ShipRight

Design and construction

Construction Monitoring

Procedure

May 2004

Lloyd's Register

Lloyd's Register Marine
Business Stream
71 Fenchurch Street
London
EC3M 4BS
Telephone 020 7709 9166
Telex 888379 LR LON G
Fax 020 7488 4796

Document History	
Document Date:	**Notes:**
November 2001	Intranet user review version
July 2002	General release
May 2004	Revisions as identified in 'Construction Monitoring Procedure, Changes incorporated in May 2004 version'.

Contents

■ SECTION 1: General

1.1 Introduction

1.1.1 The general quality of a vessel is enhanced by superior structural design, improved construction procedures and effective through life monitoring. In structural terms, the performance of structural elements or connections between members is dependent on the adoption of adequate quality control measures relating to both the quality of detail design and the construction. The detail design, the methods of manufacture and the degree of quality control significantly affect the fatigue performance of a structure. This is particularly evident at locations within the structure identified as 'critical'.

1.1.2 Misalignment, inappropriate edge preparation, excessive gap, weld sequence and weld quality alters the fatigue properties of these joints. Setting appropriate controls on the key factors affecting fatigue performance at the design stage and utilising enhanced monitoring procedures at critical locations ensures that a high degree of workmanship is achieved and avoids unnecessary remedial action in the later stages of the build process.

1.1.3 The links to FDA and SDA within the Construction Monitoring (CM) procedure ensure that a seamless transition of quality monitoring is achieved throughout the life of the vessel.

1.1.4 The ShipRight CM procedure forms an element of an integrated approach to the design, construction and monitoring of the critical areas of ship structures. The application of the CM procedure enhances not only the confidence of the Owner and Classification Society in the hull construction but also quality control procedures employed by the Shipyard at the structurally critical locations.

1.2 Objective

1.2.1 The main objective of the ShipRight CM procedure is to ensure that the locations within the ship structure, that have been identified as critical, are built to both an acceptable quality standard and approved construction procedures.

1.2.2 The CM procedure is applied in addition to the requirements for vessels built under special survey, and is based on the application of enhanced controls on alignment, fit-up, edge preparation and workmanship to the critical areas of the relevant hull structures to attain the required structural performance.

1.2.3 A secondary objective is that during the service life of the vessel, the Construction Monitoring Plan (CMP) is used to focus the attention of any future classification survey to the critical locations.

1.3 Outline of the Procedure

1.3.1 The pre-construction meeting includes advice or a presentation to the Builder's representatives and owners site manager on the specific application of the Construction Monitoring procedure. The Lloyd's Register site project manager normally gives the CM presentation.

1.3.2 At the plan development and approval stage, the application of the CM procedure identifies the areas and locations within the ship structure that may experience high levels of stress or fatigue damage assessed on the basis of SDA and FDA results and procedures. The critical areas are those areas of the ship structure that have been shown by structural analysis and service experience to have a higher probability of failure than the surrounding ship structure. The critical locations are specific points identified within the critical areas that are prone to fatigue, and where detail design improvement may have to be undertaken. Particular emphasis is placed on those primary structural locations specified as having enhanced fatigue life specifications within the FDA procedures.

1.3.3 In order to promote a satisfactory level of strength and fatigue performance, detailed construction tolerances are agreed between Lloyd's Register and the Shipbuilder for each ship considered for the CM notation in
accordance with the Construction Monitoring Standards. The CMP is prepared by the builder at the earliest possible opportunity following receipt of the approved key-plans, as a catalogue of the critical locations together with the required construction tolerances and an outline of the quality control and quality assurance procedures to be applied. The completed CMP is sent to Lloyd's Register for review and subsequent approval, however, in some cases, Lloyd's Register may require that modifications are made to the CMP prior to approval being granted.

1.3.4 The Shipyard quality personnel are responsible for the inspection and recording of results during the construction of the ship in accordance with approved yard procedures and the requirements of Lloyd's Register. The Lloyd's Register site Surveyor(s) provide third party inspection to confirm that the alignment, fit-up, workmanship and construction tolerances conform to the agreed standard specified in the CMP. Where the approved construction tolerances are exceeded, the Shipbuilder undertakes corrective action to the satisfaction of the Lloyd's Register site Surveyor and the requirements of the CMP.

1.3.5 On satisfactory completion of the CM requirements, Lloyd's Register recommends the assignment of the '**ShipRight CM**' notation or descriptive note as appropriate. Upon completion of the ship, the Lloyd's Register site surveyor sends a copy of the approved CMP to Lloyd's Register London (FEG) for archiving.

1.3.6 During the lifetime of the vessel, the CMP is maintained on board and is used to focus periodical surveys on the critical locations in order to monitor the structural integrity and performance.

1.3.7 The Construction Monitoring procedure has been subdivided into three phases to be applied sequentially as shown in Table 1.3.1.

Table 1.3.1 The Construction Monitoring Phases

CM Phase I	Plan Approval	Analysis to determine the critical locations.
CM Phase II	Survey during Construction	Survey to ensure satisfactory construction standards.
CM Phase III	Lifetime application of CMP	Monitor the structural integrity using the CMP

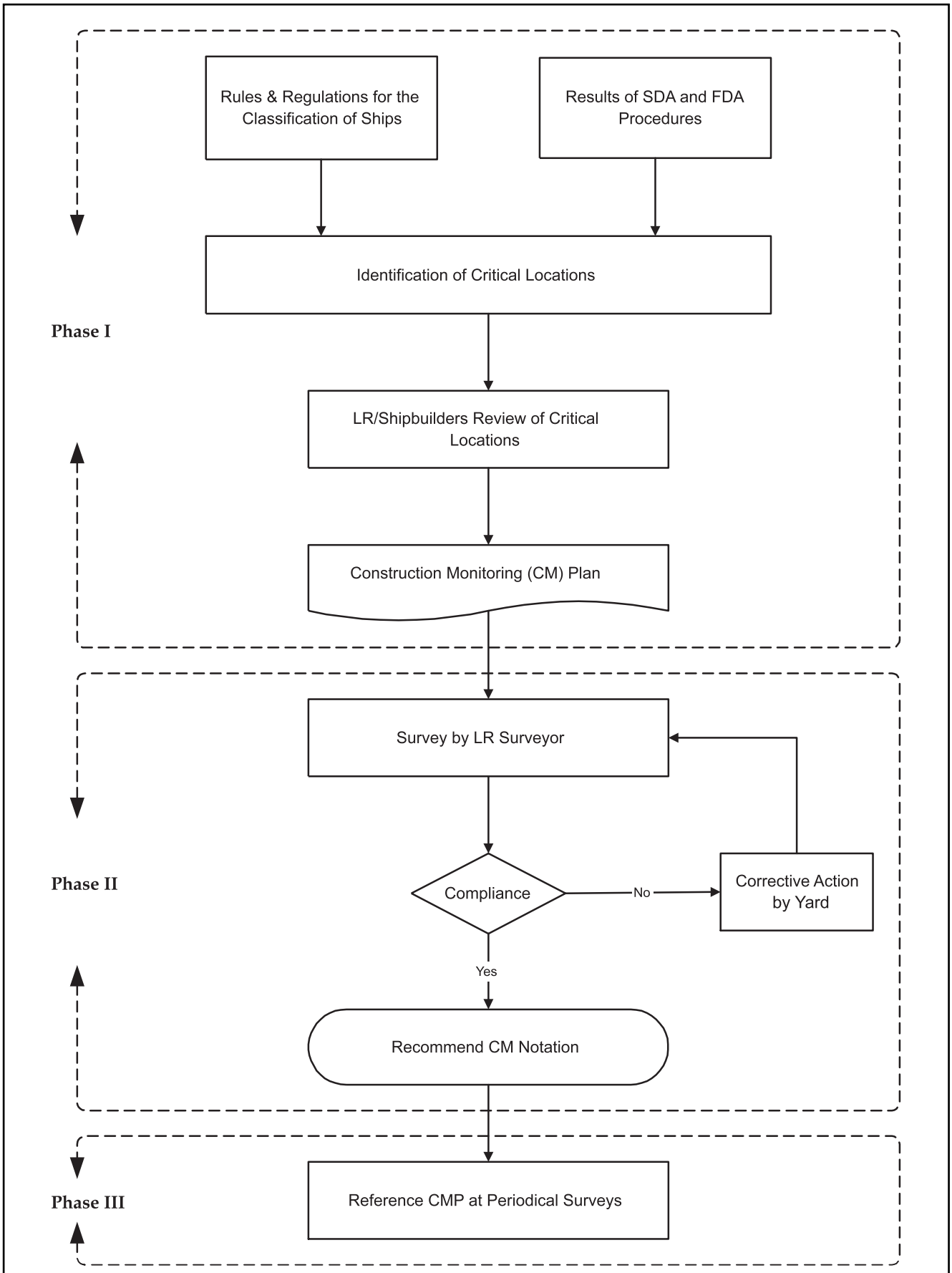


Fig. 1.3.1
Construction Monitoring Procedure

1.4 Scope of Application

1.4.1 With the exception of passenger ships, the procedure is mandatory for all vessel types where either the SDA and/or FDA procedures have been applied on a mandatory basis. In cases where the SDA and/or FDA procedures have been applied on a voluntary basis, the Construction Monitoring procedure shall also be applied.

1.4.2 This procedure is applied to areas of the structure that have been identified as being critical locations through the application of the ShipRight procedures for Structural Design Assessment (SDA) and Fatigue Design Assessment (FDA).

1.4.3 The procedure is adopted in association with Lloyd's Register's requirements for vessels constructed under Special Survey.

1.4.4 Any subsequent modifications or repairs to the ship's structure are, where applicable, to be in accordance with this procedure.

1.5 Classification Notation

1.5.1 Upon satisfactory application of this procedure, the vessels may be eligible to be assigned the Construction Monitoring notation '**ShipRight CM**' and be entered in column 4 of the Register of Ships, in addition to the Hull and Machinery class notations defined in Pt 1, Ch 2,2 of the Rules for Ships.

1.5.2 Where the ShipRight CM procedure has been applied on a voluntary basis, then an appropriate descriptive note will be entered in column 6 of the *Register Book*. *See* Pt 1, Ch 2,2.6 of the Rules for Ships.

1.6 Construction Monitoring Structural Detail Supplements

1.6.1 The development of the Construction Monitoring Procedure is an on-going process with regular updates issued by Lloyd's Register in the form of Construction Monitoring Structural Detail Supplements. These are issued to reflect the evolutionary trends in shipyards as well as traditional design and ship construction practices.

■ SECTION 2: Lloyd's Register Construction Monitoring Standard

2.1 Construction Monitoring Standard

2.1.1 The Construction Monitoring Standard (CMS) sets down the Construction Monitoring tolerances to be achieved at the critical locations in order that the requirements for the CM notation are met. The CMS covers such aspects of construction such as:

- Alignment
- Fit-up
- Remedial Measures

2.1.2 When identifying the critical locations, particular consideration should be given to critical locations identified by SDA or FDA that constitute a unit joint and critical joints assembled in areas where environmental controls are difficult to apply such as in the erection area or building dock.

2.1.3 In all cases, the construction standards and tolerances not indicated in this procedure are to be at least equivalent to the approved yard, national or international ship construction standards in use.

2.1.4 The quality standards for the alignment of critical structural components during new construction are shown in Appendix B, Table B-1.

2.1.5 The quality standards for the standard of fit-up of structural components during new construction are shown in Appendix B, Table B-2.

2.1.6 The quality standards for the repair of structural components during construction are shown in Appendix B, Tables B-3 and B-4.

2.2 Scope of the Construction Monitoring Standard

2.2.1 The CMS does not replace the shipbuilding construction standard employed by the shipyard and accepted by Lloyd's Register. It is a supplementary standard supported by a survey procedure to promote a higher level of structural performance throughout the life of the ship.

2.2.2 The construction and manufacture of the structural details in way of the identified critical areas shall be carried out in accordance with the following:

- Lloyd's Register's Rules and Regulations for the Classification of Ships.
- Lloyd's Register's FDA Level 1 Structural Detail Design Guide (where applicable).
- The approved construction tolerances contained within the Construction Monitoring Plan.
- The associated non-destructive examination (NDE) requirements, if necessary, at the discretion of the attending Surveyor.

2.3 Structural Alignment Considerations

2.3.1 The consistent application of remedial measures to correct poor fit-up and alignment is one of the key indicators that a problem may exist in the construction procedures.

2.3.2 Any inaccuracy in the welding of blocks into erection units will have an amplified effect at the erection stage. If adequate dimensional control has not been exercised it will be necessary to cut away edges to align the units being erected. This has the effect of causing further misalignments in adjacent units that will also require modification.

2.3.3 The most critical types of welded structural connection are angled cruciform joints such as the sloping hopper plate connection with the inner bottom plating and the outer longitudinal girder of double hull tankers. At these locations, adequate dimensional control is a prerequisite to ensure good alignment.

2.3.4 The application and maintenance of a suitable alignment method such as '100 mm offset lines' is recommended to aid accurate fit up and alignment. For critical structural members it is recommended that any reference marks are indicated in a permanent manner, on both sides of the plate and the actual misalignment checked using jigs/templates, if necessary.

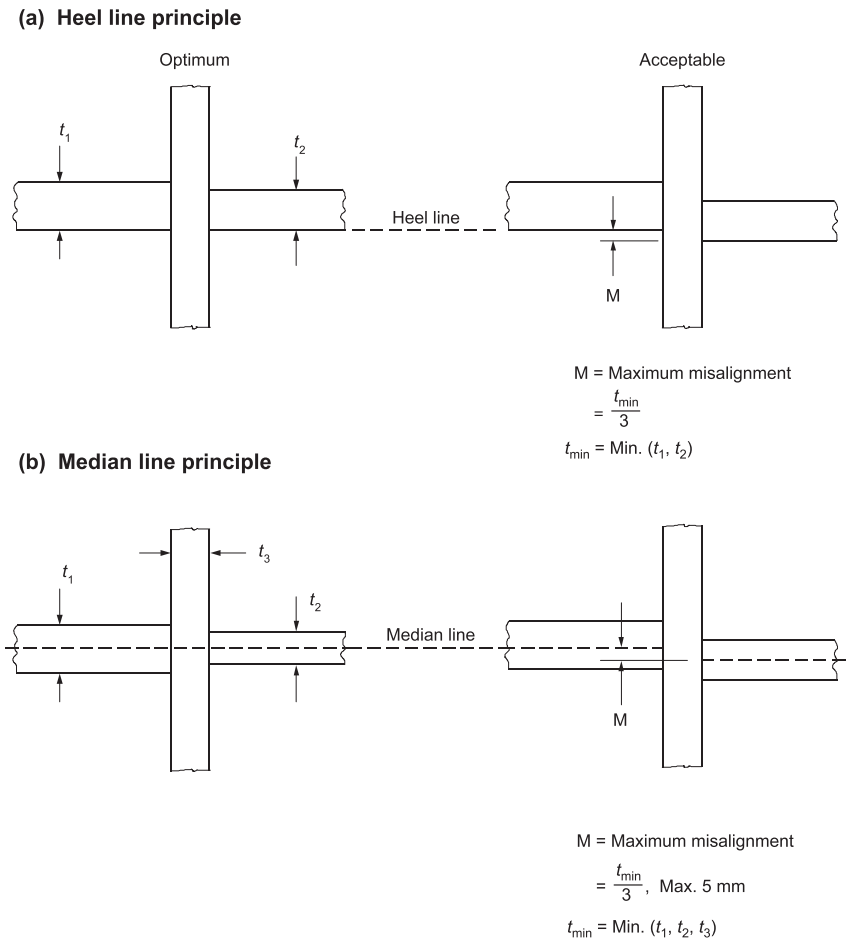
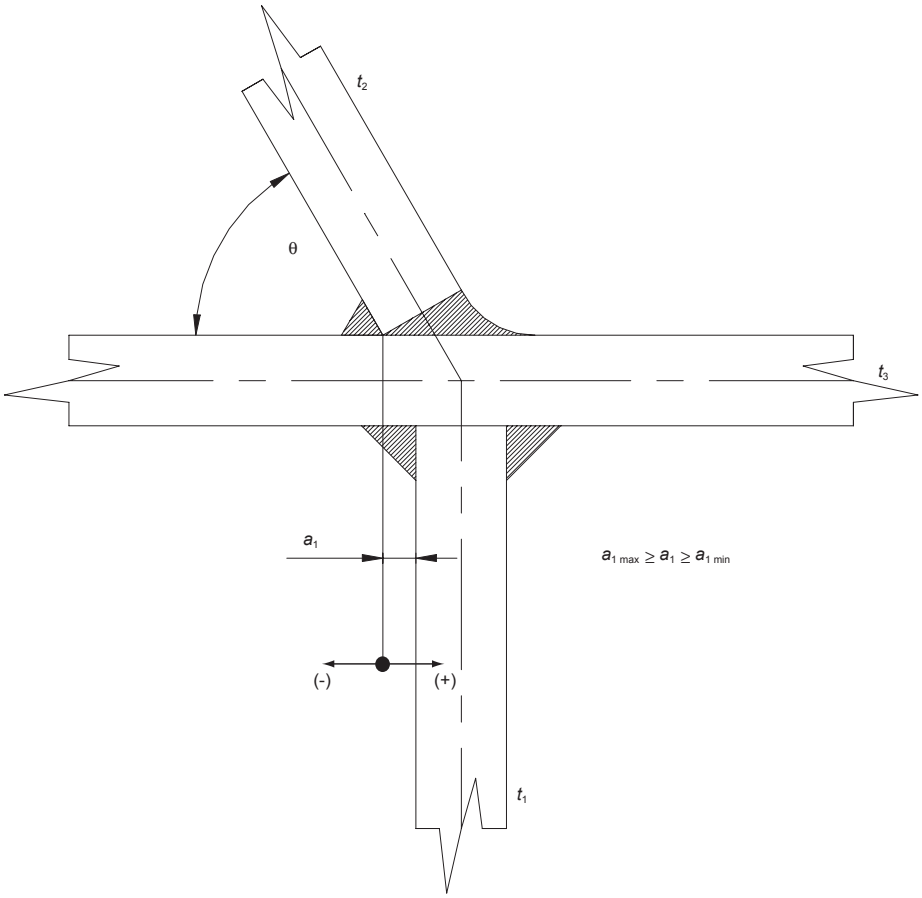


Fig. 2.4.1 Recommended alignment of primary members

2.3.5 In general, there are two types of alignment method in use; the median line principle and the heel or moulded principle. These principles are outlined in Fig. 2.4.1. Whilst both alignment methods are generally acceptable, in cases where a more onerous trading pattern is specified or enhanced service life expectations are required, consideration should be given to the application of a suitable alignment method appropriate to the design criteria in order to achieve a preferable level of alignment. In addition to alignment considerations, it may also be preferable to apply a more stringent tolerance beyond those detailed in this procedure. In order to eliminate difficulties associated with alignment, a prudent consideration by the shipyard would be to ensure, where practicable, that the thickness of all structural members is reasonably compatible within regions where critical locations are likely to be identified.

2.3.6 In addition to the basic design criteria, certain joints may be identified as requiring an enhanced level of alignment through the application of service experience. The joints identified may depend upon the ship type and the structural configuration but in general the following joints may require additional consideration:

- Lower hopper knuckle on bulk carriers and oil tankers.
- Lower stool connection to floors in way of longitudinal girders in bulk carriers.
- Lower cofferdam bulkhead cruciform joint on membrane type gas carriers.
- Upper hopper knuckle on membrane type gas carriers.
- Aft end cargo area transition zone on membrane type gas carriers.
- Fore end cargo area transition zone on membrane type gas carriers.



$$a_{1\,max} = \frac{1}{2}\left(\frac{t_2}{Sin\theta} + \frac{t_3}{Tan\theta} - t_1\right) + M \qquad M = \frac{t_{min}}{3}\ (Max\ 5\ mm)$$

$$a_{1\,min} = \frac{1}{2}\left(\frac{t_2}{Sin\theta} + \frac{t_3}{Tan\theta} - t_1\right) - M \qquad t_{min} = Minimum\ [t_1, t_2, t_3]$$

where

$a_{1\,max}$ = maximum heel line tolerance measured in the direction of the acute angle

$a_{1\,min}$ = maximum heel line tolerance measured in the direction of the obtuse angle

θ = angle of sloping plate to the horizontal

t_1 = thickness of girder or transverse member

t_2 = thickness of sloping plate

t_3 = thickness of table member

Comparison of equivalent tolerances

t_1	t_2	t_3	θ	a_{OB}	a_{IB}	Med. Line
12	22	20	60	16,5	8,5	4
12	26	20	60	18,8	10,8	4
14	22	20	45	23,2	13,9	4,7
14	26	20	45	26,0	16,7	4,7

Fig. 2.4.2 Equivalent heel line tolerances

2.3.7 When verifying the alignment of structural members, it should be noted that it is often impractical to directly measure the median line alignment and a heel line approach is used in lieu of direct measurement of alignment at median lines. Where the heel line approach is used, the maximum median line tolerances may be converted into heel line values using the equations given in Fig. 2.4.2.

2.3.8 In cases where two or more critical locations are connected by a secondary stiffening arrangement, i.e. double bottom/inner bottom longitudinals, it may be considered prudent to ensure that the alignment detail recommended in Lloyd's Register's Structural Detail Design Guide is maintained. This helps to ensure that a sound weld bead is formed without any 'overhang'.

2.4 Construction Considerations

2.4.1 At the sub-assembly stage, a high degree of accuracy may be obtained using methods such as 'back marking' prior to fit-up.

2.4.2 It is generally found that a consistently higher degree of accuracy is achieved within the assembly shop where the conditions are controlled since blocks and pre-erection units are generally of a smaller size. This makes it easier to meet the specified construction tolerances during fit-up and alignment.

2.4.3 If the critical connections are part of much larger erection joints in the building dock or berth it is much harder to control the alignment and fit-up of the interface and weld quality due to the size of the units and other external factors. During all stages of construction, but particularly when fabrication and erection takes place external to the construction hall, measures are to be taken to screen and pre-warm, as necessary, the general and local weld areas. Surfaces are to be dry and rapid cooling of welded joints is to be prevented. *See* Pt 3, Ch 10,2.12 of the Rules for Ships.

2.5 Quality Control and Quality Assurance

2.5.1 In shipyards certified under the Lloyd's Register Quality Assurance Scheme, the construction standards have received general approval as part of the certification procedures and their application to a particular vessel is included with the quality plan submitted to Lloyd's Register for approval.

2.5.2 The construction standards and tolerances to be applied to the critical areas are to be agreed between Lloyd's Register and the Shipbuilder. These standards are to be noted in the CMP and approved by Lloyd's Register. The agreed construction standard and tolerances are in all cases to be, at least, equivalent to the Lloyd's Register Construction Monitoring Standards.

2.5.3 In all cases the applied tolerances and standards are not to be less than those specified in the IACS 'Shipbuilding and Repair Quality Standard' in cases where established shipbuilding or national standards approved by Lloyd's Register do not exist.

2.5.4 Any deviation from the approved structural configuration and/or approved procedures is to be submitted to Lloyd's Register for consideration.

■ SECTION 3: Phase 1 – Plan Development and Approval

3.1 Objectives

3.1.1 The first objective of this stage is to identify the critical locations as defined in 1.2.3 of this document.

3.1.2 The second objective is to compile the CMP prior to submission to Lloyd's Register for approval.

3.2 Identification of the Critical Locations

3.2.1 Experience with ships in service has enabled Lloyd's Register to provide information to assist the Shipbuilder in determining the critical locations that may be vulnerable to fatigue. Particular emphasis is placed on areas where high stress magnitudes may be anticipated and for which correct alignment is important. The information is presented in the form of Lloyd's Register's Structural Detail Design Guide.
3.2.2 The critical locations are to be clearly identified and labelled on the appropriate structural drawings contained within the CMP and submitted to Lloyd's Register for approval.

3.3 Construction Monitoring Plan

3.3.1 The Construction Monitoring Plan (CMP) is a document compiled by the shipyard to provide a record of the enhanced quality standards and procedures employed by the Shipbuilder to ensure that an increased level of construction quality control is employed at those areas of the structure that have been identified as critical to the vessel. Where it is deemed necessary, Lloyd's Register may be consulted to provide information and guidance in the formation of the CMP and the application of the Construction Monitoring procedure.

3.3.2 The CMP is submitted to Lloyd's Register's Plan Approval Services for formal approval as soon as possible after its completion, and preferably, at the earliest opportunity prior to steel cutting. The CMP is reviewed by both Lloyd's Register's site Surveyor(s) and Plan Approval Surveyors in order that the findings of practical construction, structural analysis and fatigue analysis are uniquely reflected in the plan. Once approval is given, Lloyd's Register's site Surveyors maintain efficient contact between all interested parties to ensure that the requirements of the CMP are fully understood and are complied with.

3.3.3 The CMP is supplemental to and does not replace the Quality Plan provided by the Shipbuilder in accordance with the Rules for Ships. *See* Pt 3, Ch 15,4.7.3 of the Rules for Ships.

3.3.4 On receipt of the approved CMP, the Shipbuilder, in association with the Lloyd's Register surveyor, ensures that all
of the requirements contained within the CMP are met in addition to any shipbuilding standards used.

3.3.5 A typical CMP is to contain the following information:

- Appropriate structural plans with the critical locations clearly marked.
- Details of appropriate construction tolerances including any 'design offset' at the critical locations are to be included on the appropriate structural plans for approval.
- Where fatigue life improvement methods such as 'weld toe grinding' have been specified at the critical locations, these are to be included on the approved structural plans submitted within the CMP.
- Summary and cross-reference table of all critical locations indicating tolerances applied.
- Alignment verification methods used, i.e. Offset marking.
- Outline of quality controls in place during block construction, pre-erection and erection.
- Outline of Q.A procedures used.
- Methods for recording and reporting of inspection results.
- Details of standard remedial measures to be employed where required.

3.3.6 A copy of the approved CMP is maintained on board either in electronic or hard copy format throughout the life of the vessel. The CMP is to be used to focus survey on those areas of the structure identified during the design process as being critical to the operational effectiveness of the vessel.

3.3.7 A sample CMP is shown in Appendix A.

3.4 Fatigue Life Improvement

3.4.1 Any application of fatigue life improvement methods such as grinding, dressing etc. at the critical locations is to be discussed with the attending Lloyd's Register Surveyor, if necessary.

3.4.2 When specifying fatigue life improvement methods, detailed consideration is to be given to the application of quality control and quality assurance procedures to ensure that any potentially detrimental effects are eliminated. *See* Ch 2, Pt 2,4 of the Structural Detail Design Guide.

3.4.3 All proposed fatigue life improvements are to be detailed on the approved plans submitted within the CMP for approval. On approval, the Design Appraisal Document will draw attention to those structural details that are to be subject to fatigue life improvement procedures.

■ SECTION 4: Phase 2 – Construction Monitoring

4.1 Fabrication and Pre-erection

4.1.1 The attending Lloyd's Register Surveyor and the Shipbuilder's quality control personnel agree a satisfactory inspection routine that embodies both the Shipbuilders Quality Control and the Construction Monitoring requirements. The Owner's Representatives shall be notified of the agreed inspection routine and updated as necessary.

4.1.2 Measures are, in general, to be taken to screen and pre-warm, as necessary, the general and local weld areas. Surfaces are to be dry and rapid cooling of welded joints is to be prevented. *See* Pt 3, Ch 10,2.12 of the Rules for Ships. For any given welding method, the welding procedures are to be to a suitable national standard as approved by Lloyd's Register. In addition, the Shipbuilder ensures that all welding operators employed on that process are qualified to a suitable National or International Standard, e.g. EN288, ISO9956 etc. as approved by Lloyd's Register.

4.1.3 The fabrication plans and other appropriate specifications, procedures and work instructions necessary for each phase of the fabrication process are to be made available at the appropriate inspection locations. The Shipbuilder maintains the inspection status of the critical structural components at appropriate stages in the fabrication process. This may include the direct marking of individual components. The marking method used is to be discussed and agreed with the attending Lloyd's Register Surveyor.

4.1.4 Prior to the welding of critical joints, the Shipbuilder liaises with the attending Lloyd's Register Surveyor with respect to arranging appropriate 'fit-up' inspection, if necessary. Records of inspection and measurements are to be easily referenced against the relevant structural components and be accessible to Lloyd's Register.

4.1.5 The workmanship employed throughout the stages of material preparation and assembly of prefabricated units is to conform to the relevant standards defined in the CMP. Faulty workmanship or noncompliance with the specified tolerances noted by the Surveyor is to be rectified to the Surveyors satisfaction before progressing to the next stage of production.

4.1.6 Visual examination of welds and plating of a completed structural unit does not necessarily ensure a complete and satisfactory survey. Additional Non Destructive Examination, beyond the Rule requirements, may be requested by the attending Surveyor where it is deemed necessary.

4.2 Assembly of Units

4.2.1 The assembly welding sequences, in general, are to be agreed prior to construction and to the satisfaction of the attending Surveyor. At each stage of assembly, particular attention is to be paid to ensure that the fit-up, alignment and welding of units is in accordance with the approved plans and to the approved CM tolerances.

4.2.2 Where a critical connection is also an erection joint, the attending Lloyd's Register Surveyor is to liaise with the Shipyard to provide adequate inspection to ensure that the required construction tolerances are achieved. During unit erection it is common for plates to be released and material cropped to allow acceptable fit-up
and alignment. This process often results in damage to the surrounding plating detrimental to the strength of the structure. It is recommended that where such practices have been employed, full penetration welding is specified for the re-welding of the structure. Where insert plates have been used, e.g. at the lower hopper knuckle web frame, it is recommended that these plates are left loose until such time that acceptable fit-up and alignment has been achieved.

4.2.3 Where lifting lugs have been welded to large assembly blocks and are subsequently removed, the attending Lloyd's Register Surveyor is to ensure that they have been removed in accordance with Pt 3, Ch 10,5.7.3 of the Rules for Ships.

4.2.4 The Surveyor shall inspect the locations where lifting lugs have been removed to ensure that no cracks or other defects are present. At the discretion of the Surveyor, a full NDE, using Magnetic Particle Inspection of the finished surface of the plating may be requested in way of critical areas where lifting lugs have been removed.

4.2.5 In some instances, lifting lugs may be trimmed back to the fillet weld, usually 8 – 10 mm above the plate surface. In such instances, all sharp edges are to be ground smooth using a milling machine or similar and the stub inspected to ensure that no defects are present.

4.3 Inspection of Welds

4.3.1 Regular examination of the NDE records, in conjunction with the Shipbuilder, verifies that the quality of welding operations is satisfactory. Any departure from acceptable standards is to be investigated, including additional tests as considered desirable.

4.3.2 Finished welds are to undergo a visual inspection by the attending Lloyd's Register Surveyor. The Shipbuilder shall ensure that all welds presented for visual inspection are clean, having all rust and weld slag removed and be free of coatings that may impair the inspection, *see* Pt 3, Ch 10,2.13.4 of the Rules for Ships. The inspection is to verify that all welds are sound, free from cracks, undercut and notches and substantially free from lack of fusion, incomplete penetration, slag inclusion and porosity. The surface of all finished welds shall be inspected to ensure that they are reasonably smooth, substantially free of overlap and undercut. Fillet welds are to be inspected to ensure that they are continuous around scallops, brackets, stiffeners, etc. thus avoiding craters and incipient cracks at points of stress concentration.

4.3.3 Weld sizes shall be inspected to ensure they are consistent over their entire length and are of the correct dimensions. Finished weld profile characteristics can have a marked effect upon joint fatigue, particularly excessive flank angle. The approved dimensional requirements, including flank angle, are to be verified using a suitable gauge and shall meet the criteria specified in the CM Standard.

4.3.4 In addition to visual inspection, certain welded joints, particularly at the critical locations are to be subjected to the NDE requirements specified in Pt 3, Ch 10 of the Rules for Ships. Welds may be examined using approved methods such as Ultrasonic, Magnetic Particle, Radiographic, Eddy Current, Dye Penetrant or other acceptable methods appropriate to the configuration of the weld.

4.3.5 The Shipyard production personnel involved in the fabrication joints to undergo NDE are not to be informed of the exact locations of the NDE prior to welding. Similarly, the proposed location of NDE is not to be marked or indicated on the plates prior to welding.

4.3.6 The quality of a finished weld often varies with the method used due to factors such as heat input and the process itself. When specifying an NDE procedure, full consideration is to be given to the weld process employed to ensure that the method of NDE is suitable for the type of weld under consideration.

4.3.7 Where defects are observed, additional NDE is to be carried out to determine the full extent. Unacceptable weld defects detected by NDE inspection are to be repaired or completely removed and re-welded as appropriate using approved procedures and consumables.

4.3.8 Prior to any repair or re-welding at critical locations, the joint is to be inspected by the attending Lloyd's Register Surveyor to ensure that the alignment and gap comply with the specified tolerances.

4.3.9 In critical areas where repairs and re-welds have been undertaken, the Lloyd's Register Surveyor is to ensure that excessive welding leading to distortion, stress concentration has not taken place. Re-inspection using the appropriate method of NDE shall be carried out until no further defects are discovered.

4.3.10 The Lloyd's Register Surveyor may request additional or random NDE inspections where it is considered necessary.

4.3.11 Only where absolutely necessary should methods for fatigue strength improvement be considered at the fabrication stage and then only as remedial measures. In these cases, strict quality control procedures are to be applied.

4.4 Departure from the Approved Arrangements

4.4.1 Modifications or alterations to the design or construction of a particular structural arrangement or detail in way of an identified critical area are to be approved by Lloyd's Register.

4.4.2 In this case, the Shipbuilder is to re-submit to Lloyd's Register, the appropriate plans indicating all of the required changes. Reassessment of the structure may be a requirement along with the submission of a revised CMP. Any reassessment carried out by Lloyd's Register with regard to post-approval modifications or alterations may be chargeable to the Shipbuilder.

■ SECTION 5: Construction Monitoring Compliance

5.1 Compliance

5.1.1 The attending Lloyd's Register Surveyor shall ensure that during the various stages of the construction process, all structure in way of fatigue critical locations has been examined in accordance with the inspection plan.

5.1.2 The attending Lloyd's Register Surveyor is to ensure that, where applicable, all of the requirements of the CMP have been met in addition to any rules and standards applied.

5.1.3 On satisfactory completion of all inspections, the Surveyor shall confirm that the structure complies with the approved CM tolerances and recommend the assignment of the appropriate notation, *see* 1.5.1.

5.2 Non-Compliance

5.2.1 Throughout the various stages of construction, the attending Lloyd's Register Surveyor shall inform the Shipbuilder immediately upon completion of an inspection, of any defined critical joint or location that does not comply with the approved CMP.

5.2.2 Where the Shipbuilder is to utilise remedial measures or corrective action not stated in the CMP, an agreement should be reached on an approved remedial plan to ensure that compliance is reached through discussions between Lloyd's Register and the Shipbuilder. The proposal shall contain details of any modifications to the structural arrangement, scantlings, welding processes to be employed and NDE to be performed.

■ SECTION 6: Phase 3 – Lifetime Application

6.1 Through Life Monitoring

6.1.1 The Surveyor attending future classification surveys shall identify, from the CMP, those structural locations that will require special consideration and extended examination during survey.

6.1.2 The nature of the critical locations requires that the Surveyor pay particular attention to defects such as corrosion, local damage, evidence of cracking, and local coating breakdown.

6.1.3 All repairs undertaken at the critical locations identified in the CMP are to be undertaken in accordance with these procedures.

6.2 Structural Alterations

6.2.1 In cases where a vessel has undergone significant structural alteration, any locations subsequently identified as being critical to the structural integrity are to be constructed to the tolerances specified in the original CMP. A revised CMP is to be produced as early as practicable in the design process in accordance with these procedures (*see* 3.3) and submitted for approval.

6.2.2 Joints not previously identified but subsequently found to be critical are to be examined in detail to ensure that no construction irregularities such as severe misalignment and weld imperfections exist.

APPENDIX A: Sample Construction Monitoring Plan

CONSTRUCTION MONITORING PLAN

ABACUS SHIPYARD

YARD HULL NO. 1234

300,000 DWT OIL TANKER

General

Objective

The objective of this procedure is to ensure that all of the critical locations identified using the FDA and SDA procedures are built to acceptable standards, thereby enabling the attainment of the Class Rule requirement for the attainment of the CM notation.

Quality Criteria

Tolerances and standards such as fit-up, alignment and weld profile, not mentioned in this document, are to conform to the specifications held within the shipyard's shipbuilding quality standard accepted by Lloyd's Register.

Control procedures

Critical Locations

The critical locations are to be clearly marked on the appropriate structural drawings by the design office on the basis of FDA and SDA results.

The critical locations are to be identified by the mark 

on the appropriate drawings.

The production drawings for the hull are to contain all of the relevant information required for the accurate construction of the critical locations such as material and welding details, reference lines, fit-up information, etc.

The construction tolerances to be achieved for the CM notation shall be in accordance with Table A-1.

Verification of Alignment

Offset reference lines required for the construction of critical locations are to be clearly marked on both sides of the table member in a permanent manner.

Offset reference lines for the construction of standard joints are to be marked on the moulded side. Practical methods for checking the alignment shall be agreed with the attending Lloyd's Register Surveyor.

APPENDIX A

Construction

Block Stage

Prior to the commencement of welding, the designated Shipyard personnel are to be familiar with the relevant construction information and procedures by utilising methods such as signboard instructions, production drawings, etc.

Alignment of completed locations and structural details identified as critical is to be confirmed prior to welding. In addition to the alignment, the fairness of plating and welding preparations is to be verified by the Shipyard personnel in charge.

Unit Erection

Prior to the erection and pre-erection of units, the offset reference lines are to be refreshed using the permanent punch marks from the block stages.

Inspections, fit-ups and construction details are to be performed to the agreed inspection plan by the responsible party (yard, Lloyd's Register Surveyor) prior to welding of all critical joints. Class to be advised and monitor.

During fit-up, the designated Shipyard personnel will verify the alignment, fairness and weld preparation prior to welding to prevent the requirement for remedial measures.

Quality Assurance

Using information supplied on signboards, drawings, procedures, etc. the yard QA inspectors are to verify that high standards of construction are being employed in accordance with Class requirements.

The QA inspectors are to perform unscheduled patrol inspections in order to carry out the requirements noted above.

The attending Lloyd's Register Surveyor is to be notified of any irregularity requiring remedial action.

Any remedial action is to be agreed between the yard QA inspector and the attending LR Surveyor.

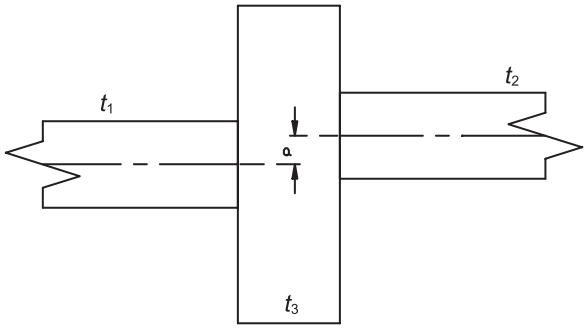
The LR Surveyor is to perform routine patrol inspections to ensure that all Class requirements are met in addition to inspections performed by the yard QA inspectors.

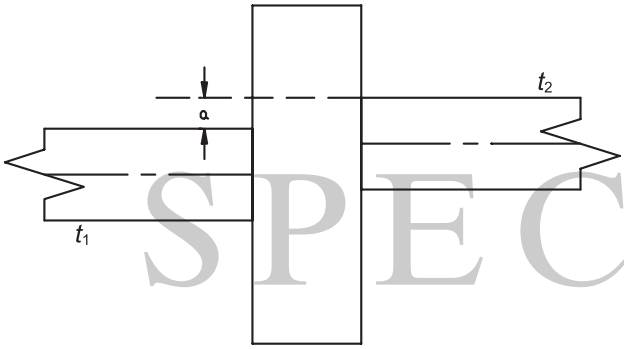
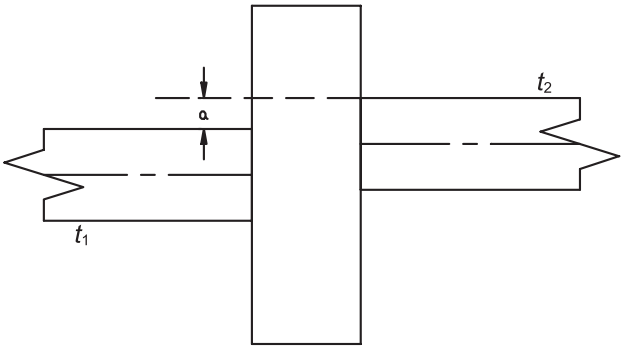
Reporting and Recording

The yard QA inspector is to record the results of the inspections performed at the critical locations prior to or during welding.

The foreman in charge is to clearly indicate the inspection results on each joint prior to welding.

Table A.1

<table>
<tr><td colspan="3">Median Line Alignment Principle</td></tr>
<tr><td rowspan="2"> 
</td><td>Tolerance</td><td>Remarks</td></tr>
<tr><td>$a \le M$
$M = \frac{t_{min}}{3}$ (Max 5 mm)
t_{min} = Min [t_1, t_2, t_3]</td><td>$M < a < 1{,}5\ M$
Increase weld leg by 15 %

$a > 1{,}5\ M$
Release and adjust over minimum 50 a</td></tr>
<tr><td> 
</td><td>$a_{1\ max} \ge a_1 \ge a_{1\ min}$
$a_{1\ max} = \frac{1}{2}(t_1 - t_2) + M$
$a_{1\ min} = \frac{1}{2}(t_1 - t_2) - M$
$M = \frac{t_{min}}{3}$ (Max 5 mm)
t_{min} = Min [t_1, t_2, t_3]</td><td>$a_{1\ max} + 0{,}5\ M \ge a_1 \ge a_{1\ max}$
or
$a_{1\ min} > a_1 \ge a_{1\ min} - 0{,}5\ M$
Increase weld leg by 15%
$a_1 \ge a_{1\ max} + 0{,}5\ M$
or
$a_1 \ge a_{1\ min} - 0{,}5\ M$
Release and re-fit over minimum 50 a</td></tr>
<tr><td colspan="3">Heel Line Alignment</td></tr>
<tr><td rowspan="2"> 
</td><td>Tolerance</td><td>Remarks</td></tr>
<tr><td>$a \le \frac{t_{min}}{3}$
Where a is the ‘overhang’ of the thinner plate
t_{min} = Min [t_1, t_2]</td><td>Misalignment Repair:
$\frac{t_{min}}{3} < a < \frac{t_{min}}{2}$
Increase weld leg by 15%
$a > \frac{t_{min}}{2}$
Release and re-fit over minimum 50 a</td></tr>
</table>

APPENDIX A

Table A.2

Reference Table for Figure A-2 Midship Section Web Frame						
Number	Space	Structure	Location	Notes	Alignment	Tolerance
001	CT03P	Deck Tran. Web at IH	TF110-204		Heel Line	+/- 3,5 mm
002	CT03P	Deck Tran. Web at CLG	TF110-204		Heel Line	+/- 3,5 mm
003	CT03P	Primary Bracket at CLG	TF110-204		Heel Line	+/- 3,5 mm
004	CT03P	Primary Bracket at TT/CLG	TF110-204		Heel Line	+/- 3,4 mm
005	CT03P	Lower Hopper Knuckle	TF110-204		Median Line	+18,6 mm, -9,3 mm
005a	CT03C	Lower Knuckle T. Webs	TF110-205		Median Line	+5,9 mm, -2,4 mm
006	CT03P	Upper Hopper Knuckle	TF110-204		Median Line	+13,2 mm, -5,2 mm
006a	CT03P	U. Hopper Knuckle Webs	TF110-205		Median Line	+5,8 mm, -2,3 mm
Reference Table for Figure A-3 Cross Ties in Tanks						
007	CT03P	Cross Tie/L.Bhd	TF110-204		Heel Line	+/- 3,5 mm
008	CT03P	Cross Tie/Inner Hull	TF110-204		Heel Line	+/- 3,5 mm
009	CT03P	Horiz. Brackets to Inner Hull	TF110-204		Heel Line	+/- 3,5 mm
010	CT03P	SS Longl. Stiff to Cross Tie	TF110-204		Heel Line	+/- 3,5 mm

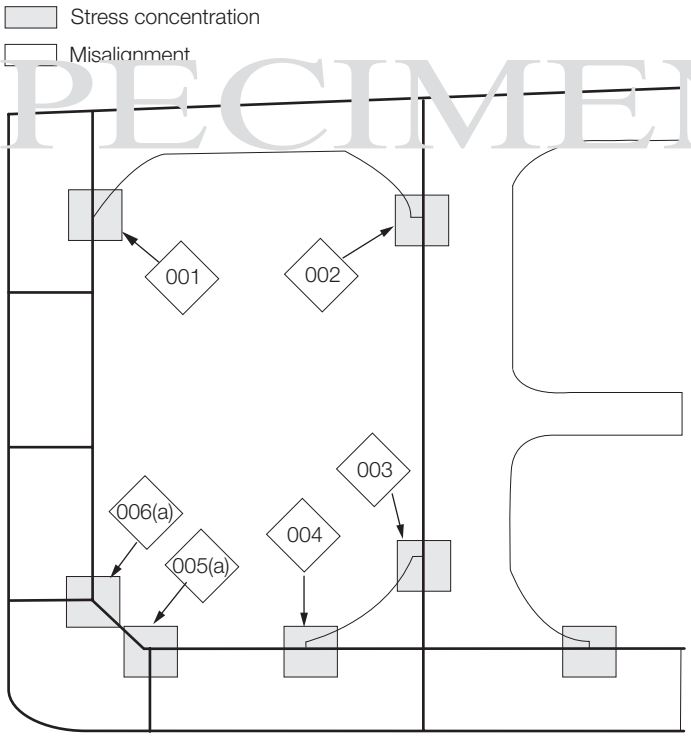


Fig. A.2 Midship Section Web Frame

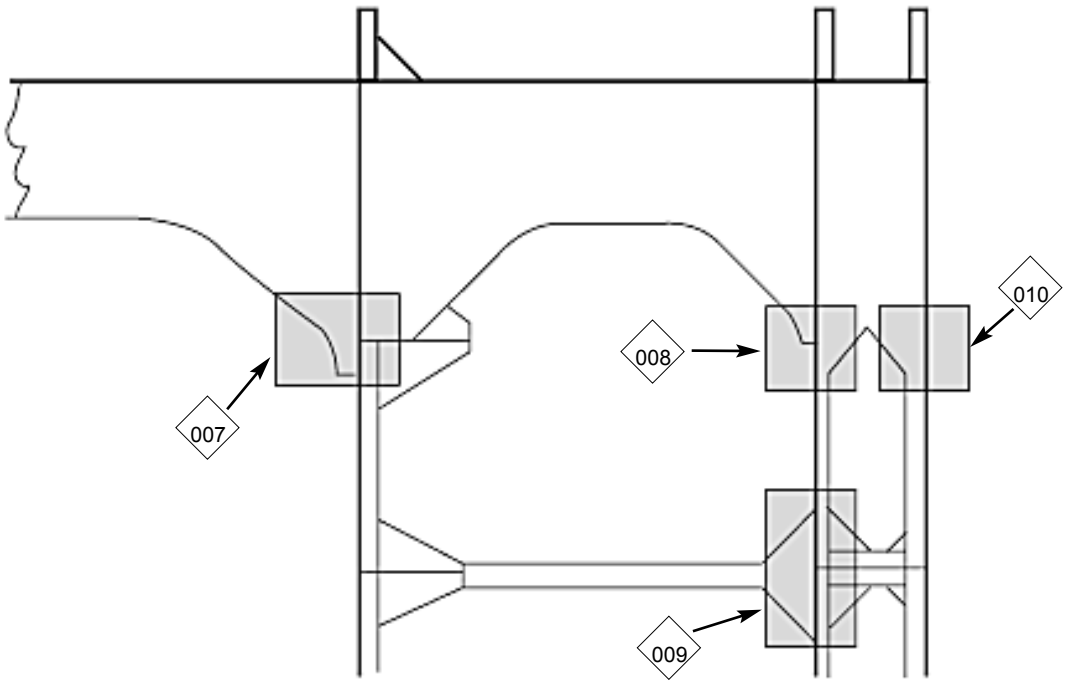


Fig. A.3 Cross Ties in Tanks

APPENIDX B: Construction Monitoring Standard

Table B.1a Median Line Principle Alignment

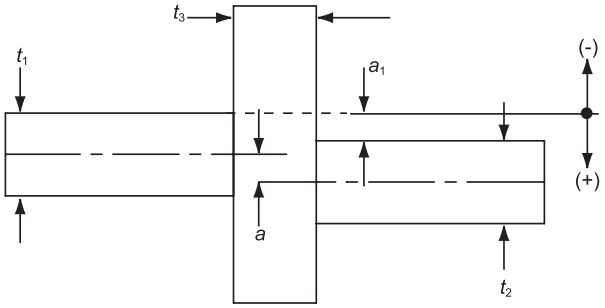
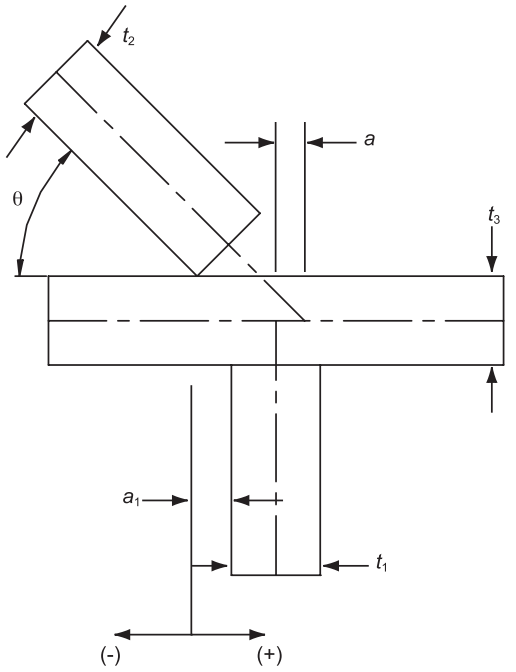
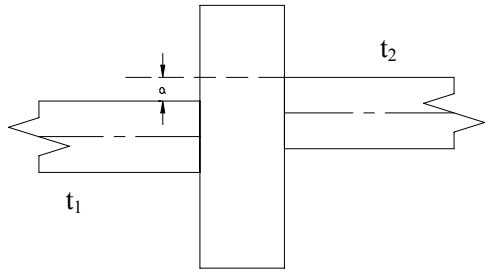
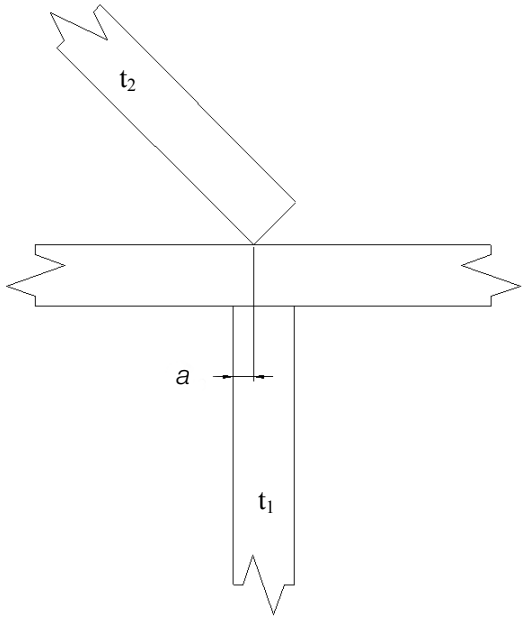
Detail	CM Standard	Notes
	$a_{1\ max} \geq a_1 \geq a_{1\ min}$ where $a_{1\ max} = \frac{1}{2}(t_1 - t_2) + M$ $a_{1\ min} = \frac{1}{2}(t_1 - t_2) - M$ measured on heel line	
	$a \leq M$ measured on the median line Median line tolerances may be converted to an equivalent heel line tolerance using the equations given below. $a_{1\ max} \geq a_1 \geq a_{1\ min}$ $a_{1\ max} = \frac{1}{2}\left(\frac{t_2}{\sin\theta} + \frac{t_3}{\tan\theta} - t_1\right) + M$ $a_{1\ min} = \frac{1}{2}\left(\frac{t_2}{\sin\theta} + \frac{t_3}{\tan\theta} - t_1\right) - M$ (measured on the heel line)	$M = t_{min}/3$ Max. 5,0 mm Where t_{min} = Minimum $[t_1, t_2, t_3]$

Table B.1b Heel Line Principle Alignment

Detail	CM Standard	Notes
	$a \leq \frac{t_{min}}{3}$ Where a is the 'overhang' of the thinner plate.	t_{min} = Minimum [t_1,t_2,t_3]
		

APPENDIX B

Table B.2 Fit-up of Tee Fillet Welds

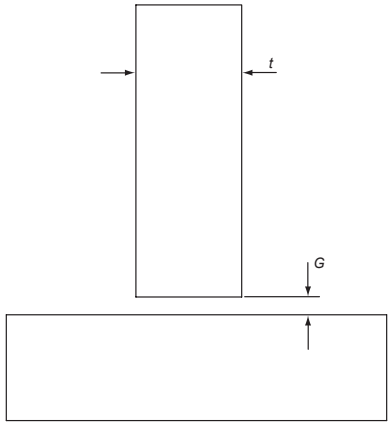
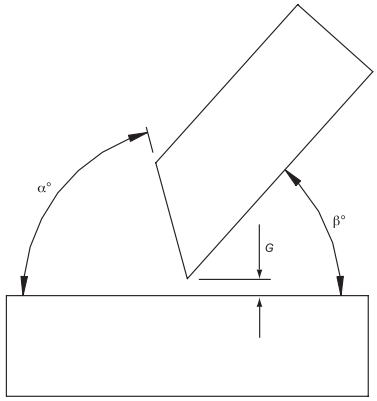
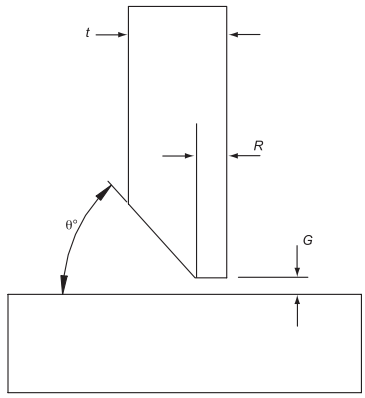
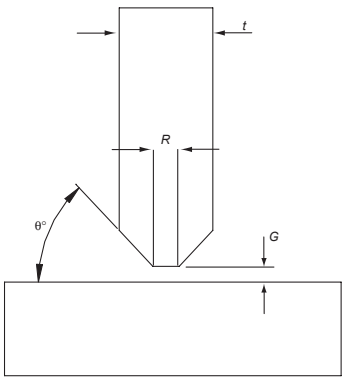
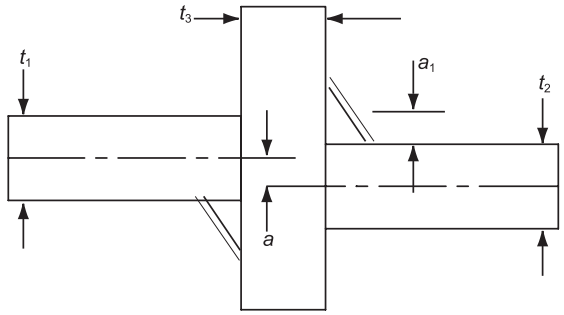
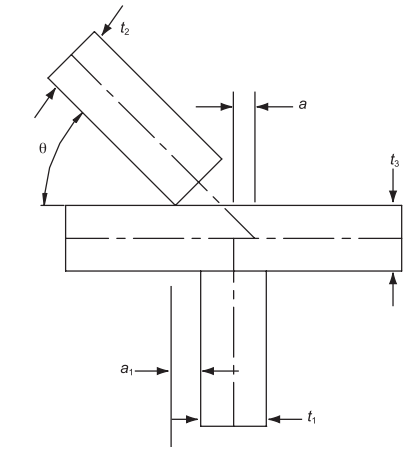
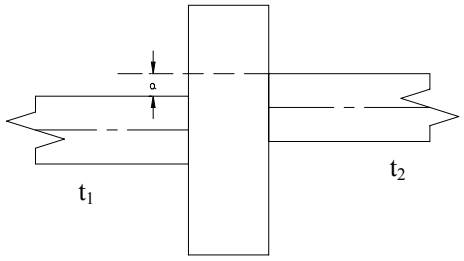
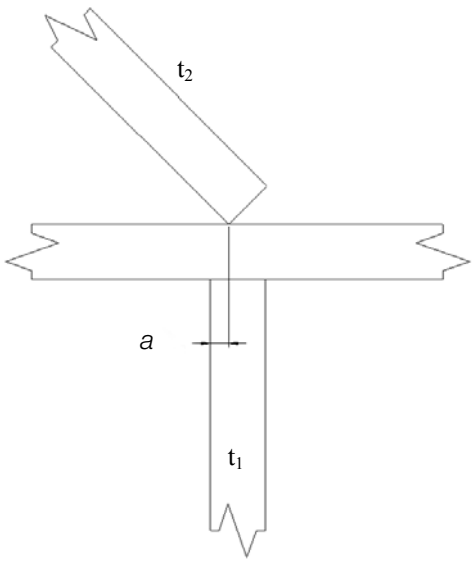
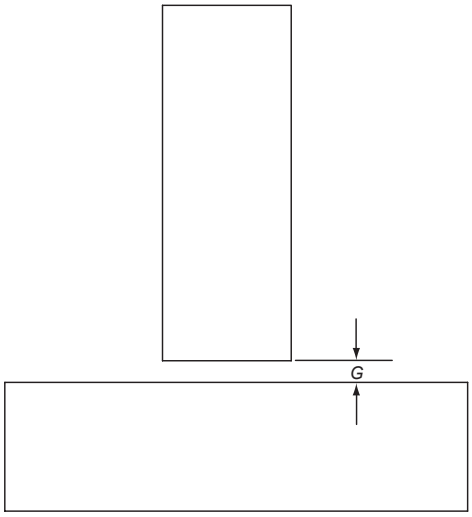
Detail	CM Standard	Notes
	G ≤ 2 mm	The high penetration of semi-automatic welding processes often results in solidification cracking and porosity. In such cases where a semi-automatic process is to be used, it is to be demonstrated as satisfactory prior to fabrication.
	a = 45° -60° b = 70° -90° *G* ≤ 2 mm	
	*G* ≤ 3 mm *R* ≤ 3 mm θ = 50°	
	*t > 19 mm* *G* ≤ 3 mm *R* ≤ 3 mm θ = 50°	

Table B.3 Misalignment Repair

Detail	CM Standard	Notes
	$t_{min}/3 < a \leq t_{min}/2$ Increase weld leg by 15% $a > t_{min}/2$ Release and re-fit over minimum 50a	Where the equivalent heel line tolerances have been calculated as given in Table A-1, the following misalignment repair is used. $a_{1\ max} + 0{,}5\ M \geq a_1 > a_{1\ max}$ or $a_{1\ min} > a_1 \geq a_{1\ min} - 0{,}5\ M$ increase weld leg by 15% $a_1 > a_{1\ max} + 0{,}5\ M$ or $a_1 < a_{1\ min} - 0{,}5\ M$ Release and refit over a minimum 50 a where $M = \frac{t_{min}}{3}$ t_{min} = Minimum $[t_1, t_2, t_3]$ $\frac{t_{min}}{3}$ not to exceed 5 mm
		
	$\frac{t_{min}}{3} < a \leq \frac{t_{min}}{2}$ Increase weld leg by 15% $a > \frac{t_{min}}{2}$ Release and re-fit over minimum 50a	t_{min} = Minimum $[t_1, t_2]$
		

APPENDIX B

Table B.4 Fillet Weld Fit-up Repair

<table>
<tr><th>Detail</th><th>Repair Standard</th><th>Notes</th></tr>
<tr><td rowspan="3"> 
</td><td>2 mm < G ≤ 5 mm - increase leg length of weld to Rule leg by + (G-2)</td><td rowspan="3">For Cruciform Joints where

3 mm ≤ G ≤ 6 mm

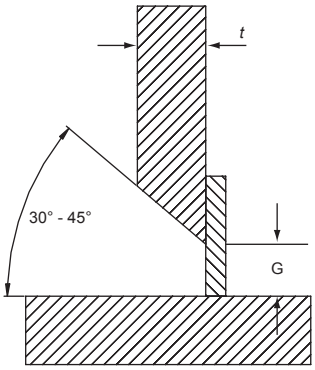
the weld should be ‘full penetration’ and subject to additional ultrasonic NDE using both 45° and 70° probes, to the satisfaction of the Surveyor.

For Cruciform Joints where

G > 6 mm

The joint is to be adjusted until compliance is reached

OR

an insert plate is to be fitted to the satisfaction of the Surveyor.</td></tr>
<tr><td>5 mm < G ≤ 16 mm - chamfer to 30° – 45° , build up with welding on one side, with or without backing bar, remove backing strip if used, back gouge and seal with weld.
 
</td></tr>
<tr><td>where
G > 16 mm
or
G > 1,5t

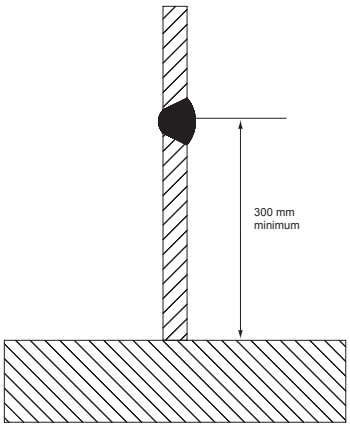
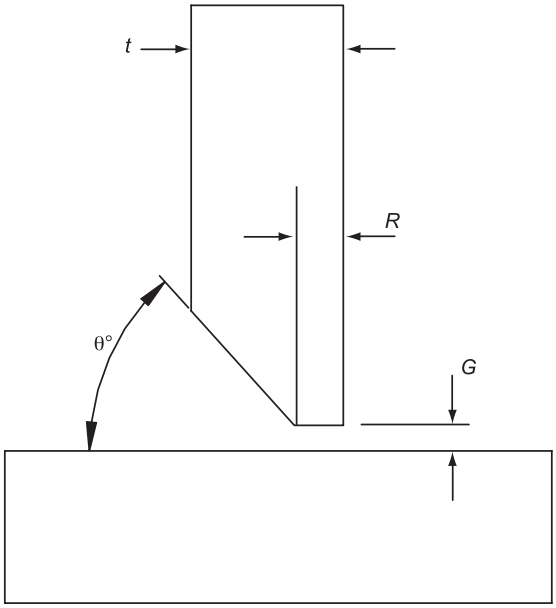
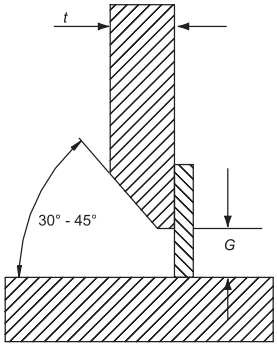
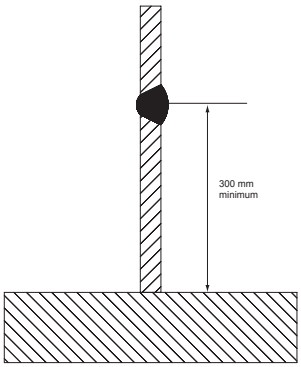
Insert plate of minimum width 300 mm to be used
 
</td></tr>
</table>

Table B.5 Typical Fillet Weld Edge Preparation Repair

Detail	Repair Standard	Notes
	2 mm < G ≤ 5 mm Build up with weld	
	5 mm < G ≤ 16 mm Build up with weld, with or without backing strip, remove backing strip if used, back gouge and back weld. 	
	where G > 16 mm or G > 1,5*t* Insert plate of minimum width 300 mm to be used. 	

APPENDIX C:
Construction Monitoring Technical Detail Supplements

To be issued.