The Scope of Stability Safety

as a workshop for Shipowners and Operators

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The Plan

- Design stability (procedure for changing the design draft)
- Operational stability (ballasting)
- Ensuring Stability during Loading/Unloading Works

Transverse Stability

- Equilibrium of the ship

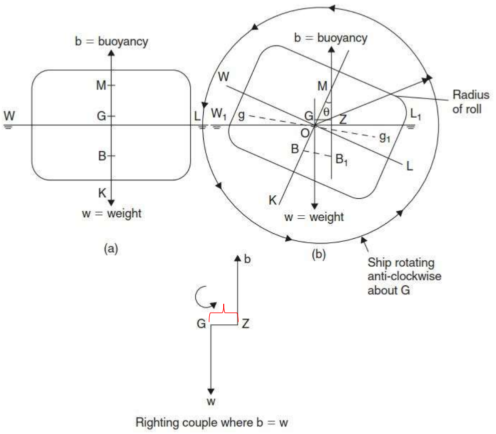
The most desirable parameter to be achieved at all times of vessels exploitation is the Stability. No doubt that Stability is the primal feature towards safety of human lives and cargo. Without stability the seaworthiness of the vessel is none.

Stability depends on simple physical law of static and buoyancy.

Understanding these principles together with consequent implementation into everyday practice will significantly help to eliminate the risk of loss.

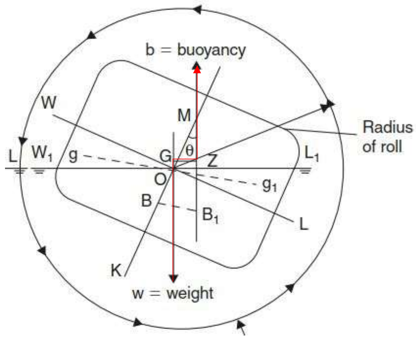
Please observe the drawings presenting the main principle (s) of transverse stability of a ship.

Principle of transverse stability



Consider a ship floating upright in still water as shown in Figure (a). The centres of gravity and buoyancy are at G and B, respectively.
Figure (c)shows the righting couple. GZ is the righting lever.

Principle of transverse stability



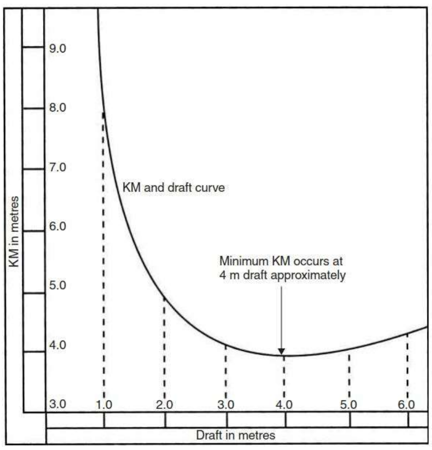
Now let the ship be inclined by an external force to a small angle (θ) as shown on the left. Since there has been no change in the distribution of weights the centre of gravity will remain at G and the weight of the ship (W) can be considered to act vertically downwards through this point. When heeled, the wedge of buoyancy WOW1 is brought out of the water and an equal wedge LOL1 becomes immersed.

In this way a wedge of transverse statical stability buoyancy having its centre of gravity at g is transferred to a position with its centre of gravity at g1. The centre of buoyancy, being the centre of gravity of the underwater volume, must shift from B to the new position B1,such that BB1 is parallel to gg1, and BB1= v*gg1/V; where v is the volume of the transferred wedge, and V is the ship's volume of displacement.

The verticals through the centres of buoyancy at two consecutive angles of heel intersect at a point called the metacentre. For angles of heel up to about 15° the vertical through the centre of buoyancy may be considered to cut the centre line at a fixed point called the initial metacentre (M).

The height of the initial metacentre above the keel (KM) depends upon a ship's underwater form. Next Figure shows a typical curve of KM's for a ship plotted against draft.

Principle of transverse stability

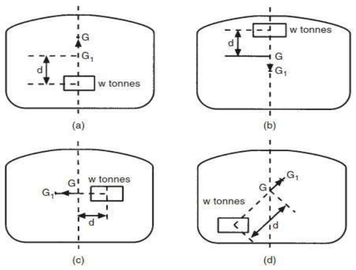


GM is crucial to ship stability. The table below shows typical working values for GM for several ship-types all at fully-loaded drafts.

Ship type	GM at fully-loaded condition:
General cargo ships	0.30–0.50 m
Oil tankers	0.50–2.00 m
Double-hull supertankers	2.00–5.00 m
Container ships	1.50–2.50 m
Ro-Ro vessels	1.50 m appr.
Bulk ore carriers	2–3 m

Potential Problems during Cargo Operations

- ***1. Mass loading/unloading– effects***



$$GG_1 = \frac{w \times d}{\text{Final displacement}} \text{ metres}$$

In each of the above figures (a-d), G represents the position of the centre of gravity of the ship before the mass of w tonnes has been loaded/unloaded. After the mass has been loaded, G will move directly towards the centre of gravity of the added mass(i.e. from G to G1). When unloaded, in opposite direction,but with modulus given by formula on right.

Potential Problems during Cargo Operations c't'd

- **2. Mass Shift thorought the Ship – effects**

In Figure below - G represents the original position of the centre of gravity of a ship with a weight of 'w' tonnes in the starboard side of the lower hold having its centre of gravity in position g1.

If this weight is discharged - ship's centre of gravity will move from G to G1 directly away

When the same weight is reloaded on deck with its centre of gravity at g2 theship's centr

will move from G1 to G2.

From this it can be seen that if the weight had been shifted from g1 to g2 the ship's centr

would have moved from G to G2.

It can also be shown that GG2 is parallel to g1g2 and th

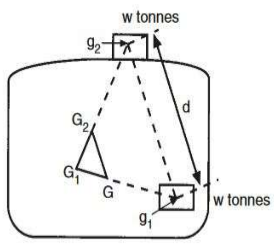
$$GG_2 = \frac{w \times d}{W} \text{ metres}$$

Where: w is the mass of the weight shifted,

d is the distance through which it is shifted and W is the ship's displacement.

The centre of gravity of the body will always move parallel to the shift of the

centre of gravity of any weight moved within the body. And will be proportional to the shifting length according to the formula.



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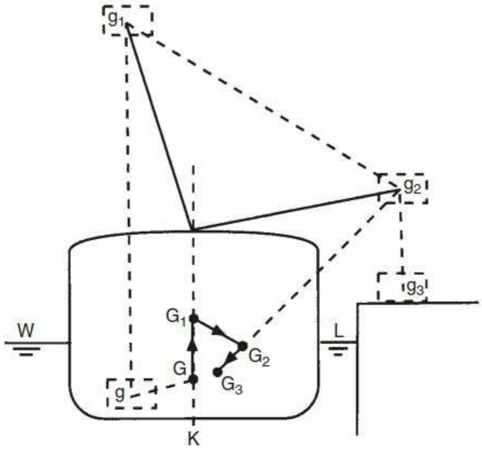
Potential Problems during Cargo Operations c't'd

- **3. Suspended weights**



Potential Problems during Cargo Operations c't'd

- **4. Liquid weights ie. Effect of free surfaces on stability**

When the ship heels, as shown in on right, the **liquid flows** to the low side of the tank such that its centre of gravity shifts from g to g1. This will cause the ship's centre of gravity to shift from G to G1, parallel to gg1.

This indicates that the effect of the free surface is to reduce the effective metacentric height from GM to GvM.

GGv is therefore the virtual loss of GM due to the free surface. Any loss in GM is a loss in stability.

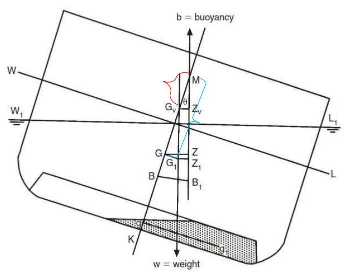
If free surface be created in a ship with a small initial metacentric height, the **virtual loss of GM due to the free surface may result in a negative metacentric height.**

This would cause the ship to take up an angle of loll which may be dangerous and in any case is undesirable.

This should be borne in mind when considering whether or not to run water ballast into tanks to correct an angle of loll, or to increase the GM.

Until the tank is full there will be a virtual loss of GM due to the free surface effect of the liquid.

It should also be noted that **even though the distance GG1 is fairly small it produces a relatively large virtual loss in GM (GGv).**



Slajd 9

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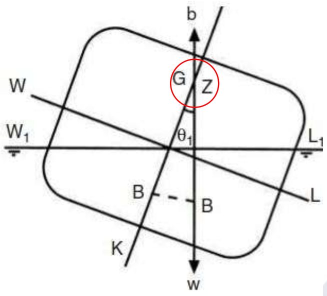
Potential Problems during Cargo Operations c’t’d

5. Negative GM. Angle of Loll

If the centre of buoyancy (B) moves out to a position G^ !
vertically under G, the capsizing moment will have disappeared as shown in figure right. The angle of heel at which this occurs is called the angle of loll. It will be noticed that at the angle of loll, the GZ is zero.
G remains on the centre line.
If the ship is heeled beyond the angle of loll from the centre of buoyancy will move out still further to the low side and there will be a moment to return her to the angle of Loll.
From this it can be seen that the ship will oscillate about the angle of loll instead of about the vertical. If the centre of buoyancy (B) does not move out far enough to get vertically under G, the ship will capsize. The angle of Loll will be to port or starboard and back to port depending on external forces such as wind and waves. One minute it may flop over to 3º PS and then suddenly flop over to 3º SB.
The danger that G will rise above M creates a situation of unstable equilibrium.



Potential Problems during Cargo Operations c’t’d

Correcting an angle of loll

If a ship takes up an angle of loll due to a very small negative GM it should be corrected as soon as possible. GM may be, for example 0.05 to 0.10 m, well below the DfT minimum stipulation of 0.15 m.

First make sure that the heel is due to a negative GM and not due to uneven distribution of the weights on board.

For example:, when bunkers are burned from one side of a divided double bottom tank it will obviously cause G to move to G1, away from the centre of gravity of the burned bunkers, and will result in the ship listing as shown.

On Container Cargo

The development of containerisation was a giant step forward in carrying general cargo by sea.

At the time, it was correctly predicted that unit costs would fall, and cargo damage would become a thing of the past.

Ship classification

The ship classification process ensures that the ship’s hull, hatch covers, lashing bridges, cell guides and fixed fittings have enough strength. Although a classification society will assess the adequacy of loose fittings and assign a class notation, this examination is additional to the mandatory ship classification process.

Multi-purpose ships may carry containers and general cargo. These ships can be cellular container ships with a stiffened tank top with the ability to ‘stopper’ (block) cell guides.

Ship behaviour

The container ship operator needs to know the container stacks' design roll angle used to determine the safety of the container stacks. Exceeding this roll angle will significantly increase the risk of stack failure and loss of containers. The container stacks' design roll angle will vary for the GM of the vessel as well as for route and season specific loading.

Alteration of the vessel's course and speed to keep the vessel's roll motion below the container stacks' design roll angle is important to ensure safe operation. There are many load components arising from a ship's motion.

Ship behaviour c't'd

Remember that during ship rolling, forces on container corner posts can be up to three times greater than the upright compression force.

Weather route to avoid the worst of the meteorological systems or areas where high seas in winter are common. Check with the loading computer or software provided. If navigating in bad weather, reduce speed, avoid beam seas and proceed with caution until the storm has passed.

Be aware of the phenomenon of parametric rolling and how changes in speed and/or course can separate pitching and rolling frequencies.

Parametric rolling

The term parametric roll is used to describe the phenomenon of large, unstable rolling, which can suddenly occur in head or stern quartering seas.

Due to its violent nature and the very large accelerations associated with the onset of parametric rolling, there is widespread concern for the safety of container ships.

Possible consequences include loss of containers,machinery failure, structural damage and even capsize.

Parametric roll is a threshold phenomenon. This means that a combination of environmental, operational and design parameters need to exist before it is encountered. These are:

Parametric rolling c't'd

• ship sailing with a small heading angle to the predominant wave direction (head or stern quartering sea)
• the wavelength of the predominant swell is comparable to the ship's length
• wave height is large
• ship's roll-damping characteristic is low

Parametric rolling c't'd

If resonance occurs between the wave encounter period and the natural, or twice natural, roll period of the ship, then parametric roll motion can be experienced.

Under parametric roll conditions, large roll angles can be experienced within a short period of time limiting the amount of preventative action the master can take.

As such, if there are parametric avoidance tools to assist the master, these should be used to support the onboard decision-making process.

Large roll motion of the vessel is the main cause of container loss.

Consequences of a parametric roll

Parametric roll can have dire consequences for container securing and for operation of machinery.

It is an extreme condition for container securing since it combines the effect of large roll and pitch amplitudes.

This scenario imposes significant loads on container securing systems.

If the container securing system considers such extreme motions, there would be a significant reduction in the number of containers that could be carried on deck.

So good seamanship is essential to avoid parametric rolling as much as possible via timely course or ship speed alterations.

The extreme roll angles reached during a parametric roll usually exceed those adopted during machinery design. Indeed, it would be very difficult to bench test a large marine diesel engine at 40-degree angles.

Possible consequences on machinery operation of the ship heeling to these very large angles include loss of cooling water suction, exposure of lubricating oil sumps and, for resiliently mounted engines, problems with the connection of services and hence shutdown of the main engine

Consequences of a parametric roll

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The following points should be borne in mind:

• Parametric roll is a relatively rare phenomenon, occurring in head or following seas, which is characterised by rapidly developed, large, unstable ship rolling.

• Risk control options exist in both design and operation of container ships that can effectively reduce the likelihood of a parametric roll occurring.

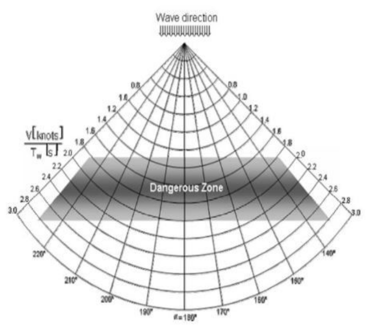
• Reducing the likelihood of its occurrence is considered a more effective approach than mitigating the consequences.

• Masters should be aware that when conditions for parametric rolling exist, i.e. head/stern seas with wave length similar to the ship's length, the action of putting the ship's head to the sea and reducing speed could make rolling worse. Alternative action to ease the ship's motion will be necessary, depending upon the prevailing weather.

• The North Pacific in winter is especially prone to these conditions.

Detecting inducing factors of PRM

• PRM occurs when the following factors accumulate:
 1. Wave direction (Head, bow, following or quartering sea)
 2. Wave length 0.5-1.0 x Vessel's length
 3. Changes in stability when waves (crest and trough) affect the vessel due to change to water plane and buoyancy available to vessel
 4. Vessel's speed (corresponding to the encounter period TE of vessel)



Parametric rolling will not occur on ships with a high GM – False.

The large bow flare and wide transom increase the effect.

The phenomenon occurs because of changes in the waterplane area, which can cause large changes in GM as waves pass. A large initial GM will provide large righting levers that can lead to violent rolling.

Recommended precautions against PRM

- Include Parametric Rolling Motion as part of the recommended list of STCW simulation training
- Adapt ship-specific guidelines using direct stability assessment.
- Integrate sea-state monitoring to onboard systems to assist mariners with identifying inducing factors of PRM sea-state
- In the future possibly include sea state monitoring system in the SOLAS mandatory list of equipment integrated with other ship automation equipment

- Mariners should avoid situations where:
  - Encounter period (TE) is close to one or half of ship roll period (TR)
  Or:
  - TE=TR or TE=1/2TR
  - TE can be found inputting vessel speed (kn), wave period(s), and encounter angle (α) into the diagram above(IMO, 2007)

How to Avoid/Mitigate PRM

- Keep a good look out for sea-state
- Adjust vessel's speed and heading accordingly
- Keep in mind stability of vessel (GM), vessel should not be too tender nor too stiff

Mitigate PRM

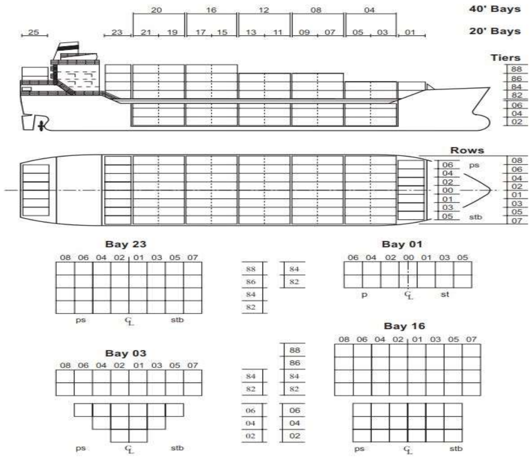
- <u>Crew must remain calm</u>
- Change the vessel's heading and adjust speed to bring vessel out of the dangerous zone of TE=TR or TE=1/2TR
- Deploy roll dampening measures where available

Cargo Securing Manual/Cargo Operations

A classification society will approve a ship for the carriage of containers.

Regulations stipulate that the ship must carry a Cargo Securing Manual. This manual will contain instructions as to how cargo should be secured in accordance with class criteria and a specified metacentric height (GM). For the approval of the arrangements in the manual, it is still expected of the master to apply good seamanship in order to mitigate excessive ship motions to reduce forces acting on the cargo stowage arrangements.

Container Loading Planning/Control



Container Stowage Planning Tips:

<u>There is proposal for common check list items in regard of proper Container Stowage Planning:</u>

- Is cargo information, including Baplie files, received before arrival to ensure that planning takes place in advance of loading?
- Are the positions for dangerous goods and refrigerated containers properly planned?
- Does the stowage of hi-cube, out of gauge and non-standard length containers meet with the requirements of ship's cargo securing manual (CSM) and on-board computer software?
- Is the stack and tier weight distribution within the limits set out in the cargo securing manual (CSM) and onboard computer software?
- Have the ballast, stability and bending moments been computed for the entire voyage?
- Have central and terminal planners been made aware of any changes which are needed or problems noted?

Container Stowage Planning c’n’t’d

- Is on-board computer software set up correctly? Are all of the alarm parameters correctly set?
- Is the lashing checklist completed satisfactorily and lashing forces checked?
- Has the final stability check been completed?
- Is the officer on watch aware of any changes to deck loading plans?
- Are the vessel draughts as expected?
- Has a final check been carried out of all container lashings and hatch covers?

Potential Problems with Container Stowage

- *Consider the stowage of twist-lock bins on deck. Their location and weight has to be included in the on-board software calculation to ensure that stowage of containers and the lashing forces are satisfactory*
- Is the verified gross mass (VGM) of all containers present and correct?
- Are there any containers which have been incorrectly stowed?
- Is the final stowage plan updated?

Have all container lashings been applied correctly according to the cargo securing manual (CSM) requirements?

Remarks on Timber cargo Stowage

Similarly to container Cargoes, some specific faeatures of Timber deck cargo may have an influnece on Stability of the ship during sea voyage.

There are most important tips on the shipping for these kind of loads as per “Code of Safe Practice for Ships carrying Timber Deck Cargoes”, 1991, chapter 2.1-6.4.

Remarks on Timber cargo Stowage

- The ship should be supplied with comprehensive stability information which takes into account timber deck cargo. Such information should enable the master, rapidly and simply, to obtain accurate guidance as to the stability of the ship under varying conditions of service.

Comprehensive rolling period tables or diagrams have proved to be a very useful aid in verifying the actual stability conditions.

- The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, should be positive and to a standard acceptable to the Administration. It should be calculated having regard to:

the increased weight of the timber deck cargo due to:

absorption of water in dried or seasoned timber, and

ice accretion, if applicable;

consumables;

the free surface effect of liquid in tanks; and

the weight of water trapped in broken spaces within the timber deck cargo and especially logs.

Remarks on Timber cargo Stowage

The master should:

- cease all loading operations if a list develops for which there is no satisfactory explanation and it would be imprudent to continue loading;
- before proceeding to sea, ensure that:
  - the ship is upright;
  - the ship has an adequate metacentric height in both departure and arrival conditions;
  - the ship meets the required stability criteria.
- Ships carrying timber deck cargoes should operate, as far as possible, with a safe margin of stability and with a metacentric height which is consistent with safety requirements but such metacentric height should not be allowed to fall below the recommended minimum.

However, excessive initial stability should be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings. Operational experience indicates that **metacentric height should preferably not exceed 3%** of the **breadth** in order to prevent excessive accelerations in rolling provided that the relevant stability criteria are satisfied.

This recommendation may not apply to all ships and the master should take into consideration the stability information obtained from the ship's stability manual.

Remarks on Timber cargo Stowage

If a list occurs

that is not caused by normal use of consumables (water and fuel), such a list can probably be attributed to one of three causes, or possibly a combination of same.

Cargo shift

A major shift of deck cargo will obviously be immediately apparent.
Deck cargo may however have shifted imperceptibly or there may have been a shift of cargo below decks.
An immediate examination should determine whether or not cargo has shifted and if this is the case the master will have several remedies available to him depending upon the exact circumstances.

The ballasting and transferring of ballast or fuel to reduce or correct a list caused by a shifted cargo should, however, be carefully considered since this action would, in all probability, result in a far greater list if the cargo should subsequently shift to the other side.

Remarks on Timber cargo Stowage

Angle of Roll

If the rolling of the ship prior to the detection of the list has been exceptionally slow and the ship has returned to the upright position in a sluggish manner, this will indicate that the ship has little or no metacentric height remaining.

The list is therefore due to the ship lolling to one side and having no righting arm to return it to the upright position.

This situation may be rectified by either adding weight to the low part of the ship (ballasting double bottom tanks) or removing weight from the high part (deck cargo).

GDOWN!

Of the two options, ballasting is usually preferable and if empty divided double bottom space is available, **the tank on the lower side should be ballasted first in order to immediately provide additional metacentric height**. After which the tank on the high side should also be ballasted.

However, special care should be taken in ballasting and deballasting to rectify the situation since this may cause a far greater list to the other side.

Processing for Draft Change

Most of typical ships may be „trimmed” towards DeadweIght change to fit for Operator’s specific needs.

When Ship is changing the maximum allowable draught assesment shall be made in following areas:

- Structural Strength
- Stability (intact and damage stability – when applicable)
- Statutory (Load Lines Convention)

Processing for Draft Change c't'd

- Changing draft shall be led under the supervision of Class Society.

Class will establish requirements to be fulfilled for compliance with the Statutory and Class Rules.

Moreover, in some cases - Class may issue some additional recommendations depending on the type of the vessel, exploitation etc.

Polish Register of Shipping is pretty well experienced in Deadweight change procedure.

Processing for Draft Change c't'd

There are some recommendations to be listed hereunder to follow when

The common vessel is expected to change the draft (deadweight)

- New Stability Document that refers to new parameters of the vessel is to be approved for compliance with PRS or IMO requirements
- Girder and local structural strength is to be confirmed by Class on the basis of structural analysis presented by the Orderer.
- In case when Polish Register of Shipping is an RO for the vessel – new Freeboard Calculations according to the LL Convention are to be approved.

Processing for Draft Change c’t’d

Consequently, the following documentation is to be send for information/ approval (for PRS classified ships)

- General Plan
- Capacity Plan
- Ships Profile
- Main Transverse
- Shell expansion
- Intact (Damage) Stability (existing onboard)
- Loading Manual (existing onboard)
- Local and girder strength analysis (for new draft)

Processing for Draft Change c’t’d

- Freeboard Plan – *when new LLC is requested*
- Freeboard Calculations (for new draft) - *when new LLC is requested*
- Body Lines

Most of data above are available in archive when ship is Registered by PRS, but in depends on case.

All Existing documents frm above list are still valid for the subject vessel. When some restrictions apppears ie: container stowage on deck (for new draft), No Ice Class etc. – these are outlined in remarks in approved documents or (and) as permanent class conditions.

References/Bibliography

1/ Ship Stability for Masters and Mates by *Captain D.R. Derrett ;*Sixth edition – Consolidated 2006

2/ MODEL MANUAL FOR GENERAL CARGO/CONTAINER VESSEL (by DNV 2004)

3/ PRS Rules

4/ PRS Publications

5/ Master’s Conatiner Securing Guide by Standard Club 2020

6/ Stowage and Lashing of Containers (GL rules for classification&technology)

7/ Code of Safe Practice for Ships Carrying Timber Deck Cargoes

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FOR YOUR ATTENTION

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