# COMMONWEALTH OF AUSTRALIA

# ORDER UNDER SECTION 427 OF NAVIGATION ACT 1912

I, PAUL BARCROFT ECCLES, delegate of the Minister for Transport and Communications, pursuant to section 427 of the Navigation Act 1912, hereby declare that the provisions annexed to this order are the provisions of Sub-section 8C of the Uniform Shipping Laws Code as in existence on the date of this Order.

Dated this day of 1989.

P. B. ECCLES
FIRST ASSISTANT SECRETARY
MARITIME OPERATIONS DIVISION

## CONTENTS

**Sub-section C—Stability Criteria**



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### C.1 Class I Vessels

C.1.1 General Provisions

C.1.1.1 For the purposes of this clause unless otherwise stated:

(a) the standard mass of a passenger shall be taken as 65 kg for operations within sheltered water areas and 75 kg for all other operational areas;

(b) the standard distribution of passengers when crowded shall be taken as 4 passengers per square metre;

(c) each passenger in the crowded distribution shall be considered to cover an area 625 mm x 400 mm;

(d) the vertical centre of gravity of a standing passenger shall be taken as 1 metre above the deck;

(e) the vertical centre of gravity of a seated passenger shall be taken as 300 mm above the seat; and

(f) the angle of flooding $\theta_f$ is the least angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

C.1.1.2 In assessing the angle of heel caused by the crowding of passengers (except as provided in C.1.3.4.1 (a)), the passengers shall be considered to be distributed to produce the most unfavourable combination of passenger heeling moment and/or initial metacentric height which may be obtained in practice, using the standard characteristics given in C.1.1.1.

C.1.1.3 The angle of heel due to wind pressure shall be derived using a wind heeling moment determined from the equation:

$$M = 0.000102\ PAh \text{ tonnes metres}$$

where $P$ = wind pressure in Pascals

$A$ = area of hull subject to wind influence being the projected lateral area of the vessel above the waterline in metres$^2$;

$h$ = lever arm being the vertical distance in metres from the centre of area A to the centre of the projected lateral underwater area.

C.1.1.4 The formula to be used in calculating the heel due to the effect of the rudder when turning shall be:

$$\text{heeling moment} = \frac{0.0053\ V^2\ \Delta d}{L}\ \text{tonnes metres}$$

where V = service speed in knots
L = waterline length of vessel
$\Delta$ = displacement in tonnes
d = vertical distance between the vertical centre of gravity of the vessel and the centre of the projected lateral underwater area in metres.

This formula applies only to vessels where $\frac{V}{\sqrt{L}}$ is less than 4.

C.1.1.5 A passenger vessel of 35 metres and over in measured length in addition to meeting the intact stability requirements of this Sub-section shall also meet the requirements of paragraphs C.11.1 (a) to (d) inclusive of Sub-section C of the Construction Section.

C.1.2 Categories of Service

C.1.2.1 Category P—Vessels of any length which engage in 'Unlimited' and 'Australian Coastal and Middle Water' operations.

C.1.2.2 Category Q—Vessels of:

(i) 20 metres in measured length or over; or
(ii) less than 20 metres in measured length carrying 50 persons or more in addition to the Master and crew;

engaged in 'Offshore' and 'Restricted Offshore' operations.

C.1.2.3 Category R—Vessels of any length carrying 50 persons or more in addition to the Master and crew and multi-deck vessels where the passenger mass/displacement ratio exceeds 0.04, engaged in 'Sheltered Water' operations only.

C.1.2.4 Category S—Vessels of less than 20 metres in measured length carrying less than 50 persons in addition to the Master and crew and engaged in 'Offshore' and 'Restricted Offshore' operations.

C.1.2.5 Category T—Vessels of any length carrying less than 50 persons in addition to the Master and crew and engaged in 'Sheltered Water' operations only.

C.1.3 Criteria to be Applied to these Categories

C.1.3.1 Categories P and Q. The stability is considered satisfactory if:

C.1.3.1.1 The area under the righting lever curve, i.e. the GZ curve, is not less than 3.15 metre-degrees up to 30° angle of heel and not less than 5.16 metre-degrees up to 40° angle of heel or the angle of flooding $\theta_f$ if this angle is less than 40°. Additionally the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and $\theta_f$ if $\theta_f$ is less than 40° shall be not less than 1.72 metre-degrees.

C.1.3.1.2 The righting lever GZ shall have a value not less than 0.2 metres at an angle of heel equal to or greater than 30°.

C.1.3.1.3 The maximum righting lever GZ shall occur at an angle of heel preferably exceeding 30° but in any case not less than 25°.

C.1.3.1.4 The initial metacentric height GM shall be not less than 0.15 metres.

C.1.3.1.5 The angle of heel shall not exceed 10° when any one of the following capsizing influences is applied or 15° when the worst two capsizing influences are applied together:

(a) the moment caused by passenger crowding using the maximum passenger heeling lever;
(b) the wind moment derived from a wind pressure of 600 Pa; and
(c) the moment derived from the effect of the rudder on the vessel when turning.

C.1.3.2 Category R. The stability is considered satisfactory if:

C.1.3.2.1 The angle of heel does not exceed 10° when all persons are crowded on one side of the vessel resulting in the maximum heeling lever.

C.1.3.2.2 The righting lever GZ, at the intersection of the curve of righting levers and the heeling lever curve due to the combined effects of passenger heel and the more severe of either wind or rudder heel, does not exceed 0.6 GZ max.

C.1.3.2.3 The area under the curve of righting levers above the passenger heeling lever curve taken up to the angle of flooding $\Theta_f$ or the second intercept with the righting lever curve (whichever is less), shall be not less than one quarter of the total area under the curve of righting levers up to the angle of flooding $\Theta_f$ or the second intercept whichever is less.

C.1.3.2.4 The wind moment derived from a wind pressure of 300 Pa in smooth water areas and 360 Pa in partially smooth water areas shall not produce a heel angle of more than 10°.

C.1.3.2.5 The moment derived from the effect of the rudder on the vessel when turning shall not produce a heel angle of more than 10°.

C.1.3.2.6 The combined moment due to passenger loading and the more severe of the heeling levers due to either wind or rudder shall not produce an angle of heel in excess of 15°.

C.1.3.3 Category S. The stability is considered satisfactory if:

C.1.3.3.1 The vessel in the intact condition is shown to have a net metacentric height GM, at any operating draft, not less than any of the following taken singly. The most severe requirement shall govern at any draft. Allowance shall be made for normally slack tanks.

C.1.3.3.2 $$GM = \frac{0.046\ Ah}{\Delta \tan \Theta} + 0.15 \text{ metres}$$

where A = projected lateral area of the vessel above the waterline in $\text{metres}^2$

h = vertical distance in metres from the centre of area A to the centre of the projected lateral underwater area

$\Delta$ = displacement in tonnes

$\Theta$ = angle of heel to one half the freeboard to the deck edge, or the angle of bilge emersion or 14° whichever is less. (Vessels having a discontinuous weather deck or abnormal sheer may have a modified value applied for the angle to the one half freeboard).

C.1.3.3.3 $$GM = \frac{N6}{23.5\ \Delta \tan \Theta} + 0.15 \text{ metres}$$

where N = number of passengers

b = distance in metres from the vessel's centre line to the geometrical centre of the deck area occupied by passengers in accordance with C.1.1.2.

$\Delta$ = displacement in tonnes

$\Theta$ = as described in C.1.3.3.2.

C.1.3.3.4 $$GM = \frac{0.0053\ V^2 d}{L \sin \Theta} + 0.15 \text{ metres}$$

where V = service speed in knots

L = waterline length of vessel

d = vertical distance between the vertical centre of gravity of the vessel, and the centre of the projected lateral underwater area in metres

$\Theta$ = as described in C.1.3.3.2.

This formula applies only to vessels where $\frac{V}{\sqrt{L}}$ is less than 4.

C.1.3.4 Category T. The stability is considered satisfactory if:

C.1.3.4.1 The vessel when subjected to the greater of the following heeling moments, does not heel more than 14° provided that the loss of freeboard does not exceed the values set out in C.1.3.4.4.

(a) $M_p = W \times \frac{B_p}{6}$

where $M_p$ = passenger heeling moment in tonnes metres

$W$ = total mass of passengers in tonnes

$B_p$ = maximum breadth of space in vessel which is accessible to passengers in metres.

(b) $M_w = P\,Ah$

where $M_w$ = wind heeling moment in tonnes metres

$h$ = vertical distance in metres from the centre of area A to the centre of the projected lateral underwater area

$A$ = projected lateral area of the vessel above the load waterline in metres$^2$

$P$ = 0.0306 for smooth water areas

= 0.0367 for partially smooth water areas

C.1.3.4.2 The mass of the passengers and other load, if any, shall be simulated by equivalent masses distributed so as to provide normal trim and the most unfavourable vertical centre of gravity (VCG) likely to occur in service.

C.1.3.4.3 On vessels having non-return closures in cockpit scuppers or on weather deck drains, such closures shall be restrained in the open position during the course of the test.

C.1.3.4.4 When subjected to the required heeling moment, the loss of freeboard due to heel measured in way of the point of least freeboard (or at a point 0.75 L from the bow if the point of least freeboard is aft of 0.75 L from the bow) shall not exceed the following:

(a) On flushed deck vessels the freeboard shall be measured to the top of the weather deck at side. The loss of freeboard shall not be more than one half of this freeboard.

(b) On well deck vessels the freeboard shall be measured to the top of the weather deck at side. The loss of freeboard shall not be more than half of this freeboard. In vessels with scuppers rather than freeing ports, immersion to the full freeboard may be permitted provided it does not exceed one quarter of the height from the load waterline to the top of the gunwale.

(c) On cockpit boats the freeboard shall be measured to the top of the gunwale. The maximum reduction in freeboard shall be calculated by:

$$\text{loss of freeboard} = \frac{f(2L-C)}{4L}$$

where $f$ = freeboard when upright in metres

$L$ = measured length of vessel in metres

$C$ = length of cockpit in metres.

(d) On open boats the freeboard shall be measured to the top of the gunwale and the maximum allowable reduction of freeboard shall be one quarter of this freeboard.

(e) Vessels carrying vehicular loads, in addition to complying with the other provisions of this Sub-section shall be tested to determine that maximum trim or heel during loading or unloading will not be excessive.

C.1.4 Special Cases relating to Categories S and T

C.1.4.1 The owner of any vessel which does not meet the criteria specified in C.1.3.3.2, C.1.3.3.3, C.1.3.3.4 and C.1.3.4.1 may, in lieu of complying with those requirements, present a complete stability submission showing conformity with C.1.3.2.

C.1.5 Damage Stability

C.1.5.1 Criteria for damage stability for passenger vessels 35 metres and over in measured length are laid down in clause C.10 and Appendix 2 of Sub-section C of the Construction Section.

C.1.5.2 Criteria for damage stability for passenger vessels less than 35 metres in measured length are laid down in sub-clause C.64.2 and Appendix 3 of Sub-section C of the Construction Sction.

## C.2 Class 2A, 2B and 2C Vessels 24 Metres and Over in Load Line Length

Unless criteria are otherwise specified in this Sub-section all vessels of class 2A, 2B and 2C, 24 metres and over in load line length shall have stability in all probable loading conditions which meets at least the following criteria:

(a) The area under the righting lever curve, i.e. the GZ curve, is not to be less than 3.15 metre-degrees up to 30° angle of heel and not less than 5.16 metre-degrees up to 40° angle of heel or the angle of flooding $\Theta_f$** if this angle is less than 40°. Additionally the area under the righting lever curve between the angles of heel of 30° and 40° or between 30° and $\Theta_f$ if this angle is less than 40°, shall be not less than 1.72 metre-degrees.

(b) The righting lever (GZ) is not to be less than 0.20 metres at an angle of heel equal to or greater than 30°;

(c) The maximum righting level (GZ) is to occur at an angle of heel preferably exceeding 30° but in any case not less than 25°; and

(d) The initial transverse metacentric height is not to be less than 0.15 metres.

## C.3 Class 2A, 2B and 2C Vessels 16 Metres and Over in Measured Length but Less than 24 Metres in Load Line Length and Class 2D and 2E Vessels 16 Metres and Over in Measured Length

C.3.1 Unless criteria are otherwise specified in this Sub-section all vessels of Classes 2A, 2B and 2C 20 metres in measured length and over but less than 24 metres in load line length and Class 2D and 2E vessels 16 metres and over in measured length shall have stability in all probable loading conditions which meets at least the criteria laid down in clause C.2.

C.3.2 Unless criteria are otherwise specified in this Sub-section, all vessels 16 metres in measured length and over but less than 20 metres in measured length, where:

(a) $\frac{f}{B}$ is between 0.1 and 0.2; and

(b) $\frac{B}{D}$ is between 1.75 and 2.15,

may in lieu of the stability data based on the criteria prescribed in clause C.2 ensure that the GM in all probable loaded conditions is greater than that calculated by the following formula:

$$GM\ (Min) = 0.60 + 0.05B - 0.25f \text{ (metres)}$$

where

| | | |
|---|---|---|
| GM (Min) | = | required metacentric height (metres) |
| B | = | moulded breadth (metres) |
| D | = | moulded depth of vessel measured amidships (metres) |
| f | = | smallest freeboard measured vertically from the top of the upper deck at side to the actual waterline (metres) |

***Note:*

$\Theta_f$ is the angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight commence to immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

To determine whether the vessel complies with the sub-clause, the vessel, unless the Authority permits otherwise, shall be subjected to an inclining or rolling period test carried out in the presence of a Surveyor. Where the rolling period test is used the GM shall be calculated from the following formula:

$$GM = \left( \frac{F_r B}{T_r} \right)^2 \text{ metres}$$

where B = moulded breadth (metres)

$T_r$ = time for one complete oscillation (i.e. for one complete roll port-starboard-port or vice versa) (seconds)

GM = metacentric height (metres)

$F_r$ = rolling period factor determined from the following table:

| *Conditions of vessels* | *Rolling period factor* |
|---|---|
| (a) Empty vessel | 0.88 |
| (b) Vessel carrying ballast | 0.88 |
| (c) Vessel fully loaded and with liquids in tanks comprising the following percentage of the total load on board (i.e. cargo, liquids, stores, etc.) | |
| 1. 20 per cent of total load | 0.78 |
| 2. 10 per cent of total load | 0.75 |
| 3. 5 per cent of total load | 0.73 |
| (Order of accuracy of factors ± 0.05) | |

The value of the metacentric height determined from the inclining or rolling period tests shall be equal to or in excess of that required.

C.3.3 Barges and lighters and similar vessels operating within partially smooth waters shall have a minimum GM allowing for any free surface corrections, which is the greater value of the following:

(a) $$GM = \frac{0.036\ Ah}{\Delta \tan \Theta} + 0.15 \text{ metres}$$

where A = projected lateral area in metres² above the waterline considered

h = vertical distance in metres from the centre of area 'A' and the centre of the underwater lateral area

$\Delta$ = displacement in tonnes

$\Theta$ = angle of heel to one half of the freeboard being immersed for particular loading being considered or five (5) degrees, whichever is less.

(b) $$GM = \frac{0.0053\ V^2 d}{L \sin \Theta} + 0.15 \text{ metres}$$

where V = service speed in knots

L = waterline length of vessel

d = vertical distance between VCG and the centre of the underwater lateral area in metres

$\Theta$ = as above.

This formula applies only to vessels where $\frac{V}{\sqrt{L}}$ is less than 4.

(c) If a derrick, deck crane or cranes are fitted on board, the vessel must have sufficient GM to ensure that it does not heel any more than the angle equivalent to one half the freeboard, in the condition being considered, or five (5) degrees whichever is less, when the cranes have their working loads extended their maximum outreach over the side.

(d) GM = 1 metre

C.3.4 Barges, lighters and similar vessels operating within smooth water limits shall have a minimum GM allowing for any free surface corrections, which is the greater of the following:

(a) $$GM = \frac{0.0274\ Ah}{\Delta \tan \theta} + 0.15 \text{ metres}$$

where A = projected lateral area in metres$^2$ above the waterline considered

h = vertical distance in metres from the centre of 'A' to the centre of the underwater lateral area in metres

$\Delta$ = displacement in tonnes

$\theta$ = angle of heel equivalent to one half the freeboard being immersed for the particular loading being considered or five (5) degrees, whichever is less.

(b) $$GM = \frac{0.0053\ V^2 d}{L \sin \theta} + 0.15 \text{ metres}$$

where V = service speed in knots

L = waterline length of vessel

d = vertical distance between VCG and the centre of the underwater lateral area in metres

$\theta$ = as above.

This formula applies only to vessels where $\frac{V}{\sqrt{L}}$ is less than 4.

(c) If a deck crane or cranes are fitted on board, the vessel must have sufficient GM to ensure that it does not heel any more than the angle equivalent to one half the freeboard, in the condition being considered, or five (5) degrees, whichever is less, when the cranes have their working loads extended their maximum outreach over the side.

(d) GM=1 metre.

## C.4 Class 2 Vessels Less Than 16 Metres Measured Length

C.4.1 The stability of a Class 2 vessel less than 16 metres in measured length may be considered satisfactory if the metacentric height (GM) in the worst anticipated condition of loading is not less than 0.75 m, and the angle of deck edge immersion at the point of lowest freeboard is not less than 14°.

C.4.2 For the purposes of sub-clause C.4.1 above, the vessel may be subjected to a Rolling Period Test, and the GM obtained from the following formula:

$$GM = \left( \frac{F_r B}{T_r} \right)^2 \text{ metres}$$

where GM = metacentric height (metres)

B = moulded breadth of vessel (metres)

$T_r$ = time for one complete oscillation (i.e. for one complete roll port-starboard-port or vice versa) (seconds)

$F_r$ = factor for rolling period and may be determined from the values given in C.3.2.

C.4.3 To determine the time for a complete oscillation (t) the following precautions should be observed:

(a) The test should be conducted with the vessel in harbour, in smooth water and with the minimum interference from wind and tide.

(b) Starting with the vessel at the extreme end of a roll to one side, and the vessel about to move towards the upright, one complete oscillation will have been made when the vessel has moved right across to the other extreme side and returned to the original starting point and is about to commence the next roll.

(c) By means of a stop watch, the time should be taken for about five complete oscillations, and this operation repeated at least twice more. If possible each time the operation is repeated the same number of complete oscillations should be timed to establish consistency within reasonable limits. From the total time for the total number of oscillations, the mean time ($T_r$) for one complete oscillation can be calculated.

(d) The roll may be induced by pulling on the mast with a rope, or by rhythmically lifting up and putting down a weight as far off the centreline of the vessel as possible—by sallying people from side to side in unison or by any other means.

(e) As soon as the induced rolling has commenced, the means by which the roll has been induced must be removed and the vessel allowed to roll freely and naturally. Where weights are used from dockside cranes the weight is to be removed to the wharf. If the vessel's own derrick is used, the weight should be landed on the deck at the centreline. Where the roll is induced by sallying people from side to side, those persons should be returned to the vessel's centreline.

(f) The timing of oscillations should only begin when it is judged that the vessel is rolling freely and naturally.

(g) The moorings are to be slack and the vessel breasted clear of the dockside.

(h) Care should be taken to ensure reasonable clearance under the keel and around the sides of the vessel.

(i) Any weights on board of reasonable size which may be liable to move during the induced rolling should be secured against such movement.

C.4.4 This method shall only be applied to vessels possessing normal geometric characteristics. For vessels of other than normal geometric characteristics and vessels of normal geometric characteristics having a GM less than 0.75 or angle of deck edge immersion less than 14° an inclining experiment is to be carried out and the vessel's stability determined in accordance with either clause C.2 or sub-clause C.3.2.

## C.5 Class 3 Vessels

C.5.1 Categories of Service

C.5.1.1 Category K—Vessels of 25 metres in measured length and over.

C.5.1.2 Category L—Vessels of less than 25 metres in measured length which engage in operations resulting in excessive weights on decks or rigging (e.g. tuna fishing, prawn trawling, beam trawling, single or double boom trawling, large fish tanks on deck etc.).

C.5.1.3 Category M—Vessels of 15 metres in measured length and over but less than 25 metres in measured length.

C.5.1.4 Category N—Vessels of 7.5 metres in measured length and over but less than 15 metres in measured length.

C.5.2 Criteria

C.5.2.1 Vessels of Categories K and L

C.5.2.1.1 The stability is considered satisfactory if the following minimum criteria is met, unless the Authority is satisfied that operating experience justifies departure therefrom:

(a) The area under the righting lever curve, i.e. the GZ curve, is not to be less than 3.15 metre-degrees up to 30° angle of heel and not less than 5.16 metre-degrees up to 40° angle of heel or the angle of flooding $\theta_f$**, if this angle is less than 40°. Additionally the area under the righting lever curve between the angles of heel of 30° and 40° or between 30° and $\theta_f$ if this angle is less than 40°, shall be not less than 1.72 metre-degrees.

***Note:*

$\theta_f$ is the angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight commence to immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

(b) The righting lever GZ is not to be less than 0.2 metres at an angle of heel equal to or greater than 30°.

(c) The maximum righting lever GZ is to occur at an angle of heel preferably exceeding 30° but in any case not less than 25°.

(d) The initial metacentric height is not to be less than 0.35 metres for single deck vessels. (For vessels with complete superstructures and vessels of 70 metres in measured length and over the metacentric height may be reduced to the satisfaction of the Authority but in any case is not to be less than 0.15 metres).

C.5.2.1.2 Where ballast is provided to ensure compliance with sub-paragraphs (a) to (d) of C.5.2.1.1 above, its nature and arrangement shall be to the satisfaction of the Authority.

C.5.2.1.3 The angle of heel at which progressive flooding of fish holds could occur through hatches which cannot rapidly be closed at sea and which are required to remain open during fishing operations shall be at least 20° unless the stability criteria of sub-paragraphs (a) to (d) of C.5.2.1.1 can be satisfied with the respective fish holds partially or completely flooded.

C.5.2.1.4 A vessel engaged in particular fishing methods, e.g. single or twin boom fishing, where additional external forces are imposed on the vessel during fishing operations, shall meet the stability criteria of paragraphs (a), (b) and (d) increased as appropriate, to the satisfaction of the Authority.

C.5.2.1.5 Taking into account the seasonal weather conditions, sea states, type of vessel and its mode of operation, the ability of a vessel to withstand the effects of severe wind and rolling and the effect of water on deck shall be demonstrated to the satisfaction of the Authority. Recommended methods of calculating the effect of severe wind and rolling in associated sea conditions and of calculating the effect of water on deck are given in Appendices A and B.

C.5.2.1.6 The number and type of operating conditions to be considered in the submission of stability data for vessels of these Categories shall include the following:

(a) departure for fishing grounds, with full fuel, stores, ice, fishing gear, etc.;

(b) departure from the fishing grounds with full catch and with appropriate quantities of fuel, freshwater and stores etc., remaining;

(c) arrival at home port with full catch and 10% fuel, stores, etc.;

(d) arrival at home port with 20% of full catch and 10% fuel, stores, etc.; and

(e) operating in the most unfavourable conditions.

C.5.2.1.7 Concerning the conditions referred to in C.5.2.1.6, the calculations shall include the following assumptions:

(a) allowance for the weight of wet fishing nets and tackle etc. on deck;

(b) homogeneous distribution of the catch, unless this is inconsistent with practice;

(c) allowance for the weight of catch on deck if anticipated in operating conditions referred to in paragraphs (b), (c), (d) and (e) of C.5.2.1.6;

(d) water ballast if carried either in tanks which are specially provided for this purpose or in other tanks also equipped for carrying water ballast; and

(e) allowance for the free surface effect of liquids and, if applicable, catch carried, based on a specific gravity for all brine/fish/air surface combinations of 1.025.

C.5.2.1.8 Concerning the condition referred to in sub-paragraph (e) of C.5.2.1.6 above, a statement shall be given by or on behalf of the owner of the vessel that the condition is based on the worst forseeable service conditions.

C.5.2.2 Vessels of Category M

C.5.2.2.1 The stability of a vessel of this Category may be considered satisfactory if it is ensured that the metacentric height (GM) corrected for free surface, in all probable operating conditions is not less than determined by the following formula:

$$GM_r = 0.6 + 0.05\,B - 0.25\,f \text{ (metres)}$$

Where $GM_r$ = minimum GM required, metres
B = moulded breadth, metres
f = minimum freeboard, metres

C.5.2.2.2 The stability may be determined by subjecting the vessel to a rolling period test as described in C.5.2.3.1.

C.5.2.2.3 The formula given in C.5.2.2.1 may only be applied to vessels where f/B is greater than or equal to 0.1 and less than or equal to 0.2; B/D is greater than or equal to 1.75 and less than or equal to 2.15. Vessels whose dimensions fall outside this range shall be inclined and shall meet the requirements of C.5.2.1.1.

C.5.2.3 Vessels of Category N

C.5.2.3.1 The vessel may be subjected to a Rolling Period Test, and the GM obtained from the following formula:

$$GM = \left( \frac{F_r B}{T_r} \right)^2 \text{ metres}$$

where GM = metacentric height (metres)

B = moulded breadth of vessel (metres)

$T_r$ = time for one complete oscillation (i.e. for one complete roll port-starboard-port or vice versa) (seconds)

$F_r$ = factor for rolling period and may be taken as:
0.8 for deep sea fishing vessels; or
0.6 for vessels with a live fish well.

C.5.2.3.1.1 To determine the time for a complete oscillation ($T_r$) the following precautions should be observed:

(a) The test should be conducted with the vessel in harbour, in smooth water and with the minimum interference from wind and tide.

(b) Starting with the vessel at the extreme end of a roll to one side, and the vessel about to move towards the upright, one complete oscillation will have been made when the vessel has moved right across to the other extreme side and returned to the original starting point and is about to commence the next roll.

(c) By means of a stop watch, the time should be taken for about five complete oscillations, and this operation repeated at least twice more. If possible each time the operation is repeated the same number of complete oscillations should be timed to establish consistency within reasonable limits. From the total time for the total number of oscillations the mean time ($T_r$) for one complete oscillation can be calculated.

(d) The roll may be induced by pulling on the mast with a rope, or by rhythmically lifting up and putting down a weight as far off the centreline of the vessel as possible, by sallying people from side to side in unison or by any other means.

(e) As soon as the induced rolling has commenced the means by which the roll has been induced must be removed and the vessel allowed to roll freely and naturally. Where weights are used from dockside cranes the weight is to be removed to the wharf, if the vessel's own derrick is used the weight should be landed on deck at the centreline. Where the roll is induced by sallying people from side to side, those persons should be returned to the vessel's centreline.

(f) The timing of oscillations should only begin when it is judged the vessel is rolling freely and naturally.

(g) The moorings are to be slack and the vessel breasted clear of the dockside.

(h) Care should be taken to ensure reasonable clearance under the keel and around the sides of the vessel.

(i) Any weights on board of reasonable size which may be liable to move during the induced rolling should be secured against such movement.

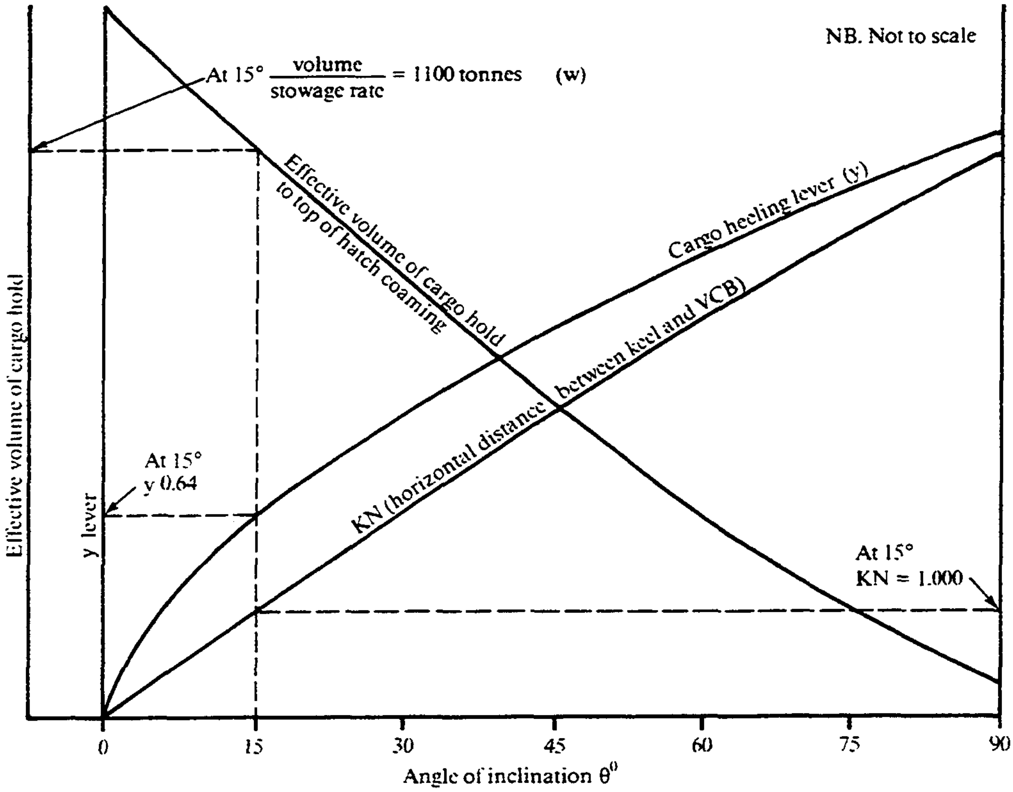
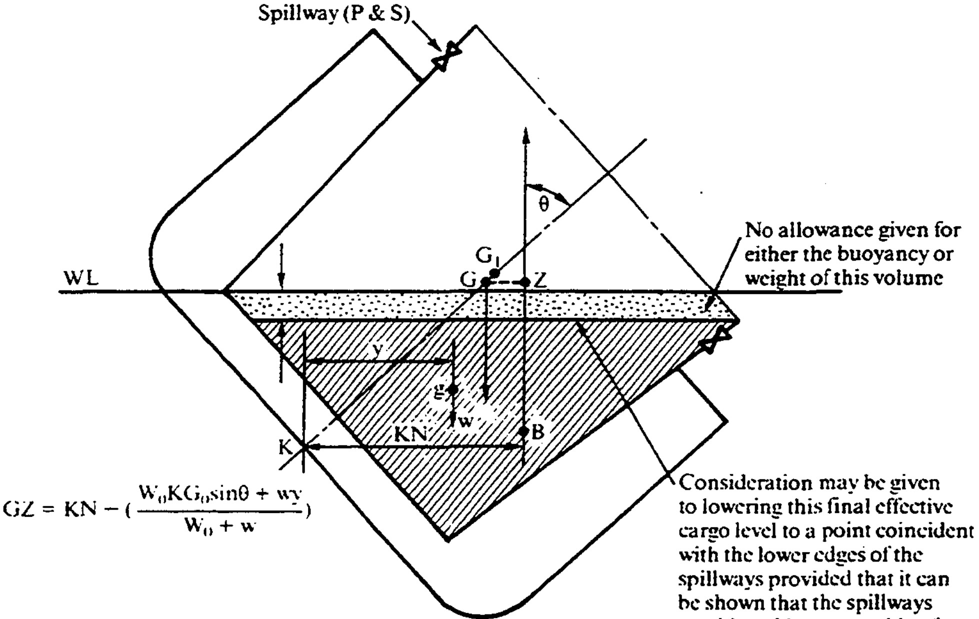

NB. Not to scale
At 15° $\frac{\text{volume}}{\text{stowage rate}}$ = 1100 tonnes (w)
Effective volume of cargo hold to top of hatch coaming
Cargo heeling lever (y)
KN (horizontal distance between keel and VCB)
At 15° y 0.64
At 15° KN = 1.000
Effective volume of cargo hold
y lever
0
15
30
45
60
75
90
Angle of inclination $\theta^0$

**Figure 1**




$W_0$ = displacement of light ship plus O/F, F/W stores etc.
$G_0$ = centre of gravity of ship at displacement $W_0$
w = weight of cargo at angle of inclination $\theta$
g = centre of gravity of cargo at angle of inclination $\theta$
G = centre of gravity of ship at loaded displacement $W_0 + w$
B = centre of bouyancy of inclined ship at loaded displacement $W_0 + w$

**Figure 2**

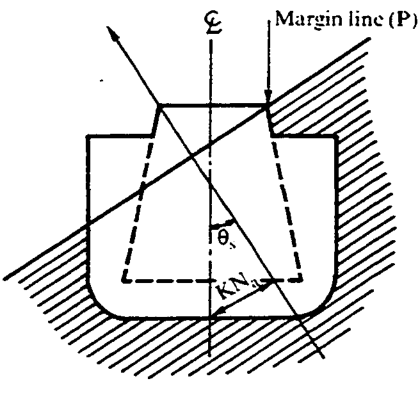



**Figure 3**

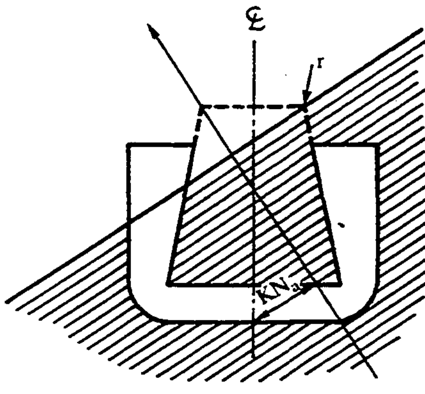



**Figure 4**

C.5.2.3.2 The stability of a vessel of this Category may be considered satisfactory if metacentric height (GM) in the 'ready for sea' condition is not less than 0.75m, and the angle of deck-edge immersion at the point of lowest freeboard is not less than 14°.

C.5.2.3.3. This method shall only be applied to vessels possessing normal geometric characteristics. For vessels of other than normal geometric characteristics and vessels of normal geometric characteristics having a GM in the 'ready for sea' condition less than 0.75m or angle of deck edge immersion less than 14° an inclining experiment is to be carried out and the vessel's stability is to be determined in accordance with either C.5.2.1.1 or C.5.2.2.1.

## C.6 Dredgers

### C.6.1 General

Such vessels are usually engaged in the dredging of sand and gravel from the sea bed for commercial use or the maintenance of channels in rivers or harbours and the dumping of the spoil at sea.

### C.6.2 Dredgers Operating with Hold Spaces Open

When these vessels require to be assigned freeboards in accordance with the Load Lines Section, they may be permitted not to fit hatchway covers to their holds provided it can be shown to the satisfaction of the Authority that when operating at that freeboard they cannot be overloaded and the stability and safety are not impaired when the hold is filled with water, cargo or a mixture of water and cargo. (See C.6.2.1, C.6.2.2, C.6.2.3 and C.6.2.4).

For this purpose cargo can be taken to mean either dredgings recovered for commercial use or spoil recovered in the maintenance of harbours and rivers.

#### C.6.2.1 Loading Arrangements

As operational and weather conditions at sea may preclude the accurate checking of draught marks, it is essential to ensure that whenever cargo is being carried the maximum draught permitted cannot be exceeded.

The maximum volume of cargo that can be carried should be determined by dividing the total cargo deadweight by the anticipated maximum saturated cargo stowage rate. If these calculations show that the maximum volume of cargo to be carried is such that the cargo space (hold and coaming) is not completely filled when the ship is at the assigned freeboard, it will be necessary to introduce spillways in the hold or the hatch coamings or to provide other suitable means to prevent possible overloading.

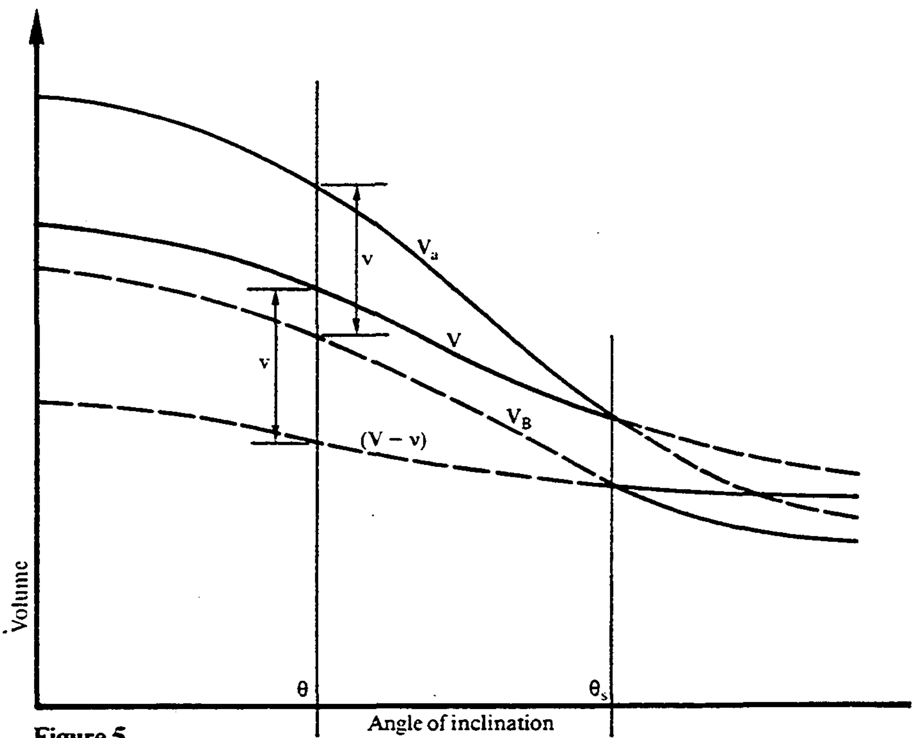



Figure 5

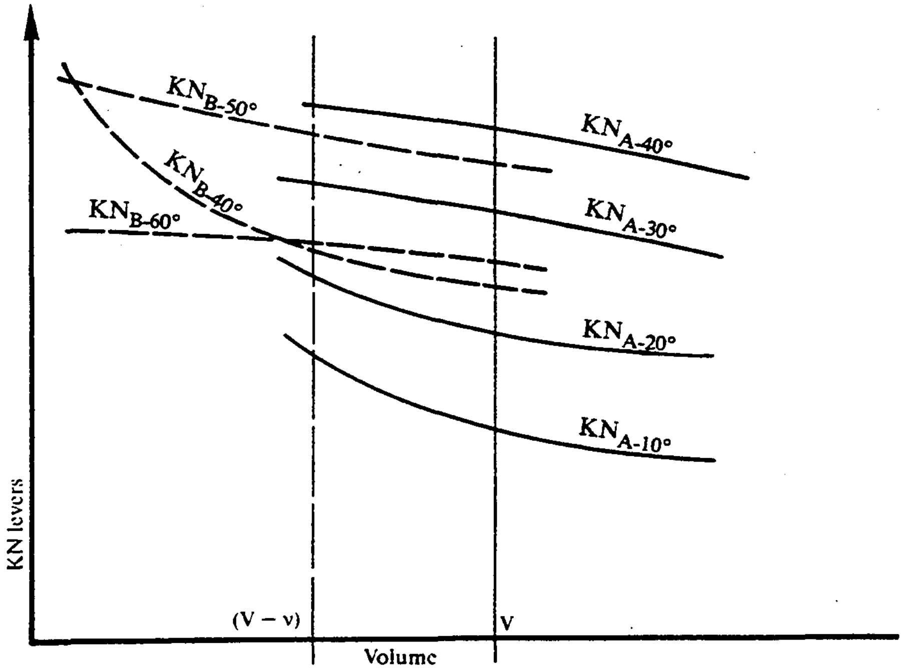



**Figure 6**

Note: These curves are diagrammatic only as the angle of submersion $\theta_s$ can vary from ship to ship and condition to condition.

*Note:* These curves are diagrammatic only as the angle of submersion $\theta_s$ can vary from ship to ship and condition to condition.

C.6.2.2 Loading Trials

A loading trial at sea will be required to prove the efficiency of the arrangements provided to prevent overloading on all ships which are not of the 'hopper' type, i.e. these not fitted with bottom doors in the shell or which do not have other means by which the cargo can be speedily jettisoned.

The surveyor should witness and report upon such trials. He should be satisfied that the distribution and area of spillways provided are sufficient to prevent an excessive build-up of cargo in the hold and that they are also capable of freeing any accumulation of water due to heavy seas breaking over the hatchway. To ascertain that the vessel is not overloaded during the trial it may be necessary to inspect the draught marks from a boat positioned alongside the ship, especially in ships which are not fitted with accurate draught indicators.

For this trial a cargo of the maximum density it is intended to carry should be loaded. The loading should continue to the point when solid material begins to overflow through the spillways prior to the commencement of draining the cargo. At no stage during the trial should the draught associated with the assigned freeboard be exceeded.

C.6.2.3 Investigation of Stability

The following 'spill out' method should normally be adopted to investigate the stability and safety of these ships. This method takes account of the spillage of saturated cargo and water overboard as the ship heels and may be developed either by direct means or by computer as indicated in sub-paragraphs (i) and (ii). Where however an owner can demonstrate that this method is not wholly appropriate to a particular case the Authority will be prepared to consider an alternative method of investigating the stability of the ship.

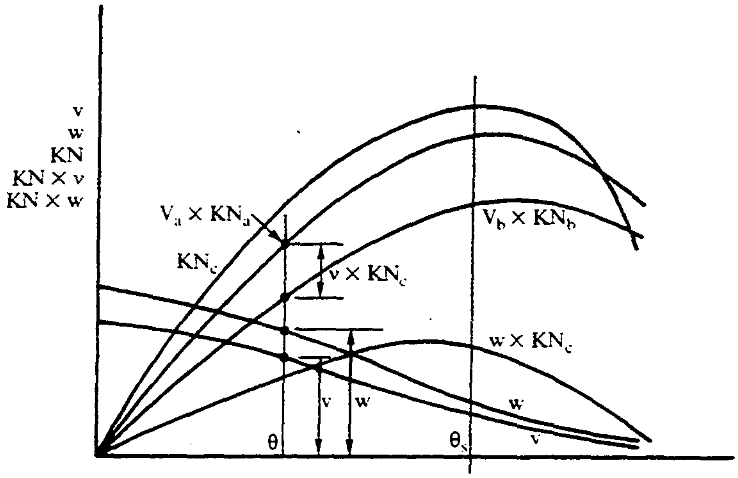
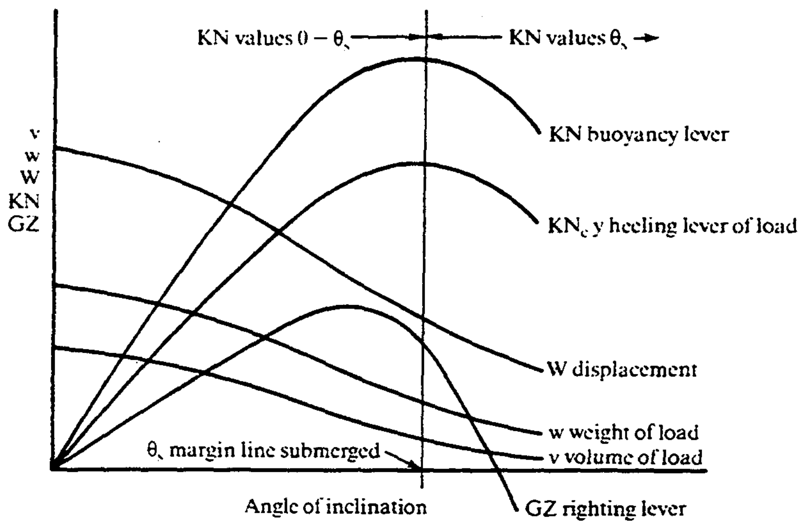



**Figure 7**




Note: Stage 4 and Figure 8 to derive KN levers and Figure 7 for $KN_c$ levers

**Figure 8**

**Stage 1**

The basic vessel should be considered to consist of two different hull forms i.e.:

Hull Form 'A'

The volume of the whole vessel below the top of the coaming (see Figure 3).

Hull Form 'B'

The volume of the vessel as Hull Form 'A' but excluding volume of the cargo hold (see Figure 4).

Stability data (i.e. volume and KN levers of the two hull forms) is derived at different draughts and angles of inclination. Additionally $θ_s$, the angle at which the top of the hatch coaming (margin line) is submerged, is also given.

From these results curves of volume and KN cross curves are drawn (see Figures 5 and 6).

**Stage 2**

From the volume curves shown in Figure 5, for any angle $\Theta$

$V_A - V_B$ = volume of cargo in hold = v

and v x specific gravity of cargo=mass of cargo = w

If W = total displacement of ship in a given loaded condition, then it follows that $W = W_o + w$

where $W_o$ =displacement of ship in 'light' conditions with fuel and stores
w =mass of cargo

and if V = volume of displacement of the vessel in a given loaded condition then:

$$V = \frac{W}{\text{specific gravity of sea water (normally 1.025)}}$$

Also in Figure 5 the point of intersection of the curves $V_A$ and V, or $V_B$ and (V—v) indicates the angle $\Theta_s$ at which the margin line (top of hatch coaming) is submerged for the particular loaded condition V.

**Stage 3**

Curves of $V_A \times KN_A$, $V_B \times KN_B$, v x $KN_c$, v,w, and $KN_c$ are drawn in Figure 7, the values for $V_A \times KN_A$ and $V_B \times KN_B$ being obtained from Figures 5 and 6.

The difference between these curves will represent the moment of volume of load, i.e.:

$$(V_A \times KN_A) - (V_B \times KN_B) = v \times KN_c$$

**Stage 4**

Using the following formula:

$$GZ = KN - \frac{(W_o \times KG_o \times \sin\Theta + w \times KN_c)}{W}$$

the curve of righting levers (GZ) for a particular 'loaded' condition can now be developed observing that the values for KN of Hull Form 'A' are used for angles of $\Theta$ which are less than $\Theta_s$ (angle at which the margin line is submerged) and of Hull Form 'B' for angles of $\Theta$ which are greater than $\Theta_s$ so that:

KN values for angles of $\Theta$ less than $\Theta_s$ are those $KN_A$ values lifted at value V on Figure 6; and

KN values for angles of $\Theta$ greater than $\Theta_s$ are those $KN_B$ values lifted at value (V - v) on Figure 6. (These values have to be modified, however, to allow for the buoyancy given by the cargo that remains in the hold). Therefore KN values for angles of $\Theta$ greater than $\Theta_s$ are obtained by the formula:

$$KN \quad \frac{(V-v)\, KN_B + (v \times KN_c)}{V}$$

With this information all values and curves for any particular 'loaded' condition can be prepared (see Figure 8).

C.6.2.4 Typical calculation of statical stability in loaded condition

1. Initial stability (ship upright)

| *Item* | *Mass (tonnes)* | *VCG (metres)* | *Vertical moment* | *Free surface correction (metres)* |
|---|---|---|---|---|
| Lightship | 500 | 3.35 | 1675 | 0.027 |
| Oil fuel | 10 | 1.52 | 15 | 0.027 |
| Diesel oil | 2 | 4.57 | 9 | 0.015 |
| Lubricating oil | 1 | 4.87 | 5 | 0.009 |
| Fresh water | 4 | 2.74 | 10 | 0.012 |
| Stores etc. | 2 | 0.30 | 1 | .. |
| Lightship, fuel, stores etc. ($W_0$) | 519 | 3.30 | 1715 | 0.063 |
| Cargo (w) | 1200 | 2.59 | 3108 | 0.610 |
| Load displacement | 1719 | 2.81 | 4823 | 0.673 |

KM = 4.13
GM (solid) = 1.32
Free Surface = 0.673

GM (fluid) = 0.647

2. Righting lever when $\Theta = 15°$

| *Item* | *Mass* | *Lever* | *Horizontal moment* | |
|---|---|---|---|---|
| Lightship, fuel, stores etc. ($W_0$) | 519 | 0.87 | (3.363 Sin 15°) | 451 |
| Cargo (w) | 1100 | 0.64 | (y from Fig. 12) | 704 |
| Loaded ship ($W_0$ + w) | 1619 | 0.713 | | 1155 |

Then GZ at 15° = 1.000 (KN from Fig. 12) — 0.713
= 0.287 metre

3. Righting lever when $\Theta = 30°$

| *Item* | *Mass* | *Lever* | *Horizontal moment* | |
|---|---|---|---|---|
| Lightship, fuel, stores etc. ($W_0$) | 519 | 1.681 | (3.363 Sin 30°) | 872 |
| Cargo (w) | 906 | 1.210 | (y from Fig. 12) | 1096 |
| Loaded ship ($W_0$ + w) | 1425 | 1.381 | | 1968 |

Then GZ at 30° = 1.880 (KN from Fig. 12)—1.381
= 0.499 metre

In the above calculations the value of KG for the lightship, fuel, stores etc., ($W_0$) is increased by the free surface correction for liquids in oil and water tanks i.e.

3.30 + 0.063=3.363 metres

C.6.3 Operating with hold spaces closed

For ships designed to operate with their hold spaces closed with either hatch covers or by permanent means the investigation of the stability by the 'spill-out' method is inappropriate. In such cases the normal free surface correction should be applied for the cargo in the hold (suitably amended for density) when calculating the stability for various conditions of loading.

The Authority is prepared however to consider dispensing with the free surface correction for the cargo in the hold provided either the shipbuilders or their consultants can show to the satisfaction of the Authority that during the collection of the dredgings the water content is removed expeditiously. In this case the ship's stability should be investigated by assuming the cargo of dredgings to shift as the ship rolls. The intact stability could then be considered adequate if after taking account of any cargo shift the following maintains:

(a) the angle of heel does not exceed 65 per cent of the angle at which the deck edge is immersed in still water; and

(b) the residual dynamic stability measured up to 30° beyond the angle of heel is not less than 0.573 metre-degrees.

The cargo shift moments for any one continuous section of the hold should be calculated as follows:

$$\text{horizontal heeling moment} = \frac{1}{12}\, p \tan a \int_0^g b^3$$

$$^{*}\ \text{vertical moment} = \frac{1}{24}\, p \tan^2 a \int_0^g b^3$$

where: g = length of section of hold
b = breadth of section of hold
p = density of cargo
a = surface angle shift (to be taken as 20°)

* This value divided by the ship's displacement will give the resultant rise in the ship's KG.

The ship will be required to comply in all other respects with the requirements of A.4.1.15, C.6.2.1 and C.6.2.2.

C.6.4 Less than statutory minimum freeboards

The Authority is prepared to consider applications for the assignment of a freeboard based on a tabular freeboard reduced to $\frac{1}{2}$ (Table B), subject to a minimum freeboard of 150 mm and to the following:

(a) the strength of the vessel being shown to be adequate at the draught associated with the decreased freeboard.

(b) the vessel being of the 'hopper' type, i.e. fitted with bottom doors in the shell or having other similar means capable of quickly jettisoning the cargo under all seagoing conditions and in an emergency. In each case details of the arrangements are to be submitted to the Authority for examination and approval.

(c) the operational limits (normally not exceeding 15 miles from land) and weather conditions having been agreed by the Authority.

(d) the intact stability criteria given in C.2 being achieved at the proposed decreased freeboard.

C.6.5 Dredgers—Bucket

When bucket dredgers and similar type vessels undertake coastal or international voyages, either under their own power or under tow, special consideration should be given to the preparation of the vessel for the intended voyage to ensure that there will be adequate stability. The Authority will take into account the following:

(a) These vessels usually have high 'beam to draught' ratios and relatively small freeboards.

(b) Owing to the large amount of top weight normally carried they are very susceptible to rolling.

(c) The necessity to prepare a 'curve of statical stability' for seagoing conditions when investigating the stability characteristics.

(d) The following stability standard which is recommended as a minimum for such vessels:

(i) the voyage freeboard should be sufficient to prevent the freeboard deck edge becoming immersed before an angle of heel of 12½° is reached;

(ii) the range of stability should be at least 45°;

(iii) the maximum GZ value should be at least 0.61 metre; and

(iv) the minimum GM value should be not less than 1.22 metres.

Whenever any such ship is required to make an extended voyage details of the preparation of the ship and the stability characteristics should be submitted to the Authority for approval.

**C.7 Crane and Derrick Barges**

C.7.1 Stability requirements for crane or derrick barges operating in smooth waters are given in C.3.4.

C.7.2 Stability requirements for crane or derrick barges operating in partially smooth waters are given in C.3.3.

C.7.3 The stability characteristics of crane or derrick barges operating in unrestricted water and having proportions which fall within the following ranges:

Length to beam 3.20 to 4.50

Beam to depth 3.40 to 4.75

Draught to depth 0.60 to 0.85

should be such that heel should not exceed an angle equivalent to half the freeboard in the condition considered, or five (5) degrees whichever is less, when the crane or derrick has its working load extended over the side at the maximum outreach.

C.7.4 Where the proportions of the barge fall outside the ranges given in C.7.3, then the dynamic check given in C.7.6 should be applied.

C.7.5 For barges with proportions falling within the ranges given in C.7.3, in lieu of the criterion given in C.7.3, the dynamic check given in C.7.6 may be applied.

C.7.6 The vessel should have residual dynamic stability between the curve of righting levers for the condition considered and the heeling arm curve for the maximum load/maximum outreach condition, not less than 4.584 metre-degrees.

The residual dynamic stability shall be measured between the first intercept and the angle corresponding to the maximum residual ordinate or 40° whichever is less. The angle of downflooding should not be less than 40°.

The mass of the load shall be taken to act at the derrick or jib head for the purposes of calculating the vertical centre of gravity.

C.7.7 When barges are in transit in a seaway under tow, conditions likely to lead to capsize may be more severe than with the derrick or crane operating. Special attention should be paid to the probable effect of strong winds upon the lateral areas. The following should be used for guidance:

(a) All practical efforts should be made to ensure that the height of the centre of gravity is such that at an angle of heel of 15°, a vertical line through the KG will not be beyond the line of the deck edge (see Figure 9).

(b) The ratio between the minimum capsizing moment as determined from the dynamical stability curve and the heeling moment produced by a wind pressure of 600 Pascals applied to the lateral windage area (the lever for this moment being measured to an axis at mid draught) should not be less than 1.75 (see Figure 10).

(c) The windage area, its centre, and the lever to mid-draught are to be stated in the stability book.

(d) When subjected to a wind moment equal to that given in (b) above, the craft should not heel to an angle where a vertical line through the KG (in the inclined position) would lie beyond the deck edge or to an angle of 15° whichever is the lesser. (see Figure 9).

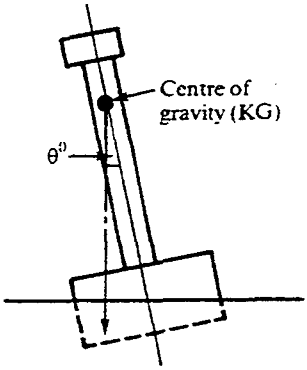
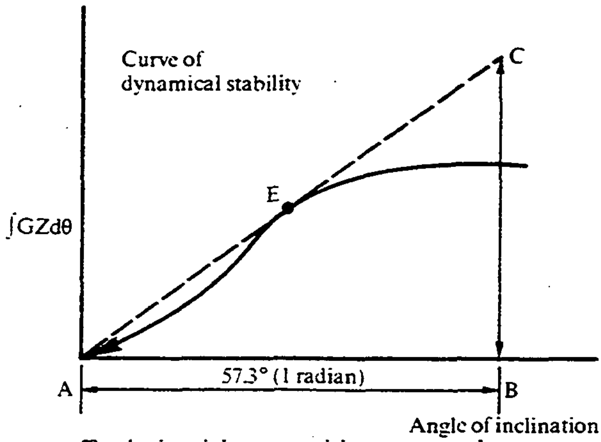



**Figure 9**




To obtain minimum capsizing moment, draw AC tangental to curve, then erect vertical BC at one radian from original point A
Ten minimum capsizing moment $\triangle$ = BC

and $\dfrac{\triangle \times BC}{\text{wind heeling moment}} \geqslant 1.75$

**Figure 10**

**C.8 Hydrofoil Boats**

C.8.1 Application

These criteria apply to hydrofoil boats which:

(a) carry more than 12 passengers but not over 450 passengers with all passengers seated; and

(b) do not proceed in the course of their voyage more than 100 nautical miles from a place of refuge.

The Authority will determine the extent to which these criteria apply to craft which exceed the limits specified above and if necessary, develop additional requirements providing the appropriate safety level for such craft.

C.8.2 Definitions

C.8.2.1 A *hydrofoil boat* is a craft which is supported above the water in normal operating conditions by hydrodynamic forces generated on foils.

C.8.2.2 *Critical design conditions* mean the limiting specified conditions chosen for design purposes, which should be more severe than 'the worst intended conditions' by a suitable margin acceptable to the Authority.

C.8.2.3 *Worst intended conditions* means the specified environmental conditions within which the international operation of the craft is provided for in the certification of the craft. This should take into account parameters such as the worst conditions of wind force, allowable wave height (including unfavourable combinations of length and direction of waves), minimum air temperature, visibility and depth of water for safe operation and such other parameters as the Authority may require in considering the type of craft in the area of operation.

C.8.3 Intact Stability

The stability of a craft in the displacement mode should be such that when in still water conditions, the inclination of the craft from the horizontal would not exceed 8° in any direction under all permitted cases of loading and uncontrolled passenger movements as may occur. A calculation of the dynamic stability should be made with respect to critical design conditions. Methods relating to the verification of the stability of hydrofoil boats fitted with surface piercing foils and fully submerged foils are outlined in C.8.4.

C.8.4 Methods Relating to the Intact Stability Investigation of Hydrofoil Boats

C.8.4.1 The stability of these craft should be considered in the hull-borne, transient and foil-borne modes. The stability investigation should also take into account the effects of external forces. The following procedures are outlined for guidance in dealing with stability.

C.8.4.2 Surface Piercing Hydrofoils

C.8.4.2.1 Hull-borne Mode

C.8.4.2.1.(a) Sufficiency

The stability should be sufficient to satisfy C.8.3 and C.8.5 of this Section.

C.8.4.2.1.(b) Heel Moment Due to Turning

The heeling moment developed during manoeuvring of the craft in the displacement mode may be derived from the following formula:

$$M_R = \frac{0.0053\, V_o^2\, \Delta\, KG}{L}$$

where:

$M_R$ = moment of heeling (tonnes metres)

Vo = speed of the craft in the turn (knots)

$\Delta$ = displacement (tonnes)

L = length of the craft on the waterline (metres)

KG = height of the centre of gravity above the keel (metres)

This formula is applicable when the ratio of the radius of the turning circle to the length of the craft is 2 to 4.

C.8.4.2.1.(c) Relationship Between the Capsizing Moment and Heeling Moment to Satisfy the Weather Criterion

The stability of a hydrofoil boat in the displacement mode can be checked for compliance with the weather criterion K as follows:

$$K = \frac{Mc}{M_v} \geq 1$$

where:

Mc = minimum capsizing moment as determined when account is taken of rolling

$M_v$ = dynamically applied heeling moment due to the wind pressure.

C.8.4.2.1.(d) Heeling Moment Due to Wind Pressure

The heeling moment Mv is a product of wind pressure Pv, the windage area Av and the lever of windage area Z.

Mv=0.000102 Pv Av Z (tonnes metres)

The value of the heeling moment is taken as constant during the whole period of heeling.

The windage area Av is considered to include the projections of the lateral surfaces of the hull, superstructure and various structures above the waterline. The windage area lever Z is the vertical distance to the centre of the windage from the waterline and the position of the centre of windage may be taken as the centre of the area.

The values of the wind pressure in Pascals associated with Force 7 Beaufort Scale depending on the position of the centre of windage are given in the Table.

**Table**

TYPICAL WIND PRESSURES FOR BEAUFORT SCALE 7 100 NAUTICAL MILES FROM LAND

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Z above waterline (metres) . . . . . | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |
| Pv (Pascals) . . . . . . . . . . . | 460 | 460 | 500 | 530 | 560 | 580 | 600 | 620 | 640 |

*Note:*

These values may not be applicable in all areas.

The value of the heeling moment is taken as constant during the whole period of heeling.

The windage area Av is considered to include the projections of the laterial sufaces of the hull, super-structure and various structures above the water-line. The windage area lever Z is the vertical distance to the centre of the windage from the waterline and the position of the centre of windage may be taken as the centre of the area.

The values of the wind pressure in Pascals associated with Force 7 Beafort Scale depending on the position of the centre of windage are given in the Table.

C.8.4.2.1.(e) Evaluation of the Minimum Capsizing Moment Mc in the Displacement Mode

The minimum capsizing moment is determined from the static and dynamic stability curves taking rolling into account.

(i) When the static stability curve is used, Mc is determined by equating the areas under the curves of the capsizing and righting moments (or levers) taking rolling into account—as indicated in figure 11 where $\theta_Z$ is the amplitude of roll and MK is a line drawn parallel to the abscissa areas such that the shaded areas $S_1$ and $S_2$ are equal.

Mc = OM if the scale of the ordinates represents moments.

Mc = OM x displacement if the scale of the ordinates represents levers.

(ii) When the dynamic stability curve is used, first an auxiliary point A must be determined. For this purpose the amplitude of heeling is plotted to the right along the abscissa axis and a point $A^1$ is found (see figure 12). A line $AA^1$ is drawn parallel to the abscissa axis equal to the double amplitude of heeling ($AA^1 = 2\theta_Z$) and the required auxiliary point A is found. A tangent AC to the dynamic stability curve is drawn. From the point A the line AB is drawn parallel to the abscissa axis and equal to one radian (57.3°). From the point B a perpendicular is drawn to intersect with the tangent in point E.

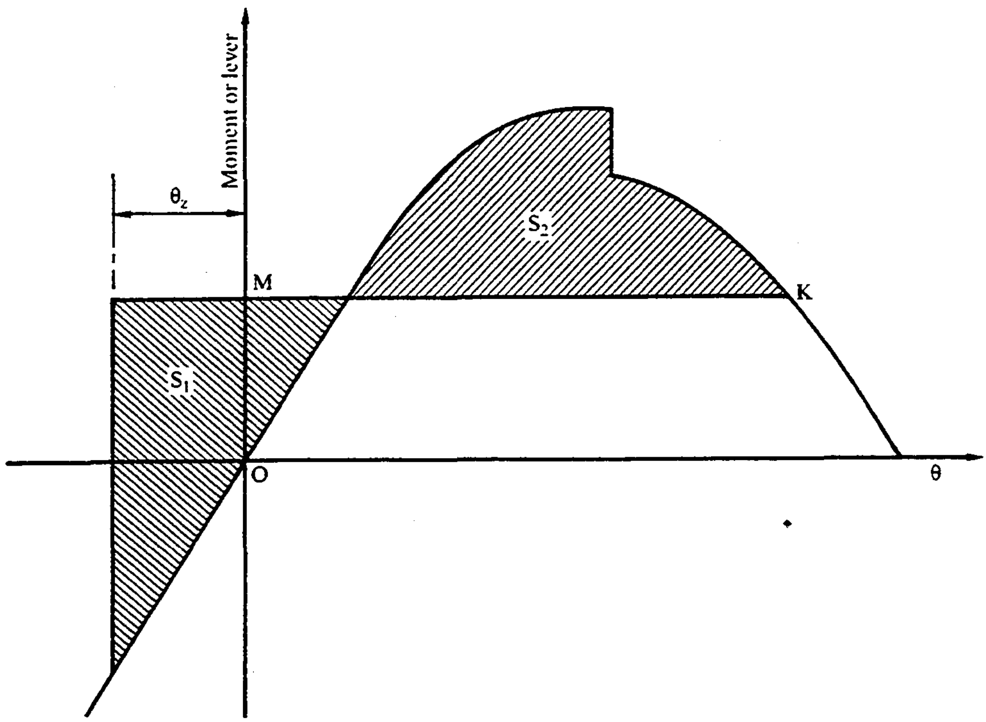



**Figure 11** STATIC STABILITY CURVE

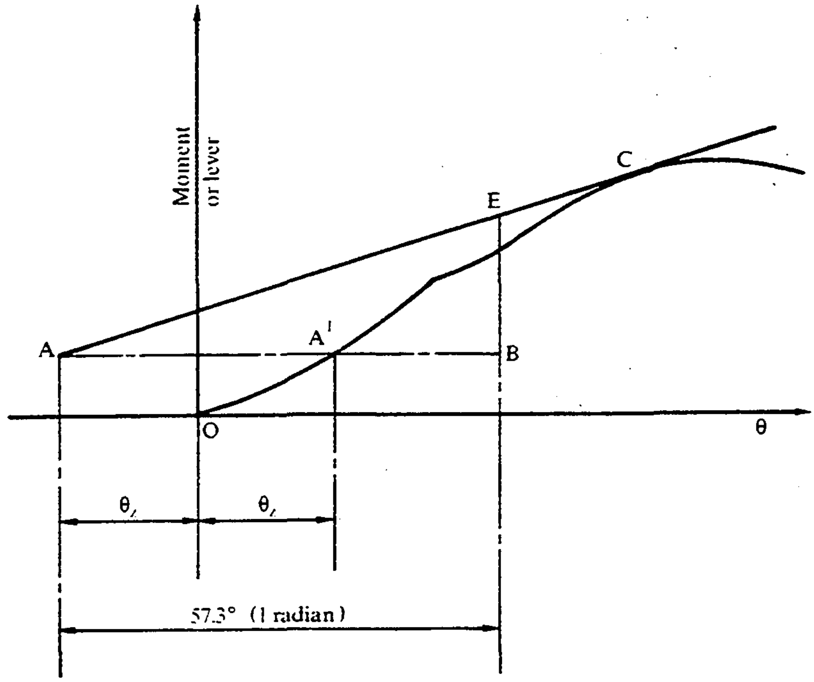



**Figure 12 DYNAMIC STABILITY CURVE**

The distance BE is equal to the capsizing moment if measured along the ordinate axis of the dynamic stability curve. If, however, the dynamic stability levers are plotted along this axis, BE is then the capsizing lever, and in this case the capsizing moment Mc is determined by multiplication of ordinate BE in metres by the corresponding displacement in tonnes.

$Mc = \Delta$ BE (tonnes metres)

(iii) The amplitude of rolling $\theta_z$ is determined by means of model and full-scale tests in irregular seas as a maximum amplitude of rolling of 50 oscillations of a craft travelling at 90° to the wave direction in sea state for the worst design condition. If such data are lacking the amplitude is assumed to be equal to 15°.

(iv) The effectiveness of the stability curves should be limited to the angle of flooding.

C.8.4.2.2 Stability in the Transient and Foil-borne Modes

C.8.4.2.2.(a) The stability should satisfy C.8.6 of this Section.

C.8.4.2.2.(b):

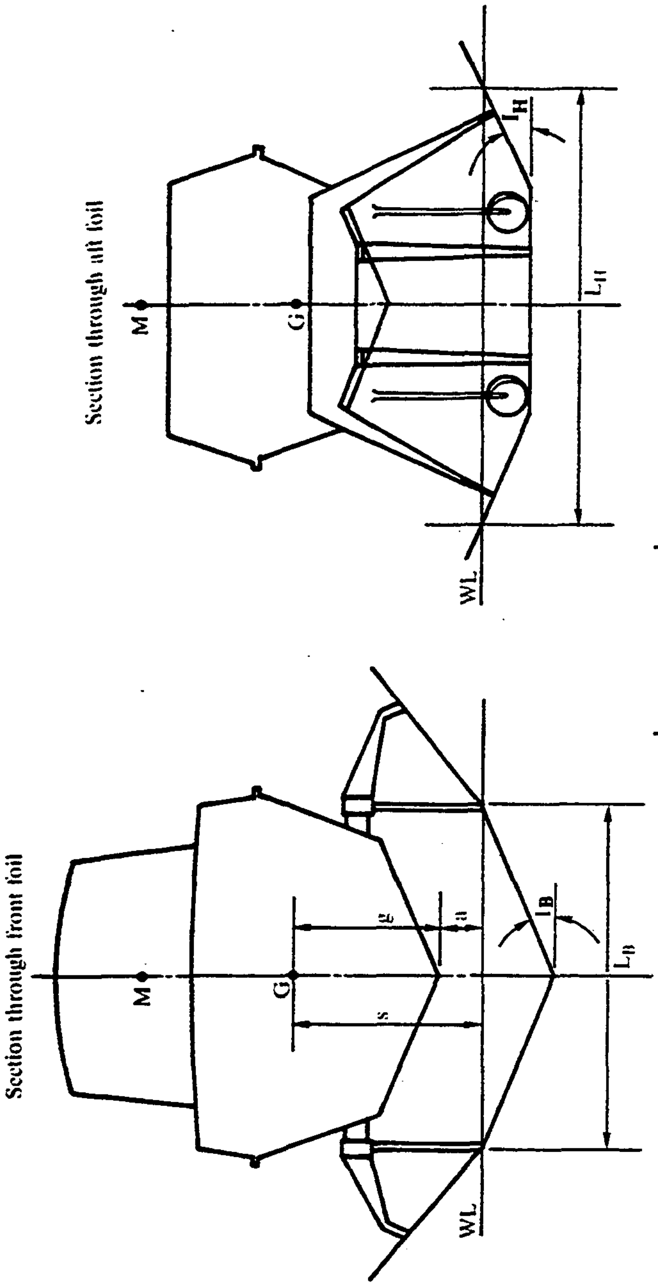
(i) The stability in the transient and foil-borne modes should be checked for all cases of loading for the intended service of the craft.

(ii) The stability in the transient and foil-borne modes may be determined either by calculation or on the basis of data obtained from model experiments and should be verified by full-scale tests by the imposition of a series of known heeling moments by off-centre ballast weights, and recording the heeling angles produced by these moments. When taken in the hull-borne, take-off, steady foil-borne, and settling to hull-borne modes, these results will provide an indication of the values of the stability in the various situations of the craft during the transient condition.

(iii) The time to pass from the hull-borne mode to foil-borne mode and vice versa should be established. This period of time should not exceed two minutes.

(iv) The angle of heel in the foil-borne mode caused by the concentration of passengers on one side should not exceed 8°. During the transient mode the angle of heel due to the concentration of passengers on one side should not exceed 12°. The concentration of passengers should be that taken from paragraph C.1.1.1.

C.8.4.2.2.(c) One of the possible methods of assessing foil-borne metacentric height (GM) in the design stage for a particular foil configuration is given in Figure 13.




$$GM = n_B\left(\frac{L_B}{2\tan l_B} - S\right) + n_H\left(\frac{L_H}{2\tan l_H} - S\right)$$

where $n_B$ = percentage of hydrofoil load borne by front foil
$n_H$ = percentage of hydrofoil load borne by aft foil
$L_B$ = clearance width of front foil
$L_H$ = clearance width of aft foil
a = clearance between bottom of keel and water
g = height of centre of gravity above bottom of keel
$l_B$ = angle at which front foil is inclined to horizontal
$l_H$ = angle at which aft foil is inclined to horizontal

**Figure 13** **STABILITY OF HYDROFOIL WHEN FOIL-BORNE**

C.8.4.3 Fully Submerged Hydrofoils

C.8.4.3.1 Hull-borne Mode

C.8.4.3.1.(a) The stability in the hull-borne mode should be sufficient to satisfy C.8.4.3 and C.8.4.5 of this Section.

C.8.4.3.1.(b) The provisions of C.8.4.2.1.(b) to C.8.4.2.1.(e) are appropriate to this type of craft in the hull-borne mode.

C.8.4.3.2. Transient Mode

(a) The stability should be examined by the use of verified computer simulations to evaluate the craft's motions, behaviour and responses under the normal conditions and limits of operation, and under the influence of any malfunction.

(b) The stability conditions resulting from any potential failures in the systems or operational procedures during the transient stage which could prove hazardous to the craft's watertight integrity and stability should be examined.

C.8.4.3.3 Foil-borne Mode

The stability of the craft in the foil-borne mode should be in compliance with C.8.4.6 of this Section. The provisions of C.8.4.3.2 of this Section also apply.

C.8.4.3.4 Stability Checks

The provisions of C.8.4.2.2.(b) should be applied to this type of craft as appropriate and any computer simulations or design calculations should be verified by full-scale tests.

C.8.5 Buoyancy and Stability Following Damage

C.8.5.1 Following any of the postulated damages detailed in C.8.5.4 and C.8.5.5, the craft in still water should have sufficient bouyancy and positive stability to ensure that in the displacement mode simultaneously:

(a) the final waterline is at least 76 mm below the level of any opening where progressive flooding could take place;

(b) the angle of inclination of the craft from the horizontal does not exceed 8° in any direction for all permitted cases of loading and for such uncontrolled passenger movements as are likely in emergency conditions. The Authority may permit angles of inclination up to 16° immediately after damage but quickly reducing to 12° provided that:

(i) suitable hand holds and efficient non-slip deck surfaces are provided; and

(ii) it is impracticable to restrict the angle of heel to 8°.

In exceptional cases the Authority may permit larger inclinations after damage provided the angle is quickly reduced to 12° and the provisions of (b) (i) and (b) (ii) above are satisfied;

(c) flooding of passenger compartments or escape routes will not significantly impede the evacuation of passengers; and

(d) the Authority should be satisfied that the range of residual stability after damage is adequate.

C.8.5.2 Following any of the postulated damage outlined in C.8.5.4 and C.8.5.5, the Authority should be satisfied that all reasonable and practicable steps have been taken to ensure that the craft, in the worst intended conditions, will have sufficient buoyancy and positive stability to remain afloat for at least 30 minutes or three times the demonstrated evacuation time plus 7 minutes whilst simultaneously ensuring that in the displacement mode:

(a) any flooding of passenger compartments or escape routes will not signicantly impede the evacuation of passengers; and

(b) essential emergency equipment, emergency radios, power supplies and public address systems needed for organising the evacuation remain accessible and operational.

C.8.5.3 Any damage of a lesser extent than that postulated in C.8.5.4 and C.8.5.5 which would result in a more severe condition should also be investigated. The shape of the damage should be assumed to be parallelepiped.

C.8.5.4 The following side damages are to be assumed anywhere on the periphery of the craft:

(a) the length of damage should be 0.1L, or 3 metres + 0.03L, or 11 metres, whichever is the least;

(b) the depth of penetration into the craft should be:

0.2B or 5 metres whichever is less.

However, where the craft is fitted with inflated skirts or with non-buoyant side structures, the depth of penetration should be at least 0.12 of the width of the main buoyancy hull or tank structure; and

(c) the vertical extent of damage should be taken for the full depth of the craft.

C.8.5.5 Bottom damages are to be assumed anywhere on the bottom of the craft as follows:

(a) the length of damage in the fore and aft directions should be + 0.1L, or 3 metres + 0.03L, or 11 metres, whichever is the least;

(b) the width of the damage should be:

0.2B or 5 metres, whichever is less; and

(c) the depth of penetration into the craft should be:

0.02B or 0.5 metres, whichever is less.

C.8.6 Stability of the Craft in the Non-Displacement Mode

C.8.6.1 The Authority should be satisfied, that when operating in the non-displacement and transient modes within approved operational limitations, the craft will, after a disturbance causing roll, pitch, heave or a combination thereof, return to the original attitude.

C.8.6.2 The roll and pitch stability of each craft in the non-displacement mode, should be determined experimentally prior to entering commercial service and be recorded.

C.8.6.3. Where craft are fitted with surface piercing structure or appendages, precautions should be taken against dangerous attitudes or inclinations and loss of stability subsequent to a collision with a submerged or floating object.

C.8.6.4 The Authority should be satisfied that the structures and components provided to sustain operation in the non-displacement mode should in the event of agreed damage or failure provide adequate residual stability in order that the craft may continue safe operation to the nearest place where the passengers and crew could be placed in safety, provided caution is exercised in handling.

**C.9 Off-Shore Supply Vessels**

C.9.1 Off-shore supply vessels should meet at least the criteria laid down in C.2.

C.9.2 Where a supply vessel's characteristics render compliance with C.9.1 impossible, the following criteria may be used:

(a) The area under the curve of righting levers (GZ curve) should not be less than 4.011 metre-degrees up to an angle of 15° when the maximum righting lever (GZ) occurs at 15° and 3.151 metre-degrees up to an angle of 30° when the maximum righting lever (GZ) occurs at 30° or above. Where the maximum righting lever (GZ) occurs at angles between 15° and 30°, the corresponding requisite area under the righting lever curve should be determined by use of the formula:

$$\text{Area} = 3.151 + 0.0573\ (30°\theta_{max})$$

where $\theta_{max}$ is the angle of heel at which righting lever curve reaches its maximum.

(b) The area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and the angle of flooding $0_f$ if this angle is less than 40°, should be not less than 1.719 metre-degrees.

*Note:* The angle of flooding $0_f$ is the least angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

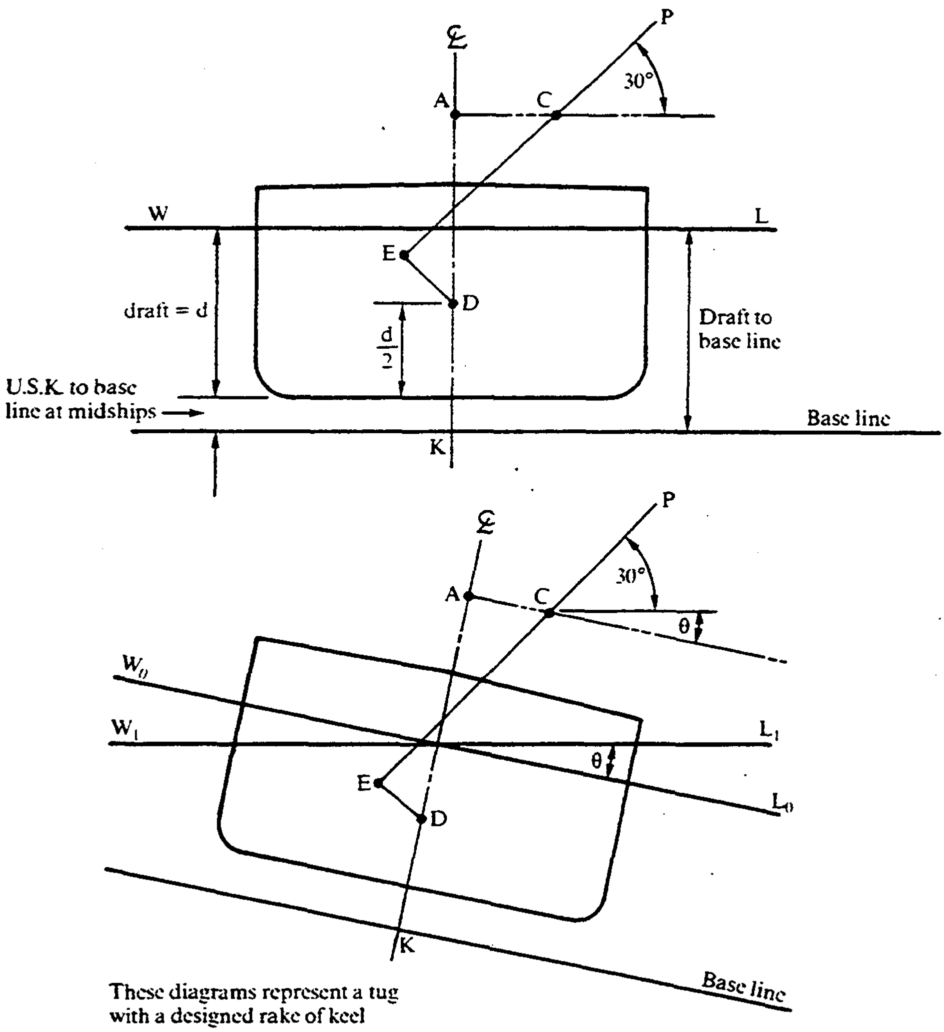



**Figure 14**

The diagrams above show a section of the vessel in way of the towing hook. On these diagrams:

| | |
|---|---|
| P | is the bollard pull of the vessel |
| C | is the position of the towing hook in its guide quadrant |
| EC | is the line of action of the tow rope pull through C acting at right angles to the vessel's centre line, and at an angle of elevation of 30° to the horizontal. |
| KA | is the height of A above the baseline |
| D | is the centre of lateral resistance. It is taken to be at half the draft to the underside of the keel at midships i.e. at d/2 above U.S.K. at midships |
| KD | is d/2 + the distance from U.S.K. to the baseline at midships |
| ED | is the shortest distance between D and the line EC |
| A | is the centre of the towing hook guide quadrant |
| AC | is the radius of the towing quadrant |

Then AD = KA-KD

The heeling moment = Bollard Pull x ED

When the vessel is inclined to angle $\theta°$ to the upright

$$ED = AD \cos(30° + \theta;°) - AC \sin(30° + \theta°)$$

and Heeling Moment at angle $\theta°$

$$= P\,[AD \cos(30° + \theta°) - AC \sin(30° + \theta°)]$$

$$\text{Now Heeling lever} = \frac{\text{Heeling Moment}}{\text{Displacement}}$$

$\therefore$ Heeling Lever at $\theta°$

$$= P \quad \frac{AD \cos(30° + \theta°) - AC \sin(30° + \theta°)}{\text{Displacement}}$$

*Note:* that the reduction in displacement due to the vertical component of P is neglected.

(c) The righting lever (GZ) should be at least 0.20 metres at an angle of heel equal to or greater than 30°.

(d) The maximum righting lever (GZ) should occur at an angle of heel not less than 15°.

(e) The initial transverse metacentric height ($GM_o$) should not be less than 0.15 metres.

C.9.3 The criteria mentioned in C.9.1 and C.9.2 above fix minimum values, but no maximum values are recommended. It is advisable to avoid excessive values, since these might lead to acceleration forces which could be prejudicial to the vessel, its complement, its equipment and to the safe carriage of the cargo.

C.9.4 Where anti-rolling devices are installed in a vessel the Authority should be satisfied that the above criteria can be maintained when the devices are in operation.

C.9.5 A number of influences such as beam wind on vessels with large windage area, characteristics of motion, following seas, adversely affect stability and the Authority may require these to be taken into account so far as it deems necessary.

**C.10 Tugs**

C.10.1 Tugs should meet the criteria laid down in clause C.2.

C.10.2 In many cases tugs will be unable to attain their maximum summer draught by filling all tanks and store spaces. It may be necessary therefore to assume the addition of deck cargo to give the required summer draught. If the resulting curve of righting levers does not meet the criteria of clause C.2 a further loading condition should be arranged which will meet the minimal criteria of clause C.2. The summer freeboard will then be increased by the Authority to correspond with this modified loading condition.

C.10.3 In all conditions where towing can be undertaken, the tow rope heeling lever curve is to be plotted on the curve of righting levers. The tow rope heeling lever curve is to be based on the application athwartships of the bollard pull assumed operating at 30° to the horizontal or such other angle as is acceptable to the Authority. The vertical component should be ignored. (See Figure 4).

C.10.4 The area of the curve of righting levers above the heeling lever curve up to 40° angle of heel (or up to the angle of flooding $\theta_f°$ if this angle is less than 40°) is to be calculated and presented. The proportion of this area to the total area of the curve of righting levers from 0° to 40° (or from 0° to $\theta_f°$ where $\theta_f°$ is less than 40°) is to be calculated and if this result is less than 40 per cent special consideration of the stability will be required.

C.10.5 The towing gear should be designed to minimise any overturning moment which may occur as a result of the lead of the towline.

C.10.6 The towing hook when fitted should have positive means of quick release which will function correctly under all operating conditions. It should not be fitted forward of the longitudinal centre of gravity but be fitted at least 2 per cent of the length of the vessel abaft midships and as low as practicable. The release mechanism should be controlled from the wheelhouse or the after control position and preferably from both of these positions.

**C.11 Class 2B and 2C Vessels Carrying Persons in Addition to the Master and Crew**

C.11.1 The stability will be considered satisfactory if it can be shown that the vessel has a net metacentric height GM, not less than the greater of the values determined in (a) and (b) below:

(a) $$GM = \frac{0.046\ Ah}{\Delta \tan \theta} + 0.15 \text{ metres}$$

where A = projected lateral area of the vessel above the waterline in $metres^2$

h = vertical distance in metres from the centre of area A to the centre of the underwater lateral area

$\Delta$ = displacement in tonnes

$\theta$ = angle of heel to one half of freeboard to the deck edge or 14° whichever is less.

(b) $$GM = \frac{0.0053\ V^2 d}{L \sin \theta} + 0.15 \text{ metres}$$

where V = service speed in knots

L = waterline length of vessel

d = vertical distance in metres between the vertical centre of gravity of the vessel and the centre of the underwater lateral area.

$\theta$ = angle of heel to one half the freeboard to the deck edge or 14° whichever is less.

This formula applies only to vessels where $\frac{V}{\sqrt{L}}$ is less than 4.

**C.12 Sailing Vessels**

C.12.1 General

Passenger carrying sailing vessels should have stability characteristics which take account of the considerations outlined below.

C.12.2 Handiness

Sailing vessels vary widely in hull and rig characteristics and are not always suitable for the passenger service desired.

A sailing vessel for commercial passenger service must be arranged to provide maximum safety for the passengers, and to allow easy handling with a relatively small crew with minimum interference by untrained passengers.

The rig fitted to the vessel must be simple and capable of being worked without assistance from the passengers. Light sails will only be accepted by the Authority where interference by passengers on deck or where the number of crew assigned will enable rapid handling of the sails. Square sails will only be accepted by the Authority where arranged for maximum ease of handling. The Authority may restrict operating weather conditions where light sails or square sails are carried.

C.12.3 Stability

Sailing vessels normally operate heeled and are more likely to be forced to large heel angles than are powered vessels. Such vessels' response throughout their range of stability is thus especially important. Requirements for initial metacentric height and freeboard cannot by themselves assure adequate stability. For example, a vessel with high initial stability, but with a relatively low range of positive stability, may seem to have adequate stability and yet be potentially dangerous in certain circumstances.

Because of the inherently large windage area, direct application of the weather criteria applicable to Class I vessels (vide clause C.1) and listed below would be unrealistic:

| | |
|---|---|
| Category P and Category Q | Wind moment derived from a wind pressure of 600 Pa |
| Category R | Wind moment derived from a wind pressure of 300 Pa |

| | |
|---|---|
| Category S | Wind moment derived from a wind pressure of 450 Pa |
| Category T | Wind moment derived from a wind pressure of 300 Pa |

A large portion of this 'windage area' is controllable and can be reduced by easing or shortening sail in heavy weather. The ease with which this can be accomplished is extremely important. Stability analysis must consider the 'handiness' and size of the rig as well as the hydrodynamic characteristics of the hull.

C.12.4 Deck Openings

The arrangement of deck openings must minimize the chance of flooding the hull at large angles of heel. Deck openings should be of moderate size and located on or near the centreline. They should be fitted with adequate coamings. Companionways shall open fore and aft. Athwartships companionways are not normally acceptable to the Authority.

C.12.5 Auxiliary Power

Installed auxiliary propulsion power, adequate to manoeuvre the vessel under emergency conditions is required. Care should be taken to ensure that the storm sails and ground tackle are suitable for the safety of the vessel and that the rig is arranged so that it can be reduced very quickly in squall conditions.

C.12.6 Existing Vessels

If the owner desires a change in the limits of operation to those of no more severe service conditions no further stability analysis may be necessary. However, an increase in passenger allowance or in severity of service may be made only after a stability analysis supporting such a change.

C.12.7 Criteria for Intact Stability of Small Sailing Vessels

C.12.7.1 These vessels vary widely in their form and proportions, and in the size of rig they carry. However, if vessels meet all of the following criteria the Authority may determine that detailed analysis is unnecessary.

1. Measured length less than 20 metres
2. Carry less than 50 passengers with no overnight accommodation for passengers
3. Operate on smooth or partially smooth waters during daylight hours only
4. Be of a type and rig that has a generally proven record of safe operation.

C.12.7.2 In making this evaluation the Authority will consider the following factors:

1. Restriction to partially smooth waters may be advisable in most cases. This will be governed by such factors as local sea and weather conditions, operating season, and probability of rescue in the event of capsize.
2. The vessel should be expected to remain afloat when flooded or capsized.
3. The vessel should be fitted with suitable hand holds or other means to allow a person to cling to the boat in event of capsize. This requirement would not be necessary on boats with large keel ballast (inside or outside) such that the boat will be self righting after a severe knockdown. Such ballast should represent between 25 and 40 per cent of the full load displacement.
4. A watertight self-draining cockpit is required.
5. Operational tests must be performed to demonstrate that the rig is in fact handy, and that the vessel shows satisfactory handling characteristics under sail (See C.12.2 and C.12.7.1).
6. Simplified stability test techniques shall be used. Where practicable the vessel should be pulled down to 90° from the upright and released. The vessel should be under bare poles with openings through which flooding may occur closed. If the vessel returns to the upright without shipping water then its stability will be regarded as being satisfactory. Otherwise the stability requirements contained in sub-paragraphs C.1.3.2.3 and C.1.3.2.4 shall be applied to the vessel under bare poles.

C.12.7.3 The following vessels tend to have tremendous initial stiffness, but a dangerously short range of positive stability. They should be referred to the Authority for an evaluation.

1. Vessels of unusual design or rig.

2. Broad, shallow draft vessels with little or no outside ballast. (For sailpowered catamarans and trimarans see clause C.14.)

C.12.8 Criteria for Assessing the Intact Stability of Large Sailing Vessels and Sailing Auxiliaries

C.12.8.1 These criteria are applicable to all vessels not meeting the criteria for small sailing vessels.

C.12.8.2 Each vessel in this category shall be inclined.

C.12.8.3 Stability Requirements

Vessels of usual form, proportion and rig should meet the following intact stability requirements. In the case of unusual vessels, or where because of other considerations such as size, application of these standards is impractical, other calculations may be required by the Authority.

1. The vessel should have a range of positive stability, throughout her range of operating drafts, from the upright to at least 70° for service on smooth or partially smooth waters and 90° in open waters.
2. The vessel under bare poles, shall meet Weather Criteria of C.1.3.3.2.
3. In addition to complying with provision 1, the adequacy of the vessel's righting arm curve as related to the sail area should be verified by application of the following procedures and criteria.
   (a) Plot the righting arm curve for the most severe operating condition to:
      1. 90°, if the angle of vanishing positive stability is equal to or less than 90°.
      2. The angle of vanishing positive stability if that angle exceeds 90° but is less than 120°.
      3. 120°, if the angle of vanishing positive stability exceeds that value.

      If the angle at which the maximum righting arm occurs is less than 35°, the curve is truncated so that the maximum is no more than the value at 35°. This is shown in Figure 5.
   (b) Assume a wind heeling arm curve of the form $HZ_\theta = HZ\cos^2\theta$ where HZ equals the heeling arm in metres at zero degrees. Compute the following values of HZ for static or dynamic balance, as indicated by subscripts A, B and C below:
      1. $HZ_A$. Static balance at deck edge immersion, see Figure 16.

$$HZ_A = \frac{HZ\theta}{\cos^2\theta}$$ where θ equals angle to deck edge immersion

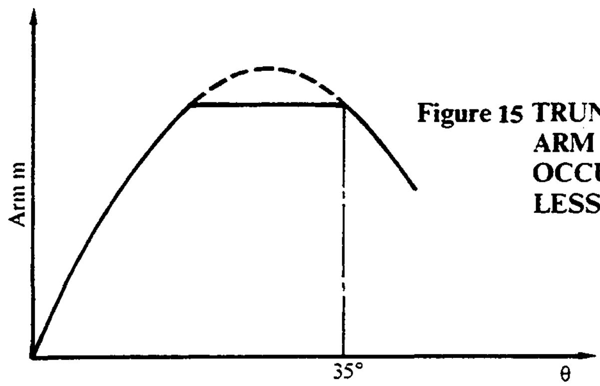



Figure 15 TRUNCATION OF RIGHTING ARM CURVE IF MAXIMUM ARM OCCURS AT AN ANGLE OF LESS THAN 35°

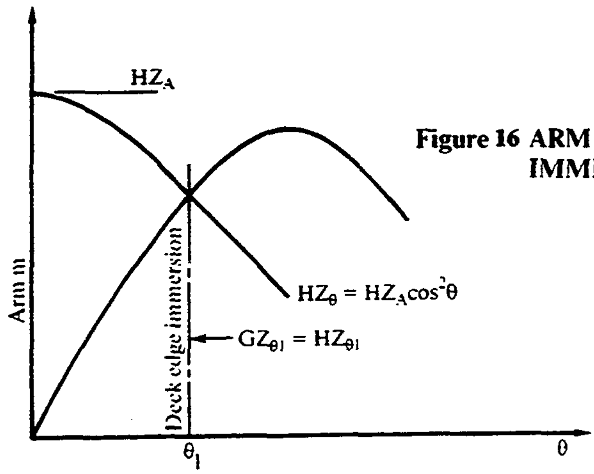



**Figure 16 ARM THROUGH DECK EDGE IMMERSION ANGLE $\theta_1$**

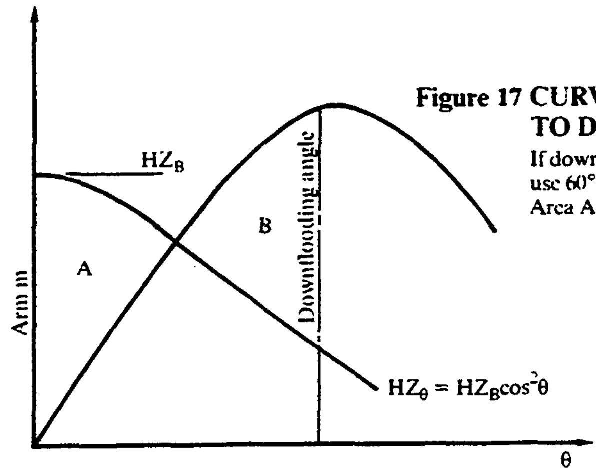



**Figure 17 CURVE TO BALANCE AREAS TO DOWNFLOODING ANGLE**

If downflooding angle exceeds 60°, use 60° in lieu of angle.
Area A = Area B

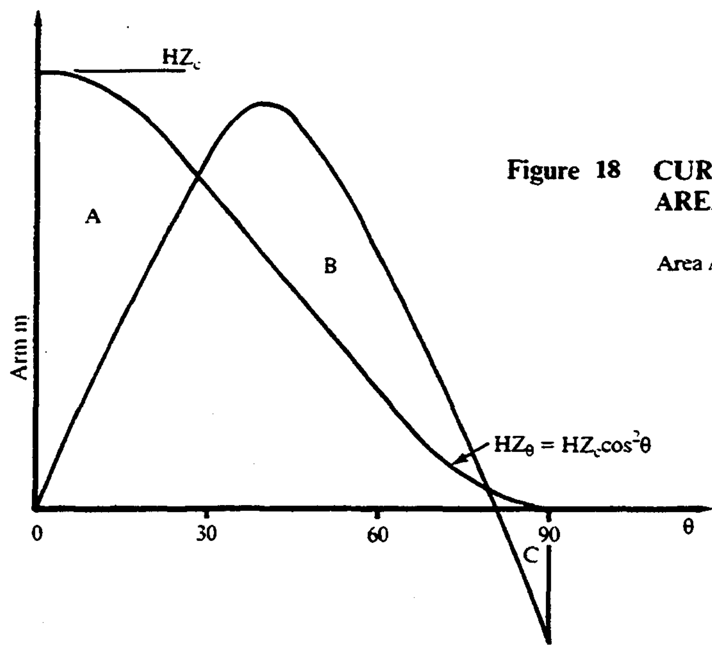



**Figure 18 CURVE TO BALANCE AREAS TO 90°**

Area A + Area C = Area B

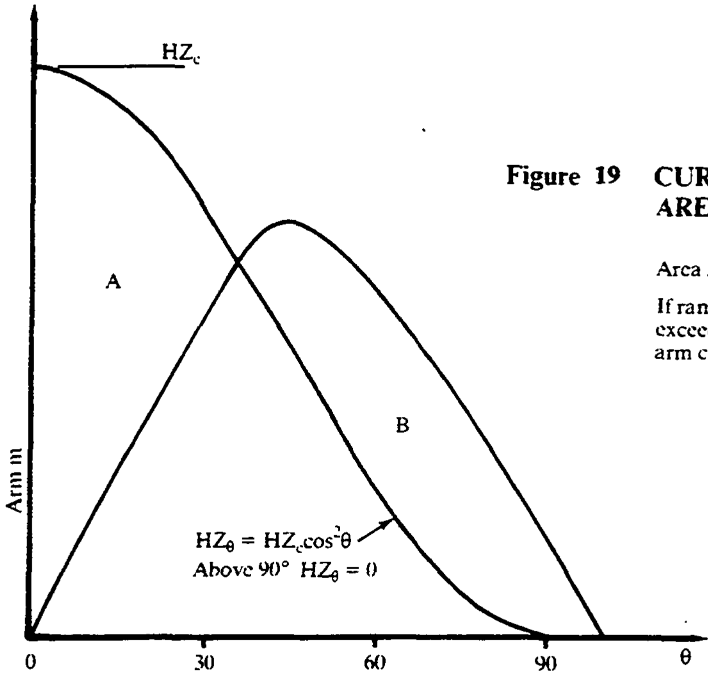



**Figure 19** CURVE TO BALANCE AREAS TO CAPSIZE

Area A = Area B

If range of positive stability exceeds 120° cut off righting arm curve at 120°

2. $HZ_B$. Dynamic balance to downflooding, i.e. angle at which water can enter the hull through hatches, side scuttles, etc. Compute $HZ_B$ so that the area under the righting arm curve equals the area under the heeling arm curve, both taken to the downflooding angle, or as shown in Figure 17 so that area 'A' equals area 'B'. If the angle of flooding exceeds 60°, use 60° in lieu of the downflooding angle.
3. $HZ_C$. Dynamic balance throughout the range of stability. Compute $HZ_C$ so that the area under the righting arm curve equals the area under the heeling arm curve. If the range is less than 90°, take the areas up to 90°, as shown in Figure 18. If the range is greater than 90°, take the area under the righting arm to the maximum angle of positive stability, but not more than 120° as shown in Figure 19.

   *Note:* $HZ_B$ and $HZ_C$ can be computed from the equation:

$$HZ_B \text{ (or } HZ_C) = \frac{I}{\frac{\theta}{2} + 14.3 \sin 2\theta}$$

   where

   I equals the area under the righting arm curve to the allowed angle in metre-degrees

   and,

   θ equals same allowed angle as for I in degrees except it shall never be taken greater than 90°.

(c) Compute the windage area (A) in square metres with all sail set and trimmed flat, and the windage lever (H) in metres as shown in C.1.3.3.2. Where the total area of the head sails is in excess of the fore triangle area the 100 per cent fore triangle area and centre may be used in lieu of those of the individual headsails.

(d) The displacement of the vessel in tonnes is designated △;

(e) The stability will be satisfactory if the following conditions are met:

$$\frac{HZ_A \times \Delta \times 10^3 \times 9.807}{AH} = \text{not less than } 105 \text{ Pascals}$$

$$\frac{HZ_B \times \Delta \times 10^3 \times 9.807}{AH} = \text{not less than } 115 \text{ Pascals}$$

$$\frac{HZ_C \times \Delta \times 10^3 \times 9.807}{AH} = \text{not less than } 130 \text{ Pascals}$$

If any one of the above relationships is not satisfied the vessel should be modified to provide compliance.

**C.13 Sail Training Vessels**

C.13.1 Sail training vessels shall comply with the criteria for sailing vessels laid down in clause C.12.

**C.14 Catamarans and Trimarans (Sail powered)**

C.14.1 Multihull sailing vessels should be capable of meeting the criteria enumerated below.

C.14.2 Statical stability curves for the necessary conditions of loading should be developed from cross curves of stability for the still water condition.

C.14.3 The statical wind heeling arm curve should be augmented for the added wind area occurring above the waterline at any given angle of heel, and for the lowering of the centre of underwater lateral resistance of the hull at that angle of heel. Allowance must also be made as necessary for the elevation of the centre of the upright wind area caused by the added wind area above the waterline and for the diminishing effect caused by the heel of the windward hull blanketing the lower portion of the sail.

C.14.4 In figure 20, curves C and D are the wind arm curves. The pressures correspond to 25 and 50 knots respectively. In each curve the wind area and wind lever are each taken to vary with the cosine.

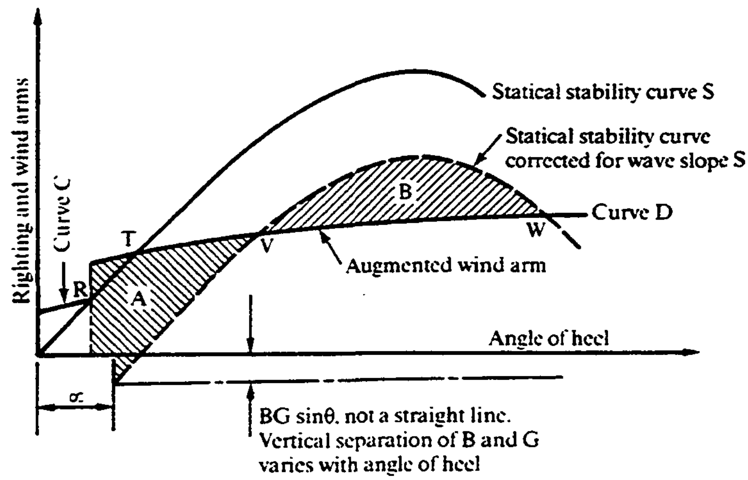
Thus for any given angle of heel, the wind heeling arm is

$$\frac{PAh \cos^2\theta}{\Delta}$$

C.14.5 With operation limited to 'reasonable operating conditions' i.e. wind not to exceed 25 knots, and disregarding wave formation, static equilibrium for heeling and righting occurs at point R. Upon knockdown, assuming a wind gust of twice the average wind velocity, wind curve D in lieu of wind curve C applies. In this case the vessel heels beyond point T and returns to equilibrium at point T assuming that the gust prevails for a reasonable time.

C.14.6 Assuming that the vessel is being broadside to the wave profile at the time of the gust, the static equilibrium point T becomes V, where V lies on the statical stability curve $S^1$ which has been corrected as shown in figure 20 for the wave slope. Use of curve $S^1$ takes account of the spill (or flip) effect of the wave on the emerged sponson as the wave passes from windward to leeward.

C.14.7 To avoid capsizing, the corrected statical stability curve shall be such as to provide an area B equal to area A, representing satisfactory absorption of heel energy enabling the return of the vessel to equilibrium at point V.




P values:
Curve C. P = 100 Pa (25 knots)
Curve D. P = 400 Pa (50 knots)
∝ = maximum wave slope angle within 4.5 m of crest (see C.14.11)

*Fig. 20*

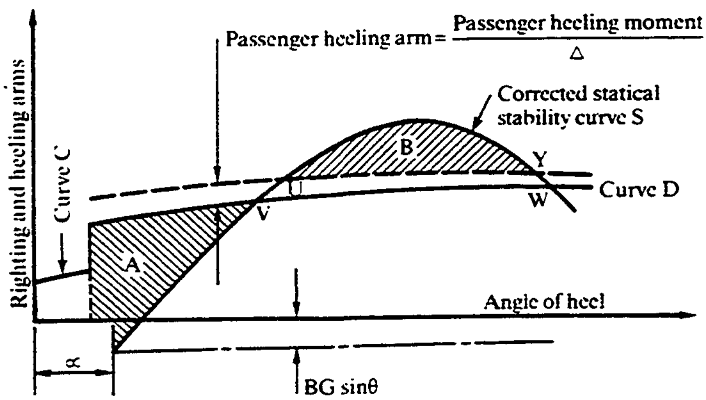



*Fig. 21*

C.14.8 The effective range of stability at an angle corresponding to point W where the heeling and righting arms are equal should be limited only by effective means of preventing the passengers from being tossed across the deck, such as seating and hand holds.

C.14.9 The treatment given above assumes that the passengers have not been used to provide a windward counter-balancing heeling moment. Where such is not the case, the passenger moment is added to the wind and wave effects when the vessel comes about. Figure 21 includes the essentials of figure 20 but also includes passenger moment. In this situation, area B must be equal to area A. The static equilibrium point is U and Y is at the limit of the range of stability (refer C.14.7 and C.14.8).

C.14.10 The above requirements for stability of catamarans include coming about, shift of wind and gusts. The Authority may impose restrictions as to wave slope, passenger heel, wind velocity having regard to local conditions.

C.14.11 The maximum wave slope angles ($\alpha$) within 4.5 metres of a wave crest (it being assumed that this dimension is about the mimimum beam dimension for catamaran types of vessel) are as follows for waves 15 to 120 metres long.

(a) Ocean waves uninfluenced by shallow bottom (deep water waves)

| $\frac{\textit{Wave length}}{\textit{Wave height}}$ | *(Slope angle)* $\alpha$ |
|---|---|
| 20 : 1. . . . . . . . . . . . . . . . . . . . . . | 8° |
| 15 : 1. . . . . . . . . . . . . . . . . . . . . . | 14° |
| 10 : 1. . . . . . . . . . . . . . . . . . . . . . | 20° |

(b) Ocean waves influenced by shallow bottom

When deep water waves enter shallow water the length/height ratio is modified in accordance with the table below in order to arrive at an effective length/height ratio.

The effective length/height ratio so determined shall be used in the table above to determine values of the slope angle.

| *Water depth* | *Effective length to height ratio* |
|---|---|
| $\frac{\text{Deep water wave length}}{10}$ | .74 x deep water ratio |
| $\frac{\text{Deep water wave length}}{5}$ | .93 x deep water ratio |

## C.15 Catamarans and Trimarans (Powered)

C.15.1 Catamarans and trimarans which are powered by means other than by sails shall meet the stability criteria applicable to the purpose for which the craft are designed. The effects of lifting a hull from the water for seagoing vessels shall be indicated.

## C.16 Landing Barges

C.16.1 Where the criteria laid down in C.2 cannot be met, the following modified criteria may be applied.

C.16.2 The area under the righting lever curve shall be:

(a) not less than 6.30 metre-degrees up to an angle of heel of 15° when the maximum righting lever occurs at 15°;

(b) not less than 4.30 metre-degrees up to an angle of 20° when the maximum righting lever occurs at 20°, or

(c) not less than 3.15 metre-degrees up to an angle of 30° when the maximum righting lever occurs at 30° or an angle greater than 30°, or

(d) an area, when the maximum righting lever occurs at angles between 15° and 20° or 20° and 30°, up to the angle of maximum righting lever, obtained by linear interpolation; and

(e) not less than 1.72 metre-degrees between the angles of heel of 30° and 40° or between 30° and the angle of flooding if less than 40°.

*Note:*

The angle of flooding is the angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight commence to immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

C.16.3 The maximum righting lever which shall occur at an angle of heel not less than 15°, shall be at least 0.2 metres.

C.16.4 The initial transverse metacentric height shall be not less than 0.15 metres.

## Appendix A

## GUIDANCE ON A METHOD OF CALCULATION OF THE EFFECT OF SEVERE WIND AND ROLLING IN ASSOCIATED SEA CONDITIONS

The ability of the vessel to withstand the effect of gusts and severe winds and rolling should be demonstrated using dynamic wind heeling moment taking into consideration the rolling angle due to waves. The criterion for adequate stability under these circumstances should show that the effect of the dynamic heeling moment $M_w$ (as indicated in Figure A1) caused by wind pressure in the worst operating condition, taking into account the rolling angle, is equal to or less than the effect of the excess restoring moment (area 'b' or the area under the corresponding excess restoring arm). This condition is considered to be fulfilled when the following condition is satisfied:

The ratio $C_{wr} = \frac{\text{area 'b'}}{\text{area 'a'}}$ should not be less than unity.

The wind force on every exposed lateral part of the vessel's side is assumed to have the same direction as the wind and to act at a height above the water level equal to the height of the centroid of the projected area of the part in question. This wind force may be calculated:

(a) for a uniform wind velocity acting on the complete profile area; or

(b) for a wind velocity which increases with the height above sea level acting on a number of elements of horizontal areas.

The wind heeling moment may be calculated as follows:

$$M_w = \tfrac{1}{2} \rho K_1^2 \sum_{n=1}^{n=N} C_D V_n^2 A_n Z_n$$

where

$M_{w1}$ = heeling moment due to steady wind (tonne metres)

$M_{w2}$ = heeling moment due to gust or severe wind (tonne metres)

$\rho$ = air density = 0.1249 kg sec²/m⁴ at 1013.25 millibars 15°C.

$C_D$ = appropriate non-dimensional drag coefficient selected from the following:

| Shape | $C_D$ |
|---|---|
| Cylindrical | 0.5 |
| Large flat surfaces (e.g. hull, deckhouse etc.) | 1.0 |
| Block effect of clustered deckhouse | 1.1 |
| Lattice structure | 1.25 |
| Exposed beams and girders | 1.30 |
| Isolated shapes (crane, etc.) | 1.50 |

$K_1$ = wind speed factor

$K_1 = 1$ for steady wind averaged over 1 hour

$K_1 = 1.5$ for gust wind averaged over 3 seconds

$V_n$ = wind speed at centroid of lateral area $A_n$ (metres per second)

(For open sea conditions a uniform steady wind velocity of not less than 55 knots should be used. If a wind velocity increasing with height above sea level is adopted, the following scale should be used:

Less than 5 metres—52 knots

5 metres and over but less than 10 metres—55 knots

10 metres and over but less than 20 metres—58 knots)

$A_n$ = projected lateral profile area gf element n (metres$^2$)

$Z_n$ = length of wind lever between centroid of $A_n$ and assumed point of action of the opposing forces (normally to be taken as mid draught position) (metres)

n = integer

N = number of elements of horizontal areas

$\theta_0$ = angle of heel under action of steady wind (degrees)

$\theta_1$ = angle of roll to windward when rolling synchronously about $\theta_0$ (degrees)

$\theta_2$ = flooding angle ($\theta_f$) or angle specified by the Authority (degrees).

The value of $\theta_1$ is to be determined as follows:

$$\theta_1 = \sqrt{\frac{138 \times f \times S}{N}}$$

where

f = effective wave slope coefficient

$$= 0.75 + 0.6 \times \frac{OG}{d}$$

d = mean draught (metres)

OG = KG–d (metres)

S = wave steepness

$$= \frac{\text{wave height}}{\text{wave length}}$$

$= K_2 - K_3 \text{ x } T_s$

(Note: $0.100 \geqslant S \geqslant 0.035$)

N = Bertin's damping coefficient

$$= 0.020 \left(\frac{1}{\text{degree}}\right)$$

$T_s$ = period of roll

$$= \frac{2\pi K}{\sqrt{g.\ GM}}$$

$$= \frac{2.01\ K}{\sqrt{GM}} \text{ seconds}$$

K = transverse radius of gyration

GM = metacentric height (metres).

$K_2$ and $K_3$ are to be selected from the following table.

| *Steady wind speed* | | | |
|---|---|---|---|
| *metres/sec.* | *knots* | $K_2$ | $K_3$ |
| 15 | 29 | 0.155 | 0.0130 |
| 19 | 37 | 0.153 | 0.0100 |
| 26 | 51 | 0.151 | 0.0072 |

Values for other speeds may be obtained by linear interpolation or extrapolation.

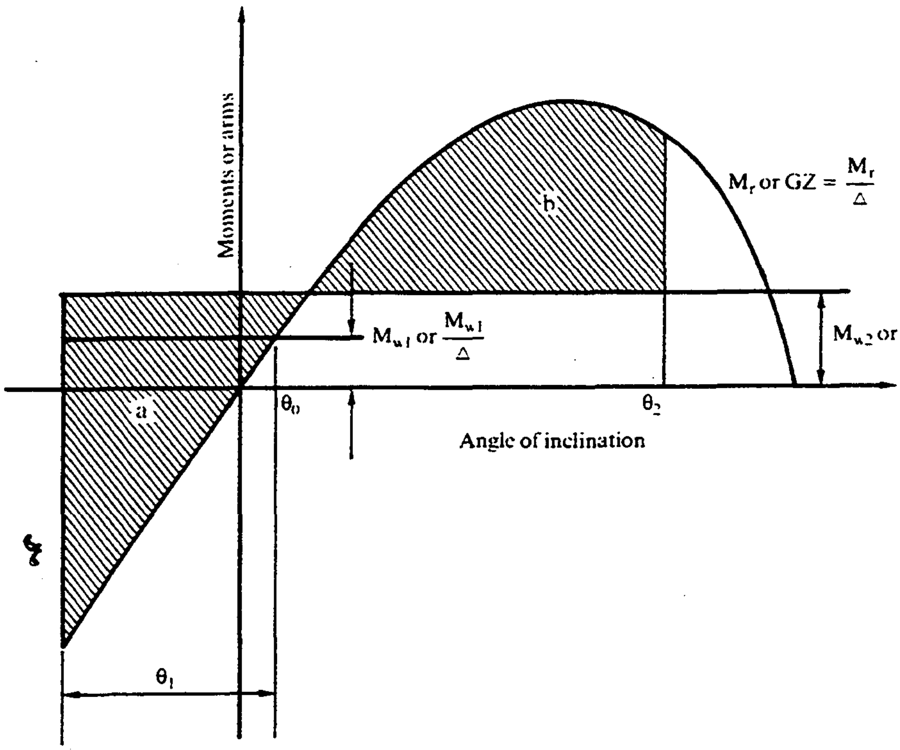



**Figure 1.** **SEVERE WIND AND ROLLING**

**Appendix B**

## GUIDANCE ON A METHOD OF CALCULATION OF THE EFFECT OF WATER ON DECK

The ability of the vessel to withstand the heeling effect due to the presence of water on deck should be demonstrated by quasi-static method, with reference to Figure B1, when the following condition is satisfied with the vessel in the worst operating condition:

The ratio $C_{wod} = \frac{\text{area 'b'}}{\text{area 'a'}}$ should not be less than unity.

The angle which limits area 'b' should be equal to the flooding angle $\theta_f$ or 40 degrees whichever is the less.

The value of the heeling moment $M_{wod}$ (or the corresponding heeling arm) due to the presence of water on deck should be determined assuming that the deck well is filled to the top of the bulwark at its lowest point and the vessel heeled up to the angle at which this point is immersed. For the determination of $M_{wod}$ the following formula should be used:

$$M_{wod} = K\ M_x$$

where

$M_x$ = static heeling moment due to water on deck

K = coefficient

(a) if $M_{wod}$ is determined by a static approach
K= 1.0 may be applied.

(b) If $M_{wod}$ is determined by a quasi-static approach, K may take into account the rolling period of the vessel and the dynamic effect of the water flow, including the effect of the disposition and configuration of deck wells and deckhouses. The value of K should be satisfactory, taking into account the type of vessel, area of operation, etc., and using the following table.

| *Angle of Deck Edge Immersion ($\theta_D$)* | *Angle of Bulwark Top Immersion ($\theta_B$)* | | *K* |
|---|---|---|---|
| Below 10° | Below 20° | greater than | 1.0 |
| 10° to 20° | 20° to 30° | | 1.0 |
| Above 20° | Over 20° | less than | 1.0 |

When calculating $M_x$ the following assumptions should be made:

(a) at the beginning the vessel is in the upright condition;

(b) during heeling, trim and displacement are constant and equal to the values for the vessel without the water on deck; and

(c) the effect of freeing ports should be ignored.

The above provisions may be adjusted, taking into account the seasonal weather conditions and sea states in the areas in which the vessel will operate, the type of vessel and its mode of operation.

Other methods for the calculation of the effect of water on deck using the dynamic approach may be adopted.

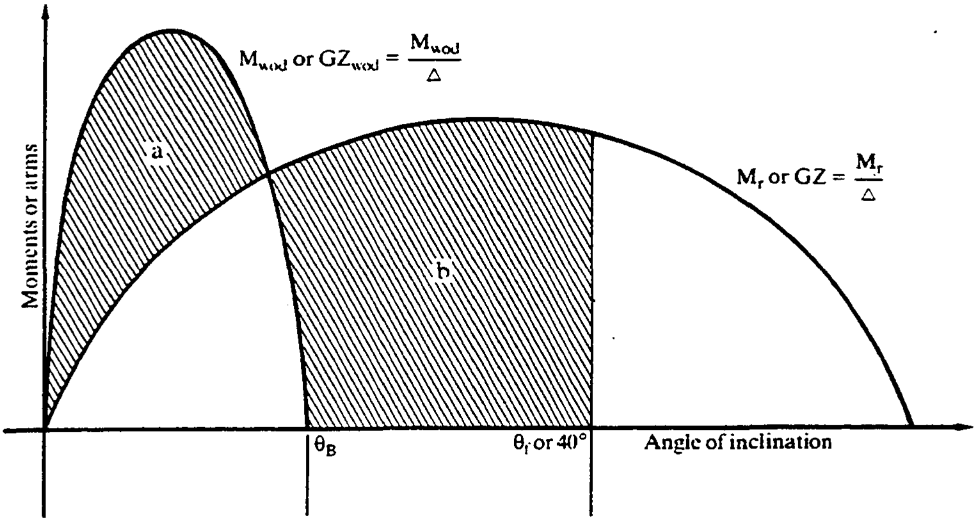



**Figure 2.** **WATER ON DECK**