SECTION 2 INTACT STABILITY

1 General

1.1 Information to the Master

1.1.1 Stability booklet

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

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

1.2 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 yacht or relocated within the yacht without the approval of the Society. Permanent ballast particulars are to be noted in the yacht's stability booklet.

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

2 Design criteria for all type of yachts

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified from [2.1.2] to [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 abovementioned criteria are not fulfilled.

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 m rad.

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 (see Ch 3, App 2, [1.3.3]).

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 yachts with a particular design (multihull for example), the Society may accept an angle of heel θ_{max} less than 25° but in no case less than 10°, 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.

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 yachts of a length L_{LL} greater than 24 m. The more stringent criteria of [2.1] and the weather criterion are to govern the minimum requirements.

3.1.2 Tab 1 can be used for the correspondence between Beaufort scale and wind pressure.

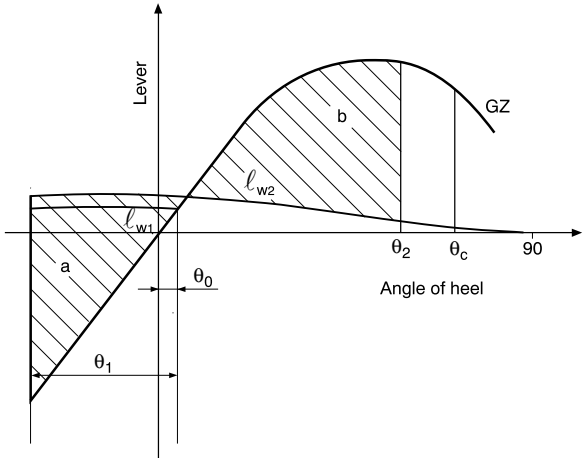
3.2 Weather criterion for motor yachts and sailing yachts with lowered sails

3.2.1 Assumptions

The ability of a yacht 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 yacht is subjected to a steady wind pressure acting perpendicular to the yacht's centreline which results in a steady wind heeling lever (ℓ_{w1})

Figure 1 : Severe wind and rolling



- from the resultant angle of equilibrium (θ_0), the yacht is assumed to roll owing to wave action to an angle of roll (θ_1) to windward
- the yacht 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].

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], should vary as the square cosine function of the yacht heel and should be calculated as follows:

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

and

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

where:

P : Is according to Tab 2

A : Projected lateral area in m², of the portion of the yacht 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.

$g = 9,81 m/s^2$

Table 1 : Beaufort scale

Beaufort	Wind pressure, in N/m²
4	19 - 41
5	42 - 71
6	72 - 118
7	119 - 177
8	178 - 255
9	256 - 363
10	364 - 491
11	492 - 648

Table 2 : Wind pressure

	$L_{LL} \leq 70$ m	$L_{LL} > 70$ m
Unrestricted navigation	reduced pressure according to [3.2.4]	504 N/m²
Restricted navigation	reduced pressure according to [3.2.4]	reduced pressure subject to the agreement of the Administration

3.2.4 Calculation of the wind pressure

For yachts with a length equal or lesser than 70 m, the wind pressure P, in t/m², is to be calculated according to the following formulae:

$$P = 0,0514\left(\frac{Z-T}{10}\right)^{1/3}$$

where :

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

T : Mean moulded draught in m, of the yacht.

3.2.5 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. Small openings though which progressive flooding cannot take place need not be considered as open (see Ch 3, App 2, [1.3.3])

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 3

X_2 : Coefficient defined in Tab 4

k : Coefficient equal to:

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

k = 0,7 for a yacht having sharp bilge

for a yacht having bilge keels, a bar keel or both, k is defined in Tab 3

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 yacht

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

s : Factor defined in Tab 4.

Note 1: The angle of roll θ_1 for yachts 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 yacht at the waterline

T_1 : Mean moulded draught in m, of the yacht

A_K : Total overall area in m^2 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 yacht roll

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

Intermediate values are to be obtained by linear interpolation from values given in Tab 3 to Tab 4.

3.3 Weather criterion for sailing yachts

3.3.1 For all the operational loading conditions of Ch 3, App 2, [1.2], the wind moment based on the three sailing combinations as described in [3.3.2], has to be calculated according to [3.3.4]. Each condition has to comply with the criteria listed in [3.3.5].

3.3.2 The three sailing combinations which have to be investigated are:

- full sails
- intermediate sails
- reduced sails.

3.3.3 The wind force should be calculated as follows:

$F = 1/2\ C_s\ \rho\ A\ V^2$

Table 3 : Values of coefficient X_1

B/T_1	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 4 : 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 5 : 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 6 : 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

where:

F : Wind force, in N

C_s : Shape coefficient. Without specific available data, this coefficient has to be taken equal to 1,1

ρ : Air mass density, equal to 1,222 kg/m^3

A : Projected area of all the exposed surfaces, in square metres

V : Maximum wind speed, in m/s, for which the yacht is able to operate for each specific combination of sails as described in [3.3.2].

3.3.4 The wind moment is the force F as calculated in [3.3.3], multiplied by the heeling lever Z. The heeling lever Z is the 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.

The wind heeling lever is calculated as follows:

$\lambda = \lambda(0)\ (\cos\theta)^2$

where $\lambda(0)$ is the wind heeling lever at 0°.

3.3.5 Criteria

Under the assumptions of [3.3.4], the following criteria are to be complied with:

- the metacentric height corrected by the free surface effects, has to be greater or equal to 0,30 m
- the angle of the static heel due to the effect of wind has to be limited to 20° or 90% of the immersion of the deck, whichever is less
- the rigthing lever GZ is to be at least 0,50 m at an angle of heel equal to or greater than 50°
- the area above the wind heeling lever λ and below the GZ curve, between the angle of static wind heel and the downflooding angle, has to be at least equal to 0.065 mrd.

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 equal or less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is above 98%. Nevertheless, in order to take into account the consumption of consumable just after departure, the requirement of [4.2.2] has to be considered.

4.2.2 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.

4.3 Water ballast tanks

4.3.1 Where water ballast 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.

4.4 GM_0 and GZ curve corrections

4.4.1 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].

4.4.2 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.

4.4.3 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
- correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated.

4.4.4 Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the yacht'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.

4.5 Remainder of liquid

4.5.1 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 Icing

5.1 Application

5.1.1 For any yacht operating in areas where ice accretion is likely to occur, adversely affecting a yacht's stability, attention is to be paid to the effect of the ice. The Society reserves its right to request additional calculations on a case by case basis.