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Welding Specification

Canadian Coast Guard

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Record of Amendments

#	Date	Description	Initials
1	April 2014	approved by DG.	
2	January 2016	Corrections made to some of the references herein, to section 5	CG
3	August 2017	CWB and NDT audit requirements, Clauses 5.6.1 and 5.6.2 Quantity of NDT required for New Construction, Clause 5.6.5.2 Undercut Acceptance Criterion, Clauses 5.6.9.2 and 5.6.10.2 Third Party Weld Inspection Requirement, Clause 5.6	L.P

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Foreword

This Specification has been prepared by Marine Engineering, Integrated Technical Services (ITS), Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.

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

When, this Specification 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.

Section 1 SCOPE

This Specification establishes the requirements of Marine Engineering, Integrated Technical Services, Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.

This Specification shall be followed whenever required by contract.

This Specification details the requirements for welding and non-destructive inspection of welds for structural steel, aluminum and stainless steel and the wide variety of other materials used for installation of pressure piping, pressure vessels and pressure containment systems and, shipboard equipment.

This Specification is intended as an Owner's requirement. In addition to this Specification, the Contractor shall meet all regulations and rules required by Transport Canada Marine Safety and Security and, the governing Classification Society as applicable.

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

Section 2 DEFINITIONS & ABBREVIATIONS

The following definitions and abbreviations apply in this Specification:

Approved (approval)	means reviewed and accepted by the Delegated Representative of the Director, Marine Engineering, unless otherwise specified.
Contractor	means the company to which a contract has been awarded by the Owner.
CWB	means the Canadian Welding Bureau.
Delegated Representative	means the individual that has been assigned the authority to represent the Director, Marine Engineering regarding matters related to the requirements of this Specification, as applied to a specific contract.
Engineer (in the referenced standards)	means the Delegated Representative.
Examination, Inspection, Testing	the act of looking at something closely, by either destructive or non-destructive methods, in order to learn more about it, to determine acceptance or rejection to a defined criterion, to locate problems.
Owner	means, in the context of this Specification as applied to a given contract, Marine Engineering, Integrated Technical Services (ITS), Canadian Coast Guard, Fisheries and Oceans Canada, Ottawa.
Pressure Piping	means any piping used to convey a fluid at a pressure above atmospheric pressure, unless otherwise stated.
Provincial Pressure Vessel Authority	means the organizations legislated by the Provinces of Canada to provide oversight for welding pressure piping, pressure vessels and pressure containment systems.
Structure (s) or Structural	means primary hull structure and secondary structure.
Structure, Primary Hull	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.
Structure, Secondary	means all of the vessel structure which is not included in the definition for primary hull structure.
Sub-Contractor	means the company to which a contract has been awarded by the Contractor.

Section 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 Specification (See Annex "A").

Use of the above-mentioned references shall be the latest edition approved by the organization issuing the publication specified at the time of contract award.

Except as noted in Chapter 1, when the requirements of other publications are in conflict with the requirements specified herein, the Delegated Representative shall be requested to establish precedence.

Section 4 ADMINISTRATION

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

For the purpose of administration, the Director, Marine Engineering shall delegate representatives that shall be responsible for measuring the Contractor's performance and ability to meet the requirements specified herein.

The Contractor shall allow the Delegated Representatives access to the facilities, files and records relative to the requirements of this Specification for the duration of the contract and warranty period.

The documentation that is to be made available to the Delegated Representatives shall include, but not necessarily be limited to, personnel qualification records, welding specifications and weld procedure data sheets, certification records, visual and non-destructive inspection results, quality control and quality assurance manuals and reports, and other associated documents.

Section 5 WELDING STRUCTURES

5.1 CONTRACTOR REQUIREMENTS

5.1.1 Steel Structures

All welding contractors shall be certified by the CWB to CSA Standard W47.1 Division 1 or 2 for new construction and work packages other than new construction.

5.1.2 Aluminum Structures

All welding contractors shall be certified by the CWB to CSA Standard W47.2 Division 1 or 2 for new construction and work packages other than new construction.

5.1.3 Welding Procedures

All welding procedure specifications and/or welding procedure data sheets shall be reviewed and approved by the CWB prior to use.

5.1.4 Welding Personnel

All welding personnel shall be approved by the CWB prior to their commencing any welding work

5.1.5 Performance and Qualification Testing

All performance and procedure qualification testing shall be fully witnessed and documented by the CWB.

5.1.6 Limitations Prior to Commencing Welding Work

All Contractors shall submit their welding personnel qualification records and approved welding procedures to the Delegated Representative prior to commencing any welding work.

All welding procedures, including welding procedure specifications and welding procedure data sheets, shall include an indication of acceptance by the Contractor (by signature, seal or other appropriate means) and a stamp of acceptance by the CWB.

5.1.7 Governing Standards for Welding

For structural steels $\geq$ 3 mm in thickness, welding shall meet the requirements of CSA Standards W47.1 and W59, except as modified by this Specification.

For structural aluminum $\geq$ 3 mm in thickness, welding shall meet the requirements of CSA Standards W47.2 and W59.2, except as modified by this Specification.

5.2 WELD DESIGN

Weld design shall be to the Rules of a Classification Society that is an approved Recognized Organization by Transport Canada Marine Safety and Security. Unless otherwise approved by the Delegated Representative, the following conditions shall be met:

- all groove welds in butt joints shall be full penetration; and,
- all corner joints shall be full penetration groove welds combined with single continuous fillet weld

A weld design schedule shall be submitted to the Delegated Representative in drawing form for review prior to commencing any welding work.

5.3 SYMBOLS FOR WELDING

Design drawings shall include weld requirement symbols and construction drawings shall include welding symbols following the requirements of CSA Standards W59 and W59.2. For fillet welds, the drawings shall indicate if the weld dimension shown in the symbol is throat size or leg length.

5.4 WELDING CONSUMABLES

This Section provides contractors means to quickly finding the information required to match welding consumables to the various grades of steel and aluminum materials used for shipbuilding and repair. For steel, cross reference is made between CSA welding consumable and shipbuilding material designations.

This Section also guides the contractor in the selection of corrosion resistant welding consumables for ships built of atmospheric corrosion resistant steels and for welds located in the external shell envelope of ice transiting ships. For welding processes other than those listed herein, consult the governing standards referenced in Chapter 5.1, Section 5.1.7 of this specification.

5.4.1 Steel

5.4.1.1 Electrode and Consumable Selection

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

Generally, the requirements of Tables 5.1- 5.5 inclusive shall apply involving use of steels having a yield stress below 360 MPa (N/mm^2) and charpy-v-notch toughness requirements at test temperatures above -45°C.

For other materials or conditions, welding electrodes and consumables shall be selected in accordance with the requirements of the following Sections of this Specification:

- Section 5.4.1.8 for higher strength notch tough steels;
- Section 5.4.1.9 for atmospheric corrosion resistant steels;
- Section 5.4.1.10 for Shell Butts & Seams – Ice Transiting Steel Ships

Welding electrodes and consumables for welding steel shall be certified by the CWB to the requirements of CSA Standard W48 or the applicable AWS A5 series of standards.

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

Care shall be taken not to overmatch weld metal mechanical properties.

5.4.1.2 Storage and Handling

Storage and handling of welding consumables, electrodes and fluxes shall be in accordance with the requirements of CSA Standard W59.

5.4.1.3 Low or Controlled Hydrogen Electrode Requirements

In addition to other factors that must be considered for matching weld metal deposits to various grades of base materials, welding processes and their respective welding electrodes and consumables produce varying amounts of hydrogen gas which may be retained in the deposited weld metal.

Although the amount of retained hydrogen may be reduced by increasing preheat temperatures, low and controlled hydrogen electrodes and consumables shall be required in accordance with Table 5.1.

Table 5.1 Selection of Low or Controlled Hydrogen Electrodes

Mandatory Use of Low & Controlled Hydrogen Electrodes		Other thanLow Hydrogen Electrodes (1)	
Material Grade	**Material Thickness**	**Material Grade**	**Material Thickness**
Gr. A Gr. E Gr. AH 32, 34 36 Gr. DH 32, 34, 36 Gr. EH 32, 34,36 Gr. FH 32, 36,40 Gr. FH 42 - 69	(t) ≥ 19 mm All Thicknesses	Gr. A	(t) ≤ 19 mm
Where (t) is the thickest member		**Where (t) is the thickest member**	

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

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

Basic or controlled hydrogen electrodes are required.

When the grades of base metals requiring low or controlled hydrogen electrodes and consumables are produced using thermo-mechanical controlled rolling practice, the Contractor may apply to the Delegated Representative for exemption from mandatory requirements listed in Table 5.1. Exemption will only be granted after due consideration of susceptibility to hydrogen assisted or induced cold cracking.

5.4.1.4 Shielded Metal Arc Welding (SMAW)

Welding electrodes for shielded metal arc welding normal and higher strength shipbuilding grade steels shall be selected following the requirements of Table 5.2.

Table 5.2 Selection of Welding Electrodes for Shielded Metal Arc Welding

Material Grade	CSA W48 Electrode
Grade A	E4300, 10, 11, 13, 27 (2) E4914, 24 (2) E4918, 28,48 (1)
Grade E	E4918-1 (1)
Grades AH32, 34, 36 DH32, 34, 36	E4918, 28, 48 (1)
Grades EH32, 34, 36	E4918-1 (1)
Grades EH40 FH-XX XX-40-69	 See Section 5.4.1.8 herein

NOTE: (1) As required in Table 5.1; (2) Restricted use as detailed in Table 5.1

5.4.1.5 Submerged Arc Welding (SAW)

Wire electrode-flux combinations for submerged arc welding normal and higher strength shipbuilding grade steels shall be selected following the requirements of Table 5.3.

Table 5.3 Selection of Wire Electrodes and Flux for Submerged Arc Welding

Base Material	CSA W48	
Grade	**Flux (1)**	**Electrodes**
Grade A	F43A1-XXXX F49A1-XXXX	XXXX-EL12 XXXX-EM12K
Grades E	F49A4-XXXX F49A5-XXXX	XXXX-EM12K XXXX-EM13K
Grades AH32, 34, 36 DH32, 34, 36	F49A1-XXXX F49A2-XXXX	XXXX-EM12K XXXX-EM13K
Grades EH32, 34, 36	F49A4-XXXX F49A5-XXXX	XXXX-EM12K XXXX-EM13K
Grades EH40 FH-XX XX-40-69	See Section 5.4.1.8 herein.	See Section 5.4.1.8 herein.

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

5.4.1.6 Flux Cored and Metal Cored Arc Welding (FCAW & MCAW)

Wire electrodes for flux cored arc welding and metal cored arc welding normal and higher strength shipbuilding grade steels shall be selected following the requirements of Table 5.4. Shielding gas type shall be in accordance with approved weld procedure data sheets for the wire electrode selected.

Table 5.4 Selection of Wire Electrodes for Flux Cored and Metal Cored Arc Welding

Base Materials	Wire Electrode					
Grade	**CSA W48**					
Grade A	E49X **See Note #2**	T	-1 (M) -5 (M) -6 (M) -8 -9 (M) -12 (M)	E490X **See Note #2**	T	-G (1) GS (1) -4 (1) -7 (1) -10 (1) -11(1)
	E49X **See Note #2**	C	-3 (M) -6 (M)	E49X **See Note #2**	C	-G (1)
Grades AH 32, 36 DH 32, 36	E49X **See Note #3**	T	-1 (M) -5 (M) -6	E49X **See Note #3**	T	-8 -9 (M) -12 (M)
	E49X **See Note #3**	C	-3 (M) -6 (M)	E49X **See Note #3**	C	-G1
Grades E EH 32, 36	E49X-T-X(X)-J, E49X-C-X(X)-J **See Notes #3 & 4** E49X-T-X(X)-J, E49X-C-X(X)-J **See Notes #3 & 4** E55X-T-X(X)-J, E55X-C-X(X)-J **See Notes #3 & 4**					
EH40 FH-XX XX-40-69	No pre-approved consumables. See Section 5.3.2.8 herein. Qualification Tests are required using the shielding gas type planned for production.					

1. Submit for approval;
2. H16 designation for the thicknesses required by Table 5.1
3. H16 designation for all thicknesses.
4. Must carry "J" designation, average impact energy of 27 j @ -40

5.4.1.7 Gas Metal Arc Welding (GMAW)

Wire electrodes for gas metal arc welding normal and higher strength shipbuilding grade steels shall be selected following the requirements of Table 5.5. Shielding gas type shall be in accordance with the approved weld procedure data sheets for the wire electrode selected.

Table 5.5 Selection of Wire Electrodes for Gas Metal Arc Welding

Base Materials	**Wire Electrodes**
Marine Grade	**CSA W48:06 CAN/ISO 14341:06**
Grade A t ≤ 19 mm…… t > 19 mm……	 ISO 14341-B-G-49A-X-X-XX ISO 14341-B-G-49A-2-X-XX ISO 14341-B-G-49A-3-X-XX
Grade E	ISO 14341-B-G-49A-4-X-XX ISO 14341-B-G-49A-5-X-XX ISO 14341-B-G-49A-6-X-XX
Grades AH 32, 36 & DH 32, 36 EH 32, 36	 ISO 14341-B-G-49A-2-X-XX ISO 14341-B-G-49A-3-X-XX ISO 14341-B-G-49A-4-X-XX ISO 14341-B-G-49A-5-X-XX ISO 14341-B-G-49A-6-X-XX ISO 14341-B-G-55A-4-X-XX ISO 14341-B-G-55A-5-X-XX ISO 14341-B-G-55A-6-X-XX
Grades : EH40 FH-XX XX-40-69	No pre-approved consumables. Section 5.4.1.8 herein. Qualification Tests are required using the shielding gas type planned for production

Wire electrodes approved by the yield strength and average impact values of 47 J, the “A” suffix method, shall be submitted to the Delegated Representative for review and acceptance. Weld procedure qualification testing is required.

5.4.1.8 Electrodes for Higher Strength Notch Tough Steels

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

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

As a minimum, welding electrodes and consumables shall match the base metal strength (UTS, YS and elongation) and notch toughness properties at the base metal test temperature.

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

Assemblages, type of tests and specimens shall be in accordance with CSA Standard W47.1. Each procedure qualification test shall be supplemented with 15 charpy-v-notch specimens; 5 specimens with the "v" notch located at the centre of the joint, 5 specimens with the "v" notch intersecting the line of fusion and 5 specimens with the "v" notch located 5 mm from the fusion line (HAZ). Charpy-v-

notch specimens shall be tested in accordance with the requirements of CSA Standard W47.1 at test temperatures equivalent to that of the base metal classification (ie. E & EH @ -40°C, FH @ -60°C, etc). The minimum acceptance requirements for each test method shall be those requirements of the test specification under which the base metal was qualified.

5.4.1.9 Electrodes for Atmospheric Corrosion Resistant Steels

Welding electrodes and consumables for joining atmospheric corrosion resistant steels such as CSA Standard G40.21 grades 350A, 350AT, 400A and 400AT including ASTM grades A242 and A588 steels shall be carefully selected to match the copper and nickel content of the base plate and the ultimate and yield strength, elongation and toughness properties. Close attention shall be paid to matching all of the chemical elements that prevent corrosion in sea water.

Butts and seams in the shell, weather decks and all welds in uncoated ballast tanks shall be performed with welding electrodes and consumables that are proven to be resistant to weld zone (weld deposit and HAZ) corrosion in accordance with the requirements of Section 5.4.1.10 herein. These requirements also apply to weld repair of scars in shell plating caused by removal of temporary attachments and permanent markings made by welding. There are no pre-approved corrosion resistant weld metal deposits for welding atmospheric corrosion resistant steels. For welds in other locations of primary and secondary structure, electrodes and consumables may be selected and matched in accordance with the requirements of CSA Standard W59.

5.4.1.10 Shell Butts & Seams – Ice Transiting Steel Ships

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

For shielded metal arc welding, E5518-C3 is approved for use without testing. There are no other pre-approved corrosion resistant consumables for any welding process.

Once the Contractor has matched a welding electrode and consumable to the minimum base plate mechanical property requirements of this Specification; coupons shall be prepared, welded and tested for corrosion resistance in sea water by conducting anodic dissolution tests as outlined in Annex “B” of this Specification. Two weld coupons shall be made for each weld metal/base metal combination; one test each at the anticipated minimum and maximum heat inputs (kj/mm) planned for production welding. Welding bead sequence for these tests must employ a stringer temper bead technique as illustrated in Annex B of this Specification. No weaving is permitted.

The target acceptance criterion sought is near equivalent loss of the base plate, heat affected zone and weld metal deposit. Since this may not always be accomplished for all grades of base metal, slight loss of weld metal is desired over any loss in the heat affected zone. Anodic dissolution test results shall be tabulated and submitted to the Delegated Representative for approval.

For finishing layers of welds located on the external shell plating of ice transiting ships, a temper bead approach shall be employed similar to what is illustrated in Figure 5.1.

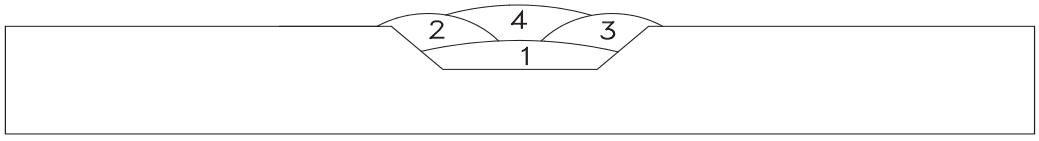


Figure 5.1 Temper Bead Approach for Finishing Layers in Shell Plating

The first layer of corrosion resistance weld metal shall be deposited 5 mm below the plate surface.

5.4.2 Aluminum

5.4.2.1 Electrode and Consumable Selection

Welding electrodes, rods and consumables shall be matched to the base metal in accordance with the requirements of CSA Standard W59.2. All welding electrodes, rods and consumables shall be certified by the CWB to the requirements of AWS A5.10.

5.4.2.2 Storage and Handling

Storage and handling of welding electrodes, rods and consumables shall be in accordance with the requirements of CSA Standard W59.2.

5.5 WORKMANSHIP

5.5.1 Environment

The work being welded shall be adequately protected against the direct effects of wind, rain and snow throughout the welding operation.

Welding steel at ambient temperatures below -18°C requires approval in accordance with CSA Standard W59. Aluminum welding shall not be carried out when the work surfaces are damp or wet or at ambient temperatures below 0°C.

Welding with processes that utilize externally supplied shielding gas shall not be performed in a draught or wind unless the weld zone is protected from loss of shielding gas as required by CSA Standards W59 and W59.2 for steel and aluminum, respectively.

5.5.2 Preheat and Interpass Temperatures

Preheating and interpass temperatures for welding steel and aluminum shall follow the requirements of CSA Standards W59 and W59.2, respectively.

5.5.3 Plate Forming

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

Heat line bending of aluminum requires special consideration and approval. Annex “C” of this Specification offers guidance notes on hot and cold forming practices for aluminum.

5.5.3.1 Personnel

Personnel performing heat line bending shall be trained and qualified prior to forming plates for production or repair of distortion. A list of qualified personnel shall be submitted to the Delegated Representative prior to any heat line bending operations.

5.5.3.2 Materials

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

5.5.3.3 Procedures

For those pre-approved shipbuilding grades of steel listed in Section 5.5.3.2 herein, forming is not to be performed between 205° C and 425° C. If the forming temperature exceeds 650° C for as-rolled, controlled rolled or normalized steels, mechanical tests are to be made to assure that these temperatures have not adversely affected the mechanical properties of the steel. Water quenching should not occur at temperatures above 550° C.

For applications where toughness is of particular concern, when the steel is formed below 650° C beyond 3% strain on the outer fibre, charpy-v-notch impact tests shall be performed to the satisfaction of the Delegated Representative to demonstrate impact properties meet material specification minimum requirements. The percent strain on the outer fibre shall be calculated by; 65 times the plate thickness divided by the outer radius.

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

5.5.3.4 Controls

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

5.5.4 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.

For tee joints in the skewed condition, the deposited leg length of fillet welds shall be adjusted based on the fitted angle and gap as required by CSA Standards W59 and W59.2 for steel and aluminum, respectively. Gaps shall not exceed 5 mm and the dihedral angle shall not exceed 135°.

5.5.5 Adjacent Weld Spacing

The minimum dimension between adjacent groove welds that do not appear on approved drawings or form part of an insert located in shell plating shall be 300 mm minimum.

The minimum dimension between a groove weld in a table member and a fillet weld to the same table member that do not appear on approved drawings shall be 30 mm minimum.

The minimum dimension between fillet welds attaching an abutting member to a table member and a groove weld in the same abutting member that do not appear on approved drawings shall be 300 mm minimum.

5.5.6 Inserts and Doublers

Where 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 1000 mm x 1000 mm. When an insert is to be located in other locations the minimum dimension shall be 300 mm x 300 mm. Welds should be connected to existing butts and seams whenever possible. The minimum corner radius used for all insert plates independent of location shall be 5 (t), 75 mm minimum.

For shell and weather deck plating, the rolling direction of an insert plate shall be fitted to match the rolling direction of the surrounding base plates.

Welding sequences shall be carefully developed in order that shrinkage stress is balanced and restraint cracking does not occur.

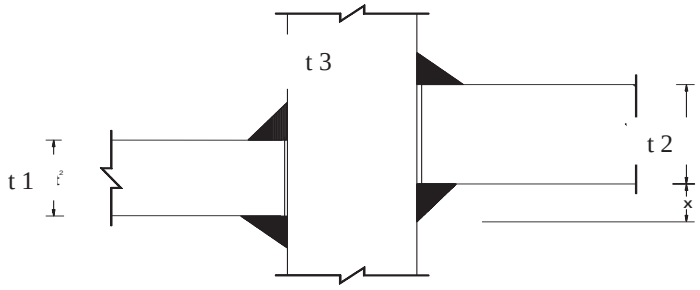
5.5.7 Edge Preparation and Fitted Tolerances

The edge preparation is to be accurate and uniform and the parts to be welded are to be fitted in accordance with the approved joint detail. Means are to be provided for maintaining the parts to be welded in correct position and alignment during the welding operation.

Occasional misalignment of joints fitted for welding shall not exceed dimensional tolerances detailed in CSA Standards W59 and W59.2 for steel and aluminum, respectively, and this Specification.

5.5.8 Intercostals

The occasional misalignment of intercostals for steel structures shall not exceed the limitations illustrated in Figure 5.2.



(X) = misalignment measured on the heel line; Where t 3 is less than t 1, then t 3 should be substituted for t 1		
For Strength Members:	- When (X) ≤ $t^1/3$	Increase Fillet Leg Size Equal to Offset
	- When (X) > $t^1/3$	Release and Re-Align
For Other Members:	- When (X) ≤ $t^1/2$	Increase Fillet Leg Size Equal to Offset
	- When (X) > $t^1/2$	Release and Re-Align

Figure 5.2 Intercostals

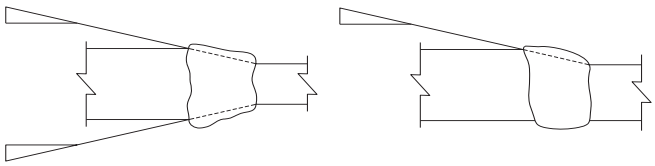
Misalignment of intercostals is not permitted in aluminum structures.

5.5.9 Dissimilar Plate Thickness

Plates of different thicknesses that are groove welded require a transition as follows:

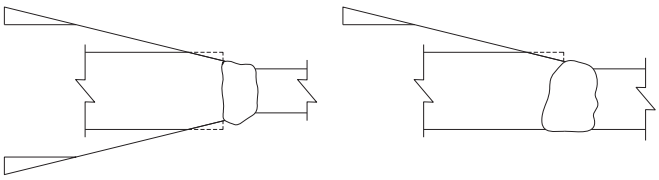
- Exterior Shell Plating of Ice Transiting Steel Ships, 1 in 4
- Other, 1 in 3

When the difference in thickness is less than or equal to 5 mm and 3 mm for steel and aluminum, respectively, the transition may be created by welding as illustrated in Figure 5.3



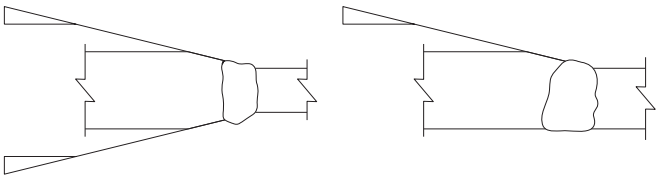
TRANSITION BY SLOPING WELD SURFACE

Figure 5.3 Sloping Weld



TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING AFTER WELDING

When the difference in thickness exceeds 5 mm and 3 mm for steel and aluminum, respectively, the transition may be achieved by chamfering or a combination of chamfering and welding as illustrated in Figure 5.4.



TRANSITION BY CHAMFERING THICKER PART PRIOR TO WELDING

Figure 5.4 Chamfering

5.5.10 Flush Tolerance

Surfaces of welds required to be flush shall meet requirements of CSA Standards W59 and W59.2 for steel and aluminum, respectively. In addition, for aluminum the weld shall be finished so as not to reduce the cross section below the base metal's mill tolerance set by the material's compliance standard.

5.5.11 Smooth Tolerance

Surfaces of groove welds required to be smooth shall be finished so as to ensure that the weld reinforcement does not exceed 1.5 mm. There shall be no valleys or grooves between individual weld beads and weld toes shall blend smoothly into the base metal without undercut or overlap.

5.5.12 Preparation of Welds for the Application of Coatings or Paints

Completed welds shall be prepared to the requirements of the coating and/or paint manufacturer prior to the materials being applied.

5.5.13 Distortion and Residual Stress

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

It should be noted, plain carbon steels are more forgiving than aluminum. The thermal expansion coefficient of aluminum is about twice that of steel. The total amount of thermal expansion varies inversely with the welding speed. As a result, fixtures should be designed so 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 more prone to cracking under restraint.

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

5.5.13.1 Submission of Welding Sequence

All Contractors shall submit a welding sequence to the Delegated Representative prior to performing any welding work. Welding sequences shall be developed for the method of construction (block or frame and plate) and for insert plates.

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

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

5.5.13.2 Restrained Joints

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

5.5.13.3 Jigs and Fixtures

Jigs, fixtures, clamping and strong backs shall be used in such a manner as to avoid restraint during welding. Strong backs welded on one side of the joint and wedged on the other are preferred. When removing strong backs, care shall be taken not to scar the material to which they are welded. Repair of scars to base plates shall be in accordance with approved procedures.

5.5.13.4 Progression

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

Welding should be started in the centre of the ship and progress outward, forward and aft. Sub-assemblies should be welded in the same manner starting in the centre, progressing outward.

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

5.5.13.5 Intersections and Release Distance

Care shall be taken when welding intersecting butts and seams. The techniques illustrated in Figure 5.5 and Figure 5.6 shall be followed.

1. Weld the butt between (B) and (C) and then the weld seam between (A) and (B).

Figure 5.5 Staggered Butt Weld

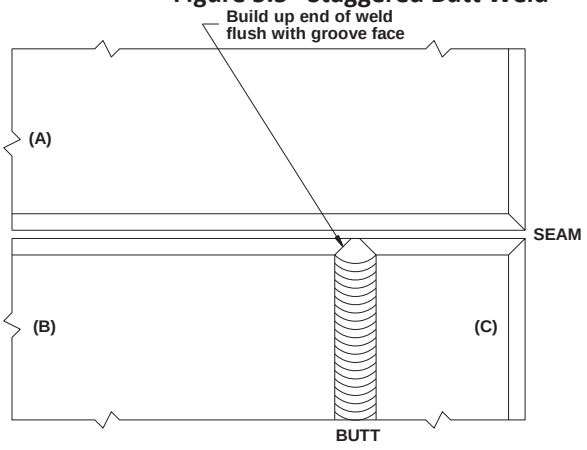
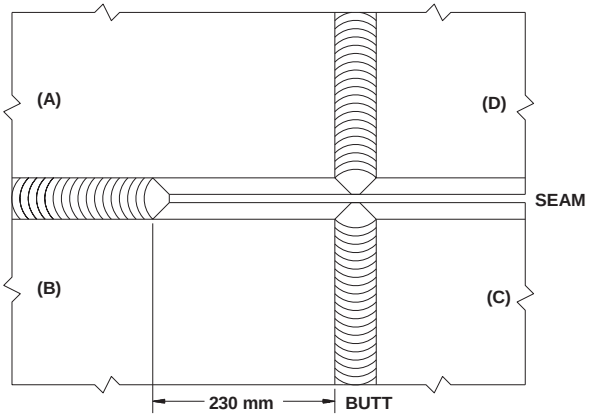


Figure 5.6 Aligned Butt Weld



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

Stiffeners fillet welded to plating that traverse butts or seams shall be released and remain unwelded for a distance of at least 230 mm in each direction until butts or seams they traverse have been fully welded. For plates $\geq$ 19 mm in thickness, release distance shall be increased to 300 mm minimum.

5.5.14 Repair of Distortion

When distortion of plating between stiffeners exceeds the limits detailed in Table 6.10 of IACS No. 47, Shipbuilding and Repair Quality Standard as reproduced below, straightening shall be required.

Members distorted by welding shall be straightened by carefully following the procedures approved by the Delegated Representative following the methods and controls offered in CSA Standards W59 and W59.2 for steel and aluminum, respectively, and this Specification.

Item	Standard	Limit	Item	Standard	Limit
Shell plate • Parallel part (side & bottom shell) • Fore and aft part	 4 mm 5 mm	 8 mm 8 mm	Forecastle & Poop deck • Bare part • Covered part	 4 mm 6 mm	 8 mm 9 mm
Tank top plate	4 mm	8 mm	Super structure deck • Bare part • Covered part	 4 mm 7 mm	 6 mm 9 mm
Bulkhead • Longl. Bulkhead • Trans. Bulkhead • Swash Bulkhead	 6 mm	 8 mm	House wall • Outside wall • Inside wall • Covered part	 4 mm 6 mm 7 mm	 6 mm 8 mm 9 mm
Strength deck • Parallel part • Covered part • Fore and aft part	 4 mm 6 mm 7 mm	 8 mm 9 mm 9 mm	Interior member (web of girder, etc.)	5 mm	7 mm
Second deck • Bare part • Covered part	 6 mm 7 mm	 8 mm 9 mm	Floor and girder in double bottom	5 mm	8 mm

5.5.15 Temporary Welds and Lug Removal

5.5.15.1 Temporary Welds

Temporary welds shall not be located on a welded butt or seam.
Temporary welds shall only be made using approved weld procedures.

5.5.15.2 Lug and Temporary Attachments

For the hull exterior, exposed bulkheads, decks, panels, superstructure, walkways, bulwarks, fairleads, bollards, and any other zone deemed necessary to avoid operational hazards and to provide a good cosmetic appearance to the vessel, all lugs, temporary fairing aids, studs, etc., shall be removed to render a flush and smooth surface.

5.5.15.3 Removal of Temporary Welds, Lugs and Attachments

Temporary welds shall be removed and the surface restored flush with the original surface.
Hammering or other mechanical means that will result in scars to base material shall be avoided.
Scars in plate surfaces shall be repaired by welding with approved procedures.

Welding electrodes and consumables for repairing scars in exterior shell plating shall be corrosion resistant in sea water and completed welds shall meet the acceptance criterion of this Specification.

Repair welds shall be ground flush or smooth as required by the Delegated Representative.

5.5.16 Arc Strikes

Arc strikes outside the area of welds should be avoided following the requirements of CSA Standards W59 and W59.2 for steel and aluminum, respectively, and of this Specification.
When an arc strike occurs in a location deemed critical by the Delegated Representative, the surface shall be lightly ground and inspected with the appropriate non-destructive inspection methods.
Repair of arc strikes shall be to the satisfaction of the Delegated Representative.

5.6 WELD INSPECTION REQUIREMENTS

All non-destructive inspections required in this Specification shall be considered the minimum requirements of the Owner and performed by a qualified third party retained by the contractor. The method and location of inspections shall be determined by the Delegated Representative. Inspection test results shall be returned to the Delegated Representative within requested time frame. No interpretation report or radiograph shall be destroyed or discarded.

The minimum number of locations ordered for examination at one time shall be a combination of any method cumulatively totalling 10, unless otherwise agreed to by the Delegated Representative.

Contractors desiring to use ultrasonic inspection in lieu of radiographic inspection to examine welds located in steel structures shall submit a detailed proposal to the Delegated Representative to consider. At the Delegated Representatives' discretion, ultrasonic inspection may be accepted in lieu of radiographic inspection if the length of inspection is as required for ultrasonic inspection in Table 5.7 herein and the ultrasonic inspection procedures and techniques are proven accurate and repeatable by 30% spot radiography of the first fifteen locations examined by ultrasonic methods. Substitute inspection methods are not permitted for examining welds located in aluminum structures.

5.6.1 Facility Welding Audits

In addition to the CWB biannual audits required to maintain certification to CSA Standards W47.1 and W47.2, at its own expense, the Owner shall retain the services of the CWB to perform audits of the contractor at a frequency deemed necessary by the Owner. The Owner's CWB auditor will not be the Certification Services Representative performing the contractor's biannual certification audits. The Owner's CWB audits shall measure the contractor's compliance with the requirements of this Specification and include as a minimum a pre-weld, weld, post weld and contractor third party inspection documentation review and check.

5.6.2 Non Destructive Inspection Audits

The Owner reserves the right to retain the services of the National Non Destructive Testing Certification Body of Natural Resources Canada (NRCAN) or another organization acceptable to the Owner to perform review and audits of NDT personnel qualifications, procedures, inspection activities and reported results. Audits shall measure the contractor's compliance with the requirements of this Specification.

5.6.3 Selection of Non Destructive Inspection Methods

The method of inspection shall be appropriate to depict discontinuities dependent on the material, joint and weld type, the orientation of potential discontinuities within the weld cross section and access to the part in need of inspection. All welds shall be examined by visual inspection.

Full penetration welds shall be selectively sampled by radiographic and ultrasonic inspection methods. Radiographic inspection shall be used for full penetration groove welds in butt joints. Ultrasonic inspection shall be used for full penetration groove welds in tee and corner joints.

Fillet welds in steel structures shall be selectively sampled by liquid penetrant and magnetic particle inspection. Fillet welds in aluminum structures shall be selectively sampled by liquid penetrant inspection.

5.6.4 Locations Subjected to Inspection

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

Table 5.6 Locations Subjected to Inspection

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

The exact position of inspections shall be determined by the Delegated Representative

5.6.5 Extent of Inspections

5.6.5.1 Visual Inspection:

All welds shall be visually inspected their entire length.

5.6.5.2 NDE Methods – New Construction

For new construction, in addition to the requirements of Section 5.6.5.1 herein, the number of locations inspected by liquid penetrant, magnetic particle, radiographic and ultrasonic test methods shall be in accordance with the calculated requirements of Table 5.7a or Table 5.7b herein.

Table 5.7a Quantity of Inspections – New Construction Vessels ≥12 m LOA

Inspection Method	Formula for Determining the Number Required	
	Steel Vessels	**Aluminum Vessels**
UT Inspections	= 0.25 x (L+B+D)	= N/A
MT or PT Inspections	= 0.50 x (L+B+D)	= N/A for MT = 0.75 x (L+B+D) for PT
RT Inspections	= 0.75 x (L+B+D)	= 1.25 x (L+B+D)
Where: PT= Penetrant Inspections, **MT**= Magnetic Particle Inspections, **RT**= Radiographic Inspections, **UT**= Ultrasonic Inspections and **L**= Overall Length in meters, **B**= Greatest Moulded Breadth in meters and **D**= Moulded Depth at Side, in meters, measured at L/2.		

For example following the requirements of Table 5.7a: A lifeboat 15 meters in length having a breadth of 4.5 meters and a moulded depth of 2 meters will require:

Inspection Method	Formula for Determining the Number Required	
	Steel Vessels	**Aluminum Vessels**
UT Inspections - 1000 mm – butts or seams - 500 mm x 500 mm– intersecting butts & seams	= 6	= N/A
MT or PT Inspections - 1000 mm	= 11	= N/A for MT = 16 for PT
RT Inspections - 440 mm – butts or seams - 300 mm x 300 mm – intersecting butts & seams	= 16	= 26

Table 5.7b Quantity of Inspections – New Construction Vessels <12 m LOA

Inspection Method	Formula for Determining the Number Required	
	Steel Vessels	**Aluminum Vessels**
UT Inspections - 1000 mm – butts or seams - 500 mm x 500 mm– intersecting butts & seams	= 0.25 x (L+B+D)	= N/A
MT or PT Inspections - 1000 mm	= 0.50 x (L+B+D)	= N/A for MT = 0.50 x (L+B+D) for PT
RT Inspections - 440 mm – butts or seams - 300 mm x 300 mm – intersecting butts & seams	= 0.75x (L+B+D)	= 1.00 x (L+B+D)
Where: PT= Penetrant Inspections, **MT**= Magnetic Particle Inspections, **RT**= Radiographic Inspections, **UT**= Ultrasonic Inspections and **L**= Overall Length in meters, **B**= Greatest Moulded Breadth in meters and **D**= Moulded Depth at Side, in meters, measured at L/2.		

For example following the requirements of Table 5.7b: A service craft 10 meters in length having a breadth of 3.0 meters and a moulded depth of 1.00 meter will require:

Inspection Method	Formula for Determining the Number Required	
	Steel Vessels	**Aluminum Vessels**
UT Inspections	= 4	= N/A
MT or PT Inspections	= 8	= N/A for MT = 8 for PT
RT Inspections	= 10	= 14

When access does not permit the use of 300 mm by 300 mm film size at intersecting butts and seams, a series of films shall be positioned to offer examination of 150 mm of weld in all directions.

5.6.5.3 NDE Methods - Other

For work packages other than new construction, in addition to the requirements of Section 5.5.6.1 herein, the number of locations inspected by liquid penetrant, magnetic particle, radiographic and ultrasonic test methods shall be in accordance with the requirements of Table 5.8 herein.

Table 5.8 Quantity of Inspections – Other

Item	Method	Number
Entire Plate Renewal – Butts & Seams (shell, decks, bulkheads, tanktop etc)	RT	6 per plate
Entire Plate Renewal – Butts & Seams (secondary structure)	RT	2 per plate
Partial Plate Renewal – Butts & Seams (primary & secondary structure)	RT	See inserts herein
Insert – Butt & Groove Welds (shell, decks, bulkheads, tanktop etc.)	RT	4 per insert
Insert – Groove Welds (other primary structure)	RT	2 per insert
Insert – Groove Welds (secondary structure)	RT	1 per insert
Hull Penetration – Pipe or Plate to Shell Plate Opening (below waterline)	UT	Entire Weld Length
Pressure Pipe Girth Welds	RT	1 of each 5 welds Full Circumference

5.6.6 Surface Preparation Prior to Inspection

Prior to inspection by any method, welds and adjacent areas shall be cleaned so as to be free from all rust, scale, primer, paint, weld spatter and other foreign matter to enable accurate interpretation of the area of interest (weld zone). Staging and lighting shall be provided to permit safe access for inspection.

For liquid penetrant, magnetic particle and radiographic inspections weld profiles and contours shall be sufficiently smooth to ensure that geometric conditions do not cause false indications.

For ultrasonic inspection, the contact surfaces shall be smooth to the extent that the finish does not interfere with the inspection. Tests performed on rough surfaces shall require special calibration procedures.

5.6.7 Delayed Inspection

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

5.6.8 Inspection Personnel Qualifications and Certificates

5.6.8.1 Visual Inspection

Individuals performing and interpreting visual inspection shall be currently certified by the CWB in accordance with CSA Standard W178.2, Certification of Welding Inspectors. The individual shall be Level 2 or Level 3 and shall maintain the following Code endorsement categories: Ships and Marine Structures; and Buildings and Industrial Structures. Level 1 personnel may only observe and/or assist Level 2 and Level 3 personnel perform the inspections.

5.6.8.2 Other Inspection Methods

Individuals performing and interpreting liquid penetrant, magnetic particle, radiographic and ultrasonic inspections shall be currently qualified by the National Non Destructive Testing Certification Body of Natural Resources Canada (NRCAN) to CAN/CGSB 48.9712 Level 2 or Level 3. Level 1 personnel may only observe and/or assist Level 2 and Level 3 personnel perform the inspections.

5.6.8.3 Certificates

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

5.6.9 Steel Structures

5.6.9.1 Inspection Procedures

Inspection procedures and techniques are to be prepared by Level 3 personnel for each inspection method required by this Specification and submitted to the Delegated Representative prior to performing any inspections of completed work. Procedures for visual inspection shall follow the requirements of Clause 7 of CSA Standard W59 and ASME Section V. Procedures for liquid penetrant and magnetic particle inspections shall follow the requirements of Clause 7 of CSA Standard W59. Procedures for radiographic and ultrasonic inspections shall follow the requirements of Clauses 7 and 8 of CSA Standard W59.

5.6.9.2 Acceptance Criterion

Visual and liquid penetrant inspection acceptance criterion shall be in accordance with Clause 12.5.4.1 of CSA Standard W59, except as modified by this Specification and the following:

- For welds in material thicknesses less than 5 mm, undercut must not exceed 0.5 mm.
- For welds in material thicknesses greater than or equal to 5 mm, undercut must not exceed 1.0 mm
- Pores open to the surface are not permitted in any weld of the primary structure as well as any weld of the secondary structure exposed to weather elements and fluids of any type.

The magnetic particle inspection acceptance criterion shall be in accordance with Clause 12.5.4.1 or 12.5.4.3 of CSA Standard W59. The radiographic inspection acceptance criterion shall be in accordance with Clause 12.5.4.3 of CSA Standard W59. The ultrasonic inspection acceptance criterion shall be in accordance with Clause 12.5.4.4 of CSA Standard W59.

5.6.9.3 Radiographic Inspection

5.6.9.3.1 Source of Radiation

Radiographs shall be made by either x-ray or gamma ray as follows:

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

5.6.9.3.2 Radiographic Film

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

- for x-ray on material thickness less than 6 mm, class II film may be used providing the 2-2(t) hole is clearly visible on the radiograph. Otherwise, class I film shall be used;
- when the material thickness is greater than or equal to 6 mm and less than 12 mm, class I film and iridium 192 gamma radiation shall be used;
- when the material thickness is greater than or equal to 12 mm, class I or class II film and iridium 192 gamma radiation may be used.

5.6.9.3.3 Display of Information and IQI Essential Holes

The exposed radiograph shall show the outline of the “Hole Type” Image Quality Indicator (IQI), shims, IQI identification number, essential hole, radiograph identification number, location markers, date it was taken, reference to the contract number or vessel identification and radiographer's initials.

- When x-ray is used on materials thicknesses < 6 mm, the image of the 2-2(t) hole shall appear clearly on the radiograph.
- When iridium 192 gamma radiation is used on material thicknesses $\geq$ 6 mm but < 12 mm where class 1 film is required, the image of the 2-2(t) hole shall appear clearly on the radiograph.
- When iridium 192 gamma radiation is used on material thicknesses $\geq$ 12 mm but $\leq$ 30 mm, the image of the 2-4(t) hole shall appear clearly on the radiograph.
- When iridium 192 gamma radiation is used on material thicknesses greater than 30 mm, the image of the 2-2(t) hole shall appear clearly on the radiograph.

5.6.9.3.4 Intensification Screens

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.

5.6.10 Aluminum Structures

5.6.10.1.1 Inspection Procedures

Inspection procedures and techniques are to be prepared by Level 3 personnel for each inspection method required by this Specification and submitted to the Delegated Representative for approval prior to use.

Procedures for visual inspection shall follow the requirements of Clause 7 of CSA Standard W59.2 and ASME Section V. Procedures for liquid penetrant, radiographic and ultrasonic inspections shall follow the requirements of Clause 7 of CSA Standard W59.2, and of this Specification.

5.6.10.2 Acceptance Criterion

The visual, liquid penetrant, radiographic and ultrasonic inspection acceptance criterion shall be in accordance with Clause 6 of CSA Standard W59.2, except as modified by this Specification and the following:

- For welds in material thicknesses less than 5 mm, no undercut is permitted.
- For welds in material thicknesses greater than or equal to 5 mm, undercut must not exceed 0.5 mm.
- Pores open to the surface are not permitted in any weld of the primary structure as well as any weld of the secondary structure exposed to weather elements and fluids of any type.

If visual inspection reveals melt-through or suck-back, the affected weld metal or material shall be dressed by mechanical methods, repair welded if required and examined by liquid penetrant inspection its entire length.

5.6.10.3 Radiographic Inspection

5.6.10.3.1 Source of Radiation

Radiographs shall be made by x-ray. The maximum permissible kilovoltages shall be as shown in Table 5.9

Table 5.9 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

5.6.10.3.2 Radiographic Film

All radiographic film shall be class I only.

5.6.10.3.3 Display of Information and IQI Essential Holes

The exposed radiograph shall show the outline of the “Hole Type” Image Quality Indicator (IQI), shims, IQI identification number, essential hole, radiograph identification number, location markers, the date it was taken, reference to the contract number or vessel identification and the radiographer's initials.

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.

5.6.10.3.4 Intensification Screens

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.

5.6.11 Double Loaded Film Requirement

All radiographic inspection shall be taken with a double loaded film technique so that two film negatives are obtained for each inspection. One film negative shall be sent to the Director, Marine Engineering and the other film negative shall remain at the work site in the possession of the onsite Delegated Representative. At contract completion, the film negatives stored at the work site shall be sent to the Director, Marine Engineering.

5.6.12 Radiographic Film Viewer

The Contractor shall have a professional radiographic film high intensity viewer capable of penetrating film densities of 1.5 to 4.5. The viewer shall be kept at the work site and available for use by the Contractor and Delegated Representatives for the entire duration of the contract and warranty period.

5.6.13 Inspection Reports

Inspection reports shall record the date of inspection, builder/Contractor's name, vessel type and hull number, Owner's name, inspection organizations name, inspection procedure number, interpretation report number, item, location, all discontinuities including single and accumulated indications, weld acceptance criteria, location of discontinuities and the name, qualification, level and signature of the individuals performing the inspection and interpretation. Inspection reports shall reference material type, thickness, joint type and geometry.

When a portion of a weld is to be inspected by liquid penetrant, magnetic particle, radiographic or ultrasonic methods, the location shall be subjected to visual inspection in advance of the other inspection method. Interpretation reports are required for both inspection methods.

5.6.13.1 Visual Inspection

For block assembly new construction methods, a visual inspection verification report is required for each fabricated block and joining of blocks to each other.

For frame and plate new construction methods or work packages other than new construction, a verification report is required for each fabricated compartment (e.g. between two adjacent bulkheads/engine room compartment).

The verification report shall be a statement signed off by the Contractor's qualified inspector which states all welds have been inspected and they conform to requirements of this Specification. Verification reports shall be presented to the Delegated Representative prior to the Owner's scheduled audit date.

5.6.13.2 Radiographic Inspection

In addition to the requirements of Sections 5.6.13 and 5.6.13.1, radiographic interpretation reports shall reference IQI design and identification number, source of radiation, source to film distance, angle of incident radiation, film type and intensification screen design (if permitted) and, material type, thickness, joint type and geometry.

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

For radiographs, each film and its duplicate shall be submitted in a paper protective folder. The identification to appear on each folder shall be Inspection #, Report # and Hull # as illustrated below.

Inspection #		Report #		Hull #
3	-	1	-	218

Each repaired location shall reference the original report of the rejected location, for example:

Location #50	-	Port R1	-	See 3-1-218

5.6.13.3 Inspection Arrangement Drawings

The Contractor shall prepare an adequate number of non-destructive inspection arrangement drawings and sketches that accurately document the location of the inspections.

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

The Contractor shall supply updated arrangement drawings to the Delegated Representative on a regular basis throughout the contract period. Three copies of the final drawings shall be supplied to the Delegated Representative at contract completion.

5.6.14 Overlapping Inspection

When a discontinuity extends to either or both ends of a location being inspected, additional overlapping inspection shall be required. The overlapping inspection shall show a portion of the original end.

When an overlapping inspection displays unacceptable discontinuities at either or both ends, the entire weld length shall be considered unacceptable unless proven otherwise by the Contractor. Under this condition, welds shall be repaired to the extent required by the Delegated Representative.

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

The Contractor shall be responsible for all costs associated with performing overlapping inspections.

5.6.15 Rejected Weld or Part

When a portion of a weld contains discontinuities not meeting the acceptance criteria of this Specification, corrective action may be taken providing the Delegated Representative has reviewed the extent of unacceptable discontinuities and is in agreement with the repair procedure.

The repaired area shall be inspected by at least the same non-destructive inspection method used for the original inspection. Care shall be taken to ensure that the inspection of the repaired area is accurately located so that it measures the original location that was rejected.

For each failed location, one new location shall be examined. All new locations shall be selected by the Delegated Representative. Each new location shall be considered in addition to the requirements of this Section. All costs associated with performing the additional inspections shall be at the Contractor's expense.

When an entire weld, base material, entire part or entire section contains unacceptable discontinuities as specified herein, no corrective action shall be taken until the repair procedure has been approved by the Delegated Representative and other interested parties.

Section 6 WELDING STRUCTURAL STAINLESS STEEL

6.1 SCOPE

The requirements of this Section shall apply to welding and inspection of all structural stainless steels.

6.2 DESIGN AND DRAWINGS

Weld design shall be to the Rules of a Classification Society that is an approved Recognized Organization by Transport Canada Marine Safety and Security.

Unless to the otherwise approved by the Delegated Representative, the following conditions shall be met:

- all groove welds in butt joints shall be full penetration; and,
- all corner joints shall be full penetration groove welds combined with a single continuous fillet weld.

A weld design schedule shall be submitted to the Delegated Representative in drawing form for review prior to commencing any welding work.

6.3 CERTIFICATION

Contractors undertaking the welding of stainless steel within the scope of this Specification shall be certified by the CWB to the requirements of CSA Standard W47.1 Division 1 or 2.

Welders, welding operators and welding procedures shall meet the requirements of CSA Standard W47.1, and of AWS D1.6 as permitted by CSA Standard W47.1.

6.4 WELDING ELECTRODES AND CONSUMABLES

Welding electrodes and consumables shall be selected following the requirements of AWS D1.6.

Welding electrodes and consumables for welding of stainless steel shall be certified by the CWB to the requirements of CSA Standard W48 or the applicable AWS A5 series of standards.

6.5 WORKMANSHIP

Welding shall meet the requirements of CSA Standard W47.1 and AWS D1.6, and of this Specification.

6.6 INSPECTION

All examination and inspection of structural stainless steel shall comply with the requirements of AWS D1.6

6.6.1 Personnel

All inspection personnel shall meet the requirements of Chapter 5.0, Section 5.6.8 of this Specification.

6.6.2 Inspections

All welds shall be visually examined along 100% of their length for correct size, profile and the presence of visible defects. Unacceptable conditions or defects shall be repaired to the satisfaction of the Delegated Representative.

Full penetration welds shall be selectively sampled. Radiographic inspection shall be used for full penetration groove welds in butt joints. Ultrasonic inspection shall be used for full penetration groove welds in tee and corner joints.

Fillet welds shall be selectively sampled by liquid penetrant and/or magnetic particle inspection.

All of the requirements of Section 5.5 of this Specification shall be met unless otherwise specified in this Chapter.

6.6.3 Acceptance Criterion

The visual inspection acceptance criterion shall be in accordance with Clauses 5.11 and 6.29.1 of AWS D1.6.

The liquid penetrant inspection acceptance criterion shall be in accordance with Clauses 6.7.6 and 6.29.4 of AWS D1.6.

The magnetic particle inspection acceptance criterion shall be in accordance with Clauses 6.7.7 and 6.29.2 of AWS D1.6.

The radiographic inspection acceptance criterion shall be in accordance with Clauses 6.9, 6.10 and 6.29.2 of AWS D1.6.

The ultrasonic inspection acceptance criterion shall be in accordance with Clause 6, Part “C” and Clause 6.29.3 of AWS D1.6.

Section 7 OTHER STRUCTURAL MATERIALS

7.1 SCOPE

The requirements of this Section shall apply to welding and inspection of all structural materials other than those included in the scope of CSA Standards W47.1, W59, W47.2 and W59.2 and AWS D1.6.

7.2 DESIGN AND DRAWINGS

Weld design shall be to the Rules of a Classification Society that is an approved Recognized Organization by Transport Canada Marine Safety and Security.

Unless otherwise approved by the Delegated Representative, the following conditions shall be met:

- all groove welds in butt joints shall be full penetration; and,
- all corner joints shall be full penetration groove welds combined with a single continuous fillet weld.

A weld design schedule shall be submitted to the Delegated Representative in drawing form for review prior to commencing any welding work.

7.3 CERTIFICATION

Welders, welding operators and welding procedures shall meet the requirements of ASME Section IX or other suitable standard(s) approved for use by the Designated Representative and the CWB.

All tests shall be fully witnessed and documented by the CWB.

7.4 WELDING ELECTRODES AND CONSUMABLES

Welding electrodes and consumables shall be selected following the requirements of ASME Section IX or other suitable standard(s) approved for use by the Designated Representative and the CWB.

Welding electrodes and consumables shall conform to the requirements of ASME Section IX and the applicable AWS A5 series of standards or other suitable standard(s) approved for use by the Designated Representative and the CWB.

7.5 WORKMANSHIP

Welding shall meet the requirements of CSA Standard W59, and of this Specification.

7.6 INSPECTION

7.6.1 Personnel

All inspection personnel shall meet the requirements of Chapter 5.0, Section 5.6.8 of this Specification.

7.6.2 Inspections

All welds shall be visually examined along 100% of their length for correct size, profile and the presence of visible defects. Unacceptable conditions or defects shall be repaired to the satisfaction of the Delegated Representative.

Full penetration welds shall be selectively sampled. Radiographic inspection shall be used for full penetration groove welds in butt joints. Ultrasonic inspection shall be used for full penetration groove welds in tee and corner joints.

Fillet welds shall be selectively sampled by liquid penetrant and/or magnetic particle inspection.

All of the requirements of Section 5.5 of this Specification shall be met unless otherwise specified in this Chapter.

7.6.3 Acceptance Criterion

The visual and liquid penetrant inspection acceptance criterion shall be in accordance with Clause 12.5.4.1 of CSA Standard W59.

The magnetic particle inspection acceptance criterion shall be in accordance with Clause 12.5.4.1 or 12.5.4.3 of CSA Standard W59.

The radiographic inspection acceptance criterion shall be in accordance with Clause 12.5.4.3 of CSA Standard W59.

The ultrasonic inspection acceptance criterion shall be in accordance with Clause 12.5.4.4 of CSA Standard W59.

Section 8 PRESSURE PIPE WELDING

8.1 SCOPE

The requirements of this Chapter shall apply to welding and inspection of all pressure piping in the absence of Classification Society oversight.

8.2 DESIGN AND DRAWINGS

Weld design for pressure piping shall be in accordance with ASME Code B31.1 - Power Piping. A weld design schedule for pressure piping shall be submitted to the Delegated Representative in drawing form for review prior to commencing any welding work.

8.3 WELDING ELECTRODES AND CONSUMABLES

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

8.4 PERSONNEL QUALIFICATIONS

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

8.5 QUALIFICATION OF WELD PROCEDURES

Welding procedures shall be qualified in accordance with ASME Section IX and ASME B31.1. Testing and approval shall be administered by the local Provincial Pressure Vessel Authority. Weld procedure qualification records shall be forwarded to the Delegated Representative prior to welding.

8.6 WORKMANSHIP

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

8.7 INSPECTION

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

8.7.1 Personnel

All inspection personnel shall meet the requirements of Chapter 5.0, Section 5.6.8 of this Specification.

8.7.2 Inspections

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

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

Repair of defects shall be performed following procedures accepted by the Delegated Representative. Second repair attempts shall not be permitted without due consideration of the conditions and agreed to by the Delegated Representative.

8.7.3 Acceptance Criterion

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

Annex A REFERENCED CODES, PUBLICATIONS AND STANDARDS

A.1 LIST OF CODES, PUBLICATIONS AND STANDARDS

ASME	B31.1	Power Piping
	Section V	Boiler and Pressure Vessel Code, Non-destructive Examination
	Section IX	Boiler and Pressure Vessel Code, Welding and Brazing Qualifications
AWS	A5 Series	Specifications for Filler Metals and Consumables
	A5.10	Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods
	D1.6	Structural Welding Code – Stainless Steel
CAN/CGSB	48.9712	Qualification and Certification of Non-Destructive Testing Personnel
CAN/ISO	14341:XX	Welding consumables – Wire electrodes and deposits for gas shielded metal arc welding of non-alloy and fine grain steels - Classification
CSA	G40.21	Structural Quality Steel
	W47.1	Certification of Companies for Fusion Welding of Steel
	W47.2	Certification of Companies for Fusion Welding of Aluminum
	W48	Filler Metals and Allied Materials for Metal Arc Welding
	W59	Welded Steel Construction (Metal Arc Welding)
	W59.2	Welded Aluminum Construction
	W178.2	Certification of Welding Inspectors

Annex B TESTS FOR RATING CORROSION RESISTANCE OF CARBON STEEL WELD METALS IN SEA WATER

B.1 SCOPE

When required by Section 5.4.1.9 and 5.4.1.10 of this Specification, weld metals shall be tested for corrosion resistance in sea water following the procedures detailed herein. This Annex specifies the requirements for welding and testing plate assemblages. Organizations performing machining, mechanical testing of welds and corrosion tests shall be approved by the Delegated Representative in advance of any tests. Welding of test assemblies shall be fully witnessed and documented by the CWB.

B.2 TEST ASSEMBLY

Test assemblies shall be made in accordance with the requirements of Figure B1 herein.

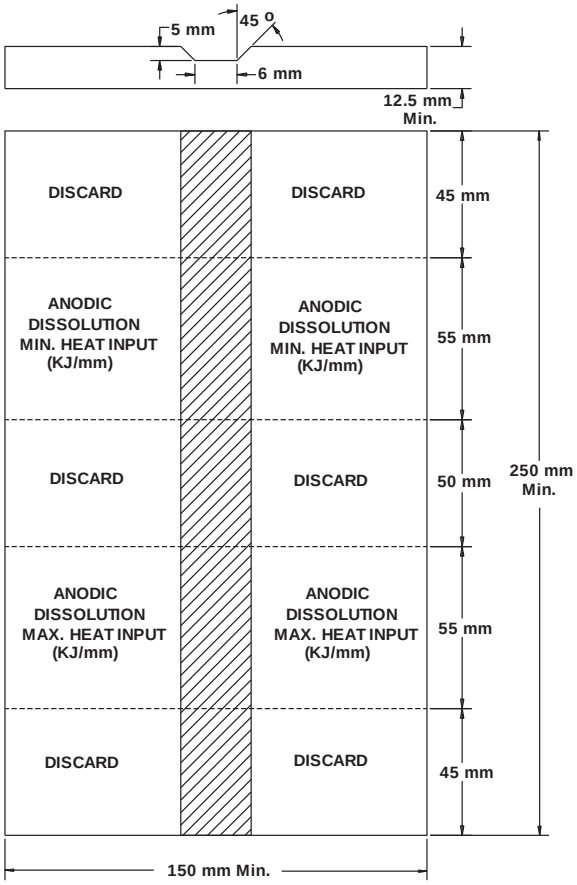


Figure B1 Anodic Dissolution Test Plate Assembly

Welds shall be deposited following a stringer temper bead sequence at the lowest and highest heat input (kj/mm) planned for production as illustrated in Fig. B2 herein. The centre 50 mm discard portion of the test assembly shall be used as a transition between low and high heat input welds (stop/starts).

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

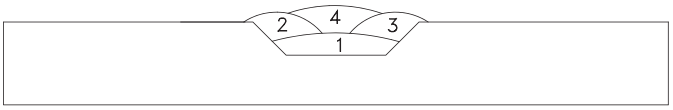


Figure B2 Bead Sequence

B.3 ANODIC DISSOLUTION TESTING

Specimens removed from the test assemblages detailed in Section B2.0 of this Annex shall be prepared by machining as illustrated in Figure B3 herein.

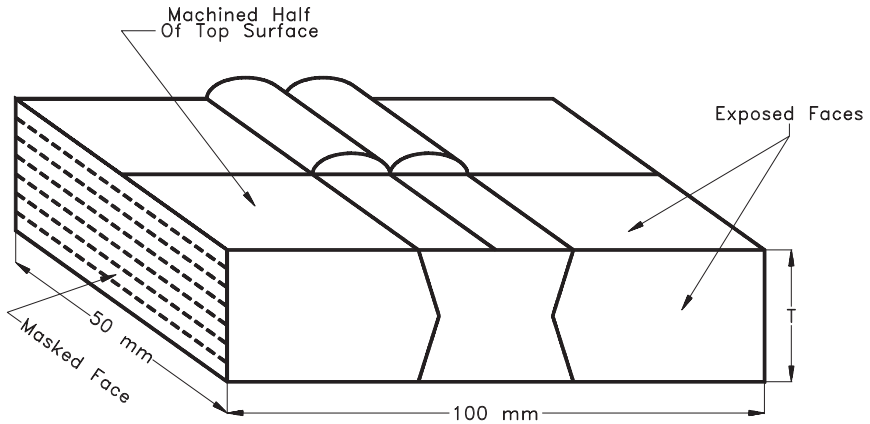


Figure B3 Anodic Dissolution Test Specimen

Each of the specimens shall be corroded at room temperature at a nominal current density of 0.88 mA/cm² for a period of 15 days. The test solution shall be 3.5% NaCl. Intermixing of the anolyte and catholyte shall be prevented by placing a membrane over the opening to the cathode compartment. The test system shall be as illustrated in Figure B4 herein.

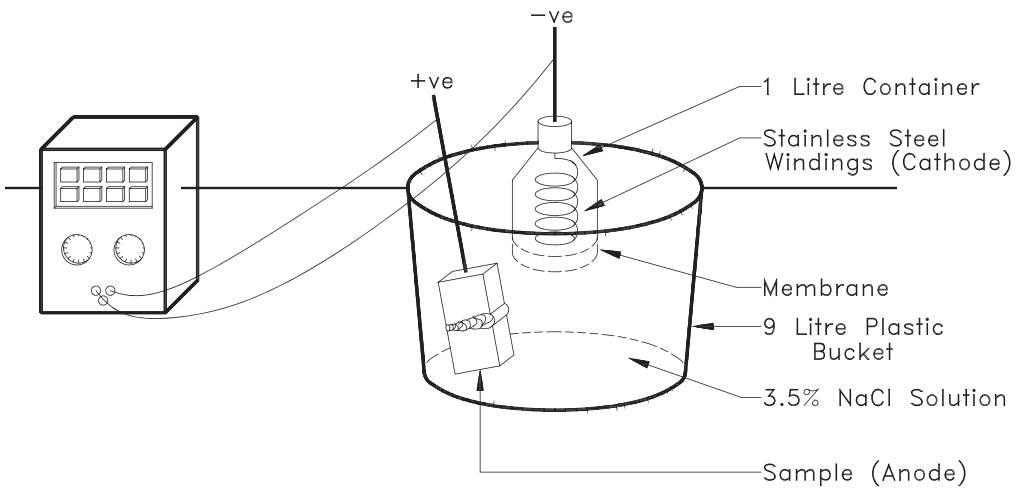


Figure B4 Anodic Dissolution Test System

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

B.4 REPORTING TEST RESULTS

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

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

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

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

Annex C FORMING & THERMAL REQUIREMENTS - ALUMINUM

C.1 HOT FORMING

All hot forming procedures shall be approved by the Delegated Representative 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 C1.

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 C1 Maximum Heat Exposure Time at Temperature Preparatory to Forming Aluminum Alloys

Holding Temperature (Note 1) 0°C	6061-T4, T5 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*

C.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.