R.RAJASEKARAN, B.A, AMNI

**Made and updated by : R.Rajasekaran,**
**Chennai / India**
**E-mail : rajsadasivam@yahoo.com**

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## BILGING

**NOV'02**

**A vessel is involved in a collision which results in side damage and substantial flooding of a large off-centre compartment on the stbd side.**
**With the aid of one or more sketches of the vessel's curve of statical stability, show the effects of such side flooding on the dynamical stability of the vessel.**

When a compartment is bilged on a side the following happens:

1. The vessel lists due to the flooding on one side.
2. The draught increases and results in reduction of freeboard
3. The angle of deck edge immersion is reduced
4. Trim changes
5. The BM decreases since the KB increases, thereby GM increases slightly.
6. The GZ is negative till the angle of list and also comparatively small over the range of +ve stability when compared with the original curve.
7. The range of positive stability is reduced
8. The net effect of this is there is a loss in dynamical stability and the area under the GZ curve is highly reduced.
9. Angle of vanishing stability is reduced dangerously.
10. The angle of list being so high, and further flooding might result in the vessel rolling over.

## RO-RO

**JUNE'2000, MAR'2000**

**Discuss the stability problems associated with the design and operation of a conventional RoRo vehicle ferry.**

The construction features of a RoRo affecting its stability are:

1. High windage area
2. Bow or stern doors open or damaged at sea
3. Bow or stern doors susceptible to damage or being open and unattended during loading/discharging operations.
4. Vehicle deck susceptible to flood due to use of water curtains, resulting in severe loss of GM (FSE; Especially in case of inadequate drainage)
5. The high KG of cargo units results in reduced GM
6. Due to severe rolling in high seas, vehicles might shift resulting in loss of water-tight integrity.

Other factors:

1. Speed of turn-around in port results in inefficient of stability calculation.
2. Exact weight and KG of cargo units may not be available, especially the internal distribution of the cargo in high vehicles.

PRECUATIONARY MEASURES:

1. To reduce FSE the draining arrangement should be very efficient
2. The vehicle deck should have plenty of sub-divisions to reduce the FSE drastically. In case of using water curtains. ($FSE= lxb^3xRD / 12n^2$).
3. Increased stability standards
4. Automatic draught gauges at the stem and the stern with remote reading to warn ship's officers of flooding of vehicle decks in.
5. Indicator lights to be provided on the bridge to warn of shell/loading doors OPEN.
6. A loadicator to be available to ship's officers in port to calculate ship's stability prior to ship's sailing and confirm its compliance with loadline regulations.
7. Heavy RoRo cargo units must be weighed ashore and exact weight and distribution of the cargo is provided to the ship's officer.
8. Heavy cargo units should be tightly secured as per the cargo securing manual and tended over the course of the voyage regularly.

## LIST

**NOV'04**

**Show with the aid of a labelled sketch, the effect on the vessel's dynamical stability on first taking the heavy lift weight on the derrick.**

- At the instant the derrick lifts the cargo the C of G of the weight is now acting at the derrick head, thus it is a weight added at a KG = Ht of derrick head.
- The ship's G moves up and towards the weight, resulting in a loss of GM as a result of increased KG.
- This loss in G has a vertical component and a horizontal component.
- The angle of list caused is given by $Tan\theta = w \times s \;/\; \Delta_f \times GM_f$
  **$GM_f$** = Initial GM – Loss of GM due to rise in G
- As long as the rise in G does not exceed the ships initial GM, the ship will remain stable (+ve GM) but with a reduced range of stability and at an angle of list.
- There is a rise in KB and BM and an increase in displacement.
- If the weight is heavy and the distance off the centre line is high the resulting rise in G and subsequent loss in GM, might result in vessel becoming unstable (-ve GM).

SUMMARISING THE EFFECT ON DYNAMICAL STABILITY:

- GM reduces
- GZ values reduced
- Reduced area of +ve stability
- Reduced range of +ve stability (Between angle of list and angle of vanishing stability)
- Reduced angle of vanishing stability

## UNSYMMETRICAL ICE

**MAR'04**

**A vessel operating in severe winter conditions may suffer from non-symmetrical ice accretion on decks and superstructure.**

**Describe with the aid of a sketch the vessel's curve of statical stability, the effects on the overall stability of the vessel.**

- The ice accumulation takes place on the windward side at sub-zero temperatures due to sea spray.
- The vessel will take an angle of heel towards the windward side as a result of the added weight, but the wind heeling moment will counter-act this as long as the vessel continues on the present course.
- Once the vessel changes course, the ice build-up acts as an added weight at a high KG and off the centre-line resulting in a vertical and horixontal shift of G; as G moves towards the weight added.
- The resultant angle of heel can be given by the formula $\tan\theta = w \times s \ / \ \Delta_f \times GM_f$ ; where **w** is the weight of the ice and **s** is the distance of the ice build up from the centre line and
  $\mathbf{GM_f}$ = Initial GM – Loss of GM due to rise in G
- Vessel now has an angle of list and the GZ values are reduced which is given by
  $GZ = KN - (KG_f \times \sin\theta)$; where $KG_f$ = Initial KG – $GG_1$

## DRYDOCKING

**JULY'04**

**Explain why the values of Trim and Metacentric height in a free-floating condition are important when considering the suitability of a vessel for dry-docking.**

$$P = \frac{\text{Trim} \times \text{MCTC}}{\text{LCF}}$$

From the formula the P force is directly proportional to the Trim. Hence larger the trim, the larger the force.

The loss of metacentric height (GM) is directly proportional to the P force. As can be seen from the formula
Loss of GM = $P \times KM_T$ / Displacement

With the increase in P force the GM decreases and might at the Critical Instant, where the P force is maximum become negative and the vessel will topple over. Hence it is very important to have a small Trim while entering drydock and adequate initial GM so that the vessel remains stable during the critical period. (Critical period is the period between the ship's first touching the blocks aft and landing overall).

Critical instant is the instant before the ship lands overall. The P force is at its greatest at this instant and the Gm lowest. (It is essential that the ship should have +ve GM at this point).

**Describe how the Metacentric height & the Trim can be adjusted prior to dry-docking so as to improve the vessel's stability at critical instant.**

- Keep minimum trim as recommended by the drydocking plan.
- Ensure vessel has adequate initial GM to ensure that it remains +ve at the critical instant.
- The loss in GM is directly proportional to the KG of the vessel, hence ensure the vessel has a low KG at the start of the operation.
- This low KG can be achieved by lowering the weights on board or by adding weights at a lower level (Emptying high tanks and pressing-up low tanks).
- Eliminate any FSE on the vessel to prevent loss in GM.

**Describe the two methods of determining the upthrust (P) force during the critical period.**

(i) P = Reduction in TMD x TPC

The force P is the difference between the displacement of the ship on entering the dock and her displacement at the time for which we wish to calculate her GM. After the ship comes flat on the blocks this calculation is simple as shown in (i) above.

(ii) $$P = \frac{\text{Trim x MCTC}}{\text{LCF}}$$

The most critical period when the P force is maximum and the Gm is lowest is at the critical instant, where the P force is calculated by the above formula as shown in (ii).

**<u>MAR'2000</u>**

**Explain why it is desirable to have a small stern trim on entering drydock.**

- When a ships is drydocked her support has to be transferred from the water to the keel blocks and shores.
- During this operation she may become unstable (during the critical period) and capsize.
- When the vessel touches the keel blocks the P force begins to act and results in loss of GM.
- If the GM goes negative before the shores were properly set up, the ship might capsize in the dock.
- It is thus of utmost importance to keep full control of the ship during the critical period and to get the shore set up as soon as possible.
- To assist in this it is desirable to have the ship trimmed a little by the stern when she enters the dock so that the heel of the stern post is the first part to touch the blocks.
- The advantage with this operation is that the decrease in GM caused by the P force is more gradual than it would be if the ship sat suddenly flat on the blocks fore and aft, so that we have more control over the ship's stability.
- In this way the risk of the ship falling over in the docks is reduced.

# SYNCHRONOUS ROLLING

**MAR'04**

**Discuss how a vessel's still water rolling period may be affected by changes in the distribution of weight aboard the vessel.**

Rolling period is the time taken by the ship to roll from one side to the other and back.

- The period of roll can be increased by winging out the weights.
- The period of roll can be decreased by concentrating the weights inwards.
- The rolling period of the ship varies with the GM; for a given ship the roll period will be longer when she is tender (small GM, Large KG) and the period will be shorter when she is stiff (Large GM, small KG).
- Ship's natural roll period $T = 0.82 \times \frac{B}{\sqrt{GM}}$ in secs OR

$$T = 2\Pi \sqrt{\frac{R}{9.81 \times GM}} \text{ in secs}$$

where: R is ship's radius of gyration
g is the force of gravity (9.81 m/sec)

Radius of gyration $R = \frac{\sqrt{B^2}}{8}$

**Explain the term synchronous rolling, describing the dangers, if any, associated with it.**

If the wave period coincides with the ship's natural roll period, then maximum angle of heel and the violence of the roll will progressively increase with each successive roll as each wave reinforces the ship's natural roll cycle. This is known as synchronous rolling and is also an example of resonance.

DANGERS ASSOCIATED WITH SYNCHRONOUS ROLLING:

- The vessel rolls to dangerously large angles of heel.
- Sometimes angle of heel increases beyond the point from which it can recover and the vessel might capsize.
- Cargo lashings can part on container and RoRo vessels.
- Parting of lashings can result in structural damage (like Fuel oil tank vents) leading to serious consequences (Example: Braer).
- Cargo shift can occur resulting in loss of stability due to heavy list and possible capsize.
- Structural damage (wracking, surge of liquids) can occur with high density cargo.
- Personnel injury

**State the action to be taken by the ship's officer when it becomes apparent that the vessel is experiencing synchronous rolling.**

- Alteration course of course towards the sea has the effect of reducing the apparent period of waves.
- Alteration of speed (reduction) is effective when the sea is other than abeam.
- Use of anti-rolling devices if equipped (stabilising fins and flume tanks)
- Since $T = 2\Pi \sqrt{\frac{R}{9.81 \times GM}}$ in secs

- Reducing the GM would result in increasing the rolling period

(i) Deballasting lower tanks
(ii) Ballasting higher tanks
(iii) Shifting weights from lower to higher position

- Winging out the weight has the effect of increasing the period of roll by increasing the radius of gyration. This can be achieved by :
    (i) Ballasting the wing tanks (This effectively reduces the GM also)
    (ii) Deballasting inner tanks

## INCLINING EXPERIMENT

**MAR'04, NOV'02**

**State the purpose of inclining experiment.**

The inclining experiment to perform to find the ship's light displacement and light ship GM and hence her light KG.

**Describe the precautions to be taken by the ship's officer, before and during the experiment.**

- There should be little or no wind, if there is wind the vessel should be head on or stern to it.
- In tidal conditions, the experiment should be conducted during slack water.
- The vessel should be floating freely, clear of the wharf so that she can heel freely.
- The mooring lines must be slacked
- There should be no barges alongside.
- There should be plenty of UKC to prevent the ship's bottom touching the seabed when inclined.
- Free surface should be minimised with either pressing up tanks and boilers fully or emptying them and all bilges must be dried.
- The vessel must be upright at the commencement of the experiment.
- All loose weights must be removed or secured.
- Only essential personnel to be retained on board.

**List the circumstances when the inclining experiment is required to take place on passenger vessels.**

- When the ship is built
- After any major modifications
- Passenger ships: Light ship displacement, VCG and LCG are checked every five years. If the light ship $\Delta$ is changed by 2% or light ship LCG changed by 1%, then another inclining experiment is required.

## LOADICATOR

**JULY'04**

**With rererence to mdern shipboard stability and stress finding instrument:**

**a) State the hydrostatic and stability data already programmed into the instrument.**

- Ship's general particulars (Dimensions, Deadweight, Tonnage, Displacement etc.)
- Cargo/tank Capacities
- LCG/VCG/FSM of all cargo spaces and tanks
- Hydrostatic particulars (Draught, Displacement, TPC, MCTC, LCB, LCF, KM, KB)
- Light ship data including KG and displacement
- KN values
- Simplified stability data, Eg. Maximum KG
- Grain loading data
- Wind heeling data
- Ice allowance data
- Stability limits (Loadline, Grain, Timber)

b) **Describe the information to be entered into the instrument by the ship's officer.**

- RD of the Sea water / Dock water
- RD of liquids (Fuel, Ballast, Liquid cargo)
- Stowage factor of bulk cargo
- Loadline zones
- Location and weight of individual items of deadweight (Cargo, Fuel, Ballast, Stores, FW)

**c) Describe the output information.**

- Deadweight summary
- Trim and draught (Fwd, Aft, Amidships and Freeboard)
- Heel
- Stability criteria (GM, GZ curve, Dynamical stability etc.)
- Simplified stability diagram and assessment
- Stress assessment
- Shear force/Bending moment/Torsion
- Grain loading assessment
- Local load assessment (Container stack weight)

## GRAIN

**JULY'03**

**State the stability criteria in the current international grain code.**

- Vessel upright on completion of loading
- The initial Metacentric height (GM) after correction of FSE of liquid in all tanks shall not be less than 0.30m
- The angle of heel due to grain shift shall not exceed $12^\circ$ or $\theta_{de}$, whichever is less
- In the statical stability diagram the net or residual area between the heeling arm curve and the righting arm curve upto the angle of heel of maximum difference between the two curves or $40^\circ$ or $\theta_f$ whichever is the least shall in all conditions of loading be not less than 0.075 mr

**Describe with the aid of a suitable diagram, how $\lambda_0$ and $\lambda_{40}$ is used to determine compliance with grain code.**

The above two values are used to ascertain the compliance with the grain code as follows:

- The values of $\lambda_0$ and $\lambda_{40}$ are used to plot the heeling arm on the statical stability curve diagram.
- the net or residual area between the heeling arm curve and the righting arm curve upto the angle of heel of maximum difference between the two curves or $40^\circ$ or $\theta_f$ whichever is the least shall in all conditions of loading be not less than 0.075 metre radians (mr)

**<u>NOV'2000</u>**
**Describe with the aid of one or more sketches, the effect on dynamical stability of a vessel during bad weather , of a transverse and vertical shift of solid bulk cargo originally trimmed level.**

**QUESTION REPEATED**
**<u>MAR'00</u>**
**During the course of a voyage the bulk cargo, originally trimmed level with the hold, shifts to one side creating vertical and horizontal shifts of the centre of gravity of the vessel.**

**a) Explain the effects of these shifts on righting levers.**
**b) Describe with the aid of specimen curves of uprighting levers, the overall effect on the ship's stability.**

- Solid bulk cargoes are liable to shift when the angle of heel due to heavy weather rolling exceeds their angle of repose.
- Hence solid bulk cargoes with low angle of repose are liable to shift more easily as the angle of heel exceeds their angle of repose.

When a solid bulk cargo shifts a large chunk of the cargo is lying off the centre line which has the effect of a weight added at a height. Thus the G moves towards the added weight and away from the centre line towards the weight loaded, so there is a virtual loss of GM due to the vertical and transverse shift of G. The vessel will be listed and there will be further listing as due to further wave action. This might continue and eventually cause the ship to capsize. However, with an increase in the angle of heel the ship's righting moment also increases until the maximum righting lever GZ is reached. Provided the rolling motion and cargo shift does not take the angle of heel beyond the point of max GZ it will become harder to heel the ship further and subsequent shifts of the cargo will diminish. This will allow the cargo to stabilise without capsizing the vessel and leaving the ship with a list.

The main factors of consideration preventing the ship from capsizing are initial adequate stability with a high GM and high residual area of stability for an assumed shift of cargo. Once the vessel heels over the effect on the statical stability are follows:

- Loss of GM
- Loss of GZ values
- Loss of dynamical stability
- Reduction in residual stability
- Reduced range of positive stability
- Reduced angle of vanishing stability
- Angle of deck edge immersion remains unchanged
- Angle of deck edge immersion is easily reached on the heeled side

## WIND HEELING / FREE TRIM

**JULY'05**

**A vessel with high deck cargo will experience adverse effects on its stability due to strong winds on lateral windage areas.**
**Describe with the aid of a sketch, the minimum stability requirements with respect to wind heeling under current regulations.**

**JULY'02**

**A vessel with high deck cargo of containers will experience adverse effects due to strong beam winds on lateral windage areas.**
**With the aid of a sketch of the statical stability curve, explain how the effects of steady and gusting winds are determined and state the main stability requirements with respect to wind heeling under the current regulations.**

**JULY'01**

**With the aid of a sketch, show the effect of a strong beam wind on a vessel's curve of statical stability.**

STATICAL STABILITY CURVE:

WIND HEELING CONSIDERATIONS FOR CONTAINER SHIPS:

- There are two hazards associated with carriage of containers on deck:

i) Possible failure of container securing arrangement causing a shift of container cargo and consequent listing of ship

ii) The large angles of heel caused by strong beam wind acting on large lateral areas above water line afforded by ship and containers.

WIND HEELING CRITERIA FOR CONTAINER SHIPS:
When the height of the lateral windage area measured from the load waterline to the top of the cargo container situated on the weather deck is greater than 30% of the beam, the ship builders prepare a curve of statical stability for the ship in the worst service condition taking into account the adverse effects of icing as appropriate.
The windage area and its centre of gravity and lever to mid draught should be stated.

STABILITY REQUIREMENT FOR CONTAINER VESSELS TO RESIST WIND HEELING (WHERE HEIGHT ABOVE THE WATER LINE OF TOP OF THE UPPERMOST CONTAINER STOW IS GREATER THAN 30% OF BEAM):

- The steady wind list under worst service conditions should not exceed 65% of angle of deck edge immersion.
- The maximum angle of heel with the ship being subjected to a gust at the end of a windward roll should not exceed the angle of flooding.

This stability criteria for container ships with regard to wind heeling are in addition to the normal stability requirement that the GZ curve of every ship must satisfy.

$$\text{The GZ at angle of heel} = \frac{\text{Heeling moments}}{\text{Displacement}} = \frac{FAd}{1000 \times \Delta}$$

When a vessel with a high windage area is subjected to a steady wind heeling moment or a gust wind heeling moment the effect on the vessel's GZ is calculated as follows:

Lever (d) is the distance of centroid of windage area from KB (1/2 draught)
Wind Force (F) per unit area (KG/$m^2$) = 48.5 / 1000 (for steady wind)
72.75 / 1000 (for gust)
Windage area (A) = Area ($m^2$)

TOTAL WIND HEELING MOMENT = FORCE x DISTANCE = Fx A x d / 1000 = tm
(FA/1000 is the total force in tonnes)
Wind heeling moment (Steady) = 48.5 x A x d / 1000 tm
Wind heeling moment (Gust) = 72.75 x A x d /1000 tm

The vessel will continue to heel over until an equal and opposite force is produced i.e. a righting moment of equal value.

Hence Heeling moment = Righting moment = $\Delta$ x GZ = Fad / 1000
Therefore GZ at angle of heel = FAd / 1000 $\Delta$

**JULY'01**
**Explain the meaning the term Free Trim and its particular relevance to offshore supply vessels.**

Free trim is the sudden and significant stern trimming moment suffered by the OSVs after a certain angle of heel due to the shift of the centre of buoyancy towards the foxle. The bow is up and the stern is trimmed down.

- Free trim effect is observed in OSVs with high foxle and a low working after deck.
- When such a ship is heeled over to immerse the after deck line the foxle remains well over the water line.
- There is considerably more reserve buoyancy at the bow than at the stern.
- This heeling results in significance forward shift of centre of buoyancy causing a stern trimming moment which will submerge the stern further and lead to a danger of aft deck being flooded.
- This sudden change of trim and consequent GZ values is said to be a free trim situation.

**Show how a curve of statical stability produced using ordinary KN values differs from a curve produced using KN values labelled free trim.**

## FREE SURFACE EFFECT

**NOV'04**
**A vessel is lying to Port at list of loll. It is proposed to rectify the situation by ballasting DB tanks.**
**a) Sketch the vessel's GZ curve in the initial condition.**

**b) Sketch the initial effect on vessel's GZ curve of first introducing water ballast into a centre tank thereby creating Free Surface Effect.**

**c) Show the effect on the vessel's GZ curve of filling an off-centre tank on the low side assuming each of the following:-**
**(i) The resulting GM is –ve**
**(ii) The resulting GM is now +ve**

**JULY'03**

a) **State the formula to determine the virtual loss of GM due to a free liquid surface within a rectangular tank, explaining each of the terms used.**

$$\text{Free Surface Correction (FSC)} = \text{Loss in GM} = \frac{L \times B^3 \times RD_{liquid}}{12 \times \Delta \times n^2}$$

where

**L** is the length of the tank in **metres**

**B** is the breadth of the tank in **metres**

**RD** liquid is the Relative density of the liquid in the tank in **t/ $m^3$**

Δ is the displacement of the vessel in **tonnes**

**n** is the **number** of tanks created by sub-divisions in the tank (Eg. One sub-division would create two tanks)

Hence the loss in GM

- Increases with the increase in tank length
- Increases with increase in tank breadth
- Increases with increase of relative density of the liquid
- Decreases with increase in displacement
- Reduces with number of sub-divided tanks
- Is unaffected by tank position or depth of the liquid in the tank

**b) Explain the effects on the virtual loss of transverse GM due to the FSE when the slack tank is equally divided in each of the following situations:-**

**(i) By a longitudinal bulkhead**

- With the introduction of a longitudinal bulkhead, the tank is divided into two where n = number of tanks created by sub-division which is 2 (i.e. n = 2)

Substituting the value of n in the formula; Loss in GM = $\frac{L \times B^3 \times RD_{liquid}}{12 \times \Delta \times 2^2}$

Loss of GM = ¼ x $\left(\frac{L \times B^3 \times RD_{liquid}}{12 \times \Delta}\right)$

Thus the loss in GM is greatly reduced.

**(ii) By a transverse bulkhead**

Introduction of a transverse bulkhead has no effect on the FSE as explained below.

- Even though the tank is divided into two equal halves, the effective length and breadth remains the same.
- The area available for the free movement of the liquid remains the same.
- Hence the FSE is the same as was before.

**c) A DB tank initially empty, is to be ballasted full of salt water. Sketch a graph to show the way in which the effective KG of the ship will change from the instant of starting to fill the tank until it is full.**

# LOADLINE REGULATIONS

**NOV’2000**

**Describe the general provisions of the current passenger ship construction rules governing the ability of a Class I passenger vessel to withstand flooding due to damage and the stability in the final condition.**

**MAR’03**

**With reference to the current passenger ship construction regulations**

a) **State the assumed hull damage used when calculating the ship’s ability to remain afloat in a stable condition after flooding.**

The assumed extent of damage is specified by regulation 8 paragraph 4 as:-

- Damaged length is 3 + 0.03 x L metres, but not greater than 11.0 metres
- Breadth penetration is 0.2 x Max waterline beam
- Vertical extent is unlimited

b) **Describe the minimum stability requirement in the damaged condition for passenger ships (other than RoRo) built after 1990, including details of the heeling moment assumed.**

In addition to usual initial stability requirement, the vessel shall have sufficient intact stability after the flooding of the required number of compartments as follows:-

In the final stage after any equalisation measures (cross flooding) the vessel must comply with the following conditions:

- Resudual GM of atleast 50mm
- Final heel not to exceed 7° (one compartment flooding)
- Or 12° (2 or more compartments flooding)
- Positive residual GZ curve with a range of atleast 15°
- Area under the residual curve to be atleast 0.015m upto either 22° (with 1 compartment flooding)
- Or 27° (with 2 compartments flooding)
- Or θf

whichever is least

- Maximum residual lever to be
- Either atleast 0.10m
- Or Heeling moment / Δ + 0.04m

Whichever is greater

- The heeling moment is to be whichever of the following gives the greatest value:

a) Crowding of all passengers to one side OR
b) Launching of fully loaded davit launched survival craft
c) Wind pressure

# LOADLINE REGULATIONS / SURVEYS

**JUNE’2000**

a) **State the surveys required in order that an international loadline certificate remains valid.**

- Initial survey for the assignment of loadlines
- Periodic surveys – Annual survey – Yearly
  Renewal survey – Every 5 Years

**b) List the items and state the nature of the examination required for each of these items during survey.**

The following items are checked for condition and/or weather-tightness (hose test as necessary):

- Loadline marks: correctly positioned and easily visible
- Access: Walkways, Ladders and safety rails
- Air pipes: Permanently attached means of closure. Gauze to fuel tanks.
- Ventilators: Effective means of closure and securing weather tight.
- Freeing ports: Free movement of flaps
- Scuppers: Inlets and discharge
- Effectiveness of non-return/storm valves
- Bulwark and guard rails in good condition
- Deck fittings and appliances for timber loadline
- Hatch covers: Effective means of closure and securing weather tight (Cleats, Clamps, Wedges, Rubber sealings)
- Other deck openings: Sounding pipe covers, ullage pipe covers, tank lids, sighting ports, man-holes, deck scuttles – Effective means of closure and of securing water tight. (Hinges, clamps, sealing arrangement)
- Port holes (Side scuttles): Effective means of closure and securing weather tight. (Clamps, sealing, hinges, deadlight operation)
- Side cargo doors: Effective means of closure and securing water tight. (Clamps, hinges, sealing arrangement)
- Super structure / deck house weather tight doors: Effective means of closure and of securing weather tight (Dogs, clamps, hinges, weather tight seals).
- Any changes to hull or structure which may materially effect stability (Eg. Significance increase in light weight of ship)
- Any departure from recorded conditions of assignment as detailed in record of particulars.
- Presence of stability information booklet and /or loading computer.

**NOV'04, NOV'03**

**The current loadline regulations require the master to be provided with stability particulars for various conditions. Detail the information to be provided for a given service condition, describing how this information may be presented.**

**JULY'03, NOV'2000**

**Describe the hydrostatic, stability and stress data required to be supplied to ships under the current loadline rules.**

Regulation 10 of the loadline requires that the master be provided with sufficient information to ensure that the vessel is loaded safely with adequate stability, suitable trim and within acceptable stress limits of the hull. This information is provided in the form of an approved stability booklet which is provided by the ship builder and endorsed by the MCA.

The stability book combined with ship's data on board should provide the following:

- A table of hydrostatic data giving values of displacement, deadweight, TPC, FWA, KM, LCB, LCF, MCTC.
- The above information shall be provided for salt water draught ranging from light ship condition to the maximum possible loaded draught.
- The values should be at draught intervals close enough to allow linear interpolation between each increment.

- The VCG and LCG for the light ship condition and a record of the inclining experiment.
- KN data allowing for the KN value at any draught and trim to be calculated in 15° steps from upright to 90° of heel.
- A table of compartment data giving values of volumetric capacity, VCG, LCG and FSM for each compartment.
- A set of sounding tables for each ballast, fuel and water tank in the vessel. This should include correction for the trim and density of the liquid in the tank.
- Light ship longitudinal weight distribution and buoyancy distribution at suitable draught to allow the bending moment curve for loaded condition to be plotted and checked against given maximum allowable hogging and sagging moment.
- A range of sample loaded conditions covering the vessel's normal operating range and including the light ship condition.
- The above should give transverse stability, trim and bending moment data for each condition. If any of the listed condition is unsuitable for sea, then they should be clearly stated.

**NOV'03**
**State the corrections required when converting basic freeboard to assigned freeboard, outlining the circumstances when freeboard is increased or decreased in each case.**

**NOV'02**
**When converting tabular freeboard into assigned freeboard as specified in the loadline regulations a number of corrections have to be applied.**
**Describe with the aid of sketches, each of the corrections to be applied for a Type A vessel.**

BLOCK COEFFICIENT CORRECTION:
The tabular freeboard is first converted into basic freeboard by the application of Cb correction. The reasons are as follows:
A larger Cb causes an increase in the underwater volume so freeboard must be increased in order that the reserve buoyancy amounts to the same percentage of the greater displaced volume as it would have been had Cb been 0.68

CORRECTION FOR DEPTH:
A standard ship has length to depth ratio of 15. If the length to depth ratio is less than 15 freeboard is increased. If the length to depth ratio is greater than 15, the freeboard may be decreased, provided that the ship has an enclosed superstructure covering atleast 0.6L amidships, a complete trunk or combination of detached enclosed superstructure which extends all over fore and aft.

CORRECTION FOR DECK LINE POSITION:
If the actual depth to the upper edge of the deck line is greater or less than the depth for freeboard (D), the difference if greater shall be added or if less shall be deducted from the freeboard.

CORRECTION FOR SUPERSTRUCTURE AND TANKS:
The standard ship has no superstructure. Efficient superstructure provides reserve buoyancy above the freeboard deck. Hence, vessels with effective enclosed superstructures are allowed a reduction in freeboard.

CORRECTION FOR SHEAR PROFILE:
Shear is defined as being a curvature of the freeboard deck in the fore and aft direction. Benefits of shear include greater reserve buoyancy at the end of ship, particularly forward ensuring good lift in a gead / following sea. Reduces water shipped on deck. Reduces risk of fore deck being submerged after collision thus improving survivability in the damaged condition and helps to maintain an acceptable angle of heel at which progressive down-flooding ($\theta f$) takes place. A deficiency in shear will increase the freeboard. Excess shear will result in reduction of freeboard.

CORRECTION OF BOW HEIGHT:
A minimum allowable bow height must be maintained when the vessel is floating to summer loadline at its designed trim. The assigned summer freeboard must be increased in order to meet the minimum bow height if necessary.

**JULY'02**

**Describe the general provisions of the current loadline rules governing the ability of Type B vessels with reduced freeboard to withstand flooding due to damage, and the stability in the final condition after such damage.**

**NOV'01**

**Describe Type A vessel under current loadline rules, including the flooding and stability requirements.**

- A ship which is designed to carry only liquid cargoes in bulk is called a Type-A ship.
- The hulls of Type-A ships designed to carry bulk liquids are divided into many weather tight tanks.
- The ship's cargo tanks have only small weather tight access hatches.
- These vessels are designed to have a high degree of water tight integrity and are less likely to flounder due to flooding.
- The above is because of the low permeability of the loaded cargo spaces.

FLOODING REQUIREMENT:

- A Type-A ship more than 150 metres in length when fully loaded at summer loadline, should be capable of remaining afloat after flooding of an empty compartment. Assumed permeability of 95% in a prescribed condition of equilibrium.
- If the vessel is over 150 metres the machinery space is regarded as a floodable compartment with an assumed permeability of 85%.

CONDITIONS OF EQUILIBRIUM:

- The final GM to be atleast 0.05m
- The final angle of heel not to exceed 15° (17° if deck edge is not immersed).
- The ship must adequate residual stability after flooding.
    - Max GZ not less than 0.1m
    - Range of stability of at least 20°
    - The ship must have residual area under curve of at least 0.015 mr
    - Final water line after flooding must be below any opening such as the top of a ventilator coaming, door sil, or any opening through which progressive flooding could take place.

**<u>MAR'02</u>**

**With regard to loadline regulations**

**a) Distinguish between Type A vessel from Type B vessel and explain why they have different tabular freeboards.**

| TYPE – A | TYPE - B |
|---|---|
| Type-A vessels (Tankers) are those which are | Type-B vessels (Non-Tankers) are those which are |

| | |
|---|---|
| designed to carry liquid cargoes in bulk only. | not designed to carry liquid cargoes in bulk. |
| The longitudinal hull framings in Type-A vessels result in a high degree of sub-division. | The transverse hull framings in Type-B vessels result in a limited degree of sub-division. |
| Access to under deck compartments in Type-A vessels is limited to small steel weather tight hatches. | Access to under deck compartments in Type-B vessels is through large hatches, which may be equipped with wooden covers. |

Because of their vulnerability to flooding Type-B ships have a higher freeboard in comparision to Type-A vessels.

**b) State the general requirements for a Type B vessel to be given the same tabular freeboard as a type A vessel of the same length.**

The general requirements for a Type B vessel to be given the same tabular freeboard as a type A vessel of the same length are:

Any Type-B60 ship over 100m long (Type-B100) satisfying the following conditions at summer draught:

- Water tight steel hatch covers
- Access to engine room from deck protected by the accommodation
- At least 50% of the length shall be protected with Open rails and not bulwarks
- The weather deck should be fitted with a protected raised steel walkway (The flying bridge) or under deck walkway along each side of the hull that are well lit, gas tight and well ventilated to allow safe access for the crew.
- If under deck walkways are provided instead of raised walkway then open rail should be fitted along the entire length of ship side.
- Shall remain afloat after flooding of any two fore and aft adjacent compartments (Permeability 95%) at summer draught.

**c) Identify the additional corrections required when converting basic freeboard to assigned freeboard, explaining the reason for each correction.**

BLOCK COEFFICIENT CORRECTION:
The tabular freeboard is first converted into basic freeboard by the application of Cb correction. The reasons are as follows:
A larger Cb causes an increase in the underwater volume so freeboard must be increased in order that the reserve buoyancy amounts to the same percentage of the greater displaced volume as it would have been had Cb been 0.68

CORRECTION FOR DEPTH:
A standard ship has length to depth ratio of 15. If the length to depth ratio is less than 15 freeboard is increased. If the length to depth ratio is greater than 15, the freeboard may be decreased, provided that the ship has an enclosed superstructure covering atleast 0.6L amidships, a complete trunk or combination of detached enclosed superstructure which extends all over fore and aft.

CORRECTION FOR DECK LINE POSITION:
If the actual depth to the upper edge of the deck line is greater or less than the depth for freeboard (D), the difference if greater shall be added or if less shall be deducted from the freeboard.

CORRECTION FOR SUPERSTRUCTURE AND TANKS:

The standard ship has no superstructure. Efficient superstructure provides reserve buoyancy above the freeboard deck. Hence, vessels with effective enclosed superstructures are allowed a reduction in freeboard.

CORRECTION FOR SHEAR PROFILE:

Shear is defined as being a curvature of the freeboard deck in the fore and aft direction. Benefits of shear include greater reserve buoyancy at the end of ship, particularly forward ensuring good lift in a gead / following sea. Reduces water shipped on deck. Reduces risk of fore deck being submerged after collision thus improving survivability in the damaged condition and helps to maintain an acceptable angle of heel at which progressive down-flooding ($\theta f$) takes place. A deficiency in shear will increase the freeboard. Excess shear will result in reduction of freeboard.

CORRECTION OF BOW HEIGHT:
A minimum allowable bow height must be maintained when the vessel is floating to summer loadline at its designed trim. The assigned summer freeboard must be increased in order to meet the minimum bow height if necessary.

**JULY'01**
**A ship is loading in a port in a tropical zone for a port in a winter seasonal zone during winter months. Describe the various precautions and considerations which must be borne in mind at the loading port in order that the voyage is accomplished safely and in accordance with the requirements of the loadline rules.**

## GZ CURVES

**JULY'04**

a) **Explain why a vessel laden to the same draught on different voyages may have different natural rolling periods.**

From the formula Rolling period T (secs) = $\frac{2 \times \Pi \times K}{\sqrt{g \times GM}}$

The GM of the vessel depends on the nature, relative density and KG of the cargo loaded. Since the GM varies for every voyage, the rolling period (T) also changes and hence the natural rolling period is different for each voyages with same draught.

**b) Sketch on one set of axes, specimen GZ curves showing STIFF and TENDER conditions for vessel laden to the same draught on different on different voyages.**

**c) Sketch a GZ curve for a vessel with small negative GM.**

**<u>NOV'03</u>**

**a) A vessel loads packaged timber cargo on deck such that there is an increase in the vessel's KG and an effective increase in freeboard. Using a sketch, show the effect of loading this cargo on the vessel's GZ curve.**

b) **Sketch showing how the GZ curve for a vessel with a zero GM is affected by each of the following:**
   - **(i) A rise in vessel's KG**
   - **(ii) A reduction in vessel's KG**

**MAR'02, NOV'01**

a) **Show by means of labelled diagrams, the difference between a GZ curve for a vessel with a list due to an off-centre weight and angle of loll.**

b) **Describe the effect of a heavy list on a vessel's stability.**

EFFECT OF HEAVY LIST ON VESSEL'S STABILITY.

- when a vessel is listed the G lies off the centre line to Port or Stbd.
- GZ is actually a capsizing lever with a –ve GZ value when the vessel is upright.
- The GZ is –ve till the angle of list and the vessel is progressively listing.
- At the angle of list GZ becomes ZERO.
- Once the ship is heeled beyond angle of list GZ is +ve and it is now a righting moment.
- The loss of GZ = $GG_H$ X Cos $\theta$
- Dynamic stability (Area under the curve) is reduced
- Range of stability is reduced.
- Since the ship is already listed external forces can easily heel the ship to more dangerous angle of heel on the listed side.
- The angle of heel at which $\theta_{de}$ remains unchanged but easily reached on the listed side when acted upon by external forces.

c) **Describe how a vessel lying at an angle of loll may be returned to a safe condition.**

CORRECTING AN ANGLE OF LOLL:

The main aim of correcting this situation is not the angle of loll but the factor that caused it – THE NEGATIVE GM". Attempts should be never made to correct the loll directly by an opposite side ballast operation as this will result in a sudden rollover from one side to the other side and the ship might capsize due to the violent movement of rollover.

Following steps can be taken to correct the situation:

- The G of the ship must be lowered by:
- Adding weights at the lower tanks by way of ballasting/transfer of fuel etc
- Lowering weights that are already in the higher side
- In the worst scenario jettisoning of cargo
- In this case where there is a centre line tank available this should be ballasted first this is done to lower the G initially and continue to ballast this tank full (to eliminate any free surface moments).
- Once the centre tank is filled up continue to ballast the tank on the port side. (the lower side). Only one tank at a time should be filled to keep the free surface moments lowest.
- This action will increase the list to the port side. Free surface effect and the added weight cause this further list but as the tank fills she will gradually come upright
- Once the tank is about 65% full it is safe to start ballasting the starboard side tank (high side).
- The higher side should not be filled first even though it is very tempting to do so. This is because the G will not be lowered as quickly as it will be if the lower side is ballasted and also as mentioned before the ship will change her list from one side to other side very violently.

**NOV'2000**

**With the aid of labelled sketches, show the effects on a vessel's curve of statical stability of each of the following:**

**(i)** **Decreasing the beam**

**(ii)** **Increasing the freeboard**

**(iii)** **Increasing the free surface effect**

**(iv)** **Shifting the weight transversely**

SUMMARISING THE EFFECT ON DYNAMICAL STABILITY:

- GM reduces
- GZ values reduced
- Reduced area of +ve stability
- Reduced range of +ve stability (Between angle of list and angle of vanishing stability)
- Reduced angle of vanishing stability

# QUESTIONS LIKELY TO BE ASKED IN SQA EXAMS

**Explain the use of stability information to be carried on boards ships.**

- Length/Breadth: Assists in the vessels berthing/unberthing details with respect to available berth, turning areas in basins etc.
- Deadweight: For cargo calculations (Fuel, ballast and Cargo + Constant = DWT)
- Capapcities and centre of gravities of Cargo, Fuel, Water & Stores: Enables to decide amount of the cargo to load, position of cargo, ascertain the KG and subsequent GM, and total cargo to load.
- Estimated weight and disposition of passengers and crew: To assess the moment of such movable cargo especially when they move to one side, or when they are in lifeboats etc.
- Estimated weight and disposition of deck cargo (including 15% max allowance): Enables to decide on the max cargo to load as well as their position in order to comply with loadline regulations throughout the voyage.
- Deadweight scale: Ascertain the vessels total weight for various conditions
- Displacement for various TMDs are given which can be used in stability calculations as well as for canal tonnage calculations.
- TPC: Gives the amount of cargo to load/discharge to achieve a desired increase/decrease in TMD.
- MCTC for SW and FW: assists in calculating the moment required to change the trim by a cm.
- Hydrostatic particulars (LCG,LCB, LCF): Assists in determining the position of lcg, lcb, lcf for a given TMD and thereby to determine the amount of trim and the direction of trim.
- KM values: The height of metacentre from the keel is used for further calculations of GM, P force, Loss of GM.
- Free surface information: assists in estimating the virtual loss of GM when the Free Surface is present due to slack tanks.
- KN tables: are used to obtain GZ values ($GZ = KN - (KG.\sin\theta)$)
- Cross curves: are used to find the GZ of the vessel for any angle of heel
- Pre worked ship condition: Drydocking – Enables the officer plan the stability condition for entering drydock.
- Ballast Arrival/Departure: gives an example to the ship's officer to establish stability condition of vessel. (Draught, Trim, Δ, GM, stress (SF and BM) conditions and also compliance status with the loadline criteria)
- Loaded arrival/departure: gives an example to the ship's officer to establish stability condition of the vessel when loaded. (Draught, Trim, Δ, GM, stresses (SF and BM) and also compliance status with the loadline criteria)
- Homogenous loaded arrival/departure condition: an example on cargo distribution for a given cargo to achieve a required stability criteria is presented enabling the officer to plan for loading of various cargoes.
- Inclining experiment reports: complete explanation of the procedure when last done and the results to enable the officer to plan for future experiments.
- Information of longitudinal stresses for vessels over 150m length
- A profile diagram indicating disposition of weights, statement of light weight, Metacentric height, curves of statical stability, warnings of unsafe conditions
- Special procedures and cautionary notes: Anything which endangers stability, any special information concerning the vessel is explained to assist the ship's officer in maintaining required stability.

**Explain as to why a vessel's light ship Δ and KG changes over a period of time.**

- Constants of the vessel keep changing due to accumulated sludge in fuel tanks / mud & rust in ballast tanks (unpumpables)
- Also the various stores remaining unconsumed might add to the constant
- Any structural changes will affect the light ship KG and light ship Δ.

**Explain increase in draught due to list / heel.**

- The Draught when heeled is given by the formula (Upright draught x Cos θ)+(1/2 Beam Sinθ)
- When the vessel heels due to either turning or due to any wind moments or any off-centre weight the vessel's centre of buoyancy shifts towards the heeled side.
- The wpa on the heeled side has changed resulting an increased Sinkage towards the heeled side.
- Thus, the draught on the heeled side increases.
- The increase in draught on the heeled side increases with the angle of heel and with the beam of the vessel.
- When a vessel turns the angle of heel depends on the speed of turn.
- Higher speed results in a higher angle of heel

**Explain angle of heel due to turning and its effect on stability.**

The angle of heel when turning $\tan\theta = \frac{V^2 \times BG}{g \times R \times GM}$

where V is the vessel's speed in m/sec
BG is the distance between centre of buoyancy and centre of gravity (BG = KG-KB) in m
g is the gravitational force ($9.81 m/sec^2$)
R is the radius of turn in m
GM is the metacentric height in m

- When a vessel is engaged in a turn it is heeled over away from the direction from the turn by two forces one is the centrifugal force (acting at G) and the other is the centripetal force (acting at B).
- The centripetal force is produced by the water acting on the side away from the centre of the turn
- The centrifugal force is produced by the water acting on the side towards the centre of the turn.
- When the rudder helm is given the forces acting on the rudder itself produces a small angle of heel towards the direction of turn
- However, the heel caused by the action of these two forces which is larger and its direction is opposite to the direction of the turn.
- Thus the final angle of heel is away from the direction of turn.
- Thus for a vessel turning to port the final angle of heel is to the starboard side and vice versa.

EFFECT ON STABILITY:

- Since a vessel is an at an angle of heel the GZ will be reduced or negative until the final angle of heel after which the righting moment will bring the vessel upright.
- As long as the vessel is heeled the area under the curve is reduced and there is a virtual loss of GM.

**Define centre of floatation with respect to water plane area.**

The centre of floatation is the centre of gravity or centroid of the water plane area and is a point about which the ship heels and trims.

**Define longitudinal centre of floatation (LCF) with respect to after perpendicular.**

The longitudinal centre of floatation is a point whose distance is measured from the aft perpendicular. It is the point about which the vessel trims either by head or by the stern. For box shaped vessel the LCF lies at the centre of the vessel , whereas for a ship shape the LCF is forward or abaft amidships depending on the shape of the waterplane. Trimming moments are about the LCF.

**Explain how the LCF changes with a change in draught.**
Since the vessel's water plane area changes with draught, the LCF which is the centre of floatation of this area also changes. Hence, the LCF changes with change in draught.

**Define true mean draught.**
The True Mean Draught is the draught of the vessel at the centre of floatation.
The TMD is the average of the forward and aft draughts when the LCF is at the centre.
If the LCF is not at the centre the TMD of vessel is calculated by the formula

$$TMD = \text{Aft Draught} \pm \frac{(\text{Trim x LCF})}{\text{LBP}}$$

**Define the term righting moment (moment of statical stability).**
When a vessel is heeled B moves towards the listed side. The force of buoyancy acts vertically upwards through B1 and the force of gravity acts vertically downwards through G. The perpendicular distance between the two lines of action of forces is GZ, the righting lever. This moment produced by two equal and opposite forces of G and B is called the righting moment.

The righting moment is also called the moment of statical stability and is given by the formula
Righting moment = $\Delta$ x GZ = $\Delta$ x GM.Sin$\theta$ (at small angles of heel)

**Define the term dynamical stability.**
The amount of work done in inclining a ship to any given angle of heel and is given by the formula
$\Delta$ x Area under the stability curve

**Describe the dangers associated with an angle of loll and an angle of list.**
DANGERS ASSOCIATED WITH ANGLE OF LOLL:
- Since the vessel had a initial –ve GM, the righting lever is –ve when the ship is inclined resulting in a capsizing moment.

- This continues until the angle of loll after which the GM becomes +ve
- If the ship is further heeled beyond the angle of loll the righting lever is +ve giving a moment to return the ship to the angle of loll.
- The ship will oscillate about the angle of loll.
- The vessel has a reduced range of dynamical stability
- Angle of vanishing stability is reduced.
- Vessel is lying at a dangerous angle of heel (angle of loll)
- The vessel is easily heeled further by wave action towards the lolled side.
- Angle of θde is reached easily as less work is required to heel the vessel on the lolled side.
- The vessel might suddenly flip over to the opposite side of angle of loll with a very violent moment causing structural damage, causing personnel injury or even causing the vessel to capsize.
- The vessel has an increased draught on the lolled side and this could result in the vessel grounding while in shallow waters.
- There is also a possibility of overflow of oil tanks if filled to max capacity.

DANGERS ASSOCIATED WITH AN ANGLE OF LIST:

- when a vessel is listed the G lies off the centre line to Port or Stbd.
- GZ is actually a capsizing lever with a –ve GZ value when the vessel is upright.
- The GZ is –ve till the angle of list and the vessel is progressively listing.
- At the angle of list GZ becomes ZERO.
- Once the ship is heeled beyond angle of list GZ is +ve and it is now a righting moment.
- The loss of GZ = $GG_H$ X Cos θ
- Dynamic stability (Area under the curve) is reduced
- Range of stability is reduced.
- Since the ship is already listed external forces can easily heel the ship to more dangerous angle of heel on the listed side.
- The angle of heel at which $\theta_{de}$ remains unchanged but easily reached on the listed side when acted upon by external forces.
- The vessel is in stable condition of equilibrium with a +ve GM.
- In still water conditions the vessel will lie at this angle of list
- Angle of vanishing stability is reduced.
- Vessel is lying at a dangerous angle of list
- The vessel is easily heeled further by wave action towards the listed side.
- The vessel has an increased draught on the listed side and this could result in the vessel grounding while in shallow waters.
- There is also a possibility of overflow of oil tanks if filled to max capacity.

**Explain the precautions to be observed when correcting a large angle of list.**

ASSUMED VESSEL IS LISTED TO PORT

On a ship with adequate GM it is not a too dangerous situation, nevertheless immediate action should be taken to ascertain the cause of list and get it corrected carefully with utmost seamanship.
After having ascertained that the heel is an angle of List and not an angle of Loll, the following procedures can be carried out:

- Stability calculations to be carried out to ensure the present GM is positive and adequate.
- Soundings to be obtained of all the tanks (Fuel/Ballast/fresh water) and any imbalances to be removed. In this case ballast the centre tank full and then ballast the starboard tank until the list is corrected.
- In case where the list is caused by uneven fuel consumption like in this case consumption of fuel from the starboard side then stop consumption there and consume from the port side tank preferably.
- Also transfer of fuel can be considered as better option ( 1 tank at a time should be done to prevent too many tanks being slack at any one given time). Transfer fuel to the starboard side tank and continue consumption from the port side fuel tank.
- Ensure the ballast tanks are always topped up in heavy weather to prevent loss of water and subsequent list.
- It is not advisable to pump put DB tanks to correct a list. This will actually reduce the GM as the G will rise up and away from the weights discharged from low tanks and this might take the vessel from an angle of list to an even more dangerous angle of loll condition by reducing the GM to negative.

**Discuss the factors to be taken into account to minimise grain heeling moments.**
Grain shift and subsequent grain heeling moments can be reduced or eliminated by the following measures:

- Fill all the holds utp the max level (coaming level)
- Trim all the grain holds
- Avoid partly filling the compartments (A full compartment has a less chance of grain shift due to sloping hopper side at the top of the hold)
- Use longitudinal sub-divisions
- Saucering stow of grain: The grain is covered with tarpaulin over which small bags og grain are packed to fill the hatch
- Bundling in bulk: A large bag of grain fills the hatch
- Overstowing: Secure the grain surface in a partly filled compartment by building a dunnage platform on top of the levelled grain and then stowing bagged grain or other cargo on top of the dunnage
- Strapping and Lashing: The platform built on the grain surface is secured using wires and bottlescrews.

**Describe the terms rolling and pitching.**
Rolling the sideways movement of a vessel from Centre-Port –Centre-Stbd-Centre about its heeling axis.

Pitching is the fore and aft movement of the ship about its trimming axis.
Both the above are caused due to wave action.
**Define Parametric rolling and the explain measures to avoid same.**
Parametric rolling is a phenomenon observed in vessel's with fine line bow and wide stern (as in large modern container vessels). This asymmetry between bow and stern line produces the tendency for the ship's pitching motion to induce rolling called the parametric rolling. This is called parametric rolling because it depends upon the parameters of ship's Δ and the righting lever. This is most marked when the pitching period is either equal to or half that of vessel's synchronous roll period.

During the alternate pitching moment the vessel's water plane area changes and hence the righting moment also changes. When the vessel is stern down there is an increased water plane area, hence a large righting lever. When the vessel is bow down the effective water plane area is less, so the righting lever is less. The vessel tries to heel further when bow down to produce the same righting moment as when stern down.

When the ship is rolling at pitching frequency there will alternate, maximum and minimum stability at reverse point.

If the ship is rolling at twice the pitching frequency then at both points of role reversal there will be minimum stability. Both the situations lead to a severe build up in synchronous rolling and large angles of heel which once again increase the asymmetry between the bow and the stern. Thus it is a continuous build up of asymmetry and loss of stability. Thus causing severe damages.

There is little a ship's crew can do to avoid parametric rolling. If the ship is slow steaming into head seas to avoid pounding and slamming, then increasing speed is not an option. Course alteration is also unlikely to change the pitching period and in fact the rudder application and subsequent heeling effect could worsen the situation. The parametric is only avoided by anti-roll tank stabilising system.

**Define the following terms with regard to damage stability:**

- **Bulkhead deck:**

The bulkhead deck is the uppermost continuous deck below which the ship is water tight and the water tight divisions within the hull must extend upto at least this level.

- **Margin line:**

Margin line is a line drawn parallel to and 760mm below the bulkhead deck.

- **Floodable length:**

Floodable length of a compartment is that compartment's maximum floodable length that will not immerse the margin line when the ship is floating at its loaded draught. The floodable length is derived from the permissible length and uses permeability values for different compartments and assumes that the ship remains upright when the compartment is flooded.

- **Permissible length:**

The permissible length is determined by applying a reduction factor known as the factor of sub-divisions or F to the floodable length value.
For any given position along the hull, permissible length = F x Floodable length
All longitudinal water tight compartments shall not exceed the prescribed permissible length. The permissible length of a compartment depends upon its position in the hull.

- **Factor of sub-division for passenger vessels:**

The factor of sub-division F is determined by the size of the vessel, the enclosed volume beneath the bulkhead deck that is given to passenger accommodation relative to cargo and machinery and the total number of passengers carried.
This factor determines the extent to which different ships carry a varying mix of passengers and freight.

- **Collision bulkhead:**

This bulkhead is to be fitted between 5% + 3m and 5% aft of the forward perpendicular.

**Describe sub-division loadlines for passenger vessels.**
A sub-division loadline indicates the max draught to which a ship can be loaded and still comply with the regs for its particular criteria of service number. The sub-division loadlines are marked beneath the tropical marks on the loadline markings. Passenger vessels designed to carry cargo and passengers alternatively will have two or more critical service numbers assigned to them. Each Cs Value will have a corresponding sub-division loadline marked on the shipside, an index C1, C2, C3 (for passenger ships making international voyages), or Ca, Cb, Cc (for passenger ships on home trade). When operating at a higher Cs value i.e. when carrying a higher proportion of passengers relative to cargo then the ship will require a greater freeboard to meet the sub-division requirement and damage stability criteria than for when it is carrying predominately cargo.

**Passenger subdivision loadline marks for International voyages**

The C1 mark allows for a deeper draught than C2 mark.
Vessel sails at a reduced passenger capacity when operating to the C1 mark.

**Describe Stockholm agreement 1996.**
This agreement applies to all RoRo-Passenger ferries operating on international voyages between or from European ports. The agreement demands that the vessel satisfies the requirements of SOLAS 90 with a constant height of water on deck as explained.

- Based on a 4m significant wave height, the height of water should be 0.5m if the residual freeboard at the damaged opening is 0.3m or less.
- 0m if the residual freeboard at the damaged opening is 2m or more.

Intermeditae values can be determined by linear interpolation. (See graph below)

For ships operating in restricted areas, where the significant wave height is less than 4m the height of water on deck will be 0m if the wave height is 1.5m or less. Intermediate values of height of water on deck for wave heights between 1.5m and 4m can be determined by linear interpolation.
**Describe minimum stability requirement for Cargo and Passenger vessels.**
CARGO VESSELS:

- Initial metacentric height (GM) not less than 0.15m
- Max righting lever (GZ) shall be at least 0.20m
- Angle of max GZ shall not be less than 30°
- The area under the curve of righting levers up to 30° shall be not less than 0.055mr
- The area under the curve of righting levers upto 40° or θf (whichever is less) shall not be less than 0.09mr
- The area between 30° and 40° or θf (whichever is less) shall not be less than 0.03mr

PASSENGER VESSELS:

- Initial metacentric height (GM) not less than 0.15m
- Max righting lever (GZ) shall be at least 0.20m
- Angle of max GZ shall not be less than 30°
- The area under the curve of righting levers up to 30° shall be not less than 0.055mr
- The area under the curve of righting levers upto 40° or θf (whichever is less) shall not be less than 0.09mr

- The area between 30˚ and 40˚ or θf (whichever is less) shall not be less than 0.03mr
- The angle of heel on account of crowding of passengers on one side shall not exceed 10˚
- The angle of heel on account of turning should not exceed 10˚

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**Describe minimum stability requirement for Timber vessels.**

- Initial metacentric height (GM) not less than 0.05m
- Max righting lever (GZ) shall be at least 0.20m
- Angle of max GZ shall not be less than 30˚
- The area under the curve of righting levers up to 30˚ shall be not less than 0.055mr
- The area under the curve of righting levers upto 40˚ or θf (whichever is less) shall not be less than 0.09mr
- The area between 30˚ and 40˚ or θf (whichever is less) shall not be less than 0.03mr

**Describe special factors affecting assignment of timber loadlines.**

- The deck cargo is protected from sea by a raised forecastle. If under 100m in length, raised superstructure aft.
- The DB tank should contain additional longitudinal subdivision in order to minimise the loss of stability through FSE due to slack tanks.
- The timber stow extends over the entire effective length of the weather deck, both forward and aft of the centre castle for ship's with midships accommodation. The above is to ensure that the reserve buoyancy of the stow is evenly distributed along the ship's length and that there is no trimming effect due to the immersion of a partial stow either near the bow or stern occurring at the end of a roll.
- The deck stow timber is adequately secured and built up evenly to a height sufficient to provide reserve buoyancy but is not excessive for the voyage weather conditions.
- The deck cargo should not interfere with ship's navigation and should be jettisonable.
- The crew should have safe access across the deck stow.
- Ventilators should be protected against damage resulting from a shift of cargo.
- The ship must be fitted with permanent bulwarks of at least 1m in height, suitably stiffened and fitted with freeing ports.

**Describe minimum stability requirement for container vessels**

- Initial metacentric height (GM) not less than 0.15m
- Max righting lever (GZ) shall be at least 0.20m
- Angle of max GZ shall not be less than 30˚
- The area under the curve of righting levers up to 30˚ shall be not less than 0.055mr
- The area under the curve of righting levers upto 40˚ or θf (whichever is less) shall not be less than 0.09mr
- The area between 30˚ and 40˚ or θf (whichever is less) shall not be less than 0.03mr
- The steady wind list, θs, under worst service conditions, should not exceed 65% of the angle of deck edge immersion θde
- The maximum angle of heel,θm, which results from the ship being subjected to a gust at the end of the windward roll, should not exceed the angle of flooding, θf.

**Describe minimum stability requirement for vessels carrying grain.**

- Vessel upright on completion of loading
- The angle of heel due to grain shift shall not exceed 12˚ or θde (which ever is least)
- In the statical stability diagram, the net or residual area between the heeling arm curve and the righting arm curve up to the angle of heel of maximum difference between the two curves, or 40˚ or the angle of flooding, whichever is the least, shall in all conditions of loading be not less than 0.075 metre-radians.

- The initial metacentric height (GM), after correction for free surface effects of liquids in tanks, shall be not less than 0.30m.

**Describe minimum stability requirement for RoRo vessels.**

- Residual GM at least 0.05m
- Positive range of stability at least 15°
- Max angle of heel not more than 7°
- Area under the curve to θf at least 0.015mr OR
- Area under the curve to 22° heel, at least 0.015mr (with one space flooded) OR
- Area under the curve to 27° heel, at least 0.015mr ( with two spaces flooded), whichever is least
- Max GZ 0.10m OR
- (Heeling moments /Δ) + 0.04m , whichever is having biggest value

**Describe stability problems associated with towing vessels.**

- Towing vessel experiences very large athwartship forces when towing
- Such large forces result in a large heeling moment which causes the vessel to heel over to a large angle thereby reducing the vessel's dynamical stability.
- This problem is more pronounced when the tow line is short and has low stretch characteristics
- Other factors affecting stability include dynamic forces during the towing operations (sudden surge in propulsion units) and
- Changes in trim caused by pull on tow line.
- Another stability problem associated with tugs is girting or girding. This is the tug being towed sideways by the vessel she is supposed to be towing, especially when the towing hook is close to midships. The resulting heeling moment can be so large so as to capsize the tow.

**Describe the precautionary measures to be taken by towing vessels.**

- Use of long tow line with good stretch or shock absorbing capability
- Use of gob rope
- Reduce height of towing point
- Slowing down the tow
- Giving the vessel a large beam length ratio
- Increasing the freeboard

**Describe the use of Simplified stability information.**

- Simplified stability information are used to check the vessel's compliance with stability criteria as recommended.
- The simplified stability information are incorporated in the ship's stability booklet either as a diagram or a table
- The simplified stability information eliminates the need to use cross curves or GZ curves for different loading conditions.
- A quick assessment of ship's stability as to whether or not all statutory criteria are complied with is achieved by means of a single diagram or table
- There are three methods of presentation
    - maximum deadweight moment or table
    - maximum permissible KG diagram or table
    - minimum permissible GM diagram or table

**Describe countermeasures which should be taken in the event of flooding.**
The main dangers associated with flooding are:

i) The vessel taking a large angle of list thereby resulting in loss of dynamical stability. This can be counteracted by cross-flooding (rapid water transfer by cross flooding or ballasting into opposite side compartment)

ii) The flood water causes Free surface moments which results in virtual loss of upright GM. The deck should have longitudinal sub-divisions and efficient pumping arrangement.

iii) The interaction of the water with the cargo:
- Explosion/Fire: Some cargoes react violently with water
- Cargo shift: Some cargoes such as coal, are liable to shift if the moisture content exceeds a certain limit creating additional capsizing moment.
- Corrosive liquids produced could damage the bilges, hence continuous flushing of bilges should be carried out.

In case of a collision the vessel should maintain small revs on the engines and remain attached to each other to prevent water ingress.

Create a list to bring the damaged area above water level.

Reduce speed to reduce water ingress.

Continuously pump out the water and use collision patches.

**Describe the changes in stability which might take place during the voyage and the effect of these on the GZ curves.**

Factor affecting the GZ curve during the course of the voyage:

**Vertical shift in G:**

Causes:

- This follows fuel/Lube oil/ballast consumption in lower tanks, stores consumption.
- Free surface moments caused by slack tanks.
- Addition of weights at heights as a result of moisture absorption by deck cargo.
- Addition of weights at heights as a result of ice accretion.
- Heavy seas shipped on deck and get entrapped on deck or between cargo.

Effect on curve:

- In all the above cases the G moves towards the weight loaded and away from the weights discharged there by increasing the KG and reducing the GM and subsequent loss in stability
- The GZ values across the range of stability are reduced especially at larger angle of heels
- The area under the GZ curve (Dynamical stability) is reduced and the vessel's ability to resist heel is reduced considerably
- The range of stability is reduced
- Reduced angle of vanishing stability
- The angle at which deck edge immersion occurs unchanged if free board is unchanged and the θde decreases with a decrease in freeboard.
- In this case since the draft increased with the displacement the freeboard decreases and the θde decreases.
- There is also the possibility of an decrease in KG when weights are added at lower levels by way of ballasting lower tanks where by the stability is improved with increased GM and increased GZ values.
- The loss/increase in GZ = GX = GGv x Sin θ

**Transverse shift of G**

Causes:

- Improper consumption of fuel / Ballast / fresh water – from tanks located off centre line
- If moisture absorption of cargo has taken place off centre line
- Unsymmetrical ice accretion on deck
- Water entrapped between cargoes as a result of heavy shipped seas in areas off centre line.
- Cargo shift (in case of grain vessel or other cargos liable to shift)

Effect on curve:

- In the above cases there is a vertical as well as horizontal shift in G causing a list
- Reduced GZ values - The transverse shift of G results in loss of GZ and this can be calculated by Loss of GZ = GGh x cos θ
- Loss in GM
- Dynamical stability is reduced
- Reduced range of stability
- Reduced angle of vanishing stability

**Describe the effects of variation of beam and freeboard on the curve of statical stability.**

EFFECT OF VARIATION OF FREEBOARD:

- Initial GM is unchanged, since only vertical movement of G will cause this change
- GZ values will be increased at angles of heel, beyond the angle of heel at which θde takes place for the smaller freeboard ships.

- Dynamical stability (area under the curve) is increased at angles of heel beyond the angle of heel at which θde takes place.
- Range of stability is increased

EFFECT OF INCREASE OF BEAM:

- Increase in B, increases the BM which in turn increases the KM and thereby the GM
- GZ is increased, since GZ = GM x Sinθ
- Area under the curve (Dynamical stability) increases
- Angle of deck edge immersion decreases
- Range of stability remains unchanged

**Describe the effect of trim on KN values and resultant curve of righting levers.**

- The KN values supplied for most ships are for an assumed condition of trim usually even keel and are calculated on a fixed trim basis.
- Any inward movement of the centre of buoyancy when the ship is heeled to large angles is ignored.
- For offshore supply vessels whose GZ curves are calculated on fixed trim basis will be more than what actually is when the vessel experiences free trim due to the shift of B towards the foxle area, when vessel is heeled beyond θde.
- Thus the stability of the ship will be over estimated.
- Hence, for such vessels KN values should be derived on a free trim basis taking into account the vessel's stern trimming moment and the vessel's trimming by the stern at large angles of heel causing reduction in GZ value.

**Outline the conditions for a vessel to be in a stiff or a tender conditions and describe the effect on the curve of righting levers.**

STIFF SHIP:

- Has a large GM
- Caused by KG being too small
- This results in ship loaded with high density cargo at low levels.
- Ship will be excessively stable
- The righting moment GZ will so large that the vessel will return to upright very quickly when heeled
- Rolling period will be very short

TENDER SHIP:

- Has A small GM
- Large KG
- Small righting moments
- Long rolling period

**Describe the use of ballast/bunkers to ensure adequate stability throughout the voyage.**

- Consumption of ballast and fuel should be done in a very planned and careful manner to ensure the vessel does not lose her stability and the GM is +ve.
- Fuel consumed from the DBs, the GM is reduced, hence it might be required to ballast lower ballast tanks.
- Additionally deballasting higher tanks will increase the GM by reducing the KG.
- Swimming pool can be discharged, to lower the G.
- Fuel/water should be evenly consumed from port and stbd side.
- Eliminate Free surface moments by transferring fuel into single tank (avoid multiple slack tanks).
- Press up ballast tanks.

**Describe the effect of zero initial GM on the GZ curve.**

- When the vessel is upright GZ is zero
- Vessel is heeled to small angle, GZ still remains zero
- When heeled beyond small angles GZ becomes +ve

**State the minimum equilibrium stability conditions for Type A, B60, B100 vessels.**

**TYPE-A:**

If the ship is over 150m in length to which a freeboard less than Type-B has been assigned, and has empty compartments when fully loaded at the summer loadline, The ship should be capable of remaining afloat after the flooding of such a compartment (assumed permeability 95%) in a prescribed condition of equilibrium. If the vessel is over 150m long then the machinery space is regarded as a floodable compartment (assumed permeability 85%).

**TYPE B-60:**

Should be capable of remaining afloat in the prescribed condition of equilibrium after the flooding of any single compartment (assumed permeability 95%) whilst floating at its summer draught.

If the vessel is over 150m long then the machinery space is regarded as a floodable compartment (assumed permeability 85%).

**TYPE B-100:**

Should be capable of remaining afloat in the prescribed condition of equilibrium after the flooding of any two fore and aft adjacent compartments (assumed permeability 95%) and if the vessel is over 150m long then the machinery space alone can be regarded as a floodable compartment (assumed permeability 85%).

**Describe the damage stability flooding criteria for Type A, B60, B100 vessels.**

- Minimum GM not less than 0.50m
- Maximum GZ not less than 0.10m
- Minimum range of stability not less than 20$^{\circ}$
- Angle of heel due to unsymmetrical flooding does not to exceed 15$^{\circ}$ and 17$^{\circ}$ if no part of deck is immersed
- Area under the righting lever curve shall not be less than 0.0175mr
- The final waterline after flooding taking into account Sinkage, heel and trim is below the lower edge of any openings through which progressive down flooding may take place.

**Describe tabular freeboard for above vessels.**

The tabular freeboard is the freeboard that would be assigned to a standard ship built to the highest recognised standards and having 5 specific characteristics as follows:

- A Cb of 0.68
- A length to depth ratio of 15
- No superstructure
- Parabolic shape of freeboard deck attaining a particular height at forward and aft perpendicular as prescribed by a formula dependent on the ship's length.
- A minimum bow height above load water line as prescribed by a formula depending on the Cb and the length of the ship.

**Describe minimum stability requirements taking into account wind heeling moments as specified in current loadline – instructions for the guidance for surveyors.**

When the height of the lateral windage area measured from the load waterline to the top of the cargo container situated on the weather deck is greater than 30% of the beam, the ship builders prepare a curve of statical stability for the ship in the worst service condition taking into account the adverse effects of icing as appropriate.

The windage area and its centre of gravity and lever to mid draught should be stated.

**Explain the effects of being in a seaway on the GZ curve.**

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R.RAJASEKARAN, B.A, AMNI

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**Made and updated by : R.Rajasekaran,**
**Chennai / India**
**E-mail : rajsadasivam@yahoo.com**

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