MARITIME & COASTGUARD AGENCY

RESEARCH PROJECT 552

Assessment of the Impact of the new Harmonized Probabilistic Damage Stability Regulations (SOLAS 2009) on the Subdivision of new Passenger and Dry Cargo Ships

Final Report

Executive Summary

Six basis ships (panamax cruise ship, ro-ro passenger cruise ferry, post-panamax cruise ship, car carrier, container feeder ship and small coaster), all compliant with the current damage stability regulations, had their subdivision re-designed to utilize the freedom offered by the new probabilistic damage stability regulations coming into force on 1st January 2009.

The main objectives of the project were:-

- to compare the equivalence of the safety levels offered by the new regulations with the existing SOLAS regulations (including the Stockholm Agreement for ro-pax ships).
- to anticipate as far as possible what effects the new regulations may have on the design of a range of ship types

It was found that in general a passenger ship optimized to meet SOLAS90 could fail the new SOLAS2009 regulations at the same draught and KGf and vice versa meaning that there is not necessarily any direct equivalence in terms of survivability between the two sets of regulations.

Abolition of the margin line concept in SOLAS2009 as used in deriving floodable lengths in SOLAS90 and also as a damage stability criterion has had a considerable effect. For example the panamax cruise ship re-designed under SOLAS2009 could, by moving escape routes and services inboard, dispense with 3 main transverse watertight bulkheads in comparison with the SOLAS90 design. When the new design is analyzed against the SOLAS90 criteria, immersion of the margin line arising from the greater distance between watertight bulkheads, results in non-compliance.

The effect of permitting margin line immersion could be more significant for ro-pax ships and this project (RP 552) has led to new research being initiated (RP 592) which will focus in more detail on the problems associated with this particular class of ships.

For some ship types the project was able to show that the effect of the new regulations would be less severe than anticipated (the container feeder ship and small coaster, for example), these vessels having already been subject to the probabilistic damage stability method in SOLAS Chapter II-1 Part B-1. For others, the new regulations will require significant design changes to be made (for example, an extra watertight deck may well be required on vehicle carriers).

This report provides a summary of the results of what was a very large project in terms of computing effort and output. The detailed findings, including plans and graphs, can be found in the individual papers and/or presentations which are referenced under each ship type in Section 5 below.

Finally, it should be pointed out that the project was carried out using the draft of the new regulations available at the time the project commenced (Ref. MSC.194(80)), contained as Annex 1 to MSC 80/24/Add.1 with the corresponding explanatory notes. Since the project was completed a later version of the regulations was issued (Ref. MSC.216(82), contained as Annex 1 to MSC 82/24/Add.1) in which a new regulation (8-1) was introduced relating to systems capabilities after a flooding casualty on passenger ships to enable the possibility of the vessel safely returning to port.

This new regulation will come into force on or after 1st July 2010, more than one year later than SOLAS 2009, and will undoubtedly have a considerable impact on the internal layout of passenger ships. No account of the effect of this new regulation on passenger ship design has been taken into consideration in this project. It is worth noting that Regulation 8-1 as yet contains no stability criteria covering safe return to port but it is intended that these will eventually be included so even after January 2009 the regulations will continue to be developed.

Contents

1. Introduction

1.1 The draft text of the major amendments to SOLAS Chapter II-1 Part B and Part B-1 covering harmonized probabilistic damage stability calculations for passenger and dry cargo ships was adopted by IMO in May 2005 (Ref. MSC.194(80)) and the final form (MSC.216(82)) is expected to be ratified at MSC 83 in October 2007 for entry into force for new vessels with keels laid on or after 1st January 2009 (henceforward known as SOLAS2009 in this report).

1.2 The MCA felt that it would be advisable, in view of the step change from a deterministic to a probabilistic damage stability calculation method, to try to find out what the likely impact would be on designs for new ships and to find out whether equivalency in safety levels between the old and new methods had been achieved.

1.3 Accordingly invitations were sent out to several organisations to prepare tender designs for the following ship types, starting with a vessel fully compliant with the existing damage stability regulations then, maintaining the original external hull forms, re-design the internal layout and watertight subdivision to meet the new SOLAS2009 regulations.

No	Type	LBP	B	D	dr	Pax+Crew	Design Aims
1	Panamax Cruise	260	32.2	11	8	2500+850	Maximise passenger numbers
2	Large Ro-Pax (Panamax)	200	32.2	17	6.5	1400+150	Long lower hold possible?
3	Small Domestic Waters Ro-Pax	90	16	6	3	650 + 25	Maximise passenger numbers + ro-ro cargo
4	Large Car Carrier (Panamax)	190	32.2	22	10	0 + 20	Maximise No of Cars (approx 6000)
5	Container Feeder	110	19	9.5	7.5	0 + minimum	Maximise TEU (approx 600), 3 hold?
6	Small Coaster	80	14	6.5	5.0	0 + minimum	Maximize cargo volume. Single Hold possible?

Table 1 – Proposed Ship Types and Design Aims

After agreed contract variations, the following basis ships were actually used:-

No	Type	LBP	B	D	dr	Pax+Crew
1	Panamax Cruise	266	32.2	10.7	8.5	2502+ 858
2	Large Ro-Pax	170	28.7	9.0	6.3	400+ 40
3	Post Panamax Cruise	293	36.8	11.3	8.5	3148+1100
4	Large Car Carrier (Panamax)	190	32.2	20.8	9.0	0 + 20
5	Container Feeder	120	22.7	10.8	7.6	
6	Small Coaster	85	13.6	7.2	5.7	

Table 2 – Particulars of Actual Basis Ships used in the Project

2. Background

2.1 The new regulations represent a step change away from the current deterministic methods of assessing subdivision and damage stability for passenger ships within SOLAS. Probabilistic methods have been employed for passenger ships since 1974 as an equivalent to Part B of Chapter II of SOLAS (Ref. IMO Resolution A.265(VIII)) but have not been extensively utilized other than for some ro-ro passenger vessels with combined transverse and longitudinal subdivision. A probabilistic approach was introduced into SOLAS Chapter II-1 for dry cargo ships over 100 metres in length in 1992 and extended to ships over 80 metres in length from 1998 (Ref. SOLAS Ch II-1 Part B-1 Regulations 25-1 to 25-10).

2.2 SOLAS2009 will supersede both IMO Resolution A.265(VIII) and the deterministic subdivision and damage stability calculations in SOLAS Ch II-1 Part B for passenger ships and replace SOLAS Ch II-1 Part B-1 for dry cargo ships. For passenger ships, concepts such as floodable length, permissible length, criterion numeral, margin line, 1 and 2 compartment standards and the B/5 maximum extent of side damage penetration will be disappearing.

2.3 The revised SOLAS2009 damage stability regulations are designed to give an equivalent level of safety to the current SOLAS regulations. Extensive analysis of existing ships and collision statistics was carried out to determine the most suitable method of formulating the probabilistic terms such as p, s, A and R (Ref. MSC.194(80) Regulations 6 and 7). Much of this work was carried out under the auspices of HARDER, a European project involving maritime academic institutions and other authorities, all reporting their findings to IMO.

2.4 Whilst extensive calculations were carried out in analysing the designs of existing SOLAS-compliant ships, little or no effort was possible in the time-scale of the project to design new ships from scratch using the new regulations. It is quite difficult to envisage how the different sections of the new regulations will interact. For example, a deterministic element has been retained to reduce the possibility of a minor damage resulting in a major casualty (Ref. MSC.194(80) Regulation 8) but it is hard to predict without actually designing a new ship whether such a set of criteria will be more or less onerous than the probabilistic regulations 6 and 7.

2.5 Some work comparing the old and new regulations was carried out in Germany and Sweden (Refs. 1 and 2) for existing ro-ro passenger ships where there are some concerns as to whether the new SOLAS2009 regulations adequately account for the water-on-deck phenomenon as covered by the Stockholm Agreement regulations. The broad conclusion of these projects was that the new regulations would account for water-on-deck correctly but it must be emphasized that most of the ships examined were designed or modified to be complaint with SOLAS90 and the Stockholm Agreement and there remains the

possibility that a ro-ro passenger ship designed from scratch to meet the new regulations may not be so effective in resisting water-on-deck, especially if the freeboard is low.

2.6 The contractors experienced some difficulties in obtaining the permission of Owners to use data for their ships in this project and the ship eventually selected as the basis ro-ro passenger ship had a substantial freeboard. As a result the calculations did not demonstrate clearly whether or not the water-on-deck phenomenon was adequately accounted for. Accordingly the MCA has sponsored a new research project (RP 592) to look at the issue again, this time specifying that the new design must be optimized to SOLAS2009 with a minimum freeboard. The results of RP 592 will be available later in 2007 and will be regarded as a further “phase” of RP 552.

3. Objectives

3.1 To take 6 different existing ship types, fully compliant with the current stability regulations and re-design their subdivision to utilize the freedom offered by the new SOLAS2009 regulations.

3.2 To analyze the revised designs to see what, if any, changes in layout and subdivision could be made within the scope of the new regulations.

3.3 To try to predict what new design features could emerge once the new regulations come into force in January 2009.

4. Methodology

4.1 The work was split between Safety-at-Sea, who covered the 3 passenger vessels, and Deltamarin who covered the 3 cargo vessels.

4.2 Having obtained the basis ship data, the contractor analyzed each ship's damage stability under the current regulations in terms of maximum permissible vertical centre of gravity to confirm the accuracy of the computer model.

4.3 The post-Panamax cruise ship had been originally designed to meet SOLAS2009 so was re-designed to meet SOLAS90 to enable comparisons to be made.

4.4 An in-house analysis program was then used to optimize the subdivision of each ship to meet the SOLAS2009 regulations, removing, adding or re-positioning internal bulkheads and decks, as appropriate.

4.5 The resulting designs were then analyzed against the new regulations and critical KG curves produced.

4.6 Finally each new design was re-analyzed against the SOLAS90 regulations and critical KG curves produced.

4.7 All 3 sets of critical KG curves were then used to compare the various safety standards.

4.8 Routine damage stability analysis was carried out using the NAPA ship design software package and the results presented in the form of Power-point presentations for each ship. All these presentations are available on the MCA web-site at http://www.mcga.gov.uk/c4mca/mcga-guidance-regulation/mcga-dqs-research_reports/mnet_mpb_min306rev_1.htm

4.9 An overview of the entire project was presented to delegates at IMO SLF during the lunchtime recess on 25th July, 2006 and this is available on the MCA

web-site at http://www.mcga.gov.uk/c4mca/mcga-guidance-regulation/mcga-dqs-research_reports/mnet_mpb_min306rev_1.htm

5. Summary of Results

5.1 The results of the project vary according to ship type and are summarized below.

5.2 Fuller results, including plans, can be found on website at http://www.mcga.gov.uk/c4mca/mcga-guidance-regulation/mcga-dqs-research_reports/mnet_mpb_min306rev_1.htm

5.3 **Ship 1 – Panamax Cruise Ship; KG values taken at load draught of 8.0 metres**

	Damage Regs.	Actual Max KG	Critical KG	A	R	Pass/Fail
Current Design	SOLAS90	15.361	15.750	-	-	P
	SOLAS2009	15.750	-	0.730	0.804	F
	SOLAS2009	15.400	15.400	0.804	0.804	P
SOLAS2009 Re-design	SOLAS2009	15.750	15.750	0.804	0.804	P
	SOLAS90	15.361	15.080	-	-	F

Table 3 – Particulars of Panamax Cruise Ship

Comments:- It can be seen that the ship re-designed to SOLAS2009 would fail to meet the SOLAS90 damage stability criteria; the main reason being margin line immersion arising from reduction in transverse watertight subdivision. If the margin line criterion is removed from the SOLAS90 regulations then the critical KG's compare quite closely with SOLAS2009 -15.83 metres for SOLAS90 excluding Margin Line immersion against 15.75 metres for SOLAS2009. Note that this project was completed before the safe return to port functional requirements were introduced at MSC 82.

Main Features of the New Design:-

The ship complies with "R", the Required Index, and with revised SOLAS Ch. II-1 Part B, Reg. 8 (minor damages). It has the same external hull form as the basis ship; similar tank volumes and distribution; maintained or increased heeling tank capacity; similar internal area for service spaces; similar positions for main fire bulkheads; same spacing for main engine room bulkheads; the number of main transverse watertight bulkheads is reduced by 3.

Use has been made of the removal of the margin line criterion and replacement with the non-immersion of openings and access passageways. Shifting these vulnerable points as near to the centre-line as possible means that considerable areas of the main deck can now be flooded after damage.

5.4 **Ship 2 – Large Ro-Ro Pax Ship; KG values taken at load draught of 6.3 metres**

	Damage Regs	Actual Max KG	Critical KG	A	R	Pass/Fail
Current Design	SOLAS90	12.221	13.514	-	-	P
	SOLAS2009	13.514	-	0.820	0.704	P
	SOLAS2009	14.110	14.110	0.704	0.704	P
SOLAS2009 Re-design	SOLAS2009	13.500	13.500	0.704	0.704	P
	SOLAS90	12.221	13.500	-	-	P

Table 4 – Particulars of Ro-Ro Passenger Ship

Comments:- The ship re-designed to SOLAS2009 meets the SOLAS90 damage stability criteria quite easily. The basis design had a relatively low number of passengers and a high freeboard and although there is 0.596 metre uplift in the critical KG curve for SOLAS2009 as against SOLAS90 for the current design this cannot be realised in practice because the intact stability criteria are more onerous. The good performance of the current design under the new regulations is attributable to the high freeboard, low passenger numbers and the presence of side casings enclosed with WT doors to mitigate the effects of water on deck. RP 592 will attempt to optimize a low freeboard, high passenger number ro-pax with a long lower hold to confirm that SOLAS2009 will provide adequate survivability for this class of ship. Note that RP552 was completed before the safe return to port functional requirements were introduced at MSC 82.

Main Features of the New Design:-

The ship complies with “R”, the Required Index, and with revised SOLAS Ch. II-1 Part B, Reg. 8 (minor damages). It has the same external hull form as the basis ship; similar tank volumes and distribution; maintained or increased heeling tank capacity; similar internal area for service spaces; similar positions for main fire bulkheads; same spacing for main engine room bulkheads. The vehicle lane capacity is maintained; number of main transverse watertight bulkheads reduced by 2 but long lower hold dimensions are maintained; side casings on car deck enclosed with watertight doors at each end are replaced with narrower side casings without WT doors resulting in greater width for vehicle transport on the car deck and a much greater open deck area.

5.5 **Ship 3 – Post-Panamax Ship; KG values taken at load draught of 8.5 metres**

The methodology for this ship differs from the other 5 cases in that the basis design was originally optimized to the SOLAS2009 regulations (excluding the safe return to port requirements) and then re-designed to meet SOLAS90. This re-designed subdivision was then checked against SOLAS2009.

	Damage Regs	Actual Max KG	Critical KG	A	R	Pass/Fail
Current Design (S2009)	SOLAS2009	17.850	-	0.8541	0.8293	P
	SOLAS2009	-	18.060	0.8293	0.8293	P
	SOLAS90	17.850	17.050	-	-	F*
Re-designed to SOLAS90	SOLAS2009	17.850	17.850	> R	< A	P**
	SOLAS90	17.850	18.100	-	-	P

Table 5 – Particulars of Post-Panamax Cruise Ship

Comments:- * Note additionally that the SOLAS2009 original design would be subject to increasing draught restrictions with increasing stern trim, due to margin line immersion, under SOLAS90. For example, at a stern trim of 0.5 metres, the draught would be reduced from 8.5 to 8.4 metres. At level trim, many of the lighter loading conditions have marginal compliance with SOLAS90 but would mostly fail if stern trim was 0.5 metres. The two deepest load conditions would fail the level keel SOLAS90 critical KG curve by up to 0.5 metre. The full load condition would, in contrast, have a safe margin of 0.55 metres on the SOLAS2009 level keel critical KG curve based on A=R.

** Note that the SOLAS2009 critical KG curve for the ship re-designed to meet SOLAS90, is governed by the deterministic minor damage criteria (Regulation 8) at deeper draughts and not the probabilistic A=R criterion. Also note that this project was completed before the return to port criterion was introduced at IMO SLF 49. This result shows that the critical KG curves for the SOLAS2009 regulations may well be governed by Reg. 8 and/or the return to port criterion for some designs of passenger ship.

Main Features of the New Design:-

The re-designed ship complies with SOLAS90 and the intact stability criteria and has the same external hull form as the basis ship. The number of main transverse watertight bulkheads is one less than in the original SOLAS2009 design. Tank volumes are maintained as are crew and public accommodation areas, the main fire and the main engine room bulkhead spacing. No changes have been made to the internal layout above deck 4 but the anti-heeling tank capacity has been increased.

5.6 **Ship 4 – Large Vehicle Carrier; KG values taken at full load draught of 10.00 metres**

	Damage Regs	Load KG	Critical KG	A	R	Pass/Fail
Current Design (1 WT deck)	SOLAS90 R25	14.113	15.900	0.569	0.566	P
	SOLAS2009	14.113	Not Calculable	0.589	0.636	F
(1 WT deck + Double Skin)	SOLAS2009	14.113	8.750	0.610	0.636	F
(1 WT deck raised 0.5 m.)	SOLAS2009	14.113	14.400	0.633	0.636	Marginal
(1 WT deck raised 1.0 m.)	SOLAS2009	14.113	15.600	0.677	0.636	P
SOLAS2009 Re-design (2WT dks)	SOLAS2009	14.113	14.750	0.646	0.636	P
	SOLAS90 R25	14.113	15.900	0.569	0.566	P

Table 6 – Particulars of Large Vehicle Carrier

Comments:- The current design passes the dry cargo ship probabilistic regulations in Regulation 25 of the current SOLAS quite easily but fails SOLAS2009 rather badly. The principal reason for this is the increased permeability of the cargo spaces required by the new regulations (0.90 – 0.95 depending on draught, against 0.70 in the current SOLAS regulations). The required index, R, has also been raised considerably under the new regulations and the weighted contributions for each draft changed, as well as the draughts themselves (3 required under the new regulations; 2 under SOLAS90 Reg.25).

Main Features of the New Design:- It was found that the most effective way of meeting the SOLAS2009 regulations was simply to make another, higher deck watertight. In the current design only deck 5 (14.04 m. above base) is watertight whereas in the modified design deck 7 is also made watertight (20.77 m. above base). The damaged waterlines resulting from the increased cargo space permeability in SOLAS2009 were found to exceed the old watertight deck height in many damage cases. The extra watertight deck contains this flood water and allows the undamaged volume above to contribute to the buoyancy. Air pipe heights and structural scantlings must be increased but otherwise the solution is fairly straightforward and has no impact on functionality.

As an experiment, various alternative ways of meeting SOLAS2009 with only one watertight deck were examined including fitting a 2 m wide double skin in the cargo spaces below the deck. Another option was to increase the deck height in increments until the design complied. The double skin option has the advantage of giving protection against minor side damages (Regulation 8 does not apply to cargo ships) but led to major loss of cargo space and still did not meet SOLAS2009. For the deck height proposal, it was found that the increase would have to exceed 0.5 metre to comply, with a resulting major impact on functionality such as longer internal and external ramps, waste volume below the watertight deck, increased lightship weight and VCG with increased ballast capacity to compensate.

5.7 **Ship 5 – Container Feeder Ship; KG values taken at load draught of 7.65 metres**

	Damage Regs	Load KG	Critical KG	A	R	Pass/Fail
Current Design	SOLAS90 R25	9.360	9.420*	0.53709	0.49415	P
	SOLAS2009	9.360	9.420*	0.59389	0.54905	P

Table 7 – Particulars of Container Feeder Ship

Note:- * The critical KG is governed by intact stability (standard IMO criteria) at full load draught. The critical KG for damage stability (which turns out to be the same for SOLAS90 and SOLAS2009) is 9.53 metres at full load draught but damage stability governs the critical KG at draughts less than around 7.5 metres

Comments:- This class of vessel was chosen for the project as it had been thought that ships designed to meet the existing SOLAS90 Regulation 25 probabilistic damage stability regulations would be unable to comply with the new SOLAS2009 regulations because, *inter alia*:-

- the Required Index (R) had been increased
- the cargo hold permeability had been altered from 0.70 to 0.80 up to 0.95, depending on draught (although the permeability at the deepest draught remains at 0.70)
- the partial Attained Indices, A_s, A_p and A_l, corresponding to full load, partial and light draughts each must be at least 0.5*R for cargo ships. Under the current regulations, it is possible for a ship to meet R whilst gaining no contribution from the partial index at the full load draught, A_s.
- No account of initial trim is made in the current regulations, all calculations being carried out at level trim. This ship operates within a stern trim range of between 1 and 1.5 metres. The new regulations allow for some trim and the calculations were carried out at a stern trim of 1.50 metres in the light service condition ($_{dl}$).

The basis ship has four cargo holds (two large ones aft, two smaller forward) and a double skin. Calculations show that at the full load draught d_s , damage to either of the two forward container holds or to the foremost of the after holds would result in capsize, as would a 2-compartment damage to the after container hold and the engine room and most of the cargo holds. It had been hoped that the new regulations might have resulted in a better survivability standard.

5.8 **Ship 6 – Small General Cargo Ship; KG values taken at load draught of 5.70 metres**

	Damage Regs	Load KG	Crit KG	A	R	Pass/Fail
Current (A), 1 hold, double skin	SOLAS90 R25	4.610	5.100	0.43435	0.41120	P
	SOLAS2009	4.610	5.200	0.47755	0.44575	P
Re-design (B), 2 hold, single skin	SOLAS2009	4.610	4.400	0.38858	0.44575	F
Re-design (C), 2 hold, double skin	SOLAS2009	4.610	5.200	0.50225	0.44575	P

Table 8 – Particulars of Small General Cargo Ship

Comments:- This very common ship type was chosen because it was generally thought that a major re-design would be needed to comply with the new regulations for reasons similar to those for the container feeder ship (see above). The basis ship was slightly unusual in that it is fitted with a double skin and even though it has a single hold it was found to comply with the SOLAS2009 regulations easily without alteration.

The design variant (B), however, had only a single skin and even though fitted with two holds still failed to meet the requirements of SOLAS2009. This seems to indicate that new ships of this type may be forced to consider fitting double skins even if they have more than one hold which will have significant impact on functionality and cargo capacity.

Again, as for the feeder ship, it is alarming to see how many of the full load damage cases involving penetration of the hold(s) still result in capsize.

6. Conclusions

6.1 The new SOLAS2009 regulations will undoubtedly have a major impact on the layout and subdivision of both dry cargo ships and passenger ships. For some ship types, for example the large vehicle carrier, the new regulations, particularly those relating to assumed permeability, will undoubtedly improve safety levels by forcing designers to add an extra watertight deck.

6.2 In other cases, particularly where margin line immersion will be permitted, the outcome is less clear. For example, it is likely that the designers of large passenger ships will exploit the replacement of the margin line by the immersion limit line by shifting vulnerable flooding points and access passageways as far as possible inboard, thus allowing considerable areas of the main deck to become immersed after damage. Whether this is a desirable feature or not remains to be seen, and may need to be re-visited if later regulations, post SOLAS2009, introduce stability criteria for safe return to port.

6.3 The project has illustrated that it is very difficult to judge whether two ships designed to fulfil the same functional requirements but compliant with probabilistic and deterministic damage stability regulations are comparable in safety terms as the methodology behind the two approaches are so different. A ship optimised to meet SOLAS90 may not meet SOLAS2009 (and vice versa).

6.4 Although, in this study, the ro-pax vessel complied easily with both sets of regulations (due mainly to the large freeboard of the basis ship), concerns remain about SOLAS2009 designs with lower freeboards subject to potential water accumulation on the car deck. Discussions are ongoing within the EU to decide whether the Stockholm Agreement can be dispensed with once the SOLAS2009 regulations come into force. The results from phase 2 of this project (RP 592) should contribute to this debate.

6.5 From the results of this project it would appear that the era of the single hold, single skin small coastal trading vessel may be over as such vessels will not be able to be designed to meet the required index “R”. Even a single hold, double skin vessel will probably struggle in this respect.

6.6 The vulnerability of container feeder ships after one compartment damage in way of the cargo hold or machinery space at full load draught is still apparent with the new regulations even though the overall safety level may have increased over and above the current SOLAS Regulation 25-1.

6.7 More detailed conclusions, plans and discussions of the design features for each of the calculated ship types can be seen at XXX website XXX, together with a brief presentation of the results given at IMO during SLF 49.

7. Recommendations

7.1 The most important recommendation is that designers, owners, operators and shipyards need to be fully aware that the new SOLAS2009 regulations coming into force for ships with keels laid after 1st January, 2009 will potentially have a major impact on the design of a wide range of dry cargo and passenger ships. They should be planning ahead now to maximise any benefits to be gained from the new probabilistic regulations, such as increase flexibility of watertight subdivision and removal of concepts such as floodable length, B/5 and non-immersion of the margin line.

7.2 Equally, approval authorities should be gearing up to cater for the new regulations, which involve a vast increase in the number of damage stability calculations and a much greater degree of complexity in the overall analysis. Issues such as the fine-ness of the mesh used to determine the number of calculations involved will become a concern if it is found that the "A" value (attained index) obtained can thereby be significantly influenced. Investment in computer hardware, updated software and personnel training will become necessary to cope with the increased workload involved in approving the new probabilistic calculations.

7.3 Care should be taken by everybody concerned not to overlook the significance of the new regulation 8.1 for the functional requirements covering the safe return to port of passenger ships. This regulation was introduced later than the rest of SOLAS2009 (after this research project was commissioned) and applies only to passenger ships constructed on or after 1st July 2010. The regulation will require separation and duplication of main control and power systems.

7.4 This project has clearly shown that ships optimized to comply with the current SOLAS90 regulations may not meet the 2009 regulations and vice versa. To assess the relative degree of survivability a third, independent approach is needed to highlight any difference between the safety levels achieved by the two methods. Such a comparison might be afforded by risk analysis and it is recommended that further studies into ships designed to both the new (SOLAS2009) and existing (IMO Res. 265 and SOLAS90 Reg. 25.1) probabilistic regulations be carried out on this basis. As new computing techniques and personal skills develop, it is desirable to continually try to determine the exposure to risk of the travelling public and ship's crew, perhaps in comparison with other modes of transport.

7.5 The large ro-ro passenger ferry chosen as the basis ship for this project had too large a freeboard to show clearly whether or not the new regulations will take proper account of the water-on-deck phenomenon. To inform this debate it is therefore recommended that further research be undertaken into optimizing a new ship to the SOLAS2009 regulations with minimum freeboard and the maximum possible size of long lower compartment. If the project confirms that the new regulations do correctly allow for water-on-deck then abolition of the Stockholm Agreement could be safely recommended.

8. References

1. “SOLAS2009 and IMO/Circ.1891 (Stockholm Agreement)
   Damage Stability Investigation of two ships and contrast of the requirements” by Jan Schreiber of Technische Universitat Hamburg-Harburg, published in May 2006 as a Dipl-Ing thesis

2. “Impact of the Stockholm Agreement on new probabilistic damage stability rules” by Andreas Hildingsson of Chalmers University, Gothenburg, published in 2006 as an M.Sc Thesis