

**Appendix C**  
**GUIDANCE ON APPLICATION OF STOCKHOLM AGREEMENT**

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# 1 UK Interpretation of the Application of Stockholm Agreement to High-Speed Craft

## 1.1 Background

The enhanced requirements for damage survivability, known as the 'Stockholm Agreement' (SA) standard, were developed primarily for application to conventional monohull vessels. However, the MCA, in common with other Marine Administrations who have signed up to the Agreement, considers it appropriate that this standard should also be applied to seagoing Ro-Ro Passenger High-Speed Craft, including multihulls. (See Regulation 3 (2) of S.I.2004 No. 2884).

## 1.2 References

1. S.I.2004 No. 2884, the Merchant Shipping (Ro-Ro Passenger Ships) (Stability) Regulations 2004.
2. S.I.2004 No. 302, the Merchant Shipping (High-Speed Craft) Regulations 2004, and any future amendment or replacement.
3. International Code of Safety for High-Speed Craft 1994, IMO Res. MSC.36(63) as amended by MSC.119(74), MSC.174(79), MSC.221(82).
4. MSN 1790 (M) as amended "Agreement Concerning Specific Stability Requirements for Ro-Ro Passenger Ships Undertaking Regular Scheduled International Voyages or Domestic Voyages between European Ports".
5. The Stockholm Agreement (Agreement Concerning Specific Stability Requirements for Ro-Ro Passenger Ships undertaking Regular Scheduled International Voyages Between or To or From Designated Ports in Northwest Europe and the Baltic Sea) 28 February 1996.
6. International Code of Safety for High-Speed Craft 2000, IMO Res. MSC.97(73) as amended by MSC.119(74), MSC.175(79) and MSC.222(82).
7. Instructions for the Guidance of Surveyors: Passenger Ship Construction Classes I, II and IIA.
8. MCA Research Project 424: Fundamentals of Damaged Ship Survivability
9. Code of Safety for Dynamically Supported Craft, IMO Res. A.373(X) as amended by MSC.37(63) (up to MSC.69(69) amendments of SOLAS), MSC.186(79) and MSC.224(82).
10. EU Directives 2003/24/EC and 2003/25/EC as amended by 2005/12/EC.

## 1.3 General Guidance

- 1.3.1 It will be noted that according to Annex 1 of MSN 1790 (M) as amended, 'water on deck' calculations are to be carried out for assumed water depths depending on the residual freeboard after damage. While this represents a relatively onerous requirement for monohull vessels, the stability characteristics of multihulls are such that in most cases compliance is achieved without the need for modifications to the subdivision arrangements etc. For large vessels where the minimum residual damaged freeboard in way of the damage is 2.0m or more, the requirements of SA are considered to be met. Further, if freeing ports on the Ro-Ro decks meet certain requirements, the calculations need not be performed (see Appendix 2, Annex 1, para 2.5 of MSN 1790 (M) as amended). It should be noted however that, in general,

the effect of freeing ports in terms of clearing water from the deck is not considered for the purpose of the SA calculations.

- 1.3.2 Compliance with the stability requirements of the HSC Code is considered equivalent to full compliance with the 'SOLAS 90' stability standard. .
- 1.3.3 In accordance with Reg. 6 of S.I.2004 No.2884 a vessel to which the SA applies is required to be issued with a certificate confirming compliance. The MCA (or flag state administration) issues these documents after examination of appropriate calculations submitted by the owner/operator.
- 1.3.4 With regard to the specific stability criteria to be applied when evaluating compliance of multihull craft, or other high-speed craft, with the SA, the regulations do not provide clear instructions. However, as the HSC Code damage stability standards for multihulls were developed in recognition of the fact that the SOLAS damage standard for monohulls is not appropriate for application to multihulls, there is no justification to apply the SOLAS-based SA compliance criteria of MSN 1790 (M) as amended to multihulls. Therefore, for 'water on deck calculations' of HSC the general SA requirements should be assumed - i.e. freeboard, significant wave height, height of water on deck, selection method of the worst case side damage to be tested, damage shape (model test method only) etc.; but, with the worst case side damage, damage length, damage shape (calculation method only) and damage stability criteria should be carried out against the appropriate issue of the HSC / DSC Code.
- 1.3.5 Experience has shown that although the model testing method is costly, it can provide for more flexible solutions for conventional Ro-Ro vessels in lieu of performing the water on deck calculations.
- 1.3.6 If it is necessary to model test a HSC vessel to meet the SA standards then the general SA requirements and methodology should be followed as far as possible. The model should be built in accordance with MSN 1790 (M) as amended. As with the deterministic calculation method, the worst case side damage (selected using the HSC standard of the minimum area under the residual stability curve up to the angle of maximum GZ) and damage length should be selected using the appropriate issue of the HSC / DSC Code. The model test should be carried out against the procedure of experiments and reviewed against the acceptance survival criteria in accordance with the test approval as dictated by MSN 1790, and where appropriate Appendix 3 of Ref. 7. (see 5 of this Appendix C for the version edited for HSC). A midship damage case test may need to be carried out. It may be necessary for the shape of the damage opening to be reassessed, to the satisfaction of the attending MCA Surveyor, to allow for stepped structure or tumble home in way of the car decks, or for the practicalities of the transverse damage (in accordance with paragraph 2.6.6.2 of 1994 HSC Code and paragraph 2.6.7 of 2000 HSC Code, as appropriate) extending beyond the breadth of one hull of a multihull.
- 1.3.7 Although Research Project 424 (Fundamentals of damaged ship survivability) gives an indicator of the behaviour of a damaged vessel in a seaway motion and of how to counteract any adverse behaviour (e.g. optimising cross flooding), it is at present not intended to replace the existing methods; a model test or deterministic calculations are still necessary. Paragraph 2.1.4 of 2000 HSC Code should be noted. Paragraph 2.2.3.2 of 2000 HSC Code does not exclude a vessel from the Stockholm requirements. Research Project 424 describes the use of a 6 degrees of freedom computational fluid dynamics program - not with the aim of this method being a replacement for the model testing technique (or the more deterministic calculation method) of determining the effects of water on deck that is required by the SA - but as a complementary method.

## 2 General Guidance Notes on the Stockholm Agreement (SLF40/Inf.14 annex 1, amended for HSC)

### 2.1 General

- 2.1.1 The most dangerous problem for a ro-ro ship with an enclosed ro-ro deck is undoubtedly that posed by the effect of a build-up of significant amount of water on that deck. The principle of additional water-on-deck has been adopted to account for the risk of accumulation of water-on-deck as a result of the dynamic behaviour, in a seaway, of the vessel after sustaining side collision damage.
- 2.1.2 It is considered that the problem of water accumulating on deck when entering through bow, stern and side doors has been addressed by the increased standards now required with respect to strength, closing and locking systems, as well as by the new requirements relating to the position of the extension to the collision bulkhead.
- 2.1.3 The damage stability requirements applicable to ro-ro passenger ships in 1990 (SOLAS '90) implicitly include the effect of water entering the ro-ro deck in a sea state in the order of 1.5m Significant Wave Height. In order to enable the ship to survive in more severe sea states those requirements have been upgraded to take into account the effect of water which could accumulate on the ro-ro deck.
- 2.1.4 In developing the new requirements the following basic elements were taken into account:-
- .1 MSC/Circ. 153 confirms that 99% of all recorded collisions occur in sea states up to 4 m Significant Wave Height ( $h_s$ ). This was therefore taken as the most severe sea state to be considered;
  - .2 compliance with SOLAS '90 standard is assumed to be equivalent to survival of the damaged ship in sea states of up to 1.5 m Significant Wave Height ( $h_s$ ) which according to the distribution function in MSC/Circ.153, covers 89% of all collisions;
  - .3 sea states between 1.5m to 4.0m Significant Wave Height ( $h_s$ ) would be covered by the additional damage stability requirements to take into account the effect of "water-on-deck"; and
  - .4 because the general requirements cover all sea conditions in which according to the statistics available collisions can be expected to occur, a reduction has been permitted in the requirement for "water-on-deck" for ships operating in geographically defined restricted areas. The Significant Wave Height ( $h_s$ ) is the qualifying parameter, in association with a 90% probability that  $h_s$  is not exceeded in that area or route.
- 2.1.5 When considering the amount of water to be assumed as accumulating on the ro-ro deck the figure of up to 0.5m, depending on the Significant Wave Height and residual freeboard, was agreed based on consideration of the following information:
- .1 an initial Nordic proposal which suggested 0.5m for the amount of "water-on-deck";
  - .2 a study by the Society of Naval Architects and Marine Engineers (SNAME) suggested that  $0.5\text{m}^3/\text{m}^2$  was a reasonable level for 4.0m Significant Wave Height on a vessel with low damaged freeboard;
  - .3 model tests carried out in Finland (Model Tests of a Car Ferry with Water on the Car Deck (M-304)) which indicated the volume at the Significant Wave Height of 4.0m was approximately equal to  $0.75\text{m}^3/\text{m}^2$ ;

- .4 investigations carried out in the United Kingdom, which indicated that the corresponding amount of water would be about 10% of the ship's displacement; and
  - .5 research carried out during the Joint North West European Project (Safety of Passenger Ro-Ro vessels) which related to a static pressure head relevant to a head of water above the deck or above the still water level.
- 2.1.6 However it was considered more appropriate to assume a variable quantity of water on deck depending not only on the residual freeboard and Significant Wave Height, but also on a variable angle of heel. With this in mind the basic assumption of up to 0.5 metres height of accumulated water corresponding to residual freeboard and Significant Wave Height was retained.
- 2.1.7 Research has clearly shown that the residual freeboard had a significant effect on the amount of water assumed to be accumulated on deck. The maximum residual freeboard ( $f_r$ ) to be taken into account was agreed as 2.0m based on both the Institute for Marine Dynamics (Canada) (IMD) model tests and the SNAME analytical predictions which indicated that the height of water on deck goes to zero as the residual freeboard/Significant Wave Height ratio rises above 0.5. Therefore in order to assume zero accumulation, in a Significant Wave Height of 4.0m, a residual freeboard of 2.0m would be required. The residual freeboard ( $f_r$ ) in this case is defined as "the minimum distance between the damaged ro-ro deck and the waterline at the location of the damage without taking into account the additional effect of sea water accumulated on the damaged ro-ro deck".
- 2.1.8 A requirement on damage stability for ro-ro passenger vessels taking into account additional flooding above the ro-ro deck was developed which clearly applies to existing as well as to new ships.

## **2.2 Scope of application of the new requirement**

This damage stability requirement should, in principle, be applied to all such passenger vessels with ro-ro decks covered by the definition "special category spaces and ro-ro cargo spaces as defined in Regulation II-2/3" (of the Class 1 to IIA Passenger Ship Construction Regulations) with the proviso that spaces which have sufficient permanent openings for water freeing purposes may be exempted from the application of the requirements of "water-on-deck". Details of the requirements for freeing ports are given in the attached notes.

## **2.3 Bulkhead height including a standard for testing**

- 2.3.1 The general requirement for the minimum height of bulkheads which may need to be additionally installed on the ro-ro deck shall apply to all ro-ro passenger vessels. However, the new requirements provide for the possibility for an Administration to accept lower heights for innovative designs of bulkheads, based on the results of model experiments.
- 2.3.2 Any transverse and longitudinal bulkheads which are fitted to enable the vessel to meet these stability regulations must be in place and secured at all times when the ship is at sea. Accesses within such bulkheads may be opened during the voyage but only for sufficient time to permit through passage for the essential working of the vessel and only at the express authority of the master.

## **2.4 Modifications which may be consequential to compliance with the new standard**

Passenger accesses; escapes; fire extinguishing, detection and monitoring systems; car deck drainage; ventilation; cargo securing etc must comply with the same safety standards as are applicable to the vessel after the fitting of any ro-ro car deck modifications. Provision must also be provided such that any accesses in transverse or longitudinal bulkheads/barriers cannot be obstructed.

## **3 Guidance Note on Annex 1 to the Stockholm Agreement (SLF40/INF.14 annex 1)**

The route, routes or areas concerned have been determined by the Administrations at each end of the route or all Administrations within a defined area. The defined route or area is one in which the determined Significant Wave Height would not be exceeded with a probability of more than 10% over a one year period for all year round operation. **Maps covering international voyages in the North-West European sea areas and the Baltic Sea can be found on pages 34 and 35 of MSN 1790 as amended. For other European sea areas such as the Mediterranean, please contact MCA HQ for further information. U.K. inshore waters for domestic voyages are covered by MSN 1747 (M) which augments S.I. 2000 (No. 2687) "The Merchant Shipping (Passenger Ship on Domestic Voyages) Regulations 2000.**

## **4 Guidance Notes on the Stability Requirements Contained in Annex 2 to the Stockholm Agreement (SLF40/INF.14 annex 1, amended for HSC)**

**N.B. SOLAS '90 is an equivalent standard to those applied in the HSC Codes.**

### **Application**

It should be noted that vessels which may operate solely in areas where the significant wave is less than 1.5m and which do not have to comply with the additional water-on-deck requirements (ie, comply only with HSC Code) are to comply with the dates of compliance set out with the Agreement.

### **Stability Standard**

Paragraph 1 of Annex 2 of The Agreement (Ref.5).

As a first step all ro-ro passenger vessels must comply with the HSC Code standard of residual stability. It is the application of this requirement that defines the residual freeboard ( $f_R$ ) necessary for the calculations required in paragraph 1.1.

Paragraph 1.1 of Annex 2 of The Agreement (Ref.5).

1. This paragraph addresses the application of a hypothetical amount of water accumulated on the bulkhead (ro-ro) deck. The water is assumed to have entered the deck via a damage opening. This paragraph requires that the vessel in addition to complying with the full requirements of the appropriate HSC Code further complies

only with that part of the HSC Code criteria contained in paragraphs 2.13 of the 2000 HSC Code and 2.3 of the 1994 HSC Code with the defined amount of water on deck. The vessel does not, for this calculation, need to comply with any requirements for the angles of equilibrium or non-submergence of the margin line.

2. The accumulated water is added as a liquid load with one common surface inside all compartments which are assumed flooded on the car deck. The height ( $h_w$ ) of water on deck is dependent on the residual freeboard ( $f_r$ ) after damage, and is measured in way of the damage (**see Fig 1**). The residual freeboard  $f_r$  is the minimum distance between the damaged ro-ro deck and the final waterline (after equalisation measures if any have been taken) in way of the assumed damage after examining all possible damage scenarios in determining the compliance with HSC Code/SOLAS 90 as required in para 1 of Annex 2 to the Agreement. No account should be taken of the effect of the hypothetical volume of water assumed to have accumulated on the damaged ro-ro deck when calculating  $f_r$ .
3. If  $f_r$  is 2.0m or more, no water is assumed to accumulate on the ro-ro deck. If  $f_r$  is 0.3m or less, then height  $h_a$  is assumed to be 0.5 metres. Intermediate heights of water are obtained by linear interpolation (**see Fig 2**)

#### Paragraph 1.2 of Annex 2 of The Agreement (Ref.5).

Means for drainage of water can only be considered as effective if these means are of a capacity to prevent large amounts of water from accumulating on the deck i.e. many thousands of tonnes per hour which is far beyond the capacities fitted at the time of the adoption of these regulations. Such high efficiency drainage systems may be developed and approved in the future (based on guidelines to be developed by the International Maritime Organisation)

The garage doors fitted at the aft end of some high speed craft are not considered to be efficient enough in this instance unless calculations of drainage are provided with evidence that the sinkage caused by the additional water on deck does not result in an equivalent head of water on the external face of the 'garage door' which will prevent the door from collapsing.

#### Paragraph 1.3 of Annex 2 of The Agreement (Ref.5).

1. The amount of assumed accumulated water-on-deck may, in addition to any reduction in accordance with paragraph 1.1, be reduced for operations in geographically defined restricted areas. These areas are designated in accordance with the Significant Wave Height ( $h_s$ ) defining the area and are detailed in Annex 1 to the Agreement (**refer also to para 3 of this document, above, for more details**).
2. If the Significant Wave Height ( $h_s$ ), in the area concerned, is 1.5m or less then no additional water is assumed to accumulate on the damaged ro-ro deck. If the Significant Wave Height in the area concerned is 4.0m or more then the height of the assumed accumulated water shall be the value calculated in accordance with paragraph 1.1. Intermediate values to be determined by linear interpolation (**see Fig 3**).
3. The height  $h_w$  is kept constant therefore the amount of added water is variable as it is dependent upon the heeling angle and whether at any particular heeling angle the deck edge is immersed or not. (**see Fig 4**). It should be noted that the assumed permeability of the car deck spaces is to be taken as 90% (MSC/Circ.649 and 2.6 of the 2000 HSC Code refers), whereas other assumed flooded spaces permeability's are to be those prescribed in 2.6 of the HSC Codes.

4. If the calculations to show compliance with the Agreement relate to a Significant Wave Height less than 4.0m that restricting Significant Wave Height must be recorded on the vessel's "passenger vessels permit to operate" certificate as a regional restriction.

Paragraphs 1.4 / 1.5 of Annex 2 of The Agreement (Ref.5).

As an alternative to complying with the new stability requirements of paragraphs 1.1 or 1.3 an Administration may accept proof of compliance via model tests. The model test requirements are detailed in Annex 3 to the Agreement. Guidance notes on the model tests are contained in Part 5 of this Appendix to this document.

Paragraph 1.6 of Annex 2 of The Agreement (Ref.5).

Conventionally derived HSC Code limiting operational curve(s) (KG or GM) may not remain applicable in cases where "water on deck" is assumed under the terms of the Agreement and may be necessary to determine revised limiting curve(s) which take into account the effects of this added water. To this effect sufficient calculations corresponding to an adequate number of operational draughts and trims must be carried out and the Stability Information Booklet re-approved as necessary.

**Note**

Revised limiting operational KG/GM Curves may be derived by iteration, whereby the minimum excess GM resulting from damage stability calculations with water on deck is added to the input KG (or deducted from the GM) used to determine the damaged freeboards ( $f_r$ ), upon which the quantities of water on deck are based, this process being repeated until the excess GM becomes negligible.

It is anticipated that operators would begin such an iteration with the maximum KG/minimum GM which could reasonably be sustained in service and would seek to manipulate the resulting deck bulkhead arrangement to minimise the excess GM derived from damage stability calculations with water on deck.

Paragraph 2.1 of Annex 2 of The Agreement (Ref.5).

As for conventional HSC Code damage requirements bulkheads inboard of the line applied under 2.6.6.2 of the 1994 HSC Code or by 2.6.7.2 of the 2000 HSC Code are considered intact in the event of side collision damage.

Paragraph 2.2 of Annex 2 of the Agreement (Ref.5)

If side structural sponsons are fitted to enable compliance with this regulation, and as a consequence there is an increase in the breadth (B) of the ship and hence the vessel's transverse extent of side damage from the ship's side, such modification shall not cause the relocation of any existing structural parts or any existing penetrations of the main transverse watertight bulkheads below the bulkhead deck (**see Fig 5**).

Paragraph 2.3 of Annex 2 of the Agreement (Ref.5)

1. Transverse or longitudinal bulkheads/barriers which are fitted and taken into account to confine the movement of assumed accumulated water on the damaged ro-ro deck need not be strictly "watertight". Small amounts of leakage may be permitted subject to the drainage provisions being capable of preventing an accumulation of water on the "other side" of the bulkhead/barrier. In such cases where scuppers become inoperative as a result of a loss of positive difference of water levels other means of passive drainage must be provided.

2. The height ( $B_n$ ) of transverse and longitudinal bulkheads/ barriers shall be not less than  $(8 \times h_w)$  metres, where  $h_w$  is the height of the accumulated water as calculated by application of the residual freeboard and Significant Wave Height (paras 1.1 and 1.3 refers). However in no case is the height of the bulkhead/barrier to be less than the greatest of:
  - (a) 2.2 metres; or
  - (b) the height between the bulkhead deck and the lower point of the underside structure of the intermediate or hanging car decks, when these are in their lowered position. It should be noted that any gaps between the top edge of the bulkhead deck and the underside of the plating must be "plated-in" in the transverse or longitudinal direction as appropriate. (see Fig 6).
3. Bulkheads/barriers with a height less than that specified above, may be accepted if model tests are carried in accordance with Part 5 of this Appendix to confirm that the alternative design ensures appropriate standard of survivability.
4. Care needs to be taken when fixing the height of the bulkhead/ barrier such that the height shall also be sufficient to prevent progressive flooding within the required stability range. This range is not to be prejudiced by model tests.

**Note:** The range may be reduced to 10 degrees provided the corresponding area under the curve is increased (Report of the Maritime Safety Committee on its Sixty-Fourth Session, MSC 64/22, refers).

#### Paragraph 2.5.1 of Annex 2 of the Agreement (Ref.5)

1. The area "A" relates to permanent openings. It should be noted that the "freeing ports" option is not suitable for vessels which require the buoyancy of the whole or part of the superstructure in order to meet the criteria. The requirement is that the freeing ports shall be fitted with closing flaps to prevent water entering, but allowing water to drain.
2. These flaps must not rely on active means. They must be self-operating and it must be shown that they do not restrict outflow to a significant degree. Any significant efficiency reduction must be compensated by the fitting of additional openings so that the required area is maintained.

Refer also to comments above on Para 1.2 of the Agreement relating to "garage doors".

#### Paragraph 2.5.2 of Annex 2 of The Agreement (Ref.5)

For the freeing ports to be considered effective the minimum distance from the lower edge of the freeing port to the damaged waterline shall be at least 1.0m. The calculation of the minimum distance shall not take into account the effect of any additional water on deck (see Fig 7).

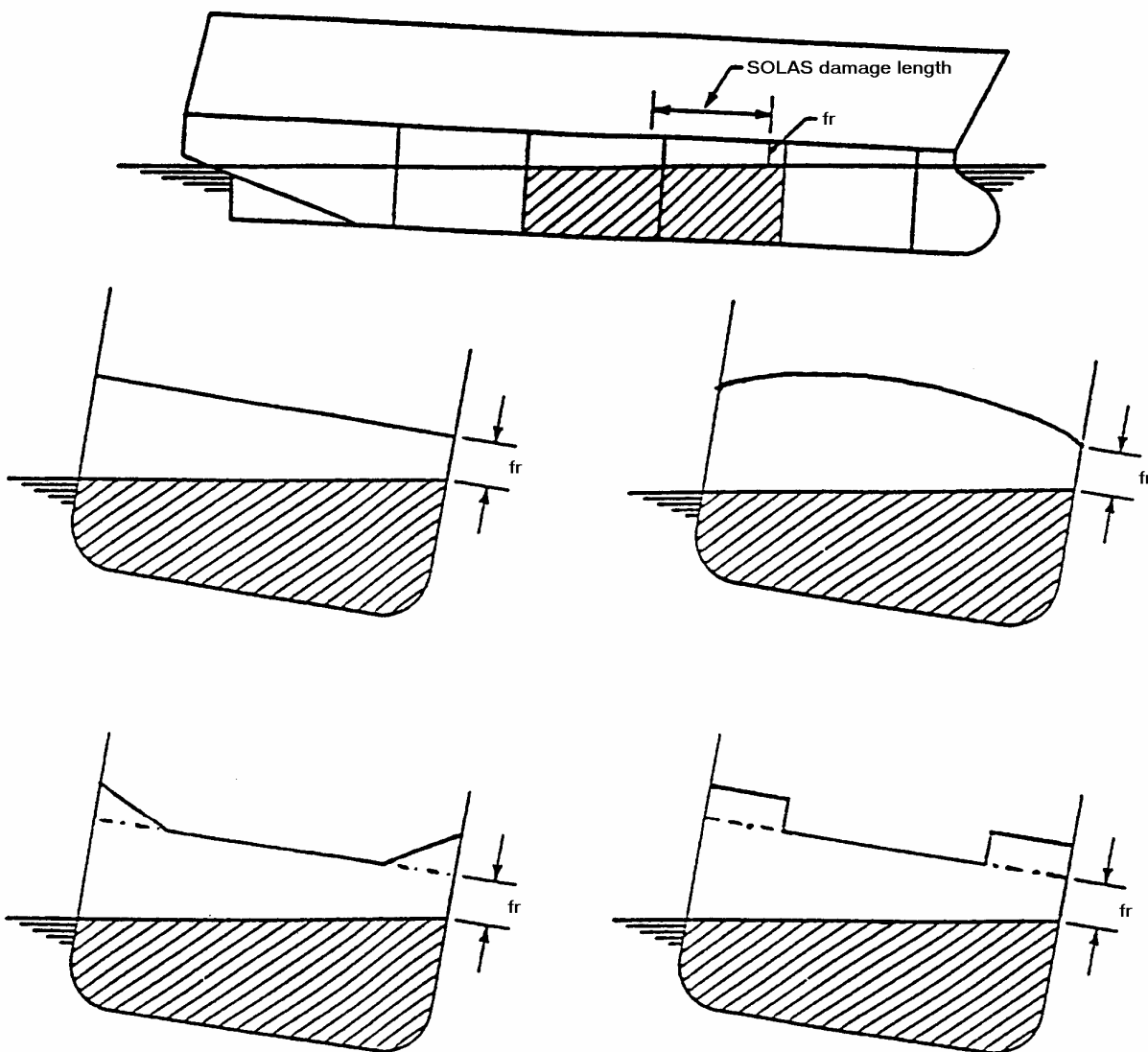
#### Paragraph 2.5.3 of Annex 2 of The Agreement (Ref.5).

Freeing ports must be sited as low as possible in the side bulwark or shell plating. The lower edge of the freeing port opening must be no higher than 2cm above the bulkhead deck and the upper edge of the opening no higher than 0.6m (see Fig 8).

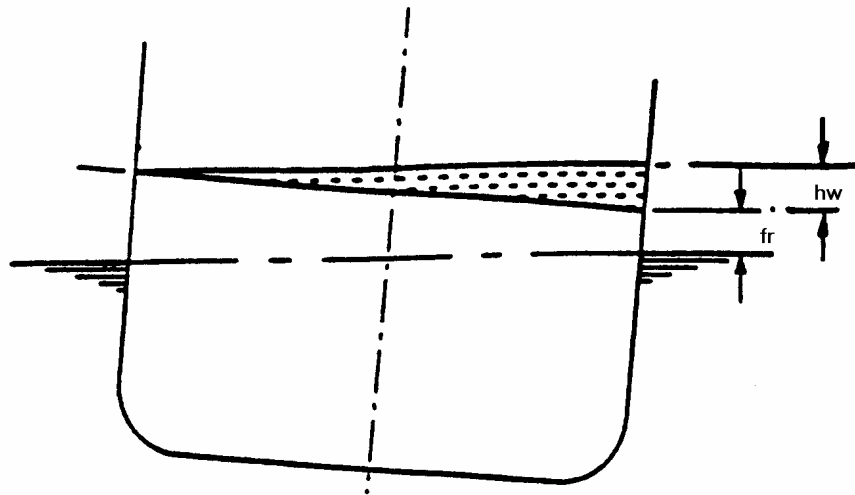
**Note:** Spaces to which paragraph 2.5 applies, i.e. those spaces fitted with freeing ports or similar openings, shall not be included as intact spaces in the derivation of the intact and damage stability curves.

Paragraph 2.6 of Annex 2 of The Agreement (Ref.5).

1. The statutory extent of damage is to be applied along the length of the ship. The damage may not affect any bulkhead or may only affect a bulkhead below the bulkhead deck or only a bulkhead above the bulkhead deck or various combinations.
2. All transverse and longitudinal bulkheads/barriers which constrain the assumed accumulated amount of water must be in place and secured at all times when the ship is at sea.
3. In those cases where the transverse bulkhead/barrier is damaged the accumulated water-on-deck shall have a common surface level on both sides of the damaged bulkhead/barrier at the height  $h_w$  (see Fig 9).

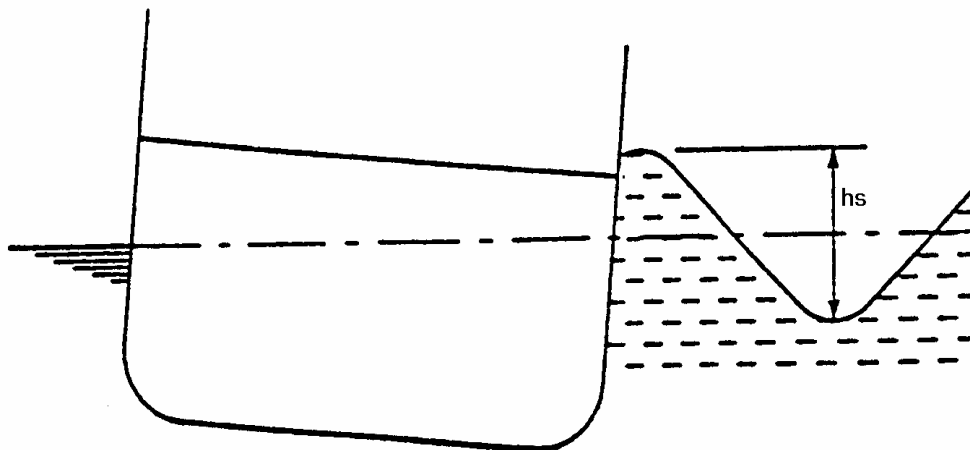


**Figure 1**



1. If  $f_r \geq 2.0$  metres, height of water on deck ( $h_w$ ) = 0.0 metres
2. If  $f_r \leq 0.3$  metres, height of water on deck ( $h_w$ ) = 0.5 metres

Figure 2



1. If  $h_s \geq 4.0$  metres, height of water on deck is calculated as per figure 3
2. If  $h_s \leq 1.5$  metres, height of water on deck ( $h_w$ ) = 0.0 metres

Figure 3

**For example**

If  $f_r = 1.15$  metres and  $h_s = 2.75$  metres,

$h_w = 0.5$  m if  $f_r$  is 0.3 m or less and 0.0 m if  $f_r$  is 2.0 m or more. By linear interpolation we get  $h_w$  is 0.25m. However this figure only applies if the SWH ( $h_s$ ) for the sea area is 4.0 metres; if the  $h_s$  for the area is 1.5 m or less,  $h_w$  is zero. By linear interpolation between these figures for an  $h_s$  of 2.75 metres gives an  $h_w$  of 0.125 m.

height of water  $h_w$  to be applied on the vehicle deck = 0.125 metres

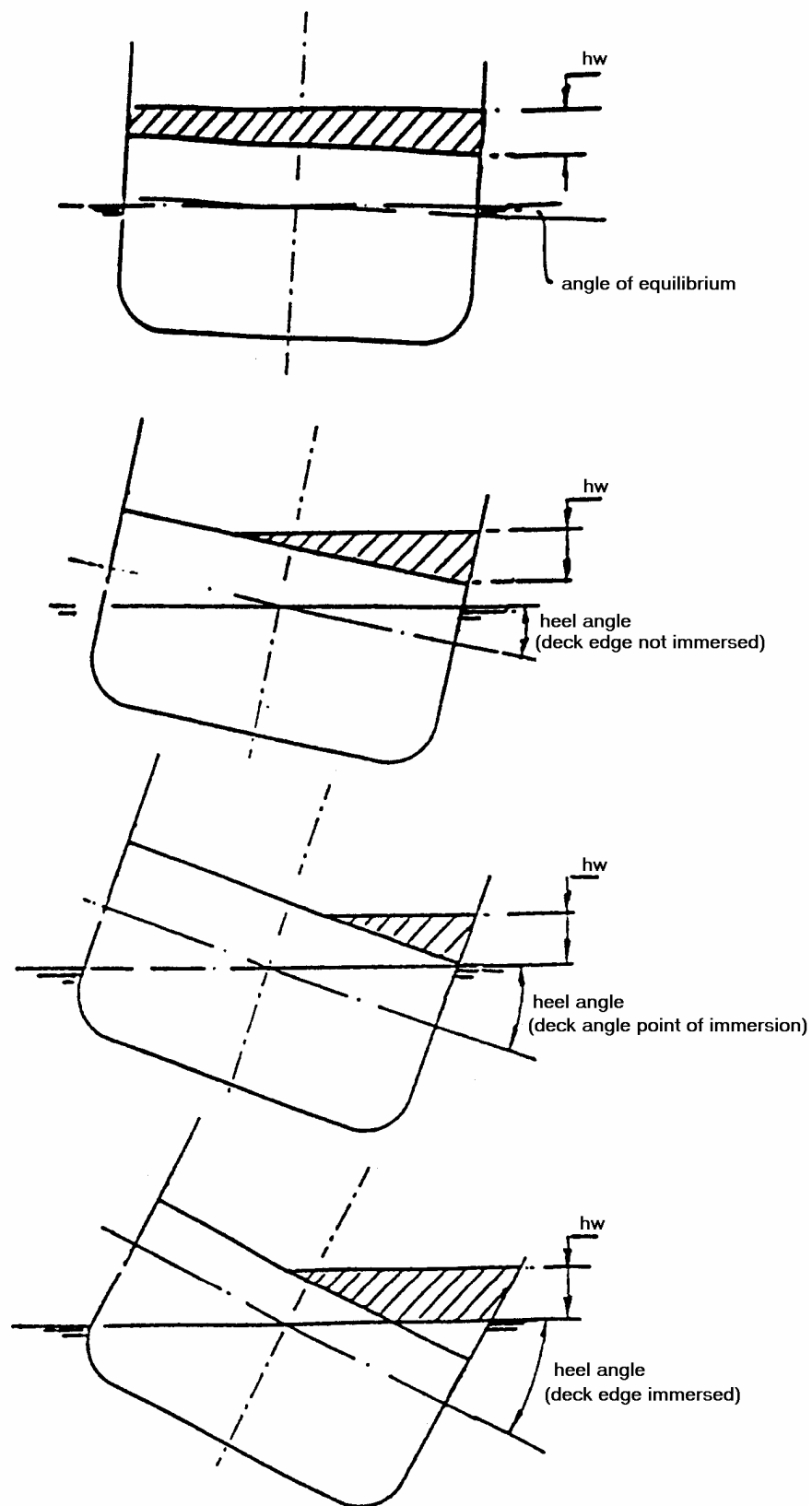
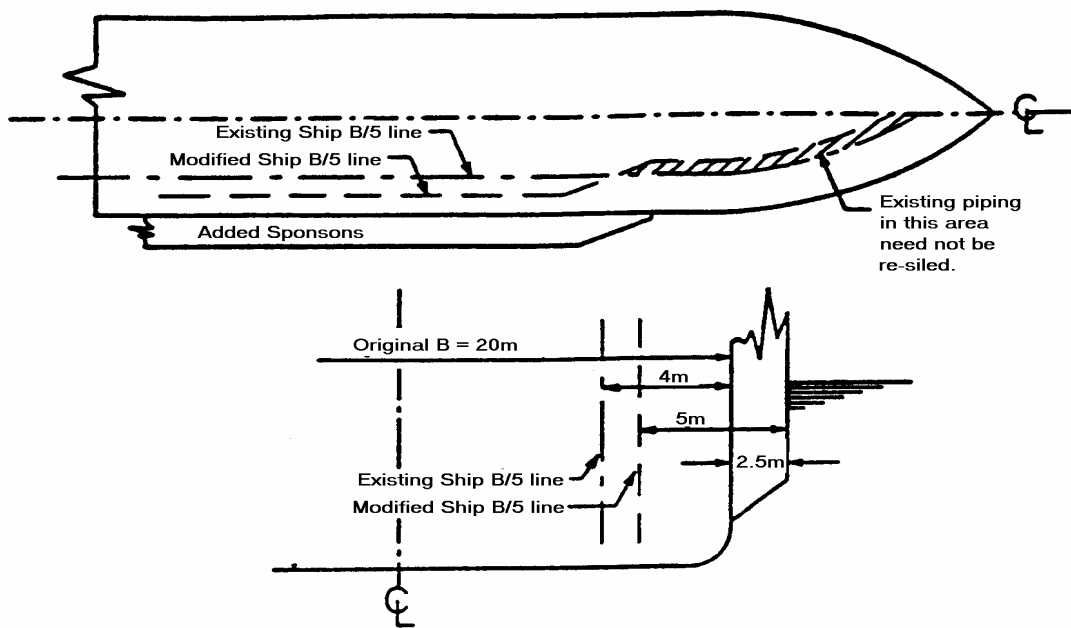


Figure 4



(Note: the phrase B/5 refers to the transverse damage extent required by the 1994 or the 2000 HSC Code for side damages).

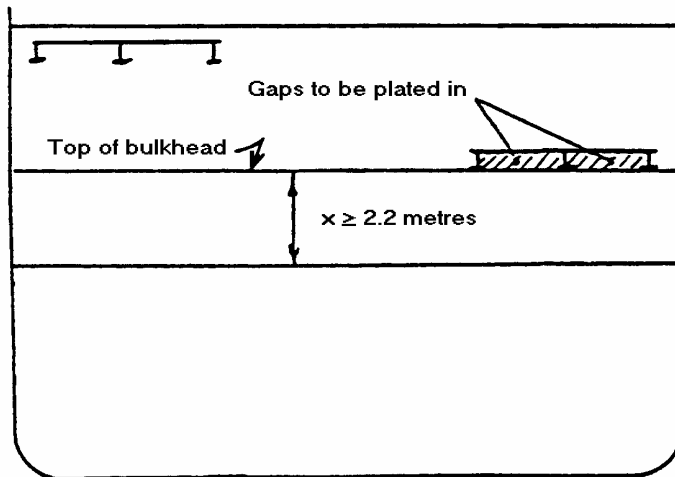
**Figure 5**

Ships without hanging car decks

Example 1

Height of water on deck = 0.25 metres

Minimum required height of barrier = 2.2 metres



Ships with hanging car deck (in way of the barrier).

Example 2

Height of water on deck ( $h_w$ ) = 0.25 metres

Minimum required height of barrier =  $x$

**Figure 6**

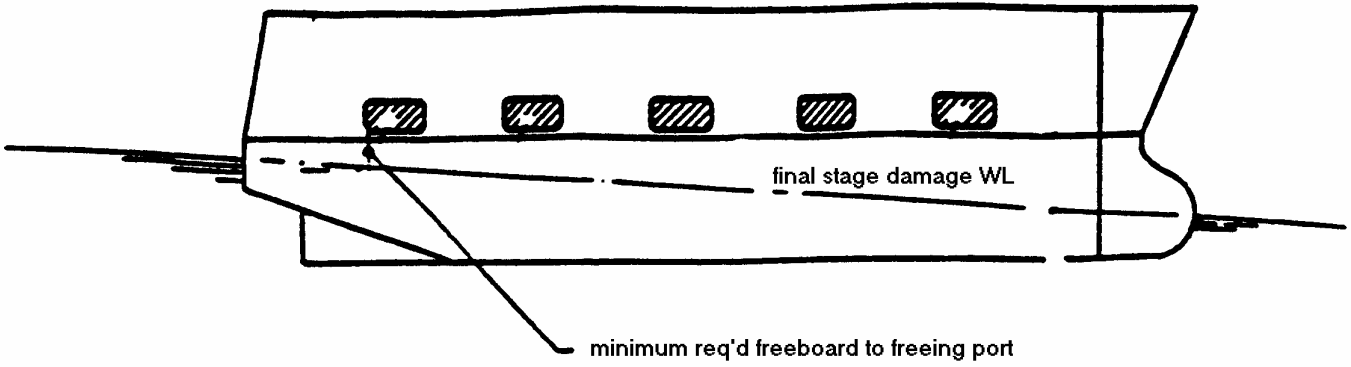


Figure 7

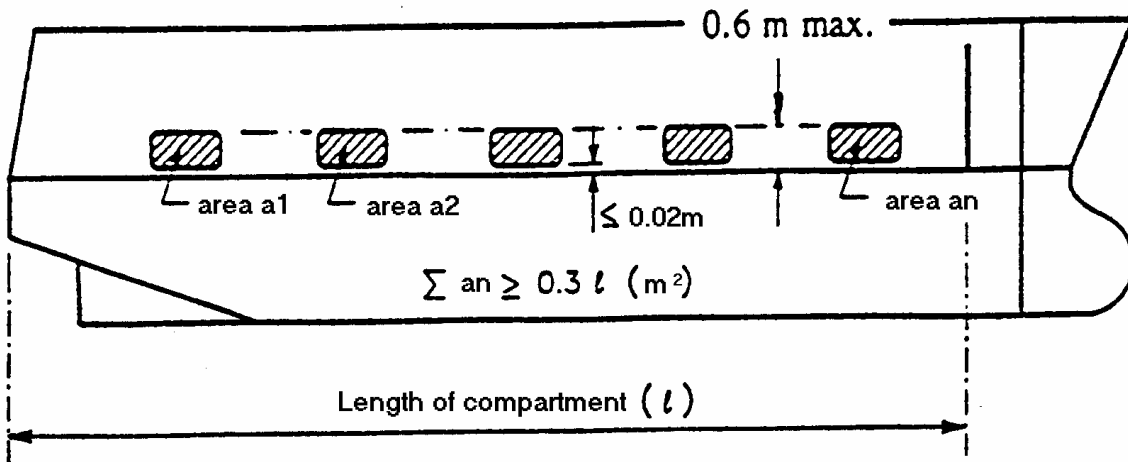
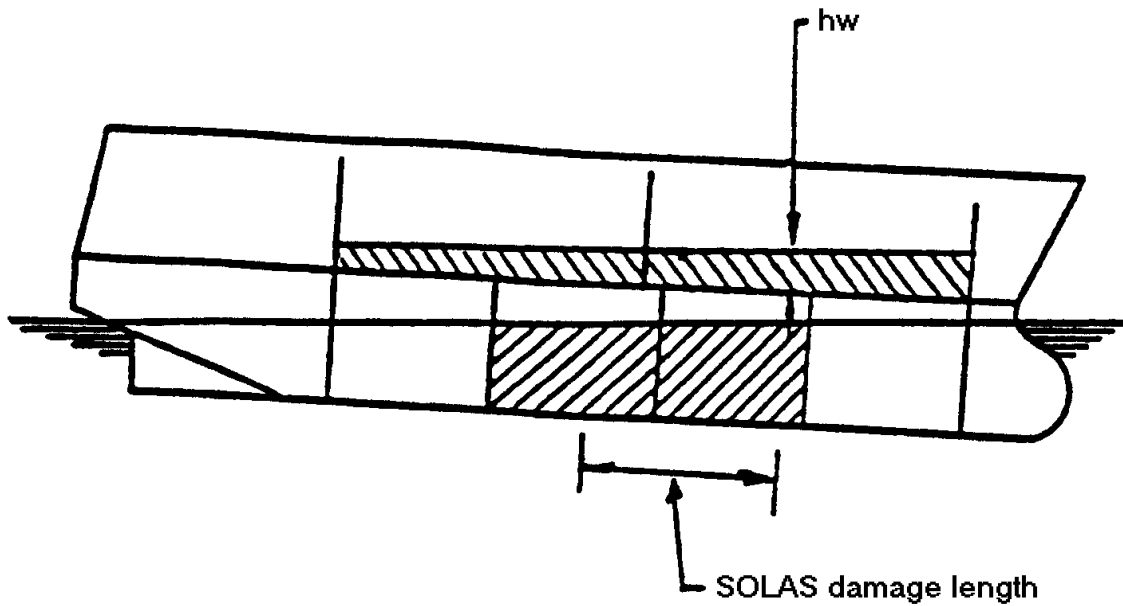
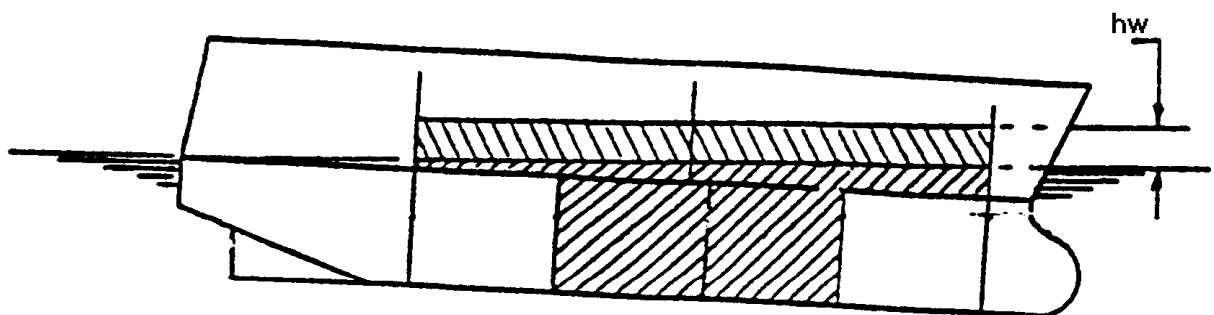


Figure 8



(Note: SOLAS damage length refers to side damage length of HSC / DSC Code.)

Deck edge not immersed



Deck edge immersed

**Figure 9**

## 5 Guidance Notes on Appendix to Annex 2 of the Stockholm Agreement (Model Test Method) (SLF40 /INF.14 annex 2 as amended, amended for HSC).

### Background

The original model test procedure that was contained in both the Stockholm Agreement (Ref 5) and IMO paper SLF40/INF.14 annex 2 has been superseded by IMO Resolution MSC 141(76) of 5th December 2002 and is reproduced in full in EU directive 2005/12/EC of 18/2/2005. The new model test is also described Annex I to MSN 1790 (M) and MSN 1790(M) Amendment 1 and 2002/12/EC. The paragraph references below relate to Annex II of MSN 1790 (M) and MSN 1790(M) Amendment 1.

It is not expected that a vessel which has gained compliance under the original model test method will need to complete testing to the new test procedure, though it is expected that this new procedure (in MSC.141(76), the EC Directive and MSN 1790(M) including Amendment 1) will be followed for any testing following the coming into force date of the EC Directive.

### Purpose

The purpose of these guidelines is to ensure uniformity in the methods employed in the construction and verification of the model as well as in the undertaking and analyses of the model tests.

### Paragraph 1 and 2 – Objectives and Definitions

The contents of paragraphs 1 and 2 of the Appendix to Annex I are considered self-explanatory.

### Paragraph 3 — Ship model

3.1. The material of which the model is made is not important in itself, provided that the model both in the intact and damaged condition is sufficiently rigid to ensure that its hydrostatic properties are the same as those of the actual ship and also that the flexural response of the hull in waves is negligible.

It is also important to ensure that the damaged compartments are modelled as accurately as practicably possible to ensure that the correct volume of flood water is represented.

Since ingress of water (even small amounts) into the intact parts of the model will affect its behaviour, measures must be taken to ensure that this ingress does not occur.

In model tests involving worst SOLAS damages near the ship ends, it was observed that progressive flooding was not possible because of the tendency of the water on deck to accumulate near the damage opening and hence flow out. As such models were able to survive very high sea states, while they capsized in lesser sea states with less onerous SOLAS damages, away from the ends, the limit  $\pm 35\%$  was introduced to prevent this.

Extensive research carried out for the purpose of developing appropriate criteria for new vessels has clearly shown that in addition to the GM and freeboard being important parameters in the survivability of passenger ships, the area under the residual stability curve is also another major factor. Consequently in choosing the worst HSC damage for compliance with the requirement of paragraph 3.1 the worst damage is to be taken as that which gives the least area under the residual stability curve.

### 3.2. Model particulars

3.2.1. In recognising that scale effects play an important role in the behaviour of the model during tests, it is important to ensure that these effects are minimised as much as practically possible. The model should be as large as possible since details of damaged compartments are easier constructed in larger models and the scale effects are reduced. It is therefore required that the model length is not less than that corresponding to 1:40 scale or 3 m, whichever is greater.

It has been found during tests that the vertical extent of the model can affect the results when tested dynamically. It is therefore required that the ship is modelled to at least three super structure standard heights above the bulkhead (freeboard) deck so that the large waves of the wave train do not break over the model.

3.2.2 The model in way of the assumed damages must be as thin as practically possible to ensure that the amount of flood water and its centre of gravity is adequately represented. The hull thickness should not exceed 4 mm. It is recognised that it may not be possible for the model hull and the elements of primary and secondary subdivision in way of the damage to be constructed with sufficient detail and due to these constructional limitations it may not be possible to calculate accurately the assumed permeability of the space.

3.2.3 It is important that not only the draughts in the intact condition are verified, but also that the draughts of the damaged model are accurately measured for correlation with those derived from the damaged stability calculation. For practical reasons a tolerance of +2 mm in any draught is accepted.

3.2.4 After measuring the damaged draughts it may be found necessary to make adjustments to the permeability of the damaged compartment by either introducing intact volumes or by adding weights. However it is also important to ensure that the centre of gravity of the flood water is accurately represented. In this case any adjustments made must err on the side of safety.

If the model is required to be fitted with barriers on deck and the barriers are less than the bulkhead height indicated below the model is to be fitted with CCTV so that any 'splashing over' and any accumulation of water on the undamaged area of the deck can be monitored. In this case a video recording of the event is to form part of the test records.

The height of transverse or longitudinal bulkheads which are taken into account as effective to confine the assumed accumulated sea water in the compartment concerned in the damaged ro-ro deck should be at least 4 m in height unless the height of water is less than 0.5 m. In such cases the height of the bulkhead may be calculated in accordance with the following:

$$B_h = 8h_w$$

where  $B_h$  is the bulkhead height; and

$h_w$  is the height of water.

In any event, the minimum height of the bulkhead should be not less than 2.2 m. However, in the case of a ship with hanging car decks, the minimum height of the bulkhead should be not less than the height to the underside of the hanging car deck when in its lowered position.

- 3.2.5 In order to ensure that the model motion characteristics represent those of the actual ship it is important that the model is both inclined and rolled in the intact condition so that the intact GM and the mass distribution are verified. The mass distribution should be measured in air. The transverse radius of gyration of the actual ship should be in the range 0.35B to 0.4B and the longitudinal radius of gyration should be in the range 0.2L to 0.25L.

*Note:* While inclining and rolling the model in the damage condition may be accepted as a check for the purpose of verifying the residual stability curve, such tests should not be accepted in lieu of the intact tests.

A non-standard method for inclining may need to be adopted for HSC multihull vessels. Refer to MCA Headquarters for advice on this.

- 3.2.6 It is assumed that the ventilators of the damage compartment of the actual ship are adequate for unhindered flooding and movement of the flood water. However in trying to scale down the ventilating arrangements of the actual ship undesirable scale effects may be introduced. In order to ensure that these do not occur it is recommended to construct the ventilating arrangements to a larger scale than that of the model, ensuring that this does not affect the flow of water on the car deck.

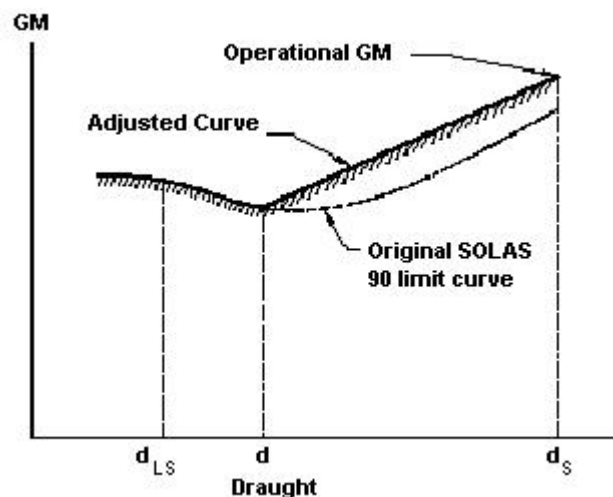
- 3.2.7 It is deemed appropriate to consider a damage shape representative of a cross section of the striking ship in the bow region. The 15° angle is based on a study of the cross section at a distance of B/5 from the bow for a representative selection of vessels of different types and sizes.

The isosceles triangular profile of the prismatic damage shape is that corresponding to the load waterline.

Additionally in cases where side casings of width less than B/5 are fitted and in order to avoid any possible scale effects, the damage length in way of the side casings must not be less than 25 mm.

- 3.3 In the original model test method of resolution 14 of the 1995 SOLAS Conference the effect of heeling induced by the maximum moment deriving from any of passenger crowding, launching of survival craft, wind and turning was not considered even though this effect was part of SOLAS. Results from an investigation have shown however that it would be prudent to take these effects into account and to retain the minimum of 1° heel towards the damage for practical purposes. It is to be noted that heeling due to turning was considered not to be relevant.

- 3.4 In cases where there is a margin in GM in the actual loading conditions compared to the GM limiting curve (derived from SOLAS 90), the Administration may accept that this margin is taken advantage of in the model test. In such cases the GM limiting curve should be adjusted. This adjustment can be done as follows:



$$d = d_S - 0.6 (d_S - d_{LS})$$

where:  $d_S$  is the subdivision draught; and  $d_{LS}$  is the lightship draught.

The adjusted curve is a straight line between the GM used in the model test at the subdivision draught and the intersection of the original SOLAS 90 curve and draught  $d$ .

#### Paragraph 4 — Procedure for experiments

##### 4.1. Wave spectra

The JONSWAP spectrum should be used as this describes fetch- and duration-limited seas which correspond to the majority of the conditions world wide. In this respect it is important that not only the peak period of the wave train is verified but also that the zero crossing period is correct.

It is required that for every test run the wave spectrum is recorded and documented. Measurements for this recording should be taken at the probe closest to the wave making machine.

It is also required that the model is instrumented so that its motions (roll, heave and pitch) as well as its attitude (heel, sinkage and trim) are monitored and recorded through-out the test.

It has been found that it is not practical to set absolute limits for significant wave heights, peak periods and zero crossing periods of the model wave spectra, therefore an acceptable margin has been introduced.

4.2 To avoid interference of the mooring system with the ship dynamics, the towing carriage (to which the mooring system is attached) should follow the model at its actual drifting speed. In a sea state with irregular waves the drift speed will not be constant; a constant carriage speed would result in low frequency, large amplitude drift oscillations, which may affect the model behaviour.

4.3 A sufficient number of tests in different wave trains are necessary to ensure statistical reliability, i.e. the objective is to determine with a high degree of confidence that an unsafe ship will capsize in the selected conditions. A minimum number of 10 runs are considered to provide a reasonable level of reliability.

## Paragraph 5 — Survival criteria

The contents of this paragraph are considered self-explanatory.

## Paragraph 6 — Test approval

The following documents are to be part of the report to the administration:

- a) damage stability calculations for worst HSC side damage and midship HSC side damage (if different);
- b) general arrangement drawing of the model together with details of construction and instrumentation;
- c) inclining experiment and measurements of radii of gyration;
- d) nominal and measured wave spectra (at the three different locations for a representative realisation and for the tests with the model from the probe closest to the wave maker);
- e) representative record of model motions, attitude and drift
- f) relevant video recordings

### Note:

All tests must be witnessed by the administration.

## 6 Merchant Shipping (Ro-Ro Passenger Ships Stability) Regulations 2004 (S.I. 2004 No. 2884)

### 6.1 General

6.1.1 These regulations implement a Regional Agreement (IMO Circular letter 1891 in accordance with SOLAS 1995 Conference Resolution 14 refers) entitled “Agreement Concerning Specific Stability Requirements for Ro-Ro Passenger Ships Undertaking Regular Scheduled Voyages Between or to or from Designated Ports in North West Europe and the Baltic Sea”. The model test method in SLF40/INF14 Annex 2 is updated in MSC.141(76) and reproduced in EC Directive 2005/12/EC and MSN 1790 (M) including MSN 1790 (M) Amendment 1.

6.1.2 The general requirement is that all Ro-Ro passenger ships (including high speed craft) will comply with SOLAS 90 or equivalent (e.g. HSC Code damage) and consider the effects of water on the vehicle deck, the amount of water being dependent on the freeboard after assumed side damage and the Significant Wave Height in the area of intended operation.

6.1.3 References to regulation numbers in this Part 6 refer to regulation numbers of the above regulations.

6.1.4 The Agreement, commonly known as the “Stockholm Agreement”, is reproduced in Merchant Shipping Notice MSN 1790(M) as amended and contains the technical requirements to be complied with. See also paragraph 6.8 of this Appendix (C).

6.1.5 Signatories to the Agreement prepared “guidance notes on the annexes of the Agreement” which were presented in a paper to the International Maritime Organisation (IMO). The text of the two annexes to the paper, SLF 40/INF.14 as amended by MSC.141(76), are reproduced in Parts 2, 3, 4, and 5 of this Appendix (C).

## **6.2 Interpretation (Regulation 2)**

This Regulation provides definition of terms used in the regulations one of which establishes to which ships the regulations apply, that is those operating a “regular scheduled service”.

## **6.3 Application (Regulation 3)**

This regulation applies the Stockholm Agreement (regional specific stability requirement for roro passenger ships undertaking regular scheduled international or domestic voyages) to high speed passenger roro craft and conventional roro passenger ships.

## **6.4 Stability Requirements of Directive 2003/25/EC (Regulation 4)**

The date by which a vessel is to fully comply with the requirements of the Agreement is described. This compliance date is fixed and no extension will be allowed. Note: New building vessels and vessels which are newly in operation in UK waters must comply with Stockholm Agreement prior to commencing service.

## **6.5 Certification (Regulation 6)**

Those vessels fully complying with the requirements of the Agreement are issued with a certificate entitled Declaration of Compliance with Stability Legislation for RoRo Passenger Ships Undertaking Regular Scheduled International Voyages, MSF 2228. This document states the Significant Wave Height that the ship may operate in. The Passenger Safety Certificate or Passenger Certificate will be endorsed to show this Significant Wave Height, together with any restrictions which may have been imposed, e.g. restricted period of operation. Surveyors should note that this Significant Wave Height stated should not be lower than that required for the area of operation of the vessels.

## **6.6 Seasonal and short time period Operation (Regulation 7)**

The Significant Wave Heights to be considered in the Agreement are for “year round operations”. This regulation allows for a reduction in the wave height where it can be justified for the restricted period of operation, e.g. summer operation only.

## **6.7 Stockholm Agreement (MSN 1790 (M))**

### **6.7.1 Guidance notes**

Annexes 1 and 2 of IMO document SLF 40/INF.14 as amended are appropriate notes on the uniform application of Annexes 1 and 2 of the Agreement. Annex 1 addresses the stability requirements pertaining to the Agreement while Annex 2 deals with the Model Test Method. Both annexes of the IMO document are reproduced at Part 3, 4, 5 and 6 of this Appendix (C).

### **6.7.2 Required submissions**

#### **6.7.2.1 Calculations**

Where calculations are the decided method to show compliance, the submission should include, for a new ship, that the requirements of the HSC Code should be followed, however paragraph 5.6.2 of the Instructions for the Guidance of Surveyors Passenger

Ship Construction Classes I, II and IIA may be used as a further guide. In addition to quoting the Significant Wave Height on which the calculations are based, the summary of the damage case calculations is to indicate the freeboards after damage and the amount of water on deck that has been considered in each case. For a vessel which has previously been submitted to the certifying authority, those details and plans referred to in the HSC Code may not be required. For the vessel in question, the surveyor will advise the owner/consultant, referring to MCA Headquarters for advice if necessary.

#### 6.7.2.2 Model test

Where it has been decided that model tests are to be undertaken, calculations are to be submitted which show the worst HSC Code damage (defined in paragraph 3.1 of Part 5 of this Appendix (C)) required by the regulations. However, if this damage is outside of  $\pm 10\%L$  from midships the worst midship damage with regard to freeboard is also to be submitted. The extent and degree of modelling and the model test program together with the calculation results are to be agreed by the Certifying Authority.

#### 6.7.2.3 Model details

Regarding modelling of double bottom tanks, the following rules should be obeyed:-

- (i) Where these tanks are included in the damage case, they are to be accurately modelled with particular attention paid to the damage opening, where both the inner and outer bottom should include a sharp edged V cut-out full penetration with horizontal, vertical, and longitudinal extents as described in the appropriate HSC Code;
- (ii) Where these tanks are intentionally omitted from the damage case, to give a worse "lesser" damage case, then they may be modelled as a solid block.
- (iii) Where these tanks are permanently filled with ballast etc, but lie within the HSC Code extent of side damage, they should be modelled as in (a) above except that their contents should be included as a weight in the intact condition. This weight shall be removed upon opening of the damage in the model side and flooding of the space takes place.

#### 6.7.3 Approval after model testing

Two copies of the test report and videos are required for retention by the Certifying Authority. All details and reports are to be held on the CM 18/03 file. As per procedure, copies should be sent to IMO upon completion, including the Declaration of Compliance with Stability Legislation for RoRo Passenger Ships Undertaking Regular Scheduled International Voyages.

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