

Improvements and updates to Intact Stability Standards applied to domestic vessels in Australia

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ABSTRACT

The National Marine Safety Committee has recently revised two standards on intact stability, the first dealing with intact stability criteria, the second with stability tests and stability information. The revision incorporates a more performance-based structure with lessons learnt from the application of the previous standards over a 25 year period.

The standard on intact stability criteria has been formulated to widen options for compliance by distinguishing between so-called comprehensive and simplified criteria; and between criteria of general application and criteria for special operations. As an example of the last of these, there are criteria for vessels engaged in towing rather than being applicable to just tugs. Likewise there are criteria for vessels engaged in trawling rather than being limited to trawlers. Significant changes have been made to ensure simplified and comprehensive criteria provide similar safety outcomes; for example heeling moments are now directly comparable. A more performance based approach has been taken for determining the maximum allowable angle of heel resulting from a static heeling moment. A major change has been a significant increase in the minimum assumed mass of persons to take into account the changing demographic characteristics of the Australian population and serious incidents that occurred in the USA.

The standard for stability tests and stability information has also been significantly revised. It has replaced discretionary clauses with specified criteria for the application of inclining experiments, lightship measurements, simplified stability tests, draft markings, stability books, abbreviated stability calculation methods and other forms of stability information. Procedures for inclining experiments and other stability tests have been revised to comply with standard experimental procedure. Both standards have been prepared with significant input from both government and industry stakeholders.

THE NATIONAL STANDARD FOR COMMERCIAL VESSELS

Responsibility for the safety regulation of domestic commercial vessels in Australia is split between the Commonwealth government and the various State and Territory governments. The National Marine Safety Committee Inc (NMSC) was established to facilitate national consistency and mutual recognition between these jurisdictions. As part of its work, the NMSC is reviewing standards for domestic commercial vessels. The current standards for intact stability are contained in the Uniform Shipping Laws Code¹ (USL Code). A new standard called the National Standard for Commercial Vessels² (NSCV) is being developed to replace the USL Code.

Subsections 8A, 8B and 8C of the USL Code specify the current standard for intact stability. These standards were developed in the 1970s. Starting with what were largely the SOLAS Regulations and US Code of Federal Regulations of the day, the USL Code stability standards were developed incorporating modifications that were distinctly local.

The standards writing activities of the NMSC are governed by a Strategic Plan³ that arose from a Council of Australian Governments agreement⁴ and has been endorsed by the Australian Transport

Council. The Strategic Plan contains a number of principles that shape the revision of standards for commercial vessels, including standards that apply to intact stability. These include:

- Incorporate recognized and relevant national and international standards;
- Encourage professional competence;
- Incorporate a performance-based approach;
- Facilitate approval of new technologies;
- Incorporate OH&S principles;
- Encourage recognition of duty of care; and
- Develop the safety system based on sound information.

The current USL Code is largely prescriptive in its application. The strategic principles require the revised standards to incorporate a performance-based approach, with a greater awareness of the safety outcomes and improved flexibility of application; but with compatibility with other relevant standards and while maintaining national consistency and mutual recognition. This provides a challenge for a number of reasons that include:

1. The “science” to model and determine the adequacy of a vessel’s intact stability taking into account the full range and probabilities of potential environmental and operational factors is still in its relative infancy.
2. Flexibility can sit awkwardly with the objective of national consistency and mutual recognition, unless the flexibility can be limited to the method of solution, while there remains consistency in the achieved safety outcomes.
3. Relevant national and international standards are themselves in a state of continual flux, and they do not necessarily sit consistently with one another.
4. The benefits of standardization have to be weighed against the costs associated with changing from the current system, including its impact on existing designs.

The process for developing standards requires input from key stakeholders at crucial stages in accordance with Council of Australian Governments’ Guidelines for Standards Setting Bodies⁵. Stakeholders are involved in the drafting, public comment and review of public comment phases. A regulatory impact statement is prepared to identify the impacts and consider their benefits and costs. Stakeholder participation serves to focus the review on issues of major import and as a barometer to check that the proposed changes on the industry are viable and justifiable.

THE NATURE AND MAGNITUDE OF INTACT STABILITY RISK

Incidents involving inadequate intact stability are amongst the most unforgiving that can befall a vessel. This is because capsize can be very sudden giving little or no time to take reasoned steps to mitigate the consequences. With so little time to prepare, responses tend to be desperate and instinctive, and the chances of survival through the various stages of escape, evacuation, immersion and rescue are far from certain.

This is illustrated by the fact that capsize was the initial incident in 36% of fatal marine accidents (both commercial and fishing) in Australia from 1992 to 1998 (O’Connor 2004⁶).

Inadequate intact stability is a latent defect that just requires the right combination of factors (loading, wind, waves, heading, etc) to become manifest. The highly sporadic nature of occurrence (just the right combination of factors) plus the likely catastrophic nature of its consequences means that reliance on limited statistical data can be highly misleading and dangerous. This is the type of hazard that may not occur for decades within a region, but then happens with high mortality from a single incident. Before the incident, the statistics look favourable. After the incident, the data is often regarded as being skewed by the single occurrence – or was it? Under the HSC Code 2000⁷ Annex 3, the tolerable probability of catastrophic loss is greater than 1×10^{-9} per hour of operation.

This equates to once in every 114,000 years^a of operation assuming 24 hours operation per day. It would probably take six or more times this amount of operation before a reliable trend could be observed. Hence, there is a need to keep statistical data in perspective as a tool rather than as a proxy for the decision maker.

An analysis of 108 Australian commercial vessel incidents over the last 15 years is given in Figure 1 (Flapan 2007)⁸. Intact stability may have been a direct contributor to the fate of vessels that foundered and were lost or missing, amounting to 58% of the total. Intact stability may play a more indirect role in the loss of the further 29% of vessels that were wrecked or involved in collisions.

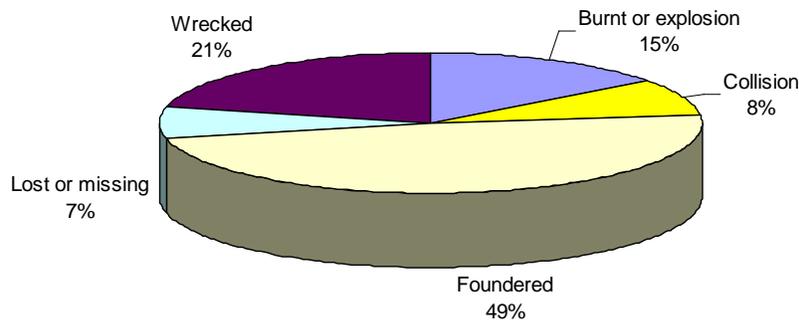


Figure 1—Analysis of 108 Australian vessel losses 1992-2007 (Flapan 2007)

An analysis of 1326 incident statistics for commercial vessels in Australian jurisdictions over the years 2005-2006 (NMSC 2007)⁹ indicates that potentially intact stability related incidents (swamping, capsizing, loss of stability and loss or presumed loss of the vessel) accounted for only 5.1% of the total. However, the relatively low occurrence is to be expected given the catastrophic nature of the consequences discussed above, and should not be grounds for complacency.

Anecdotally, there have been concerns raised as to the intact stability performance of the domestic Australian fishing fleet. Deaths of commercial fishermen are the overwhelming majority of commercial fatalities (41 out of 49). Of these, about 40% of incidents were classified as the sort that may be associated with a stability problem, comprising capsized 18%, sinking 18% and loss of stability 5%. (O'Connor 2004).

An analysis of Australian and New Zealand commercial vessels lost by foundering (Flapan 2007) highlights the relatively high proportion of fishing vessel losses attributed to capsizing. Of the total 32 fishing vessels that are recorded as having foundered since 1992, 43% were attributed to capsizing. Of the remaining 21 vessels, all of which were not engaged in fishing, capsizing accounted for 20%. In addition, 3 of 4 vessels that went missing during this period were fishing vessels.

Part of the explanation could be the relatively hazardous nature of fishing that increases the exposure of the vessel to the combination of critical factors. However, another more compelling reason is the relatively large proportion of the existing fishing fleet that still have not had stability characteristics verified against the current stability criteria. Prior to the introduction of the USL Code, very few fishing vessels were subjected to stability analysis. For historic and other reasons, the uptake of standards for fishing vessels has lagged behind those for other vessels. Thus, the relatively high stability losses in the fishing fleet are likely to be more a function of problems in implementation rather than the standards themselves.

^a While the period of 114,000 years appears excessive, another perspective can be gained by comparing it against other everyday events such as the likelihood of winning the NSW Lotto game. Statistically, if a single game is played every hour, the player could expect to win the major prize once every 580,000 years. This means that the acceptable probability of being on a commercial vessel during a catastrophic incident (a fatality of loss of the vessel) caused by any one hazard is five times greater than winning the major prize in Lotto.

THE REVISED STANDARD HAS A MORE USER-FRIENDLY FORMAT

The review of the intact stability standards has involved the complete restructuring of the format. The stability subsections that comprise NSCV Part C Section 6—Stability are arranged as shown in Table 1. Intact stability criteria have been separated from the requirements for stability tests and stability information. The stability tests are considered to be procedures for input, while the stability information provisions are specifications for output. Subsections 6A and 6C have been completed and are the subject of this paper. Work on Subsection 6B Buoyancy and Stability after Flooding is currently underway. Subsection 6C Stability Tests and Stability Information will be expanded to accommodate specific damaged stability information once Subsection 6B has been finalised.

Table 1 – Structure and contents of NSCV Part C Section 6 Stability

Subsection 6A	Subsection 6B	Subsection 6C
Intact stability criteria	Buoyancy and stability after flooding	Stability tests and stability information
1 Preliminary	Under development	1 Preliminary
2 Intact stability outcomes and solutions		2 Required outcomes
3 Determining the applicable intact stability criteria		3 Methods for establishing and verifying lightship particulars
4 Maximum displacement and longitudinal stability criteria		4 Methods for conducting simplified stability tests
5 Comprehensive stability criteria of general application		5 Presentation of Stability Information
6 Additional comprehensive stability criteria for special operations		6 Arrangements for determining draft
7 Simplified criteria of general application		
8 Simplified criteria for vessels engaged in special operations		

Key changes in the format include the following:

- The incorporation of objectives and required outcomes in accordance with the performance-based approach being adopted for the NSCV¹⁰.
- A clear differentiation between so-called comprehensive and simplified criteria, comprehensive criteria being defined as those for which a righting lever (G/Z) curve is derived.
- Clarification as to the application and options available for criteria
- Separation of prerequisites for the application of criteria as compared to criteria themselves.
- Presentation of criteria in a tabular format with numbering to reduce errors and omissions.
- The aggregation of methods of calculation as Appendices.
- Increased use of illustrations to facilitate understanding and reduce the need for interpretations.

SPECIFIC ISSUES ADDRESSED BY THE REVISED STANDARDS

Authority discretion

Many of the USL Code provisions were expressed in a way that provided for or even required surveyor discretion in order that the provision is applied. This resulted in inconsistent application of the standards. While still available in the assessment of an equivalent solution, surveyor discretion has been largely eliminated for the application of the deemed-to-satisfy solutions. This has been achieved by identifying the factors upon which discretion would have been exercised and incorporating that information as part of the standard.

Removal of anomalies between simplified and comprehensive criteria

The USL Code Subsection 8C¹¹ contains both comprehensive and simplified stability criteria. There are significant differences in the requirements and costs of the two, with the simplified criteria being much cheaper to verify. The anomaly arises because the simplified criteria also specify a lower threshold for compliance than if the same vessel were measured against the comprehensive criteria, notwithstanding that the methodology is more approximate and subject to error. Figure 2 illustrates the righting lever curve of a vessel that would meet the simplified Category S criteria from the USL Code, but would be unable to comply with the comprehensive Category P criteria. This means that vessel designers and builders argue strongly for the use of the simplified criteria, even when it is clear that the vessel form and/or operations are not properly suited to the application of simplified stability testing methods.

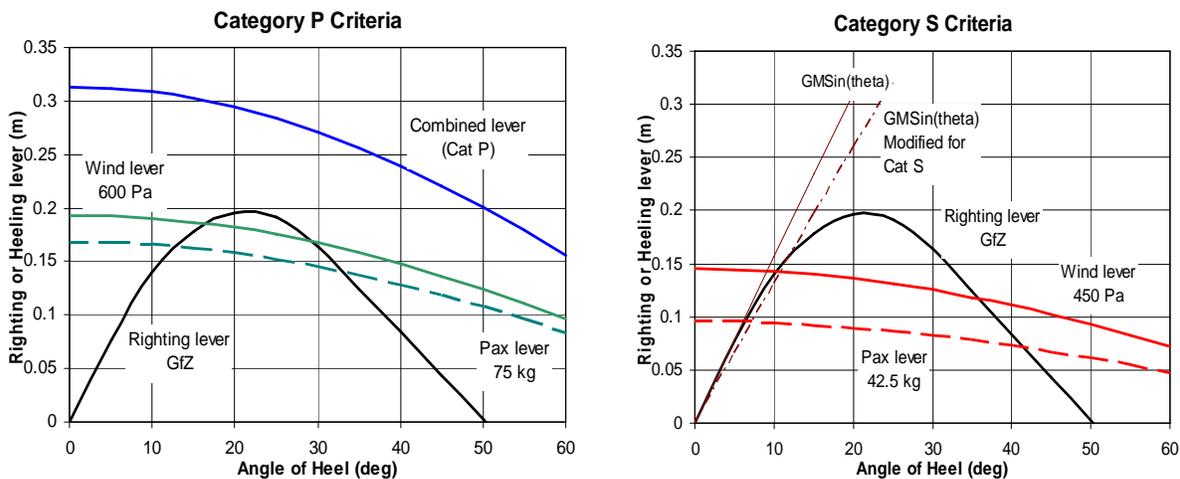


Figure 2—Comparison of Category P versus Category S criteria

The anomaly has been addressed by modifying both the comprehensive and simplified criteria so that they are consistent. The simplified criteria have been modified by:

- adjusting the passenger heeling moment to align with that used for comprehensive criteria;
- providing for testing in near laden and near light conditions of loading; and
- applying criteria for turning moments.
- allowing comparable angles of heel from single heeling influences

To help compensate for the increased threshold for stability, a safety margin that was previously added to the Australian simplified criteria has been removed, aligning the criteria to the original source criteria¹². Likewise, the comprehensive criteria have also been modified to better align with the simplified criteria by:

- allowing for comparable wind heeling moments for sheltered waters and restricted offshore operations;
- removing the combined lever requirement for vessels of size and area of operation similar to that for which the simplified criteria could apply.

Rationalization of the allowable angle of heel criteria

The USL Code criteria specify maximum allowable angles of heel that vary between 5 degrees for certain crane barges to 15 degrees for combined heeling moments. The requirements were inconsistent in that certain vessels applying Category S or T (simplified criteria) could apply up to

14 degrees for a single heeling moment, while the same vessel applying Category P, Q or R (comprehensive criteria) could only apply up to 10 degrees. The anomaly was sometimes overcome administratively by the Authorities having discretion to increase the allowable angle to greater than 10 degrees. However, this concession was exercised inconsistently and without guidance. The approach taken has been to specify performance-based maximum angle criteria within the standard itself. The maximum allowable angle of heel is determined by the risk characteristics of the vessel and its operation, see Table 2. The result is that the criteria can accommodate the different characteristics of a wide variety of vessels including most monohull sailing vessels that are arranged to sail at relatively large angles of heel.

Table 2 — Maximum allowable angles of static heel

Heel consequence level	Allowable maximum angle of static heel for heeling moment(s)		Conditions of application
	Single θ_s degrees	Combined θ_c (A) degrees	
1. High	5	5	No specified conditions of application – applicable to any vessel that is unsuited to the application of large values of heel.
2. Moderate	10	15	θ_s or θ_c (if combined lever criteria are applied) may exceed 5 degrees where— <ol style="list-style-type: none"> 1. if the vessel is fitted with a slewing crane that is subject to the lifting criteria, the crane is capable of safe operation at angles of heel up to at least θ_s, and 2. if the vessel is carrying unsecured deck cargo, the deck cargo shall either— <ol style="list-style-type: none"> i) comprise vehicles having rubber tyres; or ii) have a maximum potential moment from cargo shifting that does not exceed 20 per cent of the greatest value of M_P, M_W or M_T.
3. Low	14	18	θ_s may exceed 10 degrees or θ_c (if combined lever criteria are applied) may exceed 15 degrees where— <ol style="list-style-type: none"> 1. all cargo including deck cargo is secured against shifting; 2. seating is provided for all persons; 3. furniture is fixed when in use and/or when stowed; 4. sufficient grab rails are provided in spaces that normally contain persons; and 5. decks and deck surfaces are arranged to reduce slipping hazards.

KEY:

(A) Combined moments apply only where combined levers are specified in the criteria.

Clarifying the application of wind heeling moments

The Category P, Q and R criteria USL Code do not specify the nature of the wind heeling lever; i.e., whether it should be applied straight line, to the cosine of the heel angle, or to the square of the cosine of the heel angle, see Figure 3. As a result, different approaches have been adopted by the various jurisdictions. The new standard specifies that the wind heeling lever should reduce by a factor of $\text{Cos } \theta$ for criteria of general application. This takes into account the resolution of wind force that is normal to the projected surfaces but does not take into account any reduction in area because, as a three dimensional object, the projected area tends not to reduce at heel angles less than 40 degrees. The more conservative straight line wind lever adopted by IMO was considered but not adopted because it would be inconsistent with the $\text{Cos } \theta$ factor used for the simplified criteria (see above). Furthermore, the drafting group considered that the costs of applying the more conservative IMO approach could not justify the benefits; especially given that the larger passenger vessels have additional criteria applicable to the combined lever. It was noted that the wind moment calculation was, at best, a broad approximation with no consideration being given to wind gradient effects or drag coefficients.

The wind heeling lever applied to vessels that carry sail was also revised. The USL Code criteria had been based on the US CFR46 criteria¹³ that applied $\text{Cos}^2\theta$. However, subsequent investigations by the Wolfson Unit in the UK¹⁴ based on wind tunnel testing indicated that a more appropriate factor for sailing vessels was $\text{Cos}^{1.3}\theta$. A subsequent amendment to the USL Code¹⁵ allowed the alternative application of criteria based on the MCA Standard¹⁶ that applies $\text{Cos}^{1.3}\theta$. The new standard retains both sets of criteria applicable to vessels that set sail. However, the different methods of calculation were inconsistent with a performance based approach. This was resolved by applying the more soundly based $\text{Cos}^{1.3}\theta$ factor to both sets of criteria, see Figure 3.

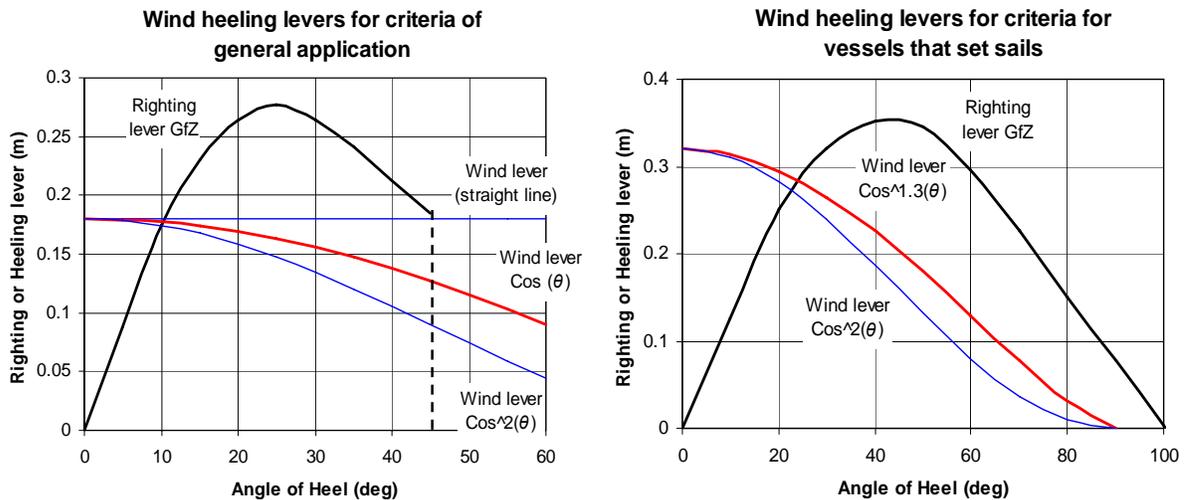


Figure 3—Comparison of wind heeling lever factors

Maximising the choice of applicable criteria

The USL Code specifies a single set of criteria applicable to a particular vessel. It then says where a vessel fails to meet the relevant criteria then the marine authority may apply discretion as to the application of alternative criteria. This leads to variations in the application of stability criteria. The revised NSCV standard is arranged so to maximise the choice of deemed-to-satisfy criteria available without having to go to the Authority for a ruling. Criteria that are better suited to catamaran vessels have been added based on HSC Code 2000 Annex 7. Criteria have also been provided for collared vessels (including RIBs). Standards that were applicable only to Hire and Drive vessels are now available for other vessel types where they have a similar area of operation and configuration. While all vessels can apply at least one set of comprehensive criteria, certain vessels can also choose between one or more sets of simplified criteria.

Criteria apply to special operations rather than particular vessel types

The USL Code contains criteria applicable to particular vessel types such as sailing vessels, tugs, trawlers, crane barges. The revised standard specifies ‘additional’ criteria applicable to vessels when engaged in special operations such as carrying sail, towing, trawling or lifting. This has two benefits. The first is that the widest choice of criteria of general application is maintained. The second is that a vessel may engage in more than one type of operation. Thus, a police boat can apply the towing criteria even though it is not a tug, or a research vessel can apply the trawling criteria even though it is not a trawler. Again, the criteria for special operations have been presented to maximise the choice available.

More realistic assumptions for the mass of persons

The USL Code assumes 75 kg per person for seagoing vessels and 65 kg per person for sheltered water vessels. These are clearly lower than the average masses in the community. Recent incidents in the USA¹⁷ have highlighted the dangers of overloading on passenger vessels with recommendations that the assumed mass of passengers be reviewed. The latest comprehensive data

for Australia¹⁸ (2004-05) on average mass are 84.0 kg for men and 68.1 kg for women, giving an overall average in the order of 76 kg (ABS 2006)^b. In 1995, the figures were 80.2 kg for men and 64.5 kg for women (ABS 1998)¹⁹, indicating an increase in the average mass of the population of about 3.7 kg or 5 per cent in a 10 year period. The minimum assumed mass of persons in the revised standard as given in Table 3. The proposed average mass of 80 kg is in excess of the average 2004-05 figure of 76 kg. The figure of 80 kg was adopted because the average weight figures are likely to underestimate the reality for two main reasons. Firstly, they are calculated from self-reported figures. ABS (1998) reports that the 1995 self-reported average mass is 1.8 kg lower than the measured average mass for males and 2.5 kg for females. Secondly, the masses quoted are likely to be for people when naked; i.e., without taking into account clothing, shoes, keys, wallets, mobile phones, hand bags or other hand luggage carried by day passengers.

Table 3 also specifies the minimum assumed mass for divers. The additional 53 kg for divers includes the mass of diving masses, diving suit, flippers, mask, wet suit, regulator and 2 filled gas bottles. Of the total additional mass, 36 kg is included in the minimum assumed mass of the diver and the other 17 kg is the minimum allowance for the second gas bottle as additional diving equipment. The effect on a vessel of the different minimum values for mass of persons and their effects is illustrated in Figure 4. The change effects both the loading of the vessel (and thus the shape of the G_fZ curve) and the person heeling lever. Note that normally, the number of divers would be reduced to result in a mass comparable to that of passengers.

Table 3 — Minimum values for mass of persons and their effects

Person type	Minimum assumed mass per person Kg per person (w)	Minimum allowance for baggage Kg per person	Minimum allowance for additional diving equipment Kg per person
Passenger or crew day only	80	Nil	Nil
Passenger or crew overnight	80	15	Nil
Diver day only	116	Nil	17
Diver overnight	116	15	17

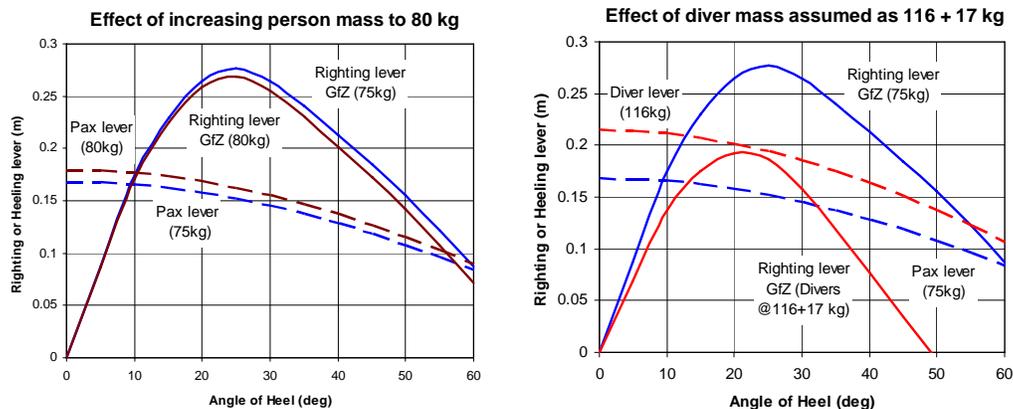


Figure 4—Illustration of the effect on a vessel of assuming 75 kg, 80 kg and diver mass for same total number of persons carried

^b As these figures relate to people 18 years of age and over, they would overestimate the average weight of a person when children are carried and underestimate it when more males than females are carried.

Revised approach for catamarans that set sail

An amendment to the sailing catamaran criteria of the USL Code in 1997²⁰ treats catamarans that set sail in a manner similar to sailing monohulls, applying a criterion that relied on dynamic balance. There were two issues with this approach. The first was that the increased windage effect of the bridge deck as the windward hull emerged was ignored. As well, the assumption that such vessel (not being an off-the-beach sailing catamaran) would still be under control and would properly recover from an incident at a large angle of heel with one hull a-flying was unsound. A criterion developed by Lock Crowther, one of the leading pioneers of sailing catamaran development, for use on his own designs has been adopted. Lock Crowther's approach was to avoid the windward hull emerging in all circumstances by adopting a principle that the draft on the windward hull should not reduce by more than 25% in average conditions. This then corresponds to approximately 50% draft loss during a gust. The approach has been interpreted by specifying a criterion that the heeling lever calculated from the mean wind pressure shall not intersect the righting lever ($G_f Z$) curve at a value not greater than 25% of the maximum righting lever ($G_f Z_{max}$). Because the heel angles are relatively small, there is no need to analyse the increased windage of the bridging deck at large angles of heel.

Stability standards applicable to small fishing vessels

The USL Code does not specify stability criteria for small fishing vessels less than 7.5 metres in length. At the time when the USL Code was first drafted, there were no stability standards applicable to recreational craft in Australia. In recent years, the Australian Builders Plate standard²¹ has required that a large proportion of recreational craft be fitted with a plate declaring that the vessel is capable of carrying a given load and number of persons in accordance with a relevant national or international standard. Maintaining the status quo for small fishing vessels would be inconsistent with the broader policy objectives of the NMSC to incorporate Occupational Health & Safety (OH&S) principles into the standards for the design, construction and operation of vessels and to encourage vessel operators to recognise their duty of care to employees and passengers. It would also be inconsistent with the requirements for recreational vessels.

The revised NSCV stability standard now specifies a range of sets of criteria applicable to small fishing vessels that include the AS1799 standard for recreational vessels²². While the vast majority of these small fishing vessels are not required to carry a certificate of survey under legislation, the criteria will still provide a benchmark for operators having to comply with their Occupational Health and Safety obligations.

Determination of lightship particulars on vessels with large stability

Designers and builders of catamarans have often objected to undertaking an inclining experiment to determine the lightship VCG on the basis that the quantity of inclining masses required to heel the vessel is excessive. The result is high costs to source, verify and transport the masses and difficulties locating, supporting and moving the masses during the experiment. Exemptions from this requirement have been granted subject to a detailed weight estimate being verified by a lightship measurement and the application of a margin of safety in the assumed VCG . Such exemptions are discretionary and have sometimes been applied subjectively and inconsistently. The revised standard allows for the determination of lightship VCG by means of detailed weight calculation with an added safety margin calculated as the lesser of 10% of KG or 0.5 metres, subject to verification of the calculated displacement and LCG by a lightship measurement. The approach is limited to vessels having a ratio of lightship GM_O to KG of more than 2.

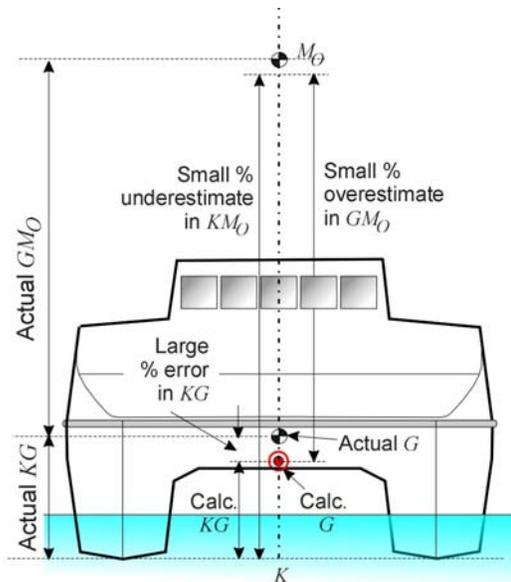


Figure 5—Cumulative effect of errors on vessels with large ratio of GMO to KG

The rationale is illustrated in Figure 5. As the ratio of GM_O to KG increases, errors in the determination of KG will be magnified by any errors in the determination of GM_O and KM_O . For example for a ratio of GM_O to KG of 3, a 2% overestimate in GM_O plus a 1% underestimate in KM_O could result in an underestimate of $2\% \times 3 + 1\% \times 4 = 10\%$ in the determination of KG . Because of the generally favourable stability characteristics of most catamarans, such errors are often of little significance for intact stability. However, catamarans frequently must also be designed to withstand unsymmetrical flooding. The error in KG may invalidate what would otherwise be a compliant damaged stability analysis, resulting in a latent defect that only becomes apparent at time of crisis. The standard acknowledges the limitations in application of an inclining experiment on vessels having a high ratio of GM_O to KG and substitutes a conservative calculation, improving the reliability while saving unnecessary cost.

CONCLUSION

The revision of the USL Code to become the new NSCV intact stability standards have been a process of evolution rather than revolution. The new standard contains many of the same criteria as the previous USL Code. However, these have been updated to reflect the experience of over 25 years of application of the previous standards. The most significant modification has been the increase in minimum assumed person mass, a change which, though unwelcome, was considered necessary if safety standards are to be maintained. The potential impact of greater assumed persons mass could be in some cases an increase in the size of the vessel needed to carry the same number of persons. But other reforms within the new standard should help to offset the additional burden by eliminating inconsistencies, increasing flexibility of application, avoiding the need for interpretation and reducing the likelihood of stability reports having to be reworked²³. The new standards establish the framework for performance-based solutions as an alternative to deemed-to-satisfy solutions. Whilst not providing the performance-based solutions themselves, the standard provides an environment that can accommodate their ongoing development and innovation.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the contributions made to the development of the standard by members of the intact stability reference group and the many stakeholders who provided public comment²⁴. Special mention should be made for the efforts of Graham Taylor, Terry Ehret and Robin Gehling.

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- ²⁴ National Marine Safety Committee Inc. *Review of Public Comment - NSCV Part C Subsection 6A; Intact Stability Requirements*. NMSC Inc. Sydney. 2007. <http://www.nmsc.gov.au/documents/NSCV%20C6A%20RG%20PC%20outcomes.pdf>