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Review of the Damaged Stability Provisions in the High Speed Code

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Un sommaire français se trouve avant la table des matières.

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16. Abstract

A study was conducted to assemble and review the proposed revisions to the International Marine Organization (IMO) High Speed Craft (HSC) Code and to determine whether they address any specific concerns that Canadian regulators may have regarding damaged stability of fast craft. The study reviewed all relevant IMO correspondence and technical papers and discussions with Transport Canada and international representatives at IMO.

It was determined that the proposed revisions to the HSC Code address most of the deficiencies in the area of damaged stability that had been identified since the HSC Code was introduced in 1994. Two issues specific to Canada that may require further attention were: the extent of side damage due to potential impact with an ice sheet and the extent and effect of icing due to spray – the latter being somewhat beyond, but related to, the damaged stability issue. Investigation of these issues indicated that modification to formulae may be required and that development of more rigorous definitions is required in some areas. Recommendations for Canada's continued active involvement in these issues at IMO are made.

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16. Résumé

La recherche a consisté à assembler et passer en revue les modifications proposées au *High Speed Craft (HSC) Code* de l'Organisation maritime internationale (OMI), afin de vérifier si elles répondent aux préoccupations que pourraient avoir les organismes canadiens de réglementation en ce qui a trait à la stabilité des engins à grande vitesse après avarie. L'étude a porté sur la correspondance de l'OMI et sur divers documents techniques touchant cette question. Des discussions ont également eu lieu avec des représentants de Transports Canada et d'autres pays membres de l'OMI.

L'étude a confirmé que la refonte proposée pallie la plupart des faiblesses touchant la stabilité après avarie relevées dans le HSC Code depuis son entrée en vigueur en 1994. Cela dit, deux questions intéressent particulièrement le Canada et mériteraient un examen complémentaire : l'étendue de l'avarie de bordé pouvant résulter de l'impact d'une nappe de glace sur l'engin, et l'étendue et les effets du givrage dû aux embruns -- ce dernier problème dépassant la question de la stabilité après avarie, sans y être tout à fait étranger. L'examen de ces questions a montré qu'il pourrait être nécessaire de modifier certaines formules et de définir avec plus de rigueur certains concepts. Il est recommandé que le Canada continue de participer activement aux travaux de l'OMI sur ces questions.

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EXECUTIVE SUMMARY

A study was conducted to assemble and review the proposed revisions to the IMO High Speed Craft (HSC) Code and to determine if these address any specific concerns which Canadian regulators may have with respect to damaged stability of fast craft.

The study included assembly and review of all IMO correspondence, committee positions and associated papers pertaining to the proposed HSC Code amendments as well as review of technical papers on safety and stability issues presented at Fast Craft conferences in recent years. Discussion with Transport Canada Marine Safety and Security personnel also took place, and finally discussions were held with International representatives attending the Design and Equipment sub-committee meeting of IMO in March.

It was determined that the proposed revisions to the HSC Code address most of the deficiencies that had been identified since the HSC Code was introduced in 1994, but that two issues of specific interest to Canada require some further investigation.

First, while a new formula has been introduced to increase the length of bottom damage due to grounding (“raking damage”) to be used in stability calculations and accounting for vessel speed, displacement and bottom materials and thickness, it may be necessary to introduce a similar formulation for side shell plating for fast vessels operating in conditions where ice may be encountered.

Second, since Canada’s East coast is within the area designated in the HSC Code as an area susceptible to icing, Canada should take particular interest in this issue. The provisions in the present Code relating to ice accretion have not been considered in the current review of the Code. They are based on current SOLAS requirements and do not appear to adequately account for the configurations of modern fast craft.

Recommendations are made for Canada to investigate these two issues to determine their significance and, if necessary, propose amendments to the next round of IMO committees. In addition, since not all the proposed amendments were adopted at the recent IMO DE41 meeting, it is recommended that Canada continue active participation in this IMO activity.

SOMMAIRE EXECUTIF

La recherche a consisté à assembler et passer en revue les modifications proposées au *High Speed Craft (HSC) Code* (la version française -- Code de sécurité des engins à grande vitesse -- reste à paraître) de l'Organisation maritime internationale (OMI), afin de vérifier si elles répondent aux préoccupations que pourraient avoir les organismes canadiens de réglementation en ce qui a trait à la stabilité des engins à grande vitesse après avarie.

L'étude a porté sur la correspondance de l'OMI, sur les positions et documents émanant de ses comités concernant le projet de refonte du *HSC Code*, ainsi que sur des communications portant sur la sécurité et la stabilité des engins à grande vitesse faites lors de conférences récentes. Des discussions ont également eu lieu avec des représentants de la Sécurité maritime de Transports Canada de même qu'avec des délégués d'autres pays membres de l'OMI présents à la réunion de mars 1998 du sous-comité Conception et équipement du navire de l'OMI.

L'étude a confirmé que telle que proposée, la refonte pallie la plupart des faiblesses touchant la stabilité après avarie relevées dans le *HSC Code* depuis son entrée en vigueur en 1994. Cela dit, deux questions intéressent particulièrement le Canada et mériteraient un examen complémentaire.

Premièrement, en plus de la nouvelle formule proposée pour accroître la longueur de l'avarie de fond en cas d'échouement (avarie par «raclage») à prendre en compte dans les calculs de stabilité (laquelle fait aussi intervenir l'allure du navire, son déplacement et la nature et l'épaisseur des matériaux qui composent le fond du navire), il y aurait lieu d'élaborer une formule semblable pour les bordés de muraille des navires à grande vitesse évoluant dans des eaux susceptibles de contenir des glaces.

Deuxièmement, depuis que la côte est du Canada fait partie de la zone désignée par le *HSC Code* comme étant sujette au givrage, le Canada se doit de porter une attention particulière à ce problème. Or, la refonte en cours fait abstraction des dispositions du Code touchant l'accumulation de glace. Ces dernières, fondées sur les exigences de la Convention internationale pour la sauvegarde de la vie humaine en mer (SOLAS), semblent mal s'appliquer aux configurations des engins à grande vitesse modernes.

Il est recommandé que le Canada examine les deux questions susmentionnées, afin d'en évaluer l'importance et, le cas échéant, de proposer des modifications lors du prochain calendrier de réunions des comités de l'OMI. De plus, comme le sous-comité DE41 de l'OMI n'a pas entériné toutes les modifications proposées lors de sa dernière réunion, il est recommandé que le Canada continue à participer activement aux travaux de ce sous-comité.

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ACRONYMS AND ABBREVIATIONS

ACV	Air Cushion Vehicle
AMV	Advanced Marine Vehicle
DE	Design and Equipment Committee (of IMO)
DSC	Dynamically Supported Craft
FTL	Fleet Technology Limited
HSC	High Speed Craft
TIES	Technical Investigation and Engineering Support
IMO	International Maritime Organization
LLC	Load Line Convention
MSC	Maritime Safety Committee (of IMO)
RINA	Royal Institution of Naval Architects
SES	Surface Effect Ship
SLF	Stability, Load line and Fishing Vessel Safety
SOLAS	Safety of Life at Sea (IMO Congress)
SWATH	Small Waterplane Area Twin Hull
TC	Transport Canada
WP	Working Paper

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1. INTRODUCTION

1.1 Description

This document reports on the findings of a study into the damaged stability aspects of the new IMO High Speed Craft Code.

1.2 Objective

The objective of the work reported herein as stated in the Work Statement is, “to provide Transport Canada with a recommended course of action pursuant to the adequacy and application of the Damaged Stability Standards as developed by the International Maritime Organization (IMO)” (for High Speed Craft).

1.3 Scope

While the original tasking focused on damaged stability, it was determined at an early stage that this could not be examined in isolation from considerations of buoyancy, collision, etc. Not only are these obviously linked from a technical viewpoint, but the layout of the HSC is such that they must be considered together. Consequently, the scope of this work was expanded to include stability, buoyancy, collision, and so on.

1.4 Related Events

Since the initiation of the project, Transport Canada (TC) has created two committees or working groups to investigate aspects of the HSC. These are a technical committee to look at where the HSC may be open to interpretation and a committee investigating the legislative implications for Canada. While this project appears to have overlapped with this effort within TC, it is hoped that the findings herein can be used by these committees.

During the progress of this study, the International Maritime Organization (IMO) held the 41st meeting of its sub-committee on Ship Design and Equipment, known as DE41, during which the working group on the High Speed Code also met, and changes to the HSC were discussed. An FTL representative working on this study had the privilege of attending as an advisor, and was able to discuss the preliminary findings of this work and thus obtain some international confirmation of the issues revealed.

2. THE HSC CODE AND AMENDMENTS

2.1 The International Maritime Organization

The first task in the study was to assemble and review the documentation related to damaged stability and the High Speed Code (HSC), principally the discussion papers and proposed amendments that had been circulated since the introduction of the HSC in 1994.

Since the HSC is a document of the International Maritime Organization (IMO), it is worthwhile to provide a brief overview of that organization as it pertains to the HSC.

The effective controlling body is the Maritime Safety Committee (MSC), which meets at about six-month intervals, and to it report numerous specialist sub-committees, of which the Design and Equipment (DE) and Stability, Load Line and Fishing Vessel Safety (SLF), meeting roughly annually, are relevant. Meetings last for one week.

DE has been charged with the overall responsibility for the HSC Code. Currently about 40 nations attend DE, of whom 15 are represented on the Working Group specifically dedicated to the High Speed Code. The agenda for a meeting is established by MSC. Any nation (or expert body) can submit papers for consideration.

To assist in reading the papers presented herein, it is worthwhile to note the paper identification system. Each paper is identified and distributed by IMO with a symbol. Thus, for the 40th session of DE, Agenda item 8, papers will be identified as “DE 40/8/....” , sequentially. Papers generated during the session, e.g., by a working group, will be identified as “DE40/WP..”.

A Working Group reports to plenary on the final day, and the sub-committee generates its report to MSC. A Working Group may pursue its work through inter-sessional correspondence. Since 1995, DE has been chaired by Australia, as was the Working Group responsible for the HSC Code.

2.2 Data Collection

With the willing assistance of staff of the International Secretariat of Marine Safety, all IMO documents were made available for review and copying, and a copy of the HSC Code was provided. Attention was focused on MSC66 and 67 (1996), DE40 (March 1997) and DE41 (March 1998), and SLF41 (February 1998), and some referenced papers from other sub-committees were scanned. In addition, some conference papers and technical magazine articles of relevance were reviewed, including technical papers from the FAST conferences and special RINA conferences on High Speed Craft Safety (see Bibliography). In general, papers presented at conferences are designed to publicize and seek feedback on proposals already being considered for IMO.

Data were also collected to identify trends in vessel configurations that may present problems with the revisions to the Damaged Stability provisions of the Code.

2.3 The Origin of the HSC Code

In the late 1960s, the surge in development and operation of ACVs and hydrofoils prompted a requirement for appropriate international safety requirements. The Dynamically Supported Craft Code (DSC Code) developed by DE in the 1970s was the result. It was also applicable to contemporary catamarans.

By the late 1980s, marine passenger traffic had become more and more ferry-oriented and with market demands and technological developments, displacement vessel designs were becoming increasingly less conventional and the vessels were at least competitive with the ACVs and hydrofoils. While, by definition, these new vessels could be regarded as DSCs, the DSC Code was neither intended nor appropriate for such ships. The conventional SOLAS and Load Line Conventions were equally inappropriate, and the rapid advances in technology and growth of the ship-builders of these vessels made the need for a new Code an urgent requirement. This was recognized in the early 1990s, and development of a new Code commenced in 1993. Again, under the auspices of DE, the work was "fast-tracked" and the resulting HSC Code was adopted in May 1994 by MSC, with a mandatory effective date of 1 January 1996.

By that time, experience with vessels and their operation which had already anticipated the introduction of the Code, and ever-increasing design, construction and equipment development, was causing concern that the Code was deficient in a number of areas. The most significant of these was the inadequacy of the provisions for stability contained in Chapter 2 and the related Annexes to cater to the very broad spectrum of vessel designs and architecture that were emerging.

2.4 Damaged Stability Provisions in the HSC Code

From the adoption of the HSC Code in 1994 to its mandatory effective date in 1996, there were three high-speed accidents involving major hull damage, and while there were no fatalities or vessel losses which were attributable to either loss of buoyancy or stability deficiency, the ensuing investigations caused the national administration concerned to examine all provisions of the Code.

The most significant accident that focused attention on the need to re-examine the Code, and especially Chapter 2, was the passenger catamaran *SAINT MALO* grounding on rocks close to its route off Jersey in the Channel Islands.

The *SAINT MALO* is a 42 m passenger catamaran of light alloy construction with seating for 350 passengers. With 300 passengers on board, the vessel grounded at about 28 kn on rocks off Jersey, and very rapidly took up a list of about 19^{o}, which then increased more slowly. Some 65% of the length of the port hull was breached, *"far in excess of the damage prescribed in current international regulations"*.

According to the current HSC Code, the extent of bottom damage to be considered for damaged stability is only 10% of the length. By calculation, the resulting list should have been about 19^{o},which was the initial list; however, subsequent down-flooding resulted in a final angle of about 28^{o}, but by that time, evacuation was complete. Evacuation, however, had been greatly hindered by the excessive list that rendered two of the four evacuation points useless, and use of the other two difficult. See **Figure 2.1**.

For the purposes of this review, because of the lay-out and content of the Code, damaged stability cannot be examined in isolation from buoyancy provisions (also in Chapter 2 of the HSC Code) and provisions in Chapter 4 regarding collision accelerations. It should be noted that a major contributor to Chapter 2 was a nation with great expertise with ACVs and conventional vessels, whereas Chapter 4 was primarily the work of a nation in the forefront of development and operation of high-speed catamarans. Chapter 2 relies heavily for its content upon SOLAS and the DSC Code, with minimal substantive reference to vessels other than conventional monohulls and ACVs; by contrast, Chapter 4 makes extensive reference to craft types, hull material, craft speed and displacement.

As a result, Chapters 2 and 4 are inconsistent both in their applicability to the broad spectrum of craft, and in the depth of their treatment.

The paragraph of immediate interest is 2.6 - *Buoyancy and Stability in the displacement mode following damage*. The text occupies just 1.5 pages, in which the word "buoyancy" appears once, in reference to its provision by foam. The bottom damage to be considered for stability calculations is almost entirely based upon SOLAS and the DSC Code, with a minor reference to catamarans, to clarify the extent of damage breadth.

The whole of Chapter 2 is strangely silent on the topics of double bottoms and collision bulkheads. In para. 2.3 - *Intact stability in the intact mode*, hydrofoils are referred to Annex 6, multi-hull craft are referred to Annex 7, while "all other craft" are provided with standard criteria in the text with the proviso that where the characteristics of the craft make these criteria inappropriate, "the Administration may accept alternative criteria". "All other craft", by inspection, means ACVs and monohulls. It is most unlikely that any new ACVs to which the Code would apply will be built; monohulls to which the Code will apply are significantly different in all respects from conventional monohulls, and therefore, the proviso for alternative criteria to be accepted will become the norm. Noting that multi-hull vessels comprise a significant proportion of the vessel population, and that there are numerous configurations and hull designs to be considered, it is suggested that Annex 7 should be closely examined to determine its validity.

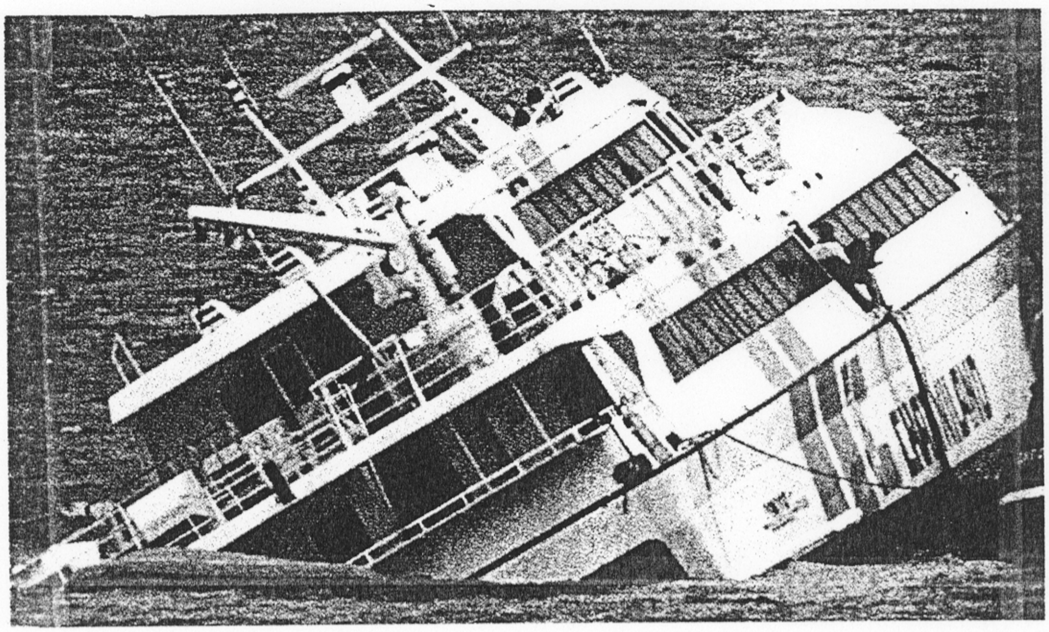


Figure 2.1 Grounding of the Catamaran *SAINT MALO*

The broad spectrum of vessel designs and configurations that Chapter 2 must address includes:

- Monohulls of very high slenderness ratios, possibly with active stabilization;
- Foil-assisted monohulls;
- Catamarans with high slenderness-ratio hulls, possibly with active stabilization;
- Foil-assisted catamarans;
- Wave-piercing multi-hulls, generally with very high slenderness-ratio hulls, active stabilization and a central bow extension which is not normally immersed;
- SWATH vessels;
- Pentamarans.

All of these vessels may be operating at 50 kn or more.

2.5 Development and Review of Revisions

As noted above, concerns that the Code needed revision surfaced even before the Code was in effect, and, therefore could not be officially voiced. The first opportunity arose at DE39 in January 1966; following IMO procedure, DE brought these concerns to the attention of MSC66 in June of the same year. At that session, MSC was also considering a note from the Chairman of the panel of experts on RO-RO Safety (MSC65/4/Rev.1), which drew attention to the applicability of their final report MSC65/4 Rev.1 to HSCs, and noting that the HSC Code needed review in this regard. This panel of experts had been charged with investigating the sinking of the RO-RO ferry *ESTONIA*, and recommending preventative measures to improve safety. Accordingly, MSC, in MSC66/WP15/Add 3, directed DE to revise the HSC Code as a high-priority item, co-ordinating inputs from SLF and other Sub-Committees.

At the outset, in DE40 (February 1997), it was agreed that a guiding principle should be that revisions should apply to new craft only, and that any requirements intended for existing craft should be developed at a later date (DE40/12, para.8.5).

Thirteen papers were considered or developed at DE40. They are listed and provided in full in **APPENDIX 1**. A review of these shows that the majority relate to, or affect Chapter 2, also that the majority were submitted by the UK. Chapter 2 is strictly within the purview of SLF, who had initiated action in September 1996 with the establishment of a correspondence group, co-ordinated by the United Kingdom, to develop proposals for revision which would be considered at SLF41 in February 1998.

These proposals are contained in SLF41/10/1 Annex, and this is the primary substantive document. At DE40, it had been possible to form a working group, which met concurrently with plenary and reported to it at the end of the session, in DE40/WP8, later supplemented by DE41/5. These are also primary documents, and their annexes, together with that of SLF41/10/1, contain the currently agreed proposals for revision to Chapter 2, and also proposals still to be resolved.

The portions of these documents that pertain to proposed revisions in areas such as damaged stability, are provided in **APPENDIX 2**. Within these proposals, there are references to other IMO documents that are reproduced for convenience in **APPENDIX 3**.

2.6 Review of Proposals

2.6.1 Perceived Concerns with the HSC Code as Approved in May 1994

The following items summarize the principal concerns about the HSC Code in the subject areas, as determined from discussion papers and technical papers presented.

1. Bottom damage to be considered for buoyancy and stability purposes does not take into account the vessel configuration, geometry or type (other than ACVs);
2. Requirements specifically for RO-RO HSCs are virtually non-existent and need to be added to provide safety equivalence with conventional RO-RO vessels, including inner bow doors;
3. Watertight integrity requirements are inadequate; in this respect, the Code is not a "stand-alone" document, and recourse has to be taken to the Load Line Convention (LLC);
4. Reserve buoyancy requirements need to be expanded;
5. The current Code has no requirement for collision bulkheads;
6. The current Code has no requirement for double bottoms;
7. Dynamic stability and stability in a seaway need to be addressed;
8. Inconsistent levels of detail in Chapters 2 and 4';
9. Some areas where definition of application requires clarification.

2.6.2 Agreed Proposed Revisions

The following summarizes the proposals that have been agreed on, and were put forward in the papers in APPENDIX 2 for consideration of the SLF41 committee in January 1998 and then on to the DE41 committee in March 1998.

1. In Chapter 1, it is proposed to add a simple but very significant footnote, which will require the Code to include the relevant provisions of the LLC;
2. A new Para.2.1.4 introduces alternative means by which compliance with the buoyancy and stability requirements may be demonstrated such as simulation, model tests;
3. Revisions to Para 2.2 bring "watertight and weathertight integrity" into the title, and new Paras. 2.2.5 through 2.2.9 have been introduced to add the LLC provisions, together with requirements for inner bow doors, worded in such a fashion as to recognize the height of vehicle decks on some HSCs, and provide for exemptions;
4. A revision to Para. 2.2.1.2 introduces the precedent-setting (for IMO) recognition of Classification Society strength requirements (this is also referred to in Chapter 3);
5. A revision to Para. 2.3 - Intact buoyancy in the displacement mode - modifies the weather criteria of Resolution A.562 to include a wind pressure co-efficient;
6. A revision to Para. 2.4.3 - Intact stability in the non-displacement mode - adds test requirements to demonstrate dynamic stability;
7. Revisions permit the hull to include sealed bottom voids with no bilge systems, and others relate to the number and standard of openings in the watertight structure, and the integrity of the hull and superstructure;
8. Revisions to Para. 2.6 - *Buoyancy & Stability in the displacement mode following damage*. These are the most significant revisions, by changing the basis for determining the extent of

damage to be considered from linear dimensions to criteria based upon *displacement* for side damage, and vessel speed, hull plating thickness and material, and displacement for bottom damage;

9. Revisions to Paras. 2.13 and 2.15 - these Paras. have the same heading as 2.6, but apply respectively to passenger and cargo vessels; they relate to consideration of down-flooding openings, and permit mutual agreements between states to modify this clause;
10. SLF has proposed that an MSC Resolution be implemented requiring existing monohull passenger HSC ships to comply with SOLAS Regulation II-1/8, and multi-hull passenger HSCs to comply with Code Annex 7.

2.6.3 Unresolved Issues

A number of issues remain unresolved, notably the need for collision bulkheads, refinement of the formula for the bottom damage to be considered, extension of bottom damage across a longitudinal bulkhead and collision acceleration levels. These, amongst others, will be actively pursued before SLF42 and DE42 (see 2.6.4 below).

2.6.4 Update from SLF41 and DE41

As a result of decisions at SLF41 and DE41, both sub-committees will continue development of the Code through correspondence groups reporting to their sessions in February and March 1999. Also, both SLF42 and DE42 will convene HSC Code working groups and exceptionally, arrangements will be made to have the outcome of the SLF working group available for DE, in order that co-ordinating body may complete the revisions of the whole code at that time.

For completeness the draft reports to DE41 of the Working Group on the HSC Code revisions, and the draft report of DE41 to the MSC are included as **Appendix 4**.

3. CANADIAN-SPECIFIC CONCERNS

3.1 Applicability

The HSC, like all IMO Instruments, is applicable to vessels on international voyages and is not applicable on the Great Lakes. However, it is unlikely that any new vessel would be designed and built without compliance, as, among other reasons, this would severely restrict its resale or operating opportunities. In Canada many of the routes being discussed are international (Canada-US) and the HSC would apply.

Some problems have already arisen due to the freedom to interpret aspects of the code, causing at least one European operator to make changes to comply with one state's interpretation of the code only to find that he failed to comply with the requirements as interpreted by the other state at the other end of his route. These examples were not in the area of damaged stability, however, but clearly need to be addressed to avoid future problems.

3.2 Damaged Stability Provisions

It is our opinion that the issues pertaining to damaged stability that were identified as deficiencies in the code have been largely addressed by the proposed revisions discussed above. Of particular note are the provisions for RO-RO ferry safety that are covered by "calling up" the SOLAS 1995 requirements for RO- RO vessels.

Outstanding issues such as those noted in section 2.6.3 above are of general international concern and not specific to Canada. However, this should not prevent Canada from actively participating in the development of solutions and resolution of the issues as more high-speed ferries come into service here.

The only two issues that might have a specific application that may be of limited interest outside Canada, except in a few northern states are:

- Extent of damage from collision with logs and or ice sheets;
- Extent of icing.

3.3 Extent of Damage

3.3.1 Proposed Code Requirements

As noted above, there is a proposal that has been agreed on to change the extent of bottom damage to reflect important parameters such as ship speed, displacement and bottom plate thickness for vessels that are not ACVs, the previous code requirements having been heavily biased by ACV experience. These recommendations stem from at least two high-speed grounding incidents and reflect the long, raking damage that can be sustained by these craft under these circumstances.

While the current HSC is based on a 10% length damage, the proposed new formula results in much greater damage lengths for a typical small catamaran.

The new formulation for bottom damage is as follows:

$$\text{Longitudinal extent of bottom damage} = \frac{\text{Displacement x (Speed)}^2}{2.5 \text{ x } E_s \text{ x } t}$$

Where:

- Displacement is in tonnes at design waterline
- Speed is maximum speed in m/s of the hull through the water
- E_s is a materials constant = 150 for steel and 75 for aluminum
- t = bottom plating thickness in millimetres

The results of the use of the proposed new formulae for a typical 40 m catamaran of 160 t displacement and a maximum design speed of 35 kn, along with variations in key parameters, are shown in **Figures 3.1(a) to (c).** There is a concern that the formulae can calculate a damaged length that is longer than the vessel length, in which case the formula should state that (obviously) the vessel length is taken.

There are three proposed formulae for the extent of side damage, which do account for displacement but not speed or shell thickness. They are:

$$\text{Extent of side damage} = .75 \text{ x (Displacement)}^{1/3}, \text{ or}$$
$$= 3 \text{ m} + 0.225 \text{ x (Displacement)}^{1/3}, \text{ or}$$
$$= 11 \text{ m}$$

whichever is the LEAST.

There is provision that the bottom damage will never be less than the side damage. Typical side damage results are also shown in the Figures 3.1(a), (b) and (c).

Figure 3.1: Extent of Damage for a 40 m Catamaran

Figure 3.1(a) As a Function of Speed

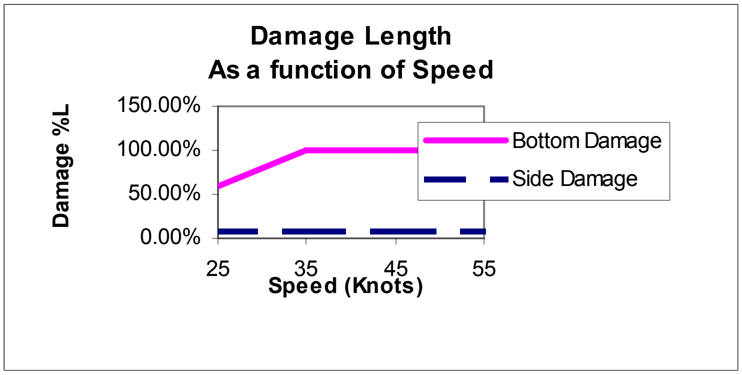


Figure 3.1(b) As a Function of Thickness

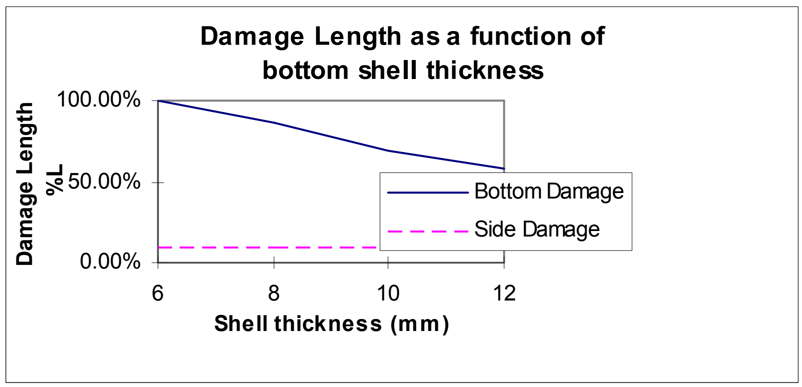
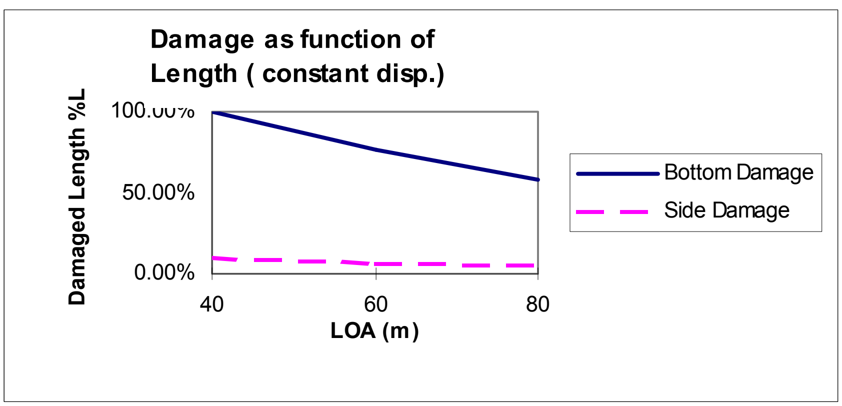


Figure 3.1(c) As a Function of Vessel Length



It is noted that neither the original HSC Code nor the proposed amendments provide a definition of "side" and "bottom" for this purpose.

The Canadian considerations here are whether or not these damage formulae are applicable to:

- damage due to impact with logs "deadheads",
- damage due to inadvertent contact with sheet ice.

3.3.2 Impact with logs

Generally a collision with a deadhead may, in extreme cases, cause an initial impact that will affect a small area of the hull, and is unlikely to open up a long damage on the side. While a log may bounce along a hull, it is not likely to have sufficient residual energy after the impact to cause penetration, unless the vessel is in shallow water and the log is grounded, in which case it acts like a bottom feature. It is our opinion that the requirements for extent of side damage are adequate to address the consequence of such an impact.

3.3.3 Sheet Ice

Operation of fast craft in ice-covered waters is not addressed anywhere in the HSC Code and, given the structure of these craft, is considered to be a situation causing restricted operation or complete shutdown of operations. However, it is felt that this is a situation that should be addressed in the future.

Dealing specifically with the damage extent aspects, it is feasible that a craft operating in Canada at the ends of the season may find itself potentially in contact with surface sheet ice, in say, the harbours. In such cases the ship speed will be slowed and damage unlikely.

However, in the event the ship encounters an ice edge at speed, the potential for a long, raking damage at the waterline exists, particularly with an unbroken, fresh water ice edge against the aluminum hull such as may be experienced in the Great Lakes. In these circumstances, the proposed formulations for side shell damage may not be adequate.

Further investigation of this may be required if operating certificates are awarded to ships in potentially ice-covered areas, such investigation examining the structural response of a typical aluminum structure also, to assess the probability of hull penetration.

Ideally the Code would introduce some minimum waterline structural scantlings for ships operating in ice-covered waters, together with side damage extent formulations that would include plate thickness and possibly speed in a manner similar to that for the bottom structure, that would result in a comparable risk of damage extent to that for non-ice operating ships in open water. These would only apply to vessels likely to operate in ice-covered waters.

3.4 Extent of Icing

Canada has a specific interest in icing as the major area of icing probability noted in Annex 5 of the HSC Code is off the Canadian East Coast and the North Atlantic. This area includes, for example, Newfoundland, Nova Scotia, Nova Scotia-Maine, and the Bay of Fundy.

The current extent of icing is expressed in the following four statements in Annex 5 of the HSC Code:

1.1 For craft operating in areas where ice accretion is likely to occur, the following icing allowances should be made in the stability calculations:

1.1.1 30 kg/m2 on exposed weather decks and gangways.
1.1.2 7.5 kg/m2 for projected lateral area of each side of the craft above the waterplane.
1.1.3 The projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging and the projected lateral area of other small objects should be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.
1.1.4 Reduction of stability due to asymmetric ice accumulations in cross-structure.

These allowances are augmented by an ice mass multiplier if the vessel is operating in areas prone to severe icing conditions, whose co-ordinates are defined.

These icing provisions appear to have been adopted from surface ship requirements with little consideration for the special configurations of fast craft. They were examined and the following problems identified.

1. The definition of side icing is somewhat ambiguous as to whether the icing is on *both* or *either* side.
2. Accretion on forward end of superstructure is not included even for sloping superstructures. A clear definition for ice accretion according to angle of the superstructure may be required, in essence, when is a highly sloping superstructure an exposed deck?
3. Ice accretion on the hull of the vessel and on the pontoons of multi-hull craft is ignored. For vessels operating in a non-displacement mode, such as hydrofoils and foil-assisted catamarans, the hull becomes a potential source of ice accretion. On wave piercing catamarans, the tips of the pontoons jut ahead of the sides of the vessel exposing them to weather and waves. Ice could accumulate on these surfaces as well as on the inner surfaces of the multi-hulls.

4. While asymmetric loading of the crossdeck structure (with ice) is to be taken into account in accordance with the HSC Code, but the method of application of this is not stated and could be better defined.
5. However, the longitudinal distribution of icing is not specified. The effects of a build-up of ice, say on the sloping foredeck, is not covered. There is insufficient knowledge at this time to determine how the ice may be distributed longitudinally as a function of craft configuration and type.

The calculation required by Annex 5 covers ice accretion over the entire projected side of the craft. It is not clear if this is realistic given the spray patterns of these craft and the high, full-length superstructure of vessels such as the HSS 1500.

To illustrate this point, **Figure 3.2** is included. This photograph shows the InCat 91 m wavepiercer which is planned to be in service in the Bay of Fundy area in 1998. The figure illustrates the spray pattern, and suggests that icing may occur aft, in the areas of the intakes, its accretion exacerbated by fittings, etc.

To determine how important the icing issue is, and to determine whether there are ambiguities in the code, a number of calculations were performed using the HSC Code and Annex 5 on a typical vessel, a 40 m Foil Cat **(Figures 3.3).** The calculations are included in **Appendix 5** and summarized in **Table 3.1**. The calculations were performed with the current code and with an additional consideration of icing over a forward sloping superstructure.

Table 3.1 Summary of Icing Calculations

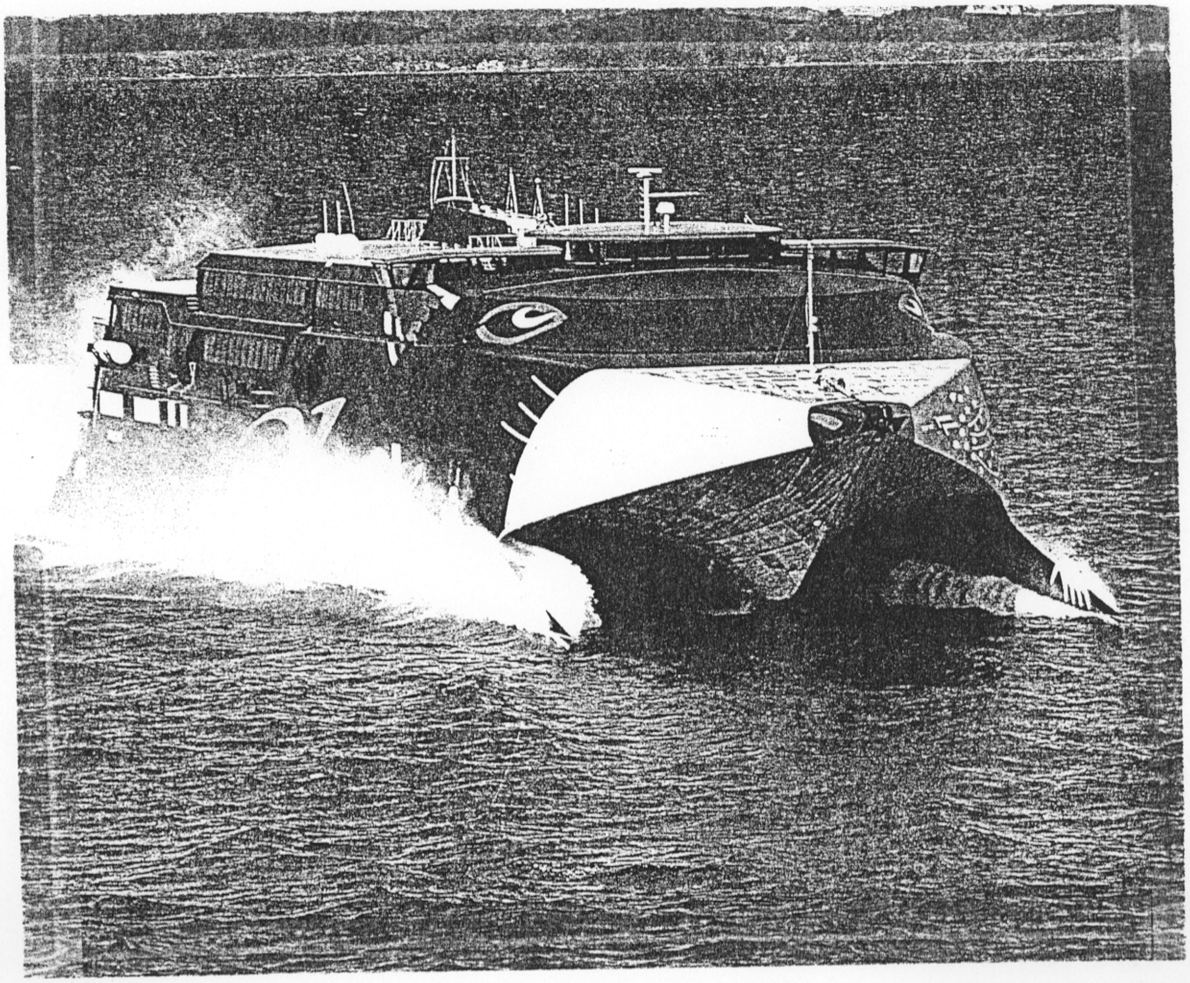
Vessel 40 m Foil Cat (150 t displ.)	Current Code	with fore S/structure
Added Weight	Up 8.5 t or 5.72%	Up 10.27 t or 6.78%
Effect on Vertical cg (KG = 4 m)	Up 130 mm or 3.27%	Up 154 mm or 3.87%
Trim effect (design 30 cm bow down)	Aft by 7.5 cm	Down 1.17 cm

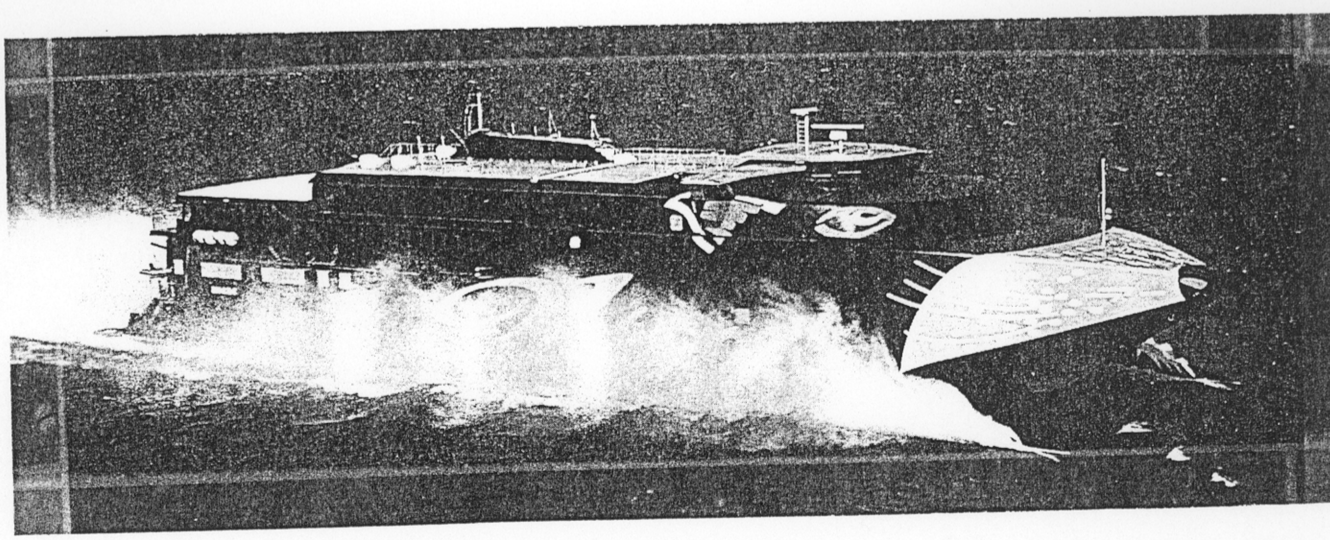
An additional observation, particularly considering the icing of the inner hulls and pontoons (point 2 above), is the potential impact of icing on the dynamic stability of the craft in addition to conventional static stability criteria. While most modern high-speed craft use a ride control system that might compensate for an icing load, the consequences of a severe "pitch down" due to icing build-up could result in serious injury to passengers as well damage to the vessel.

While the effect on damaged stability was not checked under this project, there may be some even more significant impact on this condition.

From this exercise, we concluded that the impact of icing on the weight, stability and trim of a fast craft may be significant, affecting operations, and that there is some room for interpretation of the existing code. For example, there is some ambiguity in the application of the side ice accretion formula to one or both sides.

Figure 3.2 InCat 91 m Fast Ferry at Speed
(Photo courtesy Fast Ferry International)





Flying Cat 40m *Baltic Jet*	
Length overall	40.00m
Beam moulded	10.10m
Depth moulded	3.97m
Draught	
- Without T-foils	1.60m
- With T-foils	2.20m
Gross tonnage	480 grt
Passengers	
- Main saloon	229
- Upper saloon	112
- Total	341
Service speed	
- 43 dwt/100% mcr	30.5 knots
- 43 dwt/90% mcr	29.8 knots
Main engines	2 x MTU 16V 396 TE74L 2,000 kW at 2,000 rpm
Auxiliary power	2 x MTU 68 kW
Waterjets	2 x KaMeWa 63 SII
Classification	Germanischer Lloyd + 100 A5 HSC-B 0 C2 High Speed Passenger Craft + MC HSC-B

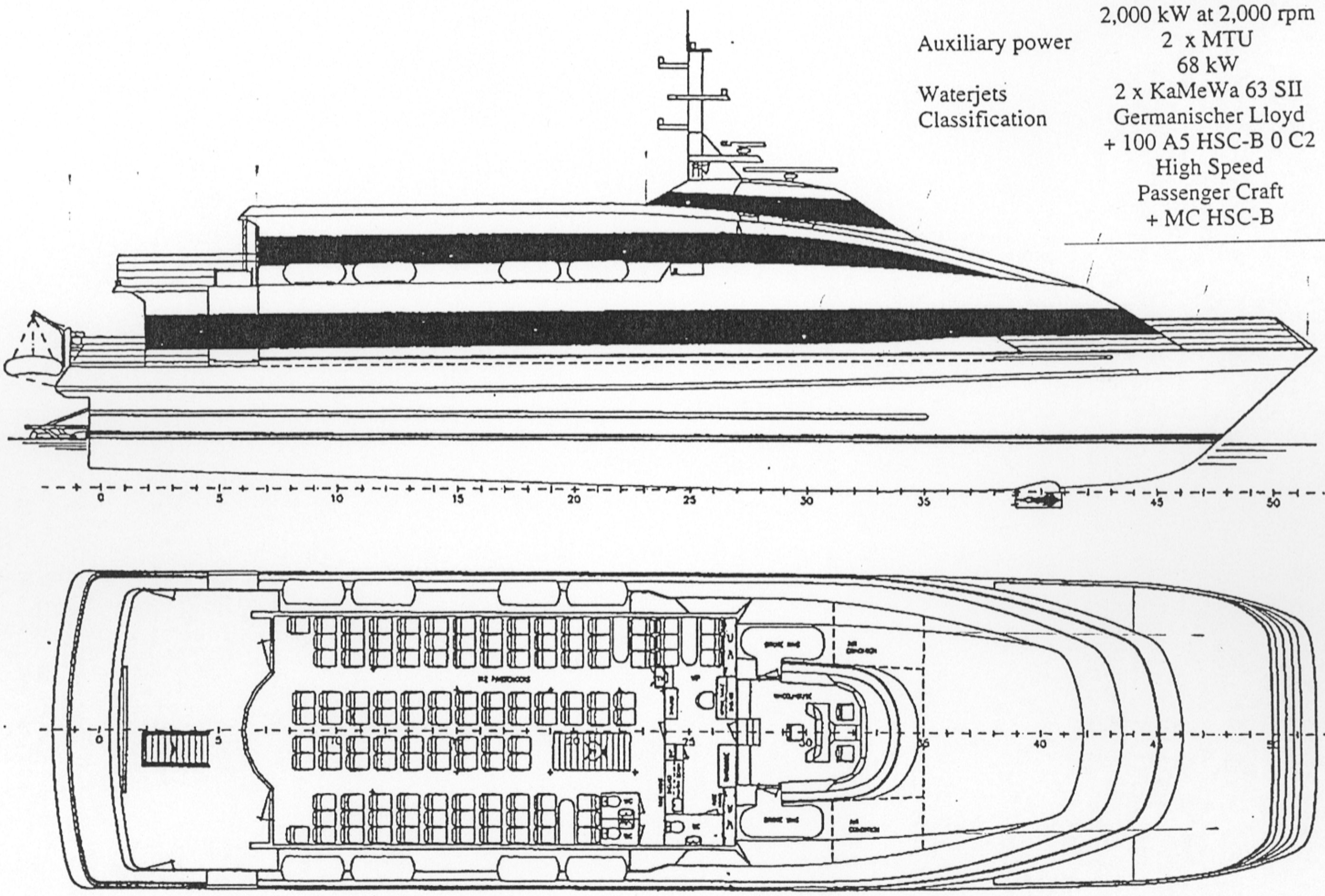


Figure 3.3 40 m FoilCat Catamaran

This vessel was chosen as it is one of the most prolific vessels in service worldwide.

4. DISCUSSION OF FINDINGS

In the area of damaged stability, the proposed amendments to the HSC appear to address most of the issues left unclear in the earlier code, with some notable exceptions. These are not necessarily specific to Canada. The recommendations for acceptable stability criteria in the damaged condition, resulting limiting angles of heel, areas under the GZ curve, and wind heeling, etc., seem to be appropriate.

Some guidance on when to use the craft specific Annexes (Multi-hulls and Hydrofoils) or some rationalization of Chapters 2 and 4 and the sections on stability criteria to assist in dealing with the different craft, particularly with hybrid vessels, remains to be addressed and is desirable.

Only two areas require some further discussion in the Canadian Specific context. These are *extent of damage due to collision* on the side with logs and/or ice, and *icing*.

Canadian operations may see impact with logs (deadheads) and some investigation should be made to ensure that such an impact will not result in penetrating damage on the side of the vessel which exceeds the currently proposed rules in the HSC Code.

For impact with ice, the currently proposed code is not likely to be adequate in the event of a hull-penetrating side impact. A formula for the side shell, similar to that proposed for the bottom, accounting for the side shell thickness and the ship speed and displacement, may be more appropriate for vessels likely to encounter ice. This could be used to determine a maximum allowable speed when there is ice around.

In addition, some clarification of the definition of side and bottom structure is desirable.

It has been shown that the application of the icing formulations that appear in Annex 5 of the HSC code and are reproduced herein as Appendix 5, may be inadequate. No proposals for changes to these have been put forward to date, and this issue was not formally discussed at the recent DE41 meeting; however, informal dialogue with northern states indicated that some work in this area may be required.

The issue is that the area over which the ice accumulation is to be calculated is rather poorly defined given the configuration of some of the more recent vessels. We demonstrated the impact of assuming the whole of a sloping superstructure front is an exposed deck. In some configurations, the forward, upper vehicle deck is open at the top, but well sheltered by high, sloping bulwarks.

Another issue with multi-hulls is the potential for ice accumulation on the *inside* of the hulls and the underside of the main deck. Does the amount of ice forming there depend on the height of the cross deck above the waterline? Also, to what degree do wavepiercing configurations improve or detract from ice build-up on the hull?

The icing issue may be of more significance with regard to:

- dynamic stability of the craft (rather than intact static stability)
- the damaged condition rather than the intact condition

It is our conclusion then that there is some work to be done in the area of definition of when and where icing accumulation occurs.

Finally, since the recent DE41 meeting did not ratify all of the proposed amendments to the HSC Code in these areas, Canada should continue to participate actively in the correspondence group and subsequent working group if it is formed, in order to ensure that these amendments are passed into practice.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview

It was the objective of this short study to review the status of the HSC Code and the proposed amendments and determine whether there were any issues in the area of *damaged stability* that were of concern in the Canadian context and to identify what action was needed.

This study reviewed technical papers, publications and IMO correspondence and position papers relating to changes needed to the HSC Code since its publication in May 1994, and discussed these with Transport Canada Marine Safety Directorate personnel.

We were also able to participate directly in the DE41 committee of IMO and the HSC Working Group and to discuss the issues with various National representatives.

As a result of this we have drawn some conclusions that are of a technical nature and some that are more concerned with our participation in IMO; we have also developed some recommendations.

These recommendations were made with full knowledge of the R&D funding position for this type of effort in Canada. Nevertheless, it is noted that in the near future, the second largest catamaran RO-RO ferry in the world will be operating on the West Coast; a fast-ferry route will be starting on the Atlantic coast; in the icing area, although on a seasonal basis, fast catamarans are operating in the lower Gulf of St. Lawrence. Canadian Coast Guard is taking delivery of very large ACVs for use in ice-covered waters, and there are proposals for a ferry service on Lake Ontario between the US and Canada.

5.2 Conclusions

- The majority of major shortfalls in the HSC Code of 1994 in the area of damaged stability and related matters are dealt with satisfactorily in the proposed agreed revisions to the Code tabled at the DE 41 meeting in March 1998. Some of these were adopted, but others will be dealt with in forthcoming meetings.

- A review of the codes suggests that they are generally adequately phrased to encompass current configurations of vessels and projected configurations such as "Outriggered" catamarans.

- An opportunity remains for improving the guidelines on when to use the various Annexes pertaining to stability for vessels that are hybrids of multi-hulls, hydrofoils, etc.

- The formulations for extent of side and bottom damage have been changed and appear satisfactory for normal collisions. The final wording and approval of these formulations has been deferred to the SLF42 and DE42 committees for this coming year, and this provides an opportunity to ensure that they are "fine tuned", for example, by adding a definition of side and bottom shell. However, the following two Canadian operating situations may require more investigation:

  a) Collision with logs causing damage to the side shell are unlikely to cause damage larger than will be used in damage stability calculations based on the new formulae for side shell damage extent, but this should be monitored for future reference as operating experience is gained in Canada.

  b) It is not known whether the side shell damage formulations are adequate for collision with the edge of an ice sheet, a possibility that exists in future Canadian operations. While the length of side damage from a moving collision with an ice edge may exceed that in the proposed formulae, it is not known to what degree the structure can resist penetration from such a collision.

- The definition of the extent of *icing* to be considered in stability calculations is somewhat imprecise given the various configurations of fast craft currently in service and planned. The current code refers to exposed decks and does not recognize the 'tween hull areas of multi-hulls, nor define the effect of a low sloping superstructure. In the absence of information on the icing of multi-hulls in particular, this may be an area where some research is needed to better define the design requirements.

- With the introduction of a number of high-speed ferry operations in Canada in the near future, and the presence of several ACVs, Canada should remain active in the IMO working groups and committees that are striving to improve the HSC Code. A modest effort to contribute in areas of particular interest to Canada, such as icing, may be valuable in ensuring that Canada's concerns are considered at IMO meetings. There appears to be some international support for investigating the provisions for icing.

5.3 Recommendations

The following recommendations are made as a result of this work.

- A small study should be conducted to determine what work has been done to quantify spray generation and icing for fast marine craft in order to plan a modest program to collect knowledge on ice accretion. This study would attempt to access data from the early 1970s when the NATO navies were developing hydrofoils and SESs for open water operation and may have addressed icing problems. Icing experience with Canada's ACV fleet is documented. It should be noted that a current study being undertaken by FTL and Robert Allen Limited in Canada has sought information from current operators on icing problems with fast ferries.

- Following the above study, a plan should be put in place to obtain data on spray and icing. An initial idea may be to install a camera in the 'tween hull area of a catamaran operating on the East Coast to quantify spray patterns that may be used in laboratory icing studies.

- A paper demonstrating the issue as it appears in the HSC with some proposed solutions, should be prepared for submission to the next SLF42, the Stability and Load Line Working Group, who can then raise the issue to the next DE meeting. The timing for this should target October 1998 for the submission to SLF42.

- An investigation into the probability of ice contact causing raking damage to the side of an aluminum craft in the event of contact with an ice edge should be conducted in order to examine the adequacy of the side shell damage extent formulations for vessels likely to encounter ice. This should be coupled with a definition of "side" and "bottom" shell limits.

- Canada should continue to be an active participant in the correspondence group for fast ferries. In view of the potential increase in the number of vessels coming into service and the inherently unique conditions in Canada, participation should be encouraged in the working group on the stability and damaged stability aspects of the HSC Code that may be formed in 1999.

6. BIBLIOGRAPHY

"International Code of Safety for High-Speed Craft" (The HSC Code): International Maritime Organization (IMO), adopted 20th May 1994.

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Blyth, A. G., "The Roll Stability of Surface Effect Ships", RINA 1993

Roberts, S.A., Cook,J., and Matthewson, B., "An Investigation into the Stability and Survivability of Passenger Carrying Catamaran Craft", RINA 1990.

Lee, C.M., "A Review of Some Performance Characteristics of Monohull High-Speed Small Craft", Marine Technology, October 1995.

Blount, D., and Codega, L.T., "Dynamic Stability of Planing Boats", Marine Technology, January 1992.

12th Fast Ferry International Conference, 20-22 February 1996, Copenhagen.

"International Symposium & Seminar on The Safety of High Speed Craft", February 1997, London, April 1997, Shanghai, The Royal Institution of Naval Architects.

APPENDIX 1

IMO DOCUMENTS PERTAINING TO HSC REVISIONS

(*Not available in electronic format/ Non disponible en format électronique*)

DE41/5/5	16 DEC 1997	Sweden
DE41/5/1	28 NOV 1997	UK
DE41/5	24 JUN 1997	WG(Part 1)
DE40/WP.8	13 FEB 1997	WG(Part 2)
DE40/WP.1	10 FEB 1997	Chairman
DE40/WP.9	14 FEB 1997	DE
DE40/8/5	13 DEC 1996	ICS
DE40/INF.2	28 NOV 1996	UK
DE40/INF.3	28 NOV 1996	UK
DE40/8/4	28 NOV 1996	UK
DE40/8/2	15 NOV 1996	UK
DE40/8/1	15 NOV 1996	Denmark, Finland Germany, Norway, Sweden
DE40/8	15 NOV 1996	Denmark, Finland Germany, Norway, Sweden
SLF41/10	16 OCT 1997	China
SLF41/10/2	12 DEC 1997	Norway
SLF41/10/1	30 OCT 1997	UK

APPENDIX 2

IMO PROPOSALS FOR HSC REVSIONS

**(*Not available in electronic format/*
Non disponible en format électronique)**

These documents are the final proposals for by DE 41 in March 1998, subject to the outcome of SLF41 that was held in January 1998.

The documents have been edited to eliminate material not pertinent to stability or damaged stability.

Contents:

SLF/41/10/1
DE/WP/8
DE41/5

APPENDIX 3

REFERENCED IMO DOCUMENTS

(*Not available in electronic format/ Non disponible en format électronique*)

The documents herein are referenced in the final proposals presented in App. 2.

The documents are:

1. Resolution 1 of the 1995 SOLAS conference - revisions to SOLAS Part B Chapter II-1, relating to stability and integrity of RO-RO passenger vessels.

2. Resolution 14 of the 1995 SOLAS conference - regional agreements on specific stability requirements for RO-RO passenger vessels, and instructions for model testing.

3. MSC/Circular 652 - Application of the 1996 LLC to HSC.

4. Regulation 20 of SOLAS Part B, Chapter II-1.

5. MSC 66/2/2/Add.1 - Note by the Chairman of the Panel of Experts on RO-RO ferry safety expressing concern regarding the adequacy of the HSC Code in respect of damaged stability, inner bow doors, water- tight integrity, and stability calculations. It was this note, dated four months before the new HSC Code came into force, that triggered the review of the HSC Code.

APPENDIX 4

DE41 DRAFT REPORTS

**(*Not available in electronic format/*
Non disponible en format électronique)**

APPENDIX 5

Calculation of Ice Accretion Effects on 40 m Catamaran

**(*Not available in electronic format/*
Non disponible en format électronique)**

These calculations use Annex 5 of the HSC Code.