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Ship’s Stability
Final Examination Var. III

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3rd study year

1. Defines “Light displacement” and “Load displacement”.

Light Displacement - is defined as the weight of the ship excluding cargo, fuel, water, ballast, stores, passengers, crew, but with water in boilers to steaming level.

Loaded Displacement - the weight of the ship including cargo, passengers, fuel, water, stores, dunnage and such other items necessary for use on a voyage, which brings the vessel down to her load draft.

2. Why TPC, “tonnes per centimeter immersion”, varies with different draughts?

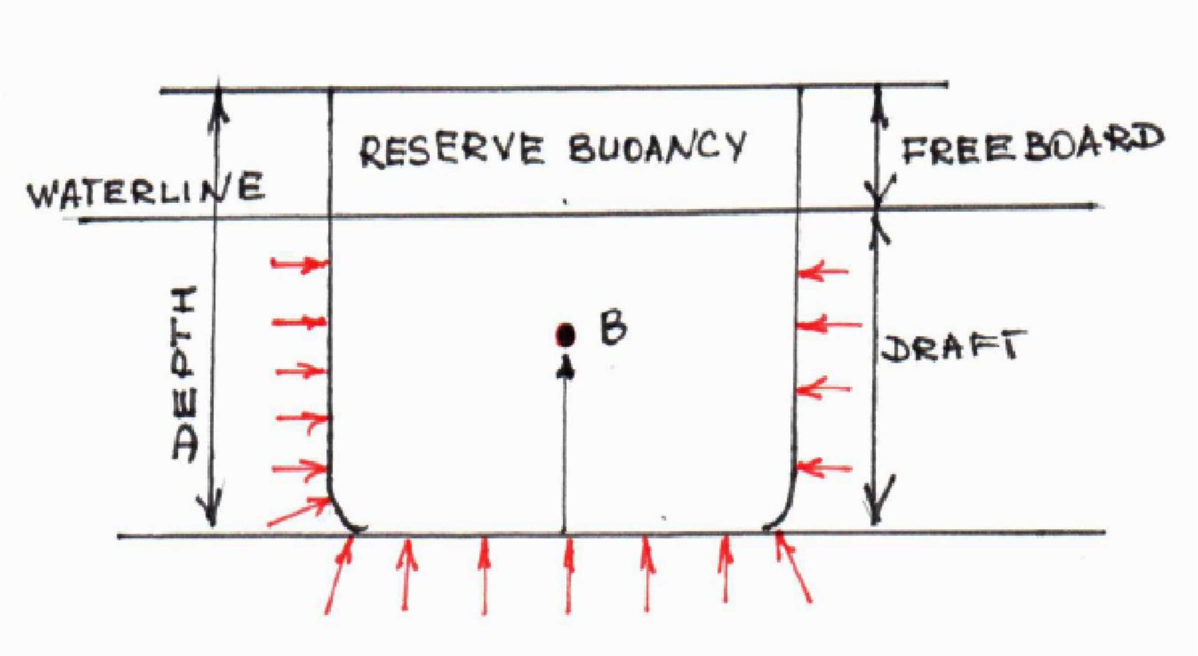
The **TPC** is the mass, which must be loaded or discharged to change the ships mean draft by 1cm.

$$TPC = \frac{WPA}{100} \times p$$

TPC varies with different draughts, because of the change in water plane area. The area of the water-plane of a box-shaped vessel is the same for all drafts if the trim be constant, and so the TPC will also be the same for all drafts. In the case of a ship the area of the water-plane is not constant for all drafts, and therefore the TPC will reduce at lower drafts and increase bigger drafts, because when draught increases, corresponding value of Buoyancy have increased and “TPC” must be increased.

3. How freeboard is related to reserve buoyancy? Please describe with aid of sketch.

Spaces above the waterline are there to provide the extra buoyancy required. Reserve buoyancy may be defined as the volume of the enclosed spaces above the waterline. It may be expressed as a volume or as a percentage of the total volume



Reserve buoyancy = Volume of vessel - Volume of water displaced

So we can define that with the change of freeboard the reserve buoyancy will also change. The Higher is the freeboard, the larger will be the reserve buoyancy.

4. Describe damage stability requirements for Type (B—100) vessels.

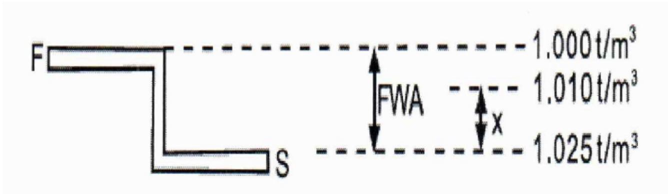
Type B ship in which the reduction in freeboard has been increased up to the total difference between the values for basic Type A and Type B freeboards, effectively making the ship a Type A ship.
The ship must meet two compartment damage stability requirements. Only a small number of ships are B-100.

Type B-100, Flooding criteria:

- LBP is 100m - 150m; Vessel must survive flooding of any 2 adjacent fore / aft compartments neither of which are the engine room
- LBP is >150m; Vessel must survive flooding of any 2 adjacent fore / aft compartments one of which may be the engine room

5. Define "Fresh Water Allowance" (FWA) and how to obtain the formula for FWA calculation.

The Fresh Water Allowance is the number of millimeters by which the mean draft changes when a ship passes from salt water to fresh water, or vice versa, whilst floating at the loaded draft.



TO FIND THE FRESH WATER ALLOWANCE (FWA)

L, B, d in metres A is waterplane area in m^2 T is TPC

Δ_F FW displacement at summer draft

Δ_S SW displacement at summer draft

Then $L \times B \times d \times C_b \times \text{density} = \text{displacement in metric tons}$

$$\Delta_F \times 1.025 = \Delta_F + A \times \text{FWA (in metres)}$$

$$\Delta_F \times 0.025 = A \times \text{FWA metres}$$

$$A \times \text{FWA metres} = \frac{\Delta_F}{40}$$

$$\frac{100T}{1.025} \times \text{FWA metres} = \frac{\Delta_F}{40}$$

$$\text{FWA metres} = \frac{1.025\Delta_F}{4000T}$$

$$\text{FWA millimetres} = \frac{\Delta_S \times 1000}{4000T} = \frac{\Delta_S}{4T}$$

6. Explain the requirements for maintaining watertight integrity.

Watertight

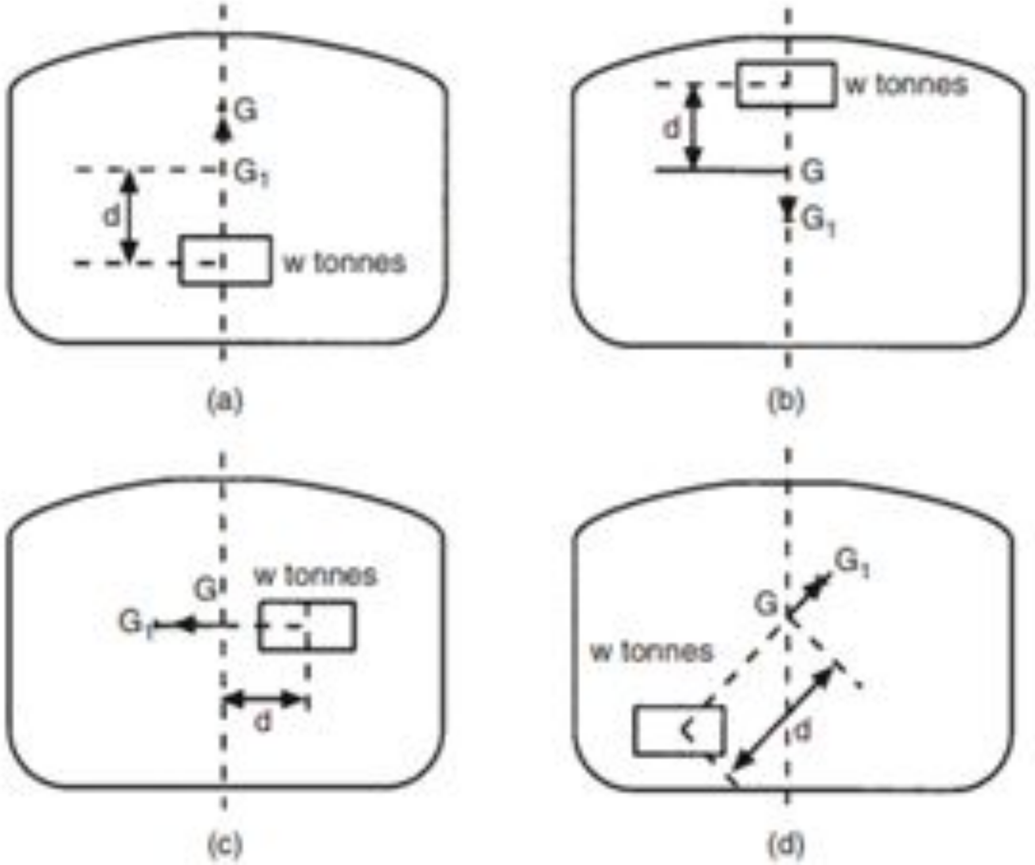
a) In relation to a fitting above deck, that it is so constructed as to resist effectively the passage of water under pressure, except for slight seepage.

b) In relation to the structure of the vessel, capable of preventing the passage of water in any direction if the head of pressure were up to the freeboard deck, which for my vessel would mean the main deck.

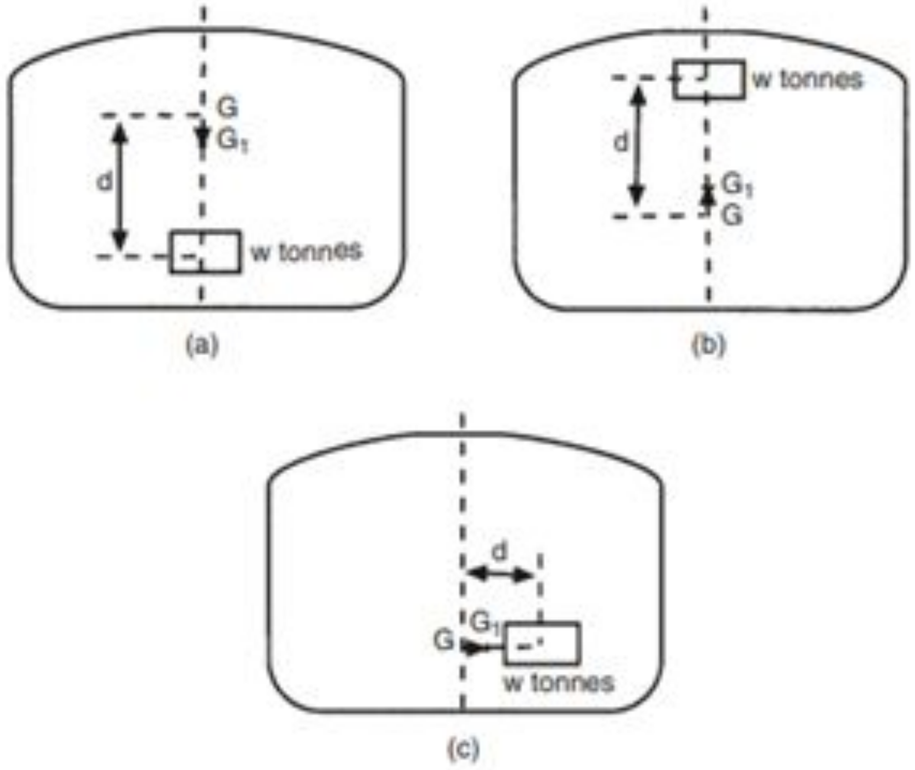
“Watertight” means that a structure is designed and constructed to withstand a static head of water without leakage. Water (or any other liquid) is not able to pass through the structure into or out of any of the watertight compartments, i.e. prevention from the passage of water in any direction. The vessel’s hull, working deck (weather deck) and bulkheads between compartments must be watertight. Watertight bulkheads must be watertight up to the working deck. Any openings on such bulkheads must be equipped with watertight closing devices.

7.1 Describe with aid of sketches how the position of G (centre of Gravity) will change due to cargo pending by ship cargo gear. Give the formula to calculate such changes.

When mass is removed from a body, the center of gravity of the body will move directly away from the center of gravity of the mass removed.



7.2 When mass is added to a body, the center of gravity of the body will move directly towards the center of gravity of the mass added.



The shift of the center of gravity of the body is given by the formula:

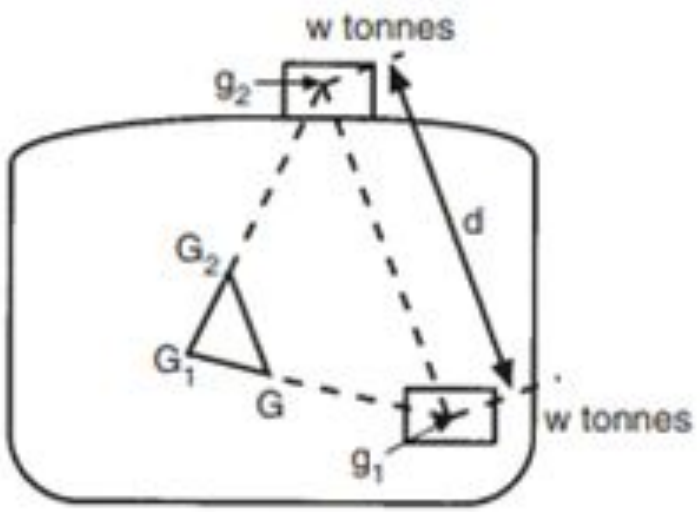
$$GG1 = \frac{w \times d}{W}$$

w – Mass of weight

W – Final mass of the body

d – Distance between centres of gravity, (when shifting weight within the ship, distance through which the weight is shifted)

7.3 The center of gravity of a body will move parallel to the shift of the center of gravity of any weight moved within the body.



When weight is moved downwards in the ship, then the ship’s overall G will also be moved downwards to a lower position. Consequently, the ship’s stability will be improved.

When weight is moved upwards in the ship, then the ship’s overall G will also be moved upwards to a higher position. Consequently, the ship’s stability will be decreased.

8. Describe and illustrate the term "righting lever GZ" and what is the righting moment.

Righting lever being formed when the vessel is heeled by the external force. The lever is known as the **GZ.**
The lever GZ is referred to as the righting lever and is the perpendicular distance between the center of gravity and the vertical through the center of buoyancy.

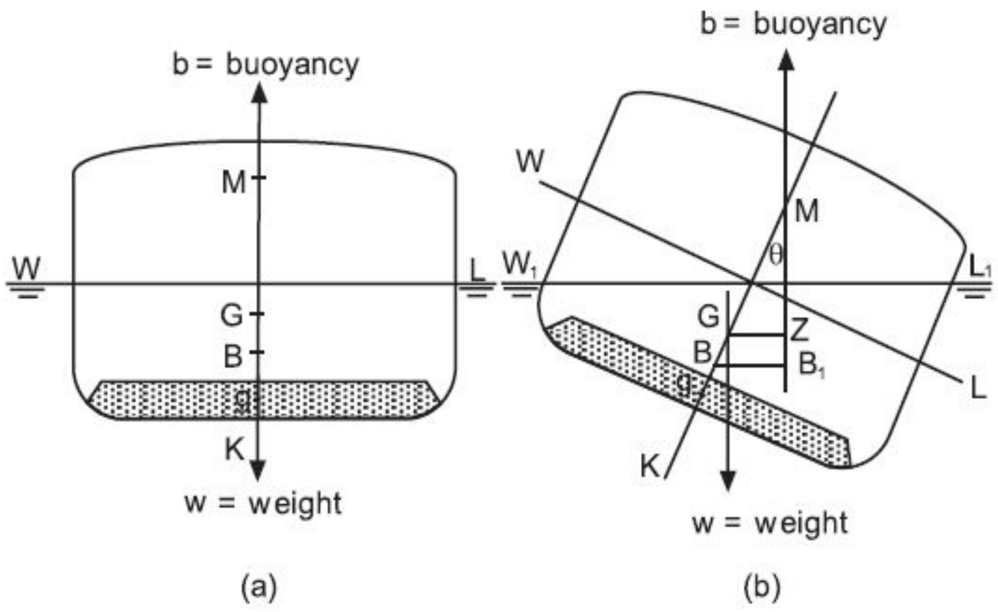


Fig. 7.1

GZ = GM x sin heel

Moment of statical stability - defined as the moment to return the ship to the initial position when inclined by an external force.

Moment of statical stability is equal to the product of the righting lever and the displacement.

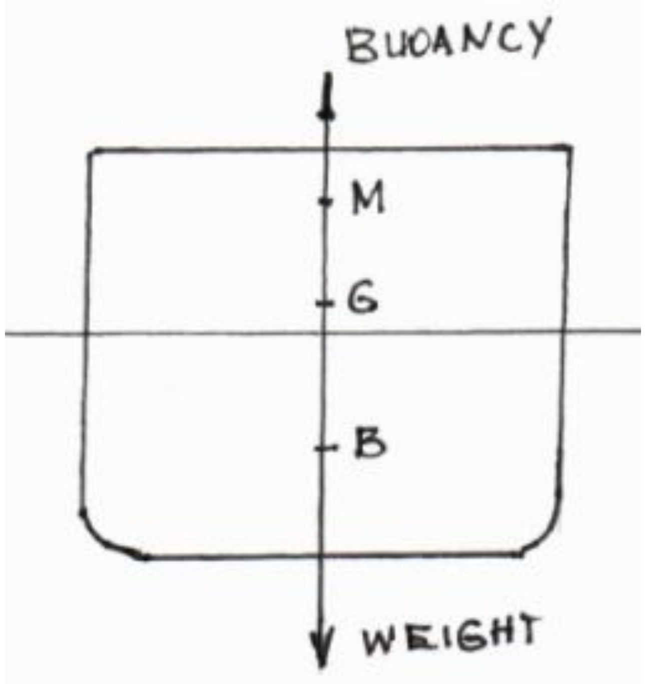
<u>Moment of statical stability = W x GZ = W x GM x sinθ</u>

9. Defines the term “Metacentric height (GM)” and illustrate it. Why it is necessary to calculate GM and how?

The vertical distance between G and M is referred to as the **metacentric height**. If G is below M the ship is said to have positive metacentric height, and if G is above M the metacentric height is said to be negative. It is calculated as the distance between the center of gravity(G) of a ship and its metacenter(M).

For small angles of heel, GZ is proportional to GM. Therefore, GM can be used as a representation of initial righting arms. These basic rules apply:

- If GM is **large,** the ship has large righting arms and will have stiff, fast rolls.
- If GM is **small,** the ship has small righting arms and will have tender, slow rolls.
- If GM is **very small,** the ship is apt to hang at the end of each roll before starting upright.
- If GM is **slightly negative**, the ship will loll (stay heeled at the angle of inclination where righting and upsetting forces are equal) and flop from side to side.
- If GM is **negative**, the ship will capsize when inclined.



$GM = KM - KG$

10. What is Stability of the vessel and what is Initial Stability?

Stability is a measure of the vessel's ability to get back on an upright position after having suffered a heel. Different factors affect a vessel's stability. Basically it is the ratio between the center of gravity and the distribution of a vessel's that determines the vessel's ability to get upright.

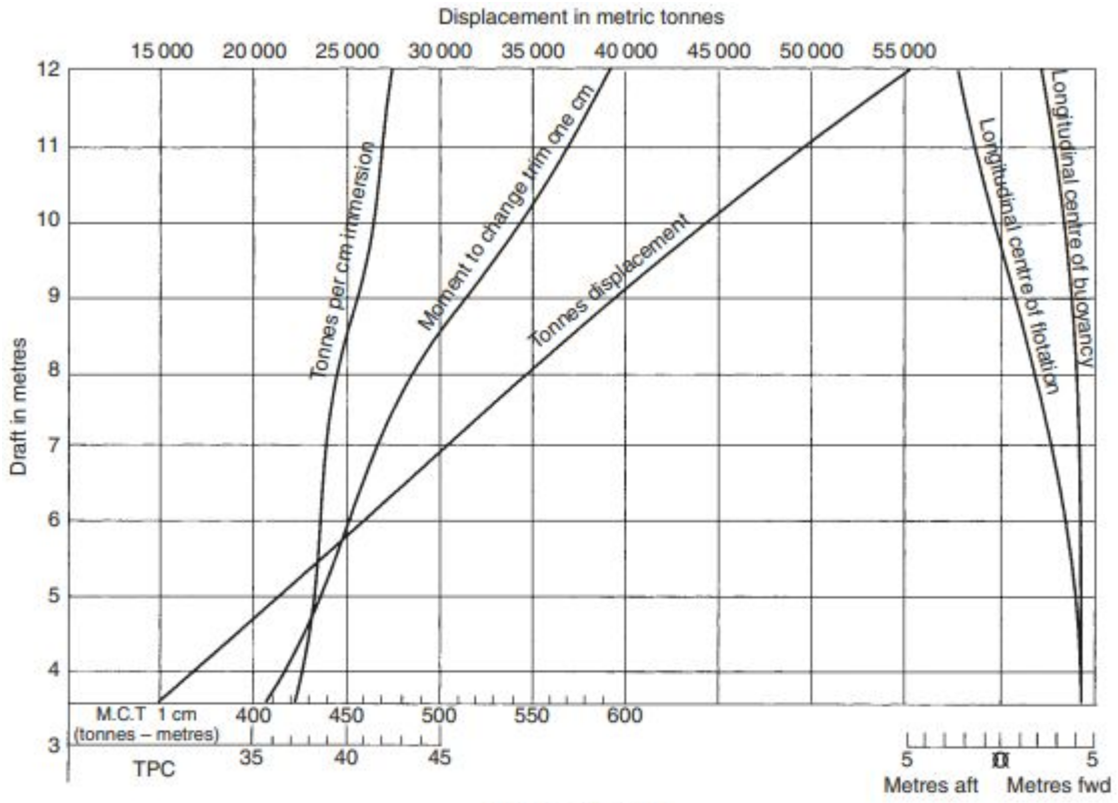
Initial stability is the stability of the vessel in her initial position and is expressed by the metacentric height. Any reduction in GM means a loss in the ship's stability.

INITIAL STABILITY is the stability of a ship in the range from 0° to 10° of inclination.

11. What is Hydrostatic Curves or “Vessel’s hydrostatic particulars”?

Hydrostatic curves - used for calculating the trim and stability values for various conditions of loading.

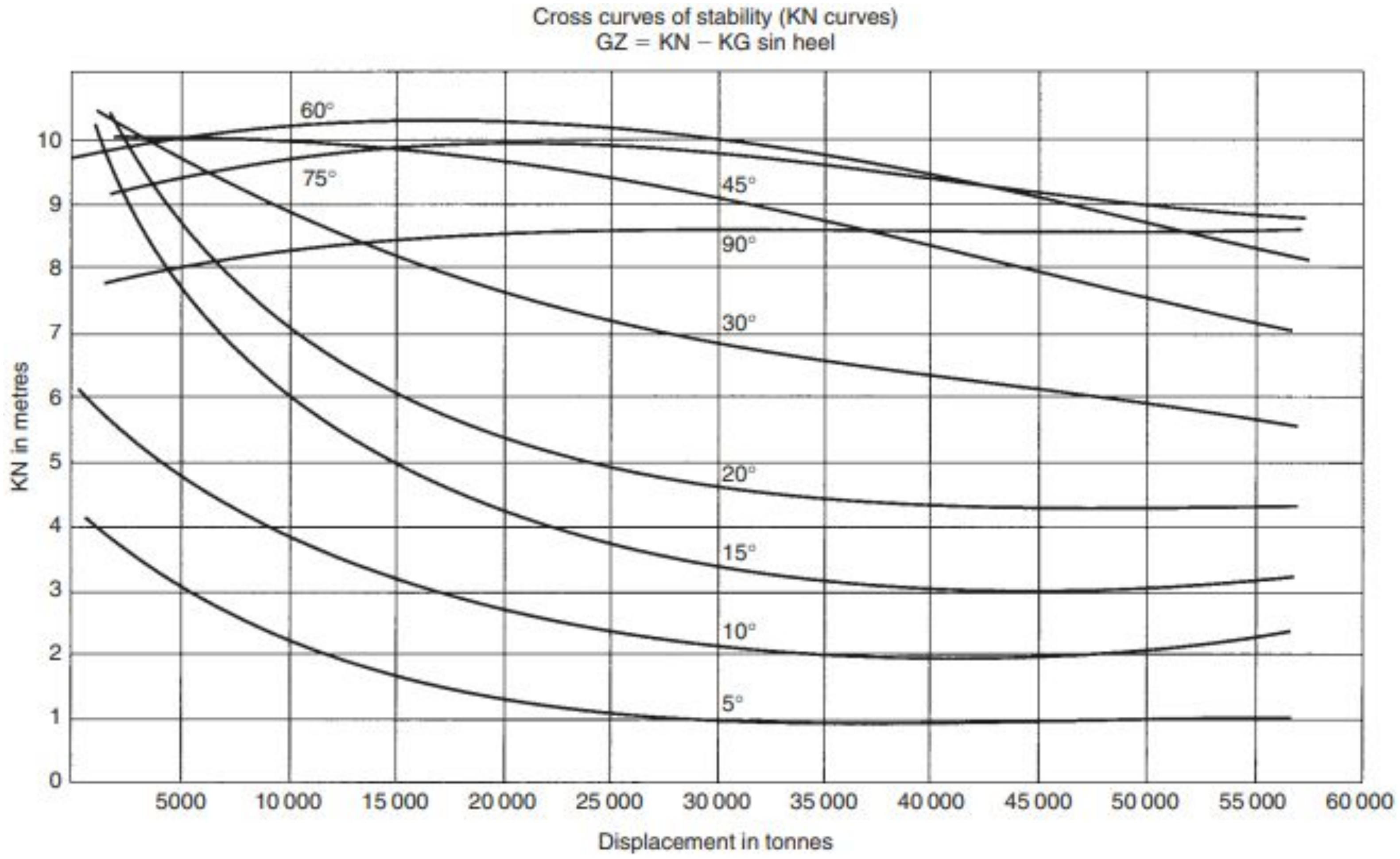
When information is required for a specific draft, first locate the draft on the scale on the left-hand margin of the figure. Then draw a horizontal line through the draft to cut all of the curves on the figure. Next draw a perpendicular through the intersections of this line with each of the curves in turn and read off the information from the appropriate scale.

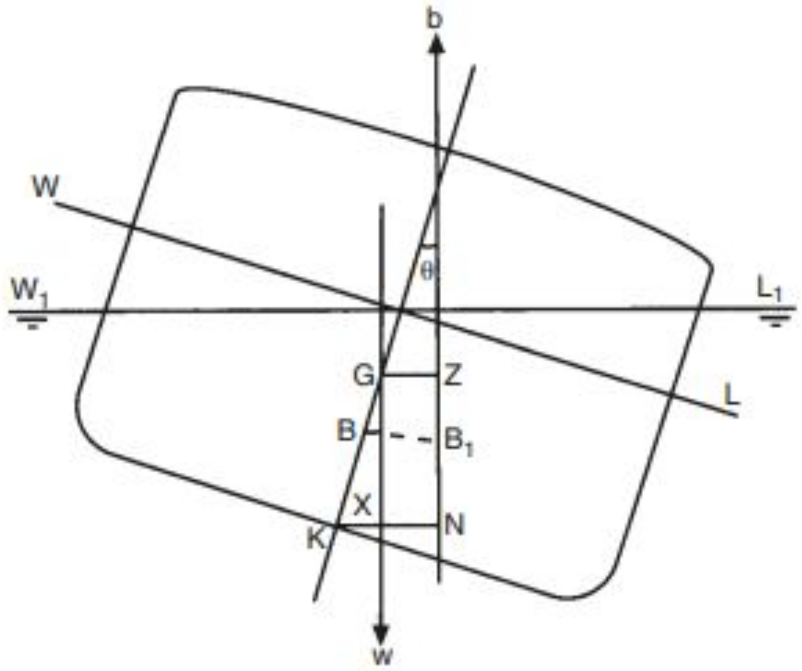


Hydrostatic curves

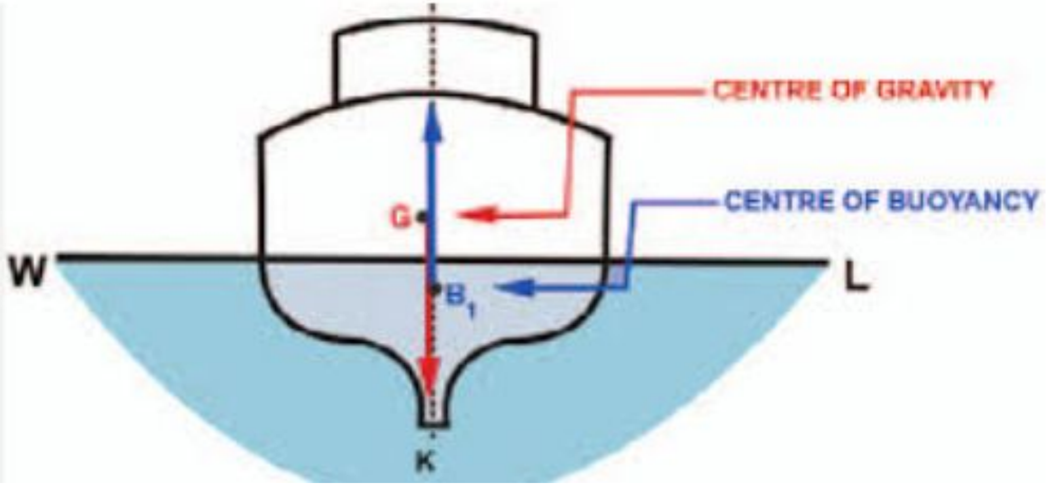
12. Please explain and show with aid of sketch what is KN?

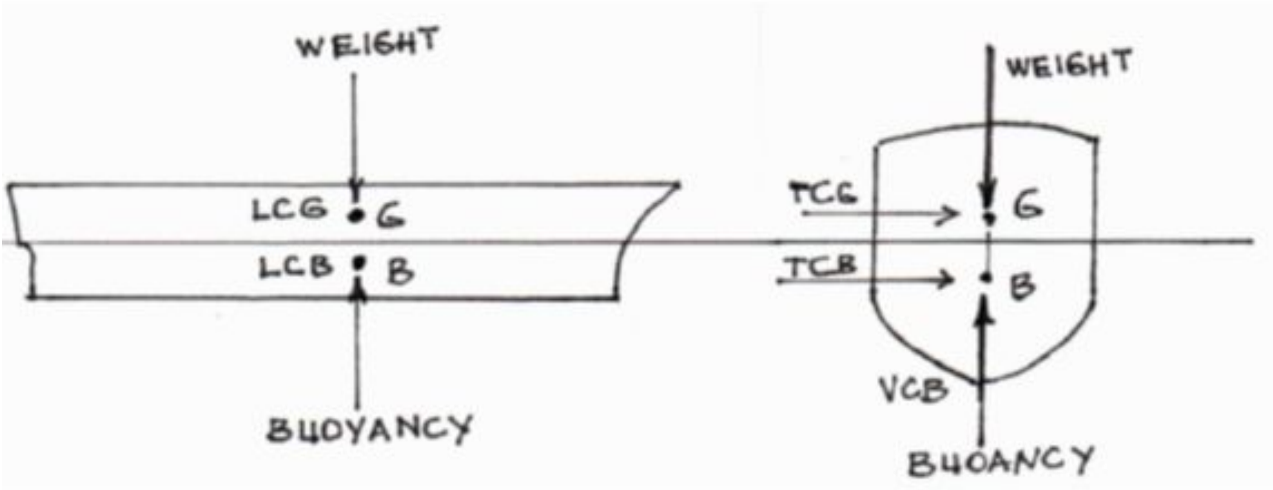
Stability Cross Curves for a ship are constructed by plotting the righting levers for an assumed height of the center of gravity above the keel. In some cases the curves are constructed for an assumed KG of zero. The curves are then referred to as KN curves, KN being the righting lever measured from the keel.

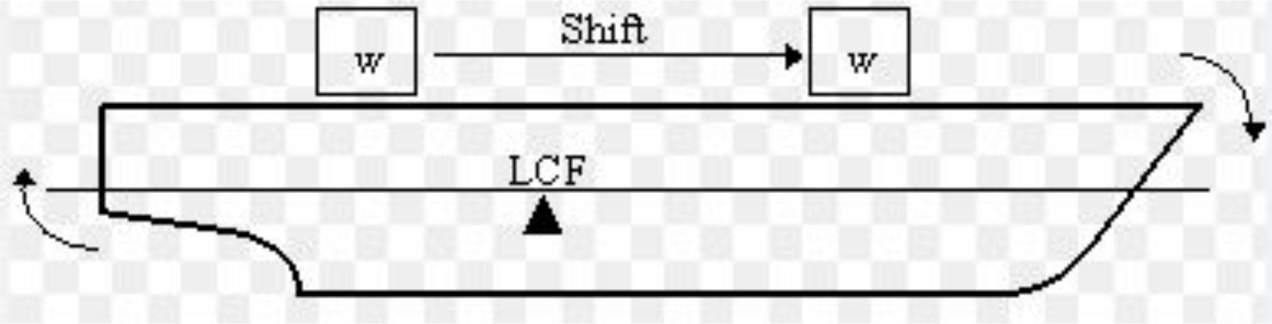




13. Describe with aid of sketches what means VCG, VCB, LCG, LCB, TCG, LCF.







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VCG - Vertical Center of Gravity - Distance from keel to the center of gravity

VCB - Vertical Center of Buoyancy - Distance from keel to the center of buoyancy

LCG - Longitudinal center of gravity. This is the point through which all of the weight of the vessel can be said to act vertically downwards.

LCB - Longitudinal Center of Buoyancy - The centroid of the underwater volume of the ship expressed as a longitudinal location. Unless otherwise specified LCB is usually understood to be the centroid when the ship is floating on its datum waterline (DWL) with zero trim.

TCG - Transverse center of gravity - The center of gravity measured to the port or starboard from the ship's centerline.

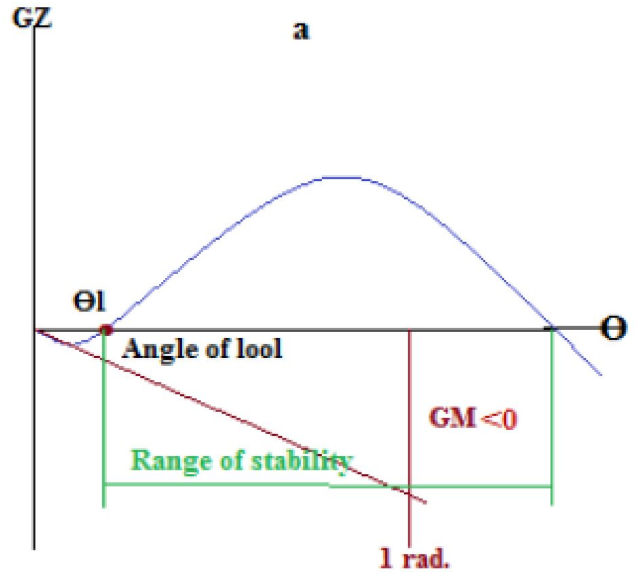
LCF - Longitudinal Center of Flotation - center of the waterplane. When the ship floats at a particular draft, any trimming moment acting on the ship would act about a particular point on the water plane. This point is the centroid of the area of the water plane, and is called the center of the floatation. The distance of the center of floatation is read with respect to either of the perpendiculars or the mid-ship.

14. Explain and illustrate the term“Angle of Loll“?

A ship with negative initial metacentric height is inclined to a small angle, the righting lever is negative, resulting in a capsizing moment. The ship will tend to heel still further.

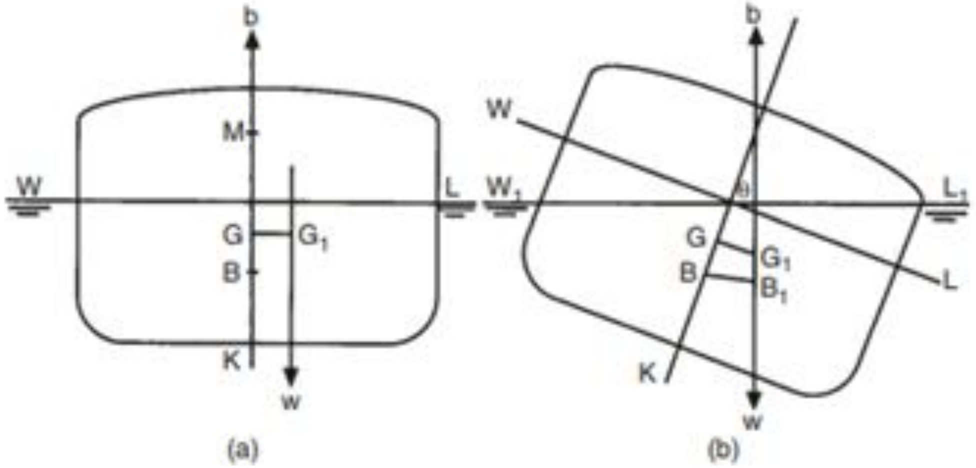
The angle of heel at which this occurs is referred to as the angle of loll and may be defined as the angle to which a ship with negative initial metacentric height will lie at rest in still water.

If the ship should now be inclined to an angle greater than the angle of loll, the righting lever will be positive, giving a moment to return the ship to the angle of loll.
From this it can be seen that the ship will oscillate about the angle of loll instead of the upright



15. What is the Listing Moment and how to calculate it?

When weight that is already on board the ship be shifted transversely such that G moves to G1. This will produce a listing moment of W x GG1, and the ship will list until G1 and the center of buoyancy are in the same vertical line.



In this position G1 will also lie vertically under M so long as the angle of list is small. Therefore, if the final positions of the metacenter and the center of gravity are known, the final list can be found, using trigonometry, in the triangle GG1M which is right-angled at G.

The final position of the center of gravity is found by taking moments about the keel and about the centerline.

Tan List = GG1 / GM

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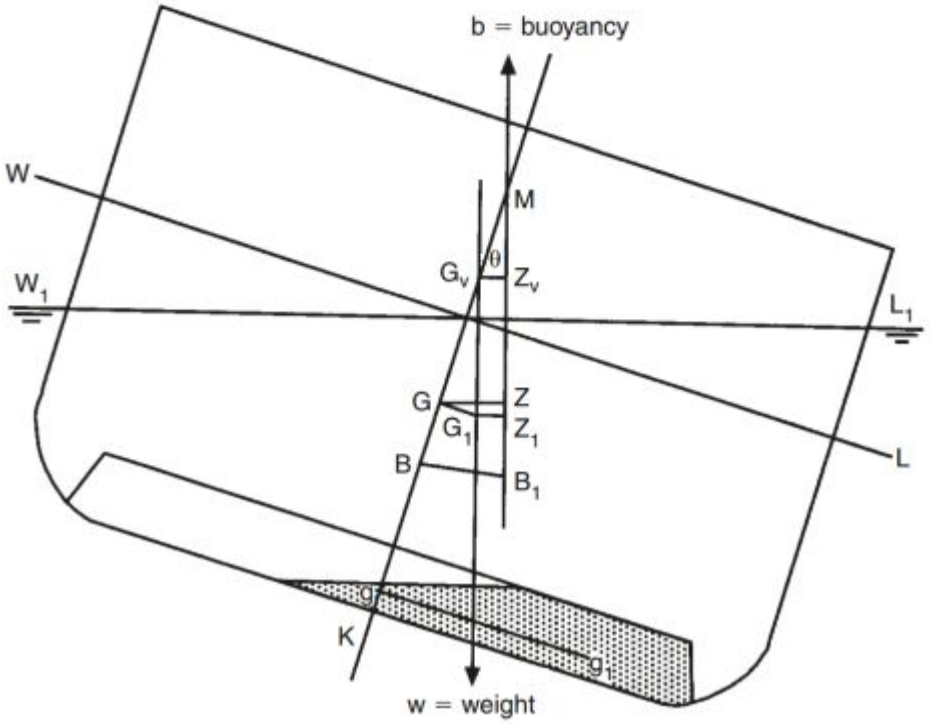
16. Describe the term “Free surface effect” and haw it is affected stability of the vessel. Give a formulae to calculate.

This free surface effect increases the danger of capsizing. When a vessel with partially filled spaces heels over, the contents of the spaces will shift. The center of gravity moves over to the side, making the vessel less stable. Because, when the ship is inclined, the liquid in the tank shifts to the lower side of the tank.



$$\text{FSE} = \text{Virtual loss of GM} = \frac{i}{W} \times \rho \times \frac{1}{n^2} \text{ metres} \qquad \text{(I)}$$

where

- i = the second moment of the free surface about the centre line, in m^4
- w = the ship's displacement, in tonnes
- ρ = the density of the liquid in the tank, in tonnes/cu. m
- n = the number of the longitudinal compartments into which the tank is equally subdivided
- $i \times p$ = free surface moment, in tonnes m

$$i = \frac{LB^3}{12}$$

where

L = the length of the free surface

B = the total breadth of the free surface, ignoring divisions

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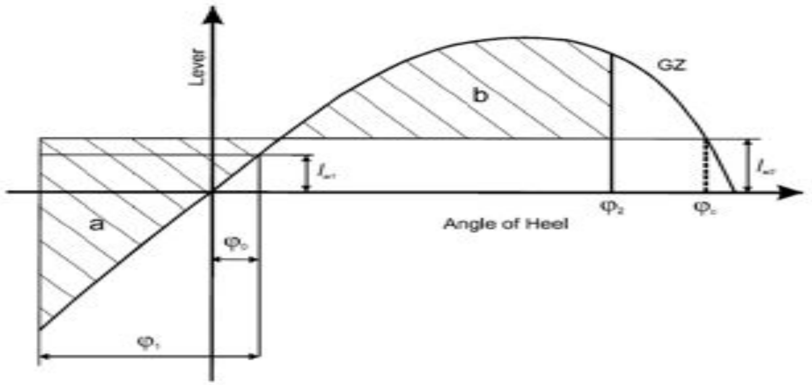
17. List with aid of sketch criteria regarding righting lever curve properties and weather criterion as per IS 2008 Code.

IMO Stability criteria

ITEMS	Symbols & Formuls
1. Wether criteria	К = b / a $\geq$ 1
2. Metacentric height, m	GMc(h0) $\geq$ 0,15 m
3. Max.righting lever, m	GZ(lm) $\geq$ 0,20
4. Angle of heel lmax, m	θm$\geq$25º
5. Vanishing angle	θv $\geq$ 60º
6. Area under the righting lever GZ θº=30, mrad	Sθ=0÷30 $\geq$ 0,055 m·rad
7. Area under the righting lever GZ θº=40, mrad	Sθ=0÷40 $\geq$ 0,090 m·rad
8. Area between righting levers 30° and 40º, mrad	Sθ=30÷40 $\geq$ 0,030 m·rad

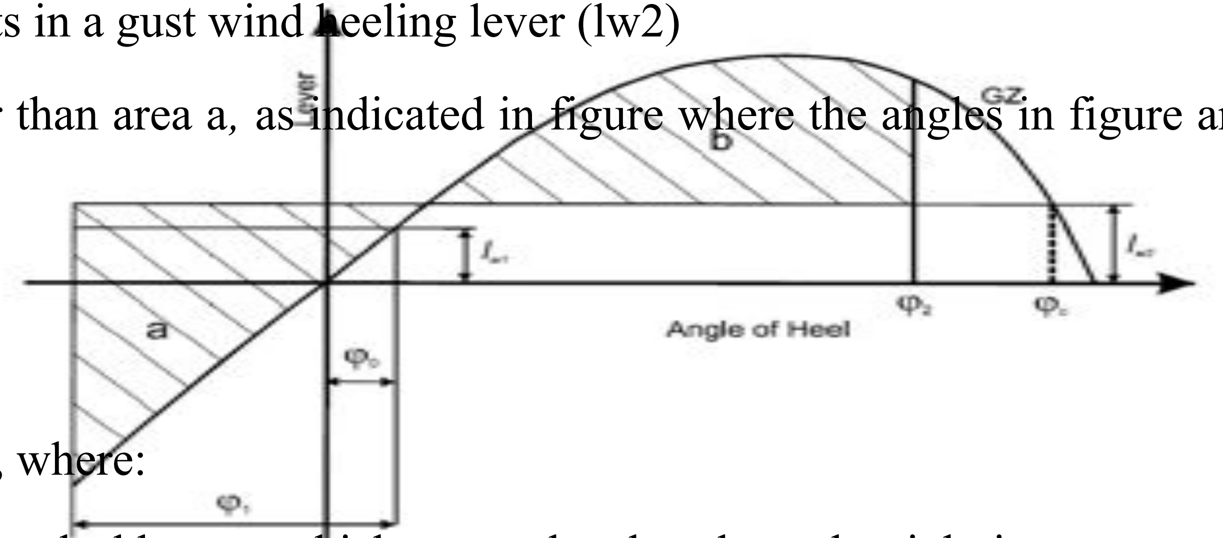


.1 The ship is subjected to a steady wind pressure acting perpendicular to the ship's centerline which results in a steady wind heeling lever (lw1);

.2 from the resultant angle of equilibrium (φ0), the ship is assumed to roll owing to wave action to an angle of roll (φ1) to windward. The angle of heel under action of steady wind (φ0) should not exceed 16^0 or 80% of the angle of deck edge immersion, whichever is less;

.3 the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (lw2)

.4 Under these circumstances, area b shall be equal to or greater than area a, as indicated in figure where the angles in figure are defined as follows:



φ0 = angle of heel under action of steady wind

φ1 = angle of roll to windward due to wave action ,

φ2 = angle of down-flooding (φf) or 50^0 or φc, whichever is less, where:

φf = 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

φc = angle of second intercept between wind heeling lever lw2 and GZ curves.

Thank you for your attention

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