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Guideline for Scope of Damage Stability Verification on new oil tankers, chemical tankers and gas carriers

1   Application

This recommendation applies for oil tankers, chemical tankers and gas carriers, excluding combination carriers.

2   Reference

2.1   IMO Instruments

2.1.1   General Instruments

- SOLAS Chapter II-1, Regulations 4.1, 4.2, 5-1 and 19;

- Part B, chapter 4 of the International Code on Intact Stability, 2008 (2008 IS Code), adopted by resolution MSC.267(85), as amended;

- Res. MSC.143(77) "Adoption of amendments to the Protocol of 1988 relating to the International Convention on Load Lines, 1966", Regulations 27(2), 27(3), 27(11), 27(12) and 27(13) [1)];

Note:

1. This recommendation applies for new oil tankers, chemical tankers and gas carriers contracted for construction on or after 1 January 2010 subject to review of impact on ships undergoing approval and delivering after said date.

2. Rev.1 applies for new oil tankers, chemical tankers and gas carriers contracted for construction on or after 1 January 2011 subject to review of impact on ships undergoing approval and delivering after said date.

3. Rev.2 applies for new oil tankers, chemical tankers and gas carriers contracted for construction on or after 1 July 2021.

4. The 'contracted for construction' date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of 'contract for construction', refer to Procedural Requirement (PR) No. 29.

Footnotes:

1)   The application of ICLL Protocol 1988, Reg.27 is explained in Annex 1.

- Res. MSC.429(98) "Explanatory Notes to the SOLAS Chapter II-1 Subdivision and Damage Stability Regulations" - special attention should be paid to Guidelines for the Preparation of Subdivision and Damage Stability Calculations specified in the Appendix;

- Res. MSC.429(98)/Rev.1 "Explanatory Notes to the SOLAS Chapter II-1 Subdivision and Damage Stability Regulations" - special attention should be paid to Guidelines for the Preparation of Subdivision and Damage Stability Calculations specified in the Appendix;

- Res. MSC.362(92)"Revised Recommendation on a Standard Method for Evaluating Cross-Flooding Arrangements";

- MSC.1/Circ.1245 "Guidelines for Damage Control Plans and Information to the Master"; and

- MSC.1/Circ.1229 "Guidelines for the Approval of Stability Instruments", paragraph 4.

2.1.2   Instruments applicable to oil tankers

- MARPOL Annex I, Regulation 28; and

- ICLL 66/88 Annex I, Reg.27 for type "A" ships with a length of more than 150m and assigned freeboard less than type "B". An overview is shown in Annex I of this document.

2.1.3   Instruments applicable to gas carriers

- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code), Chapter 2, Paragraphs 2.1, 2.4, 2.5, 2.6.2, 2.6.3, 2.7, 2.8 and 2.9;

- MSC/Circ.406/Rev.1 "Guidelines on Interpretation of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) and the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) and Guidelines for the Uniform Application of the Survival Requirements of the IBC and IGC Codes"; and

- ICLL 66/88 Annex I, Reg.27 for type "A" ships with a length of more than 150m and assigned freeboard less than type "B". An overview is shown in Annex I of this document.

2.1.4   Instruments applicable to chemical tankers

- International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code), Chapter 2, Paragraphs 2.1, 2.4, 2.5, 2.6.2, 2.7, 2.8 and 2.9;

- MSC/Circ.406/Rev.1 "Guidelines on Interpretation of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) and the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) and Guidelines for the Uniform Application of the Survival Requirements of the IBC and IGC Codes"; and

- ICLL 66/88 Annex I, Reg.27 for type "A" ships with a length of more than 150m and assigned freeboard less than type "B". An overview is shown in Annex I of this document.

2.2   IACS Resolutions

- UR L5 "Onboard Computers for Stability Calculations";

- PR7 "Procedure for the Training and Qualification of Survey and Plan Approval Staff"; and

- UI SC 156 "Doors in watertight bulkheads of cargo ships and passenger ships".

3   General

3.1   Education and training

3.1.1   Plan approval staff engaged in damage stability verification of new oil tankers, chemical tankers and gas carriers should have as minimum the following formal educational background:

- a degree or equivalent from a tertiary institution recognized within the field of marine engineering or naval architecture; and

- competent in the English language commensurate with their work.

3.1.2   Plan approval staff engaged in damage stability verification of new oil tankers, chemical tankers and gas carriers should be trained according to theoretical and practical modules defined by the Society to acquire and develop general knowledge and understanding applicable to the a/m types of ship and stability assessment according to the Society Rules and Instruments and Resolutions referred in paragraph 2 above.

3.1.3   Methods of training may include monitoring, testing, etc. on regular basis according to the Society's system. Evidence of training provided should be documented.

3.1.4   Updating of qualification may be done through the following methods:

- self-study;

- extraordinary seminars in case of significant changes in the Society's Rules or International Conventions, Codes, etc.; and

- special training on specific work, which is determined by a long absence of practical experience.

Maintenance of qualification should be verified at annual performance review.

3.2   Scope of stability verification

The scope of damage stability verification is determined by the required damage stability standards (applicable damage stability criteria) and aims at providing the ship's master with a sufficient number of approved loading conditions to be used for the loading of the ship. In general, for non-approved loading conditions (by the Administration or RO), approved KG/GM limit curve(s) or approved loading instrument software satisfying the stability requirements (intact and damage) for the draught range to be covered should be used to verify compliance on board.

Within the scope of the verification determined as per the above, all potential or necessary damage scenarios should be determined and assessed taking into account the damage stability criteria.

Damage stability verification and approval requires a review of submitted calculations and supporting documentation with independent check calculations to confirm damage stability calculation results comply with relevant stability criteria.

Examination and approval of the loading instrument software installed on board (and to be used for assessing intact and damage stability) shall also be carried out. A loading instrument comprises hardware and software. The accuracy of the computation results and actual ship data used by the software is to be verified.

3.3   Assumptions

For all loading conditions, the initial metacentric height and the righting lever curve should be corrected for the effect of free surfaces of liquids in tanks.

Superstructures and deckhouses not regarded as enclosed can be taken into account in stability calculations up to the angle at which their openings are flooded. Flooding points (including windows) incapable of weathertight closure are to be included in any list determined in accordance with paragraph 3.4.2.6. Full compliance with residual stability criteria must be achieved before any such point becomes immersed.

When determining the righting lever (GZ) of the residual stability curve, the constant displacement (lost buoyancy) method of calculation should be used (see paragraph 6.1).

Conditions of loading and instructions provided by the submitter for use of the applicable KG/GM limit curve(s) and variation of loading patterns and representative cargoes are taken to be representative of how the ship will be operated.

3.4   Documentation to be submitted for review

3.4.1   Presentation of documents

The documentation should begin with the following details: principal dimensions, ship type, designation of intact conditions, designation of damage conditions and pertinent damaged compartments, KG/GM limit curve(s).

3.4.2   General documents and supporting information

.1   lines plan, plotted or numerically;

.2   hydrostatic data and cross curves of stability (including drawing of the buoyant hull);

.3   definition of watertight compartments with moulded volumes, centres of gravity and permeability;

.4   layout plan (watertight integrity plan) for the watertight compartments with all internal and external opening points including their connected sub-compartments, and particulars used in measuring the spaces, such as general arrangement plan and tank plan;

.5   Stability Booklet/Loading Manual including at least fully loaded homogeneous condition at summer load line draught (departure and arrival) and other intended operational conditions[2]; in addition, when verifying the damage stability according to MSC/Circ.406/Rev.1 and MSC.1/Circ. 1537 the tropical freeboard needs to be considered, however, the fresh water allowance and tropical fresh water allowance need not to be taken into account according to MARPOL, IBC and IGC.

.6   coordinates of opening points with their level of tightness (e.g., weathertight, unprotected) [3], including reference to the compartment that the opening is connected to.

.7   watertight door location;

.8   cross and down flooding devices and the calculations thereof according to resolution MSC.362(92) with information about diameter, valves, pipe lengths and coordinates of inlet/outlet. Cross/down flooding should not be considered for the purpose of achieving compliance with the stability criteria (see also paragraph 9.2);

.9   pipes in damaged area when the breaching of these pipes results in progressive flooding (see paragraph 10.1);

.10   damage extents and definition of damage cases; and

.11   any initial conditions or restrictions which have been assumed in the derivation of critical KG or GM data, and which must therefore be met in service.

3.4.3   Special documents

.1   Documentation

Design documentation should include: damage stability calculations (including residual stability curves), the arrangements, configuration and contents of the damaged compartments, and the distribution, relative densities and the free surface effect of liquids.

Operational documentation should include: loading and stability information booklet (stability booklet), Damage Control Plan; and Damage Control Booklet [3].

Footnote:

2) For the purpose of making a submission of stability information for approval, the minimum number of loading conditions which should be submitted for approval is a function of the mode of operation intended for the ship. MSC/Circ.406/Rev.1 offers guidance in this respect, and identifies the concepts of the "dedicated service tanker" and "parcel tanker" for the purpose of undertaking stability approval of ships certified under the IBC and IGC Codes and the appropriate treatment of ships assigned tropical freeboards.

3) Details of watertight, weathertight and unprotected openings should be included in the Damage Control Plan and Damage Control Booklet in accordance with MSC.1/Circ.1245.

The cases and extent of progressive flooding assumed in the damage stability analysis should be indicated in the Damage Control Booklet and the Documents for Submission in accordance with the Appendix to MSC.429(98). Arrangements to prevent further flooding are to be indicated on the Damage Control Plan and in the Damage Control Booklet.

.2   Special consideration

For intermediate flooding stages before cross-flooding (see paragraphs 6.8 and 9.2), or before progressive flooding (see paragraph 6.9), occur, an appropriate scope of the documentation covering the aforementioned items is needed. The intermediate stages for cargo outflow and sea water inflow should be checked. If any stability criteria during intermediate stages shows more severe values than in the final stage of flooding these intermediate stages should also be submitted.

4   Operating Limits – Descriptions/Assumptions

In considering the scope of the verification to be conducted, consideration of the operating limits is needed.

The following loading options should be permitted:

a)   Service loading conditions identical to the approved loading conditions of the stability booklet (see paragraph 4.2); or

b)   Service loading conditions complying with the approved intact and damage stability limiting curves (where provided) (see paragraph 4.3); or

c)   Service loading conditions which have been checked with an approved on-board stability software with the capability to perform damage stability calculations (Type 2 or 3 of IACS UR L5, Rev.4 June 2020) either based on KG/GM limit curve(s) or based on direct damage stability assessment (see paragraph 4.5).

If above mentioned proof of compliance is not possible, then the intended loading conditions should be either prohibited or be submitted for specific approval to the Administration or RO. Suitable instructions to this effect should be included in the stability booklet/loading manual. An approved loading condition is one which has been specifically examined and endorsed by Administration/RO.

4.1   Specific loading patterns

Ship specific design loading patterns and loading restrictions should be clearly presented in the stability booklet. The following items should be included:

a)   Any required and intended loading conditions (including the ones corresponding to multiple freeboards when so assigned to the vessel), i.e. symmetrical/unsymmetrical, homogeneous/alternating or ballast/partial/full;

b)   Types (e.g. oil, noxious liquid substances and LNG) of liquid cargo allowed to be carried;

c)   Restrictions to different liquid loads to be carried simultaneously;

d)   Range of permissible densities of liquid loads to be carried; and

e)   Minimum tank filling levels required to achieve compliance with the applicable stability criteria.

For the verification of damage stability all loading conditions presented in the stability booklet except for ballast, light ship and docking conditions are to be examined.

4.2   Matrix of permissible loading conditions

In the absence of stability software and KG/GM limit curve(s), in lieu of approved specific loading conditions, a matrix clearly listing the allowable range of loading parameters (draft, trim, KG, cargo loading pattern and SG) that the vessel is allowed to load in order to be in compliance with the applicable intact and damage stability criteria can be developed for the stability booklet when a greater degree of flexibility than that afforded by approved specific loading conditions is needed. If this information is to be used it should be in an approved form.

4.3   KG/GM Limit Curve(s)[4]

Where KG/GM limit curves are provided, a systematic investigation of damage survival characteristics should be undertaken by making calculations to obtain the minimum required GM or maximum allowable KG at a sufficient number of draughts within the operating range to permit the construction of a series of curves of "required GM" or "allowable KG" in relation to draught and cargo tank content in way of the damage. The curves should be sufficiently comprehensive to cover operational trim requirements.

The verification of KG/GM limit curves should be conducted without any free surface correction. The actual loading condition uses the free surface correction (see paragraph 6.5) when comparing actual and KG/GM limit values.

It is to be noted that any change of filling level, draught, trim, cargo density might have a major influence to the results of a damage case; therefore the following items should be considered carefully for the calculation of the KG/GM limit curves:

a)   Intact and damage stability criteria applicable to the vessel;

b)   The maximum required damage extent and lesser extents of damage which provide the most severe damage cases;

c)   Draught range of the vessel: when verifying the damage stability, according to MSC/Circ.406/Rev.1 and MSC.1/Circ 1537 the tropical freeboard needs to be considered, however, the fresh water allowance and tropical fresh water allowance need not be taken into account under MARPOL, IBC and IGC;

d)   Trim range of the vessel (see paragraph 6.6);

e)   Full and empty cargo tanks;

f)   Partially filled cargo tanks (consideration of increments as necessary);

g)   Minimum tank fillings if required;

h)   Maximum/minimum densities of cargoes; and

i)   Ballast tank filling levels as necessary to achieve compliance.

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Footnote:

4)   To avoid difficulties associated with developing suitable KG/GM limit curves and their restriction on operational capacity it is recommended that an approved Type 3 stability software is fitted on board.

Damage stability calculations, on which the KG/GM limit curve(s) is(are) based, should be performed at the design stage. The KG/GM limit curve(s) drawn out taking stability criteria (intact and damage) into account should be inserted in the stability booklet.

4.4   Initial heel

The stability booklet should contain a note for the master to avoid initial heel greater than 1 degree. A steady heeling angle may have major influence to the stability of the vessel especially in case of damage.

4.5   Direct calculation onboard (Stability software)

The use of stability software for stability calculations is not a class requirement.

However, stability software installed onboard shall cover all stability requirements (intact and damage) applicable to the ship.

The following types of stability softwares, if approved by a classification society, (according to IACS UR L5 Rev.4 June 2020) are applicable for calculation of service loading conditions for tankers:

a) Type 2: software calculating intact stability and checking damage stability on basis of a limit curve (e.g. for vessels applicable to SOLAS Part B-1 damage stability calculations, etc.) or checking all the stability requirements (intact and damage stability) on the basis of a limit curve; and

b) Type 3: software calculating intact stability and damage stability by direct application of pre-programmed damage cases based on the relevant Conventions or Codes for each loading condition (for some tankers etc.)

The software shall be approved by the Society. The stability instrument is not a substitute for the approved stability documentation, but used as a supplement to facilitate stability calculations.

Damage Stability of Type 3 stability software shall be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model.

All damages, taking into account lesser damages, and variation of draft, cargo density, tank loading patterns and extents of tank filling should be performed to ensure that for any possible loading condition the most onerous damages have been examined according to relevant stability criteria.

All applicable combinations of damage that are possible within the relevant MARPOL Convention / Codes (IGC, IBC…) should be performed. These are all damages within the maximum applicable damage extents for side, bottom and raking; the lesser extent damages for side, bottom and raking.

Lesser extent of damages should be generated on the principle of reduction in any longitudinal, transverse or vertical extent; whist maintaining adjacent (shared boundary) compartment logic, including L-shaped damages.

The methodologies for determining compliance with relevant stability criteria should be as set out in these guidelines.

5   Hull and Compartment Modelling Tolerances

Depending on the type and scope of programs, the acceptable tolerances are to be determined differently, according to 5.1 or 5.2. Deviation from these tolerances shall not be accepted unless the Society considers that there is a satisfactory explanation for the difference and that there will be no adverse effect on the safety of the ship.

Examples of pre-programmed input data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, KM_t and MCT versus draught.

Stability data: KN or MS values at appropriate heel/ trim angles versus displacement, stability limits.

Compartment data: Volume, LCG, VCG, TCG and FSM/ Grain heeling moments vs level of the compartment's contents.

Examples of output data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, KM_t and MCT versus draught as well as actual draughts, trim.

Stability data: FSC (free surface correction), GZ-values, KG, GM, KG/GM limits, allowable grain heeling moments, derived stability criteria, e.g. areas under the GZ curve, weather criteria.

Compartment data: Calculated Volume, LCG, VCG, TCG and FSM/ Grain heeling moments vs level of the compartment's contents.

The computational accuracy of the calculation program results shall be within the acceptable tolerances, specified in 5.1 or 5.2, of the results using an independent program or the approved stability information with identical input.

5.1 Programs which use only pre-programmed data from the approved stability information as the basis for stability calculations, shall have zero tolerances for the printouts of input data.

Output data tolerances are to be close to zero, however, small differences associated with calculation rounding or abridged input data are acceptable.

Additionally differences associated with the use of hydrostatic and stability data for trims that differ from those in the approved stability information, are acceptable subject to review by the individual Society.

5.2 Programs which use hull form models as their basis for stability calculations, shall have tolerances for the printouts of basic calculated data established against either data from the approved stability information or data obtained using the approval authority's model.

Acceptable tolerances shall be in accordance with Table 1.

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Table 1

Hull Form Dependent	
Displacement	+/- 2%
Longitudinal center of buoyancy, from AP	+/- 1% / 50 cm
Vertical center of buoyancy	+/- 1% / 5 cm
Transverse center of buoyancy	+/- 0.5% of B / 5 cm
Longitudinal center of flotation, from AP	+/- 1% / 50 cm
Moment to trim 1 cm	+/- 2%
Transverse metacentric height	+/- 1% / 5 cm
Longitudinal metacentric height	+/- 1% / 50 cm
Cross curves of stability	+/- 5 cm
Compartment dependent	
Volume or deadweight	+/- 2%
Longitudinal center of gravity, from AP	+/- 1% / 50 cm
Vertical centre of gravity	+/- 1% / 5 cm
Transverse center of gravity	+/- 0.5% of B / 5 cm
Free surface moment	+/- 2%
Shifting moment	+/- 5%
Level of contents	+/- 2%
Trim and stability	
Draughts (forward, aft, mean)	+/- 1% / 5 cm
GMt (both solid and corrected for free surfaces)	+/- 1% / 5 cm
GZ values	+/- 5% / 5 cm
Downflooding angle	+/- 2^0
Equilibrium angles	+/- 1^0
Distance from WL to unprotected and weathertight openings, or other relevant point, if applicable	+/- 5% / 5 cm
Areas under righting arm curve	+/- 5% / 0.0012mrad

Notes:

1. Deviation in % = {(base value-applicant's value)/base value} *100
Where the "base value" may be from the approved stability information or the society's computer model.

2. When applying the tolerances in Table 1 having two values, the allowable tolerance is the greater of the two values.

3. Where differences in calculation methodology exist between the programs used in the comparison, this may be a basis for accepting deviations greater than that specified in Table 1 provided a software examination is carried out in sufficient detail to clearly document that such differences are technically justifiable.

4. Deviation from these tolerances shall not be accepted unless the Society considers that there is a satisfactory explanation for the difference and that it is clearly evident from the Society's stability calculations that the deviation does not impact compliance with the required stability criteria for the ship under consideration.

6   Methodology

6.1   Method of analysis

Independent analysis uses the "constant displacement"/"lost buoyancy" method.

Within the scope of damage stability analysis with the deterministic approach, depending on the subdivision of the ship, the result of applying the standard of damage as specified in the applicable requirements is the creation of a number of damage cases, where one or more compartments are open to sea.

The compartment(s) once damaged, are not considered as contributing to the buoyancy of the ship. Consequently, a new condition of equilibrium occurs. In order to define the new equilibrium condition and to assess the stability of the ship after damage the lost buoyancy/constant displacement method is used.

The new floating position can be determined by assuming that the damaged displacement is equal to the intact displacement (constant displacement) minus the weight of liquids which were contained in the damaged compartments.

Due to the lost buoyancy of the damaged compartment(s), the remaining intact ship has to compensate by sinkage, heel and trim until the damaged displacement is reached. Once the equilibrium has been reached and the final waterline is determined, the metacentric height (GM), the righting lever curves (GZ) and the centre of gravity positions (KG), can be calculated in order to verify the stability of the ship against the applicable requirements.

For the intermediate stages of flooding and the equalisation with compartments cross-connected by small ducts, i.e. not opened to the sea directly, the added weight method is used.

6.2   Arguments used in calculations

The Arguments used in the calculation for the verification of damage stability are the following:

.1   Trim: The calculation should be done for the ship freely trimming;

.2   Heel angle at equilibrium: The heel angle at equilibrium, due to unsymmetrical flooding should not exceed the maximum values as indicated in the applicable requirements. Concerning the range of positive righting levers (GZ), this should be calculated beyond the position of equilibrium to the extent as so required by the applicable requirements;

.3   Free surface of liquid: For the calculation of the position of the centre of gravity (KG), the metacentric height (GM) and the righting lever curves (GZ), the effect of the free surfaces of liquids (see paragraph 6.5) should be taken into account;

.4   Immersion of weathertight and unprotected openings (see paragraph 6.7 and 10.1)

         Unprotected openings:

         -       The positive range of righting levers is calculated from the angle of equilibrium until the angle of immersion of the unprotected openings leading to intact spaces;

Weathertight points: see paragraph 10.1 (ii);

.5 Progressive flooding through internal pipes: In case of damage of an internal pipe which is connected to an undamaged compartment, the undamaged compartment should also be flooded, unless arrangements are fitted (e.g. check valves or valves with remote means of control), which can prevent further flooding of the undamaged compartments;

.6 Permeabilities: Care should be taken to apply the permeabilities as specified in the applicable regulations. Special attention should be paid in case compartments which are separated by weathertight boundaries are modeled as one compartment. This simplified method of modeling the compartments should apply only to compartments belonging to the same category (same permeability); and

.7 Heel angles for the calculation of the GZ curve: Evaluation of damage stability criteria should generally be determined from data calculated over a range of angles from 0 to 60 degrees. It is recommended to use an increment not exceeding 5 degrees.

6.3 Adjustments for cargo run-off

.1 In cases where the damage involves the cargo hold, it is assumed that cargo is flowing out and that water starts to ingress. During the intermediate stages of flooding it is considered that both cargo and sea water are existing in the damaged tank (see paragraph 9.3).

At the final stage it is assumed that the cargo is completely lost and that the tank is filled with sea water up to the level of the waterline.

.2 The impact on the stability of the ship, due to the inflow and outflow of liquid cargo is also dependent on the following parameters:

- the density of the cargo: Liquid cargo with density greater than 0.95 t/m^3 should be considered as heavy liquid cargo. In case of lesser vertical extent of damage, i.e. damage above the tank top (see Annex 4), the release of heavy liquid cargo might lead to large angle of heel on the intact side of the ship. Depending on intact draught and cargo tank filling level, outflow of cargo of lesser density may also cause heel to the opposite side; and

- the permeability of the cargo space, taking into account that permeabilities smaller than the those specified in the applicable rules can be applied if justified.

6.4 Handling of permeabilities

.1 Permeability of a space means the ratio of the volume within that space, which should be assumed to be occupied by water, to the total volume of that space. The total volume should be calculated to moulded lines and no reduction in total volume should be taken into account due to structural members (i.e stiffeners, etc.). Account of structural members is taken in the applicable permeabilities (see also MSC/Circ.406/Rev.1, paragraph 3.11).

.2 Depending on the applicable requirements, the permeabilities assumed for spaces flooded as a result of damage should be as shown in the Table 2.

Table 2:

Spaces	Permeabilities			
	MARPOL	ICLL [1]	IBC	IGC
Appropriated to stores	0.6	0.95	0.6	0.6
Occupied by accommodation	0.95	0.95	0.95	0.95
Occupied by machinery	0.85	0.85	0.85	0.85
Voids	0.95	0.95	0.95	0.95
Intended for consumable liquids	0 to 0.95*	0.95	0 to 0.95*	0 to 0.95*
Intended for other liquids	0 to 0.95*	0.95	0 to 0.95*	0 to 0.95*

* The permeability of partially filled compartments should be consistent with the amount of liquid carried in the compartment.

[1] Regarding application of ICLL damage stability requirements please refer to Annex 1.

.3 Whenever damage penetrates a tank containing liquids, it should be assumed that the contents are completely lost from that compartment and replaced by sea water up to the level of the final plane of equilibrium.

.4 Other figures for permeability may be used for the damaged case both during cargo run-off and the final equilibrium condition under the following provisions:

.4.1 The detailed calculations and the arguments used for determining the permeability of the compartment(s) in question, is to be included in the damage stability booklet;

.4.2 The water tightness/resistance to water pressure and the means by which internal fittings/material are secured to the tank should substantiate the use of such fittings/material in reducing the permeability of a compartment. Where a ship is fitted with significant quantities of cargo insulation, the permeabilities of the relevant cargo spaces and/or the void spaces surrounding such cargo spaces may be calculated by excluding the volume of insulation material in those spaces from the flooded volume, provided that the insulating material is shown to comply with the following conditions:

.1 it is impermeable to water under hydrostatic pressure at least corresponding to the pressure caused by the assumed flooding;

.2 it will not crush or break up due to hydrostatic pressure at least corresponding to the pressure caused by the assumed flooding;

.3 it will not deteriorate or change its properties over the long term in the environment anticipated in the space it is installed;

.4 it is highly resistant to the action of hydrocarbons, where relevant; and

.5 it will be adequately secured so that it will remain in position if subjected to collision damage and consequent displacement, distortion of its supporting and retaining structure, repeated rapid ingress and outflow of seawater and the buoyant forces caused by immersion following flooding;

.4.3 The applied permeability should reflect the general conditions of the ship throughout its service life, rather than specific loading conditions; and

.4.4   Permeabilities other than those indicated in Table 2 should be considered only in cases, where it is evident that there is a significant discrepancy between the values shown in the regulations and the actual values (i.e. due to specific tank structure or insulating material).

6.5   Free-surface calculation (upright, as vessel heels and after cargo run-off)

With respect to the approval of actual **loading conditions** the following should be applied:

.1   The free surfaces of liquids lead to the increase of the centre of gravity (KG) and the reduction of the metacentric height (GM) and the righting arm (GZ curve) of the ship. Therefore corrections should be made, taking into account the change of the centre of gravity of the ship due to the moving of the centre of gravity of the liquids.

Depending on the filling level, free surfaces can exist in tanks with consumable liquids, sea water ballast and liquid cargo.

.1.1   For consumable liquids account ofn the free surfaces should be taken whenever the filling level is equal to or less than 98%.

.1.1.1 In calculating the free surface effects in tanks containing consumable liquids, it should be assumed that for each type of liquid at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account should be those where the effect of free surfaces is the greatest.

.1.1.2 Taking into account .1.1.1 the free surfaces should correspond to the maximum value attainable between the filling levels envisaged.

.1.2   During ballasting between departure and arrival condition, the correction for the free surfaces should correspond to the maximum value attainable between the filling levels envisaged. This applies also for the situation where in the departure condition the filling level of a ballast tank is 0% and in the arrival 100% (or the opposite).

.1.3   For the category of liquids referred under paragraph .1.1 and .1.2, as an alternative intermediate loading conditions may be considered, as deemed necessary, covering the stage where the free surfaces are the greatest. It may be calculated with varying free surface moments (i.e. actual liquid transfer moments), taking into account actual heel and trim, depending on the interval angles of the GZ curve. This is a more accurate method.

.1.4   Except as indicated in 1988 LL/27(11)(v), for liquid cargo the effect of free surface should be taken into account for filling level equal or smaller to 98%. If the filling level is fixed actual free surfaces can be applied.

The following two methods can be used for the calculation of the GZ curve taking into account the effect of the free surface moments for the intact compartments:

-   Calculation with constant effect of free surfaces, without taking into account the change in heel and trim, for the interval angles of the GZ curve.

-   Calculation with varying free surface moments, actual liquid transfer moments, taking into account actual heel and trim, depending on the interval angles of the GZ curve (see Annex 2).

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.2   For the damaged compartments, whenever the damage is involving cargo tanks, account should be taken on the following:

–   The impact on the stability of the ship due to the outflow of cargo and ingress of sea water can be verified with the calculation of the intermediate stages of flooding (see Section 9); and

–   At the final equilibrium the free surface correction should exclude the free surface moment of the cargo.

.3   The free surface effect should be calculated at an angle of heel of 5 degrees for each individual compartment or as per paragraph 6.5.1.3.

6.6   Treatment of operational trim

.1   For the assumed damage and the resultant damage cases, the damage stability should be assessed for all anticipated conditions of loading and variations in draught and trim.

.2   Significant forward/aft trim (greater than 1% L_{pp}) can appear in the departure and arrival condition.

In that case, damage cases involving the aft/fore part of the ship might be critical for achieving compliance with the applicable criteria. In order to limit the trim ballast water is used during the voyage, as deemed necessary. Under the provision of paragraph 6.5.1.2 and 6.5.1.3, for taking account of the free surface effect during ballasting, if intermediate stages of the voyage are considered then the loading conditions representing these stages, should be also calculated for damage stability.

6.7   Downflooding points

Downflooding point is the lower edge of any opening through which progressive flooding may take place. Such openings should include air-pipes, ventilators and those openings which are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, watertight doors including hinged type, which comply with SOLAS, ICLL, MARPOL Annex I, IGC Code and IBC Code requirements, as applicable and sidescuttles of the non-opening type.

All openings through which progressive flooding may take place should be defined: both weathertight and unprotected. As an alternative it might be accepted to consider only the most critical openings, which are considered to be the openings with the lowest vertical position and close to the side shell. Concerning the longitudinal position it depends on the aft or fore trim of the initial condition and the trim after damage at equilibrium. Unprotected openings should not be immersed within the minimum range of righting-lever curve required for the ship. Within this range, the immersion of any of openings capable of being closed weathertight may be permitted, except openings required to be fitted with weathertight closing devices under the SOLAS, ICLL, MARPOL Annex I, IGC Code and IBC Code requirements, as applicable, that, for operational reasons, are required to be kept open and should be considered as downflooding points in stability calculation (refer to MSC.1/Circ.1535/Rev.1, MSC.1/Circ.1539/Rev.1, MEPC.1/Circ.867, MSC.1/Circ.1543 and MSC-MEPC.5/Circ.11).

6.8   Cross-flooding time

Cross-flooding time should be calculated in accordance with Recommendation on a standard method for evaluating cross-flooding arrangements (resolution MSC.362(92)).

If complete fluid equalization occurs in 60 seconds or less, the equalized tank should be assumed flooded with the tanks initially to be flooded and no further calculations need to be carried out. Otherwise, the flooding of tanks assumed to be initially damaged and equalized tank should be carried out in accordance with paragraph 9.2. Only passive open cross-flooding arrangements without valves should be considered for instantaneous cases.

Where cross-flooding devices are fitted, the safety of ship should be demonstrated in all stages of flooding (see paragraph 9.2 and Section 10). Cross-flooding equipment, if installed, should have the capacity to ensure that the equalization takes place within 10 min.

Tanks and compartments taking part in such equalization should be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.

Spaces which are linked by ducts of a large cross-sectional area may be considered to be common, i.e. the flooding of these spaces should be interpreted as instantaneous flooding with the equalization of duration of less than 60 seconds.

6.9   Progressive flooding (internal/external) (see also paragraph 10.1 and 10.2)

Progressive flooding is the flooding of compartments situated outside of the assumed extent of damage. Progressive flooding may extend to compartments, other than those assumed flooded, through downflooding points (i.e. unprotected and weathertight openings), pipes, ducts, tunnels, etc.

The flooding of compartment(s) due to progressive flooding occurring in a predictable and sequential manner through a downflooding point which is submerged below the damage waterline may be permitted provided all intermediate stages and the final stage of flooding meet the required stability criteria.

Minor progressive flooding through the pipes situated within the assumed extent of damage may be permitted by the Administration, provided the pipes penetrating a watertight subdivision have a total cross-sectional area of not more than 710 mm^2 between any two watertight compartments.

If the opening (unprotected or fitted with a weathertight means of closure) connects two spaces, this opening should not be taken into account if the two connected spaces are flooded or none of these spaces are flooded. If the opening is connected to the outside, it should not be taken into account only if the connected compartment is flooded.

7   Extents of Damage Considered

7.1   Maximum extents

The following provisions regarding the maximum extent and the character of the assumed damage should be applied:

.1	**Side damage:**	MARPOL / IBC / IGC	ILLC (Type A ships)
.1.1	Longitudinal extent:	$1/3L^{2/3}$ or 14.5m, whichever is less	Single compartment between adjacent transverse bulkheads as specified in ILLC paragraph 12(d) [1]
.1.2	Transverse extent:	B/5 or 11.5m, whichever is less (measured inboard from the ship's side at right angles to the centreline at the level of the summer load line)	B/5 or 11.5, whichever is the lesser (measured inboard from the side of the ship perpendicularly to the centreline at the level of the summer load waterline) [1]
.1.3	Vertical extent:	upwards without limit (measured from the moulded line of the bottom shell plating at centreline)	From baseline upwards without limit
.2	**Bottom damage [2]:**	MARPOL / IBC / IGC	
		For 0.3L from the forward perpendicular of the ship	**Any other part of the ship**
.2.1	Longitudinal extent:	$1/3 L^{2/3}$ or 14.5m, whichever is less	MARPOL / IBC: $1/3 L^{2/3}$ or 5m, whichever is less IGC: $1/3 L^{2/3}$ or 14.5m, whichever is less
.2.2	Transverse extent:	B/6 or 10m, whichever is less	B/6 or 5m, whichever is less
.2.3	Vertical extent:	MARPOL / IBC: B/15 or 6m, whichever is less (measured from the moulded line of the bottom shell plating at centreline) IGC: B/15 or 2m, whichever is less (measured from the moulded line of the bottom shell plating at centreline)	MARPOL / IBC: B/15 or 6m, whichever is less (measured from the moulded line of the bottom shell plating at centreline) IGC: B/15 or 2m, whichever is less (measured from the moulded line of the bottom shell plating at centreline)
.3	**Bottom raking damage [3]:**	MARPOL	

.3.1	Longitudinal extent:	in tankers of 75,000 tonnes deadweight and above: 0.6L(m) measured from the forward perpendicular of the ship
		in tankers of less than 75,000 tonnes deadweight: 0.4L(m) measured from the forward perpendicular of the ship
.3.2	Transverse extent:	B/3 anywhere in the bottom
.3.3	Vertical extent:	Breach of the outer hull

[1] See Annex 3
[2] Bottom damage is not required in the ICLL
[3] Bottom raking damage is required only for oil tankers of 20,000 tonnes deadweight and above

7.2   Lesser extents

7.2.1   If any damage of a lesser extent than the maximum damage specified in 7.1 would result in a more severe condition, such damage should be considered (see paragraph 4.5).

7.2.2   In the case of gas carrier, local damage anywhere in the cargo area extending inboard distance "d" as defined in 2.4.1 of IGC Code (Res. MSC.370(93)), measured normal to the moulded line of the outer shell shall be considered. Bulkheads shall be assumed damaged when the relevant subparagraphs of 2.6.1 of IGC Code (Res. MSC.370(93)) apply.

If a damage of a lesser extent than "d" would result in a more severe condition, such damage shall be assumed.

7.3   Rationale for reviewing lesser extents including symmetrical vs. unsymmetrical tank arrangement/geometry - Calculation on weakest side

For a given loading condition, following examples of damages of lesser extent may result in a more severe situation than that caused by a maximum damage specified in 7.1:

.1   Example of damage on double bottom tanks with watertight centre girder:

–   Damage of lesser extent which could occur at the bottom plate of the ship, without damaging the centre girder, will lead to flooding of the double bottom tank on one side of the ship only . This is the case of unsymmetrical flooding. For the same location, damage of maximum extent would cause damage on the centre girder and therefore flooding of the double bottom tanks on both sides. This is the case of symmetrical flooding. (see Annex 4).

Compared to the symmetrical flooding in the case of maximum damage extent, unsymmetrical flooding of spaces, caused by damage of lesser extent might lead to a more severe situation. Of course, in case of non-watertight centre girder, the effect of damage of lesser and maximum extent would be the same.

.2   Example of damage with lesser vertical extents:

–   Damage starting from above a tank top would flood the spaces only above the double bottom (see Annex 4). This may result in a more onerous residual stability or heeling angle.

Taking into account above examples, it is necessary to review damages of lesser extents considering the symmetrical or unsymmetrical nature of tank arrangements of the ship and

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(cont)

geometry of the ship. The ship's damage stability is to be ensured, in the most severe or weakest case of damage of lesser extents.

8 Rationale Applied for Loading Pattern Evaluation

For damage stability calculations of tankers the following effects due to different loading methods should be taken into account in determining the scope of verification and specific cases of damage to be investigated.

8.1 Homogeneous vs. alternate/partial loading

For homogeneous loading conditions the damage of cargo tanks may have a major effect on residual stability. Outflow of the loaded cargo liquids (and less inflow of sea water) may reduce the vessels displacement and cause heel to opposite side of the damage. For alternate loading conditions the residual stability depends on the damaged cargo tank. Damage of a fully loaded cargo tank might cause reduction of the initial displacement and heel to the opposite side, but damage on an empty cargo tank might cause the opposite effect. For the damage of two adjacent cargo tanks, one filled and one empty, the total effect might be less severe due to two (partly) neutralizing effects.

Partial loading of liquid cargo tanks will cause a high free surface moment when the surface does not intersect with the tank overhead and will increase the heel in case of damage. However, reductions of the initial displacement and heel to the opposite side may not be as significant. Trim to the vessel as consequence of damage can be significant due to many partially filled cargo tanks.

8.2 Symmetrical and unsymmetrical loading pattern

In general damage stability calculations should be performed for both ship sides. However, the damage stability calculation for one side of the ship may be accepted for symmetrical load (alternate, homogeneous, full, partial or empty), if the ship and all openings are also symmetrical and initial heel to portside or starboard is zero.

8.3 MSC/Circ.406, Rev.1

Additional information regarding intact and damage stability matters for tankers can be found in MSC/Circ.406/Rev.1 which also recommends application of the *"Guidelines for the Uniform Application of the Survival Requirements of the Bulk Chemical Code (BCH Code) and the Gas Carrier Code (GC Code)"* to the IBC and IGC codes.

9 Intermediate Stages of Flooding Including Equalization, if any, and Cargo Run-off

Intermediate stages of flooding cover the flooding process from the commencement of flooding up to but excluding the final equilibrium damage condition (see also paragraph 3.4.3.2).

Intermediate stages should be comprehensively checked for all ships at the design appraisal stage.

9.1 Basis for checking intermediate cases of flooding and Minimum Stability Criteria Applied

The stability criteria applicable to the final equilibrium stage should also be satisfied for all intermediate stages. If any stability criteria during intermediate stages shows more severe values than in the final stage of flooding this intermediate stages should also be submitted.

9.2   Number of intermediate stages considered

A sufficient number of intermediate stages should be examined for all damage cases. It is generally recommended to apply 5 intermediate stages of flooding (see also paragraphs 6.8, 6.9 and 10.1).

If the vessel is equipped with non-instantaneous (greater than 60 secs) passive equalization arrangements or non-passive equalization arrangements of any size the following procedure is to be used:

1)   Compliance with the relevant criteria should be demonstrated without using equalisation arrangements for intermediate and final stages; and

2)   For subsequent equalisation additional 2 intermediate stages and final stages the compliance should also be demonstrated.

9.3   Cargo outflow and flood water inflow

During intermediate flooding stages a practical method of calculating the floating position and residual righting moments is the added mass method where the intact condition is corrected for the weights of inflowing floodwater and outflowing cargo.

During each stage an assumed amount of added floodwater and/or cargo outflow should be used. The following method is recommended:

i)   For a loaded tank an equal loss of liquid cargo mass and equal inflow of floodwater mass at each stage resulting in a total loss of liquid cargo at and total inflow of floodwater to the final damage equilibrium waterline; and

ii)   For an empty tank an equal inflow of floodwater mass at each stage resulting in total inflow of floodwater to the final damage equilibrium waterline.

See Annex 5 for example calculation.

Alternative methods may be accepted, for example:

i)   For a loaded tank the loss of liquid cargo mass and inflow of floodwater mass is based on a linear change of total tank content density over each intermediate stage from pure cargo at the intact condition to pure floodwater at the final damage equilibrium waterline.

ii)   For an empty tank an increasing depth of water at each stage based on the difference between the depth of water in the tank and the depth to the waterline in way of the tank, divided by the number of remaining stages, resulting in total inflow of floodwater to the final damage equilibrium waterline.

Noting that calculation of stability in the final damage condition assumes both the liquid cargo and the buoyancy of the damaged spaces to be lost it is therefore considered both reasonable and consistent to base the residual GZ curve at each intermediate stage on the intact displacement minus total liquid cargo loss at each stage.

9.4 Treatment of free surface and KG adjustment

Taking due account of the requirements of paragraph 6.5.1.1 it is generally recommended to apply actual liquid transfer moments for all tank filling levels in determining compliance with the relevant damage stability criteria through direct calculations of actual loading conditions.

With regard to the treatment of free surfaces of flooded spaces and noting that there will be combinations of empty and loaded tanks within the damaged extent all damaged compartments should be considered individually flooded during the intermediate stages – i.e. individual free surfaces. (The compartments are considered open to the sea in the final damage condition).

The correction for the free surfaces for the compartments assumed to be damaged in the final stage of flooding is not needed; the correction for the free surfaces for the compartments assumed to be damaged in intermediate stages of flooding should be considered when added weight method is used.

10 Final Stage of Flooding (Resolution MSC.281(85) to be referred to)

10.1 Watertight and weathertight integrity

The mandatory instruments referenced in paragraph 2.1 require the final waterline, taking into account sinkage, heel and trim, shall be below the lower edge of any opening through which progressive flooding may take place. Such openings shall include air-pipes (irrespective of closing devices) and those which are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, watertight doors including hinged type, which comply with SOLAS, ICLL, MARPOL Annex I, IGC Code and IBC Code requirements, as applicable and sidescuttles of the non-opening type.

Within the required range of residual stability, the immersion of any of the openings listed above and other openings capable of being closed weathertight may be permitted except openings required to be fitted with weathertight closing devices under the ICLL that, for operational reasons, are required to be kept open.

In the final equilibrium condition watertight escape hatches should not be submerged below the equilibrium damage waterline and should be treated as weathertight openings [5].

For emergency generator room the lowest point of the room should remain above the final equilibrium damage waterline. Any opening leading to this room should be treated as unprotected or weathertight, as applicable.

Footnote:

5) This specification applies only to the escapes from spaces other than tanks.

The following principles apply:

i)   Progressive flooding due to damage or submersion of air pipes

Progressive flooding may be accepted subject to the air pipes leading to relatively small compartments which are progressively flooded in a predictable and sequential manner in which all intermediate stages of flooding (with the exception of ~~on~~ no progressive flooding) and the final stage of flooding meet the required stability criteria.

ii)   Hinged watertight doors which do not comply with SOLAS, ICLL, MARPOL Annex I, IGC Code and IBC Code requirements, as applicable, and weathertight doors on the aft bulkhead of forecastle under the final waterline after flooding

Hinged watertight doors which do not comply with SOLAS, ICLL, MARPOL Annex I, IGC Code and IBC Code requirements, as applicable, and weathertight doors at the aft bulkhead of a forecastle space are permitted to be submerged after damage only when possible progressive flooding is limited to one relatively small compartment which is progressively flooded in a predictable and sequential manner in which all intermediate stages of flooding (with the exception of no progressive flooding) and the final stage of flooding meet the required stability criteria. No further progressive flooding is permitted beyond the initial flooding of that one relatively small compartment.

10.2   Unprotected openings

Residual GZ curves should be terminated at the lowest angle of submersion of an unprotected opening.

ANNEX 1

**DAMAGE STABILITY REQUIREMENTS APPLICABLE TO NEW OIL TANKERS,
CHEMICAL TANKERS AND GAS CARRIERS**

SHIP TYPE	ASSIGNED FREEBOARD	LENGTH	RULES
OIL TANKER [1]	Type "A" ship with assigned freeboard less than type "B"	L ≤ 150 m	MARPOL, ANNEX I
		L > 150 m	MARPOL, ANNEX I + ICLL, Reg.27
	Not less than type "B"	Regardless of length	MARPOL, ANNEX I
LIQUEFIED GAS CARRIER [1]	Type "A" ship with assigned freeboard less than type "B"	L ≤ 150 m	IGC
		L > 150 m	IGC +ICLL, Reg.27
	Not less than type "B"	Regardless of length	IGC
CHEMICAL TANKER [1]	Type "A" ship with assigned freeboard less than type "B"	L ≤ 150 m	IBC
		L > 150 m	IBC +ICLL, Reg.27
	Not less than type "B"	Regardless of length	IBC
[1] Ships complying with the above Regulations do not need to comply with the damage stability requirements of SOLAS, Chapter II-1, Part B-1.			

ANNEX 2

**EXPLANATORY NOTES TO THE FREE SURFACE CALCULATION WITH VARYING FREE
SURFACE MOMENTS, ACTUAL LIQUID TRANSFER MOMENTS, TAKING INTO
ACCOUNT ACTUAL HEEL AND TRIM, DEPENDING ON THE INTERVAL ANGLES OF
THE GZ CURVE**

In the figure below it is shown that the free surface moments can be reduced significantly, depending on the filling level and on the heel. Therefore calculations according to the actual liquid transfer moment represent a more realistic situation. In cases where the effect of free surfaces has a significant impact (i.e. large tanks) this method provides a more realistic account and can be used for the calculations of damage stability.
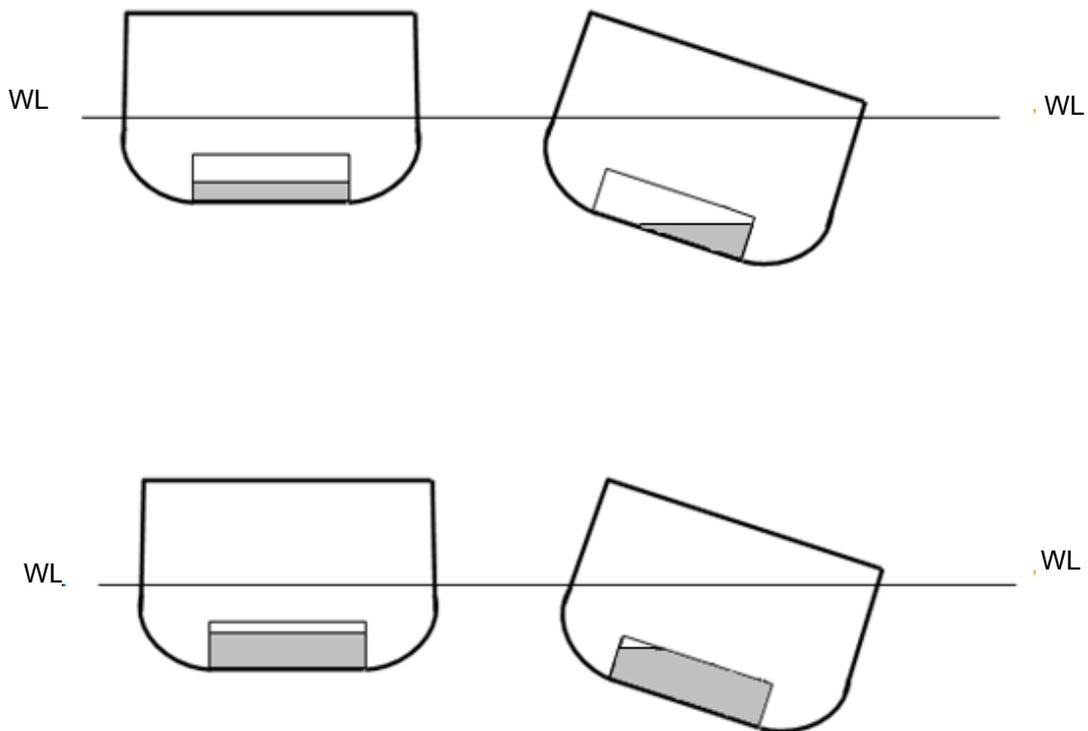
ANNEX 3

DESCRIPTION OF THE LONGITUDINAL EXTENT OF DAMAGE ACCORDING TO ICLL PROTOCOL 1988, REGULATION 27(12)(d)

The longitudinal extent of one compartment may vary depending if transversal wing tank bulkheads exceed B/5 (or 11.5m, whichever is less) or not. Please see the damages of sketch below.
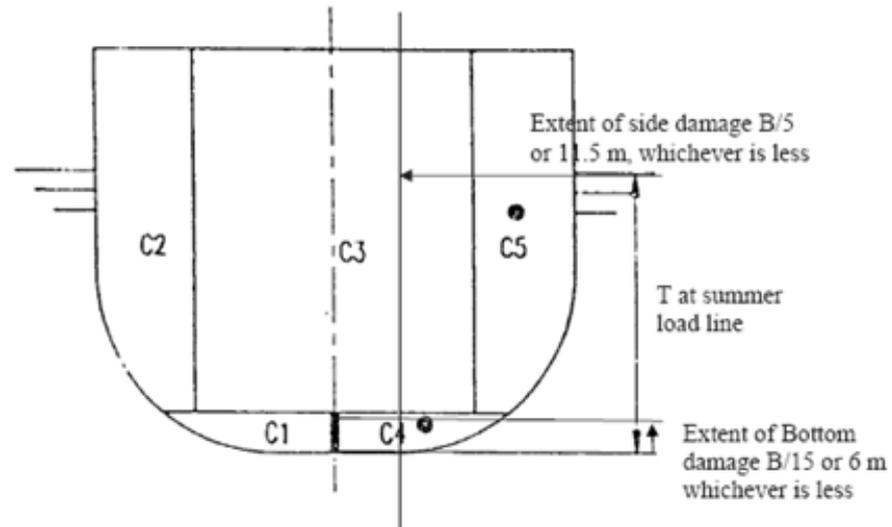
1.   Normal B/5 or 11.5m damage;

2. and 3. Transverse bulkhead exceeding B/5 or 11.5 m undamaged (two single one compartment damage cases); and

4.   Transverse bulkhead not exceeding B/5 or 11.5m damaged; partial transverse bulkhead not considered effective (one single one compartment damage case).
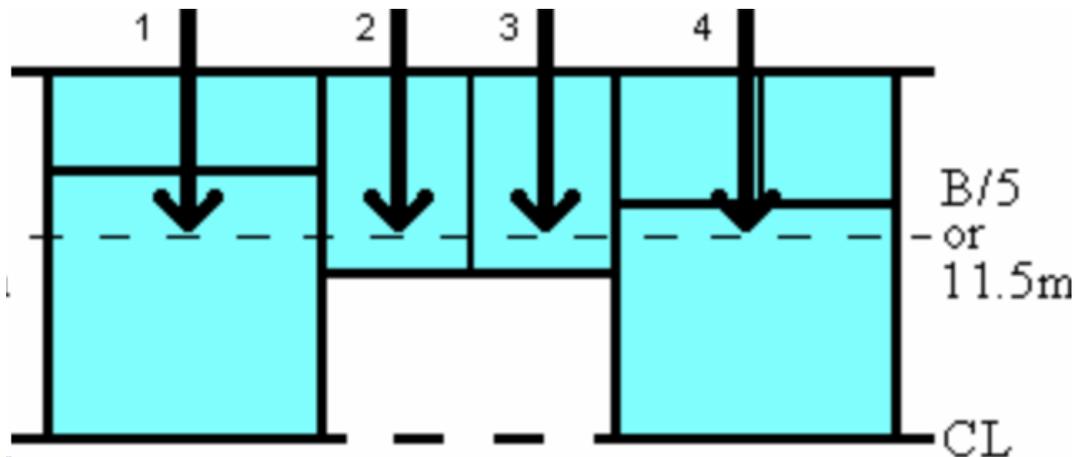
ANNEX 4

EXAMPLE ON HOW TO DEFINE DAMAGES OF LESSER EXTENT

1. SIDE DAMAGE
1.1 Damaged compartments for maximum extent:

1.1.1 C5, C3, C4

1.2 Damaged compartments for lesser extent:
1.2.1 C5
1.2.2 C5, C4
1.2.3 C3, C5

2. BOTTOM DAMAGE
2.1 Damaged compartments for maximum extent:

2.1.1 C4, C1

2.2 Damaged compartments for lesser extent:

2.2.1 C4

ANNEX 5

EXAMPLE CALCULATION OF THE LOSS OF LIQUID CARGO MASS AND INFLOW OF FLOODWATER MASS

Initial filling = 540 tonnes at SG = 1.800

Final filling at equilibrium = 240 tonnes at SG = 1.025

Stage	Assumed total mass in compartment	Assumed mass at original SG	Assumed Mass of sea water	Total volume assumed in compartment	SG assumed in compartment
0	540	540	0	300.0	1.800
1	490	450	40	289.0	1.695
2	440	360	80	278.0	1.583
3	390	270	120	267.1	1.460
4	340	180	160	256.1	1.328
5	290	90	200	245.1	1.183
6	240	0	240	234.1	1.025

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