RULES

PUBLICATION 86/P

EXPLANATORY NOTES TO SOLAS CONVENTION AND DIRECTIVE 2003/25/EC STABILITY AND SUBDIVISION REQUIREMENTS

January
2020

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków complete or extend the Rules and are mandatory where applicable.

GDAŃSK

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PRS/RP, 12/2019

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1 APPLICATION

1.1 The present Publication is a kind of guidance provided to systemize the activities which are indispensable during the analysis of the ship subdivision and stability after flooding part of its watertight spaces, within the scope required by the Rules.

1.2 The ship subdivision and stability calculation after flooding shall be carried out for cargo ships having the length L_s = 80 m and upwards, as well as for passenger ships, irrespective of length. The methodology and the requirements are given in IMO Resolution *MSC.216(82) (Annex 2*, *Part B*), which introduces amendments to the *SOLAS* Convention, effective from 1 January 2009. Other types of cargo ships may be covered by other requirements, as specified in Regulation 4. Explanations and interpretation concerning calculation methodology are given in *Resolution MSC. 281(85) Explanatory notes to the SOLAS Chapter II-1 subdivision and damage stability regulations.*

2 SELECTED DEFINITIONS

Subdivision length of the ship (L_s) – the greatest projected moulded length of that part of the ship at or below deck (or decks) limiting the vertical extent of flooding with the ship at the deepest subdivision load line.

The maximum possible vertical extent of damage above base plane is d_s+12.5 m.

Displacement of the ship (D) – mass of water, in tonnes, of the volume equal to the volume of the submerged part of the ship's hull.

Reserve buoyancy – the volume of the watertight part of the hull above waterline.

In the definition of displacement, reserve buoyancy and other parameters associated with volume, the thickness of shell plating is disregarded.

Figure 2-1 presents different examples of L_s showing the displacement of the ship and the reserve buoyancy. The limiting deck for the reserve buoyancy may be partially watertight.

Bulkhead deck – the uppermost deck up to which transverse watertight bulkheads are carried. The uppermost deck shall be understood as the deck at any point in the subdivision length (L_s) to which the main bulkheads and the ship's shell are carried watertight and the lowermost deck from which passenger and crew evacuation will not be impeded by water in any stage of flooding to be considered, as required in the *SOLAS* Convention. The bulkhead deck may be a stepped deck. In a cargo ships, the freeboard deck may be taken as the bulkhead deck.

*Draught (d)** – the vertical distance from the base plane at mid-length L_s to the summer load waterline.

Design draughts (d_s,d_l,d_p) – draughts at initial loading conditions, defined in 4.1.

Permeability of a space – the ratio of the volume which can be occupied by water to the whole volume of the space.

In calculation procedures the term – the permeability factor – is used.

Weathertightness and watertightness – a feature of a structure or a closing device, defined in details in *Part III –Hull Equipment*.

* Symbol *d* has been adopted as used in *SOLAS* and publications on subdivision.

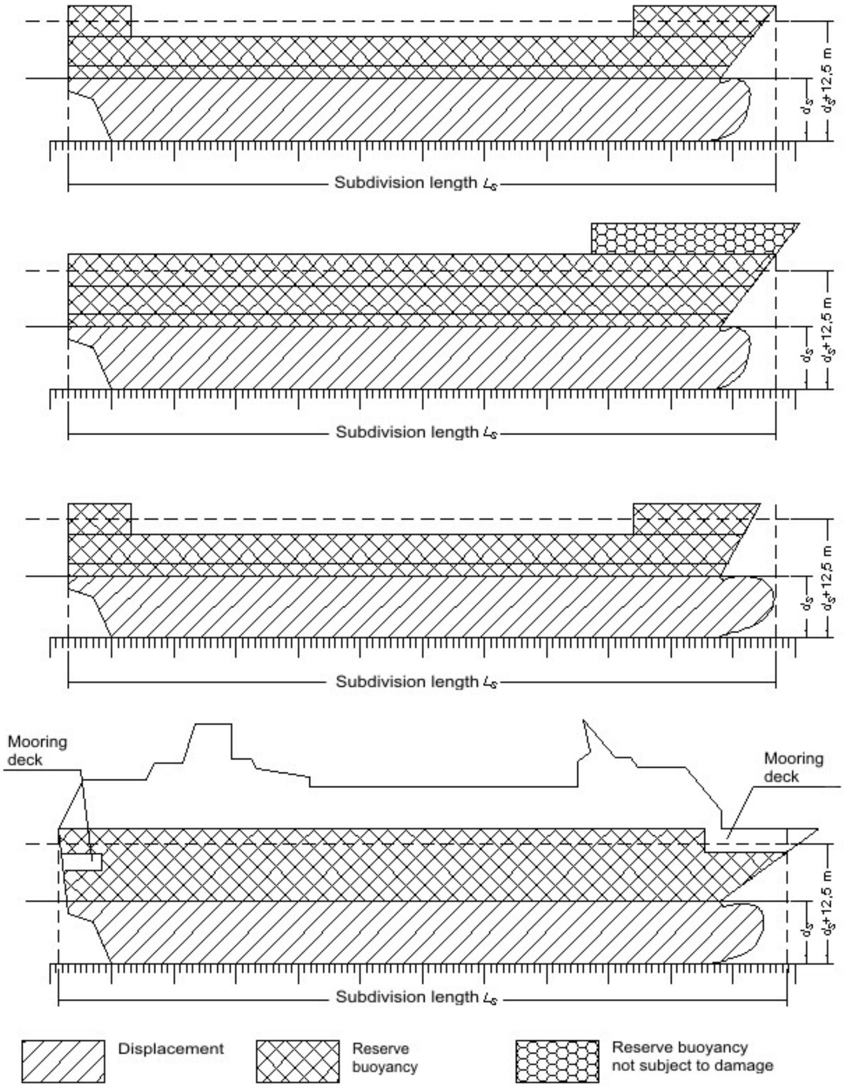


Fig. 2-1

This feature is decisive for compliance with the criteria of ship survival after flooding (the range of the positive GZ and the maximum static stability righting lever GZ_m).

3 DATA FOR CALCULATIONS

The basis for carrying out calculations is current ship technical documentation, as follows:

- body lines,
- general arrangement plan,
- plan of tanks,
- stability booklet,
- body lines with hull structural members or drawings, within the scope allowing to read the necessary dimensions,
- plans of pipelines passing through watertight structures,
- plans of internal and external openings and closing appliances.

The dimensions and other data contained in the above-mentioned documents allow to create calculation model of the ship.

Description of Hull Shape

Description of the hull shape in majority of cases is identical to that prepared for the purpose of hydrostatics and stability calculations. Special cases, such as holds or other spaces not provided with rule closing appliances shall be agreed with PRS in each particular case.

Description of Ship Subdivision

A record of all watertight spaces, as well as spaces which, due to their designation, have different permeabilities, although they are not bounded by watertight structures shall be made. For the purpose of systematics and clarity it is advisable to group the spaces according their designation and permeability. The correctness of the record shall be documented by a print-out of geometry data of all spaces (*Vnet*, *x*, *y*, *z*, *perm.)* and a sketch of the entire watertight subdivision.

Definition of Calculation Zones

The ship shall be divided into calculation zones. In the case of standard ship structures, the calculation zones shall be based on transverse subdivision. In the case of longitudinal bulkheads, inner side and/or watertight decks and the inner bottom, the record of these structures shall be entered into the definition of watertight subdivision. The purpose of this definition is to allow to sum up the calculation results of particular cases of flooding with the relevant probability. For the calculation of the probability of flooding spaces bounded below by watertight longitudinal bulkheads, the factor „*r*" shall be used; for the calculation of the probability of flooding spaces bounded below by watertight deck located above the initial waterline, the factor „*v*" shall be used. The inner bottom and watertight decks, if fitted, located below the initial waterline shall be taken into account in calculations in such a way as to allow to state whether a damage of smaller extent will not produce worse effects, as regards stability, than the flooding of the whole zone.

In special cases, the zone subdivision may have small gaps, not belonging to any of the zones. These gaps, however, must be included into multiple zone flooding. Such solution may be found practical in cases where certain elements which belong to a given zone (valves, ventilation ducts, companionways) are arranged in a way that disturb the clarity of the subdivision. It allows also to avoid excessive complexity and fragmentarization of calculation zones and consequently to avoid the creation of a great number of flooding scenarios, the probability of occurrence of which is very small.

Assignment of Spaces to Calculation Zones

All numerically defined spaces shall be assigned a symbol enabling their explicit identification in a defined calculation zones configuration. Such assignment enables an automatic generation of flooding conditions. Even when automatic generation of flooding conditions is not possible, such assignment will facilitate their manual generation.

Permeability (permeability factors)

Each space data shall be supplemented with their permeability (in calculation procedures called permeability factor), which will allow to determine the real amount of water flooding the given space. The values of permeability factors are taken according to the designation of the given space. If a space is intended for the carriage of cargo, then the value of the permeability factor is additionally dependent on the ship initial draught (this dependence is related to the dependence between the filling of the cargo hold and the ship's draught and the probability of flooding the space). The values of permeability factors shall be taken in accordance with *SOLAS II-1*, Regulation 7-3.

Definition of Openings and their Closing Appliances

The definition of opening shall contain the following elements:

- name/symbol that enables identification,
- coordinates of opening point (lying, in most cases, on the lower edge of the opening),
- type of closing appliances (watertight, weathertight),
- a list of spaces connected by the given opening or information that the given opening connects the outside,
- the effective cross-section area of opening if the opening is to be included in the flow calculation.

4 CALCULATION CONDITIONS

4.1 Initial Loading Conditions

Initial loading conditions are defined by draught, trim and metacentric height/vertical centre of gravity. *Convention SOLAS* requires that calculations shall be carried out for the following initial loading conditions:

d_s – deepest subdivision draught (maximum service draught); level trim,

d_l – the light service draught (dl) corresponds, in general, to the ballast arrival condition with 10% consumables for cargo ships. For passenger ships it corresponds, in general, to the arrival condition with 10% consumables, a full complement of passengers and crew and their effects, and ballast as necessary for stability and trim. Any temporary ballast water exchange conditions for compliance with the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 or any non-service conditions, such as dry-docking, should not be taken as d_l.

d_p – partial draught, defined as the light service draught plus 60% of the difference between the deepest subdivision draught and the light service draught; level trim.

It is recommended that *GM* (or *KG*) values for the three loading conditions should, as a first attempt, be taken from the intact stability *GM* (or *KG)*. Exception to this is draught d_l, for which the values corresponding to this loading condition are recommended.

The initial loading conditions are shown in Fig. 4.1-1.

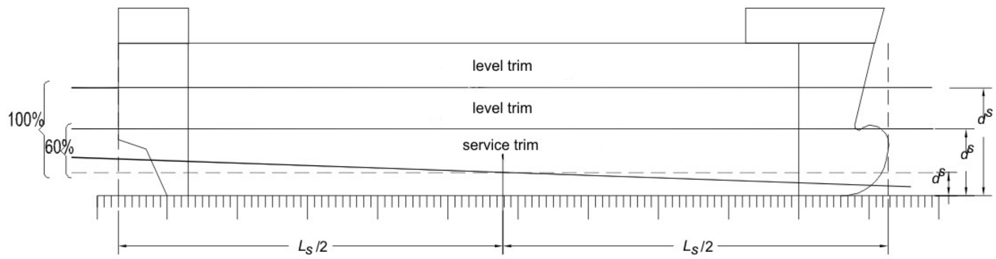


Fig. 4.1-1

The required minimum *GM* values (or maximum permissible *KG* values) shall be calculated for the three initial loading conditions. The obtained, by that means, three points constitute the basis for the design of the *GM* limiting curves. For partial draughts, the *GM* values are obtained by linear interpolation. Linear interpolation of the limiting values between the draughts d_s, d_p, and d_l is only applicable to *GM* values. Where curves of maximum permissible *KG* are developed, a sufficient number of KM_T values for partial draughts shall be calculated to ensure that the resulting maximum *KG* curves correspond with a linear variation of *GM*. When the light service draught is not taken with the same trim as other draughts, KM_T for draughts between partial and light service draught should be calculated for trims interpolated between the trim at partial draught and trim at light service draught.

Where the operational trim range is intended to exceed ±0.5% L_s, the additional sets of the limiting curves shall be constructed on the basis of operational range of trims for draughts d_s and d_p. For d_l draught only one trim shall be considered. The sets of the *GM* limiting curves shall be so constructed as to ensure that intervals of 1% L_s are not exceeded.

An example of the *GM* limiting curves envelope is shown in Fig. 4.1-2.

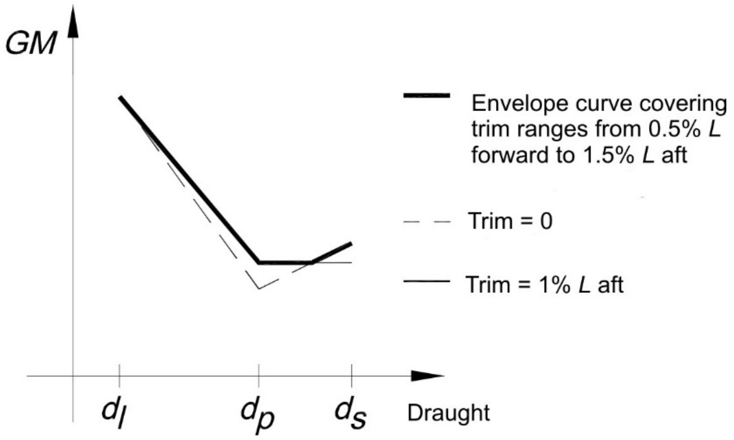
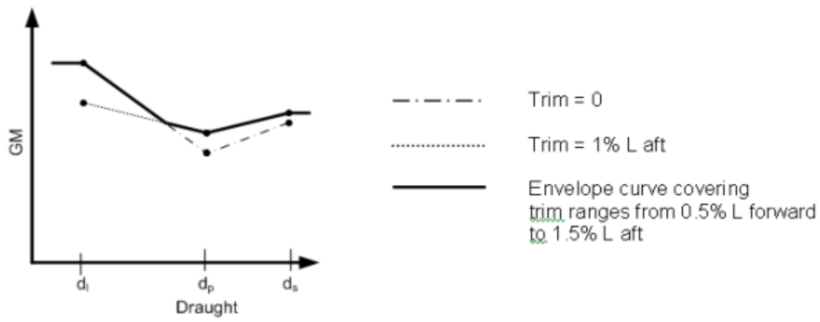


Fig. 4.1-2

If multiple *GM* limiting curves are obtained from damage stability calculations of differing trims in accordance with regulation 7, an envelope curve covering all calculated trim values should be developed. Calculations covering different trim values should be carried out in steps not exceeding 1% of *L*. The whole range including intermediate trims should be covered by the damage stability calculations. Refer to the example showing an envelope curve obtained from calculations of 0 trim and 1% of *L*.



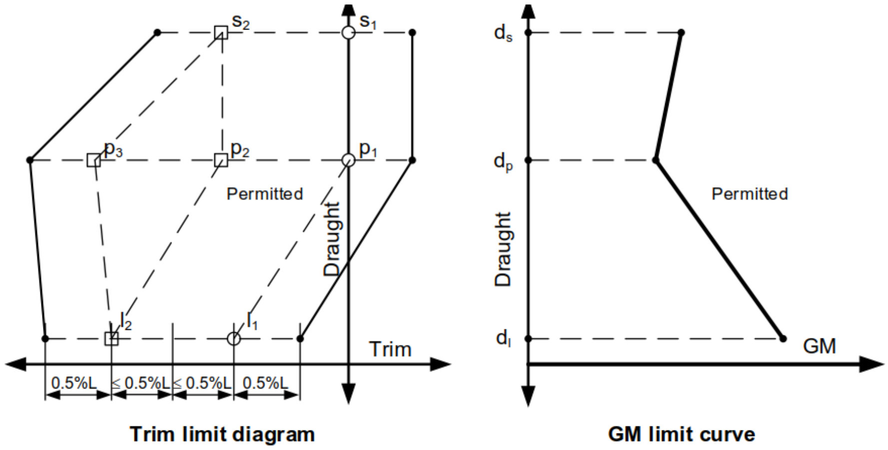
Rys 4.1-3

Temporary loading conditions may occur with a draught less than the light service draught dl due to ballast water exchange requirements, etc. In these cases, for draughts below dl, the *GM* limit value at dl is to be used.

Ships may be permitted to sail at draughts above the deepest subdivision draught ds according to the International Convention on Load Lines, e.g. using the tropical freeboard. In these cases, for draughts above ds the *GM* limit value at ds is to be used.

There could be cases where it is desirable to expand the trim range, for instance around dp. This approach is based on the principle that it is not necessary that the same number of trims be used when the GM is the same throughout a draught and when the steps between trims do not exceed

1% of L. In these cases there will be three A values based on draughts s1, p1, l1 and s2, p2, l2 and s2, p3, l2. The lowest value of each partial index As, Ap and Al across these trims should be used in the summation of the attained subdivision index A.



Rys. 4.1-4

This provision is intended to address cases where an Administration approves an alternative means of verification.

4.2 Damage Stability Conditions

The definition of damage stability condition shall contain an element which will allow its explicit identification and a list of spaces subjected to flooding, with relevant symbols. Depending on the scope of calculations, the list of symbols may be different, but it must contain at least the permeability of these spaces.

Damage stability conditions may be prepared manually, using a list and a plan of spaces containing the definition of damage zones. Use may be also made of automatic generation. Multiple flooding zone is constructed by summing up single flooding zone records.

Due to large number of damage cases, control checking, especially graphical (print-outs), is necessary. Control checking is particularly important in the stage of developing single flooding zones to avoid propagation of possible errors into multiple flooding zones.

5 CALCULATION ARGUMENTS

It is recommended that calculation methods ensuring good representation of flooding mechanism should be applied. In particular, free floating of the ship after flooding, that is hydrostatic parameters and cross-curves for free trim shall be used. Similarly, if liquids in the ship tanks are assumed, the free movement of the liquids in the tanks with the heeling of the ship shall be considered.

For the calculation of equilibrium and stability after damage (righting levers curve), constant displacement method shall be used.

6 STABILITY CRITERIA

6.1 Cargo Ships

For cargo ships, compliance with stability criteria in the final condition of flooding is sufficient. The criteria based on the parameters of the righting levers curve require calculation of the following:

– GZ_m – maximum positive righting lever,
– range of positive righting levers,
– Θ – angle of heel,
– distance between the critical opening and the waterline after flooding.

6.2 Passenger Ships

Passenger ships shall comply with stability criteria based on the parameters of the righting levers curve not only in the final conditions of flooding, but also in intermediate stages. Additionally, for passenger ships, compliance with stability criteria taking into account the following heeling moments shall be demonstrated:

– M_{hp} – from crowding of passengers to one side,
– M_{hw} – due to wind,
– M_{hr} – due to the launching of all fully loaded survival craft on one side of the ship.

7 DAMAGE STABILITY CALCULATION

A series of equilibrium and stability calculations for all developed damage conditions shall be made, assuming, one by one, each of the three initial loading conditions. Due to large number of results sets, they shall be appropriately sorted and tabularized so as to allow to state that all combinations of damage cases have been applied, in accordance with the principles of probability.

8 CALCULATION OF PROBABILITY COMPONENTS

Data on each calculated and sorted damage stability condition shall be supplemented with the relevant probability factors p_i resulting from the damage size and location on the ship. Probability factors p_i shall be calculated in accordance with the procedure specified in *SOLAS II-1*, Regulation 7-1.

For ships with longitudinal subdivision (inner side, longitudinal bulkheads), the obtained probabilities are reduced by factor r_i. All above-mentioned elements shall be so arranged as to allow to calculate partial probability pertaining to each of the element.

9 SUMMATION OF PARTIAL RESULTS

The results of damage stability calculation supplemented with the relevant probability factors constitute the basis for calculation of partial probability indices. The sum of partial probability indices constitutes the attained subdivision index *A.*

$$A_c = \sum_{i=1}^{i=t} p_i \left[v_i s_i \right]$$

where:

p_i – represents the probability that only the zone (compartment, a group of compartments) under consideration will be flooded, disregarding any horizontal subdivision, but taking into account longitudinal subdivision (using the factor r_i),

s_i – represents the probability of survival after flooding the zone (compartment, a group of compartments) under consideration, taking into account horizontal subdivision (using factor v_i).

Partial probability indices (A_s, A_p, A_l) obtained for each of the three initial loading conditions are summed (weighted) in accordance with the formula:

$$A = 0.4A_s + 0.4A_p + 0.2A_l$$

Summary of the results shall contain the following data characterizing each damage stability condition:

- calculation condition identifier,
- draught at the bow and stern,
- angle of heel (equilibrium),
- range of positive righting levers, taking into account flooding angle,
- maximum positive righting lever (GZ_m),
- vertical distance from the waterline to the critical opening,
- probability of occurrence factor , p_i,
- probability of occurrence factor, r_i,
- survival factor, s_i,
- survival factor, v_i,
- partial probabilities, A_{i}..

10 CALCULATION OF THE REQUIRED SUBDIVISION INDEX

Formulae for determining the required subdivision index, R, are given in Chapters 10.1 and 10.2:

10.1 Cargo ships:

10.1.1 Of the length L_s greater than 100 m:

$$R = 1 - \frac{128}{L_s+152} \qquad (10.1.1)$$

10.1.2 Of the length L_s of 80 m and upwards, but not more than 100 m:

$$R = 1 - \left[1/\left(1 + \frac{L_s}{100} \cdot \frac{R_0}{1-R_0}\right)\right] \qquad (10.1.2)$$

where the value of R_0 is equal to the value of R calculated according to formula 10.1.1.

10.2 Passenger ships:

$$R = 1 - \frac{5000}{L_s+2.5N+15225} \qquad (10.2)$$

where:

N = N_1+2N_2
N_1 – number of persons for whom lifeboats are provided,
N_2 – number of persons (including the crew) the ship is permitted to carry in excess of N_1.

The subdivision of a ship is considered sufficient if $A \geq R$ and if, in addition, the partial indices A_s A_p and A_l are not less than 0.9 R for passenger ships and 0.5 R for cargo ships.

10.3 Deterministic „Minor Damage" Concept

For passenger ships intended to carry 36 or more persons, the survival of damages specified in the Table, with probability factor not less than 0.9, shall be additionally demonstrated.

For passenger ships intended to carry 400 or more persons, the survival of damages specified in the Table, with survival factor = 1, shall be additionally demonstrated.

Calculations shall be made for all three initial loading conditions (d_s, d_p, d_l).

N-number of persons	Longitudinal extent of damage	Transverse extent of damage	Vertical extent of damage	Damage location
36	max(0.015L_S, 3 m)	max(0.05B, 0.75 m)	d_s+12.5 m	Between watertight bulkheads
36<N<400	Linear interpolation			
≥400	max(0.03L_S, 3 m)	max(0.1B, 0.75 m)		Anywhere in the shell plating

11 DIRECTIVE 2003/25/EC

11.1 Application

The requirements of Chapters 11-15 refer to passenger ro-ro ships engaged on regular international voyages. They cover ships carrying more than 12 passengers and provided with ro-ro or special category spaces, in accordance with the definition given in *SOLAS II-2*, Regulation 3.

11.2 Legal Basis

The requirements, referred to above, are based on *Directive 2003/25/EC of the European Parliament and of the Council* of 14 April 2003.

11.3 Selected Definitions

Regular service – a series of ro-ro passenger ship crossings serving traffic between the same two or more ports, which is operated either:

.1 according to a published timetable or
.2 with crossing so regular that they constitute a recognizable systematic series.

Significant wave height h_s – the average height of the highest third of wave heights observed over a given period.

Numbers given on maps represent significant wave heights which shall be taken for calculations respectively to the ship's operation region.

Residual freeboard, f_r – the minimum distance between the damaged ro-ro deck and the final waterline at the location of the damage, without taking into account the additional effect of the sea water accumulated on the damaged ro-ro deck, [m].

Height of water on deck, h_w – the thickness of the assumed layer of the water on the ro-ro deck determined, depending on the relevant, for the given operation area, significant wave height, [m].

12 METHODS OF DIRECTIVE 2003/25/EC REQUIREMENTS EXECUTION

12.1 Analytical Method

Analytical method consists in the calculation of ship stability in damaged condition, with assumed amount of water on deck. The damage conditions (from the list of conditions used for determining index A) to be taken for calculations shall be such as, taking into account the assumed water on deck, to represent the worst flooding scenarios. Since the requirements of *Directive 2003/25/EC* refer to *SOLAS 90* standard, the survival criteria for new ships with water on deck shall be agreed with PRS in each particular case.

12.2 Model Tests Method

Uniform guidelines and requirements regarding the model test method are contained in Annex 1 to *Directive 2003/25/EC*. According to the survival criteria the ship should be considered as surviving if a stationary state is reached for the successive test runs as required in paragraph 3.3 of Annex 1.

The angles of roll of more than 30° against the vertical axis, occurring more frequently than in 20 % of the rolling cycles or steady heel greater than 20 ° should be considered as capsizing events even if a stationary state is reached.

13 DETERMINING THE VOLUME OF WATER ON DECK

The amount of assumed accumulated sea water on deck shall be calculated on the basis of a water surface having a height h_w , as follows:

– 0.5 m if the residual freeboard is 0.3 m or less,
– 0.0 m if the residual freeboard is 2.0 m or more, and intermediate values to be determined by linear interpolation, if the residual freeboard is 0.3 m or more, but less than 2.0 m.

For ships in geographically defined restricted areas of operation, the administration of the Flag State may reduce the height of the water surface prescribed as above by substituting such height of the water surface by the following:
– 0.0 m if the significant wave height defining the area concerned is 1.5 m or less,
– the value determined as above if the significant wave height defining the area concerned is 4.0 m or above,
– intermediate values to be determined by linear interpolation for 1.5 m < h_s < 4.0 m.

14 A PRACTICAL RELATIONSHIP BETWEEN THE DIRECTIVE AND SOLAS CONVENTION

The analysis of the influence of the water on deck on damage stability is carried out as supplementary to the standard procedure, provided by the *SOLAS* Convention. The calculation results of damage scenarios with water on deck shall allow to determine the limiting operational curves *KG* or *MG* curves similarly to the standard procedure specified in *SOLAS*, Regulation 7-2. The limiting operational *KG* or *MG* curves derived from *SOLAS* calculations may not be sufficient in cases where "water on deck" is assumed under the terms of this Directive. They may be, however, taken as the first approximation and subsequently revised to comply with the required stability criteria. The revised limiting operational *KG/GM* curves may be derived by iteration.

15 INFORMATION ON STABILITY

The limiting operational *KG* or *GM* curves which take into account water on deck shall be such as to be reasonably sustained in service. If the limiting operational *KG* or *GM* curves, derived from stability calculations with water on deck, exceed the acceptable values, provision shall be made for a suitable bulkhead deck arrangement or closing devices on the ro-ro deck to minimise the excess of water accumulated on the deck.

The approved *Stability Booklet* shall contain the limiting operational *KG* or *MG* curves, taking into account the relevant requirements for the intact ship and the damaged ship with water on deck. Where arrangements confining the accumulation of water on the ro-ro deck are used, instruction on their usage shall be provided.

List of amendments effective as of 1 January 2020

Item	*Title/Subject*	*Source*
4	4.1 Initial Loading Conditions	MSC.429(98) 2.11
4	4.1 Initial Loading Conditions	MSC.429(98) 5-1.4.3
4	4.1 Initial Loading Conditions	MSC.429(98) 5-1.4.4
4	4.1 Initial Loading Conditions	MSC.429(98) 5-1.4.5
4	4.1 Initial Loading Conditions	MSC.429(98) 5-1.5
4	4.1 Initial Loading Conditions	MSC.429(98) 5-1.6
9	Summation of partial results	MSC 429(98) 7.1.2
