RULES FOR CLASSIFICATION

Yachts

Edition October 2016

Part 3 Hull

Chapter 10 Stability

**The electronic pdf version of this document, available free of charge
from http://www.dnvgl.com, is the officially binding version.**

DNV GL AS

FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

Any comments may be sent by e-mail to *rules@dnvgl.com*

CURRENT – CHANGES

This document supersedes the December 2015 edition.

Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main changes October 2016, entering into force as from date of publication

— Wording, nomenclature and chapter structure modified.
— Requirements for multihulls are more explicit.

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.

CONTENTS

SECTION 1 GENERAL

1 Objective

The objective of this chapter is to define requirements related to stability, water- and weathertight integrity.

2 Application

The requirements of this chapter apply to yachts in length $L > 24$ m for the assignment of main class.

3 Documentation requirements

The documentation requirements are given in Ch.1 Sec.3.

SECTION 2 INTACT STABILITY AND OPENINGS

1 General

All yachts shall have a sufficient reserve of buoyancy above the design waterline to meet the intact stability requirements in [3]. This reserve of buoyancy shall be calculated by including only those compartments which are:

— watertight
— weathertight for ensuring calculated range of stability.

2 Monohull criteria

2.1 Motor yachts

2.1.1 Following criteria shall be fulfilled:

— The area under the righting lever curve (GZ curve) shall not be less than 0.055 metre-radian up to φ = 30°.
— The area under the righting lever curve shall not be less than 0.09 metre-radian up to φ = 40° or the angle of flooding (angle of heel at which non-weathertight openings immerse).
— Additionally the area under the righting lever curve (GZ curve) between the angles of heel 30° and 40° or between 30° and the angle of flooding, if this angle is less than 40°, shall not be less than 0.03 metre-radian.
— The righting lever GZ shall be at least 0.20 m at an angle of heel equal to or greater than 30°.
— The maximum GZ shall occur at an angle of heel preferably exceeding 30° but not less than 25°.
— The initial metacentric height GM_0, shall be not less than 0.15 m. Recommended is a minimum GM = 0.35 m.

If the maximum righting lever (GZ) occurs at an angle of less than 25° approval of the stability shall be considered as a special case.

2.1.2 The proof of adequate stability shall be provided for at least the following conditions:

— yacht in the fully loaded departure condition, with full stores and fuel and with the full number of crew and guests with their luggage
— yacht in the fully loaded arrival condition, with the full number of crew and guests with their luggage, but with only residual stores and fuel remaining.

2.2 Sailing yachts

2.2.1 The following criteria shall be fulfilled:

— the areas B + C shall be not less than 1.4 (A + B), see Figure 1
— the righting lever at the maximum of the lever arm curve shall be not less than 0.30 m
— the stability range shall be not less than 60° for yachts without ballast keel
— the stability range shall be not less than 90° for yachts with ballast keel
— the initial metacentric height GM_0 shall not be less than 0.60 m
— the static angle of heel under sails shall not exceed 20°, but in any way shall not be more than the angle of deck immersion.
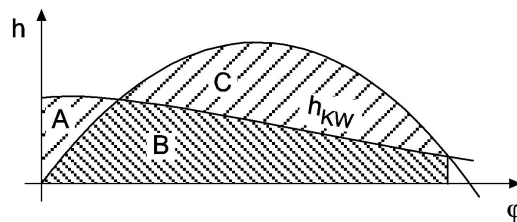
Figure 1 Lever arm curves

h_{KW} = curve of heeling levers due to lateral wind pressure.

2.2.2 The proof of adequate stability shall be provided for the yacht at least under the following conditions:

— all sails set
— half the sails set
— storm sails set
— sails struck.

In each case the permissible wind speed or force shall be determined at which the limit of stability set by the criteria is reached. With the sails struck, a lateral wind pressure equivalent to Beaufort-Force 12 (32.7 - 36.9 m/s = 63.6 - 71.7 kn) shall be tolerable.

3 Multihull criteria

3.1 Motor yachts

3.1.1 The statical intact stability curves in seagoing conditions shall meet the following criteria:

— the area under the righting lever curve (*GZ* curve) shall not be less than 0.075 metre-radians up to an angle of 20º when the maximum righting lever (*GZ*) occurs at 20º and, not less than 0.055 metre-radians up to an angle of 30º when the maximum righting lever (*GZ*) occurs at 30º or above. When the maximum *GZ* occurs at angles between 20º and 30º the corresponding area under the *GZ* curve, A_{req} shall be taken as follows:

$$A_{req} = 0.055 + 0.002(30 - \theta_{max}) \text{ metre-radians}$$

where:

θ_{max} = angle of heel in degrees where the *GZ* curve reaches its maximum

— the area under the *GZ* curve between the angles of heel of 30º and 40º, or between 30º and the angle of downflooding if this is less than 40º, shall not be less than 0.03 metre-radians

— the righting lever (*GZ*) shall be at least 0.20 metres at an angle of heel where it reaches its maximum

— the maximum *GZ* shall occur at an angle of heel not less than 20º

— after correction for free surface effects, the initial metacentric height (*GM*) shall not be less than 0.15 metres

— if the maximum righting lever (*GZ*) occurs at an angle of heel of less than 20º approval of the stability shall be considered by our classification society as a special case.

DNV GL AS

3.2 Sailing yachts

3.2.1 Curves of statical intact stability in both roll and pitch shall be prepared for at least the loaded arrival with 10% consumables. The vertical center of gravity (VCG) shall be obtained by one of the following methods:

— inclining of complete craft in air on load cells, the VCG being calculated from the moments generated by the measured forces; or

— separate determination of weights of hull and rig (comprising masts and all running and standing rigging), and subsequent calculation assuming that the hull VCG is 75% of the hull depth above the bottom of the canoe body, and that the VCG of the rig is at half the length of the mast (or a weighted mean of the lengths of more than one mast); or

— a detailed calculation of the weight and center of gravity (CG) position of all components of the vessel, plus a 15% margin of the resulting VCG height above the underside of canoe body.

3.2.2 If hydrostatic software is used to obtain a curve of pitch restoring moments, then the trim angle shall be found for a series of longitudinal centre of gravity (LCG) positions forward of that necessary for the design waterline. The curve can then be derived as follows:

$$GZ \text{ in pitch} = CG' \times \cos (\text{trim angle})$$

$$\text{trim angle} = \tan^{-1}\left(\frac{T_{FP} - T_{AP}}{L_{BP}}\right)$$

where:

CG' = shift of LCG forward of that required for design trim, measured parallel to baseline

T_{FP} = draught at forward perpendicular

T_{AP} = draught at aft perpendicular

L_{BP} = length between perpendiculars.

Approximations to maximum roll or pitch moments are not acceptable.

3.2.3 Data shall be provided to the user showing the maximum permissible wind speed appropriate to each combination of sails, such wind speeds being calculated as the lesser of the following:

$$v_W = 1.5 \sqrt{\frac{LM_R}{A'_S h \cos\Phi_R + A_D b}}$$

or

$$v_W = 1.5 \sqrt{\frac{LM_P}{A'_S h \cos\Phi_P + A_D b}}$$

where:

v_W = maximum permissible wind speed (kn)

LM_R = maximum restoring moment in roll (Nm)

LM_P = limiting restoring moment in pitch (Nm), defined as the pitch restoring moment at the least angle of the following:

    a) angle of maximum pitch restoring moment, or

b) angle at which foredeck is immersed, or

c) 10º from design trim

A'_S = area of sails set including mast and boom (m²)

h = height of combined centre of effort of sails and spars above the waterline

φ_R = heel angle at maximum roll righting moment (in conjunction with LM_R)

φ_P = limiting pitch angle used when calculating LM_P (in conjunction with LM_P)

A_D = plan area of the hulls and deck (m²)

b = distance from centroid of A_D to the centreline of the leeward hull.

Guidance note:

In following winds, the tabulated permissible wind speed for each sail combination should be reduced by boat speed.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.2.4 If the maximum safe wind speed under full fore-and-aft sail is less than 27 knots, it shall be demonstrated by calculation using annex D of ISO 12217-2 (2002) that, when inverted and/or fully flooded, the volume of buoyancy, expressed in cubic meters (m³), in the hull, fittings and equipment is greater than:

$$1.2 \times \text{(fully loaded mass in tonnes)}$$

thus ensuring this as a support to the mass of the fully loaded vessel by a margin. Allowance for trapped bubbles of air (apart from dedicated air tanks and watertight compartments) shall not be included.

3.2.5 The maximum wind speed with no sails set calculated in accordance with [3.2.3] above shall exceed 36 knots. For short range yachts this wind speed shall exceed 32 knots.

3.2.6 Trimarans used for unrestricted operations shall have sidehulls each having a total buoyant volume of at least 150% of the displacement volume in the fully loaded condition.

3.2.7 The stability information booklet shall include information and guidance on:

— the stability hazards to which these craft are vulnerable, including the risk of capsize in roll and/or pitch
— the importance of complying with the maximum advised apparent wind speed information supplied
— the need to reduce the tabulated safe wind speeds by the vessel speed in following winds
— the choice of sails to be set with respect to the prevailing wind strength, relative wind direction, and sea state
— the precautions to be taken when altering course from a following to a beam wind.

3.2.8 In vessels required to demonstrate the ability to float after inversion (according to [3.2.3]), an emergency escape hatch shall be fitted to each main inhabited watertight compartment such that it is above both upright and inverted waterlines.

4 Inclining test/lightweight measurement (light ship data requirements)

4.1 General

4.1.1 Every monohull yacht on completion of build shall undergo an inclination test and the elements of its stability determined. If an accurate inclining is not practical (multihulls), the lightship displacement and longitudinal centre of gravity shall be estimated by a lightweight survey and an accurate calculation of the vertical centre of gravity (VCG) shall be done.

4.2 Series yachts

4.2.1 A lightweight measurement shall be carried out upon completion of each yacht built in a series.

4.2.2 Sister yachts of the prototype yacht need to be inclined only, when in comparison with the light ship data of the prototype yacht, a deviation from the lightship displacement exceeding 1% for yachts of 160 m or more in length L and 2% for yachts of 24 m in length L and as determined by linear interpolation for intermediate lengths or a deviation from the lightship longitudinal center of gravity exceeding 0.5% of L is found.

4.2.3 The surveyor shall be on-site during inclining test/lightweight measurement.

5 Openings

5.1

All type of openings shall be considered in stability calculations.

5.2

Weathertightness shall be proved by hose test in presence of the surveyor.

5.3

Watertightness shall be pressure tested with a pressure height according to the most unfavorable damage waterline in presence of a surveyor.

SECTION 3 DAMAGE STABILITY

1 General

1.1

Minimum subdivision requirements are provided in Ch.2 (general arrangement design).

2 Application

The requirements in this section applies to:

— all monohull yachts with a length 48 < L ≤ 85 in (m), one compartment damages required
— all monohull yachts with a length L exceeding 85 m, two compartment damages required
— all multihull yachts.

L is the length of the design waterline at full load displacement.

3 Monohull criteria

3.1 General

Compliance with the damage stability criteria as defined under [3.3] shall be shown in all permitted conditions of loading to withstand all stages of flooding of the main compartments.

Guidance note:
It should be observed, that the damage stability result can lead to higher opening requirements (locations) than required by the International Convention on Load Lines (ICLL).

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.2 Required damage extensions

3.2.1 Assumed extensions

— longitudinal extent: 3 m plus 2.9% of the length L of the yacht or 11 m, whichever is less
— transverse extent (to be measured inboard from the ship's side, at right angles to the centre line at the level of the deepest subdivision load line): a distance of one fifth of the breadth of the yacht
— vertical extent: from the base line upwards without limit.

3.2.2 If any damage of lesser extent than that indicated above would result in a more severe condition regarding heel or loss of metacentric height, such damage shall be assumed in the calculations.

3.2.3 For damage stability calculations, the permeability for each space or part of a space shall be used as set out in Table 1.

3.2.4 Direct calculation of permeability shall be used where a more onerous condition results, and may be used where a less onerous condition results, if compared with the second item.

DNV GL AS

Table 1 Values of permeability

Definition of spaces	Permeability [%]
Control stations, accommodation rooms, kitchens, pantries	95
Machinery and ventilation rooms	85
Storage rooms, refrigerating rooms	60
Garages for automobiles and other craft	90
Tanks, bunkers, cells	0 or 95

3.3 Damage stability criteria

3.3.1 Stability after damage
The stability required in the final condition after damage, and after equalization where provided, shall be determined as follows:

— the positive residual righting lever curve shall have a minimum range of 15° beyond the angle of equilibrium
— the area under the righting lever curve shall be at least 0.015 metre-radians, measured from the angle of equilibrium to the angle at which progressive flooding occurs
— a residual righting lever shall be obtained within the range of the positive stability of at least 0.1 m.

3.3.2 Cross flooding arrangements
Efficient cross flooding arrangements shall correct large angles of heel preferably in a self-acting way. If the cross flooding system is not self-acting the required time of equalization shall not exceed 15 minutes. Sufficient time of equalization shall be demonstrated by calculation.

3.3.3 Conditions after damage
The final conditions of the yacht after damage and after equalization measures have been taken, shall be as follows:

— in case of symmetrical flooding there shall be a positive residual metacentric height of at least 50 mm
— in case of unsymmetrical flooding, the angle of heel for one-compartment flooding shall not exceed 7°, for the simultaneous flooding of two or more adjacent compartments, a heel of 12° may be permitted by the Society
— in no case shall the final waterline be less than 300 mm below the level of any opening through which progressive flooding could take place.

3.4 Damage control plan

3.4.1 There shall be permanently exhibited or readily available on the navigating bridge, for the guidance of the officer in charge of the yacht, a plan showing clearly:

— for each deck and compartment the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof
— for doors, a description of degree of tightness, operating mode, normal position, operating circumstances (opened while at sea, not normally used while at sea, not used while at sea)
— arrangements for the correction of any list due to flooding.

3.4.2 General precautions shall consist of a listing of equipment, conditions and operational procedures, considered to be necessary to maintain watertight integrity under normal yacht operations.

3.4.3 Specific precautions shall consist of a listing of elements (i.e. closures, securing of equipment/loads, sounding of alarm, etc.) considered to be vital to the survival of the yacht and its crew.

4 Multihull criteria

4.1 General

4.1.1 The watertight bulkheads of the vessel shall be so arranged that minor hull damage that results in the free flooding of any one compartment, will cause the vessel to float at a waterline which, at any point, is not less than 75 mm below the weather deck, freeboard deck, or bulkhead deck if not concurrent.

4.1.2 Minor damage shall be assumed to occur anywhere in the length of the vessel, but not on a watertight bulkhead.

4.1.3 Standard permeabilities shall be used in this assessment, as follows:

Space	Percentage permeability
Stores	60
Stores but not a substantial quantity thereof	95
Accommodation	95
Machinery	85

4.2 Damage stability criteria

In the damaged condition considered, the residual stability shall be such that any angle of equilibrium does not exceed 7º from the upright, the resulting righting lever curve has a range to the downflooding angle of at least 15º beyond any angle of equilibrium, the maximum righting lever within that range is not less than 100 mm and the area under the curve is not less than 0.015 meter-radians.
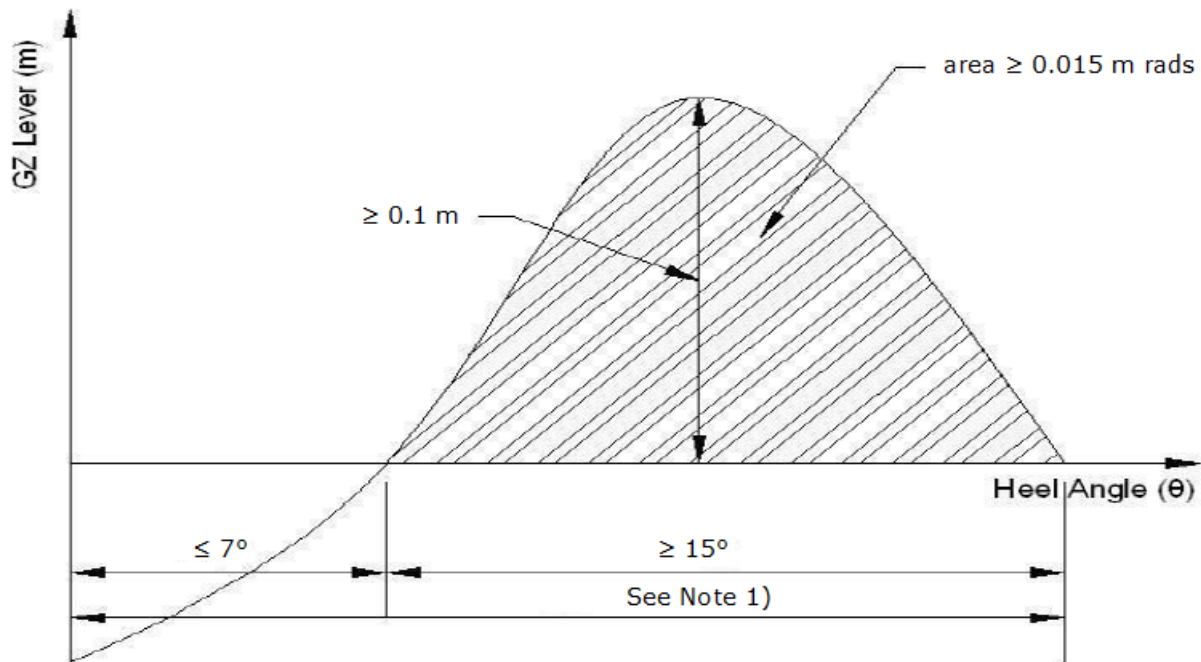
Note:

1)   Range of stability in "damaged" condition shall have regard, where appropriate, to truncation due to downflooding.

2)   The required properties of the "damaged" *GZ* curve, namely max. *GZ* ≥ 0.015 m rads. is to be achieved within the positive range of the curve taking into account any restrictions imposed by Note 1).

---e-n-d---o-f---n-o-t-e---

5 Damage control plan

5.1

The plan shall be permanently exhibited or readily available on the navigating bridge, for the guidance of the officer in charge of the yacht. The plan shall show clearly:

— for each deck and compartment the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof
— for doors, a description of degree of tightness, operating mode, normal position, operating circumstances (opened while at sea, not normally used while at sea, not used while at sea)
— arrangements for the correction of any list due to flooding.

5.2

General precautions shall consist of a listing of equipment, conditions and operational procedures, considered to be necessary to maintain watertight integrity under normal yacht operations.

5.3

Specific precautions shall consist of a listing of elements (i.e. closures, securing of equipment/loads, sounding of alarm, etc.) considered to be vital to the survival of the yacht and its crew.

6 Low density foam

Use of low density foam or other media to provide buoyancy in void spaces may be permitted, provided that satisfactory evidence is provided that any such proposed medium is the most suitable alternative and is:

— of closed cell form, or otherwise impervious to water absorption
— structurally stable under service conditions
— chemically inert in relation to structural materials with which it is in contact or to other substances with which the medium is likely to be in contact
— properly secured in place and easily removable for inspection of the void spaces.

CHANGES – HISTORIC

December 2015 edition

This is a new document.
The rules enter into force 1 July 2016.

DNV GL AS

DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16 000 professionals are dedicated to helping our customers make the world safer, smarter and greener.

SAFER, SMARTER, GREENER