SECTION 2 INTACT STABILITY

1 General

1.1 Information for the Master

1.1.1 Stability booklet

Each ship is to be provided with a stability booklet, approved by the Society, which contains sufficient information to enable the Master to operate the ship in compliance with the applicable requirements contained in this Section.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the ship is to be re-inclined.

Stability data and associated plans are to be drawn up in the official language or languages of the issuing country. If the languages used are neither English nor French the text is to include a translation into one of these languages.

The format of the trim and stability booklet and the information included are specified in Ch 3, App 2.

1.1.2 Loading instrument

As a supplement to the approved stability booklet, a loading instrument, approved by the Society, may be used to facilitate the stability calculations mentioned in Ch 3, App 2.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 11, Sec 2, [4].

1.1.3 Operating booklets for certain ships

Ships with innovative design are to be provided with additional information in the stability booklet such as design limitations, maximum speed, worst intended weather conditions or other information regarding the handling of the craft that the Master needs to operate the ship.

1.2 Permanent ballast

1.2.1 *If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the ship or relocated within the ship without the approval of the Society. Permanent ballast particulars are to be noted in the ship's stability booklet.*

1.2.2 Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified in [2.1.2], [2.1.3], [2.1.4],and [2.1.5] are to be complied with for the loading conditions mentioned in Ch 3, App 2, [1.2].

However, the lightship condition not being an operational loading case, the Society may accept that part of the above-mentioned criteria are not fulfilled.

These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship, its equipment and to safe carriage of the cargo.

2.1.2 GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0,055 m·rad up to θ = 30° angle of heel and not less than 0,09 m·rad up to θ = 40° or the angle of down flooding θ_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 θ_f, if this angle is less than 40°, is to be not less than 0,03 mrad.

Note 1: θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.This interpretation is not intended to be applied to existing ships.

The means of closing air pipes are to be weathertight and of an automatic type if the openings of the air pipes to which the devices are fitted would be submerged at an angle of less than 40 degrees (or any lesser angle which may be needed to suit stability requirements) when the ship is floating at its summer load line draught. Pressure/vacuum valves (P.V. valves) may be accepted on tankers. Wooden plugs and trailing canvas hoses may not be accepted in positions 1 and 2 as defined in Ch 1, Sec 2, [3.19].

2.1.3 Minimum righting lever

The righting lever GZ is to be at least 0,20 m at an angle of heel equal to or greater than 30°.

2.1.4 Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°.

When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°.

In cases of ships with a particular design and subject to the prior agreement of the flag Administration, the Society may accept an angle of heel θ_{max} less than 25° but in no case less than 15°, provided that the area "A" below the righting

lever curve is not less than the value obtained, in m.rad, from the following formula:

$A = 0,055 + 0,001\ (30° - \theta_{max})$

where θ_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

2.1.5 Initial metacentric height

The initial metacentric height GM_0 is not to be less than 0,15 m.

2.1.6 Elements affecting stability

A number of influences such as beam wind on ships with large windage area, icing of topsides, water trapped on deck, rolling characteristics, following seas, etc., which adversely affect stability, are to be taken into account.

2.1.7 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accretion are given in [6]) and to losses of weight such as those due to consumption of fuel and stores.

3 Severe wind and rolling criterion (weather criterion)

3.1 Scope

3.1.1 *This criterion supplements the stability criteria given in [2.1] for ships of 24 m in length and over. The more stringent criteria of [2.1] and the weather criterion are to govern the minimum requirements.*

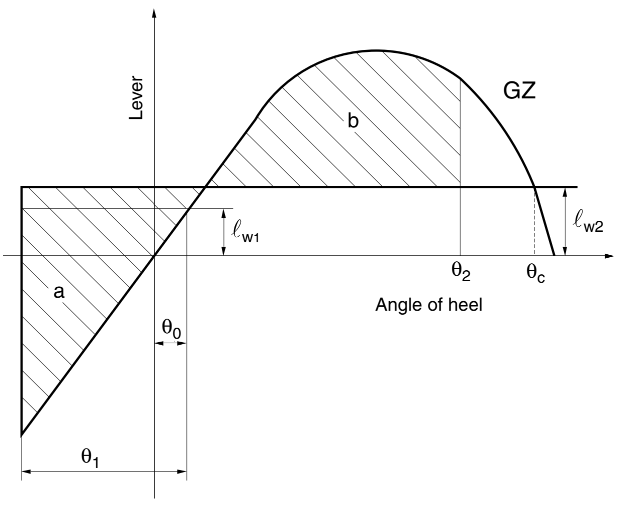
3.2 Weather criterion

3.2.1 Assumptions

The ability of a ship to withstand the combined effects of beam wind and rolling is to be demonstrated for each standard condition of loading, with reference to Fig 1 as follows:

- *the ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever (ℓ_{w1});*
- *from the resultant angle of equilibrium (θ_0), the ship is assumed to roll owing to wave action to an angle of roll (θ_1) to windward;*
- *the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (ℓ_{w2});*
- *free surface effects, as described in [4], are to be accounted for in the standard conditions of loading as set out in Ch 3, App 2, [1.2].*

Figure 1 : Severe wind and rolling



3.2.2 Criteria

Under the assumptions of [3.2.1], the following criteria are to be complied with:

- *the area "b" is to be equal to or greater than area "a", where:*
  - *a* : Area above the GZ curve and below ℓ_{w2}, between θ_R and the intersection of ℓ_{w2} with the GZ curve
  - *b* : *Area above the heeling lever ℓ_{w2} and below the GZ curve, between the intersection of ℓ_{w2} with the GZ curve and θ_2.*
- *the angle of heel under action of steady wind (θ_0) is to be limited to 16° or 80% of the angle of deck edge immersion, whichever is less.*

3.2.3 Heeling levers

The wind heeling levers ℓ_{w1} and ℓ_{w2}, in m, referred to in [3.2.2], are constant values at all angles of inclination and are to be calculated as follows:

$$\ell_{W1} = \frac{PAZ}{1000g\Delta}$$

and

$$\ell_{W2} = 1,5\,\ell_{W1}$$

where:

- *P* : *504 N/m² for unrestricted navigation notation. The value of P used for ships with restricted navigation notation may be reduced subject to the approval of the Society;*
- *A* : *Projected lateral area in m², of the portion of the ship and deck cargo above the waterline;*
- *Z* : *Vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught;*
- *Δ* : *Displacement in t;*

g = 9,81 m/s².

3.2.4 Angles of heel

For the purpose of calculating the criteria of [3.2.2], the angles in Fig 1 are defined as follows:

θ_0 : *Angle of heel, in degrees, under action of steady wind*

θ_1 : *Angle of roll, in degress, to windward due to wave action, calculated as follows:*

$$\theta_1 = 109kX_1X_2\sqrt{rs}$$

θ_2 : *Angle of downflooding (θ_f) in degrees, or 50° or θ_c , whichever is less*

θ_f : *Angle of heel in degrees, 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;*

θ_c : *Angle in degrees, of second intercept between wind heeling lever ℓ_{w2} and GZ curves*

$\theta_R = \theta_0 - \theta_1$

X_1 : *Coefficient defined in Tab 1*

X_2 : *Coefficient defined in Tab 2*

k : *Coefficient equal to:*

k = 1,0 for a round-bilged ship having no bilge or bar keels

k = 0,7 for a ship having sharp bilge

For a ship having no bilge keels, a bar keel or both, k is defined in Tab 3.

$r = 0{,}73 \pm 0{,}6\,(OG)/T_1$

OG : *Distance in m, between the centre of gravity and the waterline (positive if centre of gravity is above the waterline, negative if it is below)*

T_1 : *Mean moulded draught in m, of the ship*

s : *Factor defined in Tab 4.*

Note 1: The angle of roll θ_1 for ships with anti-rolling devices is to be determined without taking into account the operations of these devices.

Note 2: The angle of roll θ_1 may be obtained, in lieu of the above formula, from model tests or full scale measurements.

The rolling period T_R, in s, is calculated as follows:

$$T_R = \frac{2CB}{\sqrt{GM}}$$

where:

$$C = 0{,}373 + 0{,}023\frac{B}{T_1} - 0{,}043\frac{L_W}{100}$$

The symbols in the tables and formula for the rolling period are defined as follows:

L_W : *Length in m, of the ship at the waterline*

T_1 : *Mean moulded draught in m, of the ship*

A_K : *Total overall area in m² of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas,* or area of the lateral projection of any hull appendages generating added mass during ship roll

GM : *Metacentric height in m, corrected for free surface effect.*

Table 1 : Values of coefficient X_1

B/d	X_1
≤ 2,4	1,00
2,5	0,98
2,6	0,96
2,7	0,95
2,8	0,93
2,9	0,91
3,0	0,90
3,1	0,88
3,2	0,86
3,4	0,82
≥ 3,5	0,80

Table 2 : Values of coefficient X_2

C_B	X_2
≤ 0,45	0,75
0,50	0,82
0,55	0,89
0,60	0,95
0,65	0,97
≥ 0,70	1,00

Table 3 : Values of coefficient k

$\frac{A_K \times 100}{L \times B}$	k
0,0	1,00
1,0	0,98
1,5	0,95
2,0	0,88
2,5	0,79
3,0	0,74
3,5	0,72
≥ 4,0	0,70

Table 4 : Values of factor s

T_R	s
≤ 6	0,100
7	0,098
8	0,093
12	0,065
14	0,053
16	0,044
18	0,038
≥ 20	0,035

(Intermediate values in these tables are to be obtained by linear interpolation)

4 Effects of free surfaces of liquids in tanks

4.1 General

4.1.1 *For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.*

4.2 Consideration of free surface effects

4.2.1 *Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. Free surface effects for small tanks may be ignored under the condition in [4.9.1].*

4.2.2 For ships having cargo tanks with a breadth greater than 60% of the ship's maximum beam, the free surface effects when the tanks are filled at 98% or above may not be neglected.

4.3 Categories of tanks

4.3.1 *Tanks which are taken into consideration when determining the free surface correction may be one of two categories:*

- *Tanks with fixed filling level (e.g. liquid cargo, water ballast). The free surface correction is to be defined for the actual filling level to be used in each tank.*
- *Tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water, and also liquid cargo and water ballast during liquid transfer operations). Except as permitted in [4.5.1] and [4.6.1], the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.*

4.4 Consumable liquids

4.4.1 *In calculating the free surfaces effect in tanks containing consumable liquids, it is to be assumed that for each type of liquid at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account are to be those where the effect of free surface is the greatest.*

4.5 Water ballast tanks

4.5.1 *Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surfaces effect is to be calculated to take account of the most onerous transitory stage relating to such operations.*

4.6 Liquid transfer operations

4.6.1 *For ships engaged in liquid transfer operations, the free surface corrections at any stage of the liquid transfer operations may be determined in accordance with the filling level in each tank at the stage of the transfer operation.*

4.7 GM_0 and GZ curve corrections

4.7.1 *The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in [4.7.2] and [4.7.3].*

4.7.2 *In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0 degrees angle of heel according to the categories indicated in [4.3.1].*

4.7.3 *The righting lever curve may be corrected by any of the following methods:*

- *Correction based on the actual moment of fluid transfer for each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1]*
- *Correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1]*
- *Correction based on the summation of M_{fs} values for all tanks taken into consideration, as specified in [4.8.1].*

4.7.4 *Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.*

4.8 Free surface moment

4.8.1 *The values for the free surface moment at any inclination in m.t for each tank may be derived from the formula:*

$$M_{fs} = v b \rho k \sqrt{\delta}$$

where:

v : *Tank total capacity, in m³*

b : *Tank maximum breadth, in m*

ρ : *Mass density of liquid in the tank, in t/m³*

k : *Dimensionless coefficient to be determined from Tab 5 according to the ratio b/h. The intermediate values are determined by interpolation.*

δ : *Tank block coefficient, equal to:*

$$\delta = \frac{v}{b \ell h}$$

ℓ : *Tank maximum length, in m*

h : *Tank maximum height, in m.*

Table 5 : Values of coefficient k for calculating free surface corrections

$$k = \frac{\sin\theta}{12} \cdot \left(1 + \frac{(\tan\theta)^2}{2}\right) \cdot \frac{b}{h}, \qquad \text{where} \qquad \cot\theta \geq \frac{b}{h}$$

$$k = \frac{\cos\theta}{8} \cdot \left(1 + \frac{\tan\theta}{b/h}\right) - \frac{\cos\theta}{12 \cdot (b/h)^2} \cdot \left(1 + \frac{(\cot\theta)^2}{2}\right), \qquad \text{where} \qquad \cot\theta < \frac{b}{h}$$

θ b/h	5°	10°	15°	20°	30°	40°	45°	50°	60°	70°	75°	80°	85°	θ b/h
20,0	0,11	0,12	0,12	0,12	0,11	0,10	0,09	0,09	0,09	0,05	0,04	0,03	0,02	20,0
10,0	0,07	0,11	0,12	0,12	0,11	0,10	0,10	0,09	0,07	0,05	0,04	0,03	0,02	10,0
5,00	0,04	0,07	0,10	0,11	0,11	0,11	0,10	0,10	0,08	0,07	0,06	0,05	0,04	5,00
3,00	0,02	0,04	0,07	0,09	0,11	0,11	0,11	0,10	0,09	0,08	0,07	0,06	0,05	3,00
2,00	0,01	0,03	0,04	0,06	0,09	0,11	0,11	0,11	0,10	0,09	0,09	0,08	0,07	2,00
1,50	0,01	0,02	0,03	0,05	0,07	0,10	0,11	0,11	0,11	0,11	0,10	0,10	0,09	1,50
1,00	0,01	0,01	0,02	0,03	0,05	0,07	0,09	0,10	0,12	0,13	0,13	0,13	0,13	1,00
0,75	0,01	0,01	0,01	0,02	0,02	0,04	0,04	0,05	0,09	0,16	0,18	0,21	0,16	0,75
0,50	0,00	0,01	0,01	0,02	0,02	0,04	0,04	0,05	0,09	0,16	0,18	0,21	0,23	0,50
0,30	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,03	0,05	0,11	0,19	0,27	0,34	0,30
0,20	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,02	0,04	0,07	0,13	0,27	0,45	0,20
0,10	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,04	0,06	0,14	0,53	0,10

4.9 Small tanks

4.9.1 *Small tanks which satisfy the following condition using the values of k corresponding to an angle of inclination of 30° need not be included in the correction:*

$M_{fs}/\Delta_{min} < 0{,}01$ m

where:

Δ_{min} : *Minimum ship displacement, in t, calculated at* d_{min}

d_{min} : *Minimum mean service draught, in m, of ship without cargo, with 10% stores and minimum water ballast, if required.*

4.10 Remainder of liquid

4.10.1 *The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.*

5 Cargo ships carrying timber deck cargoes

5.1 Application

5.1.1 *The provisions given hereunder apply to ships engaged in the carriage of timber deck cargoes. Ships that are provided with and make use of their timber load line are also to comply with the requirements of regulations 41 to 45 of the International Load Line Convention 1966, as amended.*

5.2 Definitions

5.2.1 Timber

Timber means sawn wood or lumber, cants, logs, poles, pulpwood and all other types of timber in loose or packaged forms. The term does not include wood pulp or similar cargo.

5.2.2 Timber deck cargo

Timber deck cargo means a cargo of timber carried on an uncovered part of a freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

5.2.3 Timber load line

Timber load line means a special load line assigned to ships complying with certain conditions related to their construction set out in the International Convention on Load Lines 1966, as amended, and used when the cargo complies with the stowage and securing conditions of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (Resolution A.715(17)).

5.3 Stability criteria

5.3.1 *For ships loaded with timber deck cargoes and provided that the cargo extends longitudinally between superstructures (where there is no limiting superstructure at the after end, the timber deck cargo is to extend at least to the after end of the aftermost hatchway) and transversely for the full beam of ship after due allowance for a rounded gunwale not exceeding 4% of the breadth of the ship and/or securing the supporting uprights and which remains securely fixed at large angles of heel, the Society may apply the* criteria given in [5.3.2] to [5.3.5], *which substitute those given in [2.1.2], [2.1.3], [2.1.4] and [2.1.5] and in [3.2].*

5.3.2 *The area under the righting lever curve (GZ curve) is to be not less than 0.08 m·rad up to θ = 40° or the angle of flooding if this angle is less than 40°.*

5.3.3 *The maximum value of the righting lever (GZ) is to be at least 0.25 m.*

5.3.4 *At all times during a voyage, the metacentric height GM_0 is to be not less than 0,10 m after correction for the free surface effects of liquid in tanks and, where appropriate, the absorption of water by the deck cargo and/or ice accretion on the exposed surfaces. (Details regarding ice accretion are given in [6]). Additionally, in the departure condition the metacentric height is to be not less than 0.10 m.*

5.3.5 *When determining the ability of the ship to withstand the combined effect of beam wind and rolling according to [3.2], the 16° limiting angle of heel under action of steady wind is to be complied with, but the additional criterion of 80% of the angle of deck edge immersion may be ignored.*

5.4 Stability booklet

5.4.1 *The ship is to be supplied with comprehensive stability information which takes into account timber deck cargo. Such information is to enable the Master, rapidly and simply, to obtain accurate guidance as to the stability of the ship under varying conditions of service. Comprehensive rolling period tables or diagrams have proved to be very useful aids in verifying the actual stability conditions.*

5.4.2 *For ships carrying timber deck cargoes, the Society may deem it necessary that the Master be given information setting out the changes in deck cargo from that shown in the loading conditions, when the permeability of the deck cargo is significantly different from 25% (see [5.5.1]).*

5.4.3 *For ships carrying timber deck cargoes, conditions are to be shown indicating the maximum permissible amount of deck cargo having regard to the lightest stowage rate likely to be met in service.*

5.5 Calculation of the stability curve

5.5.1 *In addition to the provisions given in Ch 3, App 2, [1.3], the Society may allow account to be taken of the buoyancy of the deck cargo assuming that such cargo has a permeability of 25% of the volume occupied by the cargo. Additional curves of stability may be required if the Society considers it necessary to investigate the influence of different permeabilities and/or assumed effective height of the deck cargo.*

5.6 Loading conditions to be considered

5.6.1 *The loading conditions which are to be considered for ships carrying timber deck cargoes are specified in Ch 3, App 2, [1.2.2]. For the purpose of these loading conditions, the ship is assumed to be loaded to the summer timber load line with water ballast tanks empty.*

5.7 Assumptions for calculating loading conditions

5.7.1 *The following assumptions are to be made for calculating the loading conditions referred to in Ch 3, App 2, [1.2.2]:*

- *the amount of cargo and ballast is to correspond to the worst service condition in which all the relevant stability criteria reported in [2.1.2], [2.1.3], [2.1.4] and [2.1.5], or the optional criteria given in [5.3], are met.*
- *In the arrival condition, it is to be assumed that the weight of the deck cargo has increased by 10% due to water absorption.*

5.7.2 *The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, is to be positive and* in compliance with the stability criteria of [5.3]. *It is to be calculated having regard to:*

- *the increased weight of the timber deck cargo due to:*
  - *absorption of water in dried or seasoned timber, and*
  - *ice accretion, if applicable (as reported in [6])*
- *variations in consumable*
- *the free surface effect of liquid in tanks, and*
- *the weight of water trapped in broken spaces within the timber deck cargo and especially logs.*

5.7.3 *Excessive initial stability is to be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings.* Unless otherwise stated in the stability booklet, *the metacentric height is* generally *not to exceed 3% of the breadth in order to prevent excessive acceleration in rolling provided that the relevant stability criteria given in [5.3] are satisfied.*

5.8 Stowage of timber deck cargoes

5.8.1 *The stowage of timber deck cargoes is to comply with the provisions of chapter 3 of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (resolution A.715(17)).*

6 Icing

6.1 Application

6.1.1 *For any ship operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances are to be included in the analysis of conditions of loading.*

6.2 Ships carrying timber deck cargoes

6.2.1 *The Master is to establish or verify the stability of his ship for the worst service condition, having regard to the increased weight of deck cargo due to water absorption and/or ice accretion and to variations in consumable.*