APPENDIX 4

A/AMAX CALCULATION PROCEDURE

MSC/CIRC.574
3 JUNE 1991

THE CALCULATION PROCEDURE TO ASSESS THE SURVIVABILITY CHARACTERISTICS OF EXISTING RO-RO PASSENGER SHIPS WHEN USING A SIMPLIFIED METHOD BASED UPON RESOLUTION A.265(VIII)

1 The Maritime Safety Committee, at its fifty-ninth session, considered the proposal put forward by the United Kingdom, to extend the standard of residual stability known as the 'SOLAS 90' standard, by amending the SOLAS regulation II-1/8 as set out in circular letter No.1470 of 25 October 1990.

2 After detailed consideration of the matter, the Committee concluded that a different approach should be adopted. This amended approach would be aimed at improving the survivability characteristics of existing ro-ro passenger ships over a period of time of five years.

3 It was decided further that the time when the ferries are required to be modified should be based on their survivability characteristics such that those having the lowest characteristics are modified first. In order to determine the survivability characteristics of the individual ferries the Committee decided that it should be done on the basis of calculations first presented to the SLF Sub-Committee at its thirty-sixth session and subsequently reviewed by the Committee at its sixtieth session with a view to adopting an amendment to the SOLAS Convention to implement the SOLAS 90 standard by means of an agreed timescale.

4 In respect of modifications made by the Committee it was considered that the comparison of the attained subdivision 'A' with the 'maximum' attained index 'A_{max}' as defined in the annex hereto, would provide a more sound and meaningful basis for the consideration of the matter by the SLF Sub-Committee, than the comparison of 'A' with the required subdivision index 'R'. As a consequence, it was decided to delete the reference to the required index 'R' in the calculations to be undertaken.

5 The Committee urges its Members to carry out calculations in accordance with the annex hereto, as soon as possible, and submit results therefrom, with a copy to the Secretariat, to the United States*, the co-ordinator of this work, by not later than 31 October 1991.

6 The Committee requests those Members who have already started their calculations, in accordance with the method given in annex 5 to SLF 35/20, to adjust them in order to take account of the changes in the concept as set out in the annex.

ANNEX

THE ATTAINED SUBDIVISION INDEX 'A' FOR EXISTING RO-RO PASSENGER SHIPS

The calculation procedure to assess the survivability characteristics of existing ro-ro passenger ships when using a simplified method based upon resolution A.265(VIII)

1 General comments

1.1 At the thirty-fifth session of the SLF Sub-Committee, following a proposal by the United States (SLF 35/4/23), it was agreed that a simplified version of resolution A.265(VIII) should be used to assess the survivability characteristics of existing ro-ro passenger ferries (SLF 35/20, paragraphs 4.21, 4.27 to 4.32 and annex 5 refers).

1.2 The method proposed involves a calculation procedure which contains all the essential probabilistic elements of the full resolution A.265(VIII) method given in the "Regulations on subdivision and stability of passenger ships as an equivalent to Part B of chapter II of the International Convention for the Safety of Life at Sea, 1960".

1.3 The principal probabilistic elements mentioned in 1.2 are the factors 'a', 'p', 'r' and 's'.

'a' is a factor which estimates the probability of damage occurring at a particular position in the ship's length;

'p' is a factor which estimates the probability of the longitudinal extent of damage;

'r' is a factor which estimates the probability of the degree of penetration in from the ship side (this factor is only relevant where longitudinal subdivision is taken into account); and

's' is a factor which is a measure of survival probability. When s = 0, this means that there is no contribution to the index 'A' for the damage case being considered. When s = 1, this means that all the conditions for survival given by the specified residual stability criteria are fully met.

1.4 The factors 'a' and 'p', which refer to the centre of damage and longitudinal extent of damage, are to be taken directly from formulae (III) and (IV) of regulations 6(b) and 6(c) respectively.

1.5 Where longitudinal subdivision is provided, allowance can be given for this - and it should be noted at this point that such subdivision may be inboard or

outboard of the B/5 line. In such cases, the 'r' factor given at formula (X) of regulation 7(b) (ii) is to be used. However, the deterministic requirement of a minimum double bottom height of B/10 of regulation 7(a)(i) is not to be applied.

1.6 In the case of the 's' factor, however, the formula for 's' is to be that which was first proposed by the USSR in SLF 35/4/9, and is reproduced in page 3, annex 5, of SLF 35/20. The use of this formula ensures that in all cases where all the SOLAS 90 criteria are met, the 's' factor is equal to 1.

1.7 Further simplification has been introduced by specifying that the calculation of 's' is to be confined to the deepest subdivision draught, rather than the three draughts d_1, d_2 and d_3 and corresponding s_1, s_2 and s_3 values given in regulation 6(d)(ii) of the full resolution A.265(VIII) method.

1.8 Finally, to limit as far as possible the number of damage stability calculations which need to be carried out and also to standardise the calculation procedure, regulation 6(a)(ii), should be applied only as far as the words "... the summation is also taken for all possible pairs of adjacent compartments." The remaining wording of regulation 6(b)(ii) should be ignored for the purposes of this simplified method.

2 The calculation procedure

2.1 Establish the following principal parameters:

.1	the subdivision length, L_s	Regulation 1(b)
.2	the subdivision breadth, B_1	Regulation 1(d)(i)
.3	the subdivision breadth, B_2	Regulation 1(d)(ii)
.4	the deepest subdivision draught, d_s	Regulation 1(a)(ii)
.5	the number of main compartments	
.6	the ship's maximum operational KG at the deepest subdivision draught.	

2.2 For each of the main compartments establish the following:

.1	the values X_1, X_2	Regulation 6(b)
.2	the corresponding ξ_1, ξ_2 and ξ_{12} values	Regulation 6(b)
.3	using the values obtained from .1 and .2, calculate:	
	'a' - see regulation 6(b), formula (III)	
	'p' - see regulation 6(c), formula (IV)	

'r' - see regulation 7(b)(ii), formula (X)
(where longitudinal subdivision is concerned).

2.3 The calculation of the 's' factor is by the use of the formula given in page 3, annex 5, of SLF 35/20. The formula is:

$$s = c \cdot 2.58 \cdot \sqrt[4]{GZ_{max} \cdot Range \cdot Area}$$

When the criteria for compliance with the requirements of regulation II-1 of the 1974 SOLAS Convention, as amended, are fully met, then s = 1 is to be assumed. The 's' factor is only to be calculated for the deepest subdivision draught (d_s), rather than for the three draughts specified for the full resolution A.265(VIII) method. The deepest subdivision draught in this instance is the subdivision draught appropriate to the vessel.

2.4 The damage stability results which are used to obtain the residual stability characteristics, that is, GZ_{max}, range and area under the curve, are to be based on the ship's maximum operational KG at the deepest subdivision draught. Level trim is to be assumed.

2.5 A tabular summary of 'a', 'p', 'r', 's' should now be made for all the main compartments. The product $a \cdot (pr) \cdot s$ is to be calculated for each damage case to obtain the contribution to the index 'A' (say, $\delta A > 0$). A summation of the 'δA' values is then made to obtain the contribution to the 'A' value from the single compartments alone.

2.6 The procedure outlined above is now performed for all cases involving the assumed flooding of two adjacent compartments.

2.7 If the vessel is not fully compliant with the required residual stability standard, then at least one of the damage cases appropriate to the subdivision standard will have an 's' value which is less than 1, i.e:

.1 for a two-compartment vessel, at least one two-compartment damage case will have $s < 1$;

.2 for a one-compartment vessel, at least one one-compartment damage case will have $s < 1$.

2.8 After this the KG described in 2.4 above is to be modified such that the results of the worst damage case just meet the required residual stability standard, i.e. $s = 1$ for the worst case.

2.9 A subdivision index A_{max} is then calculated at the same draught and trim used in 2.4 above but using the modified KG value described in 2.8 above. All single and two-compartment groups contributing to the index are to be included. For a vessel having a two-compartment standard, this means that all 's' values will be equal to 1. For a vessel having a one-compartment standard, all one-compartment damages will have 's' values equal to 1.

The use of the probabilistic concept in assessing the residual stability standards of existing ro-ro passenger ships

(The text below contains only the probabilistic parts of IMO resolution A.265(VIII) which are to be applied for this assessment only)

The primary objective is to calculate the attained subdivision index 'A', by modifying the normal calculation procedure as indicated below, for a substantial sample of existing ro-ro passenger ships.

Therefore, it is only necessary to consider those parts of regulations 1 to 8 inclusive which should apply for the sake of this exercise.

Of these eight regulations, all those which are deterministic in nature are either ignored or adapted to conform to probabilistic principles.

Regulation 2 - Subdivision index

For the purposes of this exercise this regulation is to be ignored.

Regulation 4 - Permeabilities

4(a) Applies.

4(b) Replace the permeability value for cargo spaces by a constant value of 0.90 for freight/vehicle spaces.

Regulation 5 - Subdivision and damaged stability

5(b)(iii) Applies.

5(c)(i)(1) The requirements for the GM values (in the final stage of flooding) are to be replaced by the requirements given in USSR paper SLF 35/4/9 - See later for a full description of these requirements.

5(c)(i)(2) The maximum permitted equilibrium angle after flooding is included in the requirements of regulation 5(c)(i)(1).

5(c)(i)(3) This is to be interpreted as non-immersion of the bulkhead deck - note that this is not the margin line - in the final stage of flooding.

5(c)(ii) Applies.

5(c)(iii) Applies.
In respect of the time for equalisation of cross-connected spaces, the provisions of resolution A.266(VIII) should be applied.

5(c)(iv) Applies.

A standard of residual stability during the intermediate stages of flooding, for the purposes of this exercise only, is to be governed by the heel angle given in this regulation, i.e. 20°.

5(d) Applies, except that in place of the final sentence - "For each initial trim … flooded condition" put "The ship shall be at its design trim (i.e. zero trim in most cases) at the deepest subdivision loadline".

Regulation 6 - Attained subdivision index

6(a)(i) Applies, except that the words "In addition to complying with regulation 5" should be ignored.

6(a)(ii) Applies, except that a full stop should be placed after "… for all possible pairs of adjacent compartments" and the rest of the subparagraph should be ignored.

6(a)(iii) Applies, except that the words "according to Regulation 5" should be ignored.

6(b) Applies, except that when the end bulkheads of a compartment contains a step, or steps, then the length of such a compartment is to be based upon the position of those end bulkheads at the ship side.

6(c)(i) Applies.

6(c)(ii) Applies.

6(c)(iii) Applies.

6(d)(i) Replace the formula (VIII) by the formula for 's_i' from the paper SLF 35/4/9 - see below for full details. In respect of GM_R, this should be taken as the GM corresponding to the intact condition at the deepest subdivision loadline.

6(d)(ii) In place of the weighted 's' value i.e. $s = 0.45s_1 + 0.33s_2 + 0.22s_3$, 's' for the deepest subdivision loadline should be used.

6(d)(iii) Applies.

Regulation 7 - Combined longitudinal and transverse subdivision

7(a)(iii) Applies.

7(b) Applies.

7(c) Applies.

The 's' factor to be used for this exercise only

$$s = c \cdot 2.58 \cdot \sqrt[4]{GZ_{max} \cdot Range \cdot Area}$$

where:

GZ_{max} is the maximum positive residual righting lever (m) within the range of 15° beyond the angle of equilibrium, but not more than 0.1 m;

Range is the range of positive righting levers beyond the angle of equilibrium, in degrees, but not more than 15°;

Area is the area under the righting lever curve (m.rad), measured from the angle of equilibrium to the lesser of the angles at which progressive flooding occurs, or 22° (measured from the upright) in the case of a one-compartment flooding, or 27° (measured from the upright) for the flooding of two or more adjacent compartments, but not more than 0.015 m.rad.

In respect of the 'Area', please note that the allowable area is up to a heel angle, measured from the upright 22°/27°, depending on whether flooding of a single compartment or two adjacent compartments is concerned.

and c is determined according to the following:

c = 1 where the final angle of equilibrium θ_c is not more than 7°,

c = 0 where the final angle of equilibrium θ_c is more than 20°, else

$$c = \sqrt{\frac{20^\circ - \theta_c}{20^\circ - 7^\circ}}$$

Tabular statement concerning the survival capability of an existing ro-ro passenger ship

Application of MSC/Circ.574

Ship designation for identification purposes

1. Principal particulars (in metres)

Subdivision length Ls	Breadth B1	Depth	
		To bulkhead dk.	To dk. limiting the allowed buoyancy

2. Give the number of compartments - below the bulkhead dk. - bounded by the main transverse bulkheads.	
3. Of the compartments mentioned at 2., how many rely on longitudinal subdivision (inside B/5) to meet the deterministic requirements? Give in terms of % Ls.	@ % Ls
4. Year of build.	
5. Year of issue of the initial Passenger Certificate.	
6. Lifeboat capacity.	
7. The total number of persons permitted to be on board (passenger and crew).	
8. Deepest subdivision loadline, d_s.	
9. The SOLAS regulations which apply.	
10 According to 9., what compartment standard?	
11 Give the actual ship KG (in metres) for the loading condition (at draught d_s) used in the damage stability calculations. If the KG used is not the actual KG, give further details at 17.	
12. Is the freight/vehicle cargo carried below the bulkhead deck? Is the freight/vehicle cargo carried above the bulkhead deck?	
13. Attained subdivision index A.	
14. Give the notional ship KG such that the s-values appropriate to the compartmental standard at 10. are equal to 1.	
15. Maximum subdivision indes A_{max}	
16. Ratio A/A_{max} in %	
17. Additional relevant information	

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INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974, AS AMENDED

Interpretations of provisions of resolution MSC.26(60) and MSC/Circ.574

1 The Maritime Safety Committee, at its sixtieth session (6 to 10 April 1992), adopted, by resolution MSC.26(60), an amendment to chapter II-1 of the 1974 SOLAS Convention introducing retroactive regulations in respect of residual stability standards for existing ro-ro passenger ships.

2 To ensure that this upgrading procedure would proceed in a logical and orderly manner, a calculation method was agreed whereby a ratio, A/Amax, was to be used to establish a ranking order for the upgrading process. The annex to MSC/Circ.574 gives details of this calculation method, which is a simplified version of the probabilistic parts of resolution A.265(VIII).

3 Recognising the need for consistent guidance, the Maritime Safety Committee, at its sixty-third session (16 to 25 May 1994), approved interpretations of the provisions of resolution MSC.26(60) and MSC/Circ.574 developed by the Sub-Committee on Stability and Load Lines and on Fishing Vessels Safety as set out in the annex.

4 Member Governments are invited to use these interpretations when applying amendments to the 1974 SOLAS Convention, adopted by resolution MSC.26(60), and the calculation procedure for assessing the survivability characteristics of existing ro-ro passenger ships set out in MSC/Circ.574.

ANNEX

INTERPRETATIONS OF PROVISIONS OF RESOLUTION MSC.26(60) AND MSC/CIRC.574

1 Residual righting lever curve
(paragraph 2.4, annex to MSC/Circ.574)

When determining the positive righting levers, GZ, of the residual stability curve, the displacement used should be that of the intact condition. That is, the constant displacement method of calculation should be used.

2 Potential downflooding openings
(resolution MSC.26(60))

2.1 Where the location of openings can lead to significant downflooding, they should be taken properly into account when carrying out the A/Amax calculations. Their status should be identified by an on-board survey and the details of such openings should be updated, if necessary, on the damage control plan.

2.2 When carrying out the calculations to establish the A/Amax ratio, such downflooding openings should be assumed closed watertight, or weathertight, as appropriate.

2.3 In order that a contribution to the 'A' value can be made, such downflooding openings should be closed to a credible degree of tightness. Where internal doors are shown to be situated above both the intermediate and final waterlines after assumed damage, they are not required to be strictly watertight.

3 Permeabilities to be used in the A/Amax calculation
(SOLAS regulation II-1/8.3 and MSC/Circ.574)

3.1 The Convention permeability of 60 % for cargo spaces is too low for use with ro-ro cargo spaces. A value of 90 % should be assumed for ro-ro cargo spaces above the bulkhead deck.

3.2 When spaces below the bulkhead deck are appropriated for the use of cargo, a permeability of 60 % can be used only where it is demonstrated that such spaces regularly contain cargo, other than ro-ro cargo. Otherwise, a permeability of 95 % should be assumed. That is, the space should be treated as a void space.

3.3 When spaces are appropriated for the carriage of liquids, a permeability value of 95 % should be assumed, unless such spaces are to be permanently filled with ballast in the form of liquid. That is, the liquid should be used as "locked-in" ballast.

4 Assumed damage penetration in way of sponsons

If sponsons are fitted, it is necessary to establish the maximum assumed damage penetration (B/5) to be used when deciding on the various damage cases. For this purpose, the breadth 'B' in the way of such sponsons should be measured to the outside of the sponsons. Clear of any such sponsons, the breadth 'B' should be the midship breadth measured to the outside of the original shell. In other words, the assumed penetration of B/5 is the same as that which applied before the fitting of sponsons.

5 Calculation of the A/Amax ratio
(resolution MSC.26(60) and MSC/Circ.574)

5.1 Identical assumptions should be made regarding the extent of damage penetration when calculation the 'A' values for both the actual and notional ship KG values. This damage penetration extent should be no less than B/5, measured inboard from the ship side. However, contributions to these 'A' values may be included for damage cases involving penetration extents in excess of B/5.

5.2 Where there is a longitudinal bulkhead nearer to the ship side than B/5, it should be assumed to be penetrated. In such a case, there may be a further damage case to be considered within the same longitudinal damage zone. Both the 'A' values should be calculated accordingly.

5.3 Where a ship has been constructed to a two-compartment standard of subdivision, 'A' should be calculated using a notional ship KG appropriate to that for which all the 's' values calculated for the two-compartment damage cases are unity. In such a case, it may be assumed that all the 's' values for the one-compartment damage cases are also unity. The corresponding A/Amax ratio is then given by the ratio:

$$\frac{A1 + A2}{A\max 1 + A\max 2}$$

where:

A1 is that part of the 'A' value calculated for the one-compartment damage cases, using the actual KG;

A2 is that part of the 'A' value calculated for the two-compartment damage cases, using the actual KG;

Amax1 is that part of the 'A' value calculated for the one-compartment damage cases, using the notional KG;

Amax2 is that part of the 'A' value calculated for the two-compartment damage cases, using the notional KG.

5.4 Where a ship has been constructed to a one-compartment standard of subdivision, 'A' should be calculated using a notional ship KG appropriate to that for which all the 's' values calculated for the one-compartment damage cases are

unity. For the purposes of future analysis, the A/Amax ratio should be calculated using the formula:

$$\frac{A1 + A2}{A\max 1 + A2}$$

6 Acceptance of A/Amax calculations by the Administration (resolution MSC.26(60))

6.1 Where the A/Amax ratio, expressed as a percentage, for a ship is 95 % or more, the Administration should accept that the requisite survivability standard for that ship has been achieved, and it should consequently be exempt from the upgrading process.

6.2 The survivability of a ship may be upgraded step by step, in accordance with the scale outlined in regulation II-1/8.9 of the SOLAS Convention adopted by resolution MSC.26(60). In such a case, a further A/Amax calculation should be performed, and then approved by the Administration, prior to the date specified by which the further upgrading should be completed.

6.3 The residual stability standard to be achieved after upgrading should correspond to the modified SOLAS 90 stability criteria as expressed in regulation II-1/8.2.3.5 of the SOLAS Convention, adopted by resolution MSC.26(60).

6.4 The Administration, on receiving the A/Amax calculation for a ship, should confirm that the calculation has been made according to the procedure outlined in MSC/Circ.574, together with any agreed interpretations, and, in particular, that specific approval is given for the A/Amax ration.

7 Ships subject to modifications of a major character (resolution MSC.26(60) and regulation II-1/1.3.2 of the SOLAS Convention, as amended)

When alterations have been made to a ship which are intended solely to achieve a higher survivability standard, they should not be regarded as modifications of a major character.

8 Ships constructed to resolution A.265(VIII)

The subdivision and stability requirements of resolution A.265(VIII) should be regarded as fully equivalent to the subdivision and stability standards represented by the SOLAS 90 standard adopted by resolution MSC.12(56). Therefore, ships constructed, or modified, such that they are in full compliance with the provisions of resolution A.265(VIII), should be considered to have a survivability standard equal to that provided by the SOLAS 90 standard. As a consequence, such ships need not be subject to any upgrading process, and should not be considered as part of any A/Amax calculation exercise.