic Inspection is used, the methods set forth in ASTM Standard E164 shall be implemented. The weld acceptance criteria shall be in accordance with Section 10.14 herein.

When nondestructive inspection is used, all reports shall display a reference to the inspection procedure or techniques used. Inspection procedures and techniques shall be submitted for approval in a manual form prior to commencing fabrication.

In circumstances when the time period for approval is inadequate, the following shall apply:

- When inspection procedures and techniques have not been submitted in manual form and inspection has occurred, the procedure and technique used for the inspection shall be attached to the interpretation report. If the attached procedure is considered unacceptable, the inspection shall be re-taken 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 testing.

10.4 LOCATIONS SUBJECTED TO INSPECTION

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

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.
Others:	Deck plating; Tank top plating; Inserts and closure plates; Cruciform welds; Terminal welds.

The length of locations to be inspected for each nondestructive inspection method used shall be as specified herein:

Visual Inspection:	Entire weld length;
Liquid Penetrant Inspection:	1000 mm;
Radiographic Inspection Intersections:	300 x 300 mm;
Other:	440 mm;
Ultrasonic Inspection:	1000 mm.

NOTE: *With intersections, if the size of radiographic film available is insufficient in dimension, then two films should be used to cover the desired area and taken in one exposure. If two films are used in lieu of one film of adequate dimension, then this shall be considered as one inspection location.*

Repairs of a rejected location shall not occur prior to the Inspection Authority's review of the extent of the discontinuities being rejected.

Results of nondestructive inspection tests shall be returned to the Inspection Authority at the agreed upon time of receipt.

No radiograph or interpretation report regardless of the inspection method used shall be destroyed or discarded.

10.5 SURFACE PREPARATION PRIOR TO INSPECTION

For visual inspection, the surfaces of welds and the adjacent base material shall be cleaned adequately to allow accurate interpretation of the area of interest (weld zone).

For liquid penetrant inspection, the surfaces of welds and adjacent base material shall be free from oxide, paint, weld spatter and other foreign matter. Weld profiles and contours shall be sufficiently smooth to ensure that geometric conditions are not such that false indications appear.

For radiographic inspection, the surfaces of welds and adjacent base material shall be cleaned adequately to allow accurate interpretation of the area of interest (weld zone). Discontinuities appearing on the radiographic film that subsequently are determined to be surface discontinuities shall be repaired and the location shall be re-inspected by radiographic methods.

For ultrasonic inspection, the surfaces of welds and adjacent base material shall be free from oxide, paint, weld spatter and other foreign matter to enable accurate interpretation of the area of interest (weld zone). The surfaces upon which the probe makes contact shall be smooth to the extent that the finish roughness does not interfere with the sound beam velocity. Tests performed on rough surfaces shall take the beam velocity losses into consideration during the calibration procedure.

10.6 ADJACENT OVERLAPPING INSPECTION

When a 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 discontinuities originally revealed at the location end. The contractor shall be responsible for all associated costs of performing adjacent overlapping inspection.

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

All adjacent overlapping inspection shall be taken prior to repair of the originally rejected location.

10.7 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 at the contractor's expense. Care shall be taken to ensure 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 inspected at the Contractor’s expense.

All new locations shall be selected by the Technical and Inspection Authorities.

10.8 INTERPRETATION REPORTS

When a portion of a weld is to be inspected by liquid penetrant, 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 shall be required.

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

When 100% visual inspection is required and unit construction is used, the qualified inspector shall provide a Verification Report for each unit fabricated.

When 100% visual inspection is required and unit construction is 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 the qualified inspector (see Section 10.10) which verifies that welds have been inspected and that they conform to Section 10.10 within this Standard. The Verification Report shall be presented to the Inspection Authority prior to performing audit on the completed unit or compartment (e.g., scheduled Dry Survey).

10.9 INSPECTION PERSONNEL CERTIFICATES

When nondestructive inspection of welds occurs, a copy of the inspecting and interpreting individuals current-year qualification certificate, for the inspection method used, shall be attached to the initial interpretation report or verification report supplied to the Inspection Authority. If a new validation year is entered or if a different individual is used, the appropriate qualification certificate shall be supplied with the applicable interpretation report being submitted. Samples of the qualification certificates for each inspection method are illustrated within Appendix "C" of this Standard.

10.10 VISUAL INSPECTION

Individuals performing and interpreting visual inspection shall be 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 within at least one of the following categories:

- Ships and Marine Structures
- Buildings and Industrial Structures

Prior to commencing plate work, the contractor shall provide the Inspection Authority with an adequate supply of chalk, that is of a distinguishable colour and not used by the contractor's personnel, for marking work that should be put inhand as a result of the inspection activity.

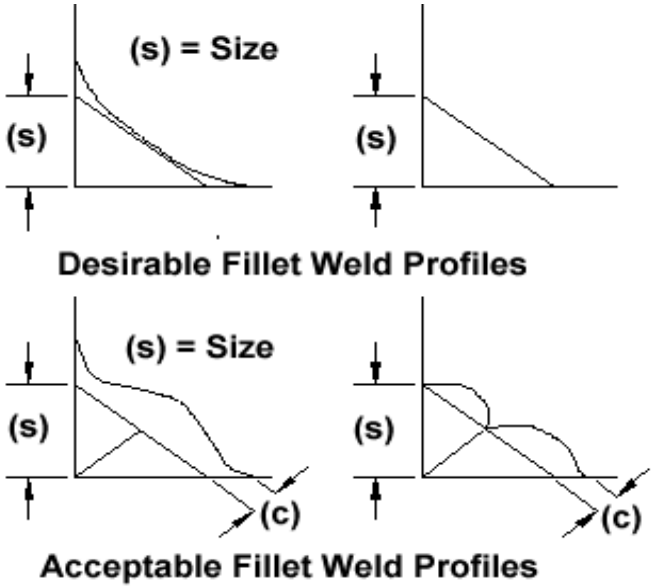
Prior to inspection, the welds shall be cleaned of all spatter, magnesium oxide products, paint and primer. Staging shall be provided to permit safe access for inspection.

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

- that weld profiles are in accordance with this section;
- that welds have been deposited to the layer/pass size and sequence requirements of approved weld procedure data sheets;
- that all welds located in primary and secondary structures have no visible porosity. If visible porosity is located it shall be examined by destructive (e.g., grinding) or nondestructive techniques, such techniques being suitable to the Inspection Authority;
- that there shall be no visible fusion type defect;
- that there shall be no visible overlap;
- that craters are filled to the full cross section (designed size) of a continuous weld;
- that there shall be no visible cracks.

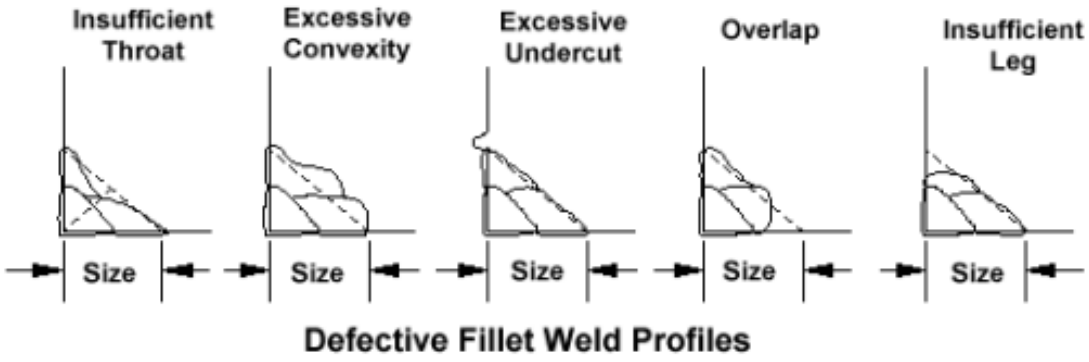
The faces of fillet welds may be slightly convex, flat or slightly concave. Acceptable profiles are specified in Figure 10-1. Unacceptable profiles are specified in Figure 10-2.

Figure 10-1 Desirable and Acceptable Fillet Weld Profiles



Convexity "C" shall not exceed: 0.1S + 1.5 mm

Figure 10-2 Defective Fillet Weld Profiles



Undercut shall not exceed 1 mm in depth for fillet welds.

The finishing passes of all butt and corner joints shall provide a reinforcement at the center of the weld not exceeding 3 mm. Acceptable profiles are shown in Figure 10-3 Unacceptable profiles are shown in Figure 10-4.

Figure 10-3 Acceptable Butt Weld Profile

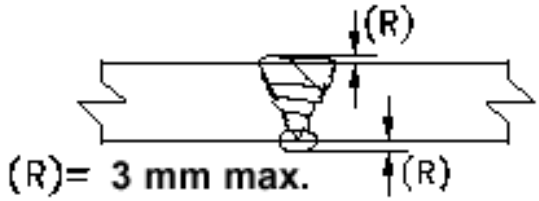
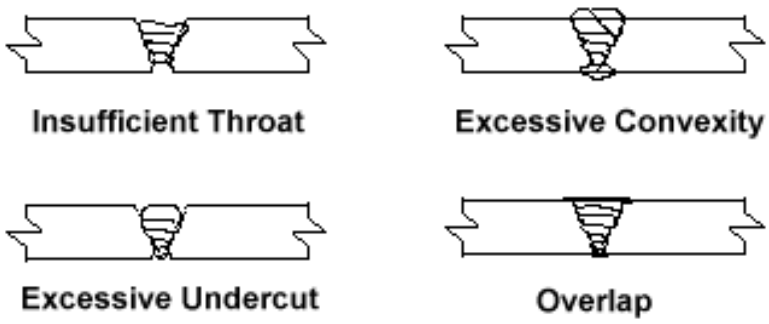


Figure 10-4 Defective Butt Weld Profiles



There shall be no objectionable valley or groove along the edge or the center of the weld. The deposited metal shall be smooth and uniform in cross section. The ends of butt joints shall be of sound metal finished smoothly and conforming to the cross section of the welded joint.

Surfaces of groove welds 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 specified in Table 10-2, unless otherwise specified in the Vessel Specification.

Table 10-1 Flush Tolerance

Maximum Reinforcement	Maximum Concavity
5% (t) Maximum 1 mm	5% (t) Maximum 0.5 mm

Table 10-2 Roughness

Maximum Roughness	Finish Parallel To Primary Stress	Finish In Any Direction
12 µm	6 µm 12 µm	6 µm

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 (stringer technique); and, that the weld toe blends smoothly into the base metal without undercut or overlap (e.g., Exterior Shell Welds).

Undercut shall not exceed 1.0 mm in depth for groove welds.

If visual inspection reveals melt-through, the affected weld metal shall be removed, re-welded and the repaired zone further examined by liquid penetrant inspection methods.

10.11 LIQUID PENETRANT INSPECTION

Individuals performing and interpreting liquid penetrant inspection shall be 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 within at least one of the following categories:

- Ships and Marine Structures
- Buildings and Industrial Structures

In addition to CSA Standard W178.2, the individual shall be currently qualified to CGSB Standard 48.9712 Level II or III.

A weld subject to liquid penetrant inspection shall be evaluated on the basis of the requirements for visual inspection (see Section 10.10).

10.12 RADIOGRAPHIC INSPECTION

Individuals performing radiographic inspection shall be currently qualified to CGSB Standard 48.9712 Level I, II or III. Individuals qualified to Level I must be supervised by a Level II or III.

Individuals interpreting radiographic films shall also be 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 within at least one of the following categories:

- Ships and Marine Structures
- Buildings and Industrial Structures

All radiographic inspections shall be taken with a double loaded film technique in order that two negatives are obtained. One film shall be sent to the Technical Authority, Ottawa, and the other film shall remain with the Inspection Authority until contract completion, at which time they shall be transmitted to the Technical Authority, Ottawa.

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

The area of interest (weld zone) being inspected shall not be inhibited for interpretation with interference from image quality indicators (IQI) and/or identification 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 IQIs.

The contractor shall provide a high intensity film viewer capable of penetrating film densities of 2.0 minimum to 3.5 maximum throughout the contract and warranty period.

Radiographs shall be made by X-ray. Maximum permissible kilovoltages shall be as shown in Table 10-3.

Table 10-3 Thickness vs Maximum Kilovoltage

Thickness	Max Kilovolts
Up to 6 mm	80
6 mm to 13 mm	80 to 120
13 mm to 19 mm	120 to 130
19 mm to 25 mm	130 to 150
Greater than 25 mm	**170 maximum**

Radiographic 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 received that display water stains, blotches, streaks, fingerprints, sharp lines, milky zones, brownish tones and fog shall not be accepted as providing adequate measurement of the weld if it interferes with the interpretation of the area of interest (weld zone). Films displaying the aforementioned conditions shall be re-taken at the request of the Inspection and Technical Authorities.

All radiographic film shall be CLASS I only.

The exposed radiograph shall show the outline of all of the image quality indicators, the outline of the shims, the image quality indicator identification number, the image of the essential hole, the radiograph identification number, the location number, the date it was taken, reference to the contract number or vessel identification and the radiographers initials.

For material thickness less than 5 mm the 2-1 (t) essential hole shall appear clearly on the radiograph. For material thickness 5 mm and over, the image of the 2-2 (t) essential hole shall appear clearly on the radiograph.

Table 10-4 IQI Essential Holes

Material Thickness Range	Image Quality Indicators Thickness		Essential Hole	
(inches)	(inches)	N°	2-1(t)	2-2(t)
Up to ¼	0.010	10	0.010	0.020
Over 1/4 to 3/8	0.012	12	0.012	0.024
3/8 to 5/8	0.015	15	0.015	0.030
5/8 to ¾	0.017	17	0.017	0.034
3/4 to 1	0.020	20	0.020	0.040
1 to 1 ¼	0.025	25	0.025	0.050
1 1/4 to 1 ½	0.030	30	0.030	0.060
1 1/2 to 2	0.035	35	0.035	0.070

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

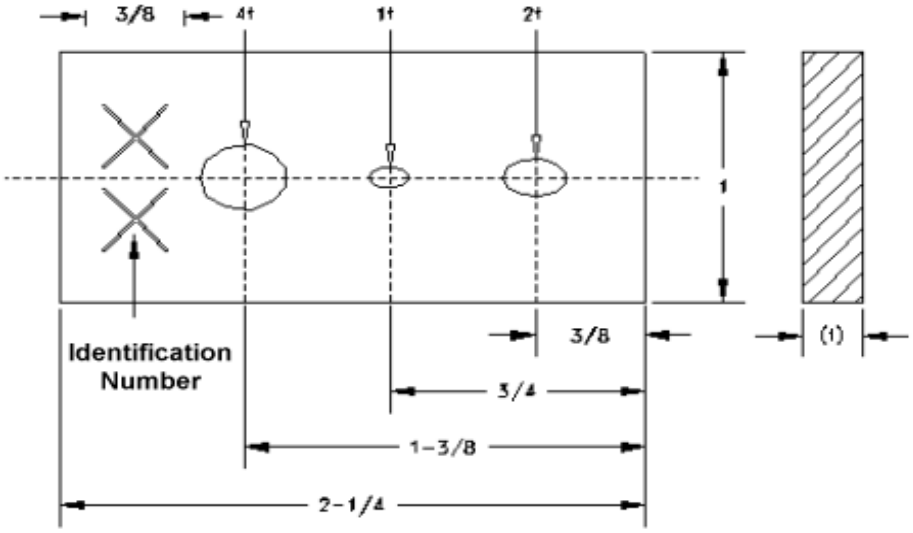
Image quality indicator design shall be in accordance with Figure 10-5.

Image quality indicators (IQI) shall meet the following requirements:

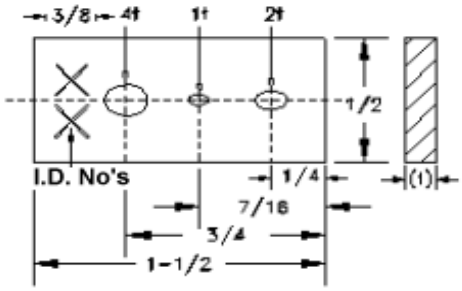
- IQIs and Shims shall be made of an aluminum alloy which has radiographically similar properties as the material being examined. All IQIs shall be certifiable as to ASTM 142 or ASME Section V, SE142. Wire type IQIs are not allowed.

- IQI thickness, identification and essential hole dimensions shall be in accordance with Table 10-4.

Figure 10-5 IQI Design



Essential Hole Diameters



IQI (t) ≤ 0.050 inches **IQI (t) ≥ 0.60 inches (t) ≤ 0.160 inches**

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

For materials of equal thicknesses, one (1) IQI shall appear at each film end as shown in Figure 10-6.

For materials of unequal thickness, three (3) IQIs shall be used as shown in Figure 10-7.

Figure 10-6 IQI Placement for Materials of Equal Thickness

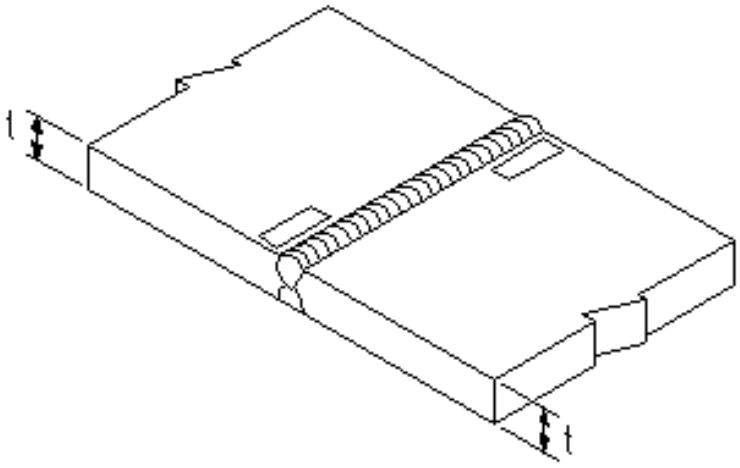
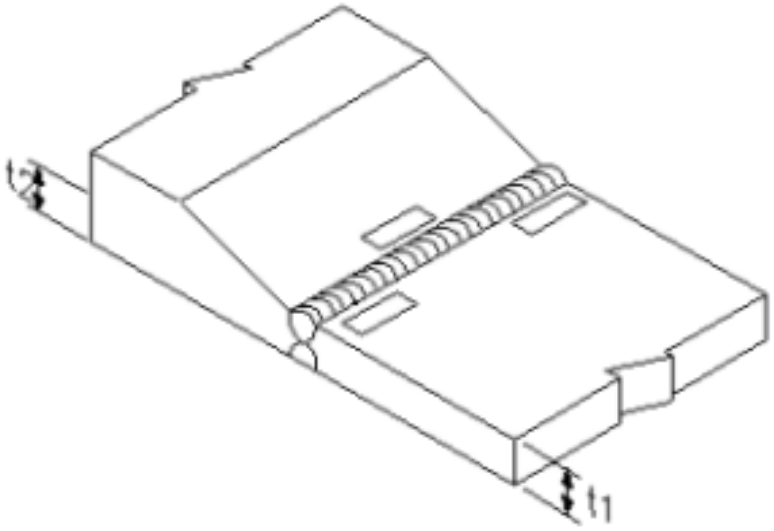


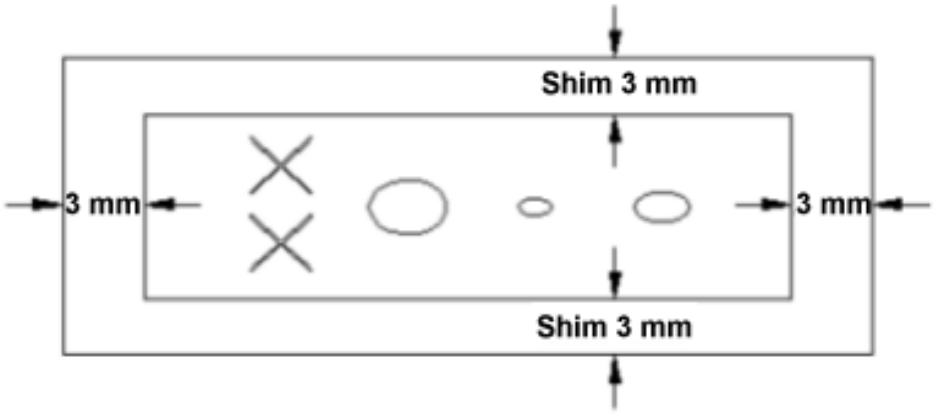
Figure 10-7 Placement for Materials of Unequal Thickness



IQIs shall be placed as close as possible to the weld toe without inhibiting the interpretation of the area of interest (weld zone). IQIs shall only be placed on the source side of the part to be examined.

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 10-8.

Figure 10-8 Shim Dimensions



NOTE: Shim overlap 1.5 to 3 mm all around IQI and the outline shall not interfere with the area of interest (weld zone).

Intensification screens shall not be used. If adequate contrast cannot be achieved with a single film when examining unequal thicknesses a dual exposure technique shall be used.

The radiographic technique used shall be of sufficient sensitivity to display the Image Quality Indicator'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 minus 15% or plus 30% from the density through the body of the Image Quality Indicator within the minimum/maximum allowable density ranges specified an additional IQI shall be used for each exceptional area or areas and the radiograph re-taken. The transmitted film density through the radiographic image of the body of the appropriate IQI and the area of interest (weld zone) shall be 2.0-3.5 for X-ray.

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

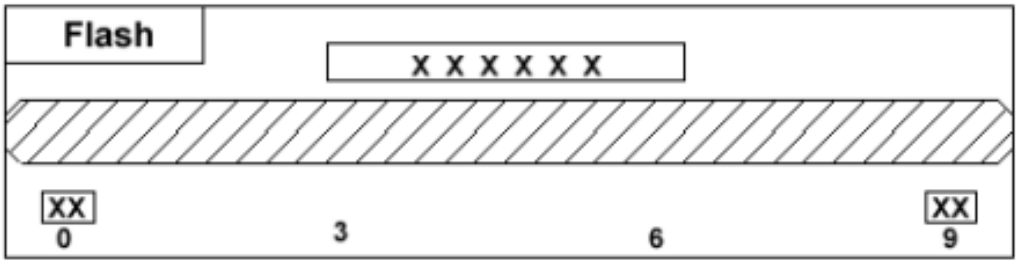
Geometric unsharpness of the radiograph shall not exceed the values specified in Table 10-5.

Table 10-5 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"

The permanent identification to appear on radiographic films shall utilize a system of flash and lead markers in accordance with Figure 10-9.

Figure 10-9 Film Identification



Flash Identification

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

Lead Markers

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

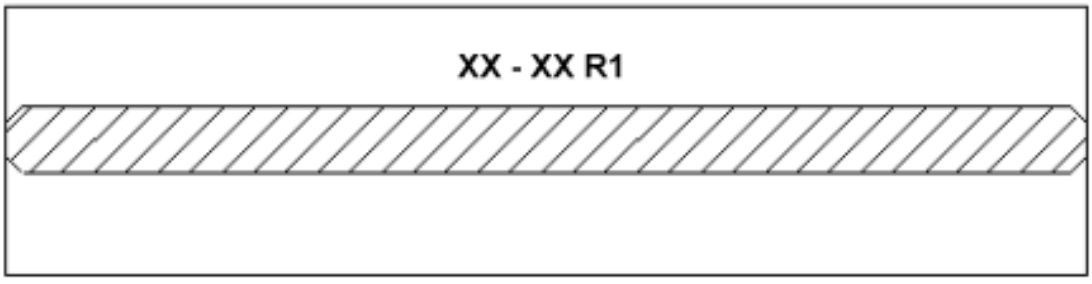
All lead marker identification shall be placed on the part being examined.

A system of weld identification shall be developed, submitted and approved by the Technical Authority prior to the first radiograph being taken.

Films not displaying the correct identification shall be re-taken at the request of the Inspection and Technical Authorities.

The letter "R" and the appropriate number shall appear when it is a radiograph of a weld which has subsequently been repaired as shown in Figure 10-10.

Figure 10-10 Repair Identification



R1 = 1st Repair Attempt, R 2 = 2nd Repair Attempt within the same location.

Interpretation reports shall reference:

- Radiographic procedure;
- IQI design and identification number;
- Source type;

- Source to film distance;
- Angle of incident radiation;
- Film type;
- Material type, thickness, joint type and geometry.

Interpretation reports shall display/record:

- Date the radiograph was taken;
- Builder's / Contractor's name:
- Vessel type and hull number;
- Owner's name;
- Inspection organization's 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;

A weld subject to radiographic inspection shall be evaluated in accordance with ABS Rules for Nondestructive Inspection of Hull Welds. All evaluations are to be to Class A.

10.13 RADIOGRAPHIC INTERPRETATION

All personnel interpreting radiographs should take great care in making the correct definition of defects. For example, the difference between a fusion defect and a crack. If there is doubt, angle shots should be taken to ensure correct interpretation.

In the case of porosity, care shall be taken in comparing these with the specifications with regard to aligned porosity, individual dimensions of pores, etc.

For aligned linear discontinuities, in any 150 mm length of weld, the sum of the greatest dimension of all discontinuities larger than 0.39 mm shall not exceed the allowable incomplete penetration of non-fusion allowance of ABS Rules.

For clustered or concentrated porosity, in any 25 mm length of weld, the sum of the total calculated area of all discontinuities larger or equal to 0.39 mm shall not exceed 10% of the allowable for 150 mm of weld.

Both aligned linear discontinuities and clustered or concentrated porosity shall be evaluated taking into consideration the multiple indication requirements of ABS Rules.

In examining radiographs for porosity in welds joining plates less than 12.5 mm in thickness, representative acceptance charts following ABS Rule requirements shall be produced, for each material thickness range under examination, and submitted to the Technical Authority for approval.

10.14 ULTRASONIC INSPECTION

10.14.1 Purpose

The purpose of the following requirements is to establish the procedures for ultrasonic examination of welds and heat affected zones in aluminum weldments. This procedure is based on the requirements defined in ABS Rules for the Ultrasonic Inspection of Hull Welds, Section 3, Appendices "A" and "B".

10.14.2 References

This procedure has been prepared using the following documents:

- ABS Rules for Nondestructive Inspection of Hull Welds
- ASTM E164 - Standard Practice for Ultrasonic Contact Examination of Weldments
- ASME Section V, Nondestructive Examination.

10.14.3 Personnel Qualifications

Personnel responsible for conducting ultrasonic tests are to be thoroughly familiar with the equipment being used, properly qualified by training and experience to perform the necessary calibrations and tests, and to interpret and evaluate indications in accordance with the pertinent specifications or approved plans.

Personnel performing the ultrasonic tests shall be currently qualified to CGSB 48.9712, Level II or Level III.

The qualification or certification records of each individual performing tests shall be presented to and filed with the on-site Inspection Authority prior to conducting tests.

10.14.4 Basic Instrument Qualifications

Basic instrument qualification of performance characteristics shall be in accordance with ASTM E317, Standard Recommended Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-echo Testing Systems, Method "A".

a) Amplitude (Vertical) Linearity

Amplitude linearity deviation between the limits of 20% and 80% of the screen height, shall not exceed 10% of the ideal 2:1 ratio of the two (2) echo signals used for evaluating vertical linearity.

b) Distance (Horizontal) Linearity

The multiple reflection indications used for evaluating horizontal linearity shall not deviate from the appropriate scale divisions by plus or minus 2% of full scale.

Evaluation of the horizontal scale positions of each multiple reflection indication shall be made when the amplitude of each successive echo to be measured as brought to 60-80% full screen height.

c) Resolution - Longitudinal Waves - Straight Beam Testing

Resolution shall be determined using the aluminum IIW Block.

The testing system (transducer cable and ultrasonic unit) shall resolve to the baseline a full scale indication from the 50 mm surface and the depth resolution notch for the far surface resolution at the reference gain used for evaluation purposes.

d) Resolution - Shear Wave Angle Beam Testing

Resolution determination for angle beam testing shall be performed using the sensitivity reference block in accordance with ASTM E164.

Unless otherwise approved, the system shall be capable of providing distinct indications from reflector spacing of a minimum of 3 mm of the vee path.

10.14.5 Calibration Blocks

This Standard requires the use of aluminum calibration blocks of similar alloy and condition as the materials to be inspected.

An aluminum IIW Block is to be used for calibrating test ranges for both straight beam and angle beam scanning, for checking resolution and determining beam angles and beam exit points.

Calibration for test sensitivity shall be performed using an aluminum sensitivity reference block containing basic calibration reflectors (side drilled hole, square notch) in accordance with ASTM E164.

Unless otherwise approved, the reference hole diameters shall be in accordance with ASTM E164. Where necessary, both 1/4 t and 3/4 t holes shall be drilled at opposite ends of the block. For material thicknesses of less than 25 mm, a single 1/2 t reference hole may be used.

For examination of circumferential or longitudinal welds in curved work pieces (cylindrical) with diameters less than 500 mm, calibration of the test system shall be performed using curved reference blocks of the same diameter and thickness as the material to be tested.

10.14.6 Mock-up Reference Weldments as Basic Reference Blocks

Wherever possible, or as required by the Technical and/or Inspection Authorities, mock-up or reference weldments are to be used for calibration purposes.

Basic calibration reflectors are to be machined into the reference weldment along the axis of the weld. The side-drilled holes may be drilled into the work piece weldment if its presence in the weldment is not detrimental to the structure.

Mock-up or reference weldments shall be fabricated from the same material and condition as the work piece, using the same welding process. All mock-up or reference weldments shall be subjected to radiographic inspection for internal flaws and suitability prior to use.

10.14.7 Surface Condition

The scanning surfaces of the base material shall be clean and free from weld spatter, loose paint, other foreign matter of roughness sufficient to produce inaccurate readings during inspection, or interfere with valid interpretation results. The width of the surfaces cleaned shall be sufficient to allow search of the entire weld zone.

The weld metal surfaces shall be sufficiently smooth to prevent interference with the interpretation of discontinuity indication and shall merge smoothly into the surfaces of the adjacent base material.

10.14.8 Transfer Correction

To compensate for differences in coupling between the sensitivity reference block and the material to be examined, or if there is a difference in sound attenuation, a transfer mechanism is to be used.

The resulting transfer correction factor or gain value shall be added to the reference gain established as the basic test sensitivity.

The transfer mechanism and/or transfer correction factor shall be included in the test report.

10.14.9 Couplant

The coupling medium should be selected so that its viscosity is appropriate for the surface finish of the material to be inspected.

A liquid, semi-liquid or paste type couplant shall be used to wet the surface of the material and the contact face of the transducer or probe and eliminate any air space between them. Typical couplants are water, oil, grease, glycerin or cellulose gum. A glycerin based couplant such as Hamikleer is recommended.

The same couplant shall be used for calibration purposes and field testing; care must be taken to ensure that the application and temperature of the couplant during calibration represents field conditions.

10.14.10 Transducer

The active element of any transducer used shall not exceed 25 mm in diameter. Transducer frequencies may be either 2.25 MHz or 5MHz.

Lower frequencies may be utilized for higher resolutions and at the discretion of the CGSB Level III inspector for improved penetration of material of heavy cross section.

Angle beam transducers shall be affixed to suitable wedges designed to induce shear waves in the aluminum material under test at the recommended beam angles. Recommended beam angles are offered in ASTM E164, - Procedures Recommended for Common Weld Configurations.

For examination of circumferential welds or longitudinal welds in curved work pieces (cylindrical), the angle beam wedges are to be machined to match the curvature of the work piece when the diameter of the work piece is less than 500 mm.

10.14.11 Examination Procedures

Scanning procedures shall be in accordance with ABS Rules, Section 3, Figure 3.3 for welds in plate not ground flush. Examination procedures for other common weld configurations shall be in accordance with ASTM E164.

10.14.12 Calibration for Test Sensitivity

Straight beam calibration for detection of plate lamellar discontinuities.

The area of base metal through which the sound will travel during angle beam examination of the weld shall be scanned with a straight beam (compression wave) technique.

The system shall be calibrated such that a minimum of two back wall echo signals are displayed within the test range. By adjustment of the gain control, the first back wall echo amplitude shall be set at 80% of full screen height. Any reflector which produces an equivalent signal amplitude, or a total loss of the back wall echo signal shall be reported.

When these inspections reveal lamellar discontinuities which would interfere with the angle beam examination at the weld, the examination is to be made from the opposite side of the weld.

10.14.13 Calibration for Single Beam Test Sensitivity

a) Distance Amplitude Curve

In accordance with ABS Rules Section 3, paragraph 3.2.6a, a geographical calibration method relating amplitude values with changes in signal path length is to be used for establishing angle beam test sensitivity, otherwise known as the "Distance Amplitude Curve Technique".

b) Sensitivity Calibration Angle Beam

Using the recommended angle beam transducer and basic sensitivity reference block corresponding to the weld thickness being examined, maximum amplitudes from the 1/8, 3/8, 5/8, 7/8 and 9/8 Vee paths to the hole shall be obtained.

The sensitivity (gain) control shall be adjusted to provide an 80% full screen amplitude from the hole at the Vee path distance which gives the highest amplitude. The peak of the indication on the screen shall be marked with a grease pencil or water soluble ink marker.

Without changing the gain control and by manipulation of the transducer, maximum amplitudes from the Vee path positions to the hole shall be obtained. The peaks of the indications shall be marked on the screen at their appropriate positions on the baseline of the instrument.

The screen marks shall be connected to provide the distance amplitude curve for the side-drilled reference hole.

This Distance Amplitude Curve with a maximum amplitude of 80% full screen height is designated as the Amplitude Rejection Level (ARL).

The screen at each of the Vee path indication points shall be marked to produce a second curve with an amplitude which is half that of the ARL curve. This curve is designated as the Disregard Level (DRL).

10.14.14 Electronic Distance Amplitude Correction

When electronic distance amplitude correction instruments are used, the indication amplitudes from reference at various Vee path segments shall be equalized over the Vee path range required to examine the total volume of the weld, at the 80% full screen height level for the Amplitude Rejection Level (ARL) and 40% full screen height for the Disregard Level (DRL).

10.14.15 Calibration Periods

The test system (instrument, connecting cable and transducer) shall be calibrated with the reference standards each time it is used, and shall be re-calibrated whenever the electric power has been interrupted, whenever transducers or angle beam wedges are changed, or whenever the calibration of the equipment is suspected of being in error.

10.14.16 Weld Inspection

Weld inspection shall be conducted in accordance with ABS Rules Section 3, Paragraph 3.27a, b and c.

a) Plate Lamellar Discontinuities

The plate material adjacent to the weld shall be inspected by a straight beam technique to reveal lamellar discontinuities which might interfere with angle beam inspection of the weld.

b) Longitudinal Discontinuities

In order to detect longitudinal discontinuities, the transducer shall be moved in an overlapping pattern similar to that shown in Figure 3.3 of ABS Rules.

Inspection shall be carried out from both sides of the weld from the same surface, or on opposite surfaces from the same side of the weld.

c) Transverse Discontinuities

In order to detect transverse discontinuities, the transducer is to be angled about 15° from the weld axis and moved parallel to the weld lengths as shown in Figure 3.3 of ABS Rules.

The scan is to be repeated on the same surface at the other side of the weld or on the opposite surface from either side of the weld.

10.14.17 Discontinuity Length Determination

Discontinuity length determination is to be conducted in accordance with ABS Rules, Section 3, Paragraph 3.28, Sub-paragraphs a) and b). This method of discontinuity length determination is conventionally described as the 50% (6dB) drop method. Reference is made to ASTM E164, Paragraph 10.2.1 and Figures 17 and 18 for detailed information on reflector evaluations.

10.14.18 Ultrasonic Inspection Reports

Ultrasonic inspection reports are to be filed for record in accordance with ABS Rules, Section 3, Paragraph 3.2.9. Typical report forms are offered in Figure 3.4 of ABS Rules.

10.14.19 Acceptance Criteria

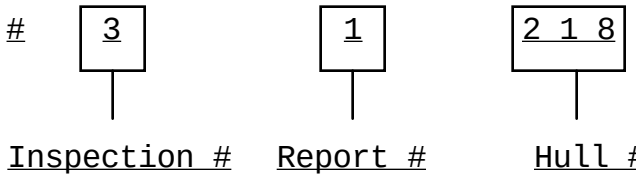
Acceptance criteria shall be in accordance with ABS Rules, Section 3, Paragraph 3.6, Class "A".

10.14.20 Other Requirements

All other requirements of ABS Rules for Ultrasonic Inspection of Hull Welds, Section 3 not outlined in these procedures are applicable, including Appendices "A" & "B".

10.15 REPORTING AND DOCUMENTATION OF RESULTS

Each interpretation report shall contain a report number. The report number shall include the shipyard's hull number, (i.e., Report #1-218, etc.). Each location listed on the report shall be identified with and inspection number (i.e., Location #50 port is Inspection #3). Each **individual** radiograph, including its duplicate shall be submitted in an **individual** protective paper folder. The identification to appear on each folder shall be Inspection #, Report # and Hull # as illustrated.



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

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

The contractor shall prepare an adequate number of nondestructive inspection arrangement drawings and sketches to be used for accurately locating where nondestructive inspection has occurred.

During construction, the contractor shall issue one working copy of the nondestructive examination arrangement drawing to the onsite Inspection Authority, which shall be used by the contractor to locate inspections on a progressive basis. The frequency of updates shall be to the satisfaction of the on-site Inspection Authority.

The method of inspection used, weld identification number and abbreviations used, 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 drawing supplied or may be supplied separately prior to commending the construction or repair period.

The contractor shall provide reasonable access to the above referenced drawings throughout the contract and warranty period as required for review by the Inspection and Technical Authorities.

Three (3) copies of each completed drawing shall be provided to the Technical Authority at contract completion.

ANNEX A REFERENCED PUBLICATIONS

A.1 LIST OF CODES, PUBLICATIONS AND STANDARDS

ASME	Section V	Nondestructive Examination
	Section IX	Welding and Brazing Qualifications
ASTM	E165	Liquid Penetrant 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
	A 5.10	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
	D.1.2	Structural Welding Code – Aluminum
CGSB	48.9712	Qualification and Certification of Nondestructive Testing Personnel
CSA	W47.2	Certification of Companies for Fusion Welding of Aluminum
	W178.2	Certification of Welding Inspectors
ABS	Rules for Nondestructive Inspection of Hull Welds	

ANNEX B WELD TECHNIQUES

Figure B - 1 Fillet Weld - Skip Technique

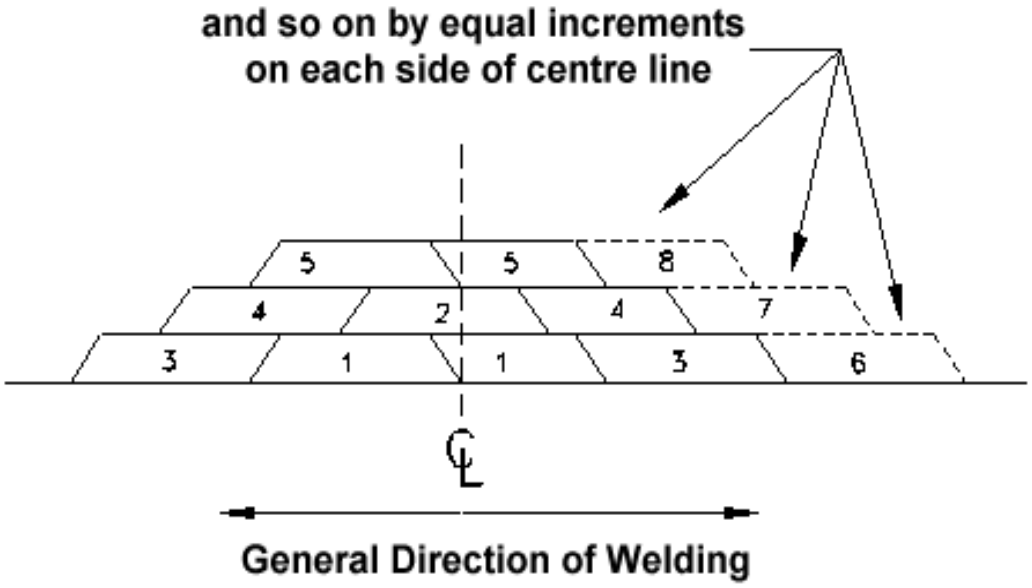


Figure B - 2 Groove Weld - Back Step Technique

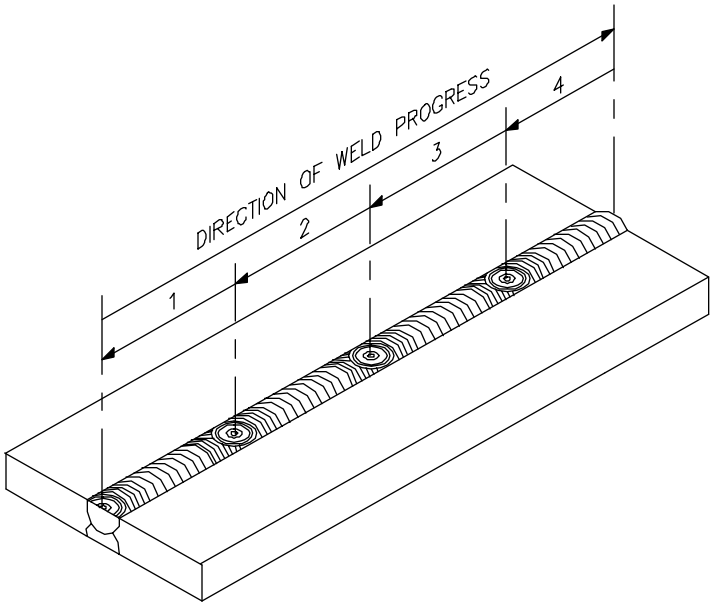


Figure B - 3 Groove Weld – Block Technique

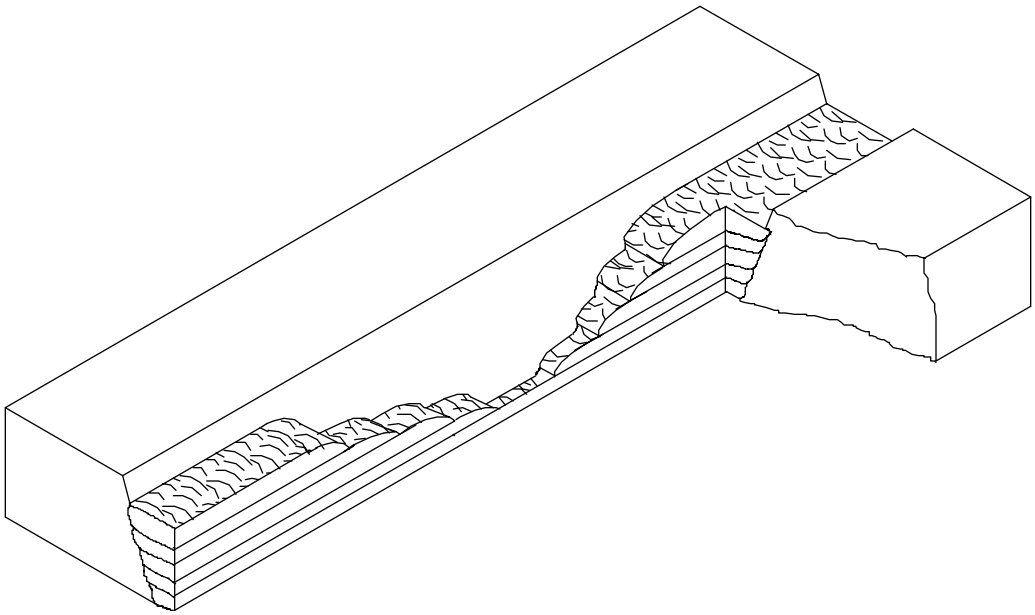
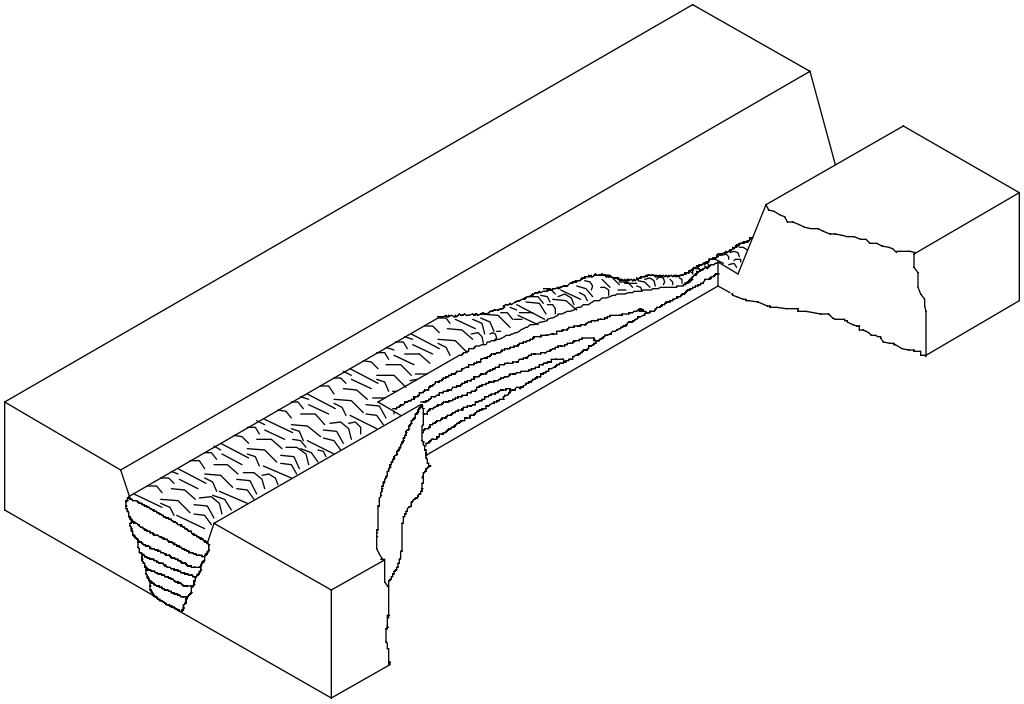


Figure B - 4 Groove Weld – Cascade Technique



ANNEX C INSPECTION PERSONNEL CERTIFICATES

C.1 GENERAL

This appendix provides sample copies of Inspection Personnel Qualification Certificates which are required to be collected as detailed within Chapter 10 of this standard.

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

C.2 CSA STANDARD W178.2 CERTIFICATE SPECIMEN

(FRONT)

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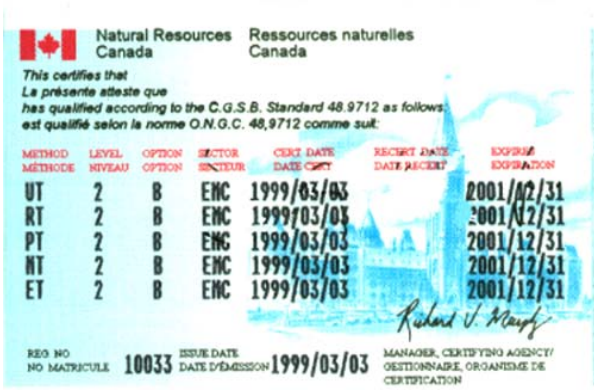
C.3 CGSB STANDARD 48.9712 CERTIFICATE SPECIMEN



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ANNEX D HOT FORMING AND THERMAL REQUIREMENTS

D.1 HOT FORMING

All hot forming procedures shall be approved by the Technical Authority in advance of hot forming operations.

The majority of aluminum sections can be formed cold. For severe forming, heat may be used. Maximum holding times for the forming of aluminum alloys at various temperatures are given in Table D-1.

Hot forming of 5000 series aluminum alloys is generally conducted at temperatures between 260°C and 425°C. Appropriate temperature control methods are to be used in all hot forming and stress relieving operations. In hot forming or stress relieving, exposure of the 5000 Series alloys to the 65°C to 200°C temperature range is to be minimized by the use of appropriate cooling techniques.

Table D-1 Maximum Heat Exposure Time at Temperature Preparatory to Forming Aluminum Alloys

Holding Temperature (Note 1) 0°C	6061-T4, 6061-T5, Alclad 6061-T4, Alclad 6061-T5, 6063-T5, 356.0-T4, (Note 2)	5454 (Note 3)	5083, 5086, 5154, 5254, 5456
430	NR(4)	50 Hours	50 Hours
260	NR(4)	50 Hours	50 Hours
230	5 Minutes	50 Hours	50 Hours
220	15 Minutes	50 Hours	50 Hours
205	30 Minutes	50 Hours	50 Hours
190	1-2 Hours	50 Hours	NR(4)
175	8-10 Hours	50 Hours	NR(4)
120-165	50 Hours	50 Hours	NR(4)

NOTES: *1) Equal formability may be obtained with shorter periods of heating at correspondingly higher temperatures. Time at temperature for clad alloys should be kept at a minimum to prevent diffusion of the cladding into the core alloy. Heating should be as rapid as possible, particularly for temperatures 205°C and above. Excessive time to approach the desired temperatures can have deleterious effects similar to those resulting from excess time at temperature.*

2) Losses in strength for these alloys in the T6 temper will not exceed about 5% when heated at the temperature and for the periods shown. Strength of the T4 temper alloys will increase.

3) These alloys will be annealed at 345°C and above.

4) NR = Not Recommended

D.2 COLD FORMING

Cold forming of 5000 series aluminum alloys is to be conducted at temperatures below 50°C, except for the 5454 alloy, where the maximum temperature may be 150°C. When the extent of cold forming is such that base plate properties are changed beyond acceptable limits, appropriate re-heat or stress relief treatments are to be used to re-establish acceptable properties.

ANNEX E MINIMUM NONDESTRUCTIVE INSPECTION REQUIREMENTS

E.1 APPLICATIONS

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 Appendix does not apply.

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

The length of inspections are specified in Chapter 10, Section 10.4 for each individual inspection method used.

E.2 INSPECTIONS

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 the overall dimensions of the vessel.

Legend:	**LPI**	= Liquid Penetrant Inspections
	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)
LPI Inspections		= 1.00 x (L+B+D)
RT Inspections		= 2.00 x (L+B+D)

EXAMPLE

A Life Boat of 16 meters in length having a moulded breadth of 4.5 meters and a moulded depth of 2 meters will require:

Number		Length
UT Inspections	=	11 as per 10.4
LPI Inspections	=	22 as per 10.4
RT Inspections	=	45 as per 10.4

ANNEX F WELDING STANDARD FOR MINOR ALTERATIONS AND REPAIR OF ALUMINUM AND ALUMINUM ALLOYS

F.1 SCOPE

This Standard states the requirements of Integrated Technical Support (ITS), Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa for welding aluminum. This Standard shall be used whenever required as specified by a contract issued on behalf of the Regional Superintendent, Vessel Support, Fleet Services, Canadian Coast Guard, Fisheries and Oceans Canada. This Standard is intended only for minor alterations or repairs.

In addition to this Standard, the contractor shall meet all regulations and standards required by the Marine Safety Directorate of Transport Canada and the Applicable Classification Society.

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

F.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, aluminum 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 support 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 Regional Marine Safety Directorate, Transport Canada.
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 the thinnest member of the connection to be welded.

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

F.3 APPLICABLE DOCUMENTS

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

CSA	**W47.2**	Certification of Companies for Fusion Welding of Aluminum
	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**	Standard Welding Terms and Definitions
	A5.10	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
	D1.2	Aluminum Structural Welding Code
	D3.7	Guide for Aluminum Hull Welding

F.4 DESIGN, DRAWINGS, WELD DETAILS & SEQUENCE

Unless otherwise approved by the Technical Authority:

- 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 70°shall be used.
- 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.
- 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.

F.5 MATERIALS, WELDING PROCESS, CONSUMABLES, EQUIPMENT, TECHNIQUE AND PREHEAT

Materials fitted into the structure shall be marine grade aluminum alloys and preferably of the same alloy group and temper of the material that was originally fitted. Plates normally are 5086 H34 and formed shapes (extrusions) are 6061 T6. Since ultimate and yield strengths are significantly altered by temper, substitutes should be carefully examined.

Gas Metal Arc Welding and Gas Tungsten Arc Welding are the only approved methods for welding aluminum. To ease welding operations, push/pull wire feeders using pulsed output power sources should be used for the Gas Metal Arc Welding method, and square wave power sources fitted with torches having a gas lens, should be used for the Gas Tungsten Arc Welding method.

Aluminum alloy 5356 filler metal may be used for joining plating to plating and extrusions to plating. For extensive joining of extrusions to each other, 4043 filler metal should be used. Pure welding grade argon is the preferred shielding gas. Filler rods should be manufactured to the requirements of AWS 5.10.

Aluminum alloys should only be preheated when absolutely necessary. For the 5000 series aluminum having a magnesium content greater than 3%, preheat or interpass temperature should never exceed 65° C. Holding within the temperature range from 65°C - 230°C must be avoided in order to minimize the possibility of sensitization to exfoliation and stress corrosion cracking.

Filler metal 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.

Wire for Gas Metal Arc Welding should be tested for cast and helix to ensure fluctuations in wire feed speed does not occur. The greater the dimension of cast and the least possible amount of helix is desired.

Molten aluminum has a high affinity for absorption of free hydrogen; the major cause of porosity. The major sources of free hydrogen are: welding wire, surface contaminants and atmospheric air.

Suppliers of wire shall be carefully selected. The lubricants applied to wire by the manufacturer for improved feeding is the greatest cause of hydrogen induced porosity. The standard for approving welding wires permits significant amounts of porosity. Thorough testing prior to selecting a supplier is strongly recommended. Larger wire diameters at optimum parameter settings produce best porosity free results. Rods intended for manual Gas Tungsten Arc Welding should be degreased with commercial solvents and cleaned of dense oxide with stainless steel wool just prior to use.

Contaminants that are able to produce free hydrogen can come from many sources. Exceptional house keeping is needed to produce porosity free welds in aluminum. Scratch brushes shall be made of stainless steel only and degreased prior to use. Lint free white rags containing no colour dye shall be used for degreasing materials. Compressed air systems for tooling shall supply oil free dry air only. Moisture must be removed from the supply lines by use of dryers. Grinding disks shall be carefully selected to ensure the aluminum is not contaminated by wheel particles and dust.

Joints fitted for welding should be welded shortly after cleaning and fit up, otherwise they should be protected from shop or field contamination by taping. Tape should be carefully selected and applied so as not to contaminate the joint with harmful glue residue.

Degreasing should always occur prior to fitting joints never after fitting prior to depositing the first pass (root bead). Interpass degreasing can take place after the first pass is complete along the entire joint length.

Lubricant pads should never be used to improve wire feeding.

Dust covers should house wire spools at all times.

Atmospheric air may enter the arc zone by winds and draughts or by leaks in the compressed shielding gas regulators, hoses and fittings or condensation may accumulate over extreme temperature changes. Equipment should be checked at regular intervals and well maintained and stored in such a manner as to reduce the potential for condensation build up. The gas dispensing fittings in the torch nozzle should be checked at regular intervals to ensure ports are not clogged with spatter and there is even gas flow. Extra precautions may have to be taken when the atmospheric temperature and humidity conditions render total high humidity in the welding environment.

Residue magnesium oxide (black or gray smut) shall be removed thoroughly prior to depositing subsequent beads. Residue spatter shall be removed thoroughly prior to depositing subsequent beads. When using Gas Metal Arc Welding, weld toe splatter should be removed thoroughly by dressing prior to depositing subsequent beads.

When welding with the Gas Metal Arc Welding process using smaller wire diameters, a reduction in solidification rate is often needed. This can be best achieved by pulsed power sources and helium – argon mixed shielding gas. A mixture of 75% Helium and 25% Argon is recommended.

Only welding grade pure argon should be used for Gas Tungsten Arc Welding methods.

F.6 QUALIFICATIONS OF WELDERS

Welders shall be qualified to CSA Standard W47.2 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 W47.2 to the satisfaction of the Technical Authority.

F.7 QUALIFICATIONS OF WELD PROCEDURES

Welding should occur with procedures approved by the Canadian Welding Bureau as being compliant with CSA Standard W47.2. The procedure should be for the same joint, position of welding, material and process planned on being used.

In joining aluminum, torch manipulation techniques such as weaving and whipping are not permitted. Stringer beads are the only accepted practice unless otherwise proven by weld procedure qualification tests.

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

Procedures approved by a provincial pressure vessel branch or Classification Societies such as Lloyd's Register of Shipping (LR), American Bureau of Shipping (ABS) or Det Norske Veritas (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 W47.2 to the satisfaction of the Technical Authority.

F.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 0°C except when approved by the Technical Authority.

The work zone shall be adequately protected against the direct effects of winds and drafts.

Surfaces and edges of plates to be welded shall be clean and free of deleterious materials such as paint, heavy oxide, water stain, oil, grease and moisture.

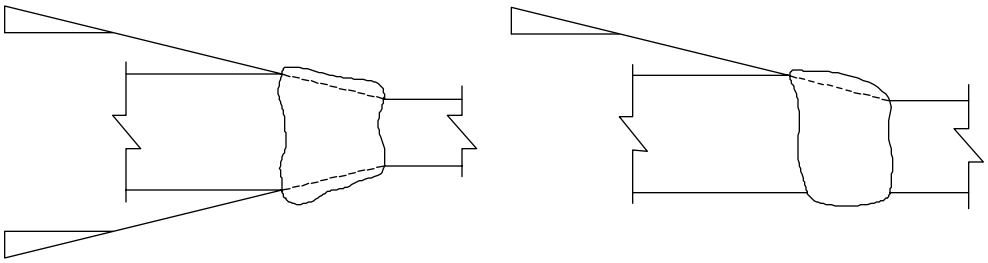
Surfaces and edges of plates shall be clean, smooth, uniform and free of discontinuities that will affect the structure, strength of the weld connection and the completed weld. The minimum surface area to be cleaned prior to welding shall be 50 mm from the anticipated location of each weld toe. Care shall be taken in selecting the correct cleaning methods. Guidance can be found in Appendix "E" of CSA Standard W47.2 and AWS D3.7 Guide for Aluminum Hull Welding.

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 by the Gas Tungsten Arc Welding method and ground smooth prior to fit up.

The contractor will use accepted cutting practices for aluminum and aluminum alloys. Guidance can be found in Appendix "E" of CSA Standard W47.2 and AWS D3.7 Guide for Aluminum Hull Welding.

When groove welds are used to join plating of different thickness and the difference in thickness is less than or equal to 3 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 as illustrated in Figure F-1.

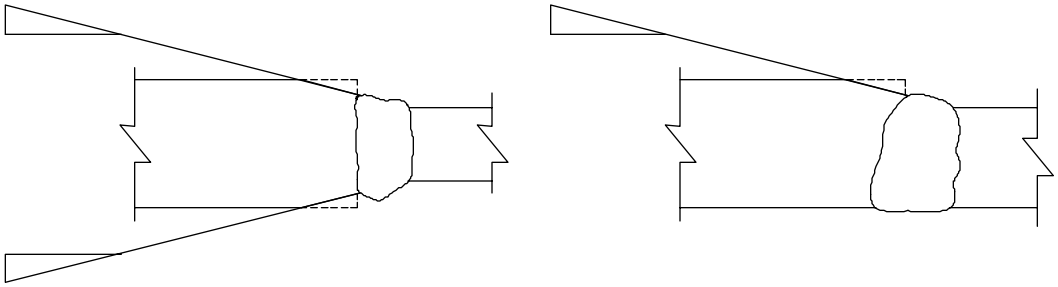
Figure F - 1 Slope by Welding



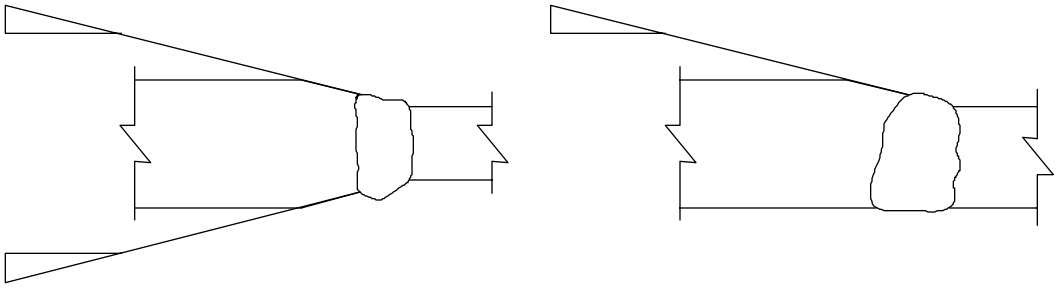
TRANSITION BY SLOPING WELD SURFACE

When the difference in thickness exceeds 3 mm, then the transition should be achieved by chamfering to the desired slope as illustrated in Figure F-2.

Figure F - 2 Slope by Chamfering



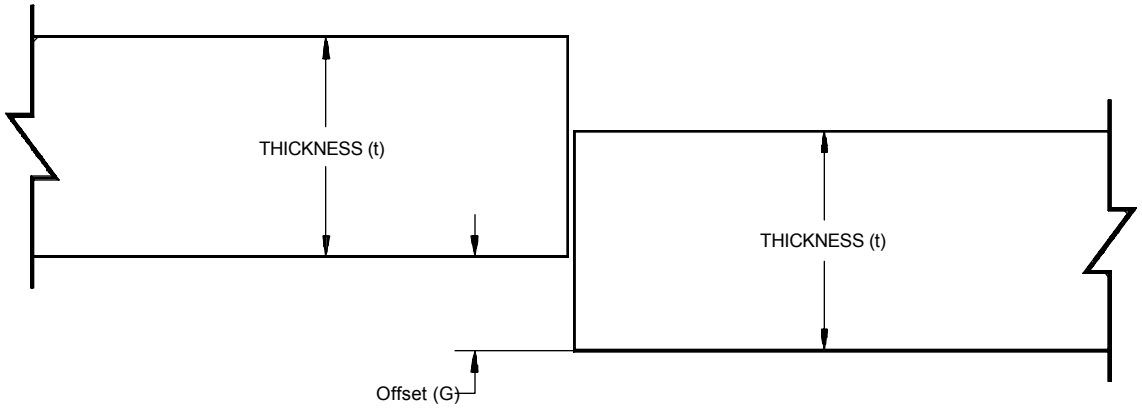
TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING AFTER WELDING



TRANSITION BY CHAMFERING THICKER PART PRIOR TO WELDING

Alignment of 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 F-3.

Figure F - 3 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 F-4.

Figure F - 4 Tee Joints

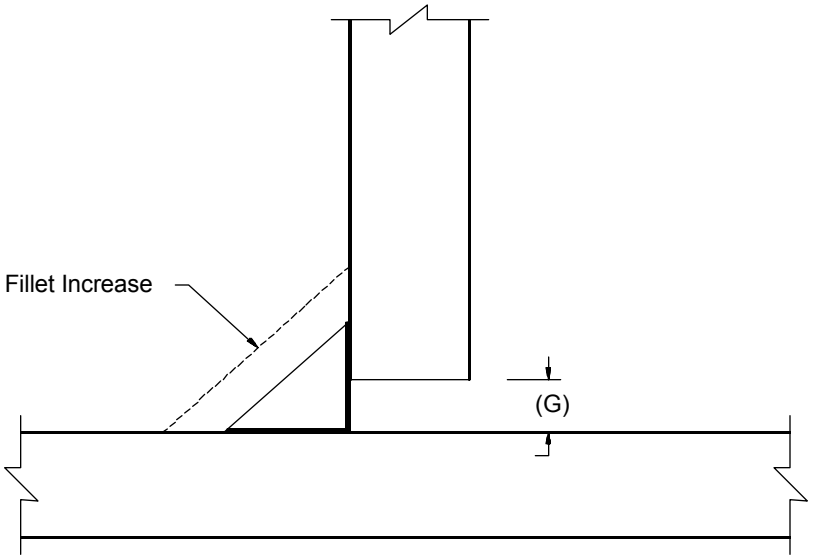
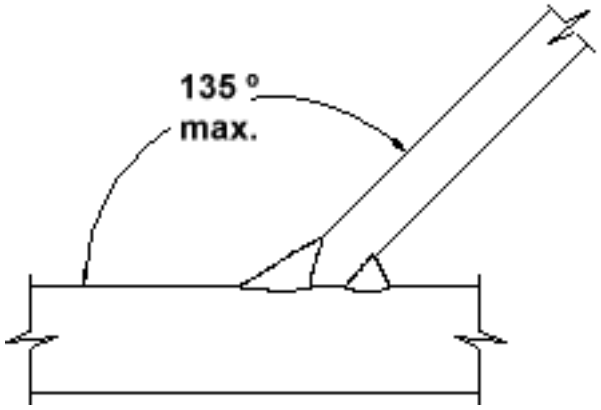


Figure F - 5 Skewed Tee Joints



For Tee joints in the skewed condition (see Figure F-5), the deposited leg length of fillet welds shall be adjusted based on the fitted angle and gap as provided in Table F-1.

Table F - 1– 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

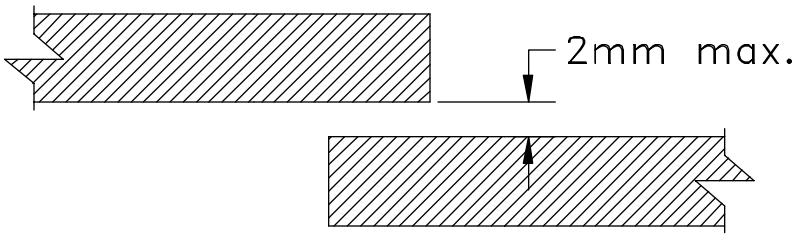
EXAMPLE

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 2 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 F-6.

Figure F - 6 Lapping Structure



When fitting plating for corner joints, the plate shall be edge prepared to a minimum include angle of 55° 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 F-7.

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 F-8.

Figure F - 7 Corner Joints

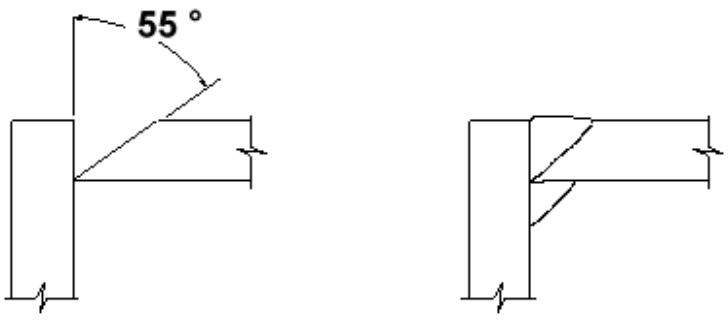
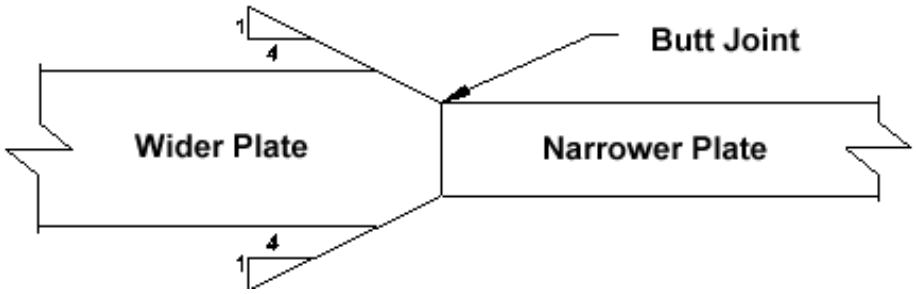
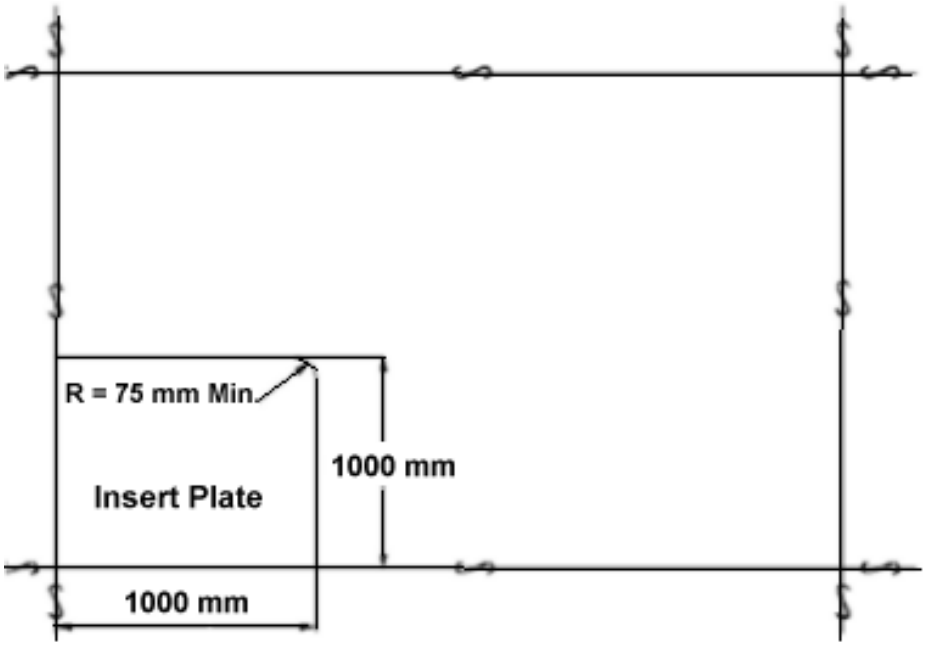


Figure F - 8 Transition for Flange Width



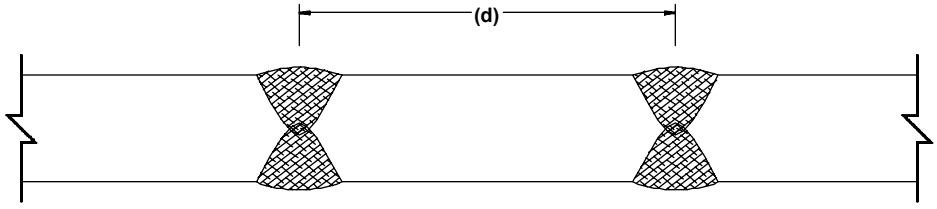
Where a local increase in plate thickness is required, insert plates shall be used instead of doubler plates. Insert plates should be as large as is practicable and preferably tied into existing weld butts and seams. For shell plating, inserts should be at least 1000 mm in dimension. The minimum corner radius used for all insert locations shall be 8 (t) 75 mm minimum as illustrated in Figure F-9.

Figure F - 9 Insert Plates



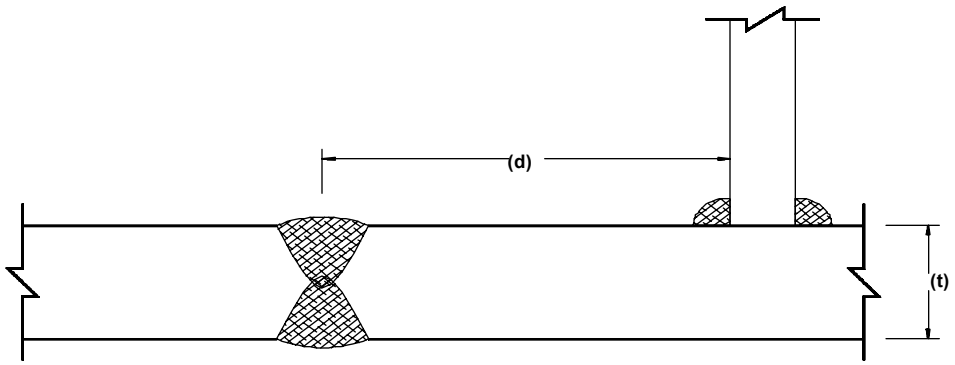
The dimension between adjacent groove welds in fabricated plating shall be not less than 300mm as illustrated in Figure F-10.

Figure F - 10 Distance Between Groove Welds



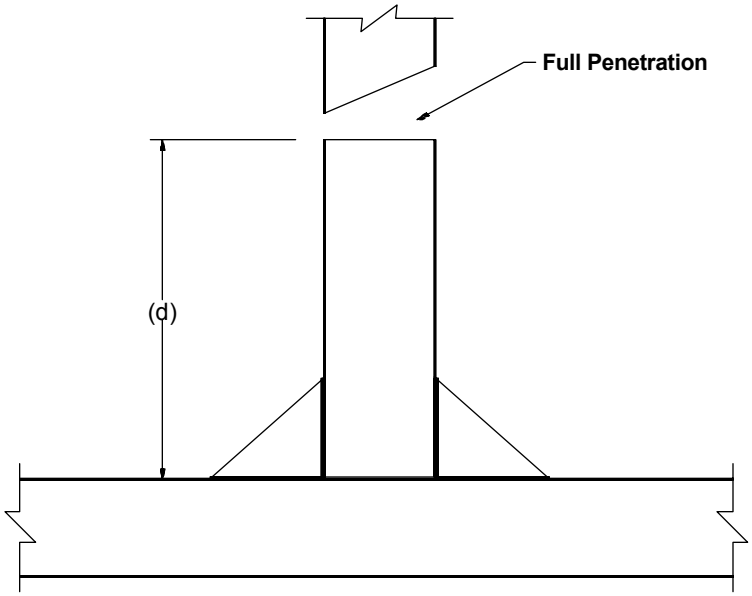
The dimension between a groove weld in plating to a fillet weld attaching a stiffener to the plating shall be at least 30mm as illustrated in Figure F-11.

Figure F - 11 Distance Between Groove and Fillet



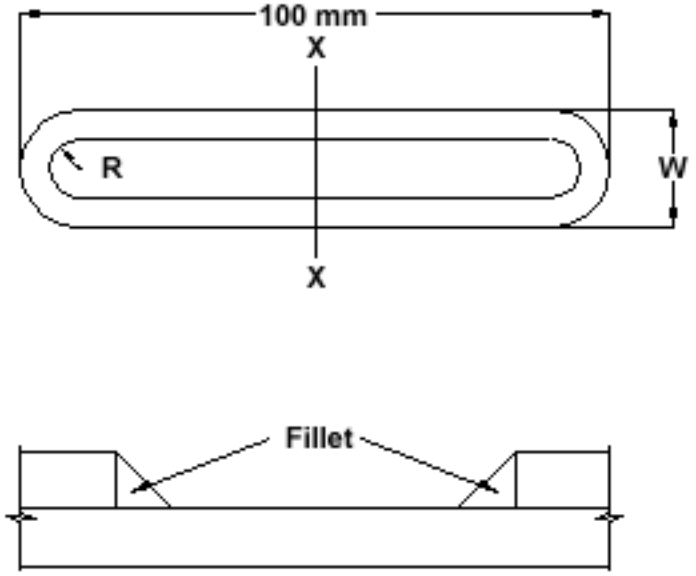
The dimension between a groove weld in the web of a stiffener to a fillet weld attaching a stiffener to the plating shall be at least 150mm as illustrated in Figure F-12.

Figure F - 12 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 F-13.

Figure F - 13 Slot Welds



length	100 mm (minimum)
width	2.5 (t) (t) = slotted plate thickness
slot spacing	150 mm (maximum)

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 38 mm radius should be used to permit proper access for 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, using the same grade of filler metal required to weld the joint.

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 Gas Tungsten Arc Welding. Any reinforcement remaining or caused by repair welding shall be removed flush with the base metal.

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 Gas Tungsten Arc Welding and ground flush with the base metal and examined.

Melt through shall be repaired by removing to sound metal and Gas Tungsten Arc Welding.

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 D3.7 Guide for Aluminum Hull Welding. The thermal expansion coefficient of aluminum is about twice that of steel. The total amount of thermal expansion varies inversely with the speed of welding. As a result, fixtures should be designed so that plate alignment will accommodate twice the dimensional change normally expected for welding a similar steel component. Unlike steel, restrictions apply to correcting distortions in aluminum caused by welding. In addition, as-deposited weld metal elongation properties are 5 - 7% on average rendering weld deposits prone to cracking under restraint.

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 F-14 and Figure F-15.

Figure F - 14 Back Step Technique

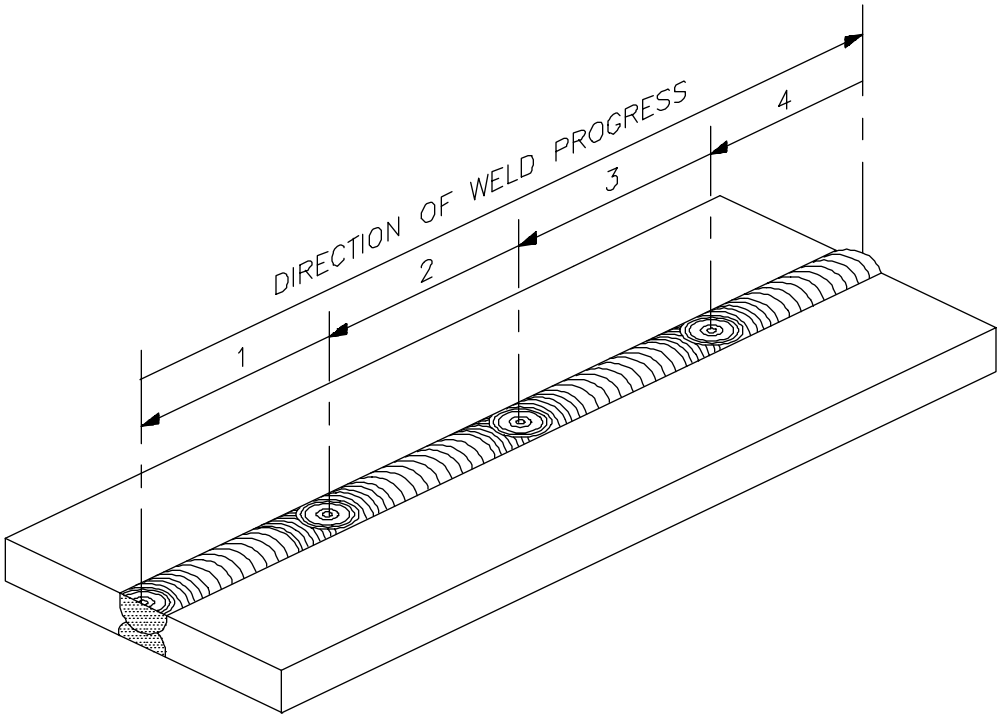
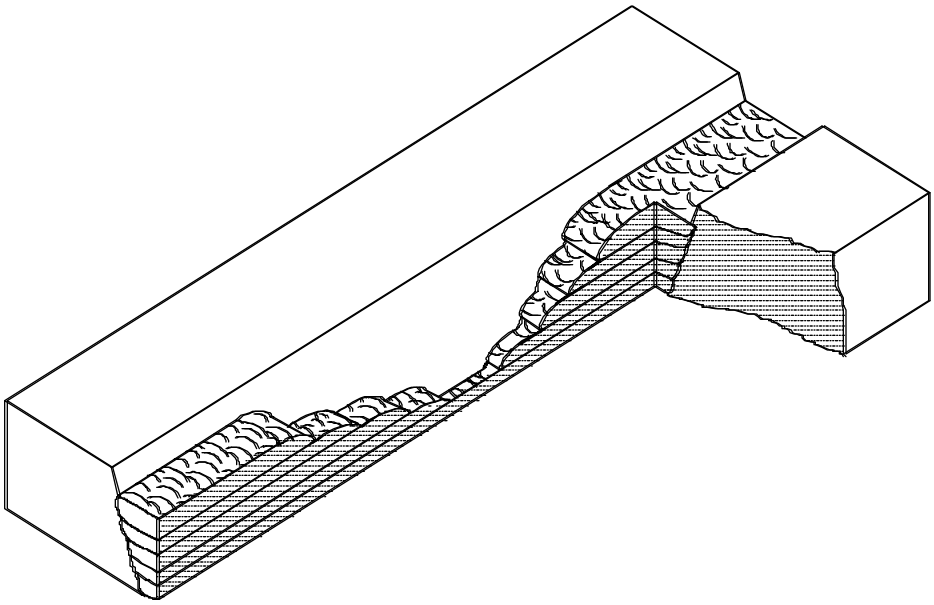
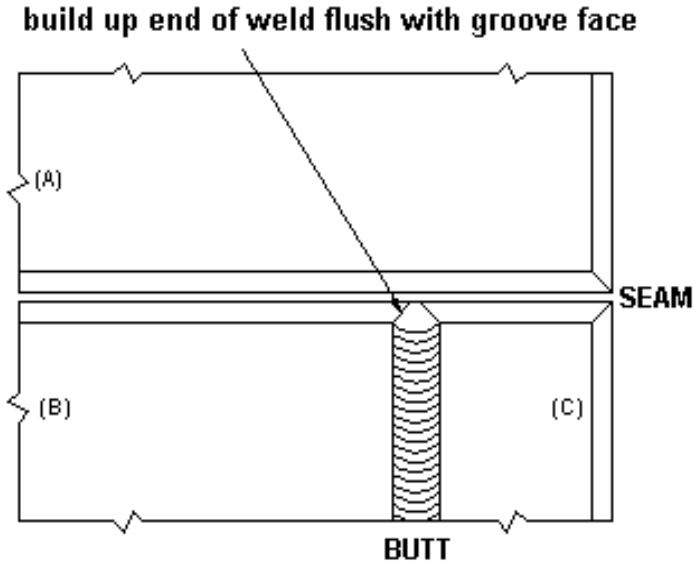


Figure F - 15 Block Technique



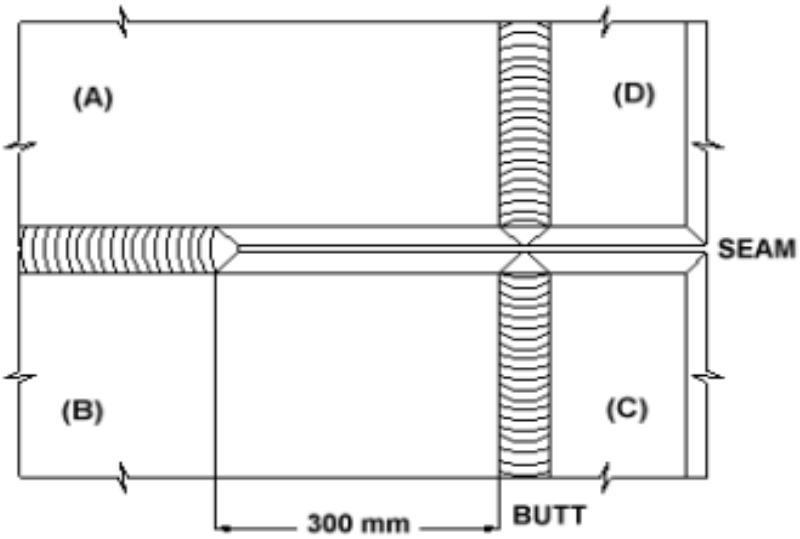
Jigs, fixtures, clamping devices and strong backs should only be used in such a manner as to avoid restraint during welding after tack welds are in place. Strong backs welded on one side of the joint and wedged on the other are preferred. For individual panels consisting of a number of plates, butts shall be welded before seams as illustrated in Figure F-16.

Figure F - 16 Weld Butt before Seam



For four way intersections of butts and seams, the seam can be welded up to a distance of 300 mm from the unwelded butts. Once the butts have been fully welded, then the seam can be welded as illustrated in Figure F-17.

Figure F - 17 Release Distance for Seams



Stiffeners fillet welded to plating shall remain unwelded at edges of plating for a distance of at least 300 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 D3.7 Guide for Aluminum 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 AWS D1.2, Clause 3.7. 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.

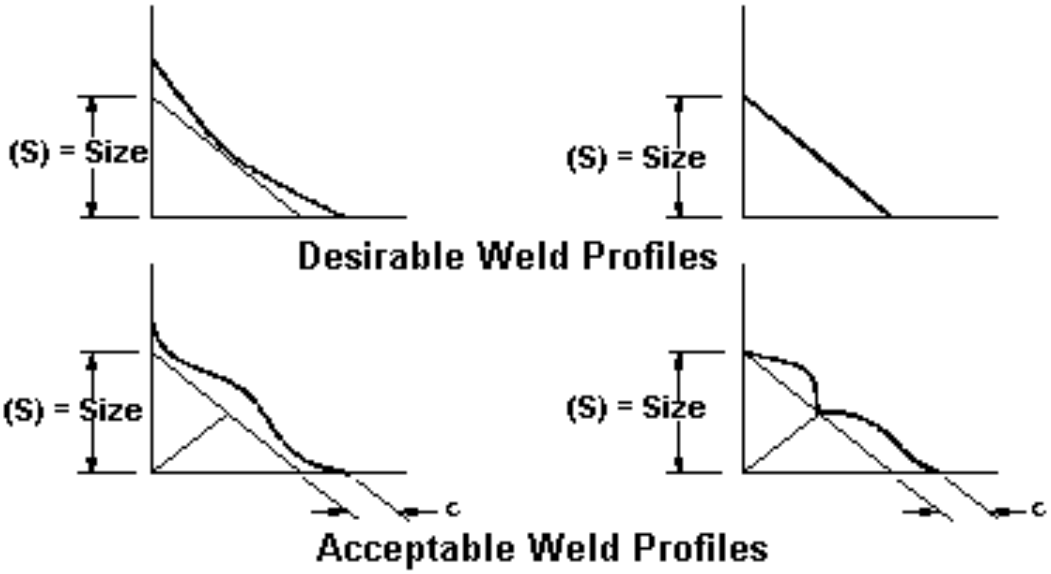
F.9 INSPECTION

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 F-18.

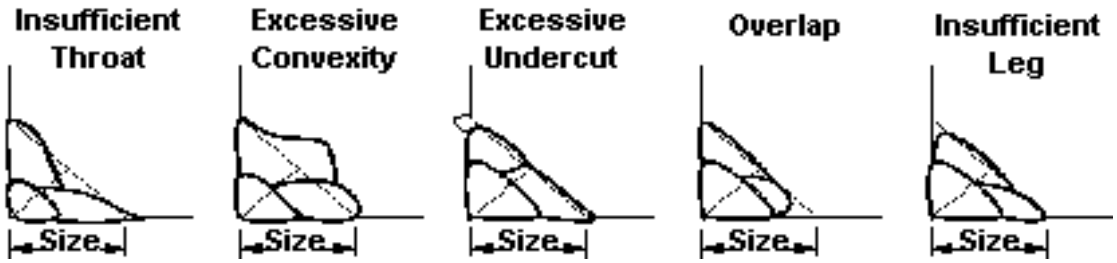
Figure F - 18 Fillet Weld Profiles

Desirable Profiles



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

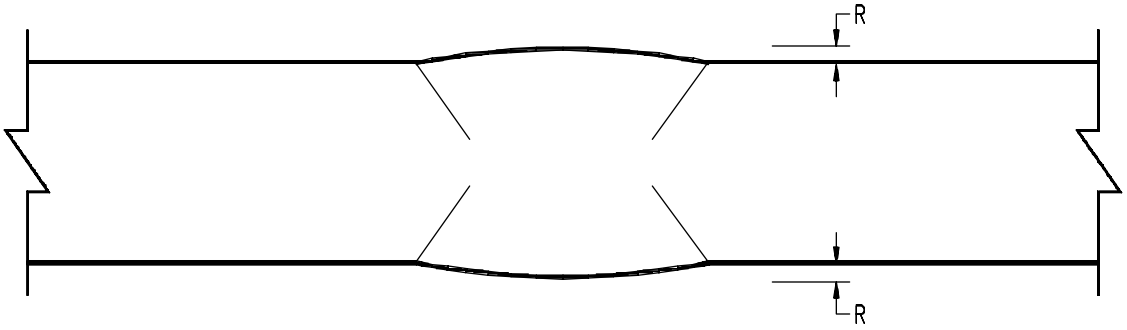
Undesirable Profiles



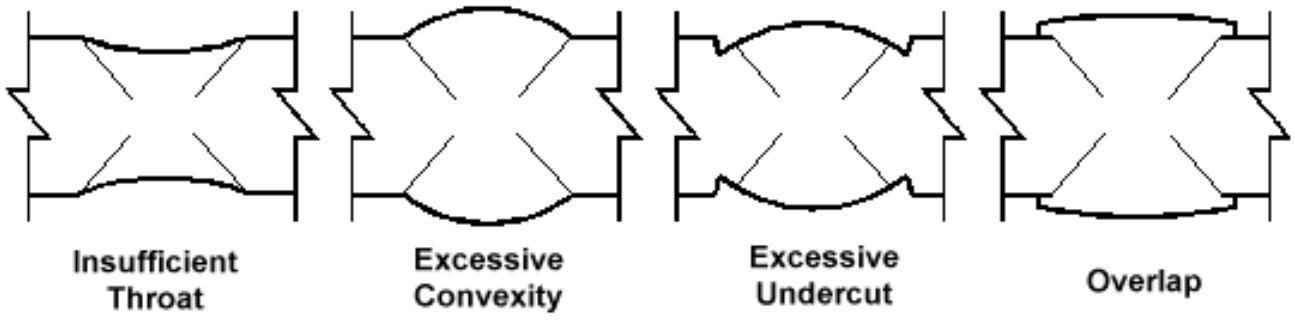
Groove welds in butt joints shall fill the groove completely not having a reinforcement greater than 3 mm. Reinforcement shall be smooth without grooves or valleys along the length of the weld. Toes of welds shall blend smoothly into the base metal. Desirable and undesirable profiles are illustrated in Figure F-19.

Figure F - 19 Groove Weld Profiles

Desirable Profile



Undesirable 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 I film and X-Ray shall be used for all material thickness. Film density shall be between 2.0 and 3.5 and film sensitivity shall be at least 2-2t, preferably 2-1t.

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 for in Table F-2 and as illustrated in Figures F-20, F-21 and F-22. IQI's shall be certifiable to ASTM or ASME Standards.

Table F - 2 Image Quality Indicators

Material Thickness Range (inches)	Image Quality Indicators		Essential Hole	
	Thickness (inches)	ASTM N°	2 - 1 (t)	2 - 2 (t)
Up to ½	0.0100	10	0.010	0.020
Over ½ to 5/8	0.0125	12	0.0125	0.025
5/8 to ¾	0.0150	15	0.0150	0.030
¾ to 7/8	0.0175	17	0.0175	0.035
7/8 to 1	0.0200	20	0.0200	0.040
1 to 1¼	0.0250	25	0.0250	0.050

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

Figure F - 20 Image Quality Indicator

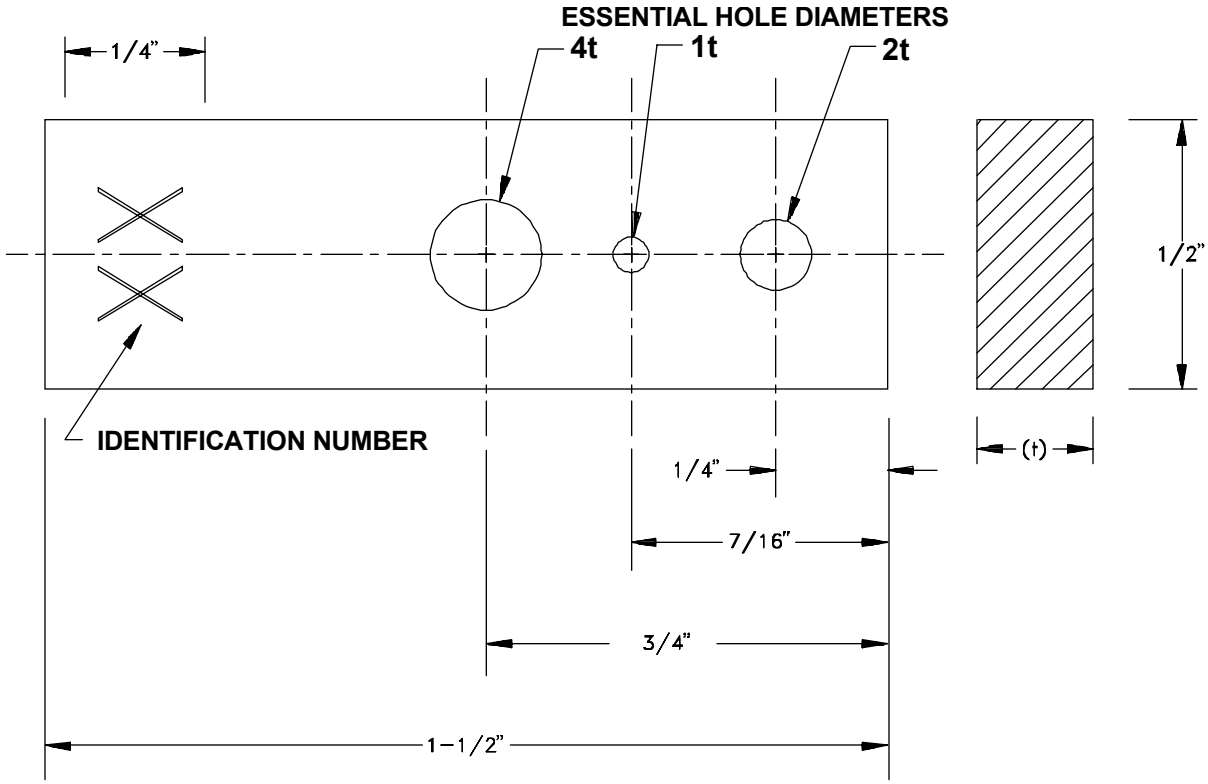


Figure F - 21 IQI Placement for Same Plate Thickness

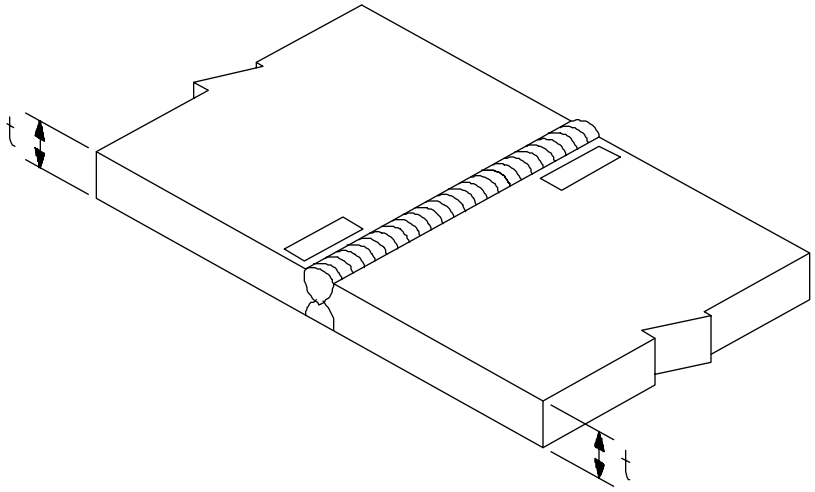
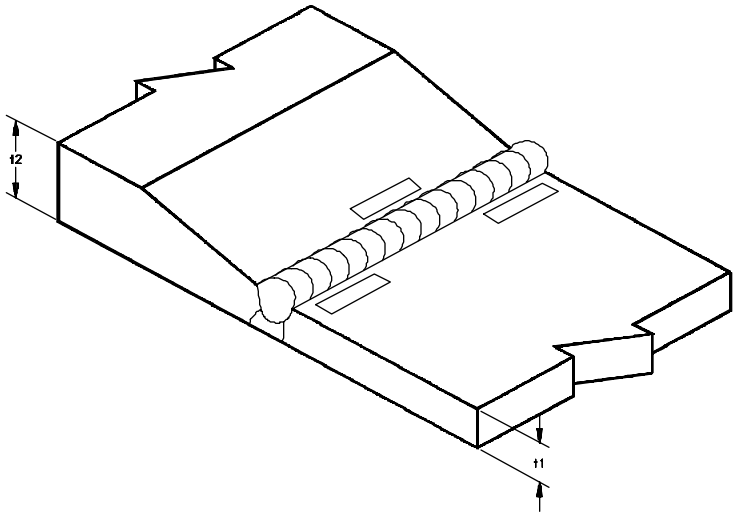


Figure F - 22 IQI Placement for Differing Plate Thickness

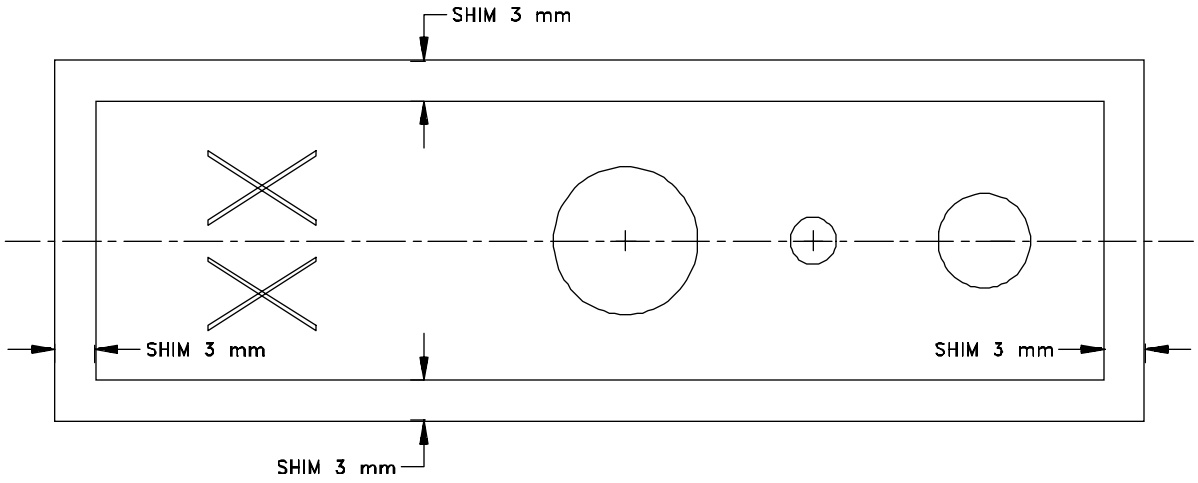


Intensification screens shall not be used. A lead symbol "B" shall be placed on the back side of the film as an indicator of insufficient protection from back scatter radiation. Films displaying the symbol "B" shall be retaken. Film length should be 440 mm.

Shims of a thickness equal to weld reinforcement shall be placed under IQI's as illustrated in Figure F-23.

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 Regional 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).

Figure F - 23 Shims for IQI's



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 all 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 Regional 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 nondestructive examination arrangement drawings in three copies.