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Ships and marine technology — Bulk carriers — Construction quality of hull structure

*Navires et technologie maritime — Vraquiers — Qualité de construction
de la structure de la coque*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15401 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 8, *Structures*.

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Introduction

The aim of this International Standard is to provide guidelines for good shipbuilding production conditions.

Details, where appropriate, given in this International Standard were developed with reference to applicable International Association of Classification Societies (IACS) rules and requirements.

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Ships and marine technology — Bulk carriers — Construction quality of hull structure

SAFETY PRECAUTIONS — It is the responsibility of the user of this International Standard to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.

1 Scope

This International Standard specifies the quality requirements for the hull construction of steel bulk carriers. It does not apply to double-skin bulk carriers.

Requirements for the maintenance and repair of steel bulk carriers are given in ISO 15402.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 8501-1:1988, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings* and its Informative Supplement of 1994, *Representative photographic examples of the change of appearance imparted to steel when blast-cleaned with different abrasives*.

ISO 8503-1:1988, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces*.

IMO A.798 (19), *Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tank*.

ISO 15402, *Ships and marine technology — Bulk carriers — Repair quality of hull structure*.

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1

bulk carrier

ship which is generally constructed with a single deck, topside tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk

3.2

length L

the definition is taken from the rules of classification societies

4 Quality control through construction

4.1 Steel material

4.1.1 Upon arrival in the yard, all steel materials intended for ship construction shall be checked against quality certificates. A visual inspection shall be carried out to confirm their quality.

4.1.2 All steel materials shall be stored according to sizes and brand and kept flat.

4.1.3 All steel materials shall be issued against material allocation sheets according to the construction plan.

4.1.4 A quality inspection shall be carried out on the steel materials before processing.

Special attention shall be paid to the following points of quality control:

- a) material quality documentation;
- b) size, brand, charge number and batch number;
- c) minus tolerance in thickness for plates and sections;
- d) lamination and surface defects;
- e) any defects in large forgings and castings.

4.2 Steel processing

4.2.1 Marking and cutting

4.2.1.1 Necessary pretreatments such as: levelling, straightening, derusting and application of shop primer shall be carried out on the plates and sections before putting them into production.

4.2.1.2 Numerical control cutting and other highly efficient high-precision cutting shall be used to the widest possible extent to improve cutting accuracy.

4.2.1.3 Information related to material property, charge number and batch number shall be filed for important members.

4.2.1.4 Special attention shall be paid to the following points of quality control:

- a) size deviation;
- b) angular deviation;
- c) marks such as processing symbols, codes and technological numbers;
- d) cutting accuracy;
- e) dimensions of configuration.

4.2.2 Forming

4.2.2.1 Hot or cold bending of steel plates and sections shall be performed according to the applicable technology requirements for different properties and grades of materials.

4.2.2.2 Special attention shall be paid to the following points of quality control:

- a) heating temperature;
- b) accuracy of bending.

4.3 Fitting and assembly

4.3.1 Fitting and assembly of parts and members

4.3.1.1 The accuracy requirements of block assembly shall be met for the fitting and assembly of parts and members. Protective primer shall be repaired after welding.

4.3.1.2 Special attention shall be paid to the following points of quality control:

- a) geometrical dimensions of parts and members;
- b) installation locations;
- c) excessive gap before welding;
- d) deformation.

4.3.2 Block assembly

4.3.2.1 Block assembly should generally be carried out on a platform or jig.

4.3.2.2 Pre-outfitting of parts and members shall be done according to applicable design drawings.

4.3.2.3 The accuracy that meets the requirements given in the following pages for general assembly shall also be met for block assembly.

4.3.2.4 Block assemblies may be coated after inspection.

4.3.2.5 Special attention shall be paid to the following points of quality control:

- a) marking accuracy;
- b) installation accuracy of internal structure joints inside the block;
- c) accuracy of block configuration and its dimensional size;
- d) accuracy of block edges;
- e) correctness of assembling reference lines;
- f) flatness of face plate and location deviation of main engine bed;
- g) installation locations of key components, such as shaft boss, rudder horn, etc.

4.3.3 Erection on shipway/dock

4.3.3.1 Marking on the shipway/dock shall be carried out with corresponding symbols and marks.

4.3.3.2 Placing the reference block in position, and then proceeding with successive blocks shall be done according to the shipway/dock assembly schedule.

4.3.3.3 During the construction process, all temporary openings in strength members and their closing-up shall comply with the requirements set out in the applicable construction drawings and/or standards.

4.3.3.4 Removing temporary welding pieces and lifting eyepieces shall be done according to usual practice (refer to Table 37).

4.3.3.5 After completing shipway/dock assembly, the hull shall be coated or the (block) coating repaired according to specified requirements before launching.

4.3.3.6 Special attention shall be paid to the following points of quality control:

- a) accuracy of marking on the shipway/dock;
- b) correctness of location of the reference block;
- c) frame spacing at block junctions;
- d) alignment accuracy of structural members;
- e) straightness of base line;
- f) alignment accuracy of propeller shaft centreline;
- g) marking accuracy of loadline and draft marks;
- h) principal dimensions of the hull.

4.4 Welding

4.4.1 Preparation before welding

Welding materials, preparation of weld joints and assembly accuracy shall comply with classification society requirements set out in quality control documents.

The welding zone shall be free of rust, scales, grease, moisture or other dirt.

The environmental condition of the welding area shall be kept in good order.

Tack welding shall be carried out according to specified technological procedures.

Wherever new materials or new welding technologies are adopted, test reports and welding procedures shall be submitted to the classification society for approval.

4.4.2 Welding process

All welding shall be carried out according to the methods and conditions as required by the welding technology procedures. Proper measures for minimizing welding deformation shall be taken.

4.4.3 Welding inspection

4.4.3.1 Inspection of welding shall be carried out throughout the whole process of welding including inspections before, during and after welding, as well as the inspection of finished weldments.

4.4.3.2 All welds shall be visually examined first.

4.4.3.3 Quality inspection of welded seams shall be carried out according to specified requirements. Either X-ray detection, ultrasonic detection or other inspection methods approved by the classification society shall be adopted.

4.4.3.4 Leg sizes (leg length and throat depth) of fillet welds shall comply with the design plan and relevant codes as approved by the classification society.

4.4.3.5 Welded joints on the strength deck, shell plate and interior strength members in the mid-length region shall be inspected in accordance with the non-destructive inspection plan approved by the classification society.

4.4.3.6 Welds not conforming to the requirements of quality standards shall be rectified and repaired, and shall be inspected again.

4.4.4 Quality control

Special attention shall be paid to the following points of quality control:

- a) qualification of welders;
- b) welding materials;
- c) welding codes;
- d) groove sizes and seam clearance;
- e) cleanness of welding region;
- f) preheating and heat-retaining;
- g) welding deformation;
- h) sizes of welded seams;
- i) integrity of all-around welds;
- j) surface and inner defects in welding seam.

4.5 Tightness test

4.5.1 General requirements

4.5.1.1 The tightness test shall be conducted after the main hull and the structure are completed. All accessories affecting the tightness should be fixed and non-destructive testing shall be correctly completed.

4.5.1.2 All welding seams related to the tightness test, shall be free of scales, slugs, coatings (excluding primers) or any grease (refer to Table 48).

4.5.1.3 The tightness test for the hull structure shall be performed with either water jet, hydrostatic pressure, air pressure or other equivalent methods depending on the hull strength and tightness requirement.

4.5.1.4 The tightness test may be performed on blocks.

4.5.1.5 The location and requirements for the tightness test shall be in compliance with the requirements of the classification society.

4.5.2 Quality control

Special attention shall be paid to the following points of quality control:

- a) cleaning of welded seams;
- b) test pressure;
- c) test procedure;
- d) test duration;
- e) inspection for deformation and leakage.

4.6 Coating

4.6.1 Pretreatment of steel surface

Surface pretreatment of steel shall be done in general by means of shot-blasting, abrasive blasting and chemical cleaning (shop primer shall be applied after derusting).

Surface pretreatment shall be done in accordance with the quality stipulations given in Table 45.

Shop primer shall be applied according to the quality stipulations given in Table 46.

4.6.2 Shop primer touch-up

Any damaged shop primer shall be touched up after completion of the welding process.

4.6.3 Second derusting and surface cleaning

Second derusting and surface cleaning shall be done in accordance with the quality stipulations given in Table 47 and Table 48.

4.6.4 Coating work

4.6.4.1 Precoating

Precoating shall be done for the spots and areas that cannot be easily accessed or which are difficult to reach to obtain the required film thickness by spraying.

4.6.4.2 Coating

Coating may be done by means of either airless spraying or roller application, etc.

4.6.4.3 Quality control

Special attention shall be paid to the following points of quality control:

- a) environmental conditions affecting coating operation;
- b) appearance of coat;
- c) wet film thickness or dry film thickness;
- d) film thickness allocation.

5 Hull construction accuracy

5.1 Steel material

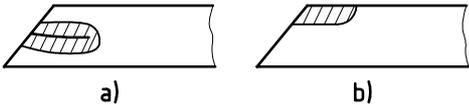
5.1.1 Surface defects of steel plates shall be kept within the limits given in Table 1.

Table 1 — Surface defects of steel plates

Items	Requirements
Pits, flaking, scars, scratches and air bubbles	<div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p style="text-align: center;">Depth of defect, d (mm)</p> <p style="text-align: center;">Defect area ratio (%)</p> </div> <div style="flex: 2; padding-left: 20px;"> <p>(1) Zone A is in excellent order, with very slight surface defects less than 0,2 mm and no repairing is required.</p> <p>(2) Zone B is in good order, with a certain amount of permissible surface defects, and no repairing is required. Area enclosed by full line denotes plate with thickness less than 20 mm and area enclosed by dotted line (including straight line) denotes plates with thickness from 20 mm to 50 mm.</p> <p>(3) Zone C is in disorder, and repairing is required, i.e. there are certain amounts of impermissible surface defects that shall be repaired according to the requirement.</p> <p>(4) Repair method for surface defects:</p> <p>for $d < 0,07 t$, by grinding (but in any case $d \leq 3$ mm);</p> <p>for $0,07 t \leq d \leq 0,2 t$, by built-up welding and followed by grinding, where d is defect depth, in millimetres; t is plate thickness, in millimetres.</p> <p>When the defect depth exceeds 20 % of the plate thickness and the defect area exceeds 2 % of the plate area, this part of the plate shall be replaced.</p> </div> </div>

5.1.2 Lamination of steel plate shall be treated according to Table 2.

Table 2 — Lamination of steel plate

Items	Requirements
Local lamination 	<p>(1) When the range of lamination is fairly small, it may be chipped out and built-up by welding as given in Figure a). When the range of lamination is fairly small and near the plate surface, it is preferable to do built-up welding as given in Figure b).</p> <p>(2) When the lamination is severe and defective, it shall be carefully examined and repaired by an appropriate method. If welding extending over 20 % of the plate edges is used as a method of repair, non-destructive testing shall be applied to this area.</p>
Severe lamination	<p>(1) It is recommended to exchange part of the plate in case the lamination is fairly extensive.</p> <p>(2) Minimum breadth or length of the part of standard size plate to be replaced. For shell plate or strength-deck plate: within 0,6 L amidship — 1 600 mm; outside 0,6 L amidship — 800 mm. For other members: 300 mm or 10 times the plate thickness, whichever is greater. In specific cases, the above dimension may be reduced to 50 mm + 4 t; where t is the plate thickness in millimetres.</p> <p>(3) The whole plate shall be replaced when the lamination is extremely severe and extensive.</p>

5.1.3 The minus tolerance in thickness for plates of the hull structure shall be in compliance with the requirements given in Table 3.

Table 3 — Minus tolerance in thickness for plates of hull structure

Dimensions in millimetres

Items	Allowable limits
Minus tolerance in thickness for plates of hull structure	0,30

5.1.4 Surface defects of casting steel shall be treated according to Table 4.

Table 4 — Surface defects of casting steel

Items	Remarks	
When the depth of the defect is over 20 % of the item thickness	Repairing and building up shall be done according to the requirement and regulations of the classification surveyor	
When the depth of the defect is below 20 % of the item thickness	the defect is over 25 mm in depth or 150 mm in length	Repairing and building up shall be done by an appropriate method after non-destructive inspection
	the defect is below 25 mm in depth and 150 mm in length	Repairing and building up shall be done by an appropriate method
Air bubbles, flaws and other harmful defects	Repairing and building up shall be done by an appropriate method after non-destructive inspection	

5.2 Marking

5.2.1 The position deviation of marking shall be kept within the limits given in Table 5.

Table 5 — Position deviation of marking

Dimensions in millimetres

Items	Standard range	Allowable limits
Deviation of centreline, theoretical lines, alignment lines, check lines and installation position line	$\pm 2,0$	$\pm 3,0$

5.2.2 The deviation of marking dimensions of parts and members shall be kept within the limits given in Table 6.

Table 6 — Deviation of marking dimensions of parts and members

Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks
Length	$\pm 2,0$	$\pm 3,0$	
Breadth	$\pm 1,5$	$\pm 2,5$	
Difference between diagonals	$\pm 2,0$	$\pm 3,0$	For rectangular plate
Curved configuration	$\pm 1,5$	$\pm 2,5$	
Straightness	$l \leq 4 \text{ m}$	$\leq 1,0$	For straight edges of parts or members
	$4 \text{ m} < l \leq 8 \text{ m}$	$\leq 1,2$	
	$l > 8 \text{ m}$	$\leq 2,0$	
Angle	$\pm 1,5$	$\pm 2,0$	For every metre
Cut out, opening	0 to 1,5	0 to 2,0	

5.2.3 The deviation of marking dimension of block structure shall be kept within the limits given in Table 7.

Table 7 — Deviation of marking dimension of block structure

Dimensions in millimetres

Items	Standard range	Allowable limits
Deviation of marking line of panel block, compared with designed dimensions	$\pm 2,5$	$\pm 3,5$
Location of member for installing on block, compared with designed position	$\pm 2,5$	$\pm 3,5$

5.3 Cutting

5.3.1 Gas cutting

5.3.1.1 The surface roughness of gas cutting shall be kept within the limits given in Table 8.

Table 8 — Surface roughness of gas cutting

Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks	
Free edges of members	Important members	Automatic, semiautomatic cutting	0,10	0,20	(1) For steel sections, tolerance of machine cutting is the same as those for manual cutting (2) Burrs on free edges should be removed
		Manual cutting	0,15	0,30	
	Others	Automatic, semiautomatic cutting	0,10	0,20	
		Manual cutting	0,50	1,00	
Weld chamfers	Important members	Automatic, semiautomatic cutting	0,10	0,20	
		Manual cutting	0,40	0,80	
	Others	Automatic, semiautomatic cutting	0,10	0,20	
		Manual cutting	0,80	1,50	

5.3.1.2 The notches of gas cutting shall be kept within the limits given in Table 9.

Table 9 — Notches of gas cutting

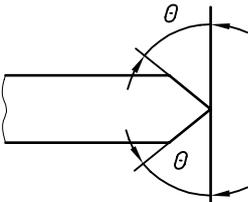
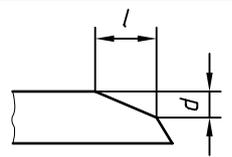
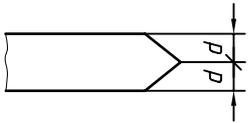
Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks	
Free edges of members	Upper edge of sheer strake, strength deck, and free edges of opening on shell plate within 0,6 L amidship		—	No notch	(1) "Notch" is defined as groove more than 3 times the surface roughness. (2) Repairing method: a) finishing by grinding; b) bead welding may be applied where required, but short bead shall be carefully avoided.
	Important longitudinals and transverses		—	< 1,0	
	Others		—	< 3,0	
Weld edges	Butt weld	Shell plate and strength deck within 0,6 L amidship	—	< 2,0	Notch shall be repaired by grinding or built-up welding
		Others	—	< 3,0	
	Fillet weld		—	< 3,0	

5.3.1.3 The deviation of gas-cutting dimension shall be kept within the limits given in Table 10.

Table 10 — Deviation of gas cutting dimension

Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks
Straightness of plate edge	Automatic welding seam	0,4	0,5	
	Semi-automatic and manual welding seam	1,0	2,5	
Dimensions of chamfers	Angle of groove, θ		$\theta = \pm 2^\circ$	$\theta = \pm 4^\circ$
	Length of taper, l		$l = \pm 0,5d$	$l = \pm 1,0d$
	Depth of groove, d		$d = \pm 1,5$	$d = \pm 2,0$
Size of member	Size of member as compared with correct size	$\pm 3,5$	$\pm 5,0$	For members with high accuracy demand such as floors and girders, etc. in double bottom
		$\pm 2,0$	$\pm 4,0$	
	Breadth of face bar as compared with correct size	$\pm 2,0$	+ 4,0 - 3,0	

5.3.2 The deviation of shearing dimension shall be kept within the limits given in Table 11.

Table 11 — Deviation of shearing dimension

Dimensions in millimetres

Items	Standard range	Allowable limits
Length of member	$\pm 3,0$	$\pm 4,0$
Breadth of member	$\pm 2,0$	$\pm 3,0$
Breadth of face bar, height of floor	$\pm 2,0$	$\pm 3,0$
Straightness of the edge	$\pm 1,0$	$\pm 1,5$
Curved edge	$\pm 1,5$	$\pm 2,0$

5.3.3 The deviation of planed and milled edges shall be kept within the limits given in Table 12.

Table 12 — Deviation of planed and milled edges

Dimensions in millimetres

Items	Standard range	Allowable limits
Edge straightness	$\leq 0,5$	$\leq 1,0$
Angle of edge preparation	$\pm 2^\circ$	$\pm 3^\circ$

5.4 Bending

5.4.1 The deviation of flanging shall be kept within the limits given in Table 13.

Table 13 — Deviation of flanging

Dimensions in millimetres except where otherwise stated

Items	Standard range	Allowable limits	Remarks
Breadth of flange, b	$\pm 3,0$	$\pm 5,0$	
Depth of web, h	Principal members	$\pm 3,0$	
	Others	$\pm 5,0$	
Deviation of flange, a	$\pm 2,5$	$\pm 4,5$	per 100 in breadth
Curvature in the plane of flange	± 10	± 25	Per 10 m in length
Curvature in the plane of web	± 10	± 25	

5.4.2 The deviation of corrugated plate shall be kept within the limits given in Table 14.

Table 14 — Deviation of corrugated plate

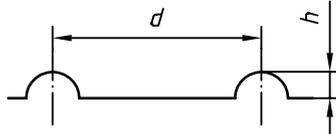
Dimensions in millimetres

Items	Standard range	Allowable limits
Depth of corrugation, h	$\pm 3,0$	$\pm 6,0$
Breadth of corrugation, b_1 and b_2	$\pm 3,0$	$\pm 6,0$

5.4.3 The deviation of channelled plate shall be kept within the limits given in Table 15.

Table 15 — Deviation of channelled plate

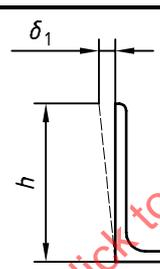
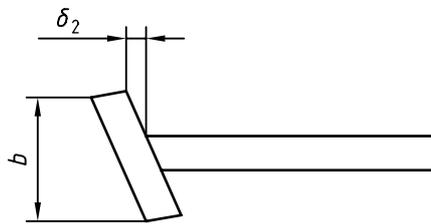
Dimensions in millimetres

Items		Standard range	Allowable limits	
Depth of channel, h		$\pm 2,5$	$\pm 5,0$	
Pitch of channel, d		regular	$\pm 2,0$	$\pm 3,0$
		irregular	$\pm 6,0$	$\pm 9,0$

5.4.4 The bending deviation of sections and built-up profiles shall be kept within the limits given in Table 16.

Table 16 — Bending deviation of sections and built-up profiles

Dimensions in millimetres except where otherwise stated

Items		Standard range	Allowable limits	Remarks	
Sections	Angular deviation, δ_1		$\pm 1,5$	$\pm 2,0$	per 100 in h
	Local bending deviation				
Build-up profiles	Bending deviation		$\pm 2,0$	$\pm 4,0$	per 10 m in length, compared with template
	Inclination of face plate, δ_2				

5.4.5 The bending deviation of shell plates shall be kept within the limits given in Table 17.

Table 17 — Bending deviation of shell plates

Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks
Plate with single curvature	Gap between curved plate and template	≤ 2,5	≤ 5,0	Within each frame spacing
	Straightness of check line on triangular template	≤ 2,5	≤ 5,0	
Plate with double curvature	Deviation between drawn line and reference line on template	± 2,0	± 3,0	Within each frame spacing
	Gap between plate and box template in breadthwise direction	≤ 4,0	≤ 5,0	
	Gap between plate and box template in lengthwise direction	≤ 3,0	≤ 5,0	

5.4.6 The heating procedure shall be according to the requirements given in Table 18.

Table 18 — Heating

Items			Standard range	Allowable limits	Remarks
Maximum heating temperature on surface	High tensile steel Ceq > 0,38 %	Water cooling immediately after heating	Under 650 °C	650 °C	Calculation formula for carbon equivalent: Ceq = C + Mn/6 +(Cr+Mo+V)/5 +(Ni+Cu)/15
		Air cooling after heating	Under 900 °C	900 °C	
		Air cooling and subsequently water cooling after heating	Air cooling under 900 °C, water cooling started when temperature below 500 °C	Air cooling at 900 °C, water cooling started when temperature at 500 °C	
	High tensile steel Ceq ≤ 0,38 % Grades A, D	Water or air cooling immediately after heating	Under 1 000 °C	1 000 °C	
High tensile steel Ceq ≤ 0,38 % Grades E	Water or air cooling immediately after heating	Under 900 °C	900 °C		

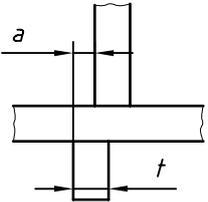
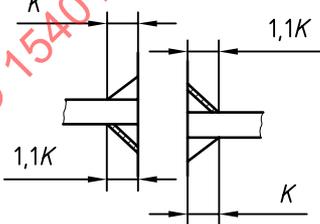
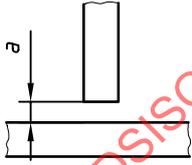
5.5 Fitting and assembly

5.5.1 Fitting and assembly accuracy for various welding joints

5.5.1.1 The position deviation of fillet-welding joints shall be kept within the limits given in Table 19.

Table 19 — Position deviation of fillet-welding joints

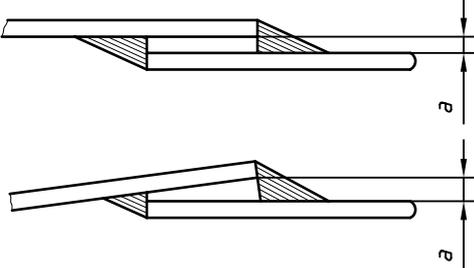
Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks
Alignment of fillet joint	 <p><i>a</i> is misalignment <i>t</i> is thickness of thinner plate</p>	Primary strength members	$\leq t/4$	<p>(1) When $t/3 \leq a \leq t/2$, the leg of fillet welding should be increased as shown in the figure below</p>  <p><i>K</i> is specified dimension of fillet</p> <p>(2) when $a > t/2$, joint should be reassembled</p>
	Others (stressed members)			$\leq t/3$
Gap before fillet welding			≤ 2	<p>Treatment for exceeding allowable limit:</p> <p>(1) When $3 \leq a \leq 5$, leg length shall be increased by $(a-2)$</p> <p>(2) When $5 < a \leq 16$, liner or build-up weld may be adopted</p> <p>(3) When $a > 16$, vertical plate shall be cut and replaced by new plate with height not less than 300 mm</p>

5.5.1.2 The deviation of lap-welding joints shall be kept within the limits given in Table 20.

Table 20 — Deviation of lap-welding joints

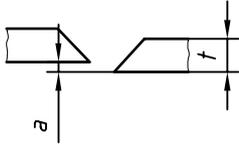
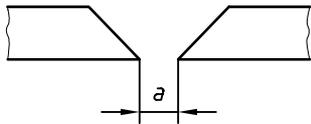
Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks
	≤ 2	≤ 3	<p>Treatment for exceeding allowable limit:</p> <p>(1) when $3 \leq a \leq 5$, leg shall be increased by $(a-3)$;</p> <p>(2) when $a > 5$, reassembly is required.</p>

5.5.1.3 The deviation of butt-welding joints shall be kept within the limits given in Table 21.

Table 21 — Deviation of butt-welding joints

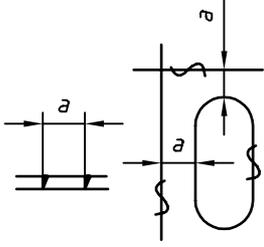
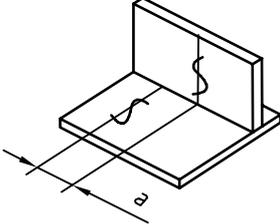
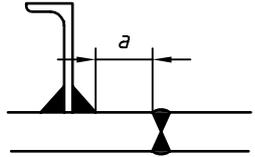
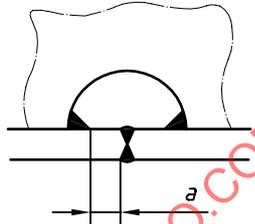
Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks	
Deviation of welding seam		Important members $\leq 0,1t$, and ≤ 3	$\leq 0,15t$, and ≤ 3	Deviations exceeding allowable limits shall be reinstalled. a is misalignment; t is thickness of thinner plate.
Others	$\leq 0,15t$, and ≤ 3	$\leq 0,2t$, and ≤ 3	Treatment when exceeding allowable limit: (1) When $5 < a \leq 16$, a) add steel backing bar and weld the front; b) remove steel backing bar and finish back weld. (2) When $16 < a \leq 25$, a) add steel backing bar, welding main seam only after one slope of the front is in correct form; b) remove steel backing bar and finish back weld. (3) When $a > 25$, renew the plate partially and reinstall.	
Gap of chamfers by manual welding		2 to 3,5	$\leq 5,0$	

5.5.1.4 The distance between welds shall be in accordance with the limits given in Table 22.

Table 22 — Distance between welds

Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks		
Between butt welds		—	≥ 30	When the details of construction are not defined in the approved plans, they shall be decided by mould lofting or in working drawings, and within the limits given in the sketch shown on the left.	
		—	≥ 0		
Between butt and fillet welds		Principal members	—	≥ 10	
		Others	—	≥ 0	
		Principal members	—	$\geq 5,0$	
		Others	—	≥ 0	

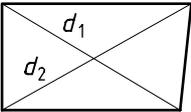
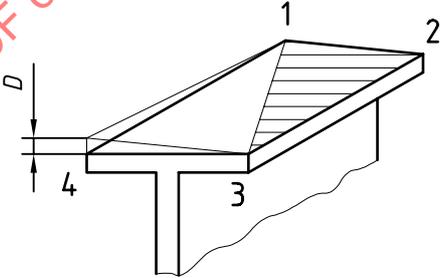
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5.5.2 Sub-assembly

5.5.2.1 The accuracy of installation dimensions for flat and curved sub-assemblies shall be in compliance with the requirements given in Table 23.

Table 23 — Accuracy of installation dimensions for flat and curved sub-assemblies

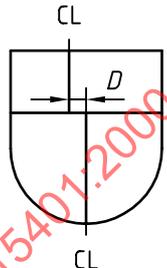
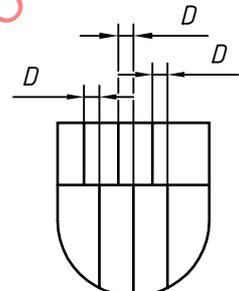
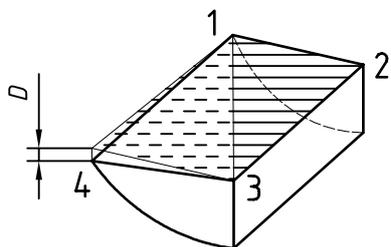
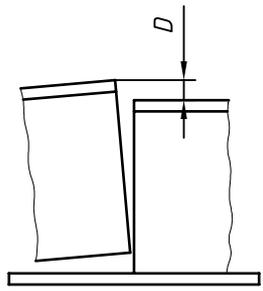
Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks
Breadth of sub-assembly	Flat	± 4	± 6	
	Curved		± 8	
Length of sub-assembly	Flat	± 4	± 6	
	Curved		± 8	
Squareness of sub-assembly (difference D between diagonals d_1 and d_2 in final marking)	Flat	4	8	$D = d_1 - d_2$ 
	Curved	10	15	
Distortion of sub-assembly (measured on face plates of beam or girder)		10	20	 <p>D = vertical distance of point 4 from plane 1, 2, 3</p>
Deviation of the distance between joints of interior members and skin plate		± 5	± 10	

5.5.2.2 The accuracy of installation dimensions of block assemblies shall be in compliance with the requirements given in Table 24.

Table 24 — Accuracy of installation dimensions of block assemblies

Dimensions in millimetres

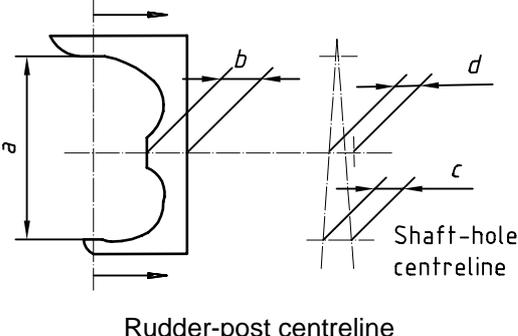
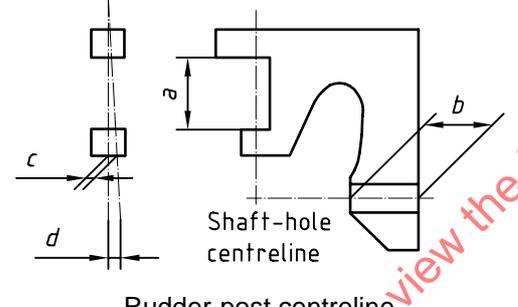
Items		Standard range	Allowable limits	Remarks
Deviation of centrelines between upper and lower planes	Flat block	5	10	
	Curved block	7	15	
Deviation of frame lines between upper and lower planes	Flat block	5	10	
	Curved block	7	15	
Twist of assembly (for large, rigid block assembly)	Flat block	10	20	
	Curved block	15	25	
Deviation of height ^a for structures at the same level		± 4	± 6	
Deviation in height ^a for structures at two different levels		± 5	± 10	
Others, same as for plane and curved sub-assemblies in Table 23		—	—	

^a The "height" means vertical distance from the same datum plane.

5.5.2.3 The accuracy of installation dimensions of block assemblies of stern frame shall be in compliance with the requirements given in Table 25.

Table 25 — Accuracy of installation dimensions of block assemblies of stern frame

Dimensions in millimetres

Items	Standard range	Allowable limits
Distance between upper and lower rudder carriers, <i>a</i>		± 5
Distance between aft edge of boss and aft peak bulkhead, <i>b</i>		± 10
Inclination of sub-assembly, <i>c</i>		5
Deviation of rudder-post centreline from shaft centrelines, <i>d</i>		4
Others, same as for those in Table 24.	—	—

5.5.2.4 The accuracy of installation dimensions of assemblies including the main engine foundation shall be in compliance with the requirements given in Table 26.

Table 26 — Accuracy of installation dimensions of assemblies including main engine foundation

Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks
Flatness of face plate of main engine foundation	≤ 5	≤ 10	
Length and breadth of face plate of main engine foundation	± 4	± 6	If the foundation is the part of longitudinal girder construction, measure the deviation from the centreline
Others, same as for those in Table 24.	—	—	

5.5.2.5 The assembly deviation on the shipway/dock shall be kept within the limits given in Table 27.

Table 27 — Assembly deviation on the shipway/dock

Dimensions in millimetres

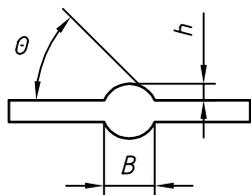
Items		Standard range	Allowable limits	Remarks
Deviation between centrelines of	double-bottom sub-assembly and shipway/dock	$\leq 3,0$	$\leq 5,0$	
	deck, platform, transverse bulkhead and double bottom	$\leq 5,0$	$\leq 8,0$	
	fore and aft terminal points and shipway/dock	$< h/1\ 000$	$< 1,5\ h/1\ 000$	h is the height of fore/aft terminal
	superstructure and deck	$\leq 4,0$	$\leq 8,0$	
	upper rudder carrier and shipway/dock	$\leq 4,0$	$\leq 8,0$	
	stern shaft hole and shipway/dock	$\leq 5,0$	$\leq 8,0$	
Levelness or planeness	levelness at four corners of bottom, platform and deck	$\pm 8,0$	$\pm 12,0$	
	planeness of bulkhead (port/starboard, fore/aft)	$\pm 4,0$	$\pm 6,0$	
	planeness of side sub-assembly (fore/aft)	$\pm 5,0$	$\pm 10,0$	
	levelness at four corners of superstructure	$\pm 10,0$	$\pm 15,0$	
Height of positioning	bulkhead	$\pm 3,0$	$\pm 6,0$	
	side sub-assembly	$\pm 5,0$	$\pm 8,0$	
	superstructure	$+ 10,0$	$+ 15,0$	
Frame spacing at sub-assembly joint		$\pm 10,0$	$\pm 20,0$	
Perpendicularity of bulkhead		$< h/1\ 000$ and $< 10,0$	$< 1,2\ h/1\ 000$ and $< 12,0$	h is the height of bulkhead

5.6 Welding

5.6.1 The deviation of welding dimensions shall be kept within the limits given in Table 28.

Table 28 — Deviation of welding bead dimensions

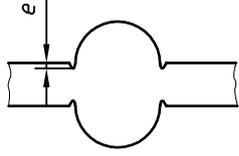
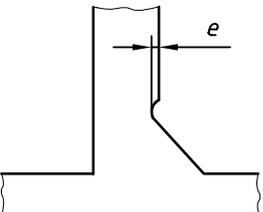
Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks
Height of reinforcement of weld, h		$h \leq 0,2\ B$	$h \leq 0,3\ B$ max. 6 mm	Grinding  Built-up welding
General		$\theta \leq 60^\circ$	$\theta < 90^\circ$	
Flank angle, θ		—	$\theta \leq 60^\circ$	

5.6.2 The weld undercut shall be in compliance with the requirements given in Table 29.

Table 29 — Weld undercut

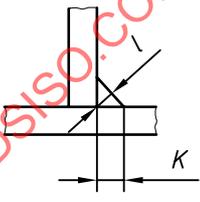
Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks
Butt weld 	—	For main structures such as shell plate, deck, longitudinal girders, etc. within 0,6L amidship. $e \leq 0,5$ For others: $e \leq 0,8$	(1) If e is between 0,5 and 0,8, the sharp cutting edge shall be repaired even if angle of undercut is larger than 90° for the case of undercuts continuous for at least 90 mm. (2) The sharp configuration of fillet weld shall be repaired.
Fillet weld 	—	$e \leq 0,8$	

5.6.3 The deviation of dimensions of fillet welds shall be kept within the limits given in Table 30.

Table 30 — Deviation of dimensions of fillet welds

Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks
Specified dimension of fillet, K Actual dimension of fillet, K_a Specified throat depth, l Actual throat depth, L_a 	—	$K_a \geq 0,9K$ $L_a \geq 0,9l$	Where the fillet or throat depth are not within allowable limits, they shall be corrected by further welding using small electrodes.

5.6.4 The short bead, tack-welding bead and repairing bead shall be in compliance with the requirements given in Table 31.

Table 31 — Short bead, tack-welding bead and repairing bead

Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks	
Bead length	500 MPa high-tensile steel	$Ceq > 0,36 \%$	—	When the bead length is less than the allowable limits, it is necessary to preheat at $(100 \pm 25) \text{ } ^\circ\text{C}$
		$Ceq \leq 0,36 \%$	—	
	Grade E mild steel	—	—	≥ 50

5.6.5 The arc-strike shall be in compliance with the requirements given in Table 32.

Table 32 — Arc-strike

Dimensions in millimetres

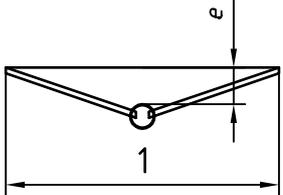
Items	Standard range	Allowable limits	Remarks
50 MPa high-tensile steel, Grad E mild steel, cast steel	—	Not allowed	When an arc-strike was made, it is required to do repairs as below: a) Weld over a short bead over 50 mm on the arc-strike b) Remove the hardened zone by grinding.

5.6.6 The welded joint distortion shall be kept within the limits given in Table 33.

Table 33 — Welded joint distortion

Dimensions in millimetres

Items	Standard range	Allowable limits	Remarks
Shell plate within 0,6L amidship, e	—	≤ 6	When it exceeds allowable limits, it shall be repaired or rewelded after correcting or cutting.
Shell plate at fore and aft, e	—	≤ 7	
Others, e	—	≤ 8	



The diagram shows a cross-section of a welded joint between two plates. A central weld bead is visible. A vertical arrow labeled 'e' indicates the maximum distortion of the shell plate from its original position. A horizontal double-headed arrow labeled '1' indicates the frame spacing. Below the diagram, a key defines '1' as 'Frame spacing'.

e is distortion of shell plate in a frame span

Key
1 Frame spacing

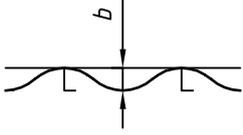
5.7 Flatness and finishing

5.7.1 Flatness

5.7.1.1 Local flatness shall be in compliance with the requirements given in Table 34.

Table 34 — Local flatness

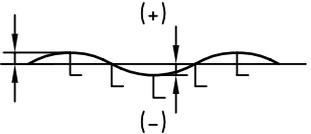
Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks
Shell plate	Parallel midbody (side plate, bottom plate)	4	6	 <p><i>b</i> is the flatness for every frame spacing</p>
	Sub-assembly of parallel midbody (side plate, bottom plate)	4	6	
	Fore and aft curved parts	5	7	
	Joints at fore and aft parts	6	8	
Double bottom	Tank top plate	4	6	
Bulkhead		6	8	
Upper deck	Parallel midbody (including longitudinal and transverse structure)	4	6	
	Fore and aft parts	6	9	
	Non-exposed part	7	9	
Second deck	Exposed part	6	8	
	Non-exposed part	7	9	
Superstructure deck	Exposed part	4	6	
	Non-exposed part	7	9	
House walls	Exposed part	4	6	
	Both sides of non-exposed part	7	9	

5.7.1.2 Overall flatness shall be in compliance with the requirements given in Table 35.

Table 35 — Overall flatness

Dimensions in millimetres

Items		Standard range	Allowable limits	Remarks
Shell plate	Parallel midbody	± 2 //1 000	± 3 //1 000	Measuring method: Minimum measuring length <i>l</i> = 3 000 but about 5 000 for bulkhead and outside wall 
	Fore and aft parts	± 3 //1 000	± 4 //1 000	
Deck and tank top		± 3 //1 000	± 4 //1 000	
Bulkhead		± 4 //1 000	± 5 //1 000	
Superstructure	Deck	± 3 //1 000	± 4 //1 000	
	Outside wall	± 2 //1 000	± 3 //1 000	
Others		± 5 //1 000	± 6 //1 000	

5.7.1.3 The deviation from the straight line related to the length of inner stiffeners shall be in compliance with the requirements given in Table 36.

Table 36 — Straightness of inner stiffeners

Dimensions in millimetres

Items	Standard range	Allowable limits
Principal members, such as deck transverse, deck girder, web frame, floor and girder, etc.	5	8
Other members, such as longitudinal, frame, beam and stiffener, with length l :	$3 + \frac{2l}{1000}$	$6 + \frac{2l}{1000}$
"H" type pillar between decks	4	6
Cross tie	6	10

5.7.2 Finishing

5.7.2.1 Staging sockets and lifting eyepieces shall be finished according to the requirements given in Table 37.

Table 37 — Staging sockets and lifting eyepieces

Dimensions in millimetres

Items		Requirements	Remarks
Staging sockets	In water and oil tanks	May be retained totally	(1) After removing those lifting eyepieces which affect appearance and passage, the surface shall be finished as flush as the base plate. (2) Such pieces may be removed by gas cutting at other places, root may be retained, but for those parts, especially important to strength, built-up welding shall be made to smooth and flush after cutting
	In engine room	Only those affecting appearance and passage shall be removed	
	In cargo hold	Only those at lower level and on hatch coaming shall be removed	
	On exposed part of shell and upper deck, etc.	To be removed totally	
Lifting eye pieces	In water and oil tanks	May be retained provided not affecting passage	Except fixed eyepieces
	In cargo hold	10 mm of root may be retained on back side of deck plate	
	On exposed part of shell and upper deck, etc.	To be removed totally	

5.7.2.2 Temporary pieces shall be finished according to the requirements given in Table 38.

Table 38 — Temporary pieces

Dimensions in millimetres

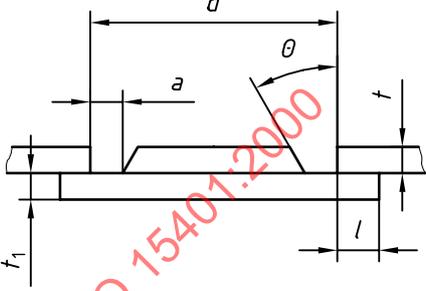
Items	Requirements	Remarks
Where good appearance is required	Outside surface of shell plate, deck and superstructure shall be chipped flush and smooth. Undercut of temporary pieces may have a depth of 0,5 mm. Above this limit, the cut shall be welded over and ground flush.	Temporary pieces must be avoided on sheer strake and corner plates as far as possible. Any notches due to removal operations must be built up and ground flush.
Where good appearance is not required	Temporary pieces inside holds and similar places shall be chipped off if they are at particularly conspicuous places. Undercut may have a depth of 0,5 mm to 1,0 mm and a length not more than 30 mm. Over these limits, they shall be welded over and finished, but may not be chipped and ground.	

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5.7.2.3 Holes made erroneously shall be treated according to the requirements given in Table 39.

Table 39 — Holes made erroneously

Dimensions in millimetres

Items		Allowable limits	Method of treatment
$d < 200$	Main strength members on shell plate or upper deck	(1) Cut an opening over 75 in diameter, then treated by method A. (2) Cut an opening over 200 in diameter, then treated by method B	<p>A: Spigot patch</p>  <p>$l = 50$ $a = 4 \text{ to } 6$ $t_1 = 0,5t \text{ to } 1t$ $\theta = 30^\circ \text{ to } 40^\circ$</p> <p>B: Repair and weld by insert plate C: Built up and repair welded by doubler (to same thickness as base plate) D: If it is difficult from the structural point of view to cut an opening over 200 in diameter, it may be processed by a low-hydrogen electrode after preheating followed by radiographic examination or ultrasonic inspection.</p>
	Others	Cut an opening over 200 in diameter, then treated by method B, C or D	
$d \geq 200$	Main strength members on shell plate or upper deck	Treated by method B	
	Others	Treated by method B or C	
Triangular opening, scallop, rectangular opening		Treated by method B or C	

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