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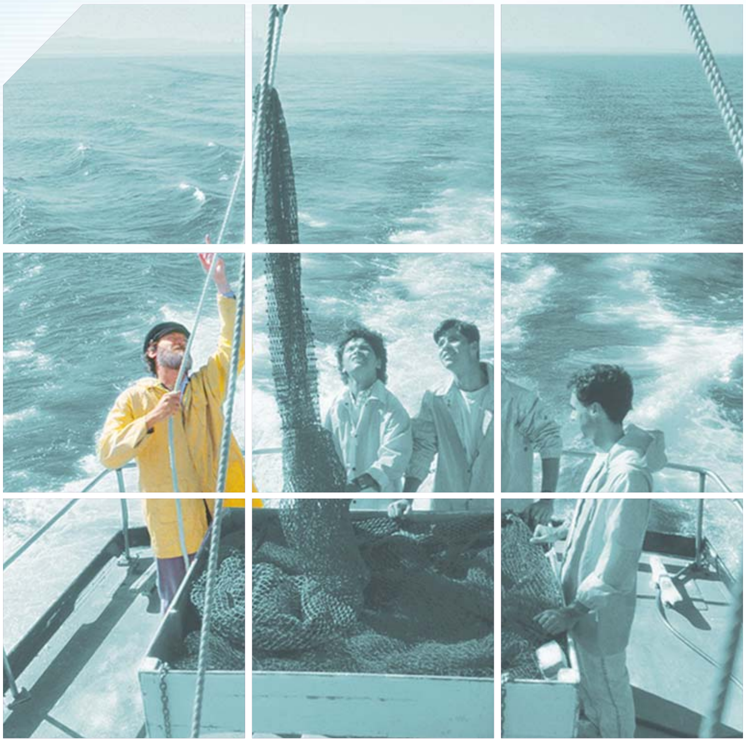

Learner's Guide

STABILITY A

Coxswain Level
Master 5 Level

Government of Western Australia

www.westone.wa.gov.au

MARITIME LEARNING RESOURCE

STABILITY A

COXSWAIN LEVEL

MASTER 5 LEVEL

LEARNER'S GUIDE

Training Sector Services
Telephone: 08 6212 9789
Email: sectorcapability.ip@dtwd.wa.gov.au
Website: www.dtwd.wa.gov.au

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WestOne Services

Prospect Place West Perth WA 6005
Tel: (08) 9229 5252 Fax: (08) 9229 5292
E-mail: sales@westone.wa.gov.au
Website: www.westone.wa.gov.au

INTRODUCTION TO STABILITY A AND STABILITY B

This Maritime resource contains all the requirements for Stability at the Coxswain, Master 5 and Master 4 levels.

It is accordingly divided into 3 sections.

Stability A contains the material for Coxswain and Master 5. *Stability B* is for Master 4 students and has been printed separately.

Within each section there are activities for you to work through and most contain self-test questions for you to check that you have understood what you have just been studying.

At the end of several Sections, in the Master 4, are Mastery Assignments. These are longer and will take some time to work through. The worked answers are given for these. As the final assessment will contain calculations, it is important that they are practised.

TEXTS

For Coxswain and Master 5:

- the booklet entitled 'Fishing Vessel Stability' (reproduced by kind permission from the National Fishing Industry Training Council)
- Simplified Stability Information for MV Twosuch, WestOne Publication (reproduced)

For Master 4:

- D.R. Derrett, Ship Stability for Masters and Mates, 5th edition, Stanford Maritime, London
- Simplified Stability Information for MV Twosuch, WestOne Publication (reproduced)
- Simplified Stability Information for MV Onesuch, WestOne Publication (reproduced)

STABILITY

COXSWAIN

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SECTION 1

VESSEL STABILITY

A simple understanding of what makes a boat stable is critical to the safe navigation of any craft – in small craft this is more so. The tolerances are much smaller and small movements of weights can have BIG effects as we may have found out in small tenders when a passenger has stepped on the gunwale.

Stability is calculated for a vessel in ordinary trim and without a list. Vessels with an excessive trim will have considerably reduced stability. A list always reduces stability.

The first Section is an introduction to the subject and so needs to be studied carefully so that the basic terms are understood.

This first Section covers two of the training package requirements.

Learning Outcomes:

- Describe the principles of stability and trim in a small vessel and the disposition of passengers and cargo required to maintain stability and trim within safe limits.
- Explain the effects of loss of watertight integrity.

Unit 1.1 Basic Principles of Stability

The question is, "What is stability?" What does it mean when we say a vessel is stable? How often have we heard statements like:

"Great little tender, very stable"

"Most stable boat I have been on"

"She is so stable you can sit down for a meal in a force 7"

"Really dry boat"

"Doesn't roll much"

"Lots of freeboard, really stable"

"Has a good centre of gravity"

"Really stable, you would never get sick on her"
(Are seasickness and stability related!!)

What do all these statements tell us? That there are many ideas about what stability is. So we will use a very simple definition:

Stability is the ability of a vessel to return to her initial position.

A vessel rolling in a seaway rolls around her initial position (usually upright) and in calm water returns to that position. A yacht sailing along at some angle will roll around that angle as the wind gusts. When the wind stops gusting, she will return to her original angle.

In the transverse or athwartships direction, stability is more easily endangered and easier to understand than in the fore and aft or longitudinal direction.

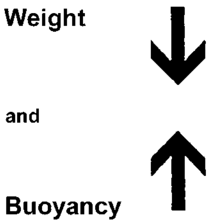
Unit 1.2 Forces Involved

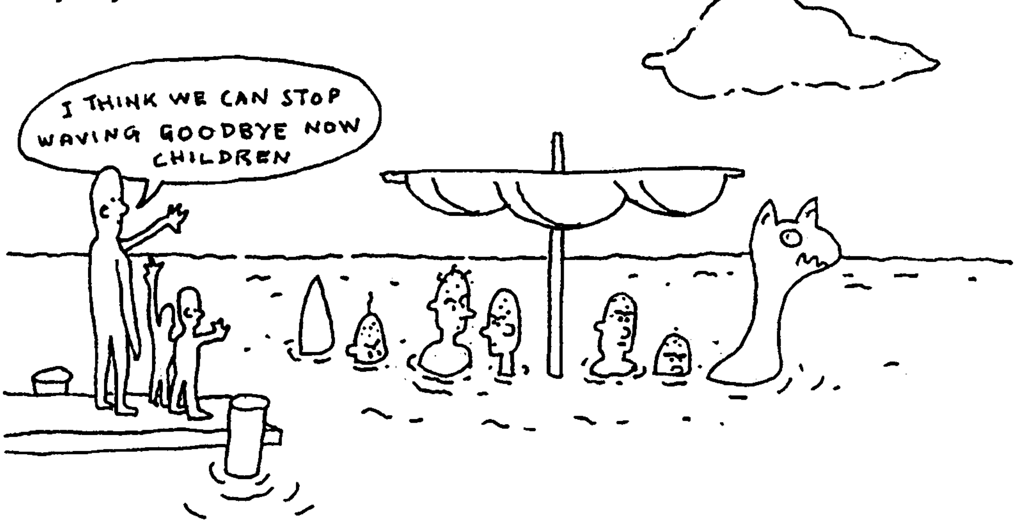
The most obvious thing about a boat is that it floats. The boat, using its own weight, pushes some water out of the way and creates a hole in the water in which it can sit. Lift the boat out, the water goes back.

When we lower the boat into the water it floats at the point where the weight of the boat pushing down is equal to the force of the water pushing up. So, when a boat is floating, there are two forces acting equally and in opposite directions.

Now the force acting down is obviously the weight of the boat and the force acting up is called buoyancy. When they are equal and opposite the boat floats.

This simple fact applies to every object floating. Weight acts vertically down ↓ and buoyancy acts vertically up ↑.





Stability is all about the interaction between these two forces. So, to understand stability properly, we need to clearly understand these two forces.

Q. What is the difference between a beachball and a dinghy?

A. The beachball will float upside down.

Unit 1.3 Centre of Gravity

If you have ever taken some of the uninitiated out in a small dinghy, you will know how important it is for them to sit in the centre to keep it upright.

What about vertically? What happens when they stand up?

Weight has moved up in the boat and it is now less stable and feels it!

We know this in practice. Let's have a look at the theory behind this.

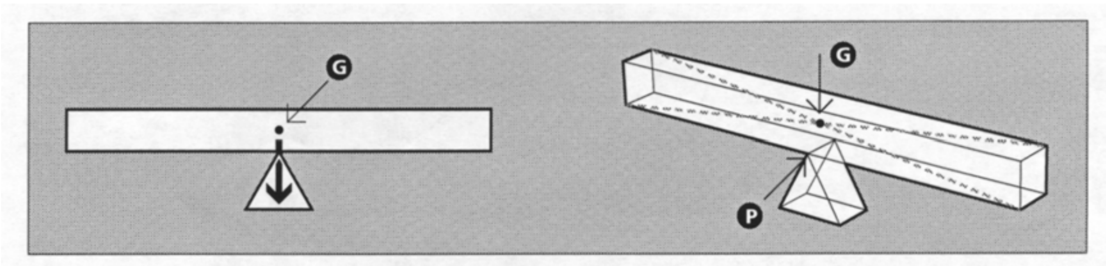


Fig 1.1

If we take a plank of wood – it has a point about which it balances. This point through which we could consider the weight is acting, vertically downward, is called the centre of gravity. The centre of gravity actually lies at the centre of the plank, the geometric centre, and the plank will rock around point P without falling off.

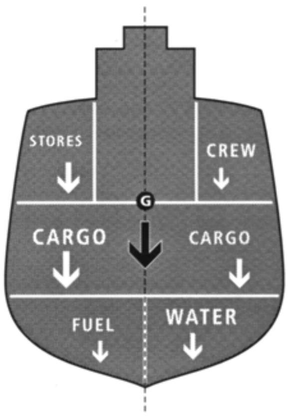
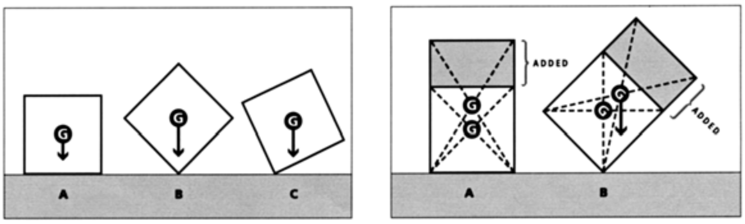


Fig. 1.2

The sum of the weights of everything in the vessel such as structure, stores, fuel, water, fish, and cargo is the vessel's weight and can be considered as one force acting downward through a single point, called the Centre of Gravity – G.

The centre of gravity stays in the same point independent of the vessel's motion.

Figure 1.3 shows how moving the centre of gravity upwards reduces stability (just like when the person stands up in the dinghy).



We can see that A is stable, B balanced and C is going to fall over.

If G is raised, A is still stable but B, at the same angle, is now unstable.

Fig. 1.3

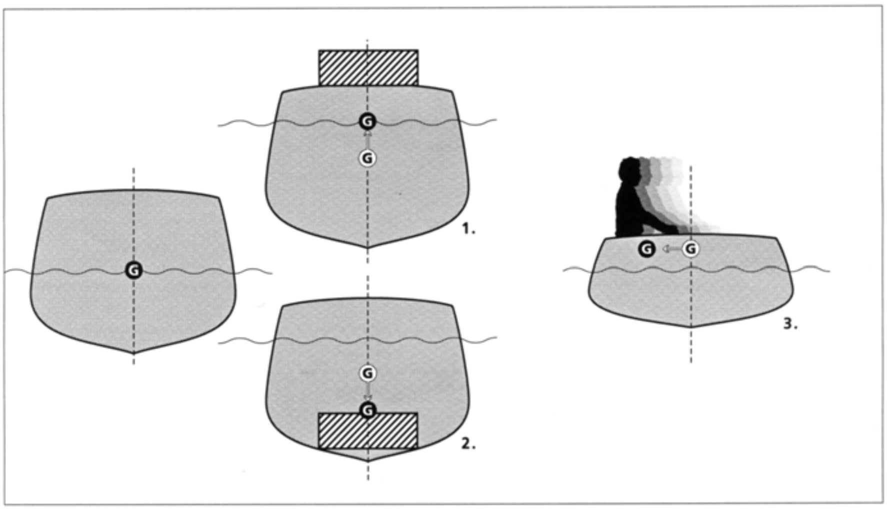


Fig. 1.4

Principle: when a weight is added, the centre of gravity moves towards the added weight.

In (1.) upwards, in (2.) downwards and, when the weight is discharged, it will move back to its original position; that is, away from the weight discharged.

There is a third situation …

If you were sitting in a dinghy, you and the dinghy combined would have a certain centre of gravity.

What happens to the centre of gravity if you move sideways?

The centre of gravity moves sideways; that is, parallel with your movement. **G** is no longer on the centre line and the dinghy has a *list*.

Unit 1.4 Where is the Centre of Gravity?

Of course boats are not like blocks of wood. Not only are they all different shapes and sizes, but will have weights in all sorts of different places.

So, where is the centre of gravity?

The answer to this is in two parts:

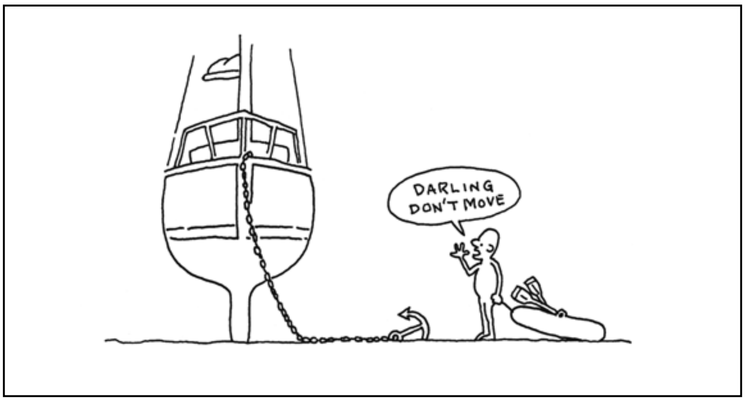
1. When the boat is brand new – fresh off the shelf, as it were – with no fuel, oil, water, stores, passengers, crew, etc, then it is in what is called the "light ship" condition. For this condition the designer (naval architect) has worked out where the centre of gravity will be.

2. You come along as the skipper and start putting things in (fuel, water, stores, etc) and where they go will determine where the centre of gravity will move to. For some things this is more or less fixed (fuel, water) and for others it is very much up to you – for example, how many passengers you have on board and more importantly where they are. For example if some, or all, of your passengers are on the flying bridge the centre of gravity will be higher than if they are all on the main deck.

In other words the final position of the centre of gravity is determined by you, the skipper.

To summarise so far:

1. Stability: the ability of a vessel to return to its initial position.
2. Centre of Gravity: the point through which a weight is said to act vertically downwards.
3. The centre of gravity will move towards a weight added.
4. The centre of gravity will move away from a weight discharged.
5. The centre of gravity will move parallel with a weight moved.
6. **Don't stand up in dinghies.**

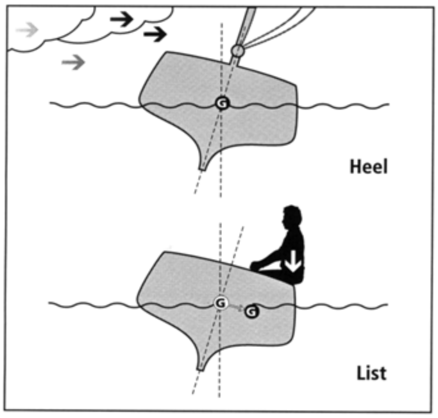


Unit 1.5 Terminology I

Just a few terms to note:

***Heel*:** When an external force acts on a boat it will incline to some angle. This is called the angle of heel (*remember yachts heel*) and G has not moved.

***List*:** When a weight is moved off the centre line the centre of gravity will also move and the vessel will now be inclined at some angle. This angle is called a list. (See Fig. 1.5.)

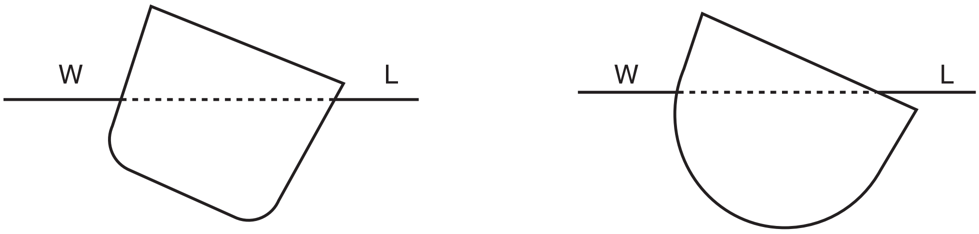


Heel: an inclination caused by *an external force*.

List: an inclination caused by *an off centre weight*.

Fig. 1.5

Generally the freeboard should be sufficient to prevent the decks becoming immersed as shown in the sketch below:



A vessel with low freeboard may dip her decks underwater when heeled, resulting in a loss of stability.

UNIT 1.6 Buoyancy

Now, what about buoyancy?

Let us go back to our block of wood, which is now floating.

We saw before that G is the point through which the weight was considered to act vertically downwards and that for the block to float there must be another force, buoyancy, acting vertically upwards through a point which must be in line with G acting vertically downwards.

This point, the *centre of buoyancy* B, is at the centre of the underwater volume. For the block of wood, this is easily found by drawing diagonals and getting the centre of the underwater volume. In ship shape boats, this is worked out by the naval architect.

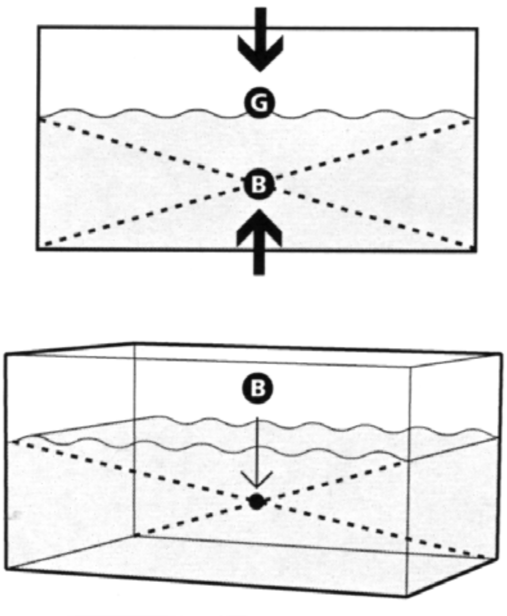


Fig. 1.6

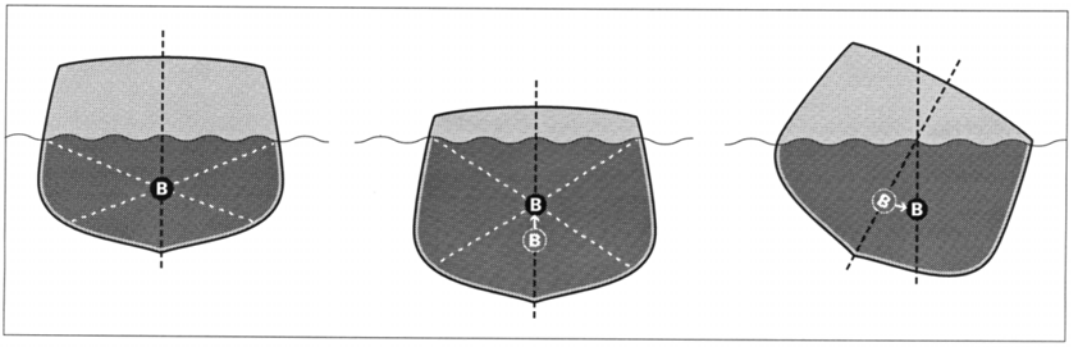


Fig. 1.7

The Centre of Buoyancy B is the point through which the total force of buoyancy acts vertically upwards. For a vessel at rest it acts in the same vertical line as G but in the opposite direction.

As the boat rolls in a swell so the underwater section changes and the centre of buoyancy moves. (See Fig. 1.7.)

The force of buoyancy

What happens when a yacht is heeled due to a wind?

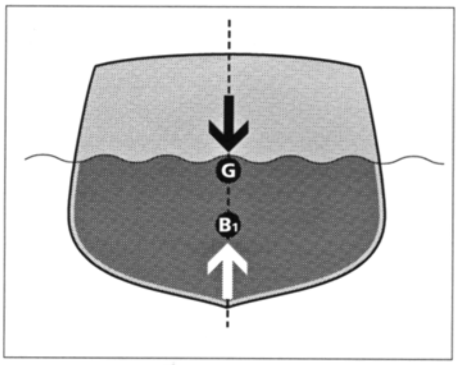


Fig. 1.8

The yacht is inclined to some angle and, provided the strength of the wind does not change, it will stay at that angle.

So if there is some force trying to heel the boat, then there must be an equal and opposite force holding the boat at that angle and preventing it from heeling right over.

In Fig. 1.8 we can see G and B_1 are in the same vertical line.

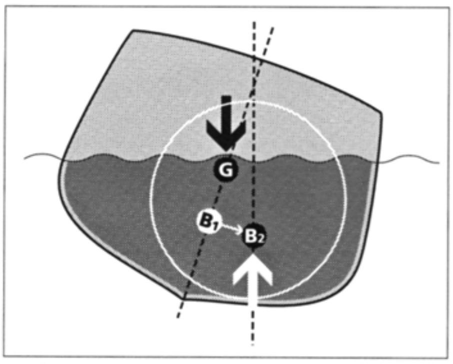


Fig. 1.9

In Fig. 1.9 the centre of gravity has not moved as there has been no change or movement of the weights on board.

What about B_1?

The underwater shape of the vessel has changed so the centre of buoyancy now moves to the new centre B_2.

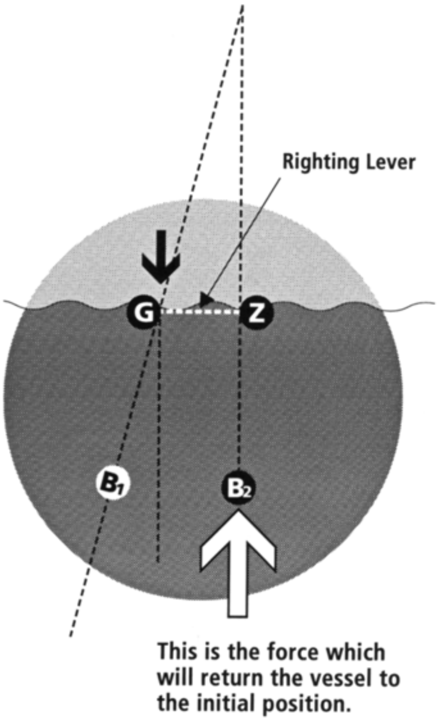


Fig. 1.10

So in a vessel which is heeled, it is the buoyancy acting through the centre of buoyancy which tries to bring the vessel back to the initial position. This, of course, applies to every floating object from a dinghy to a supertanker.

The final point to note from Fig. 1.9 is the horizontal distance between G acting down and B acting up. This creates a lever (GZ) for the buoyancy to push up.

In the heeled position the force of buoyancy acting upwards is not in line with the force of gravity acting down and creates a lever called the righting lever. (Fig. 1.10)

Heel and list in combination

Now if some weight W had moved on board so that G_1 was now at G_2, (that is, vessel has a list) whilst the buoyancy at B_2 is the same, the length of the lever has been reduced and consequently the ability of the buoyancy to right the vessel is reduced.

What does this mean out on the water?

Simply, a boat with a list (G off the centre line) is less stable – remember the definition – than one which is upright.

So to increase stability the list must be reduced.

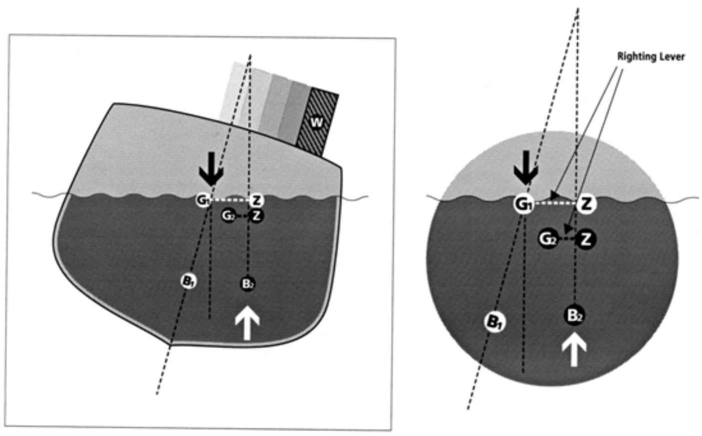


Fig. 1.11

Unit 1.7 Terminology 2

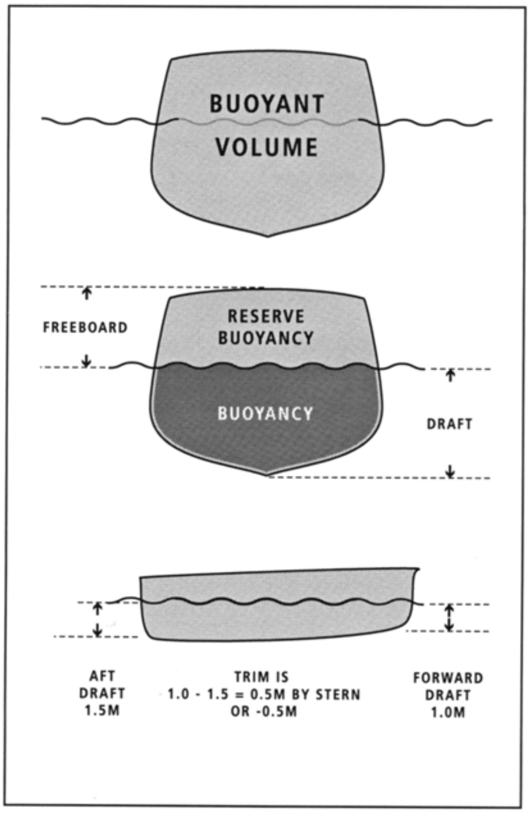


Fig. 1.12

Draft: The height between the keel and the waterline.

Trim: The difference between the fore and aft draft. Either called *positive* when the forward draft is greater than the after draft or *negative* when the after draft is greater than the forward draft.

Freeboard: The distance from the waterline to the lowest watertight deck.

The buoyant volume is the volume of the watertight part of the hull. The part below the waterline is called buoyancy and the part above is called reserve buoyancy. When additional weight is put into the vessel, reserve buoyancy is used up. The reserve buoyancy largely determines the ship's stability and the freeboard gives an approximate measure of the reserve buoyancy.

UNIT 1.8 Free Surface

There is an effect called *free surface* which creates a lot of problems on vessels.

Get a washing up bowl and put in a litre of milk (still in the carton), pick up the bowl...

Now put a litre of water in the bowl and pick it up.

How does it feel?

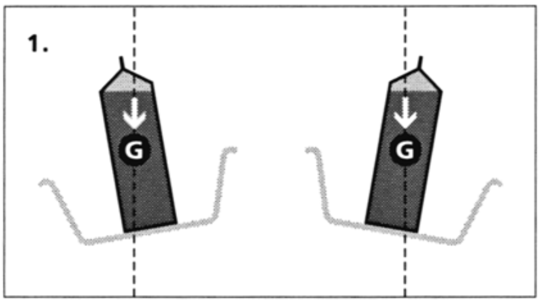


Fig. 1.13

Quite difficult to keep it horizontal...

Why?

When the liquid cannot move as shown in Fig. 1.13, when the bowl moves the carton of milk makes a whole unit with the bowl and the centre of gravity does not move.

When the liquid is free to move [Fig. 1.14(a) and (b)] we have a double problem:

- The centre of gravity is free to move independently of the movement of the bowl.
- The moving liquid carries its own momentum - so it does not stop moving when the bowl stops moving.
- The combined effect of these two will cause G to rise making GZ shorter and reducing stability.

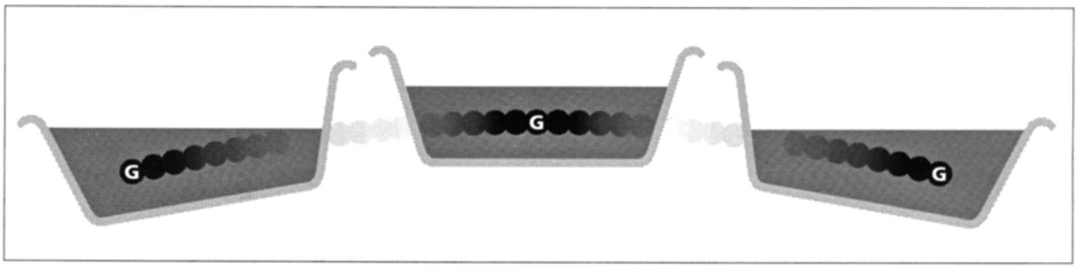


Fig. 1.14(a)

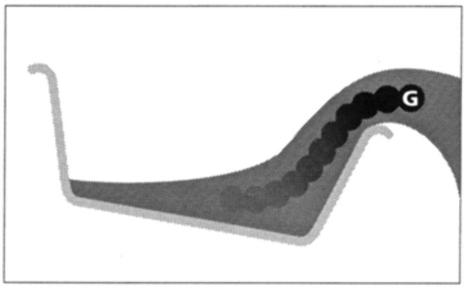


Fig. 1.14(b)

The effect of free surface

What does this mean on a boat?

If the fuel or water tanks are partially full then there will be a reduction in GZ. Generally this will make very little difference to a boat's stability.

However, if the water is trapped on deck there will be a rise in G (G moves towards the weight added) with a reduction in GZ. The importance of keeping decks dry, for this reason, cannot be over-estimated. Large quantities of fish landed on deck will have a similar effect and need to be contained as soon as possible.

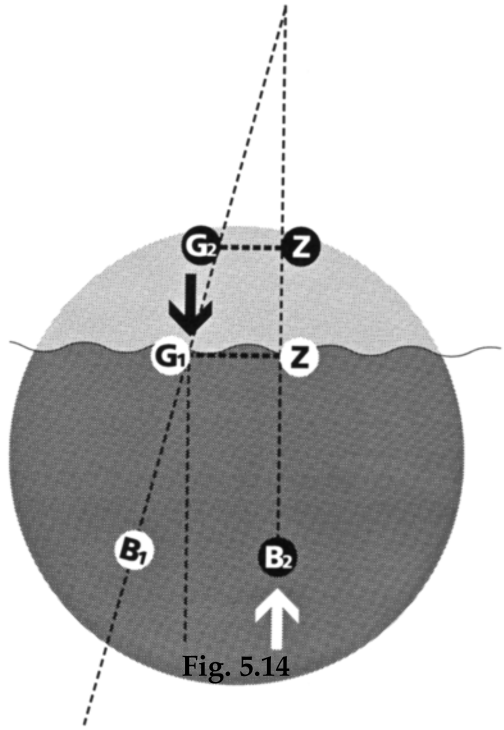
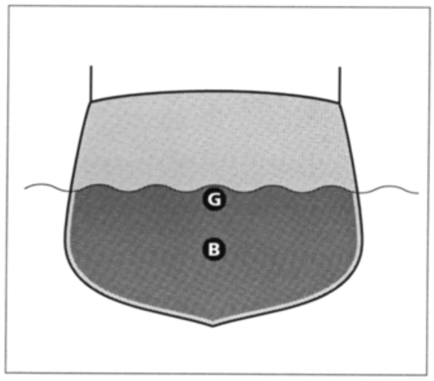
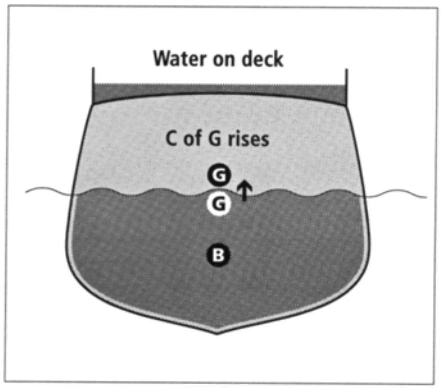


Fig. 5.14

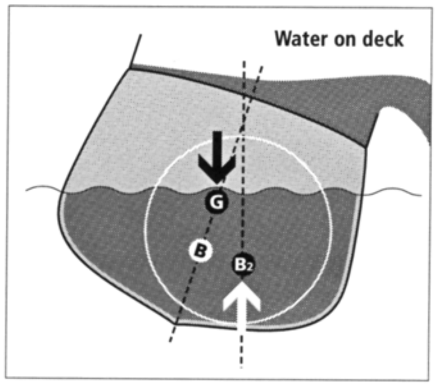
(a)



(b)



(c)



Free surface (either water on deck or a partly filled tank) will cause the centre - of gravity G to move off the centre when the vessel is heeled and effectively rise, thus reducing the GZ, making the vessel less stable.

Fig. 1.15

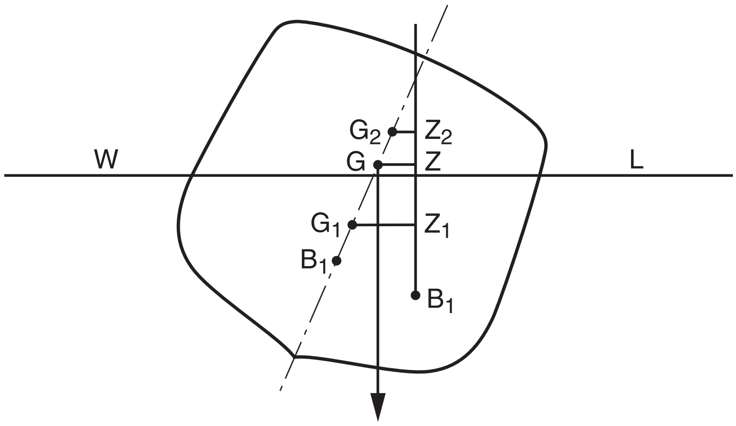


Fig. 1.16

We can see that as G becomes lower in the vessel the GZ increases G moves down to G1 and GZ increases to G1Z1 making the vessel more stable (able to return to the upright).

As weight moves higher GZ reduces to G2Z2 and the vessel becomes less stable.

This is why survey requirements control the number of passengers on upper decks. Any excess can lead to reduction in stability.

Underwater Shape

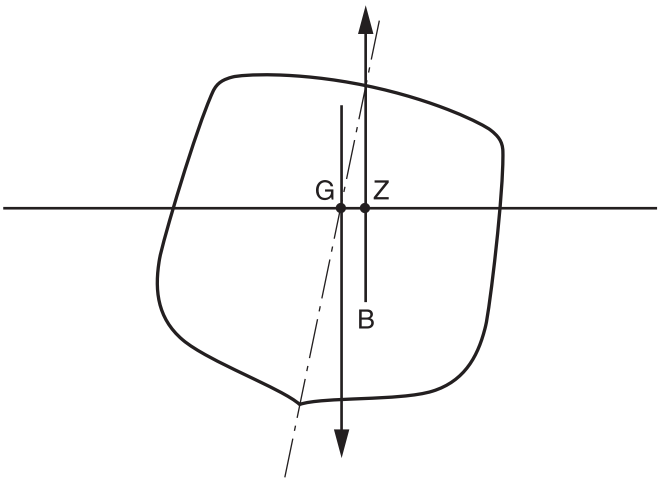


Fig. 1.17

We can see in the above that beam plays an important role in the stability of a vessel.

In Fig. 1.18, the vessel having the larger beam allows the centre of buoyancy to move out further when she is inclined. This causes an increase in the GZ, making the vessel more stable.

Note: As soon as the deck edge immersion is reached then B will not move out any further. This, in theory, will give the maximum GZ.

In practice, this is not so for various fairly complex reasons to do with the underwater shape.

Once deck edge immersion has been reached, if all watertight doors and openings are not shut down then it is possible for down flooding to take place. As the vessel is already inclined, more weight (water) will rapidly cause the vessel to capsize.

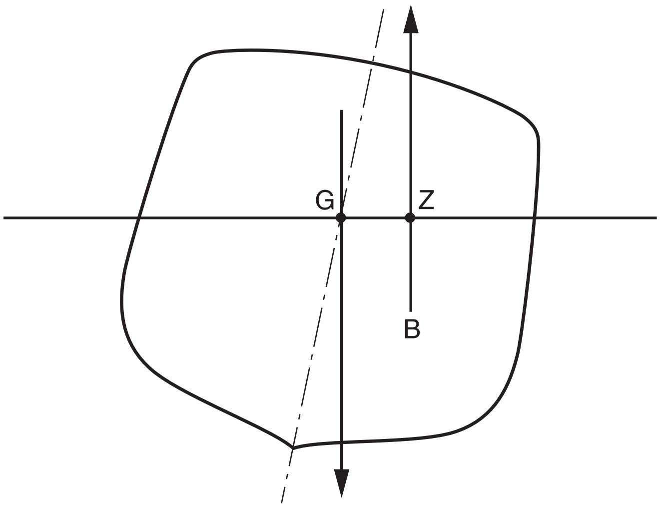


Fig. 1.18

Unit 1.9 Summary

1. Stability - ability of a vessel to return to its initial position.
2. Centre of Gravity - a point through which a weight is said to act vertically down.
3. The centre of gravity will move towards a weight added.
4. The centre of gravity will move away from a weight discharged.
5. The centre of gravity will move parallel with a weight moved internally.
6. Don't stand up in dinghys.
7. Heel - inclination caused by an external force.
8. List - inclination caused by an internal force.
9. Centre of buoyancy is at the centre of the underwater volume and is the point through which the force of buoyancy acts vertically upwards.
10. The underwater shape of the vessel changes as the vessel moves, so the centre of buoyancy continuously moves.
11. Righting Lever - when a vessel is heeled the horizontal separation between G (acting down) and B (acting up) is the righting lever, GZ. Generally, the lower the centre of gravity the larger the GZ will be.
12. A vessel with a list is less stable than a vessel which is upright.
13. Water trapped on deck (free surface) will reduce the vessel's stability. Always keep freeing ports clear.


Stability is not
an accident

.

Unit 1.11

Read and then study the booklet 'An Introduction to Fishing Vessel Stability' which is reproduced at the end of this section, as Appendix A, by kind permission of the National Fishing Industry Training Council.

Unit 1.12 In Conclusion

This section has introduced you to the principles of Vessel Stability.

What you need to do now is look at how you, the Coxswain, can control the stability of your vessel. Important concepts were discussed; they included, Beam, Centre of Buoyancy, Centre of Gravity, Freeboard, Free Surface Effect, and the righting lever GZ. Let's look at each and see which the Coxswain has direct control over.

- *Beam* is a design feature of the vessel; the Coxswain has *no control over Beam.*
- *Centre of Buoyancy* is controlled by the vessel shape. For any displacement (total weight of the vessel) the Centre of Buoyancy is fixed by that design; it doesn't change as you move those weights around. Therefore the Coxswain *does not control Centre of Buoyancy.*
- *Centre of Gravity* is decided by where weights are loaded. A Coxswain is responsible for this, and therefore *controls Centre of Gravity.*
- *Freeboard* is a design feature but is then affected by the total weight added. A Coxswain is responsible for this, and therefore *controls Freeboard.*
- *Free Surface Effect* is liquid that has space to move such as slack tanks and bilge water. The Coxswain is responsible for this, and therefore *controls Free Surface Effect.*
- *The righting lever, GZ,* is controlled by the Centre of Buoyancy and the Centre of Gravity. As noted, we do not control the Centre of Buoyancy but we do control the Centre of Gravity. Therefore, the Coxswain controls the GZ but only through control of the Centre of Gravity.

To summarise this, the Coxswain directly controls:

1. Centre of gravity
2. Freeboard, and
3. Free Surface Effect.

So what comes next is not very surprising!

As a Coxswain, whenever you think *stability* you should ask yourself three questions:

1. What effect does this have on the Centre of Gravity?
2. What effect does this have on Freeboard?
3. What effect does this have on Free Surface Effect?

Then review these questions:

- Lowering the Centre of Gravity or moving it back to the centreline is good. Raising it or moving it off centre is bad.
- Increasing the Freeboard is good, decreasing it is bad.
- Removing Free Surface Effect is good, introducing it is bad.

One of the best illustrations of this is water on deck. Think about how this affects stability. Write down your thoughts, and then compare your notes to the following:

1. Water on deck is weight added high, therefore the Centre of Gravity will move up towards the added weight. **Raising the Centre of Gravity - bad for stability.**
2. Water on deck is an added weight, increasing Draft therefore the Freeboard will be reduced. **Decreasing the freeboard - bad for stability.**
3. Water on deck is not contained, therefore it has Free Surface Effect. **Introducing Free Surface Effect - bad for stability.**

Water on deck is bad in all three cases, it is very bad for stability, thus the importance of your freeing ports (often called scuppers) to allow the water to drain quickly.

Another example:

A suction line for the engine cooling splits and you start taking water into the engine room bilge. Again, think about how this affects stability, write down your thoughts, and then compare your notes to the following:

1. Water in the bilge is weight added low, therefore the Centre of Gravity will move down towards the added weight. **Lowering the Centre of Gravity - good for stability.**
2. Water in the bilge is an added weight, increasing Draft therefore the Freeboard will be reduced. **Decreasing the freeboard - bad for stability.**
3. Water in the bilge is not contained, therefore it has Free Surface Effect. **Introducing Free Surface Effect - bad for stability.**

You may think that lowering the Centre of Gravity, in this case, should increase stability; it does but the benefit is more than outweighed by Free Surface Effect and the loss of Freeboard.

Free Surface Effect is a bit of a wild card in the stability pack. Its effect can be anywhere from good to devastating and it can go between the two extremes in seconds (as the liquid moves). Therefore we always consider it at its worst.

Remember that the extent of Free Surface Effect is controlled, not by the amount of liquid moving, but by the space that it has to move in. In the two examples above there is lots of room: from one side of the deck to the other and from one side of the engine room bilge to the other. You will notice that tanks built into boats are not normally very wide; this is to help control Free Surface Effect as a vessel will always have some slack (partially full) tanks.

Think: Stability

Check-your-progress Assignment 1

Question 1.

When a weight is added, the centre of gravity moves ……………….. the weight added.

Question 2.

When a weight in a boat is moved horizontally, the centre of gravity:

(a) moves up

(b) moves down

(c) moves horizontally

Question 3.

Which items are not part of the light ship condition?

(a) fuel

(b) engine

(c) stores

(d) crew

Question 4.

Don't ………….. …….. in dinghies.

Question 5.

Heel is caused by objects being moved on board.

T / F

Question 6.

List is produced by an external force – ie a sailing boat listing with the wind.

T / F

Question 7.

Centre of buoyancy is:

(a) at the centre of the waterplane area

(b) at the centre of the underwater volume

(c) the same as the centre of gravity

Question 8.
When a boat is inclined by an external force, it comes back to the upright because of the:

(a) centre of buoyancy acting up

(b) centre of gravity acting down

(c) small GZ

(d) low centre of gravity

The answer is:

(a) a and d

(b) a and c

(c) b and a

Question 9.

Trim is positive when the aft draft is greater than the forward draft.

T / F

Question 10.

A boat is heeled.

Draw a cross section showing the relative positions of B. G. GZ. B2

If the centre of gravity was lowered, show on your diagram what would happen to GZ.

Question 11.

Draw a cross section of 2 box-shaped barges, the one being wider than the other.

Show which one is more stable.

Question 12.

Your 11.5 metre fishing charter vessel is going offshore with 15 passengers.

As soon as she is clear of the land she starts to roll violently.

List 5 steps you would take to correct this if you assumed it was a stability problem.

NOW CHECK YOUR ANSWERS AGAINST THOSE PROVIDED ON THE FOLLOWING PAGES.

Check-your-progress Assignment Answers

Question 1.

When a weight is added, the centre of gravity moves **towards** the weight added.

Question 2.

When a weight in a boat is moved horizontally, the centre of gravity…

(a) moves up

(b) moves down

(c) moves horizontally

Question 3.

Which items are not part of the light ship condition?

a. fuel

b. engine

c. stores

d. crew

Question 4.

Don't **STAND UP** in dinghies.

Question 5.

Heel is caused by objects being moved on board.

T / **F**

Question 6.

List is produced by an external force – ie a sailing boat listing with the wind.

T / **F**

Question 7.

Centre of buoyancy is:

(a) at the centre of the waterplane area

(b) at the centre of the underwater volume

(c) the same as the centre of gravity

Question 8.

When a boat is inclined by an external force, it comes back to the upright because of the:

(a) centre of buoyancy acting up

(b) centre of gravity acting down

(c) a high centre of buoyancy

(d) low centre of gravity

The answer is

(a) a and d

(b) a and c

(c) <u>b and a</u>

Question 9.

Trim is positive when the aft draft is greater than the forward draft.

T **<u>/ F</u>**

Question 10.

A boat is heeled.

Draw a cross section showing the relative positions of B. G. GZ. B2

See Fig 1.10.

If the centre of gravity was lowered, show on your diagram what would happen to GZ.

See Fig 1.16.

Question 11.

Draw a cross section of 2 box-shaped barges, the one being wider than the other.

Show which one is more stable.

See Fig 1.17 and Fig 1.18.

Question 12.

Your 11.5 metre fishing charter vessel is going offshore with 15 passengers.

As soon as she is clear of the land she starts to roll violently.

List 5 steps you would take to correct this if you assumed it was a stability problem.

FILL UP ANY SLACK TANKS.

PUT WEIGHTS LOW IN THE VESSEL.

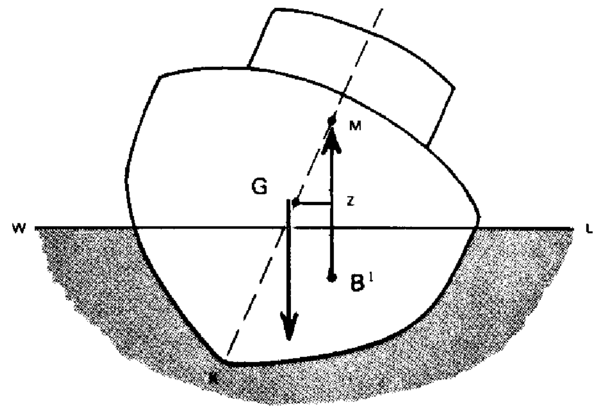
LOWER WEIGHTS HIGH UP IN THE VESSEL.

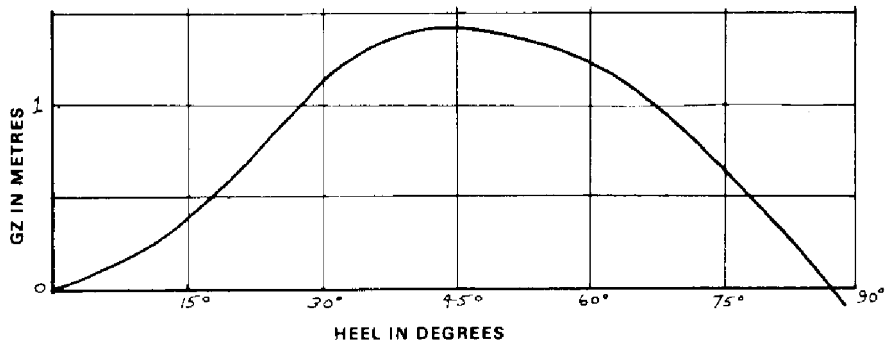
ALTER COURSE TO REDUCE EXCESSIVE ROLLING.

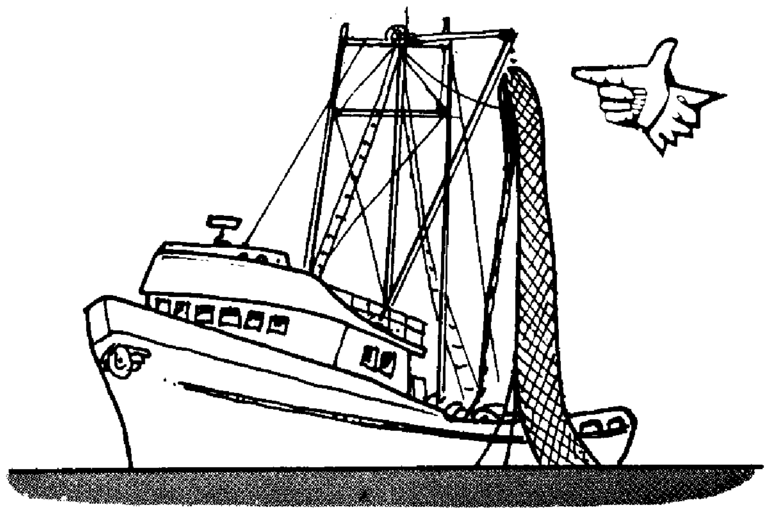
PUT PASSENGERS BELOW.

APPENDIX A

AN INTRODUCTION TO FISHING VESSEL STABILITY







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AN INTRODUCTION TO THE PRINCIPLES ASSOCIATED WITH VESSEL STABILITY THE FACTORS INFLUENCING STABILITY AND THE TERMINOLOGY USED

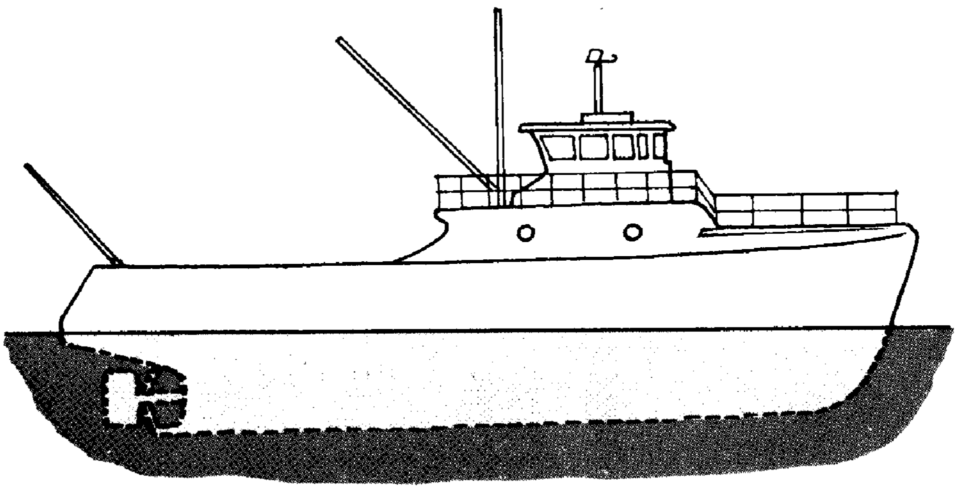
The term "stability" normally refers to the ability of a vessel to return to the upright position after being heeled by an external force. The following is a brief explanation relating to some of the influencing factors and terminology encountered when dealing with vessel stability.

This booklet is not intended to be a complete course of study in fishing vessel stability, but an introduction to it. Ship stability courses can be undertaken at the Australian Maritime College of Launceston, Tasmania and the TAFE College in each State.

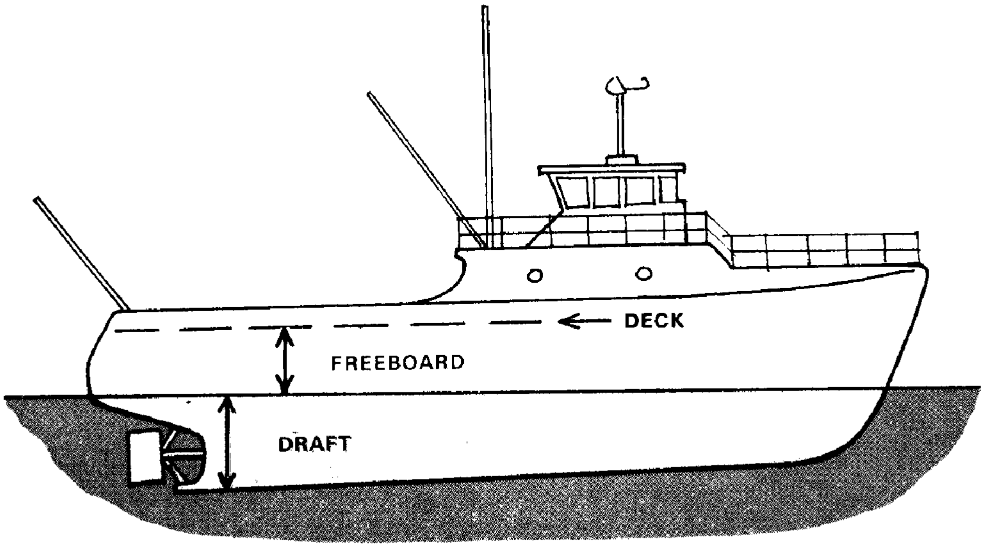
DISPLACEMENT

ARCHIMEDES PRINCIPLE

Every floating body displaces its own weight of the liquid in which it floats.



For a ship to float freely in water the weight of the ship must be equal to the weight of the volume of water it displaces.



DRAFT

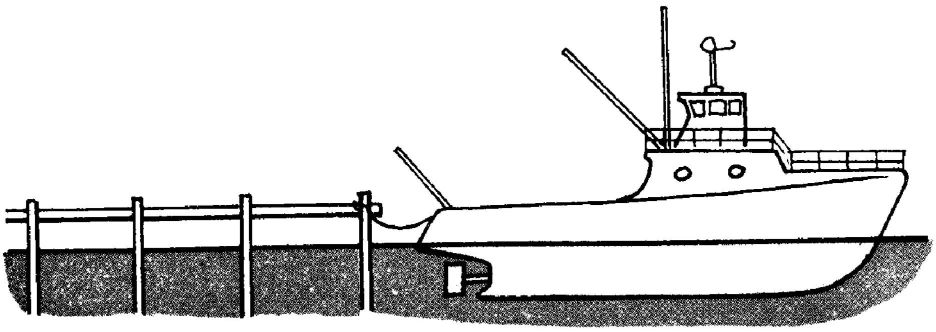
Draft relates to the depth of water required for a vessel to float freely and is measured vertically from the underneath side of the keel to the waterline.

FREEBOARD

The vertical distance from the waterline to the lowest point of the main deck.

TONNAGES

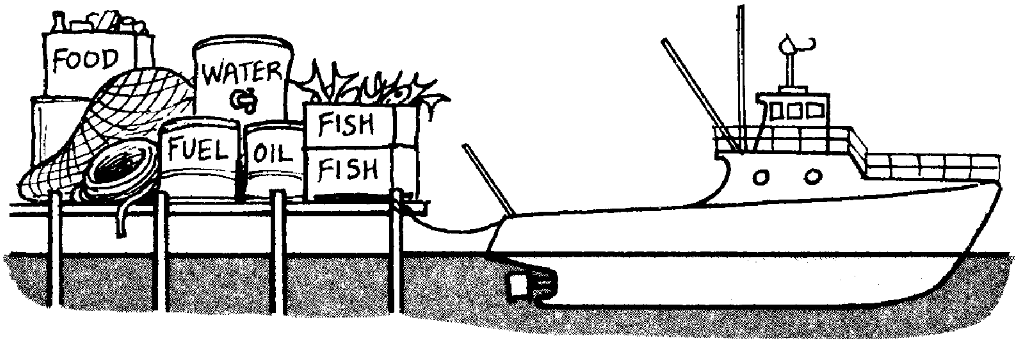
Gross or net tonnages are measurement of the volume of the vessel (1 ton = 100 cubic ft or 2.83 cubic metres).



LIGHTSHIP WEIGHT

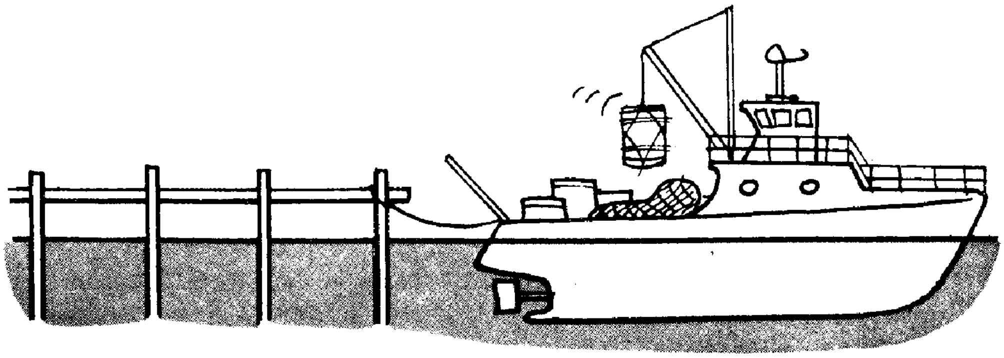
Actual weight of a vessel when empty.

2



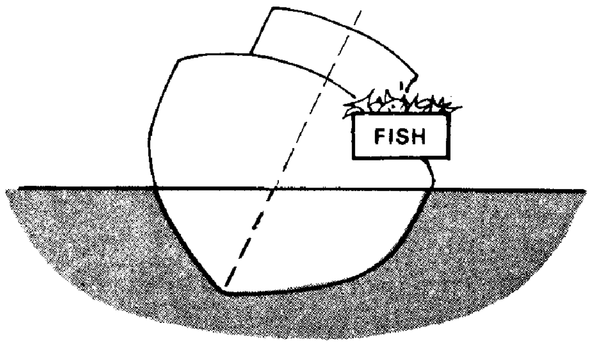
DEADWEIGHT

Deadweight is the actual amount of weight in tonnes that a vessel can carry when loaded to the maximum permissible draft. (Includes fuel, fresh water, gear, supplies, etc.)



LOAD DISPLACEMENT

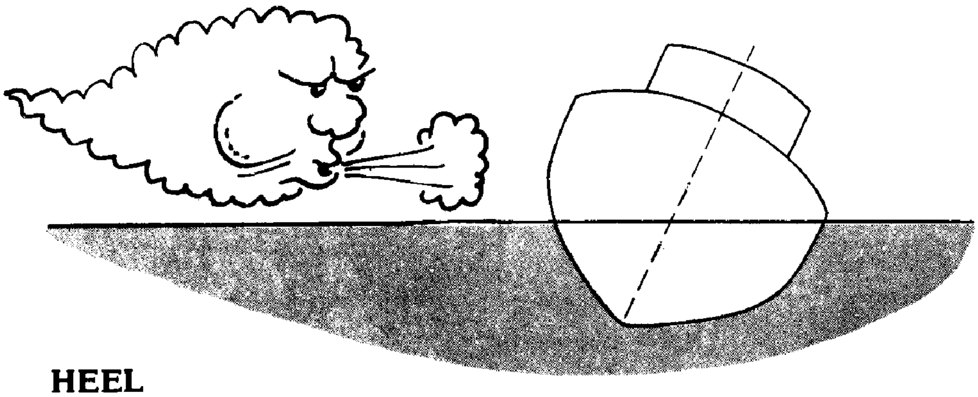
Lightship + Deadweight = Load Displacement.



LIST

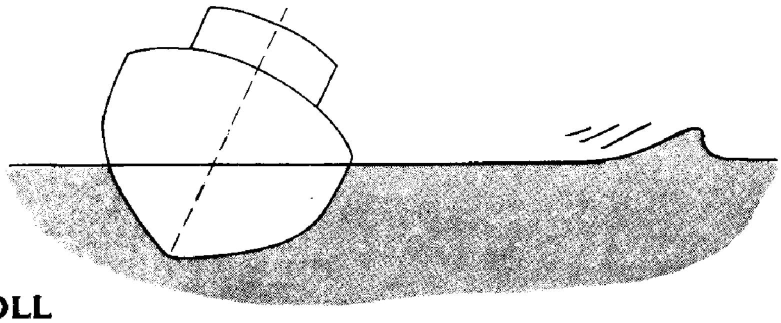
A ship is said to be listed when she is inclined by forces within the ship e.g. movement of weight within the ship.

3



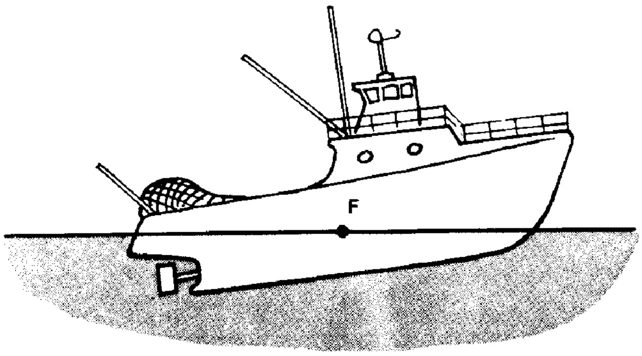
HEEL

A ship is said to be heeled when she is inclined by an external force.



LOLL

The term "loll" describes the state of a vessel which is unstable in the upright position and which floats at an angle from the vertical to one side or the other.

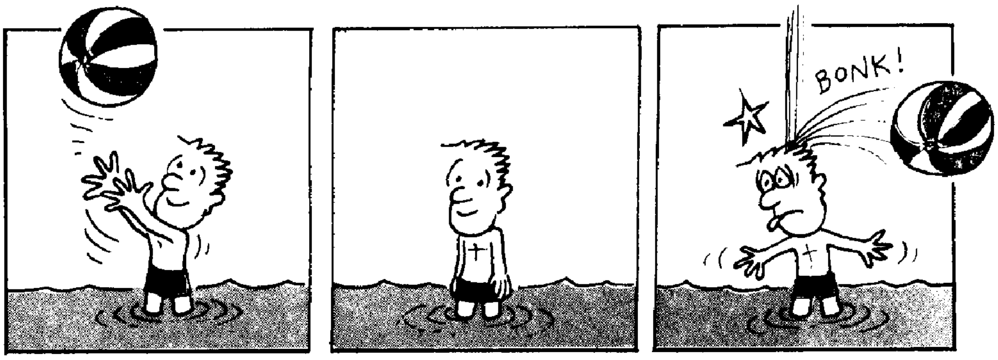


TRIM

Trim may be considered as the longitudinal equivalent of list, however, instead of being measured in degrees it is measured by differences in draft fore and aft.

The point about which a vessel trims is the centre of gravity of the water plane area and is called the CENTRE OF FLOTATION or TIPPING CENTRE.

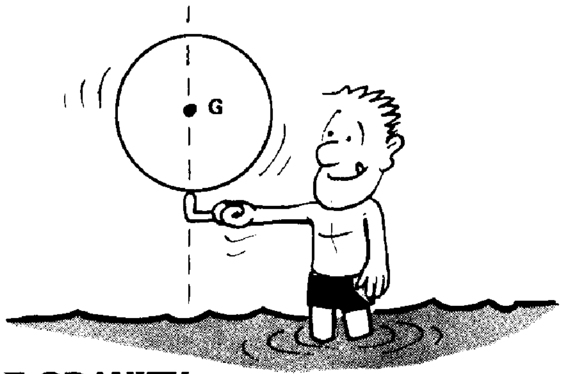
4



GRAVITY

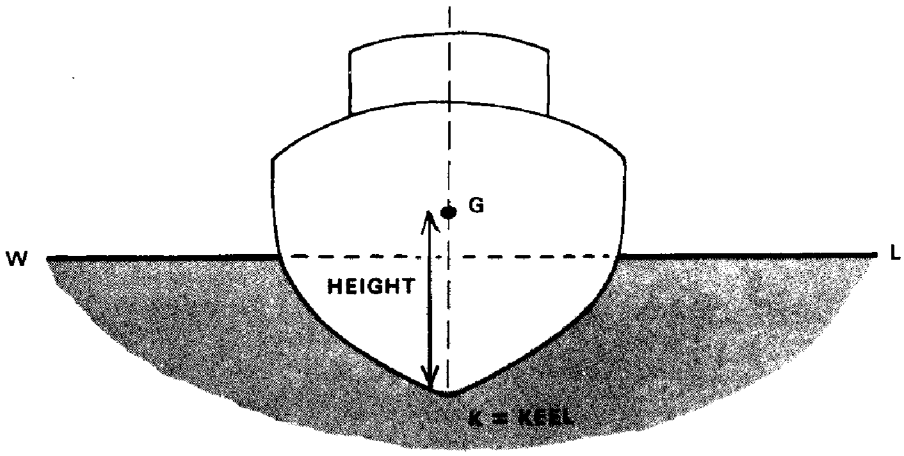
"What goes up must come down".

Throw a ball in the air. It soon comes back down in response to the earth's gravitational pull.

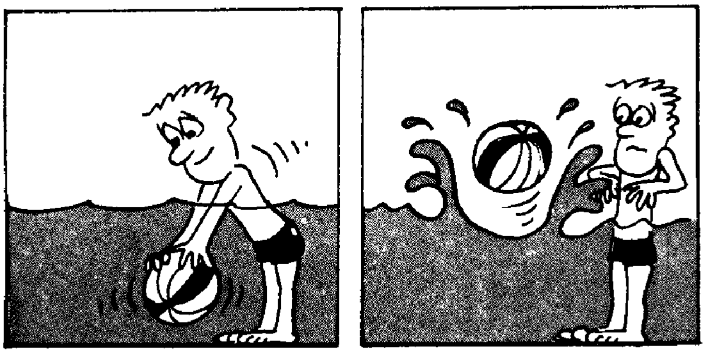


CENTRE OF GRAVITY

Centre of gravity is the point at which the whole weight of a body can be said to act vertically downwards.

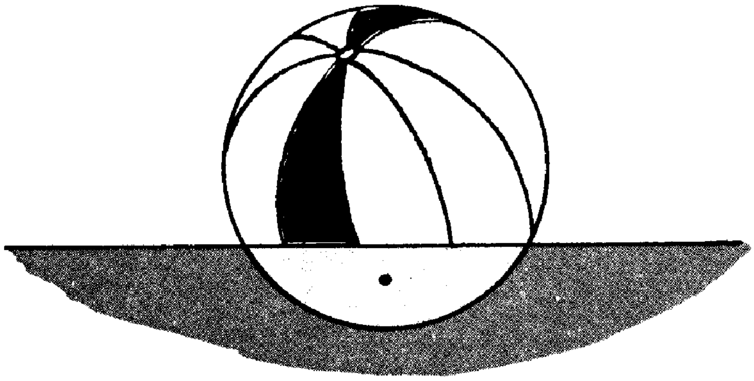


The centre of gravity depends upon weight distribution within the vessel and its position can be found by use of an inclining experiment. The height of the centre of gravity is measured vertically from a reference point, usually the keel line.



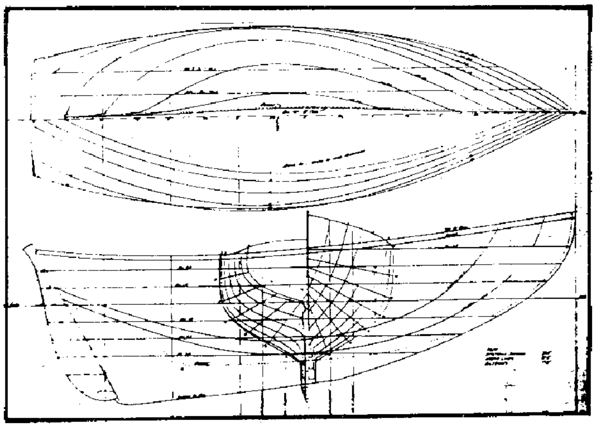
BUOYANCY

If a ball is pushed underwater it will soon bob up again. This force is called buoyancy.



CENTRE OF BUOYANCY

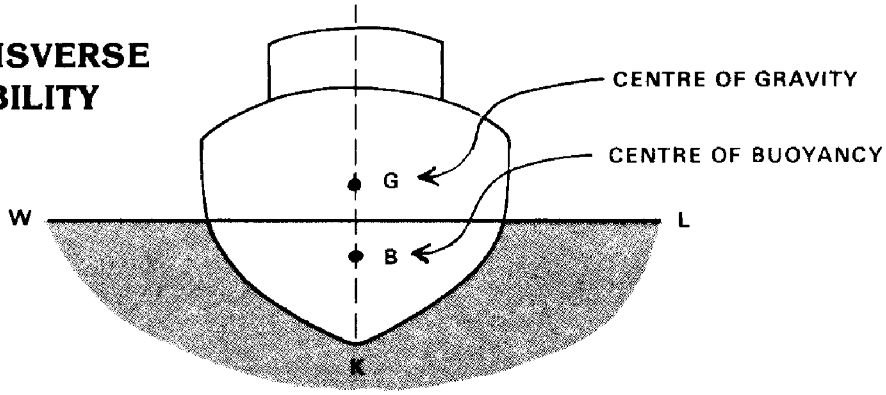
The centre of buoyancy is the point through which the force of buoyancy is considered to act vertically upwards. It is the geometric centre of the underwater section.



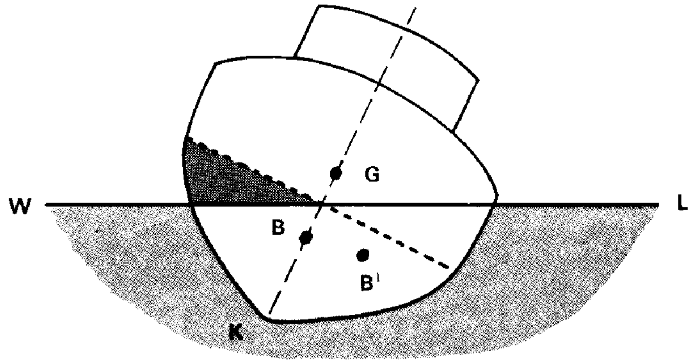
Because the shape of the hull of a vessel is known, a ship designer can calculate the centre of buoyancy for the various degrees of load and heel.

6

TRANSVERSE STABILITY

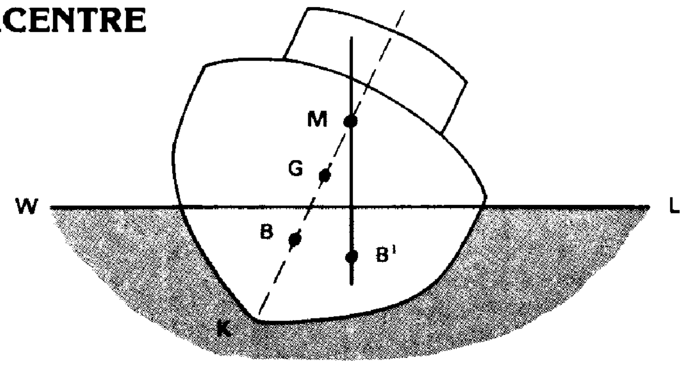


When a vessel is floating upright in still water the centre of buoyancy (upthrust) and the centre of gravity (downthrust) will be found to be in line with each other vertically above the keel.



If the vessel is inclined by an external force (i.e. without moving internal weight) a wedge of buoyancy is brought out of the water on one side and a similar wedge of buoyancy is immersed on the other side. The centre of buoyancy being the centre of the under water section has now moved to point B^1.

METACENTRE

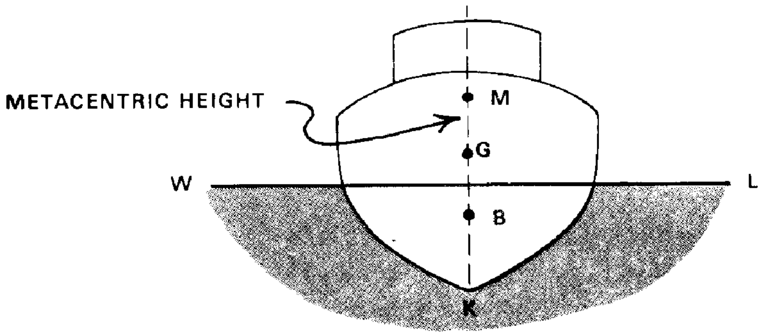


Vertical lines drawn from the centre of buoyancy at consecutive angles of heel will intersect at a point called the metacentre. The metacentre can be considered as being similar to a pivot point when a vessel is being inclined at small angles of heel.

7

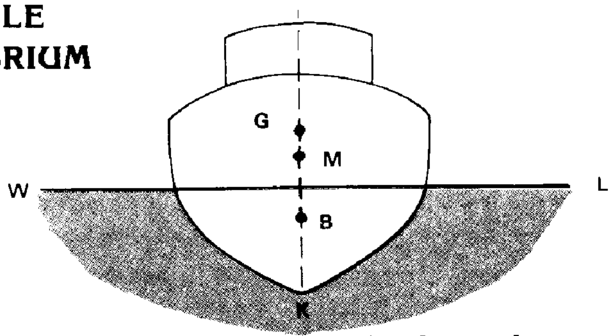
EQUILIBRIUM

A ship is said to be in stable equilibrium if when inclined she tends to return to the vertical position. For this to occur the centre of gravity must be below the metacentre.



A stable vessel in the upright position is said to have positive metacentric height i.e. when the metacentre is found to be above the centre of gravity. This is usually referred to as having positive G.M. The distance between G and M is known as metacentre height.

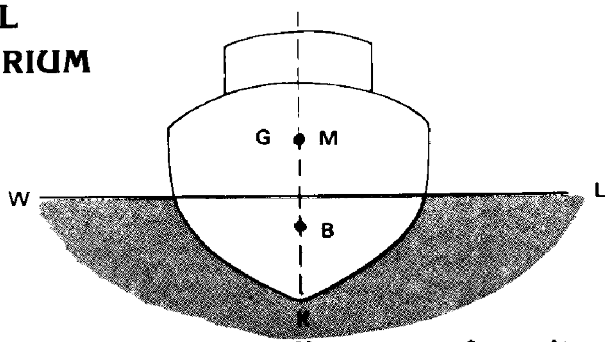
UNSTABLE EQUILIBRIUM



If the centre of gravity of a vessel is above the metacentre the vessel is said to have negative G.M.

When inclined to a small angle a vessel in this condition will tend to heel further over and could be in danger of capsizing.

NEUTRAL EQUILIBRIUM



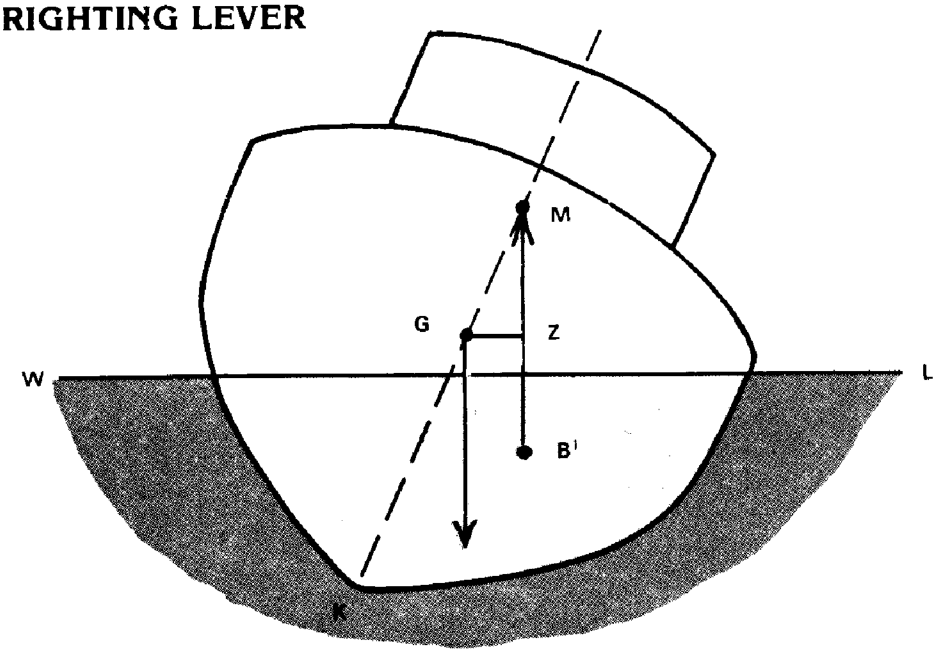
When the position of a vessel's centre of gravity and metacentre coincide the vessel is said to be in neutral equilibrium (Zero G.M.) and if inclined to a small angle will tend to remain at the angle of heel.

8

ROLLING TEST

The approximate metacentric height (GM) of a vessel can be ascertained by conducting a rolling test. This is achieved by accurately timing the natural rolling period of the vessel.

RIGHTING LEVER



RIGHTING LEVER

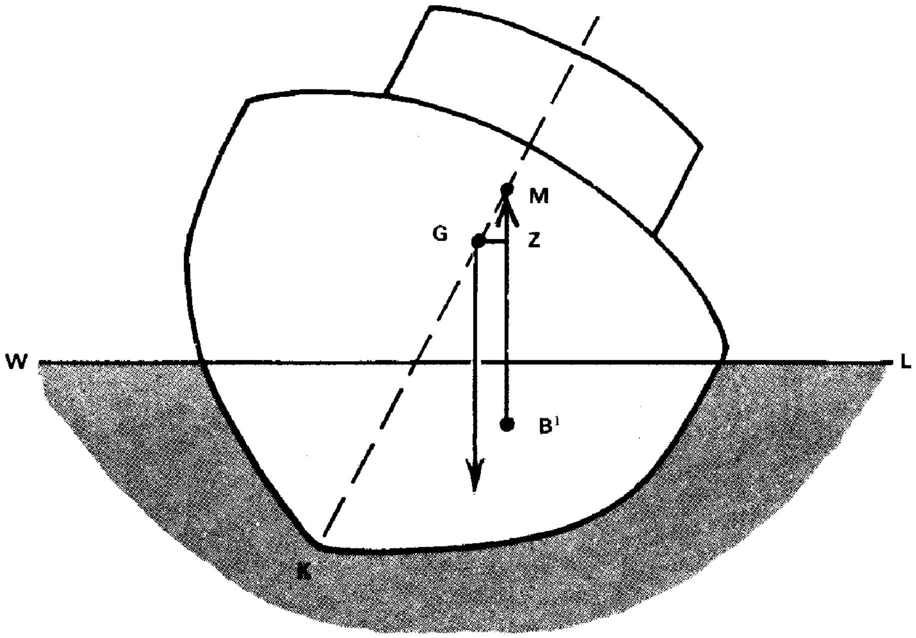
When heeled by an external force the centre of gravity of a vessel is unaffected by the heel and the weight is considered to act vertically downward through G. The centre of buoyancy always being the centre of the underwater section has moved to a new position B¹ and the force of buoyancy (equal to the weight of water being displaced) is considered to act vertically up through the centre of buoyancy and the metacentre.

The distance from the centre of gravity (G) to a vertical line from B¹ to the metacentre (M) is called the righting lever. This distance can be measured and is usually referred to as GZ.

Therefore, the force involved in returning the vessel to the upright position is the weight of the vessel bearing down through the centre of gravity (G) multiplied by the righting lever (GZ). This is referred to as the MOMENT OF STATICAL STABILITY.

9

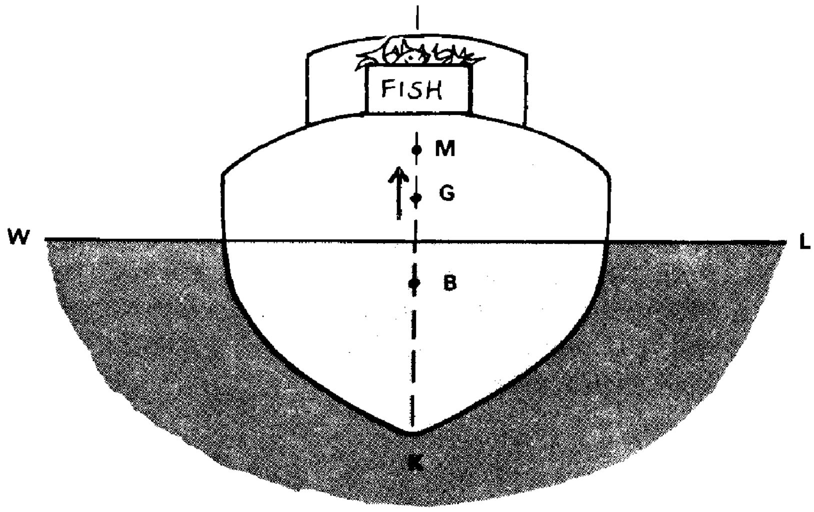
The centre of gravity of a vessel has a distinct effect on the righting lever and consequently the ability of a vessel to return to the upright position.



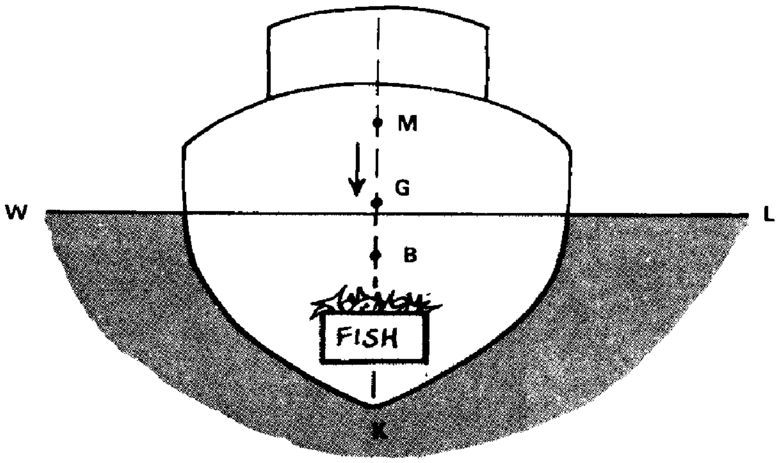
Should the centre of gravity (G) be near the metacentre (M) the vessel will have only a small metacentric height and the righting lever GZ will also only be a small value. Therefore, the forces involved in returning the vessel to the upright position will be considerably less than that of the previous illustration.

STIFF AND TENDER SHIPS

When weight is added to a vessel the centre of gravity of the vessel always moves in the direction of the added weight.



Weight added at deck level results in the vessel's centre of gravity rising, causing a decrease in the vessel's metacentric height. A vessel with little or no metacentric height is said to be TENDER.



Weight added low down in the vessel lowers the centre of gravity and consequently causes an increase in the vessel's metacentric height. A vessel with a large metacentric height is said to be a STIFF SHIP.

A stiff ship tends to be comparatively difficult to heel and will roll from side to side very quickly and perhaps violently. If this condition is thought to be a problem it can be corrected by raising the vessel's centre of gravity.

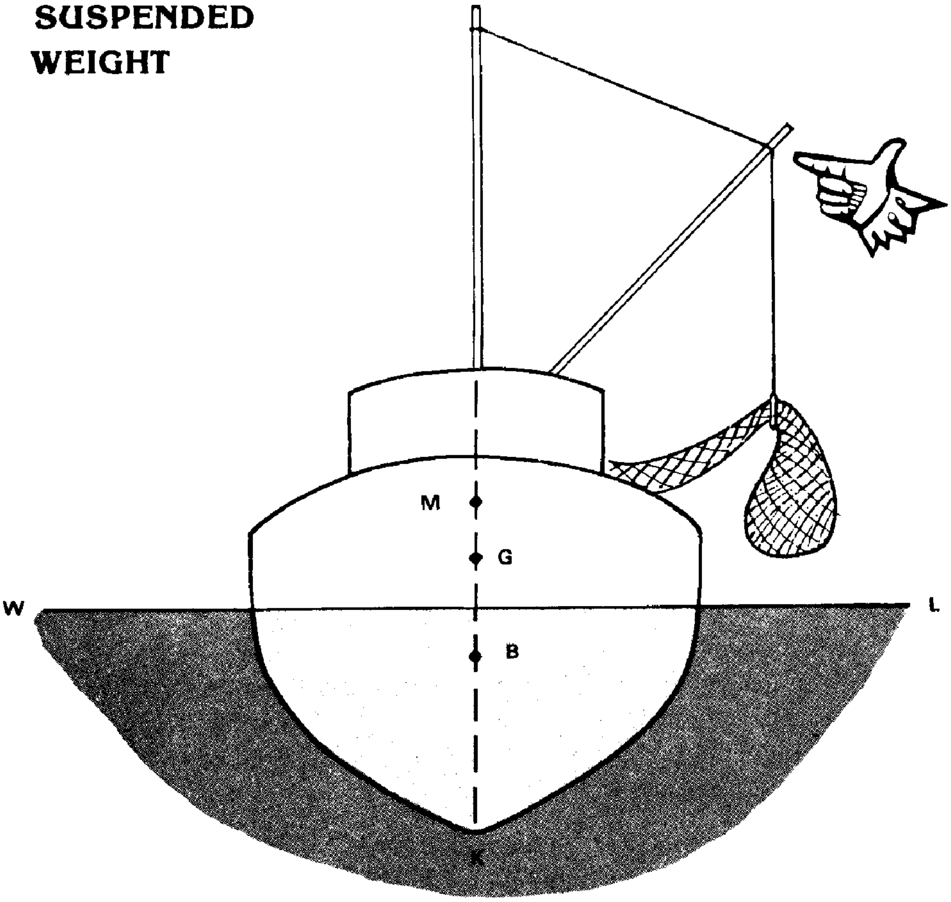
A Tender ship will be much easier to incline and will not tend to return quickly to the upright position. The time period taken to roll from side to side will be comparatively long. This condition is not desirable and can be corrected by lowering the centre of gravity.

11

LOLL

The term loll describes the state of a ship which is unstable when in an upright position and therefore floats at an angle of heel to one side or the other. If disturbed by some external force, caused by wind or waves, the vessel will lurch to the same angle of loll on the opposite side. Loll is quite different from list, being caused by different circumstances and requiring different counter-measures to correct it, and it is therefore most important that the seaman should be able to distinguish between the two.

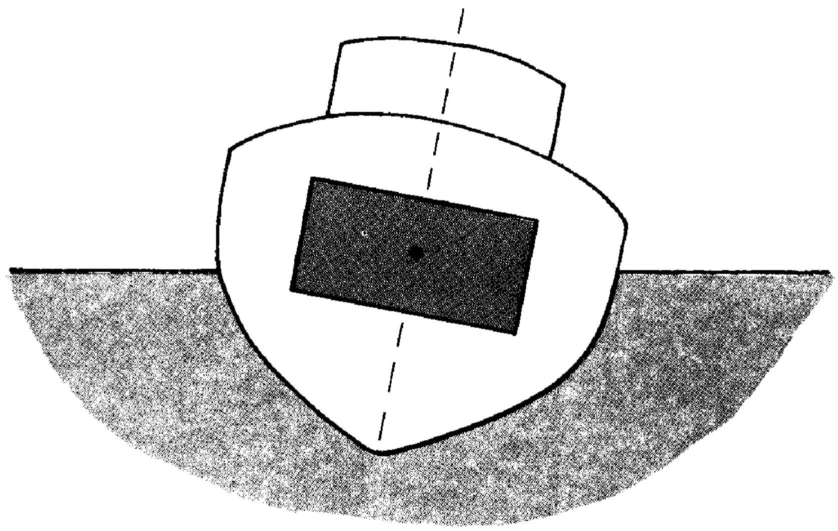
SUSPENDED WEIGHT



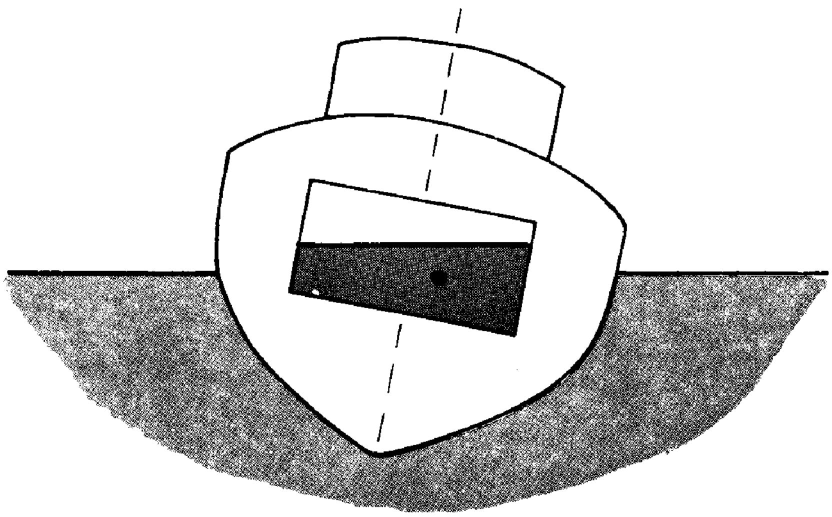
The centre of gravity of a suspended weight can be considered to be at the point of suspension. Therefore, a trawl cod end when being lifted clear of the water has the same effect on the vessel centre of gravity as if the weight were actually the head of the boom. It also exerts a heeling force upon the vessel.

12

FREE SURFACE EFFECT

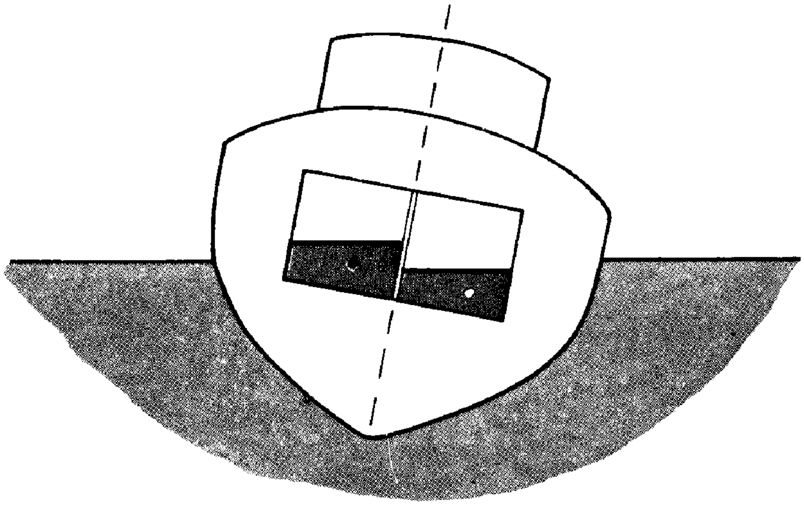


When a vessel with full tanks is heeled the liquid within the tank acts like a solid mass, its centre of gravity being the centre of its volume remains constant and therefore does not cause any change in the vessel's metacentric height.

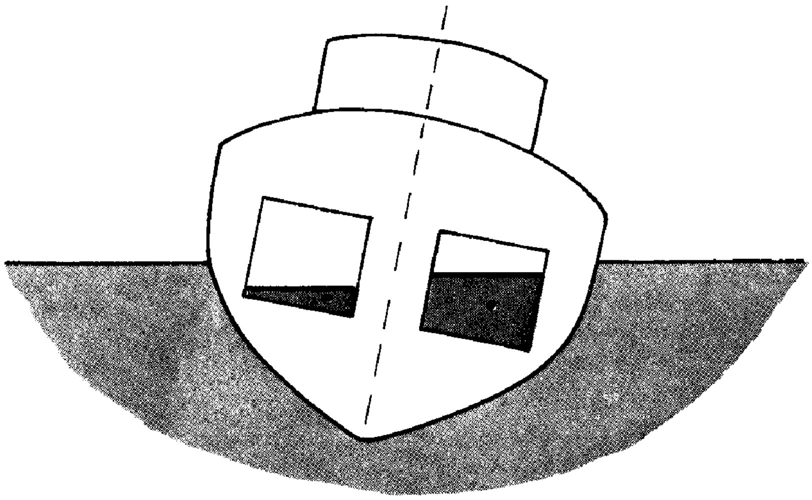


When a vessel with a half filled tank is heeled the liquid will seek to remain parallel with the waterline. The centre of gravity of the liquid being the centre of its volume will move with the liquid and can have a considerable effect upon the vessel's metacentric height.

13



Half filled tanks have the greatest adverse effect upon a heeled vessel's metacentric height. The division of the tank into two equal parts by the use of a watertight baffle will reduce the adverse effect on the vessel's metacentric height to a quarter of that of an undivided tank.



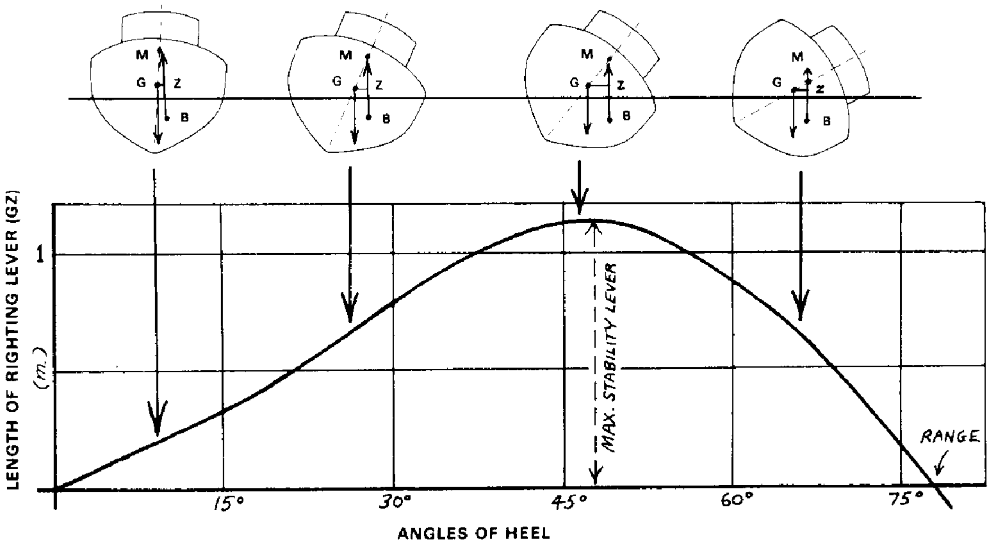
Care should be taken when endeavouring to correct a list by the filling of tanks. Having two half filled tanks will create additional free surface effect. Therefore, in this situation it is recommended that the tank on the low side be filled before commencing to fill the tank on the high side.

14

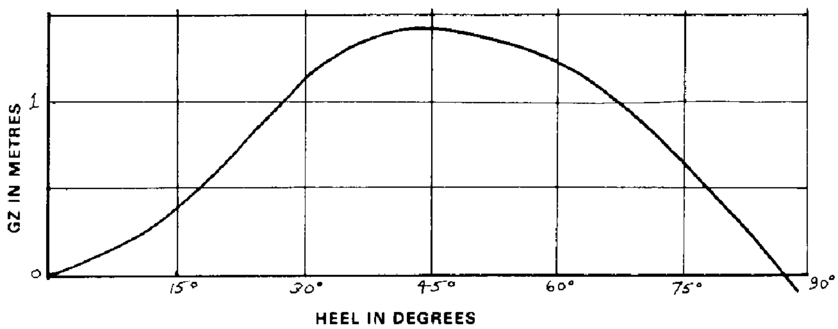
STABILITY CURVES

The operation of a fishing vessel varies considerably from that of a trading vessel. A trading vessel is usually loaded in port, whereas a fishing vessel "hopefully" takes on the largest part of its load at sea.

The effects which the various conditions of loading have on load lines etc is more difficult to observe at sea, therefore, a knowledge of the effects of the loading or unloading of tanks and holds has on a fishing vessel's stability is desirable.



Stability curves are used to show graphically the levers exerted by a vessel to return itself to a position of equilibrium from the various conditions of heel.



The stability information usually provided shows the varying righting levers exerted at the changing conditions of loading and heel.

Structural features can result in performance differences between vessels e.g. Beam/Draft Ratio and Freeboard. An increase in beam will result in an increase in the righting lever (GZ) for all angles of heel.

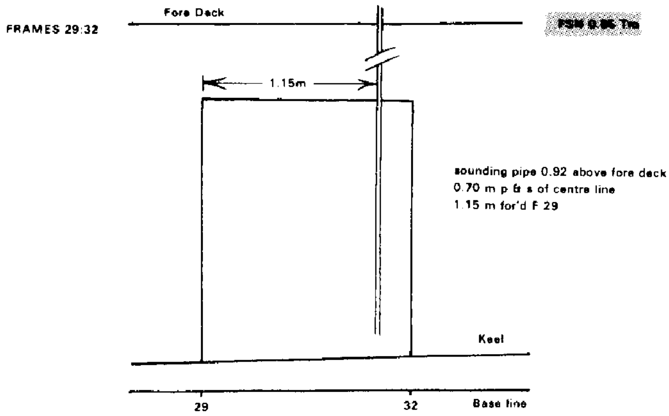
Australian fishing vessels may be supplied with a booklet in which stability information is presented in the form of curves of "Limiting KG".

"Limiting KG" is a measure of the minimum stability required to ensure that a vessel has the ability to remain stable throughout a voyage. "Limiting KG" is determined by the Naval Architect at the vessel's design stage.

The booklet will contain sets of reference tables indicating the changing values for the various conditions of loading. From these tables it will be possible to calculate the vessel's KG, compare it with a predetermined curve of maximum acceptable limits and ascertain whether or not the vessel is within the specified limits.

Example

FRESH WATER TANKS
PORT AND STARBOARD



SOUNDINGS (m)	CAPACITY (Tonnes)	V.C.G. (m)	L.C.G. (m)
0.2	0.1	0.65	+4.7
0.4	0.2	0.75	+4.72
0.6	0.4	0.85	+4.74
0.8	0.65	0.95	+4.77
1.0	0.95	1.15	+4.8
1.2	1.30	1.25	+4.82
1.4	1.70	1.35	4.85
1.6	2.1	1.45	4.88
1.8	2.45	1.55	4.91
2.0	2.85	1.65	4.94
2.2	3.2	1.75	4.97
2.4	3.6	1.85	4.99
2.6	4.0	1.95	5.02

DISPLACEMENT TABLE

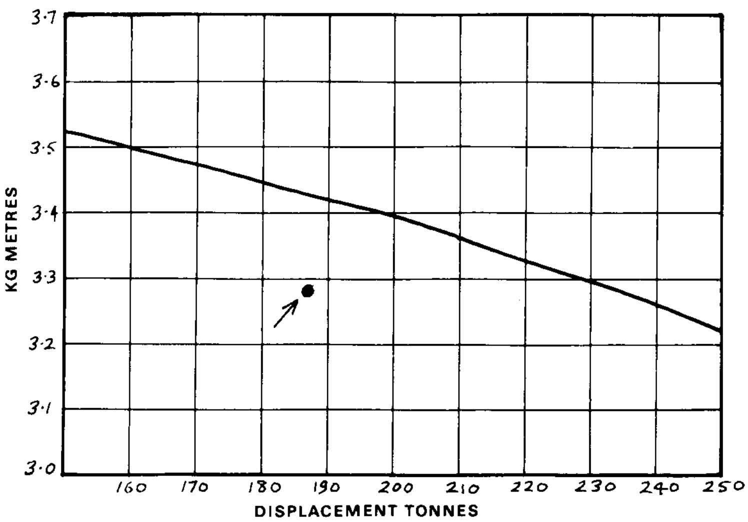
Condition No. 5 Fishing 100% Catch 20% Fuel and Water

Item	Weight Tonnes (1)	V.C.G. m (2)	Vertical Moment Tm (3)	L.C.G. ford/aft amidship m (4)	Long-Al Moment	Free Surface Numeral (6)
Fresh Water	1.70	1.35	2.29	+4.85	+ 8.24	0.65
E. R. Wings FO	9.50	2.25	21.37	−4.77	− 45.32	0.88
Lub. Oil	0.10	2.59	0.25	−7.90	− 0.79	0.18
Crew & effects	1.00	4.00	4.00	+6.00	+ 6.00	-
Stores	2.00	3.00	6.00	-	-	
Provisions	0.40	2.00	0.80	+7.00	+ 2.80	-
Catch	24.00	2.60	62.40	+0.50	+ 12.00	
B Deadweight	38.70		97.11		− 16.62	1.71
C Lightship	148.46		516.61		− 96.00	
D Displacement	187.16		613.72	−0.60	−112.62	

$$\text{Calculated KG} = \frac{613.72}{187.16} = 3.28$$

CURVE OF LIMITING KG

In any condition of loading the KG from line G of the Displacement Table must line within the area under the curve.



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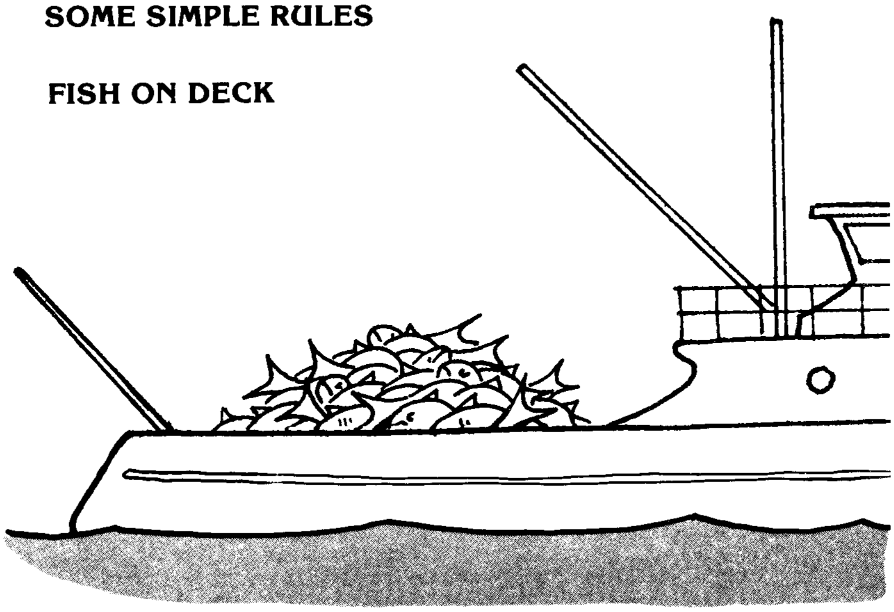
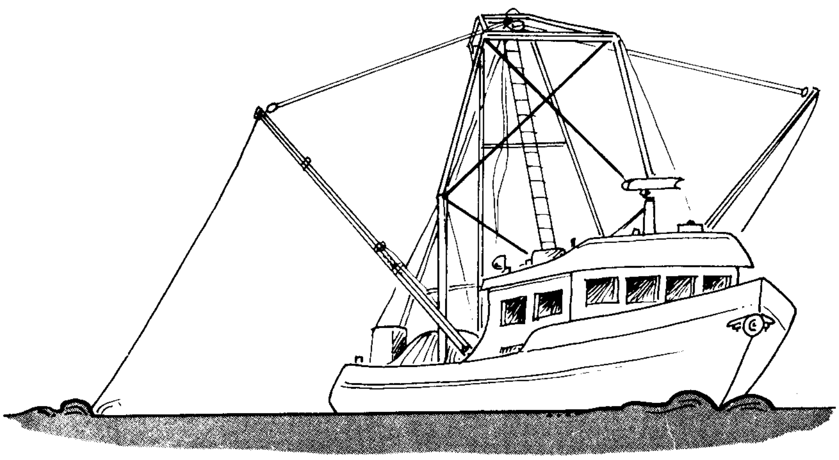
SOME SIMPLE RULES

FISH ON DECK



Large quantities of fish should not be held on deck as their weight will raise the vessel's centre of gravity which in turn will affect the vessel's righting lever and could cause a condition of instability.



High towing point for trawl nets should be avoided as they can have a detrimental effect on both the transverse and longitudinal stability.

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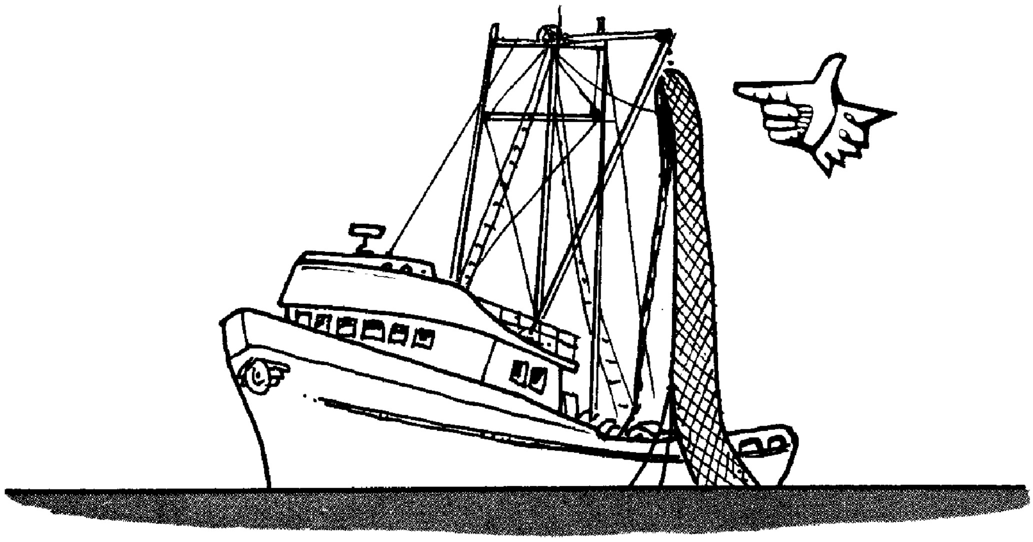
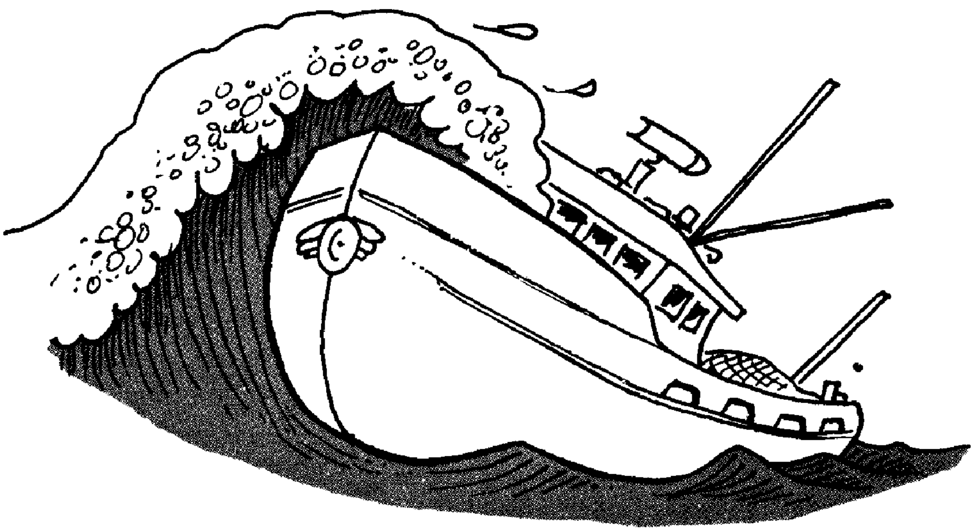


Care must be exercised when lifting heavy weights from high purchase points.



FREEING PORTS

To enable the water to run off quickly a vessel should have adequate freeing ports.

There are regulations specifying the number and size of these ports. They should be kept clear at all times.

FREE SURFACE EFFECT

Fuel and water tanks should have watertight divisions in them to reduce the free surface effect. Fish holds should also be divided by the use of pound boards.

SOME SUGGESTIONS FOR PRESERVING SAFE STABILITY

The following measures are recommended by the International Maritime Organisation. They should be considered as preliminary guidance on matters influencing the safety of fishing vessels generally, and specifically as related to safeguarding stability.

1. **All doorways and other openings through which water can enter the hull or deckhouses, forecastle, etc. should be suitably closed in adverse weather. Accordingly, all appliances for this purpose should be maintained aboard in good and efficient condition. Enclosed spaces like deckhouses above the weather deck contribute to stability but if their doors or openings are forced open to the sea and water collects inside this may be slow to drain away. In this case, the flooding could become dangerous to the safety of the vessel.**
2. **Hatch covers and flush deck scuttles should be kept properly secured when not in use during fishing.**
3. **All deadlights should be maintained in good condition and securely closed in bad weather.**
4. **All fishing gear and other large weights should be properly stowed and placed as low as possible.**
5. **Care should be taken when the pull from fishing gear might have an adverse effect on stability, e.g. when nets are hauled by power block or the trawl catches obstructions on the sea bed. This is particularly the case when the vessel is manoeuvring with the trawl abeam and is the worst for small vessels. Gallows frames are the same size in general for small vessels as for the larger ships which means for the former a relatively greater lever. The point of action of the weight is at the hoist block of the frame or derrick head.**
6. **Gear for releasing the deck load in fishing vessels carrying catch on deck, e.g. herring, should be kept in good working order for immediate use when necessary.**
7. **Freeing ports in bulwarks which are provided with closing appliances should always be capable of functioning and should not be locked, especially in bad weather. Devices for locking freeing port covers should be regarded as potentially dangerous. If locking devices in particular**

cases are considered essential for the service of the ship, they should be of a reliable type, operative from a position which would always be accessible. When operating in areas subject to ice formation, it is recommended not to fit covers at all. Water on deck in the well between bridge and forecastle or elsewhere can be a hazard to stability unless cleared rapidly. Moreover, this can build-up by an equal amount with the onset of each successive wave.

8. **When the weather deck is prepared for the carriage of deck load by division with pound boards, there should be slots between them of a size such that an easy flow of water to the freeing ports will be ensured, i.e. good drainage.**
9. **Never carry fish in bulk without first being sure that the portable divisions in the fish hold are properly installed. The cargo must not shift.**
10. **At any one time keep the number of partially filled tanks to a minimum.**
11. **Observe any instructions given regarding the filling of water ballast tanks. Remember that slack tanks can be dangerous.**
12. **Any closing devices provided for vents to fuel tanks etc. should be secured in bad weather.**
13. **Reliance on automatic or fixed steering is dangerous as this prevents speedy manoeuvring which may be needed in bad weather.**
14. **Be alert to all the dangers of following or quartering seas. These may cause heavy rolling and/or difficult steering. If excessive heeling or yawing occurs, reduce speed or alter course or both.**
15. **Maintain a seaworthy freeboard in all conditions of loading. Remember that this has a very marked effect on the vessel's maximum righting and recovery powers and the range of heeling angles over which the ability to recover depends.**
16. **Pay special attention to the formation of any ice aboard the vessel and reduce it by all possible means. Standing wire rigging will ice-up to a greater extent than struts or yards. If icing cannot be controlled leave the area with all possible speed long before it becomes a serious menace.**

The National Fishing Industry Training Committee gratefully acknowledges the assistance given by the Commonwealth through the Department of Employment and Industrial Relations and the National Training Council in the production of this booklet.

STABILITY

MASTER 5

CONTENTS – Master 5 Level

TOPIC 1 BASIC PRINCIPLES OF STABILITY

Section 1 Basic Stability

TOPIC 2 LONGITUDINAL AND TRAVERSE STABILITY

Section 2A List and Trim

Section 2B Stability in Seaway

TOPIC 3 FACTORS AFFECTING STABILITY

Section 3 Factors Affecting Stability

Section 4 Twosuch Guide Notes

Appendix A: Simplified Stability Information for M.V. 'Twosuch'

Assignment 1

Assignment 2

TOPIC 1

BASIC PRINCIPLES OF STABILITY

Syllabus

Learning Outcome

On completion of this learning outcome the learner will be able to describe the basic principles of stability relevant to small vessels.

Assessment Criteria

- Explain the relationship between weight and buoyancy in relation to floating bodies
- Explain the meaning of terms commonly used in relation to the stability of a vessel
- Explain why a vessel's draft would change when moving from fresh water to salt water
- Explain the relationship between light displacement, load displacement and dead-weight tonnage

Text

National Fishing Industry Training Committee: *An Introduction to Fishing Vessel Stability* (included in the Coxswain's section of this learning resource)

SECTION 1

BASIC STABILITY

Introduction

Stability is a word which is put to several uses:

- the steering of a vessel can be stable, meaning that it responds nicely to the helm and does not heel over excessively when making a tight turn
- directional stability refers to the vessel's ability to maintain its course with very little helm required
- a vessel is said to be stable in a seaway - meaning that it will not capsize under the forces of the waves and wind
- a vessel is also said to be stable when it tends to right itself after being heeled by an external force.

Although all the above uses of the term "stability" are related, it is primarily with the last meaning listed above that we will be concerning ourselves in the remainder of this course.

Objectives

By the end of this Section you should be able to:

- explain what is meant by the term Equilibrium
- state the law of flotation and show how a body is in equilibrium when floating freely in a fluid
- explain what is meant by the term Centre of Gravity (C.G.) and show how the C.G. of a body can be located
- explain what is meant by the term Centre of Buoyancy (C.B.)
- define the following terms:
    - draft
    - freeboard
    - displacement
    - deadweight (DWT)
    - trim
    - tonnes per centimetre immersion (T.P.C.)
    - fresh water allowance (F.W.A.)
    - loadline
- relate the above definitions to a block of wood floating in fresh water and salt water

Unit 1.1 Archimedes' Principle

Many years ago a Greek scholar named Archimedes became intrigued by the rise in water level every time he had a bath. He investigated this phenomenon and came up with a principle which has stood the test of time.

> ***Archimedes' Principle***
>
> *When a body is wholly or partially immersed in a fluid, it appears to suffer a loss in mass equal to the mass of fluid it displaces.*

This relationship between weight and volume is called density. It is expressed as a ratio of the weight of a substance for a unit of volume. In our metric system, one metric tonne of fresh water has a volume of one cubic metre. It has a density of one tonne per cubic metre. Salt water on the other hand is heavier. One cubic metre weighs 1.025 tonnes and has a density of 1.025 tonnes/m^3.

Frequently we use the term *Relative Density*, which is simply a comparison of the density of a substance with the density of fresh water. It is also expressed as a ratio:

$$RD = \frac{Density\ of\ Substance}{Density\ of\ Fresh\ Water}$$

This is a pure number and has no units. The R.D. of sea water is therefore 1.025.

READ and then STUDY Archimedes Principle on page 1 of your text, *An Introduction to Fishing Vessel Stability* (F.V.S).

Weight vs Buoyancy

Now let us refer back to Archimedes. Suppose we have a body or block that measures 1 cubic metre and weighs 3000 kg. If we now lower the block into fresh water, it will displace 1 cubic metre of fresh water – which, as we now know, weighs 1000 kg. In other words, there is a force acting *upwards* of 1000 kg and a force acting *downwards* of 3000 kg; the resultant force has to be 2000 kg *downwards*. That is, the block will sink.

Let us now take the same 3000 kg block and re-mould it into a hollow box with a volume of 3 cubic metres of fresh water - which also weighs 3000 kg. In this case the upward force now *equals* and is *opposite* to the downward force. That is, the box will now (just) float.

If we now take the original 3000 kg block and mould it into a hollow box with a volume of 5 cubic metres and then place it in fresh water, it has sufficient volume to displace 5 cubic metres of fresh water. If the box were now completely submerged it would experience an upward force of 5000 kg.

However, the downward force of the box is still only 3000 kg, thus the downward resultant force will be 2000 kg upwards. In this case the box will rise out of the water to a level where the forces are equal and opposite. This box will now have a draft equal to 3/5 of the maximum depth.

If one cubic metre of iron is immersed in fresh water, it will displace one cubic metre of the water which we know to weigh 1 tonne. As 1 m^3 of iron weighs 7.8 tonnes, it is clearly not displacing its own weight.

Now consider the same weight of iron with an enlarged volume, say 2 m^3 (an air space of 1m^3 having been introduced in the centre of the iron).

If this enlarged block of iron is immersed in fresh water, 2 m^3 of fresh water is displaced. This will cause an apparent reduction in weight of 2 tonnes - still not enough to cause it to float. When the volume of the block and air space reaches 7.8 m^3, the block will just float as it is displacing its own weight of the liquid in which it is floating. If the volume is further increased, it will float with a certain amount of freeboard;

i.e. Force of Buoyancy = Weight

Consider a rectangular wooden log with a relative density of 0.6. It has a volume of 2.5 m^3 and weighs 1.5 tonnes.

In Figure 1.1, the weight of the log acts directly downwards through its centre of gravity (G), and the force of buoyancy acts vertically upwards through the centre of buoyancy (B).

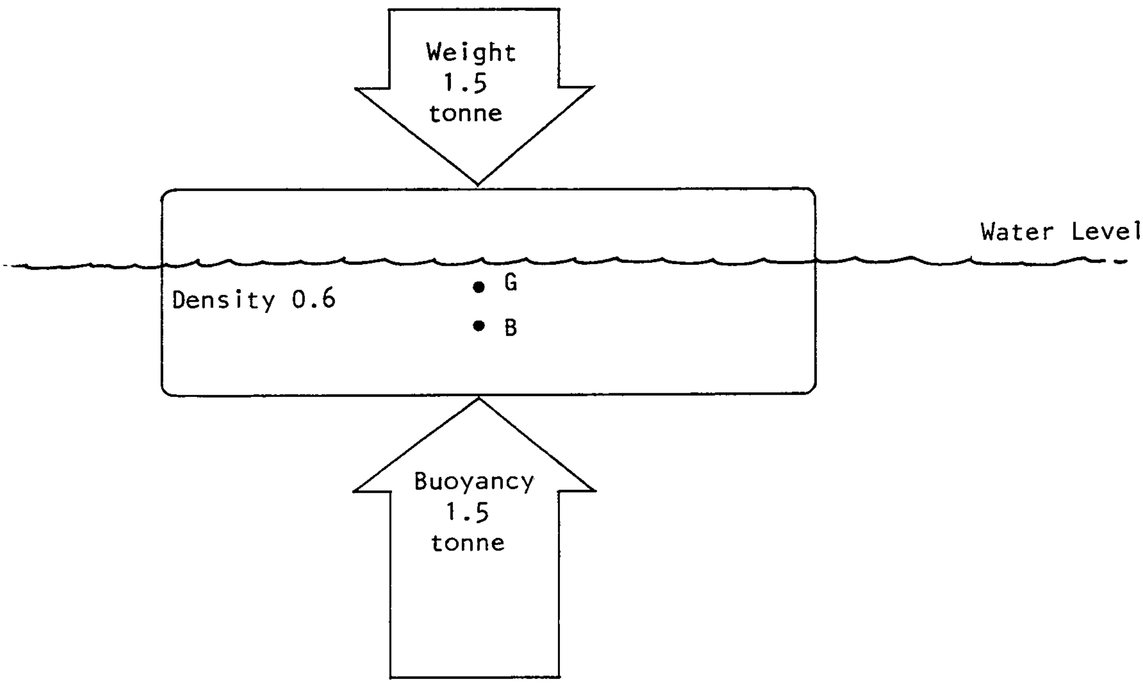


Fig. 1.1 Weight vs Buoyancy

Unit 1.2 Centre of Gravity, Centre of Buoyancy

- STUDY the definitions of 'buoyancy' and 'centre of buoyancy' on page 6 of your text, *An Introduction to Fishing Vessel Stability*.
- STUDY the definition of 'gravity' and 'centre of gravity' on page 5 of your text.
- STUDY the following notes.

The centre of gravity of a body is the point about which a body will balance.

There are many ways to find this balance point. In a homogenous body the centre of gravity is found at the centroid. The material of which a homogenous body is made is uniformly distributed throughout its volume; i.e., if you take 1m^3 of the material from one part of the body it will weigh exactly the same as 1 m^3 of the material from any other part of the body.

In the shapes in Figure 1.2 the 'G' represents the centroid. If each area was suspended from this point the shape would balance:

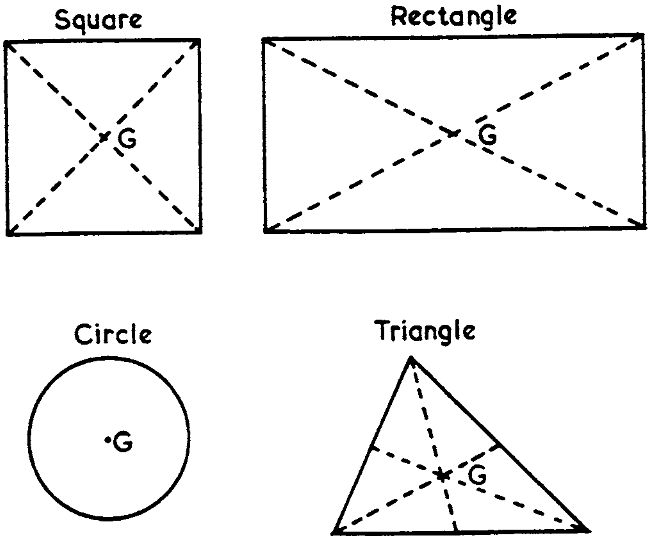


Fig. 1.2 Centroids

To find the centre of gravity of a rectangular wooden log is relatively simple; you would do it by locating the centroid as shown in Figure 1.2 for a rectangle.

It is more difficult to exactly locate the C.G. of a non-uniform wooden log. One could however quite easily find the vertical line through which 'G' acts.

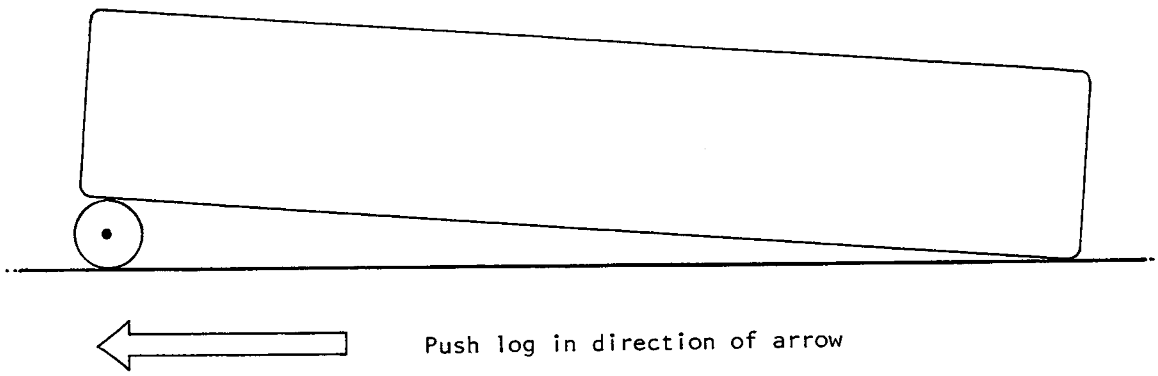


Fig 1.3

Lift up one end of the log and place a roller underneath it, as shown in Figure 1.3. Now push the log towards the roller and the log will slide on top of the roller. When the log balances on the roller, the centre of gravity is directly above the centre of the roller and approximately in the centre of the log as shown in Figure 1.4.

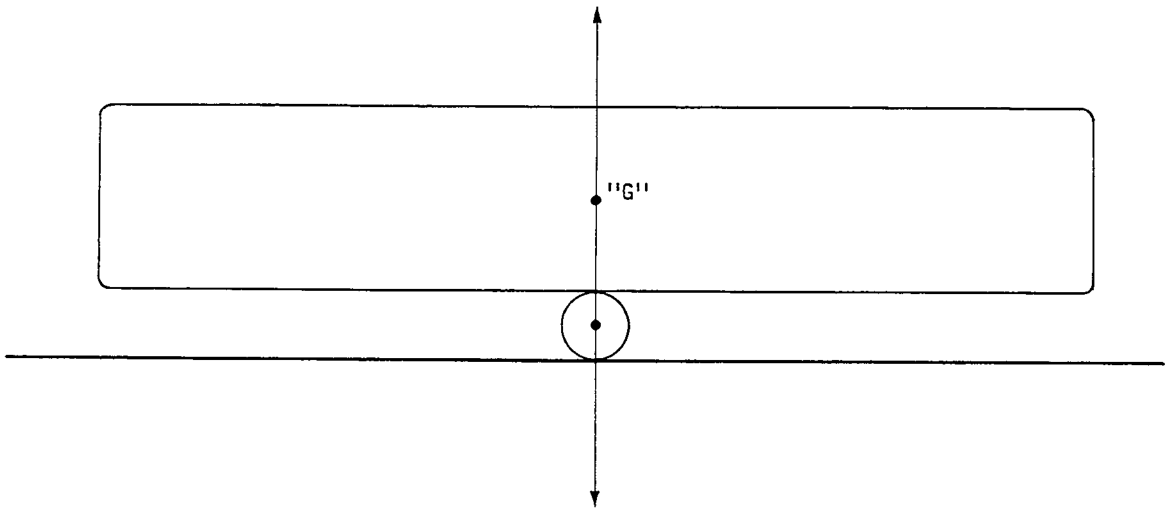


Fig. 1.4

Consider a rectangular log floating in fresh water. The volume of water it displaces weighs the same as the log. The force of buoyancy acts vertically upwards through the centre of buoyancy. Because the log is homogenous and of uniform dimensions, the waterline will be parallel to the top and bottom edges of the log. The centre of buoyancy and the centre of gravity will be in the same vertical line.

If we were to disregard all above the waterline, the centre of buoyancy will be the centre of gravity of the underwater portion as shown in Figure 1.5.

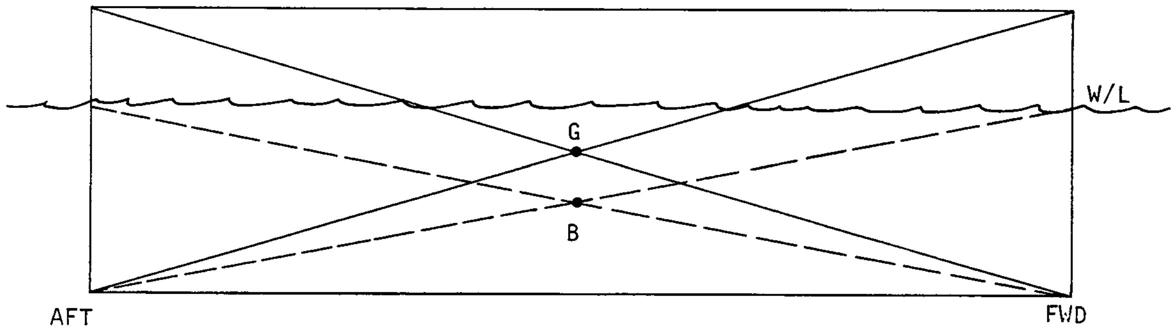


Fig. 1.5

In a ship shape body, the external dimensions are not nice and simple to measure and more complex methods are used to calculate the position of the centre of buoyancy. The principle however is the same, and B is always located at the geometric centre of the underwater part.

Unit 1.3 Draft, Freeboard and Trim

STUDY the definitions of 'draft', 'freeboard', 'list' and 'trim' on pages 2, 3 and 4 in your text book.

A few new terms are introduced here. The centre of flotation is the centroid of the water plane area. Consider the block in Figure 1.6.

In this case the block is floating on an even keel with no list and no trim.

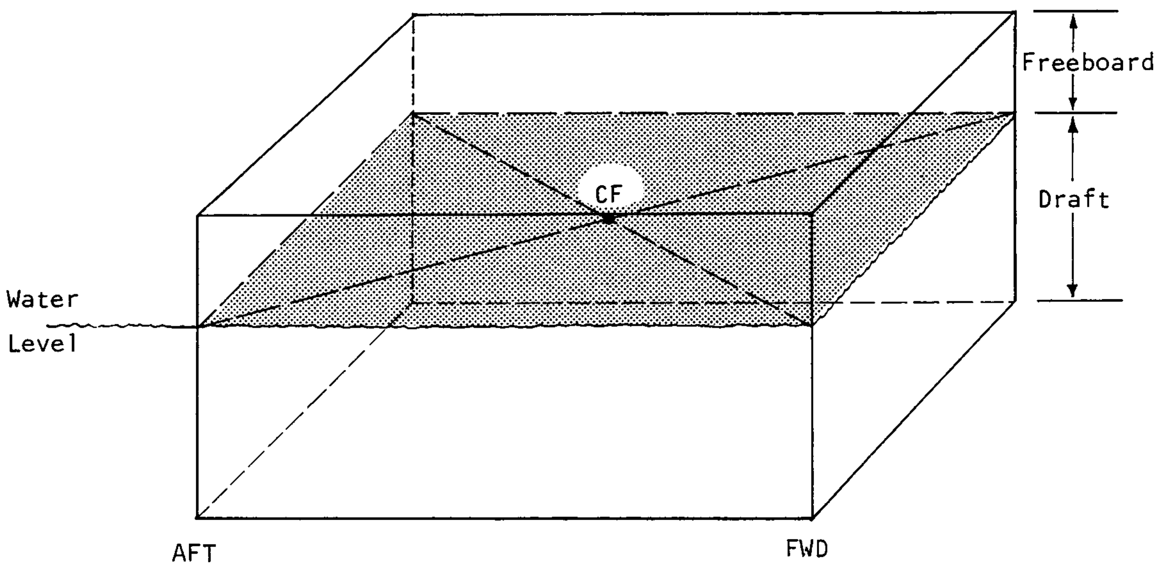
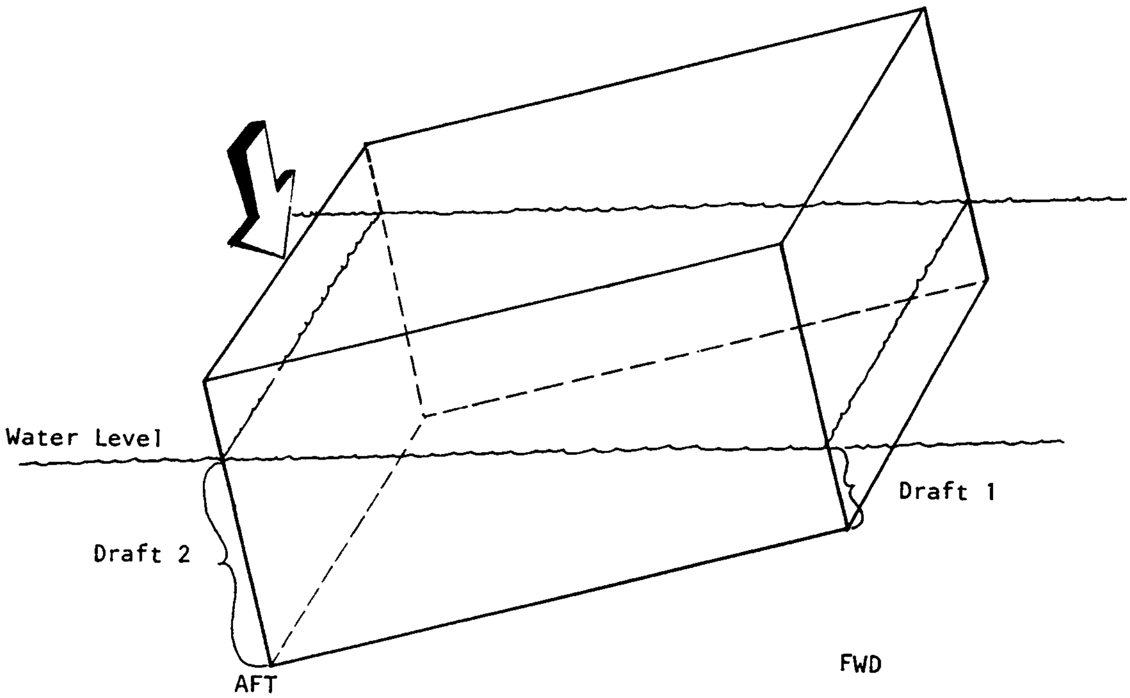


Fig. 1.6

C.F. is the position of the centre of flotation. This is sometimes known as the 'tipping centre' since it is the point about which a floating body pivots. If a small weight was placed on the left-hand end of the log, this end would sink slightly, causing the log to have a trim. The draft underneath the weight would increase and the draft at the other end would decrease. The difference between the two drafts would be the trim as shown in Figure 1.7.

Draft 1 minus Draft 2 = Trim.



Draft 1 minus Draft 2 = Trim.

Fig. 1.7

NOTE that the left-hand side has been called the after end and the right-hand side the fore end. When drawing diagrams of ships, this is the usual way it is done. NOTE also that a trim by the stern is by convention, in Australia, designated as negative, and a trim by the bow, positive.

Remember that a block floating in fresh water floats at a deeper draft than in salt water.

Example
Consider a rectangular, homogenous block of relative density 0.8 and with the following dimensions: length 10 m, breadth 2 m, depth 1 m. What will be its draft in:

(a) fresh water?

(b) sea water, density 1.025?

Answers

Weight of Block	=	Volume × Density
Weight of Water Displaced	=	Volume × Density
∴ 1 × b × d × density (block)	=	1 × b × draft × density (water)
∴ depth × density (block)	=	draft × density (water)

$$\boxed{\therefore \; Draft = \frac{depth \times density((log)}{density\,water}}$$

This formula is good for all rectangular shaped floating objects.

(a) $\text{In fresh water, density} = 1$

$$\therefore \text{ draft} = \frac{1\text{m} \times 0.8}{1}$$
$$= \mathbf{0.8\,m}$$

(b) $\text{In salt water, density} = 1.025$

$$\therefore \text{ draft} = \frac{1\text{m} \times 0.8}{1.025}$$
$$= \mathbf{0.78\,m}$$

Unit 1.4 Displacement, T.P.C., F.W.A., Load Line and Deadweight

- STUDY the definitions of 'displacement', 'load displacement' and 'deadweight' on pages 1 and 3 in your text.
- STUDY the following notes ...

Displacement
When we refer to the displacement of a vessel, we mean the weight of water that it displaces. We know this to be the weight of the vessel (Archimedes' Principle), but it is

easier to measure the volume of water that a floating body displaces than to actually weigh the body, especially when the body is a ship weighing several thousand tonnes.

Example

If a block of wood with R.D. of 0.75 weighs 1.5 tonnes:

(a) what will its volume be?

(b) what will be the volume of water it will displace in

(i) fresh water?

(ii) sea water, density 1.025?

Answers

(a) $$\text{Volume} = \frac{\text{Weight}}{\text{Density}}$$

$$\therefore \text{ Volume} = \frac{1.5}{0.75}$$

$$= \mathbf{2\,m^3}$$

(b) (i) $$\text{Volume} \times \text{Density (water)} = \text{Volume} \times \text{Density (wood)}$$

$$\therefore \text{ Volume (water)} = \frac{\text{Volume} \times \text{Density (wood)}}{\text{Density (wood)}}$$

$$= \frac{2 \times 0.75}{1}$$

$$= \mathbf{1.5\,m^3}$$

(ii) $$\text{Volume (water)} = \frac{\text{Volume} \times \text{Density (wood)}}{\text{Density (water)}}$$

$$= \frac{2 \times 0.75}{1.025}$$

$$= \mathbf{1.463\,m^3}$$

From this, it is clear to see that the volume of water displaced by a floating body in fresh water is greater than the volume of water displaced by the same floating body in sea water.

We saw (in Unit 1.3) that a block of wood floating in fresh water would have a deeper draft than it would have if it was floating in salt water. This difference is known as the Fresh Water Allowance (F.W.A.).

F.W.A. is a useful quantity to know. It is usually expressed in millimetres. In the example in Unit 1.3 the F.W.A. would be 20 mm. F.W.A. is the number of millimetres by which the mean draft changes when a ship passes from salt water to fresh water (or vice versa) when floating at its loaded draft.

LOAD DRAFT is the draft at which a vessel floats when loaded to her load displacement.

Tonnes Per Centimetre Immersion (T.P.C.)

The T.P.C. for any draft is the weight which must be loaded or discharged to change a ship's mean draft, in sea water, by one centimetre.

To find T.P.C. all that will be necessary is to calculate the weight of the additional water displaced when the draft is increased 1 cm.

To do this we would have to calculate the volume of the additional water displaced and multiply it by the density (1.025).

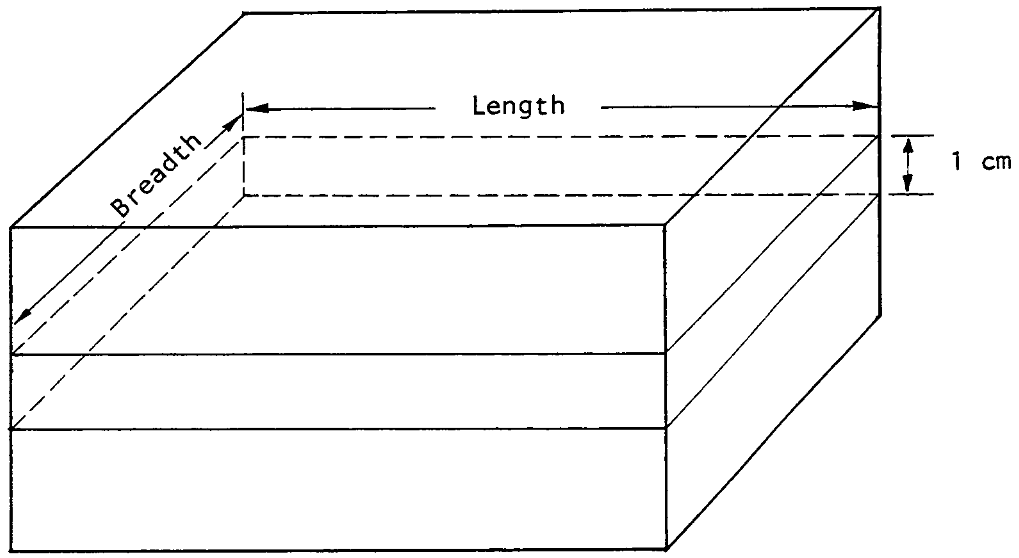


Fig. 1.8

Consider the block in Figure 1.8. If it had a length of 6m and a breadth of 3m its T.P.C. would be found as follows:

T.P.C. = Length × Breadth × 1 cm × Density

NOTE:

(i) $1\text{cm} = \frac{1}{100}$

(ii) Density of Sea Water = 1.025

(iii) Length x Breadth = Area of Waterplane (A_w)

When A_w is in square metres (m^2) this formula is good for all vessels.

For the block in Figure 1.8:

$$A_w = 6 \times 3 = 18\,m^2$$

$$\therefore \text{ T.P.C.} = \frac{1.025 \times 18}{100}$$

$$= \mathbf{0.185 \text{ tonnes per centimetre}}$$

Unit 1.5 Self-test Questions

1. (a) What is Archimedes' principle?

   (b) What is Relative Density and how can you express it as a ratio?

2. Calculate the relative density of salt water whose density is 1,025 kg/m^3.

3. Calculate the density of a fuel oil whose relative density is 0.92.

4. When a double-bottom tank is full of fresh water on a vessel, it holds 12 tonnes. Calculate how many tonnes of oil of relative density 0.84 it will hold.

5.

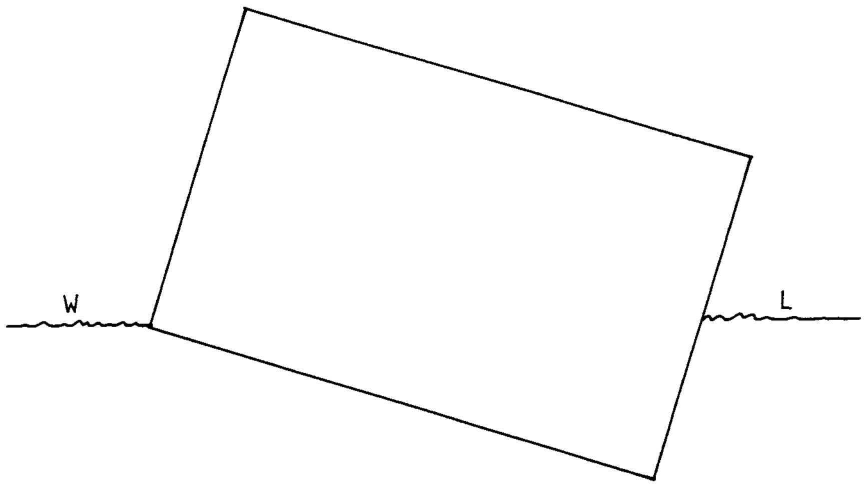


Fig. 1.9

Figure 1.9 shows a homogenous block of wood heeled over by an external force.

(a) Reproduce Figure 1.9 and show clearly the positions of G and B on your drawing.

(b) Sketch the same block floating in equilibrium when the external force has been removed. Show on your sketch the positions of G and B.

On both sketches draw arrows showing clearly the directions in which the forces of buoyancy and weight are acting.

6. A box-shaped vessel 10.5 m long, which has a 3 m beam and a 2 m height, is floating upright in fresh water. If it displaces 19.5 tonnes calculate the volume of reserve buoyancy and mean draft.

7. When a double-bottom tank is full of fresh water, it holds 12 tonnes. Calculate how many tonnes of oil of relative density 0.84 it will hold.

ANSWERS TO SELF-TEST QUESTIONS

Unit 1.5

1. (a) Every floating body displaces its own weight of the liquid in which it floats.

   (b) Relative Density refers to the comparison of density between a substance and the density of fresh water. It can be expressed in the following ratio:

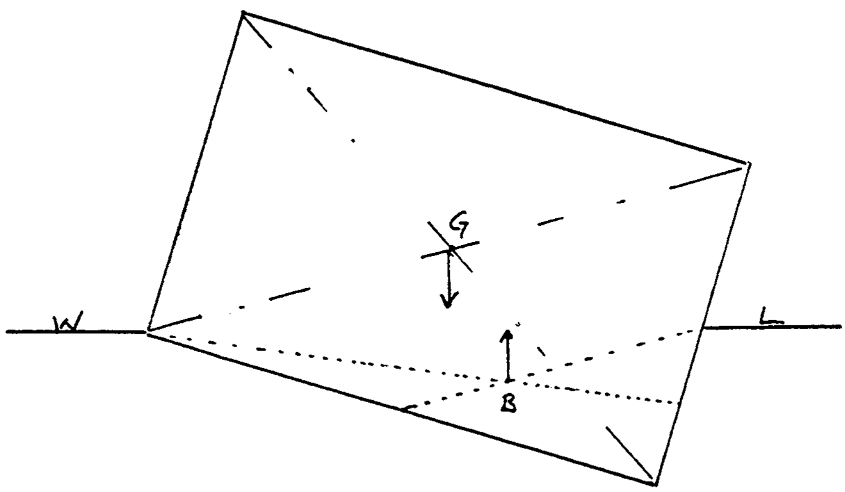
$$\boxed{RD = \frac{Density\ of\ Substance}{Density\ of\ Fresh\ Water}}$$

2.
$$\text{R.D.} = \frac{\text{Density of salt water in kg per m}^3}{1000}$$
$$= \frac{1025}{1000}$$
$$\therefore \text{ Relative Density of salt water } = 1.025$$

3.
$$\text{Density in per m}^3 = 1000 \times \text{S.G.}$$
$$= 1000 \times 0.92$$
$$\therefore \text{ Density } = 920\,\text{kg}/\text{m}^3$$

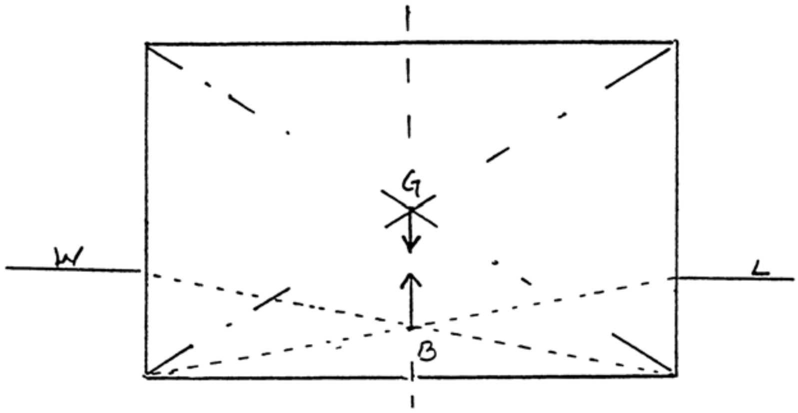
4.
$$\text{Relative Density} = \frac{\text{Mass of Oil}}{\text{Mass of Fresh Water (F.W.)}}$$
$$\therefore \text{ Mass of oil} = \text{Mass of F.W.} \times \text{Relative Density}$$
$$= 12 \times 0.84 \text{ tonnes}$$

5. (a)



The centre of buoyancy is the centre of the underwater section.

5. (b)



G = Centre of Gravity found by dividing the block (corner to corner)

B = Centre of buoyancy found by dividing the under section of the block

NOTE: G and B are vertically in line

6. $\text{Volume of vessel} = \text{length} \times \text{breadth} \times \text{depth}$

$$= 10.5 \times 3 \times 2$$

$$= 63\,\text{m}^3$$

$\text{Underwater volume} = \text{draft} \times \text{length} \times \text{breadth}$

$$19.5\,\text{m}^3 = \text{d} \times 10.5 \times 3$$

$$\text{d} = \frac{19.5}{10.5 \times 3}$$

$$\therefore \ \mathbf{draft = 0.6\,m}$$

Reserve buoyancy is volume of enclosed space above water

$$= 63 - 19.5$$

$$\mathbf{= 43.5\ m^3}$$

7. In case of fresh water:

$\text{Mass} = \text{volume} \times \text{density}$

$= 12\,\text{cubic metres} \times 1$ (relative density of fresh water is 1)

$= 12\,\text{tonnes}$

In case of oil:

$\text{Mass} = \text{volume} \times \text{density}$

$= 12\ \text{m}^3 \times 0.84$

$= 120.08\ \text{tonnes}$

TOPIC 2

LONGITUDINAL AND TRANSVERSE STABILITY

Syllabus

Learning Outcome

On completion of this learning outcome the learner will be able to apply stability principles to the safe operation of a small vessel.

Assessment Criteria

- Differentiate between transverse and longitudinal stability and explain the causes of list and trim
- Describe the movement of a vessel's centre of gravity and metacentric height when weights are loaded to, discharged from or shifted onboard a vessel
- Describe the conditions of stable, neutral and unstable equilibrium and explain the significance when a vessel is disturbed from the upright
- List the steps to be taken to bring an unstable vessel to a stable condition
- Describe the factors which will affect the rolling period of a vessel
- Describe the information contained in simplified stability data supplied to small vessels and explain how it is used to maintain the vessel in a stable condition during operations

Text

National Fishing Industry Training Committee: *An Introduction to Fishing Vessel Stability* (included in the Coxswain's section of this learning resource)

SECTION 2A

LIST AND TRIM

In this Section we will be looking at List and Trim in greater detail than is given in your text.

Objectives

By the end of this Section you should be able to:

- explain what is meant by the terms Longitudinal and Transverse, and relate these to the centres of gravity and centres of buoyancy in ship-shaped vessels
- predict the direction of the change in position of the centre of buoyancy with a change in draft
- explain the association between list and movement of the centre of gravity and centre of buoyancy, off the centre line of a vessel
- explain the association between trim and the movement of the longitudinal centres of gravity and buoyancy with respect to each other.

Unit 2A.1 Longitudinal and Transverse Centres of Gravity and Centres of Buoyancy

We frequently refer to the Longitudinal Centre of Gravity (LCG) or the Longitudinal Centre of Buoyancy (LCB).

The dictionary defines Longitudinal as "pertaining to longitude or length".

We use LCG and LCB when studying Trim.

Figure 2A.1 shows a longitudinal profile of a vessel. The position of LCB and LCG are shown relative to the length of the vessel:

FP is the Forward Perpendicular. AP is the After Perpendicular.

It must be remembered that LCB and LCG are in exactly the same position as the transverse centre of buoyancy and the transverse centre of gravity of the vessel.

The dictionary defines Transverse as "lying or being across, or in a crosswise direction; athwart".

When considering the list of a vessel we frequently study the locations of the Transverse Centre of Gravity (TCG) and the Transverse Centre of Buoyancy (TCB) (see Figure 2A.2).

In both cases, transverse and longitudinal, it is usual to simply label the positions of the centres of gravity and buoyancy as G and B respectively.

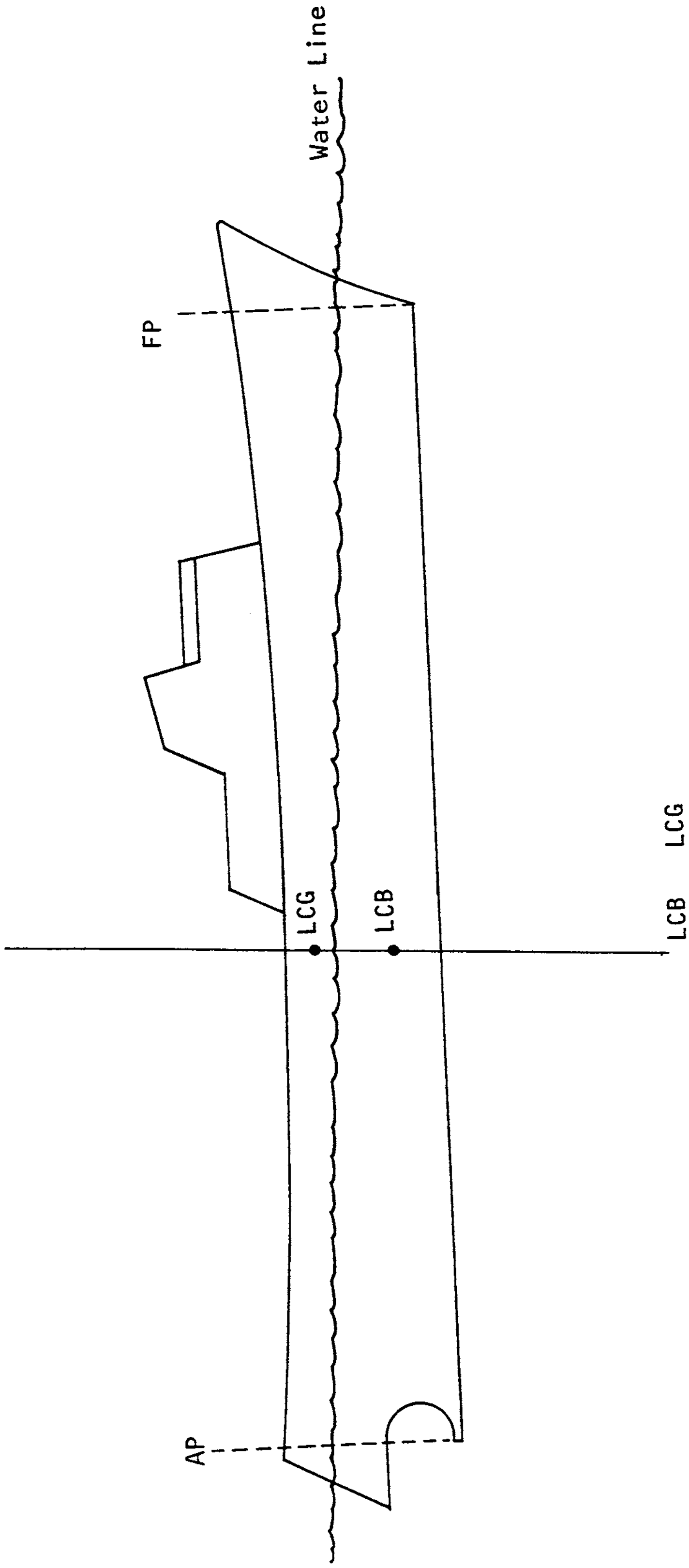


Fig. 2A.1 Longitudinal centre of buoyancy and longitudinal centre of gravity

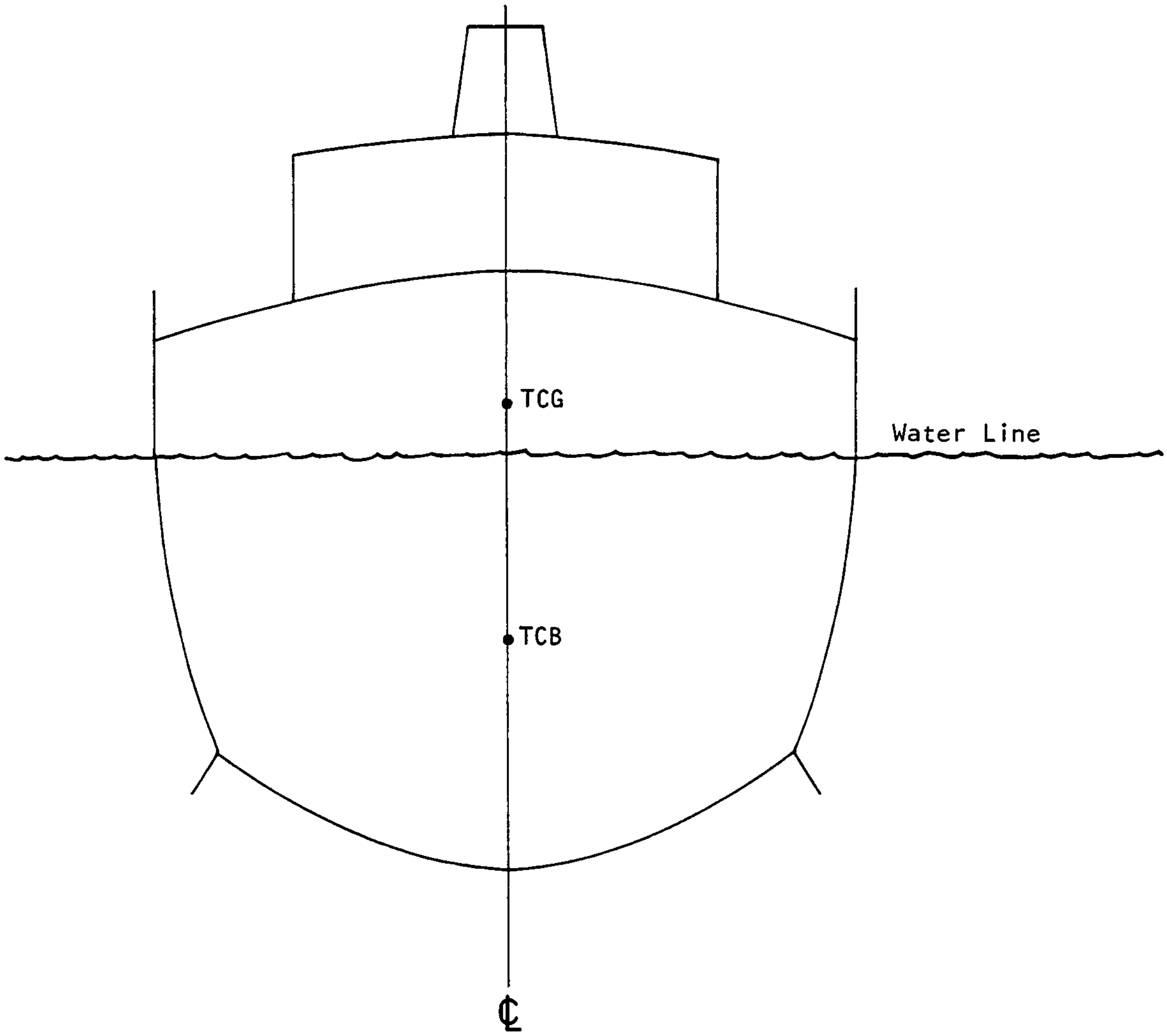


Fig. 2A.2 Transverse centre of gravity and transverse centre of buoyancy

Unit 2A.2 Changes of B with Draft

In order to be able to predict the change in B with draft, it is necessary to have an appreciation of the underwater shape of the vessel. In nearly all cases, the bow of a vessel is finer than the stern, and the underwater volume of the vessel is greater aft of midships than forward.

Figure 2A.3 shows a lines diagram of a small, round-bilge hull form vessel. The line plans show the contours of the vessel at regular stations along its length (body plan), its breadth (profile plan) and its depth (half-breadth plan).

Studying the half-breadth plan, it is easy to see that, as the draft increases from Waterline 1 (WL 1) to Waterline 2 (WL 2) and on to the Load Waterline (LWL), the water plane area not only increases, but its geometric centre moves aft. It follows therefore, that the geometric centre of the underwater volume (Centre of Buoyancy) should also move aft with an increase in draft. This, in fact, is true for nearly all vessels.

Figure 2A.4 shows the change in the position of the Longitudinal Centre of Buoyancy with a change in draft.

As the draft increases from WL 1 to WL 2, the position of B moves from B_1 to B_2.

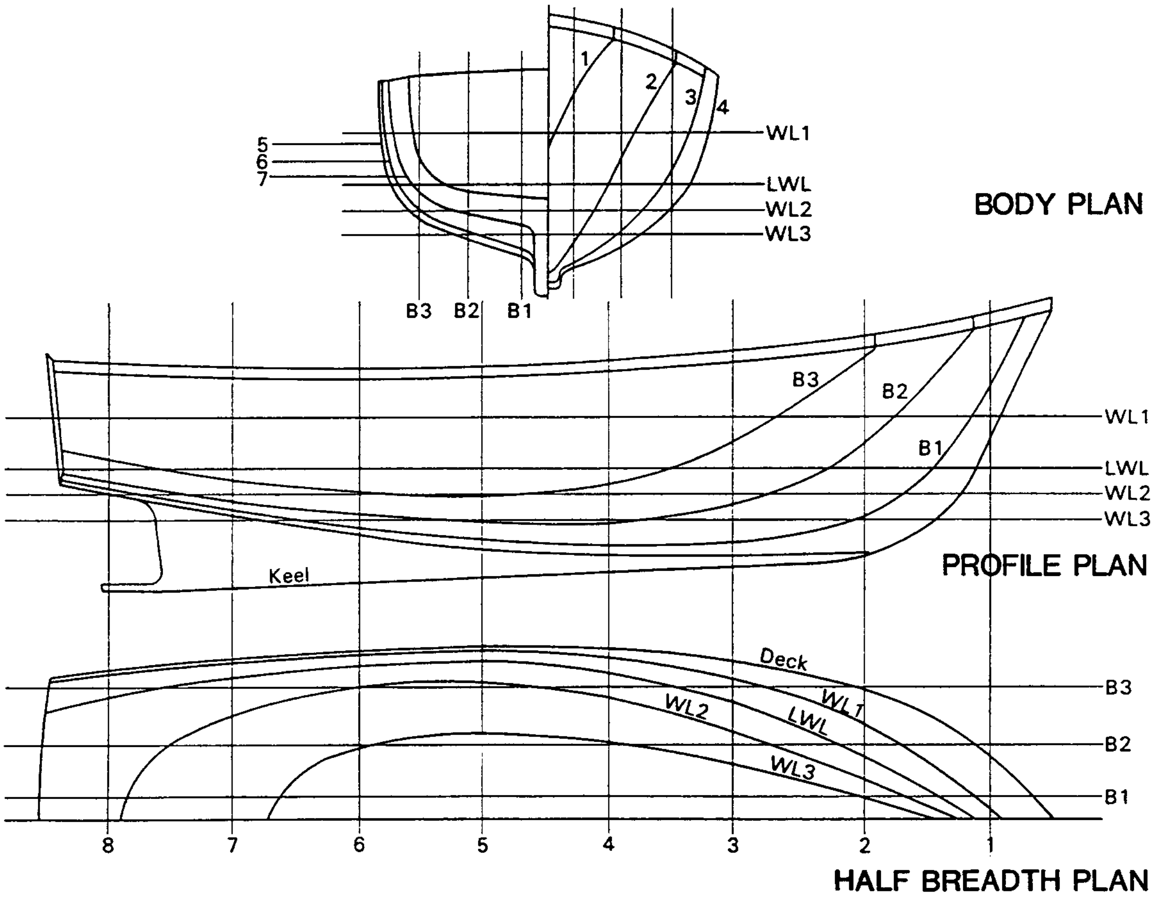


Fig. 2A.3

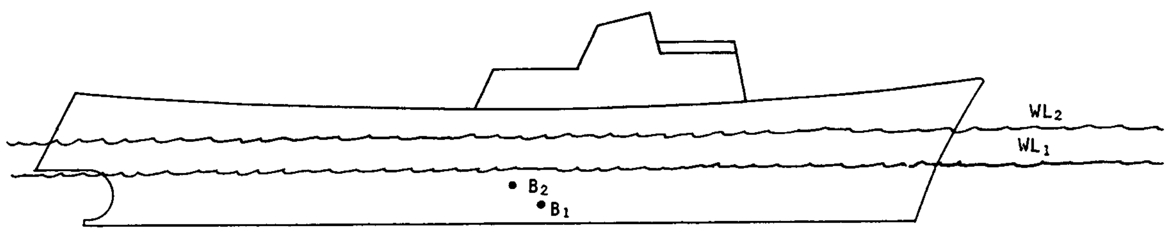


Fig. 2A.4 Movement of B with change in draft

Transverse Centre of Buoyancy

The TCB behaves in a similar manner, but instead of moving upwards and aft with an increase in draft (as does the LCB), the TCB only moves upwards and downwards while the vessel is upright. In Figure 2A.5, once again, as the draft changes from WL 1 to WL 2, the geometric centre (B) moves from B_1 to B_2 and vice versa.

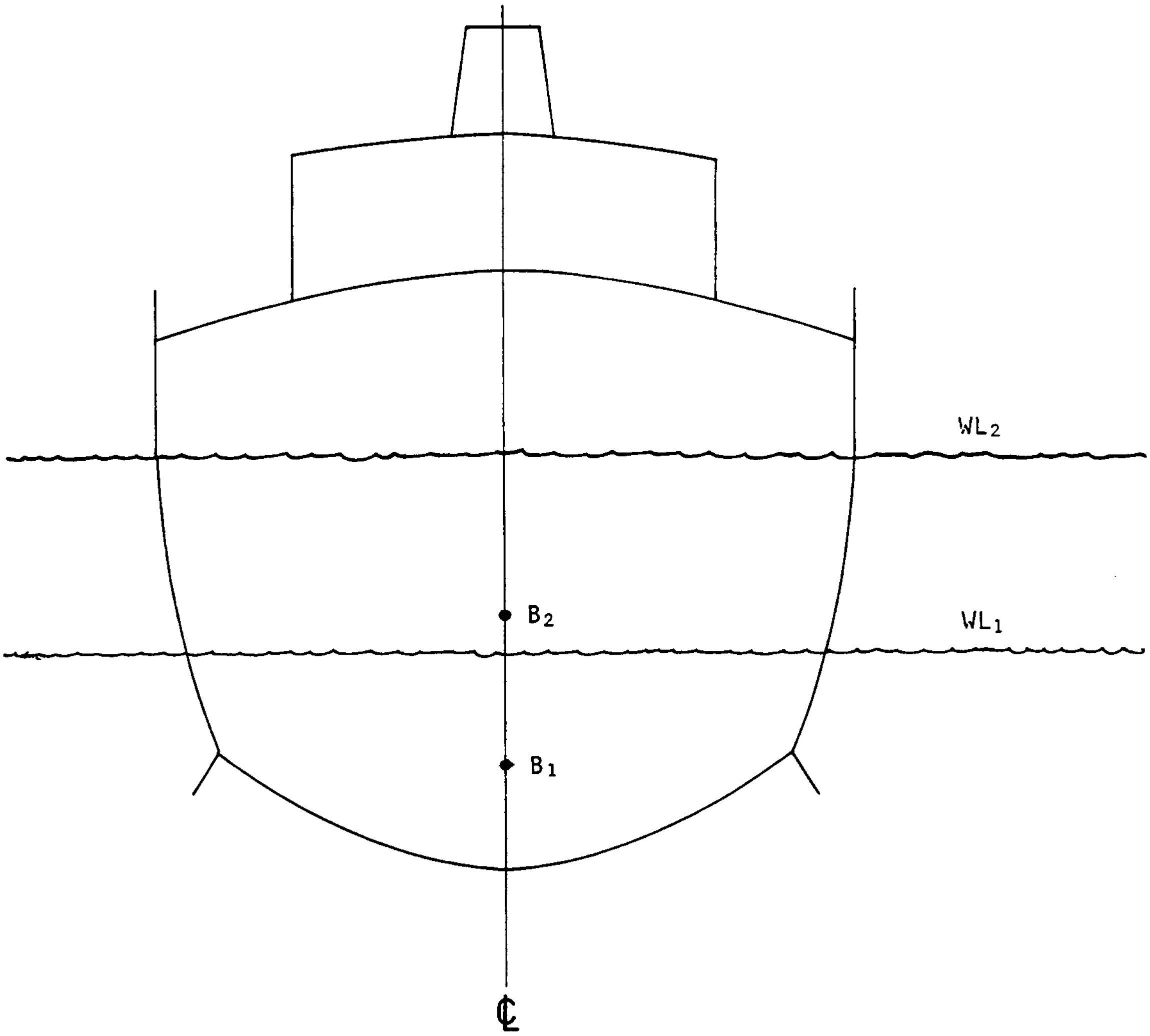


Fig. 2A.5 Change of B with draft

Unit 2A.3 List

For a vessel to float upright, both the centre of gravity and the centre of buoyancy must be on the transverse vertical centre line (see Figure 2A.6).

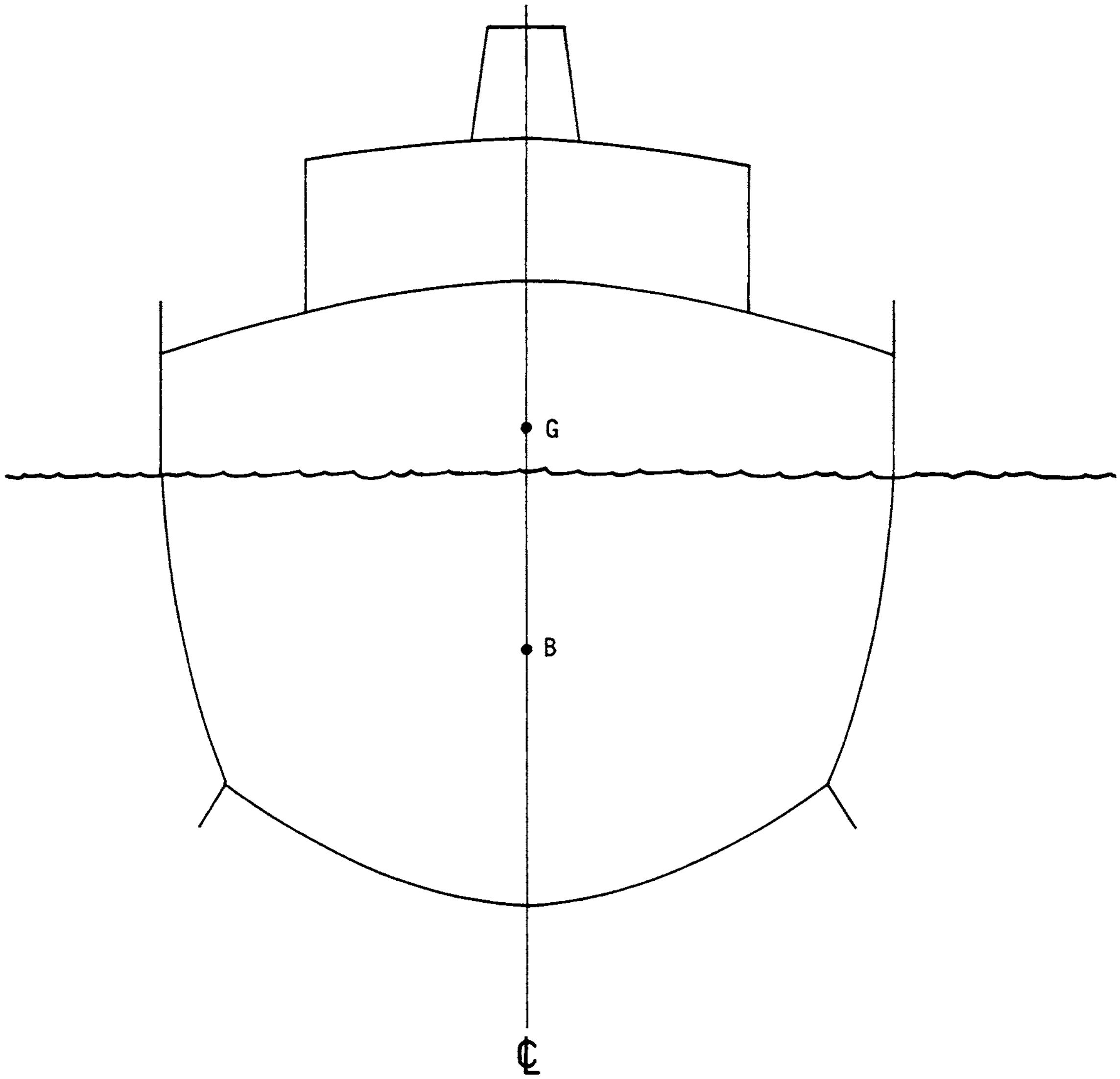


Fig. 2A6 Upright freely floating vessel

Imagine what would happen if G was not on the centre line (see Figure 2A.7).

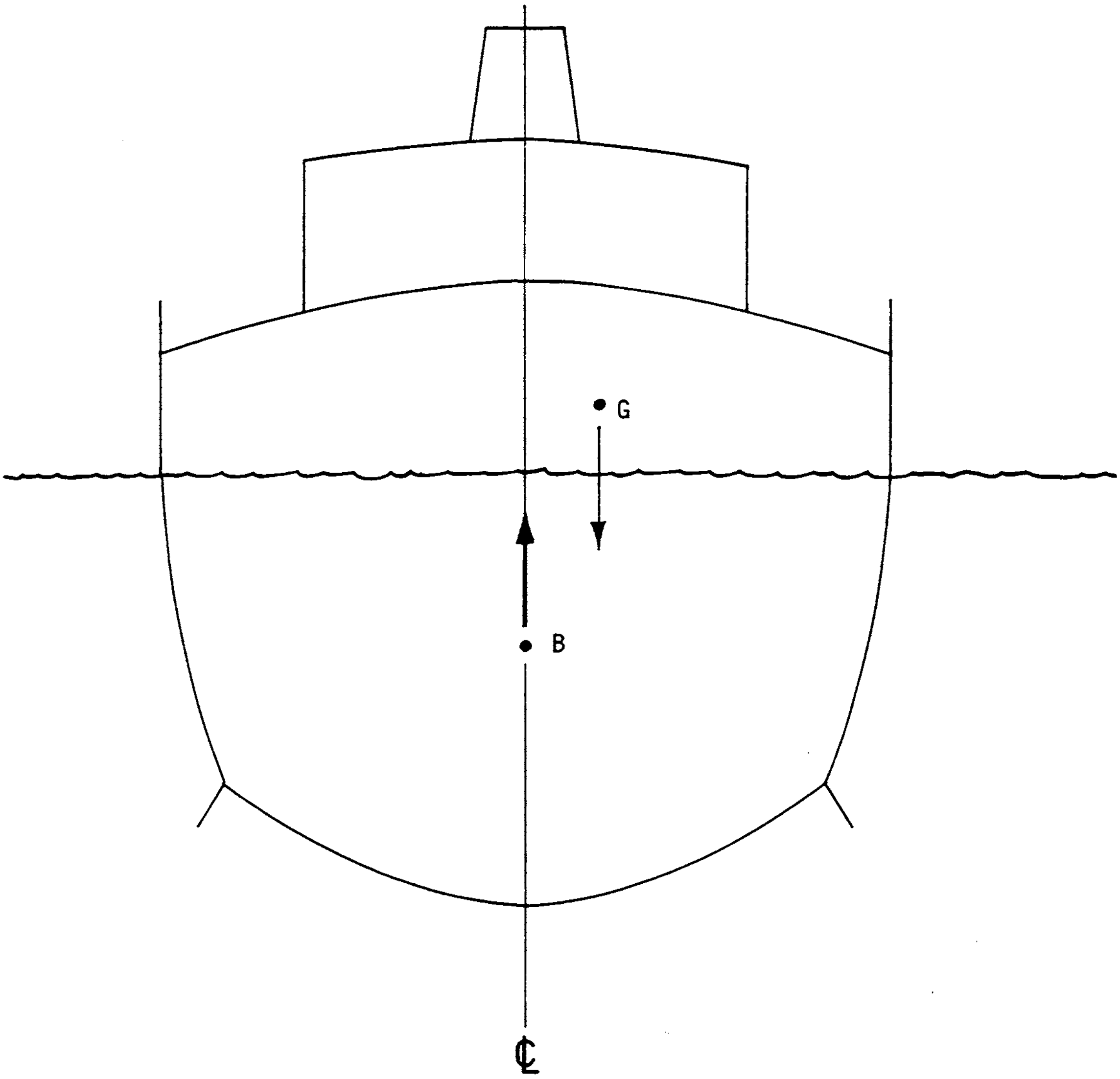


Fig. 2A.7 Displacement of G required to produce a list

The weight acts directly downwards, the force of buoyancy vertically upwards, and the vessel will experience a clockwise turning moment (the listing moment) which will cause it to roll over.

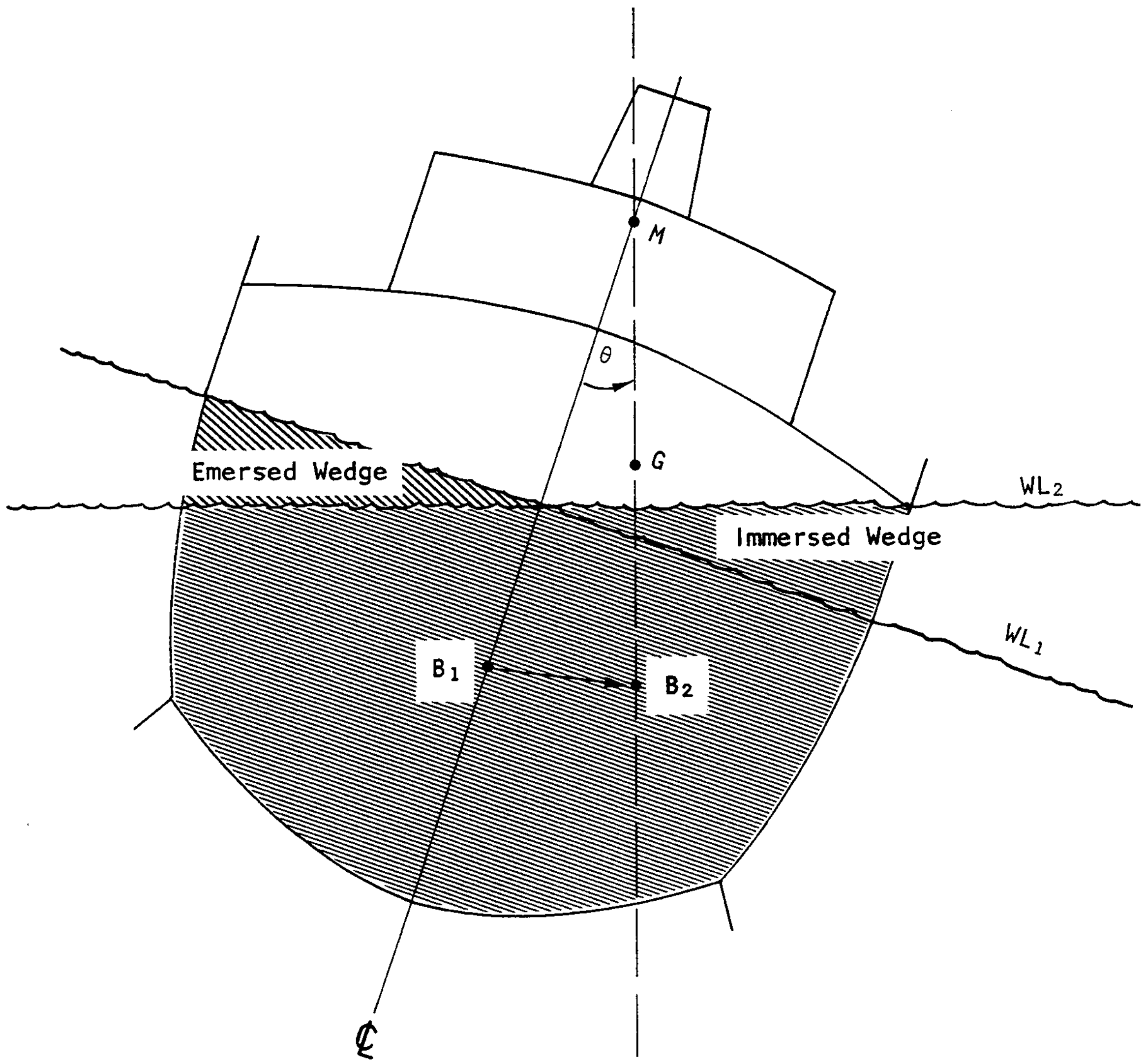


Fig. 2A.8 Resultant list

As the vessel rolls, the low side of the vessel becomes submerged and the high side emerges from the water. This results in a change in the shape of the underwater volume. The entire volume of the emersed wedge shown in Figure 2A.8 is effectively relocated in the position of the immersed wedge between WL_1 and WL_2. Since B is still located at the geometric centre of the underwater section, it begins to move to the right. When B eventually reaches a position where it is directly underneath G, equilibrium is reached (the forces of B and G are equal and opposite) and the vessel will float at an angle of list, 0°. If the situation arose where B never reached a position directly underneath G, the vessel would capsize.

The vertical line passing through B_2 and G intersects the centre line at M. For small angles of heel this position is regarded as the metacentre. The height of the metacentre above G is used in determining the stability of a vessel. More about this will be discussed in Section 3.

Unit 2A.4 Trim

For a vessel to float at equilibrium on an even keel with no trim, the centres of buoyancy, flotation and gravity must be in the same vertical line (see Figure 2A.9).

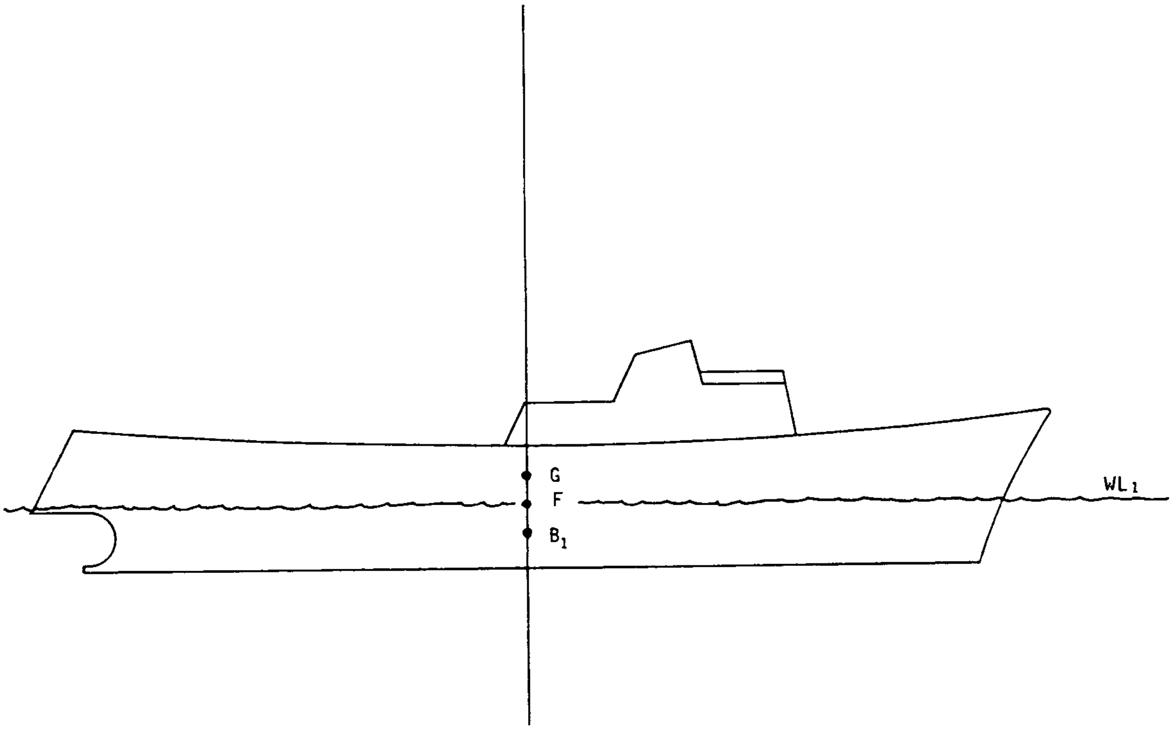


Fig. 2A9 Vessel floating on even keel

Trim may be regarded as a type of longitudinal list. Consider Figure 2A.10. When the vessel is on even keel, G and B are not in the same vertical line. The vessel will experience an anti-clockwise turning moment (trimming moment) causing a negative trim.

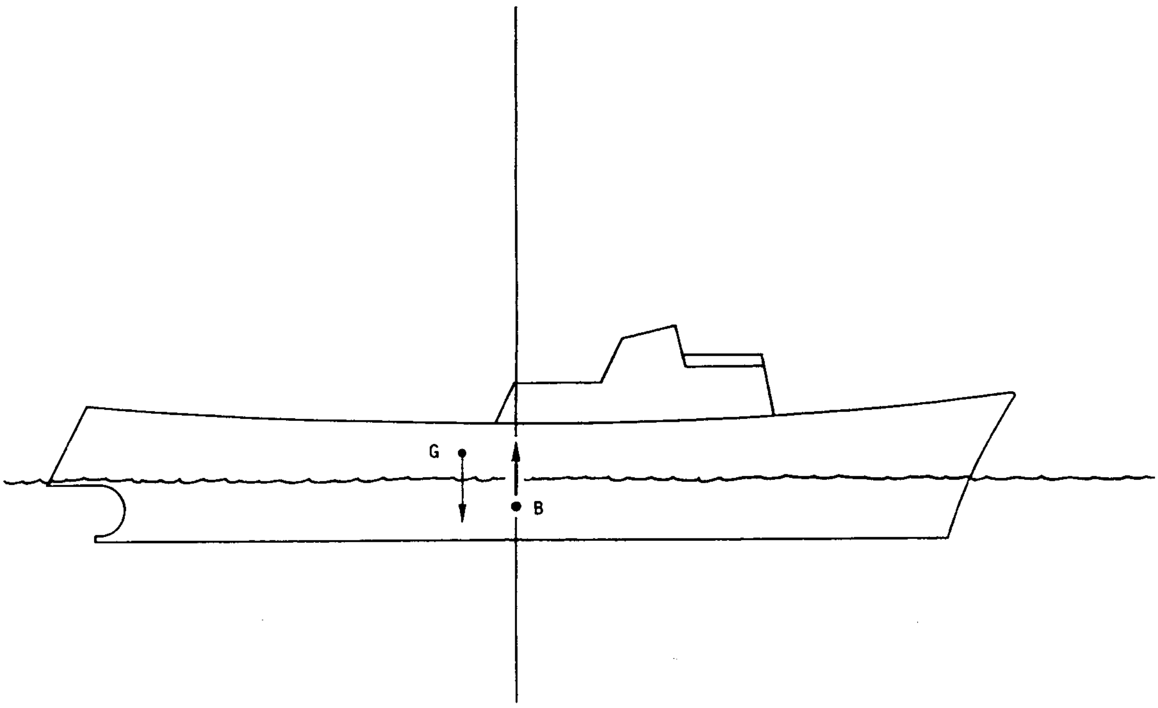


Fig. 2A.10 Displacement of G to produce a trim

As a result, the stern will begin to sink and the bow to rise. B will begin to move aft as the underwater volume increases aft and decreases forward. When B reaches a position where it is directly below G, equilibrium has been reached and the vessel will float with an angle of trim, 0°. We measure trim, however, by the difference between the fore and after drafts:

TRIM = FORE DRAFT – AFTER DRAFT

If the answer is negative (–, or minus) the trim is by the stern; if positive (+, or plus) the trim is by the head.

The vertical line passing through B_2 and G intersects the old vertical line passing through B_1 at M_L. This is the longitudinal metacentre. The height of ML above G is commonly referred to as GM_L (See Figure 2A.11).

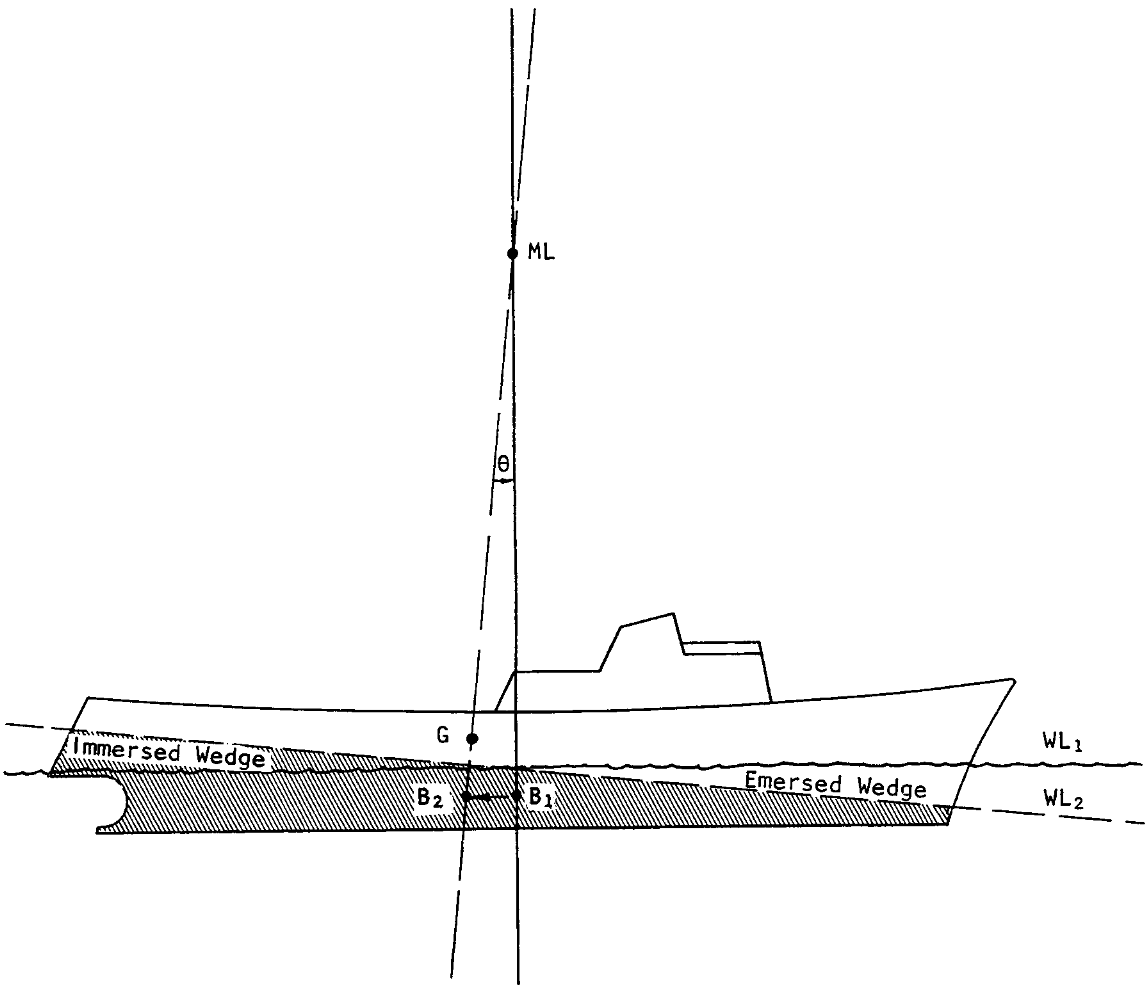
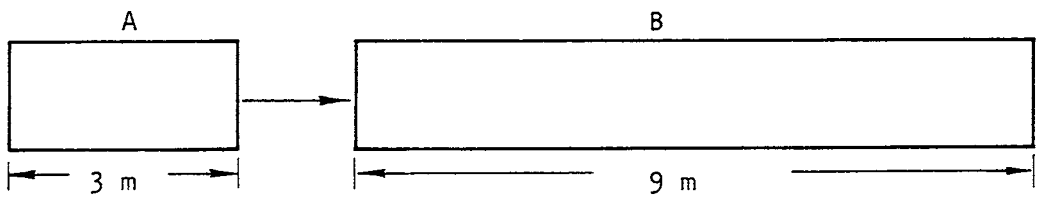


Fig. 2A.11 Resultant trim

Unit 2A.5 Self-test Questions

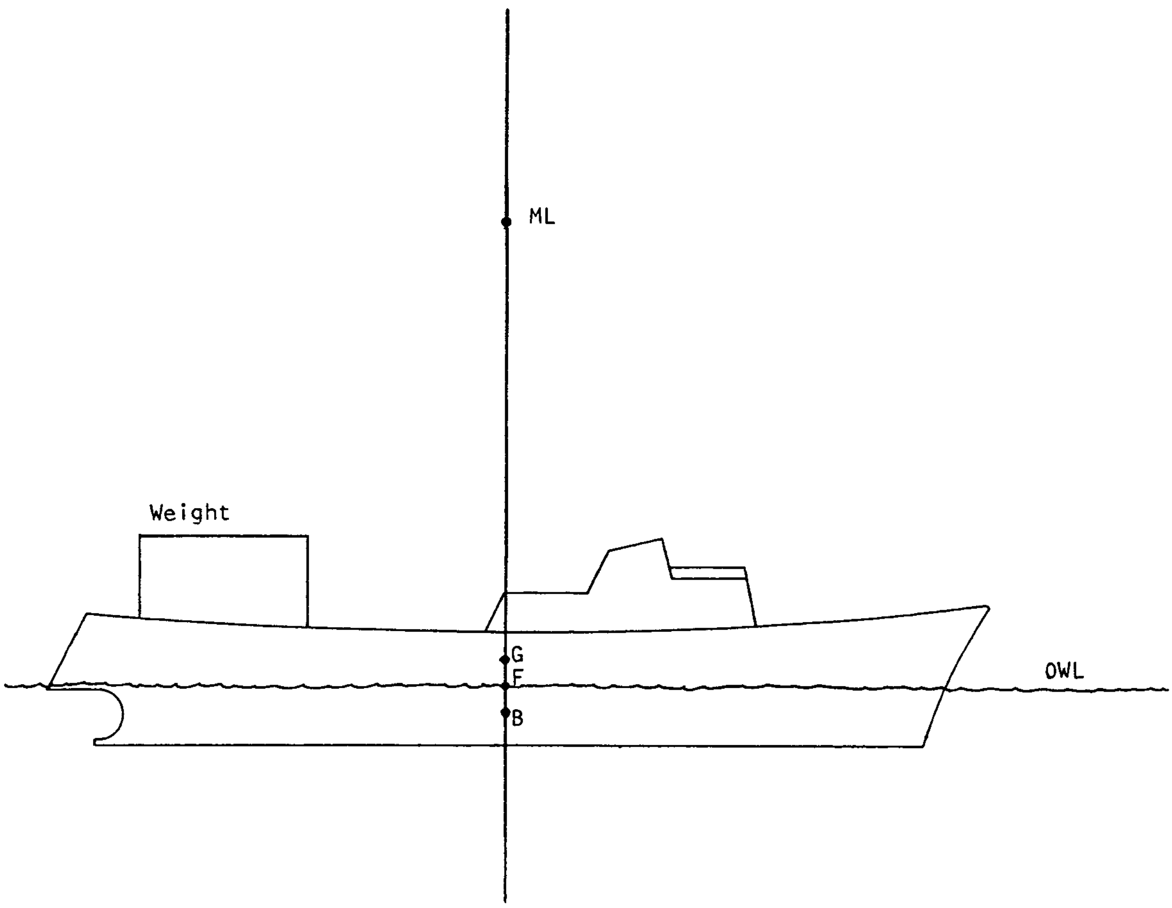
The answers to these questions are to be found at the end of this Section.

1. Explain what happens to the position of the centre of gravity when block A is joined to block B to form one unit.



They are rectangular blocks with identical cross-sectional dimensions.

2. A vessel is floating upright and on an even keel. A weight is loaded on the after deck. Show with a sketch the positions of the old and new centres of gravity, flotation, buoyancy, and the old and new waterlines. Show also a possible position of M_L and the angle of trim 0.



3. In Question 2, is this a positive or a negative trim?

4. Is this a desirable state of trim?

5. Using the sketch provided, show what would happen to the vessel if a weight was loaded on the deck in the position indicated. Show the positions of:

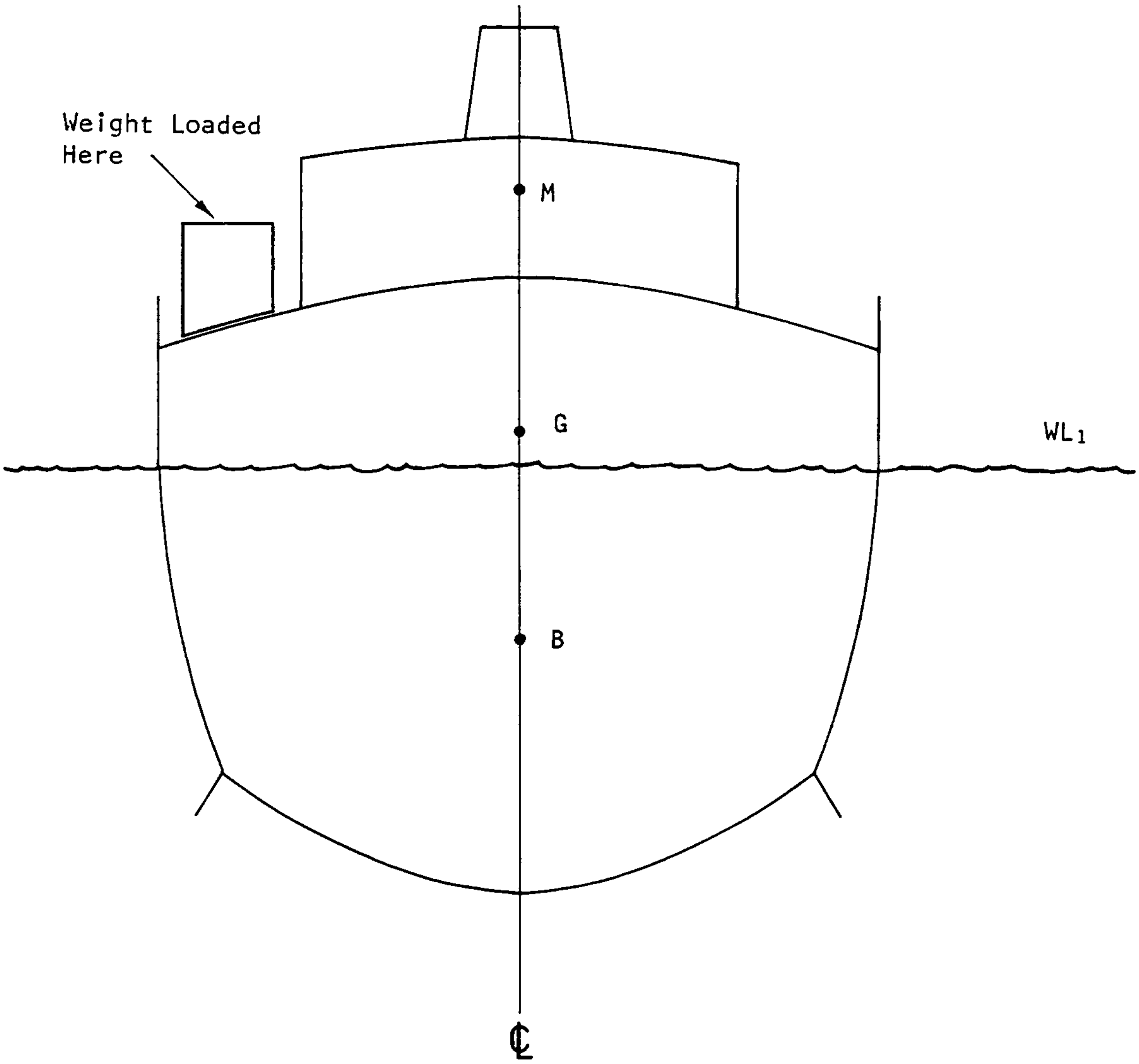
   (a) G_1

   (b) B_1

   (c) angle of list

   The weight is not heavy enough to capsize the vessel.

   Also indicate the new waterline.



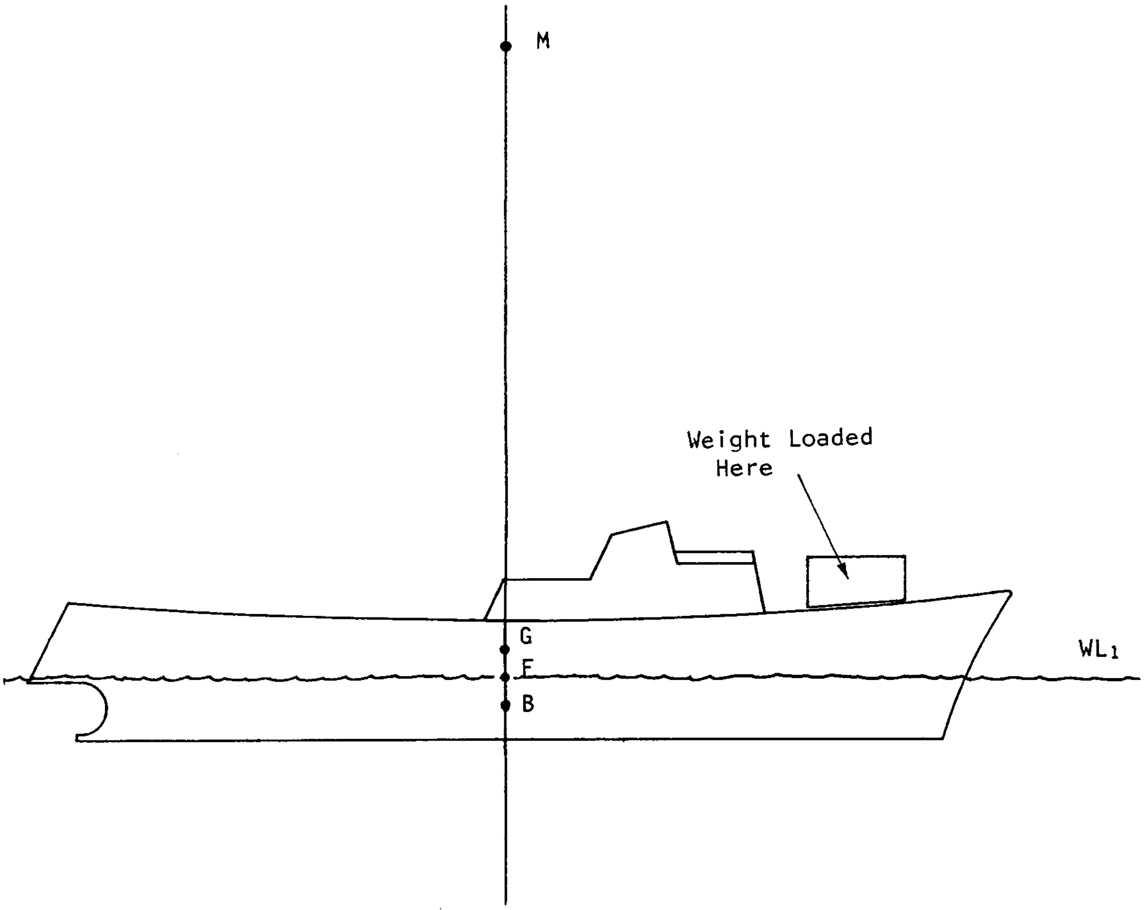
6. A vessel is floating on an even keel with the positions of B, G and F in the positions indicated. A weight is loaded on the fore deck as shown. Indicate on the sketch:

   (a) (i) The new positions of B, G and the new waterline

       (ii) The angle of trim

   (b) Is this trim positive or negative?

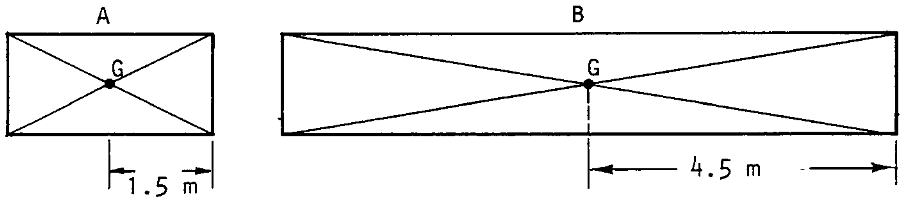
   (c) Is this desirable? Explain why.


M
Weight Loaded
Here
G
F
B
WL1

ANSWERS TO SELF-TEST QUESTIONS

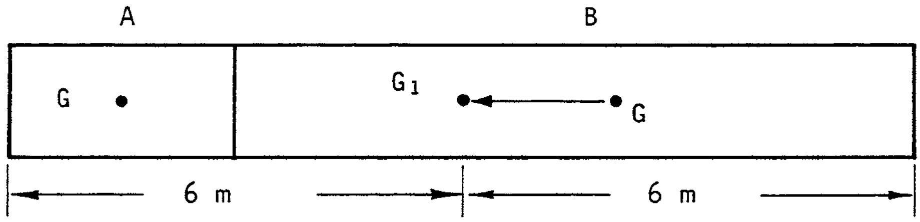
Unit 2A.5

1.



GA is located 1.5 m from the ends of block A.

GB is located 4.5 m from the ends of block B.

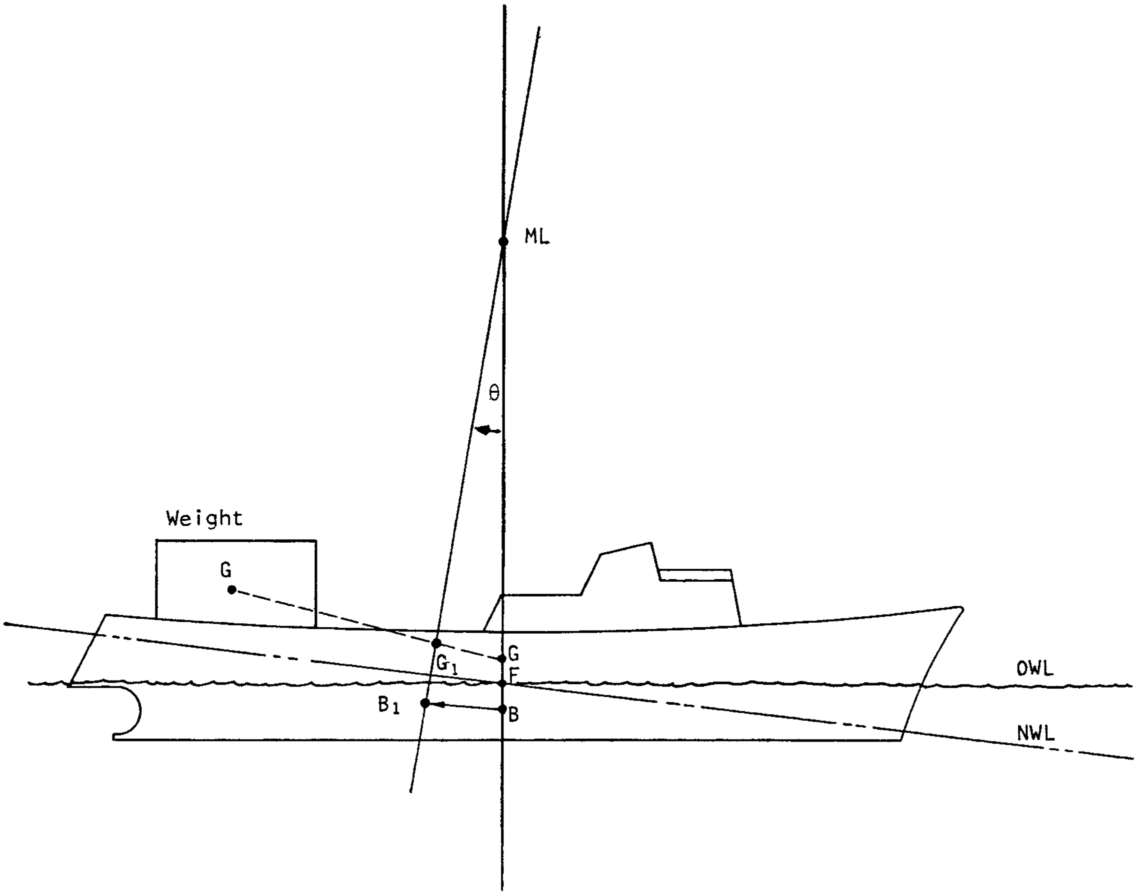


The final position of G is located at G_1, 6 m from either end.

Conclusion:

When a weight is added to a body, the position of G will shift to G_1. The line GG_1 is along the line connecting the two centres of gravity – the original body and the added weight.

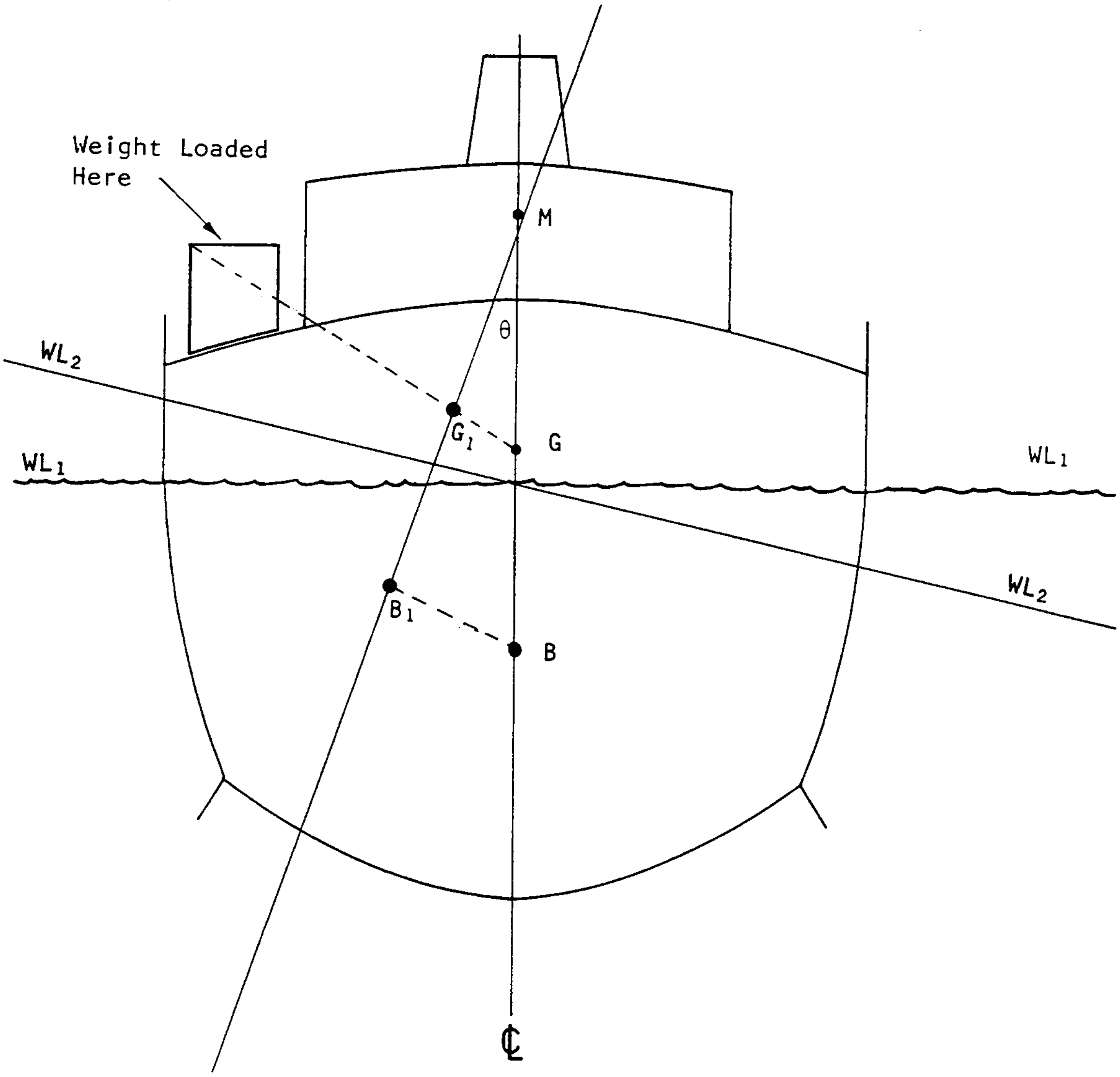
2.



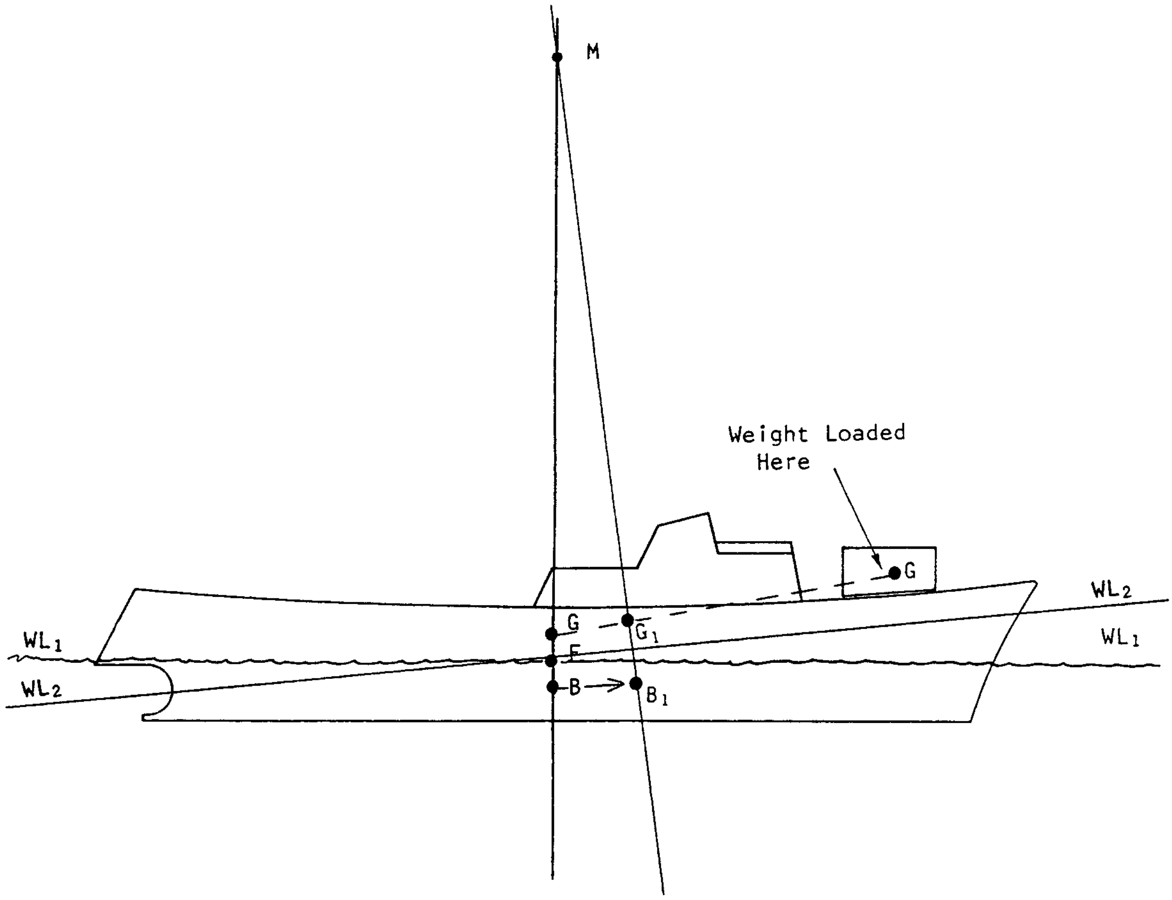
3. The vessel has a negative trim; ie, trim by the stern.

4. Yes. It is generally more desirable to be trimmed by the stern than by the head. Your rudder and propeller are more effective.

5.



6. (a)



(b) Trim is positive.

(c) Not a good trim. Vessel likely to take water over bow. More tendency to broach in a seaway. Rudder and propeller less effective.

SECTION 2B

STABILITY IN SEAWAY

We have so far discussed vessels in calm waters. Stability as related to wooden blocks has also been considered. While the wooden block analogy has its uses, very few of us will ever put to sea on a wooden block.

The time has come to leave behind the wooden blocks and dead calm seas and consider stability in a more realistic sense. In this Section, we will be discussing the factors affecting a vessel's stability in a seaway, as well as the way she would behave.

Objectives

By the end of this Section, you should be able to:

- define, with respect to ship-shape vessels, the following terms:
  - (a) metacentre
  - (b) metacentric height
  - (c) righting lever
- define stable, unstable and neutral equilibrium
- explain with the aid of diagrams the significance of three conditions of equilibrium when a vessel is disturbed from rest
- explain with the aid of sketches the relationship between metacentric height and righting lever
- explain the terms 'range of stability', 'flooding angle' and 'loll'.

Unit 2B.1 Righting Lever (GZ)

It is now necessary to consider the actual forces that work together to give a vessel the ability to return to the upright position when forcibly inclined by an external force.

We are already familiar with the terms G (Centre of Gravity) and B (Centre of Buoyancy); it does not matter if G is above or below B. The two important facts are that G is fixed (for a particular condition of loading) and, providing weights cannot move, will remain fixed even when the vessel is forcibly inclined. B, however, changes position every time the underwater volume of the vessel changes. Let us now consider this phenomenon. Figure 2B.1 shows a vessel in the upright position; Figure 2B.2 shows the same vessel when forcibly inclined by an external force:

Because the underwater volume has changed, B moves to B_1 (the new Centre of Buoyancy). If we now further study Figure 2B.2, we should be able to see that G will continue to act vertically downwards, and B_1 will continue to act vertically upwards. However, they no longer act in an equal and opposite direction (Figure 2B.3).

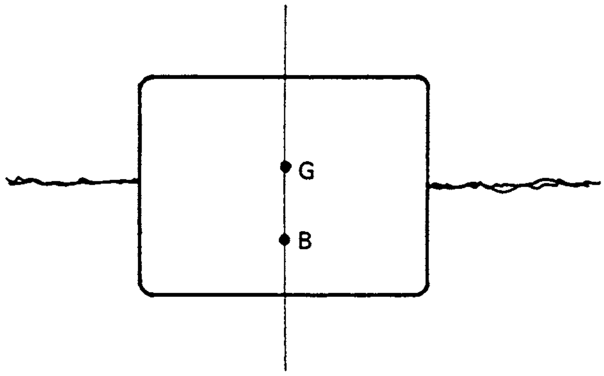


Fig. 2B.1

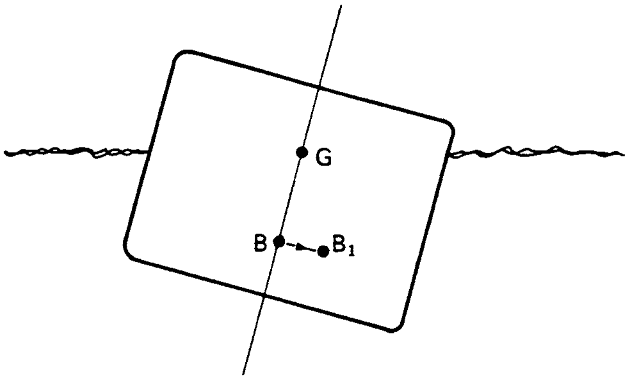


Fig. 2B.2

In effect, a righting couple has been formed. If we construct a line from G at right angles to the force of G, it will meet the upwards force of B_1 at a point which is called Z. In effect, GZ is the righting lever between G and B_1.

If we draw in the upwards force of buoyancy from B_1 at some point, it will cut the centre line of the vessel. This point is known as M (the *Metacentre*). For small angles of heel (up to 15°) M can be considered to be a fixed point.

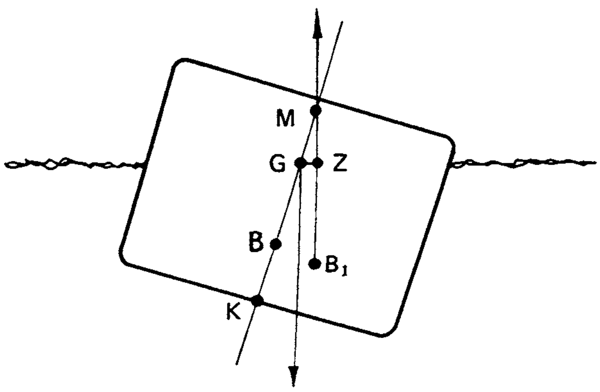


Fig. 2B.3

Thus the forces of G and B combine together through the righting level (GZ) to produce a righting moment which will return the vessel to the upright position and the forces of G and B once again cancel each other out.

The terms GZ, GM and KM should be committed to memory as they constitute the basics of ship stability.

Unit 2B.2 Equilibrium

From the foregoing unit, it is possible to now define 'upright'. In general terms, it can be stated that for a vessel to be in an upright condition the points G, B and M must be in the same vertical line, but does this necessarily mean that the vessel is stable? In other words, has the vessel the ability to return to the upright after being forcibly inclined?

In reality, there are three possible conditions that a vessel can be loaded to:

- Stable Equilibrium
- Neutral Equilibrium
- Unstable Equilibrium

(a) Stable Equilibrium

The term *stable equilibrium* refers to a vessel when forcibly inclined, having the ability to return to her original position (see Figure 2B.4).

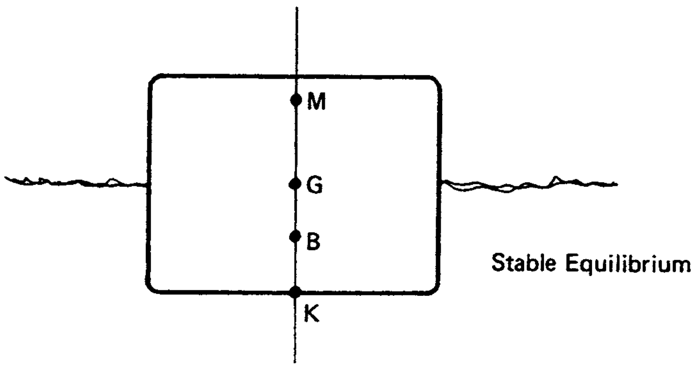


Fig. 2B.4

If the vessel in Figure 2B.4 is now forcibly inclined, B will move to B_1 and the righting moment will return the vessel to its original position (see Figure 2B.5).

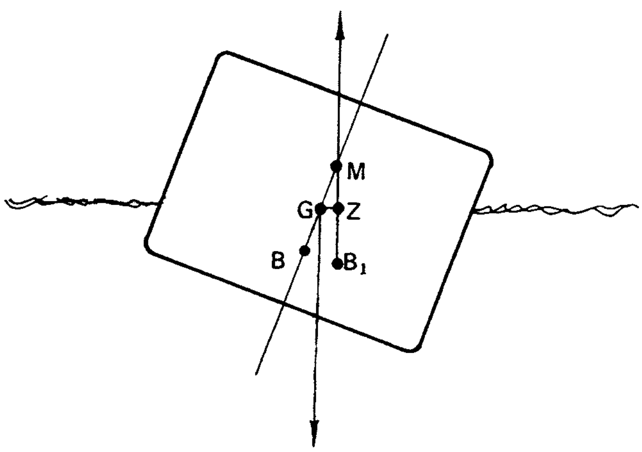


Fig. 2B.5

This will apply whether B is above or below G and also if the vessel is listed already.

(b) Neutral Equilibrium

The term *neutral equilibrium* refers to a vessel, when forcibly inclined, tending to remain at that angle of heel until another external force is applied.

For this to occur the position of G must be the same as M; that is, zero GM. Figure 2B.6 should clarify this point for you.

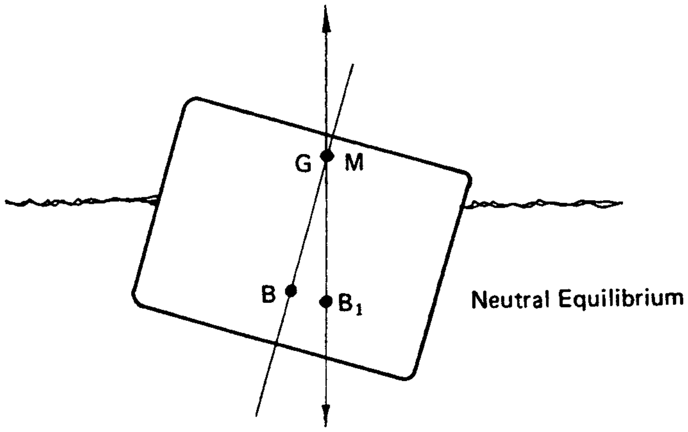


Fig. 2B.6

(c) Unstable Equilibrium

The term *unstable equilibrium* refers to a vessel, when forcibly inclined, being inclined to heel over further; that is, the righting moment wants to capsize the vessel altogether. For this to occur, G must lie above M (see Figure 2B.7).

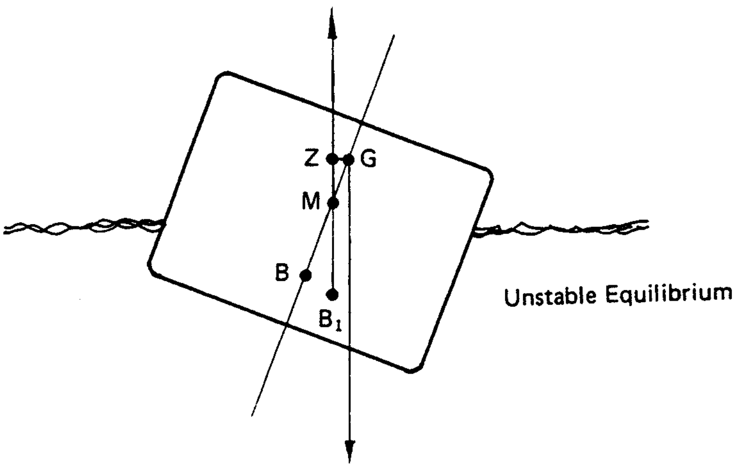


Fig. 2B.7

(Figure 2B7 should be compared to Figure 2B.5.)

Thus, for a vessel to have unstable equilibrium she must have what is called 'negative GM'.

Fortunately in this instance as will be seen in a later unit, the vessel will not continue to capsize although unstable equilibrium and the resultant state are extremely dangerous.

Unit 2B.3 Metacentric Height (GM)

It should now be apparent that there is a direct relationship between the position of G, M and GM or the *metacentric height*.

The larger the GM, the larger the righting lever GZ will be for any given angle of heel. The larger the GZ the larger the righting moment.

Thus a vessel with a large GM, when forcibly inclined, will return to its original position quicker than a vessel with a small GM. The motion of a vessel with a large GM can be violent, after being forcibly inclined, as she returns to her original position. Such a vessel is said to be "STIFF".

A vessel with a small GM will have a much smoother, slower motion and will be very comfortable. Although comfortable this condition is not desirable and it is very close to neutral equilibrium. A vessel in this condition is said to be "TENDER".

Neither condition is desirable and a compromise between the two must be reached.

Unit 2B.4

It was stated earlier that the position of M was only considered to be fixed for small angles of heel (up to 15°). It was also stated that, for a vessel with a negative GM, the vessel would not necessarily capsize.

It is because of the fact that M is not fixed at larger angles of heel that an unstable vessel will not necessarily capsize.

If we consider the underwater volume of a vessel as she is inclined further, so B will continue to move towards the low side. At some angle of heel B will again lie below G (see Figure 2B.8).

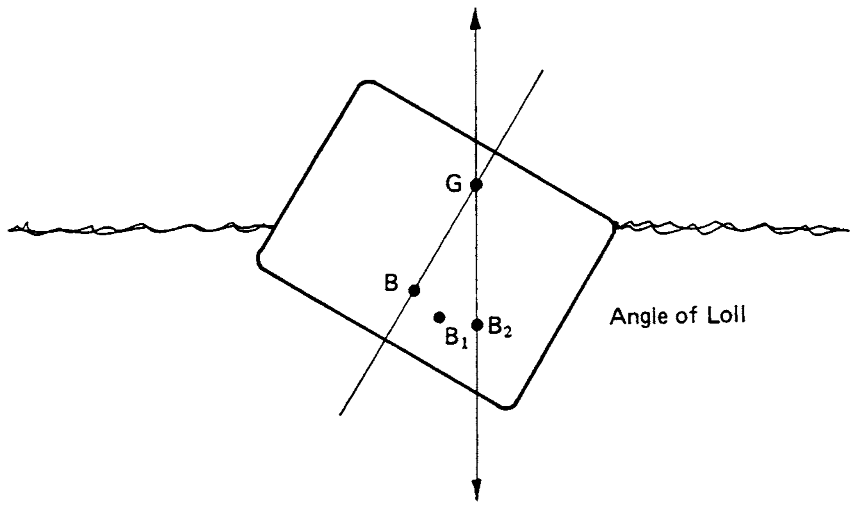


Fig. 2B.8

As the vessel is forcibly inclined, so B will move to B_1 and then B_2. When it is directly below G, the vessel is once again in neutral equilibrium. The angle of heel at which she regains stability is known as the "ANGLE OF LOLL".

Any further inclination by external forces will once again produce a righting moment (Figure 2B.9).

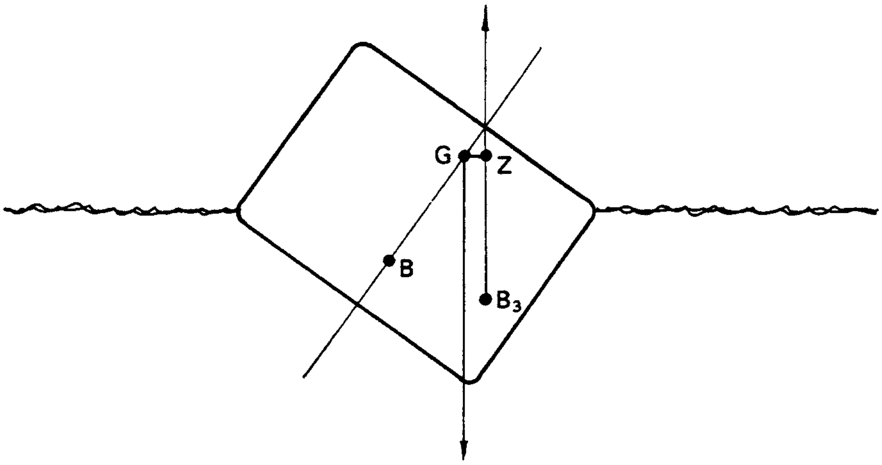


Fig. 2B.9

This righting moment will cause the vessel to return to the point at which she became stable (the angle of loll). In effect she will now oscillate around the angle of loll. It should be emphasised that, if the *centre of buoyancy* cannot move out far enough to get vertically under G, then the vessel must and will capsize.

A further source of danger is that of the external forces being strong enough to rotate the vessel back through the upright position. Should this happen, the vessel will flop heavily onto the other side and in all probability capsize, as any righting moments produced will not be strong enough to overcome this movement.

From the above it should be obvious that not only is an angle of loll undesirable but it is also very dangerous.

There are only two reasons why your vessel would suddenly heel over while at sea, and then remain heeled over. The first is a list caused by shifting cargo or weights. You should be able to determine quickly if that is the case. The other is loll caused by a negative GM. If this is the case you must waste no time in taking steps to lower your centre of gravity.

If you have slack water in your ballast tanks, pump them up, filling the tanks on the low side first. The last thing you want is your vessel to flop over to the other side - which will happen, if you fill the high side's tanks - with the possibility of disastrous consequences.

If you don't have slack tanks, or you have no ballast tanks at all, you must re-stow your deck cargo as low down as possible. Have all your crew sit as low as possible in the boat. If there is no way you can restow your deck cargo so that it is lower in the boat, then you have no alternative but to jettison it. This may be a painful decision to a fisherman whose gear on deck is causing the stability problem, but the gear is no use to him when he's dead and it cannot be used when his boat is upside down!

Factors affecting the rolling period

There are two main factors affecting the movement of a vessel in a seaway: the sea state and the vessel's roll period.

A vessel disturbed in still water will have a natural roll period. Whilst the size of the roll will decrease the period will stay the same. This is the natural roll period of the vessel, like the period of a pendulum.

The roll period depends on the beam of the vessel, height of G and can be modified by moving weights outboard. In practice, only the centre of gravity is adjustable by the master through the use of tanks, positioning of cargo and the movement of passengers.

Once in a seaway, the situation becomes complex as there is a natural period for the sea waves and the swell waves which are also interacting with each other. As the vessel moves through the sea there is now an apparent wave period, similar to the true/relative (apparent) wind.

When the apparent wave period becomes similar to the vessel's own natural period then synchronous rolling takes place where the movement of the sea reinforces the rolling of the vessel. This can cause the vessel to go to large angles and may capsize.

The roll period is also an indicator of a vessel's stability.

The metacentric height can be found approximately by the formulae: GM = $(0.8 \times \text{Beam/ Roll period})^2$.

The roll period is the time from upright to upright going in the same direction. It should be done over several rolls and averaged. This formulae depends on the .8 which would vary from .88 for a small cargo vessel in ballast to .75 for a fully laden cargo vessel.

Unit 2B.5

Turn to page 15 of your text and STUDY the segment on stability curves. A lot of information can be found from a GZ curve.

Let's construct a GZ curve for a vessel with the following righting levers:

Angle of Heel	15	30	45	60	75	90
Righting Lever (GZ)	0.35 m	0.95 m	1.16 m	0.90 m	0.10 m	–1.0 m

Initial GM was 0.8 m

Figure 2B.10 shows the curve.

The following information can be gained from the GZ curve:

1. The *range of stability.* This includes all the angles of heel for which the vessel has a positive GZ. In this case it is from 0 – 77½°
2. The *angle of vanishing stability*. This is the maximum angle of heel at which GZ becomes zero. In this case it is also 77°, but you should note that the angle of vanishing stability and the range of stability are not always the same.
3. *The maximum GZ lever and the angle at which it occurs.* In this case it is 1.16 m at 45°.
4. *The point at which the deck edge immerses.* This is known as the point of contraflexure; i.e., where the shape of the curve changes from concave to convex. In this case it is approximately 23°.
5. *The approximate GM.* The tangent drawn to the slope of the curve at its origin, extended to intersect the vertical line through 57.3° (1 Radian), will give the GM. In this case it is 0.8 m. Usually the initial GM is known and the tangent is drawn in to find the original slope of the curve.

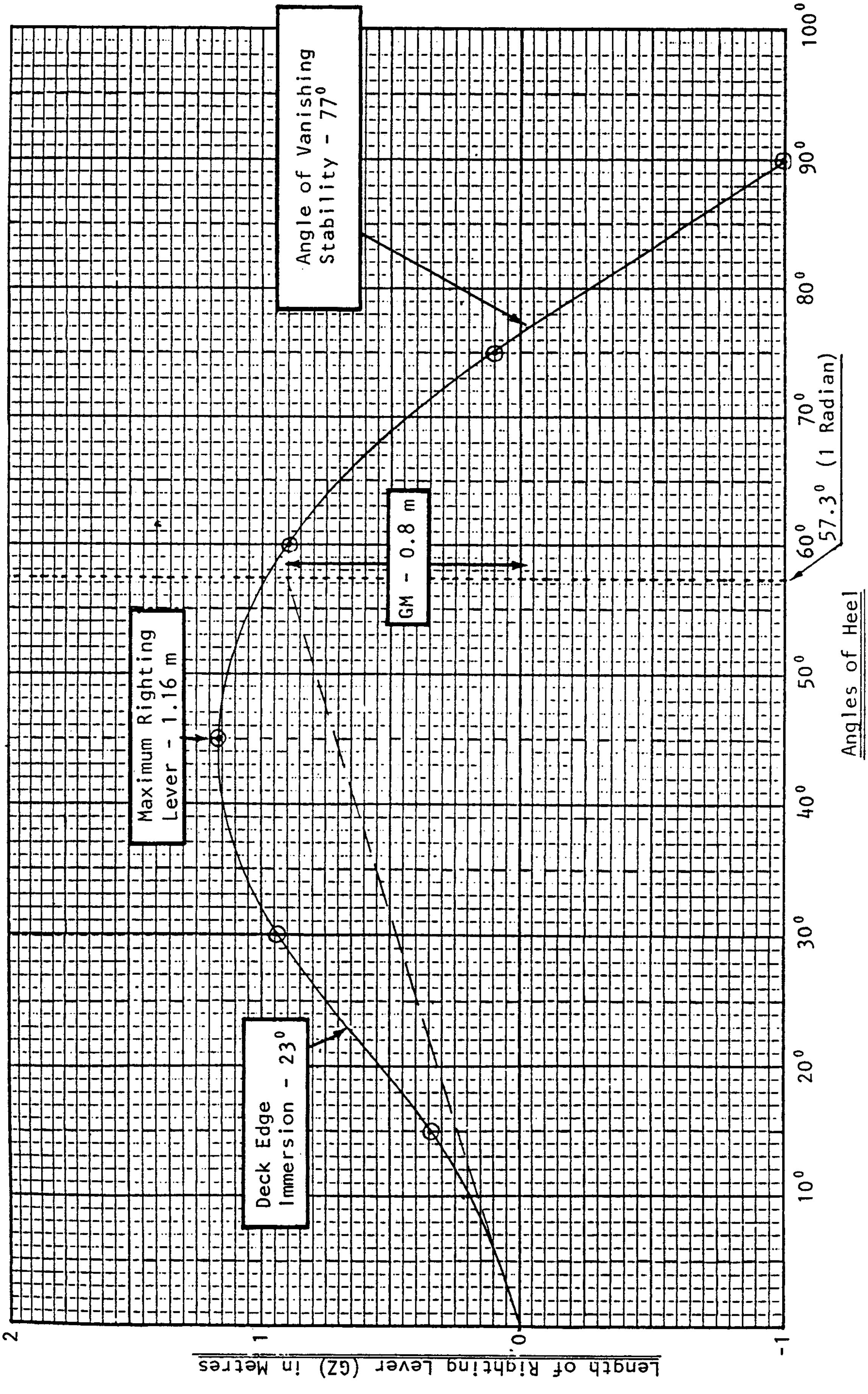


Fig. 2B.10 Stable equilibrium

There is one other important angle to be considered, and this is the *angle of flooding.*

Angle of flooding occurs when the vessel heels to a point when water enters the hull through openings that cannot be made watertight. Usually when this happens the vessel sinks. The angle of flooding should not be confused with the potential angle of flooding. The potential angle of flooding is the angle to which the vessel must be heeled to submerge the external watertight doors and openings. The potential for flooding would exist at this angle if the watertight doors and openings were not sealed.

Unit 2B.6 Self-test Questions

1. What does the term Loll describe?

2. There are two main reasons why a vessel will suddenly list over while at sea. What are they? Give a brief description of any remedial action necessary.

3. What is the main precaution that should be taken into account when correcting an angle of loll by the filling of tanks?

4. What is the difference between a stiff and a tender ship? Use diagrams to explain your answer.

5. Sketch and describe stable, unstable and neutral equilibrium.

6. What information can be obtained from a GZ curve?

7. Figure 2B.11 shows a fishing trawler in the process of swinging a laden net on board. Where does the centre of gravity of the suspended weight act and what effect does this have on the centre of gravity of the vessel?

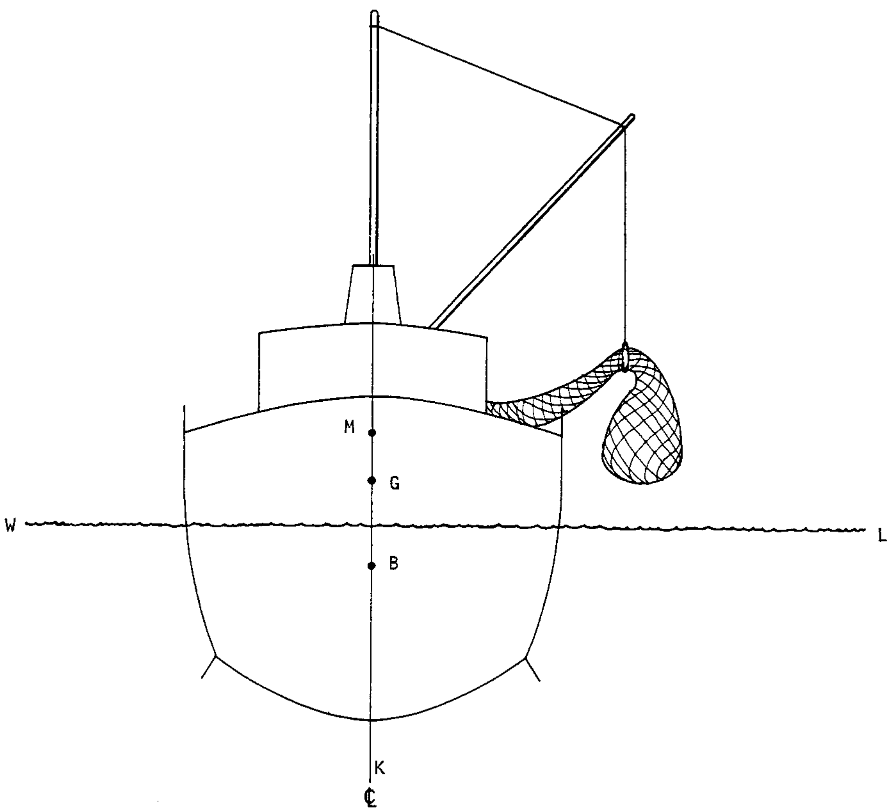


Fig. 2B.11

ANSWERS TO SELF-TEST QUESTIONS

UNIT 2B.6

1. *Loll*

   The term loll describes the state of a ship which is unstable when in an upright position and therefore floats at an angle of heel to one side or the other. If disturbed by some external force caused by wind or waves, the vessel will lurch to the same angle of loll on the opposite side. Loll is quite different from list, being caused by different circumstances and requiring different counter-measures to correct it, and it is therefore most important that the seaman should be able to distinguish between the two.

2. The two reasons are:

   (a) Shifting of cargo or weights.

   (b) Loll caused by a negative GM.

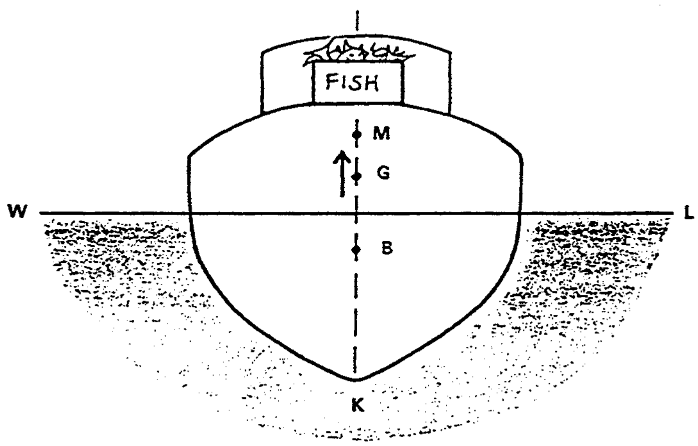
   A may be rectified by distributing the weights more evenly.

   B may be rectified by lowering the centre of gravity.

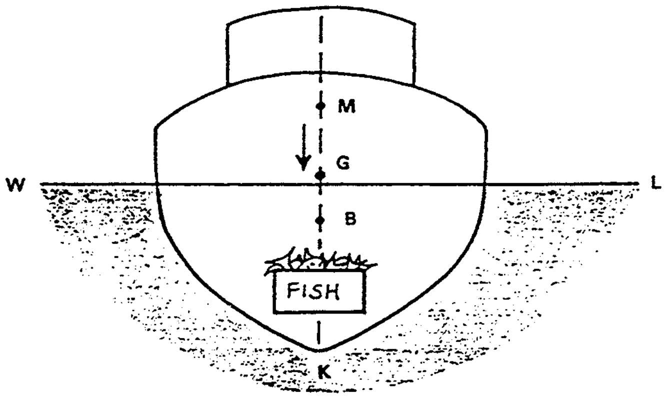
3. Where possible the tank on the low side should be filled first to prevent the vessel flopping heavily onto the other side as it will probably capsize the vessel.

4. 'STIFF' and 'TENDER' Ships

   When a weight is added to a vessel, the centre of gravity of the vessel always moves in the direction of the added weight.



   Weight added at deck level results in the vessel's centre of gravity rising, causing a decrease in the vessel's metacentric height. A vessel with little or no metacentric height is said to be TENDER.



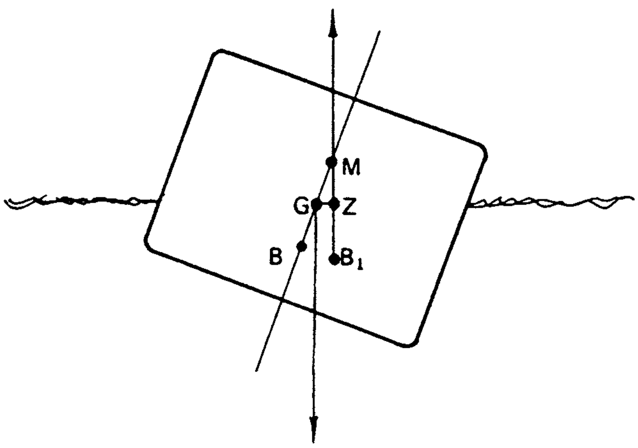
Weight added low down in the vessel lowers the centre of gravity and consequently causes an increase in the vessel's metacentric height. A vessel with a large metacentric height is said to be a STIFF ship.

A stiff ship tends to be comparatively difficult to heel and will roll from side to side very quickly and perhaps violently. If this condition is thought to be a problem it can be corrected by raising the vessel's centre of gravity.

A tender ship will be much easier to incline and will not tend to return quickly to the upright position. The time period taken to roll from side to side will be comparatively long. This condition is not desirable and can be corrected by lowering the centre of gravity.

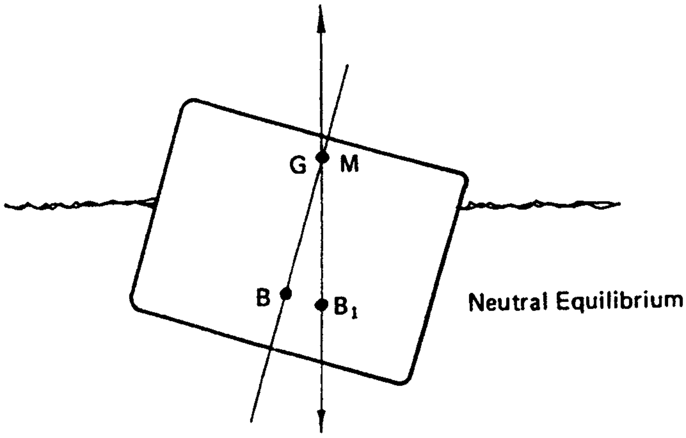
5. (a) Stable Equilibrium

The term stable equilibrium refers to a vessel, when forcibly inclined, having the ability to return to her original position.



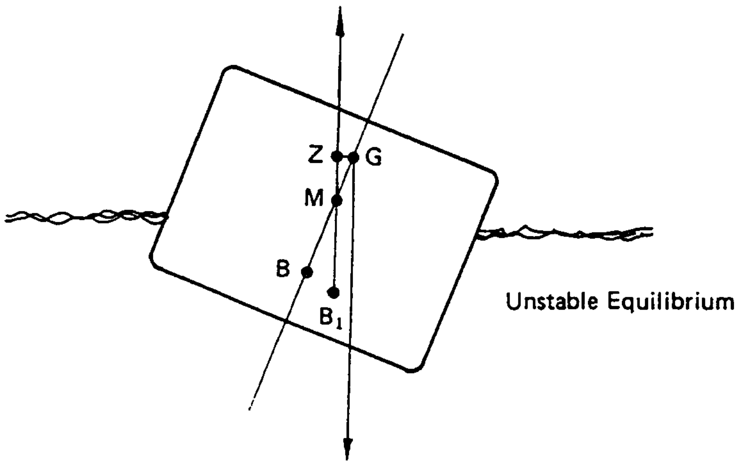
(b) Neutral Equilibrium

The term *neutral equilibrium* refers to a vessel, when forcibly inclined, tending to remain at that angle of heel until another external force is applied.



(c) Unstable Equilibrium

The term *unstable equilibrium* refers to a vessel, when forcibly inclined, being inclined to heel over further; that is, the righting moment wants to capsize the vessel altogether. For this to occur, G must lie above M.



6. A GZ curve gives the following information:

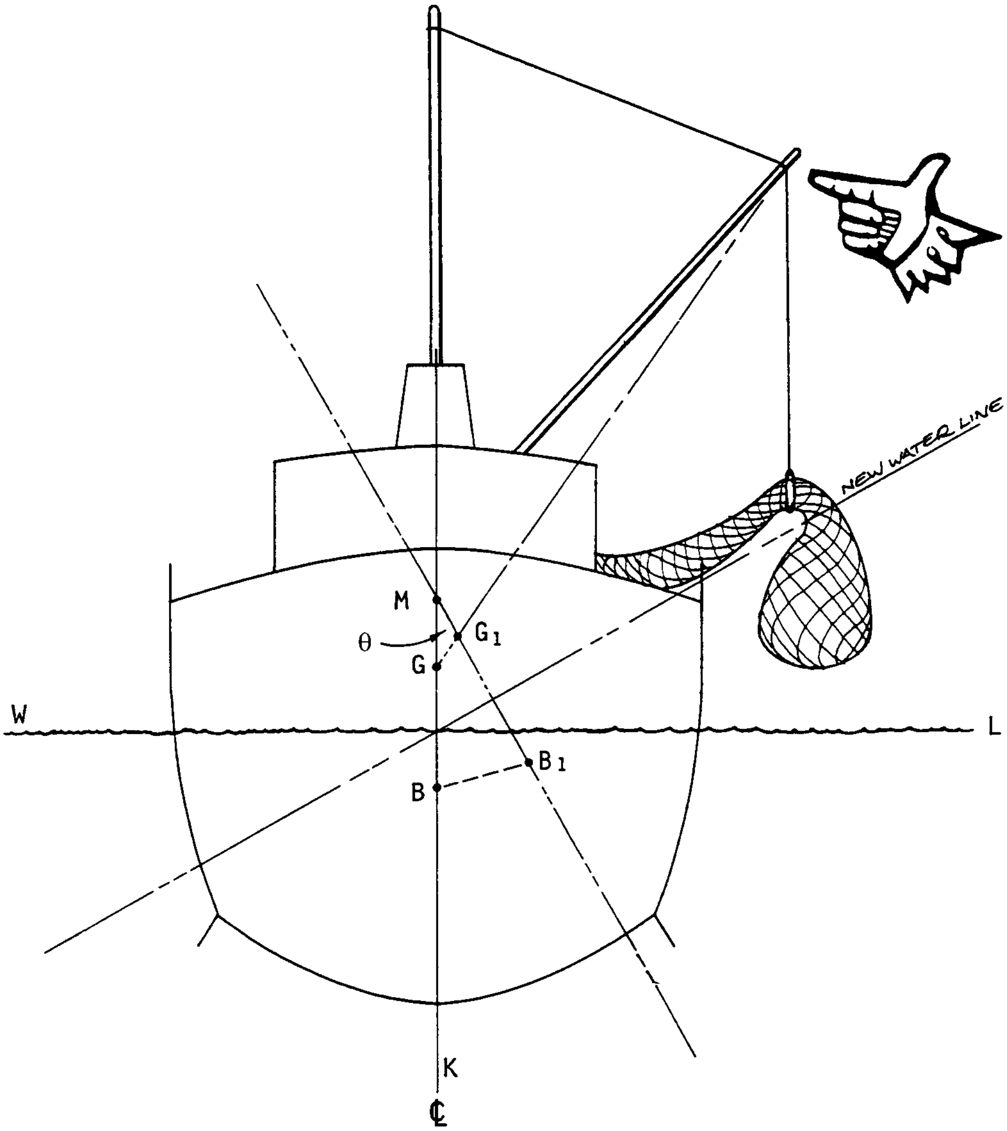
   (a) the range of stability

   (b) the angle of vanishing stability

   (c) the maximum GZ lever and the angle at which it occurs

   (d) the point at which the deck edge immerses.

7.



The centre of gravity of a suspended weight can be considered to be at the point of suspension. Therefore, a trawl cod end, when being lifted clear of the water, has the same effect on the vessel's centre of gravity as if the weight were actually the head of the boom. It also exerts a heeling force upon the vessel. G moves along the line connecting G and the point of suspension. The new G becomes G_1 and θ is the angle of heel. B moves to B_1.

TOPIC 3

FACTORS AFFECTING STABILITY

Syllabus

Learning Outcome

On completion of this learning outcome the learner will be able to recognise factors that have an adverse effect on the stability of a small vessel and describe appropriate action to ensure the safe operation of the vessel.

Assessment Criteria

- Describe the effect of suspended weights on the stability of a vessel when using cargo gear or fishing gear to load and discharge heavy weights
- Describe the precautions to be taken on board a fishing vessel when clearing a net which is caught fast on an underwater obstruction
- Describe the causes of free surfaces on the stability of a vessel
- Describe onboard arrangements inlcuding safe working practices to reduce free surface effects
- Describe the effect of water on deck on the stability of a small vessel and the means of reducing that effect
- Differentiate between list and loll and describe the actions to be taken to correct an angle of loll
- Explain the term 'Resrve Buoyancy'
- Describe the effect on the stability of a vessel that has been 'bilged'
- List the actions to be taken to contain flooding in the event of underwater damage to the hull
- Explain the precautions required when making alterations to a vessel that may affect stability

Text

National Fishing Industry Training Committee: *An Introduction to Fishing Vessel Stability* (included in the Coxswain's section of this learning resource)

WestOne Publication: *Simplified Stability Information for M.V. Twosuch* (included as an appendix in this learning resource)

SECTION 3

FACTORS AFFECTING STABILITY

These are the last two Sections that you will study on stability. Thus far we have discussed the principles of ship stability. You should be acquainted with the terms relating to ship stability and have a general idea of the changes that occur when a vessel is rolling or listing. In Section 3, we will consider the various aspects of stability that are under your control and for which you, as a Master, are directly responsible.

Objectives

By the end of this Section you should be able to:

- show how the loading, discharging and moving of weights on board a vessel affects its stability
- show how the free surface effect of liquids or fish affect the stability of the vessel
- explain what effect bilging has on trim and reserve buoyancy
- show how sudden and constant loads on gear affect a vessel's stability
- show how structural changes to a vessel may be regarded as weights added or removed, and explain the need to develop new stability data for a vessel after structural changes.

Unit 3.1 Loading, Discharging and Shifting Weights

STUDY pages 11, 12, 18 and 19 in your text book for this Section, *An Introduction to Fishing Vessel Stability*, then STUDY the following notes.

The Master has total control over the position of the centre of gravity of his vessel, and so has total control over the stability of his vessel.

A centre of gravity too far forward will result in a positive trim (trim by the head). This would result in difficulty in manoeuvring and reduce the vessel's ability to ride over head seas. There is also a reduction of her reserve buoyancy forward and seas coming on deck may overcome her. She would also be very sluggish and slow to respond to helm.

A centre of gravity too far aft will result in excessive trim (negative) by the stern. Such a vessel will heel over excessively when helm is applied, and will be over responsive to her helm.

In a large following sea she will be almost impossible to control and will have a tendency to broach.

When the centre of gravity is off centre, the vessel will have a list.

With a centre of gravity too high – she is tender; too low – she is stiff.

With careful consideration to the stowage of cargoes and the amount of ballast on board, all of the above problems can easily be avoided.

Adding Weights

Whenever a weight is added to a ship, the centre of gravity moves in the direction of the added weight.

When we refer to the position of G, we mean the position of G with respect to the ship plus its cargo (see Figures 3.1(a) and 3.1(b)).

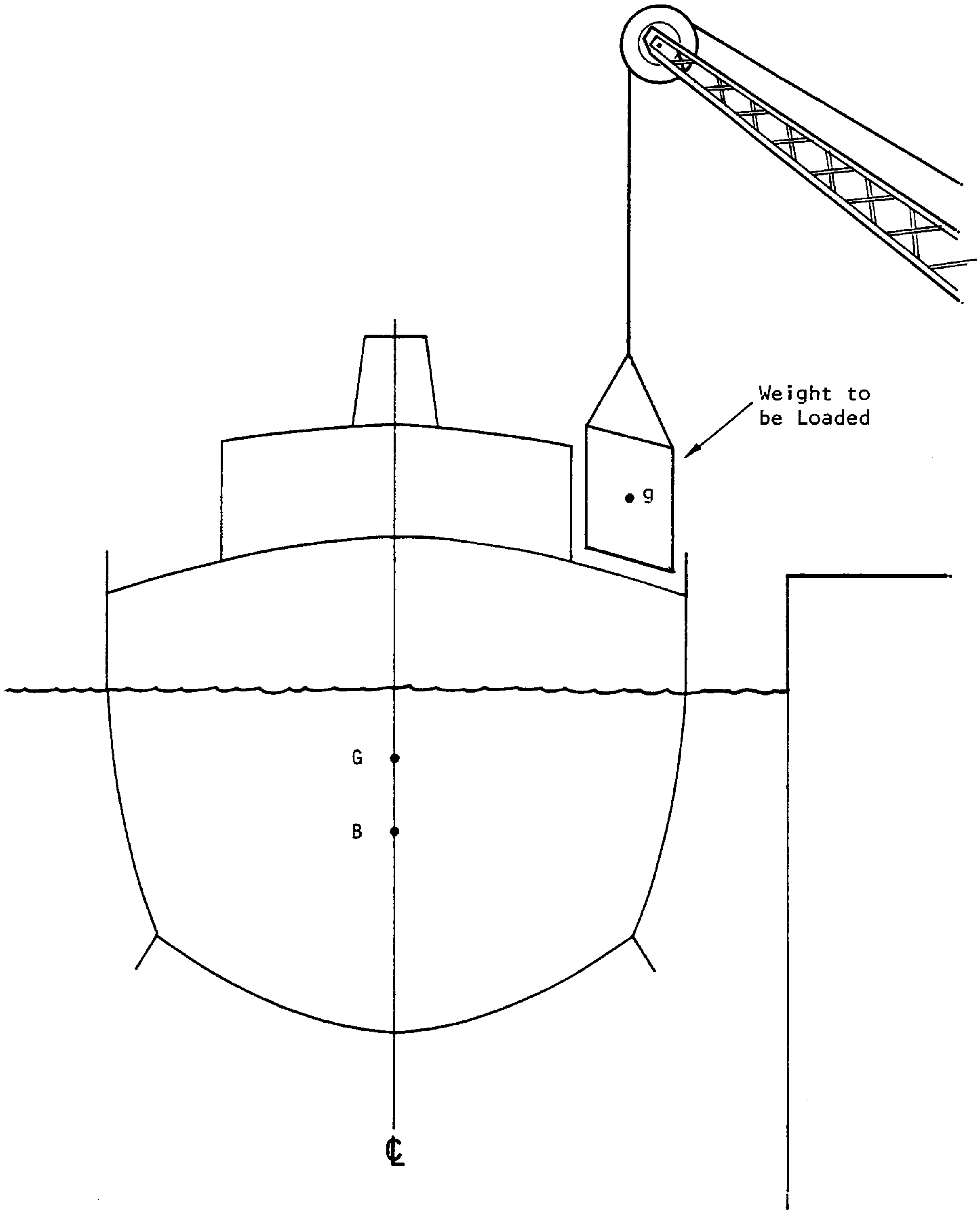


Fig. 3.1(a)

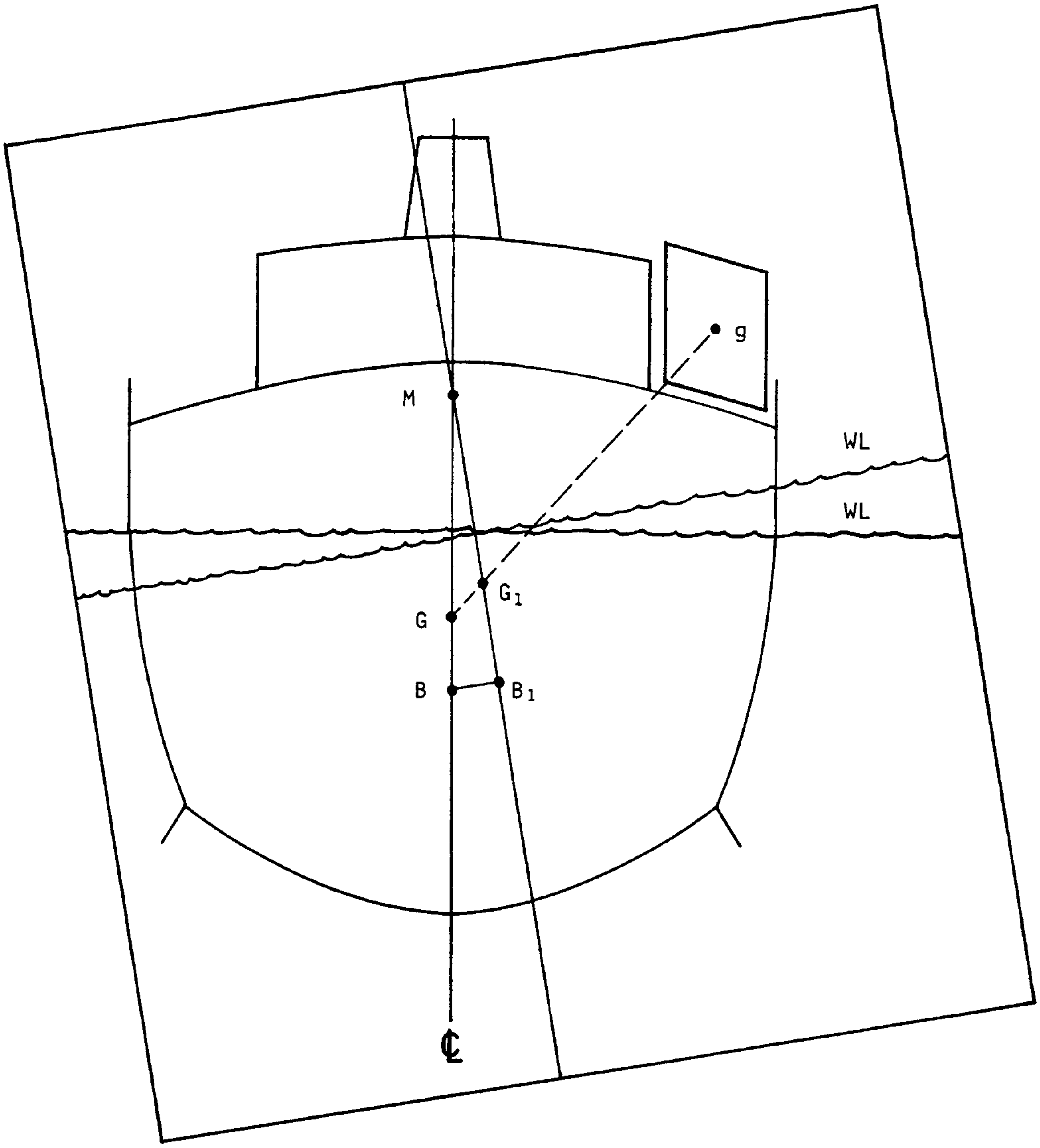


Fig. 3.1(b)

Once a weight has been loaded, we no longer consider the weight on its own, but rather the effect that it has had on the centre of gravity of the vessel as a whole.

When a weight is removed, the centre of gravity of the vessel moves directly away from the removed weight (see Figures 3.2(a) and 3.2(b)). When the weight is moved, the centre of gravity moves parallel to the line connecting the initial and final positions of the centre of gravity of the moved weight. (See Figures 3.3(a) and 3.3(b))

In Figures 3.1(a) and (b) a weight is loaded on the Port side on deck. This causes a list to Port. G moves to G_1 and GM is reduced to G_1M.

In Figures 3.2(a) and (b) a weight is discharged from the starboard side. This also causes a Port list. G moves to G_1 and GM is increased to G_1M.

In Figures 3.3(a) and (b) a weight is moved from the after deck to the fore deck. This results in a change of trim and G moves in the same direction as the weight.

Figures 3.4(a) and (b) show a weight being moved from the port side on deck to the starboard side below deck. This causes a starboard list, even though GM is increased.

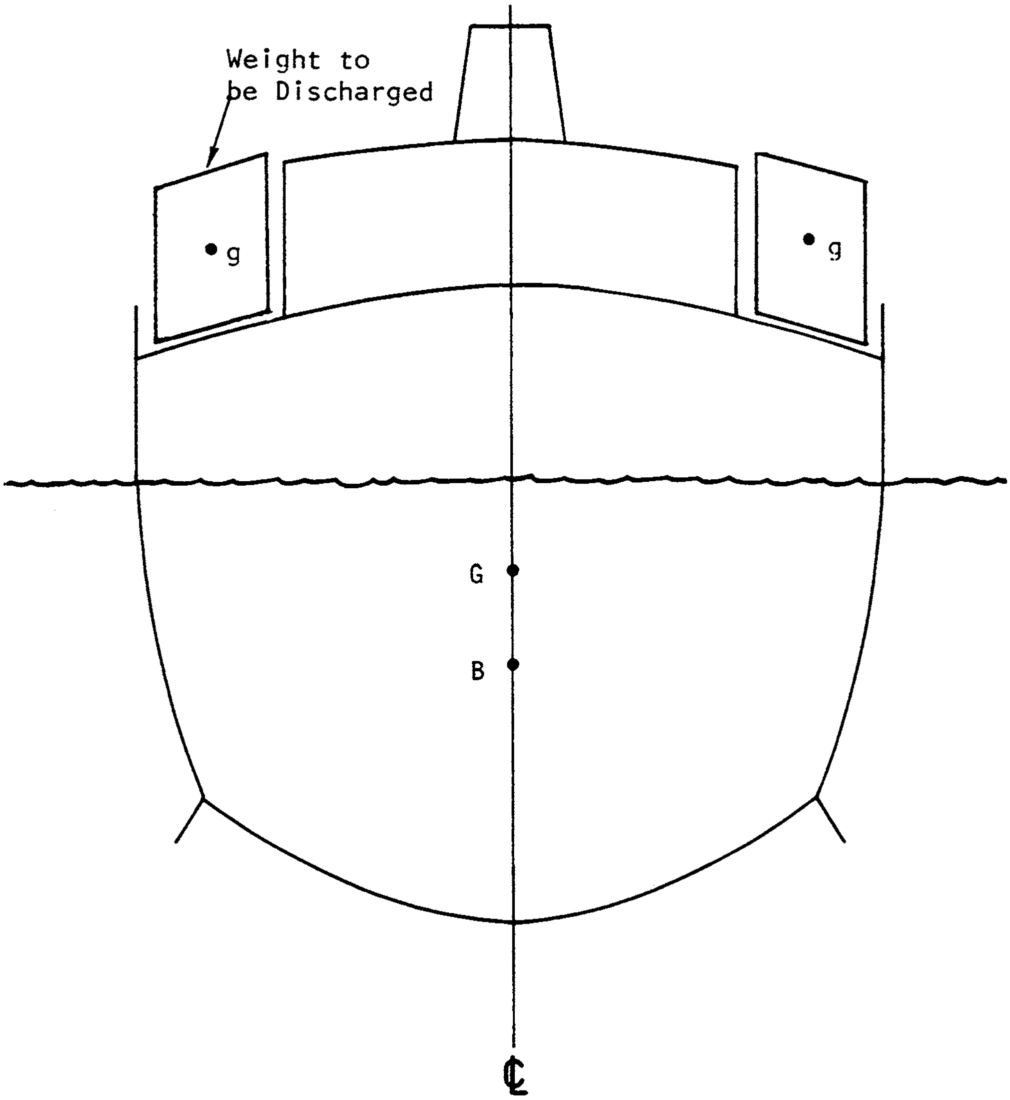


Fig. 3.2(a) Before discharging a weight

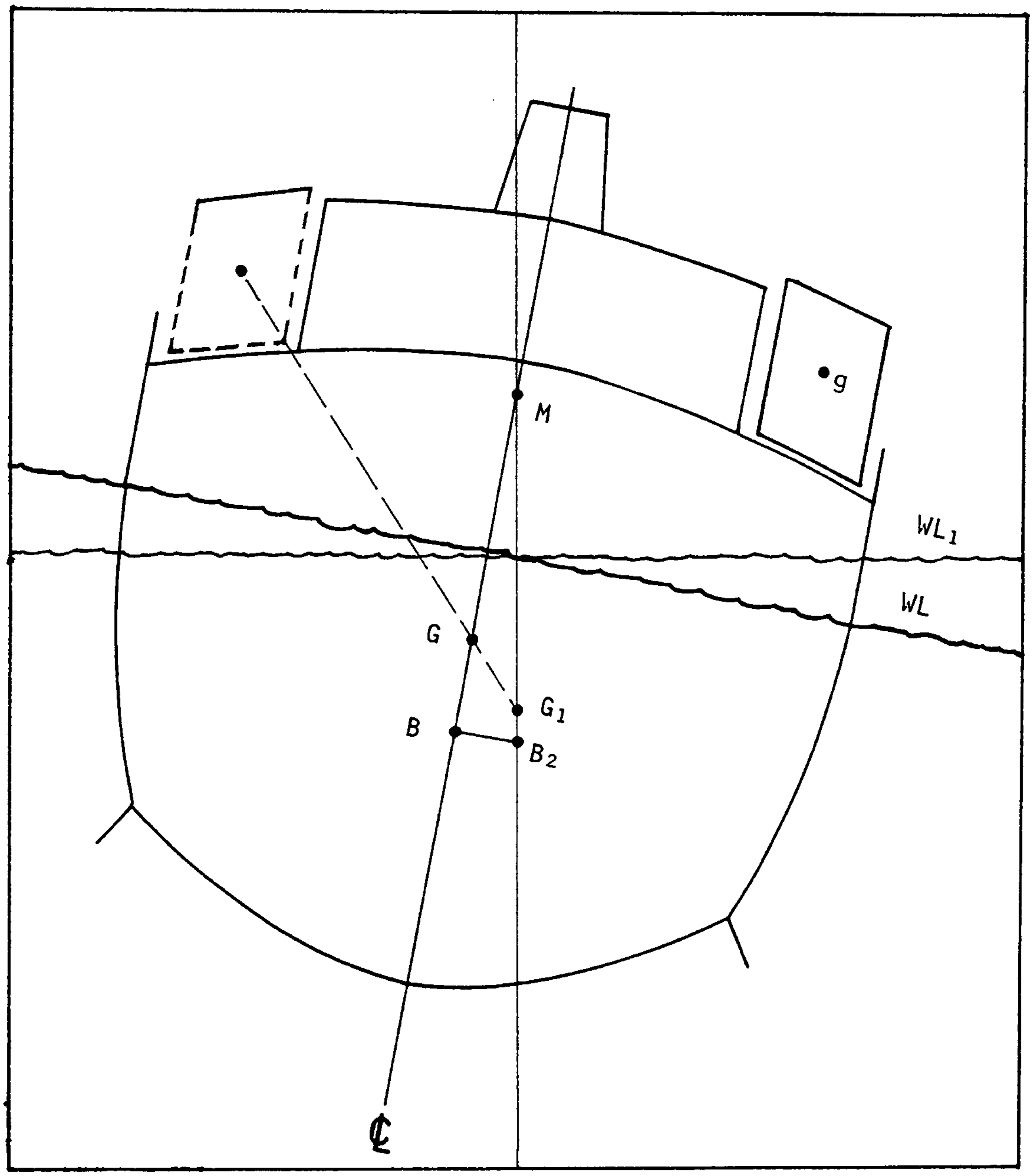


Fig. 3.2(b) After discharging a weight

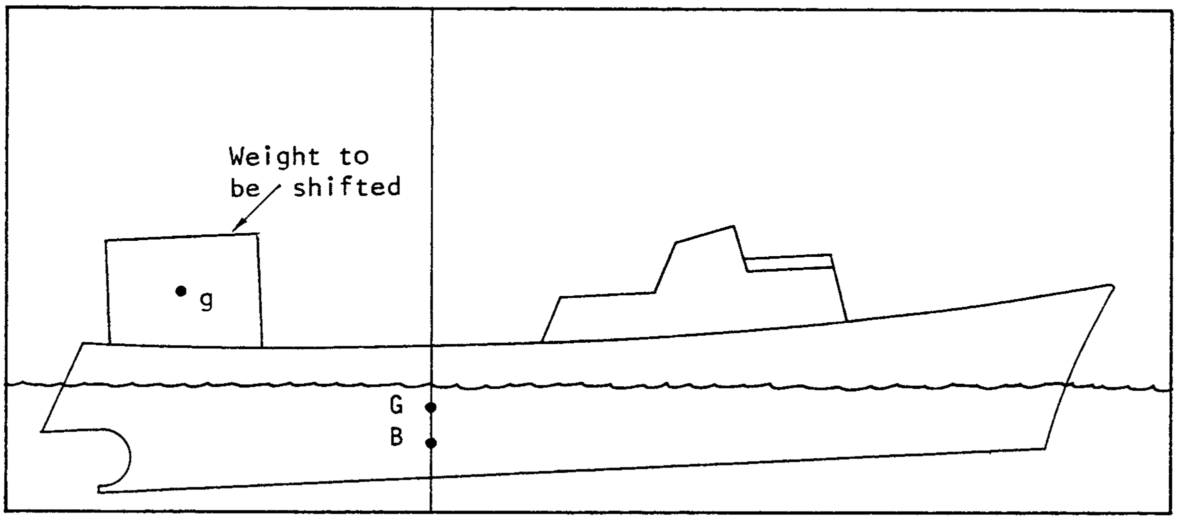


Fig. 3.3(a) Before shifting weight

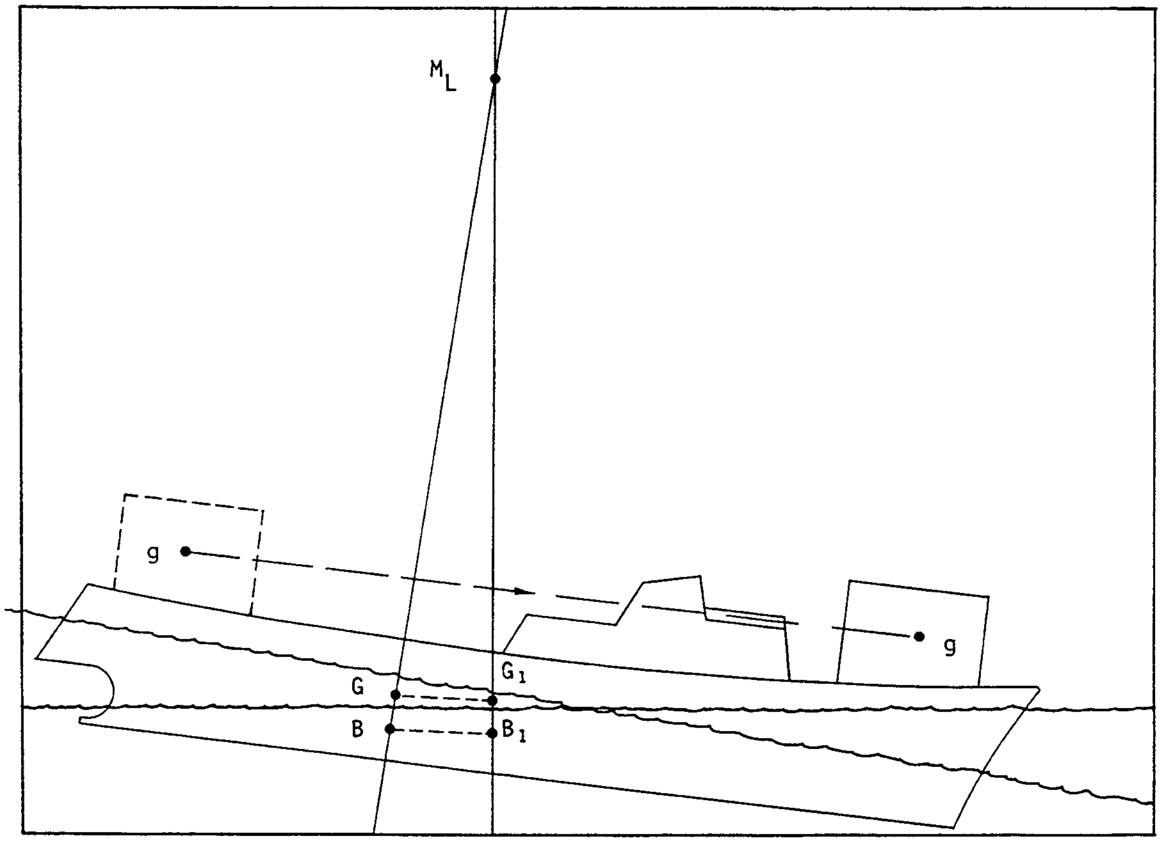


Fig. 3.3(b) After shifting weight

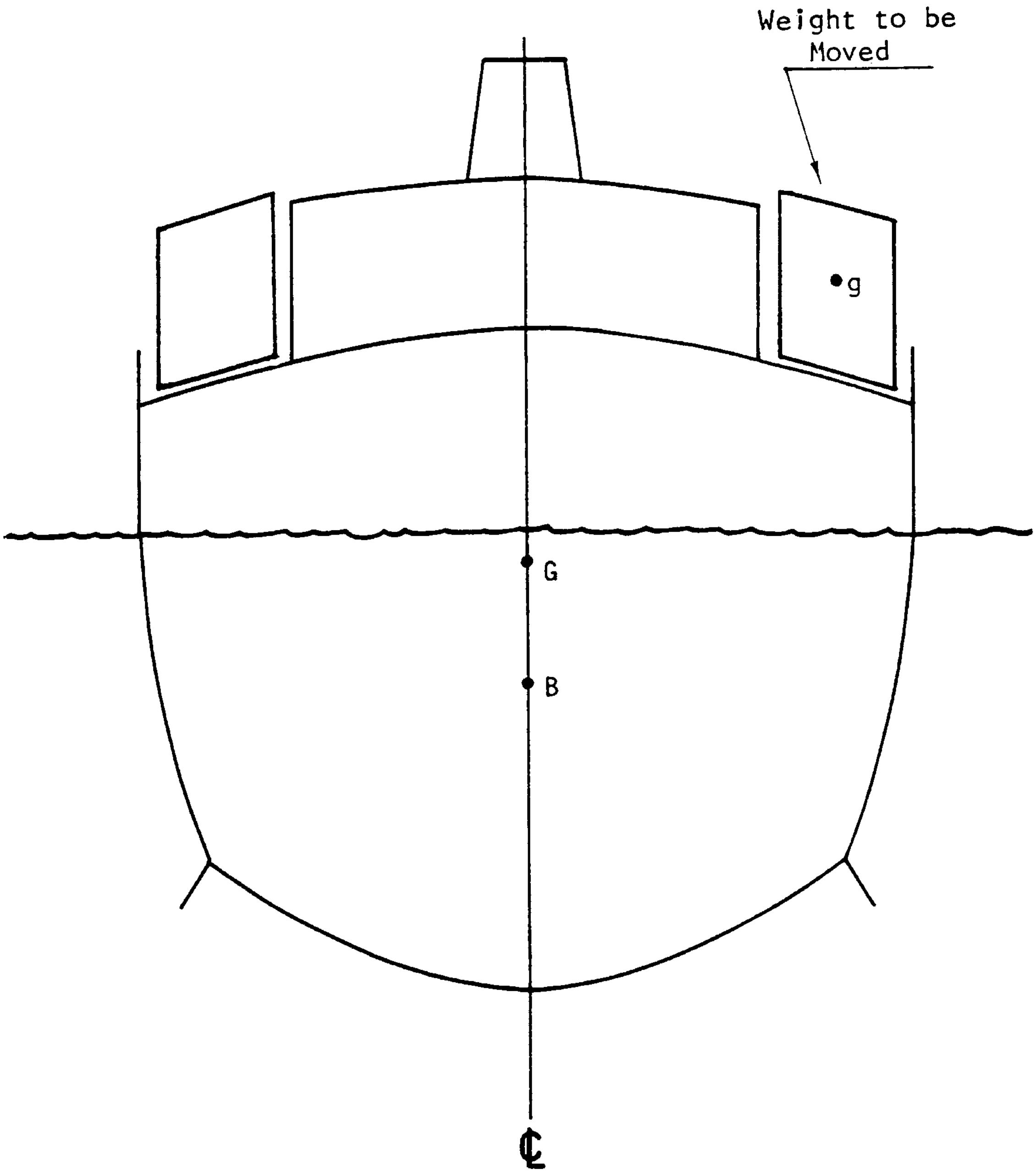


Fig. 3.4(a) Before weight is removed

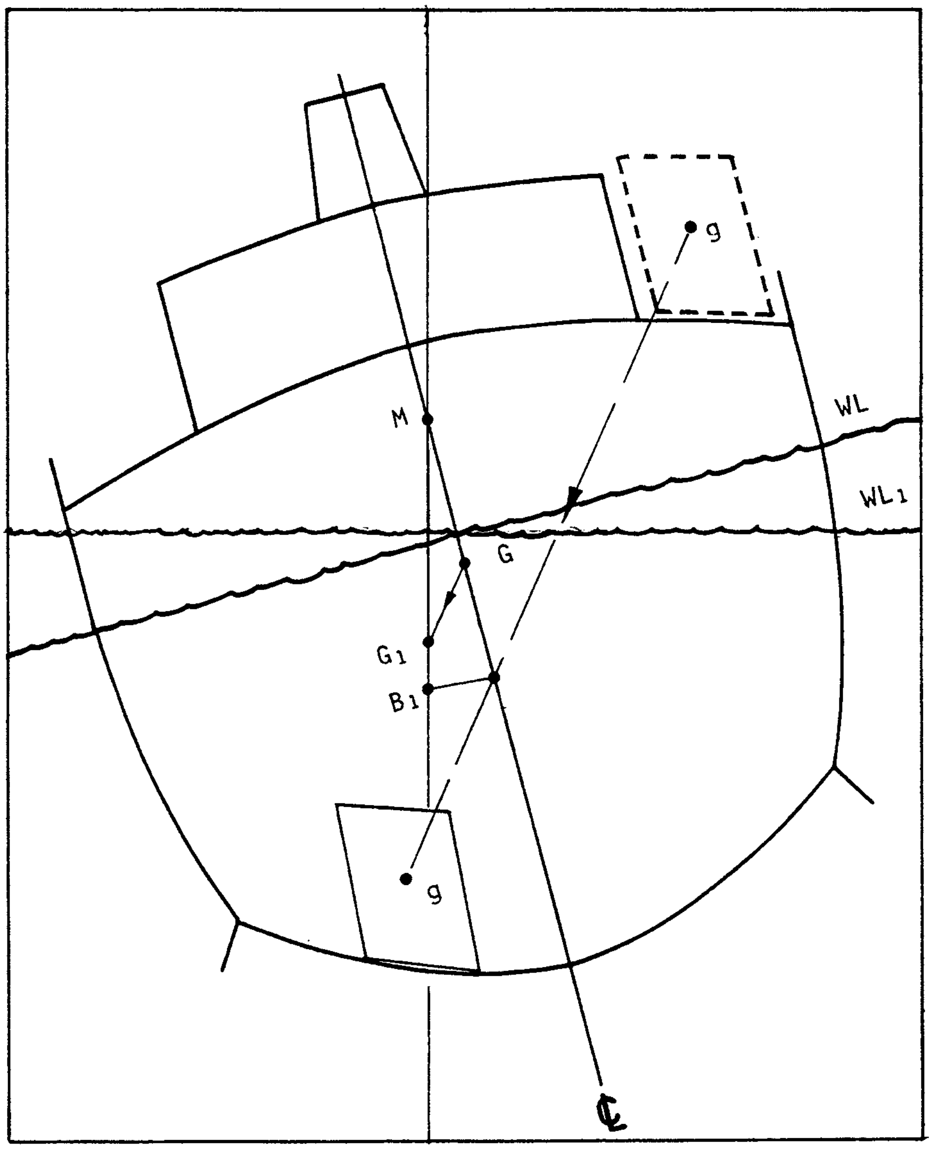


Fig. 3.4(b) After weight is removed

A final word about loading weights and cargoes on deck should be made.

Apart from reducing GM, there is the added danger of deck cargoes trapping water that comes on deck. If the water does not drain away, the added weight high up could be very serious. Deck cargoes of pipes are especially liable to cause water entrapment. So remember, when carrying deck cargoes that could trap water, make sure that you have a large GM. It is not easy to estimate the effect that a wave on deck would have on your vessel's stability, but you can be sure that it is *always* detrimental.

Unit 3.2 Free Surface Effect

STUDY pages 13 and 14 of your text under the heading "Free Surface Effect".

Any cargo that is free to move has a 'free surface' and will produce the same effect on the stability of the vessel as liquids in a partially filled tank. This includes fish on deck or in a hold. They move around quite easily with the rolling of the vessel. Once they are frozen solid, the problem doesn't exist, but until then and unless the fish hold is longitudinally subdivided, a dangerous situation could exist.

Let's examine what happens to a vessel that is rolling and has a large transverse tank, partially filled.

Figures 3.5(a), 3.5(b) and 3.5(c) show two vessels being heeled, one with a filled tank and one with a half filled tank.

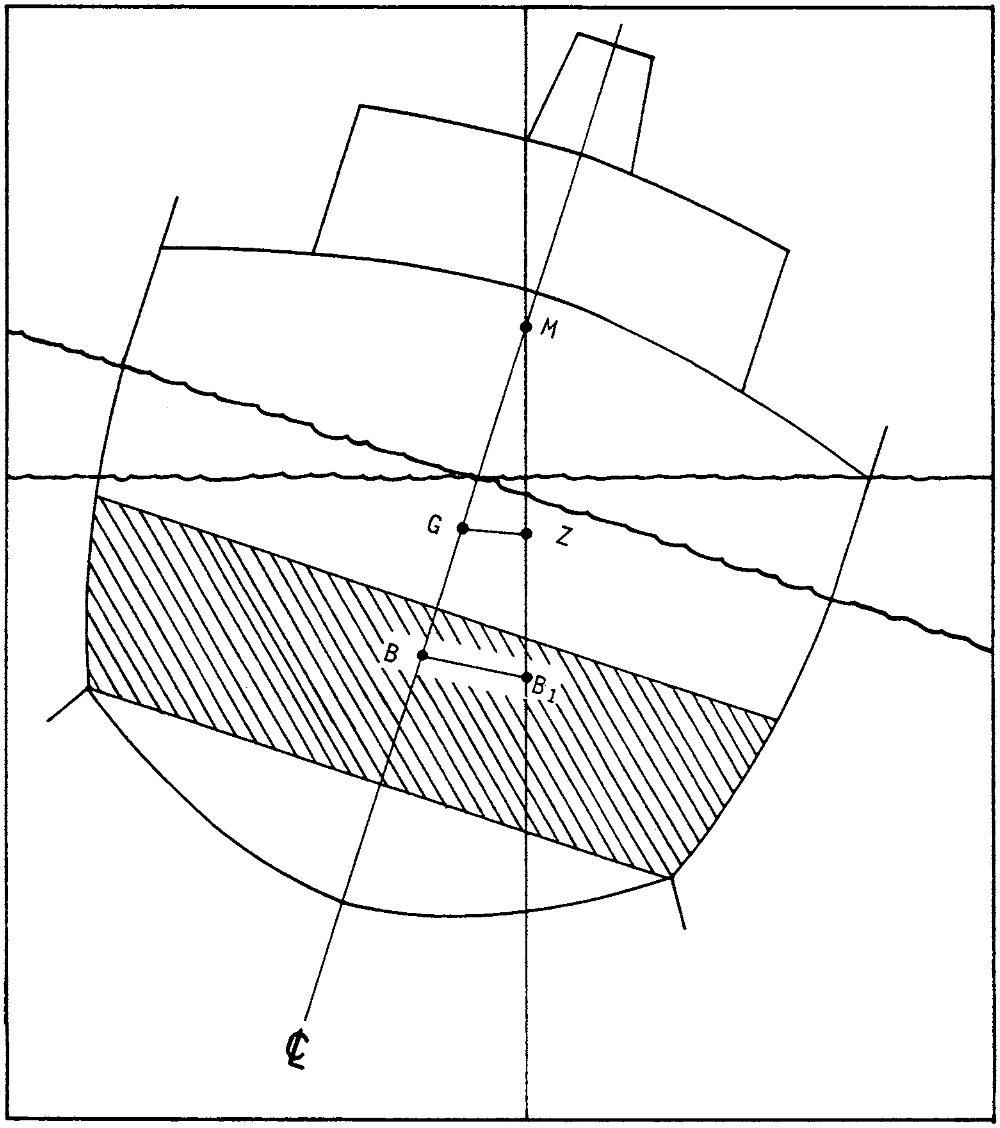


Fig. 3.5(a) Vessel heeled – filled tank – no free surface

In Figure 3.5(a) the vessel is heeled. No free surface effect exists because the tank is completely filled. (The surface of the liquid is not free to move.) She has a nice positive GM and a large righting lever. This is a stable vessel and no problems exist. But what will happen if that tank was only half full? In Figure 3.5(b), the positions of B, G and M are shown. The centre of gravity of the liquid in the tank is shown by 'g'. Figure 3.5(c) shows what happens when that vessel heels over to port. The liquid in the tank flows to the low side and g moves to g_1. This results in a shift of G to G_1. G_1Z becomes the new righting lever which is considerably smaller than GZ as shown in Figure 3.5(a). The weight of the vessel now acts vertically downwards through G_1. Even though the metacentric height does not change, the righting lever is the same as if G were actually at Gv. There is a virtual reduction in GM to GvM. It is important to note that even though there is only a small shift in the position of G to G_1 there is a large reduction in GM. Clearly, if the initial GM were less than the virtual reduction in GM caused by the free surface (GGv), the vessel would capsize.

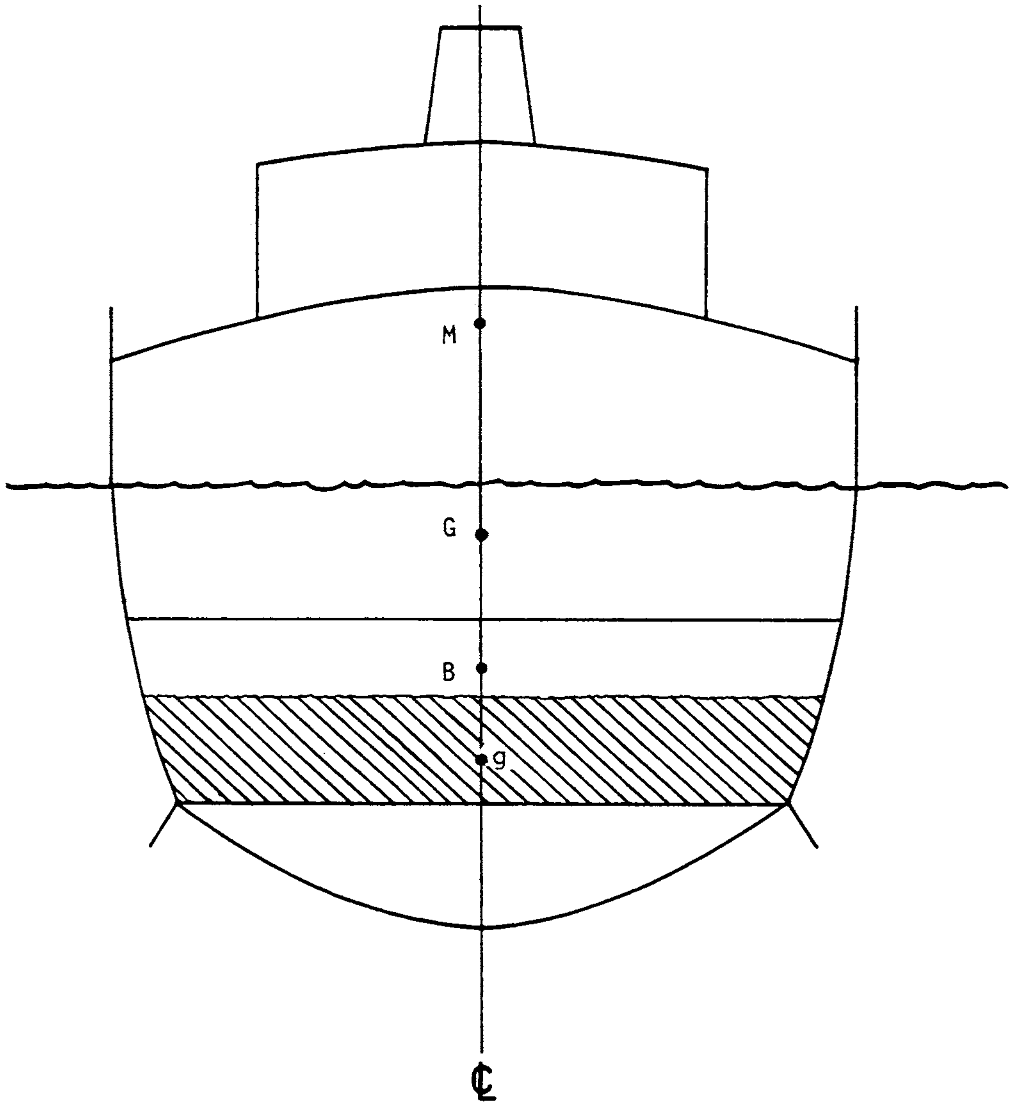


Fig. 3.5(b) Before heeling – partially filled tank – large free surface

Any free water that comes on deck will have the same effect on the stability of the vessel, until it has drained away. For this reason, it is important that freeing ports are kept clear all the time. The situation could arise on a fishing vessel where the day's catch is on deck and the freeing ports blocked by fish. All this weight on deck will cause the centre of gravity of the vessel to rise, effectively reducing the GM, and of course her stability. With the rolling of the vessel, the fish would slide back and forth, creating their own free surface effect. If a wave then breaks on deck, the already dangerous situation could quite easily turn into a disastrous one! The added weight of the water on deck, causing a further loss of GM, plus the additional free surface created by the water that cannot drain away due to fish blocking the freeing ports, may be all that is needed to create an unstable condition. The vessel would capsize so quickly that in all probability there would not be enough time for anyone to don life preservers of any sort.

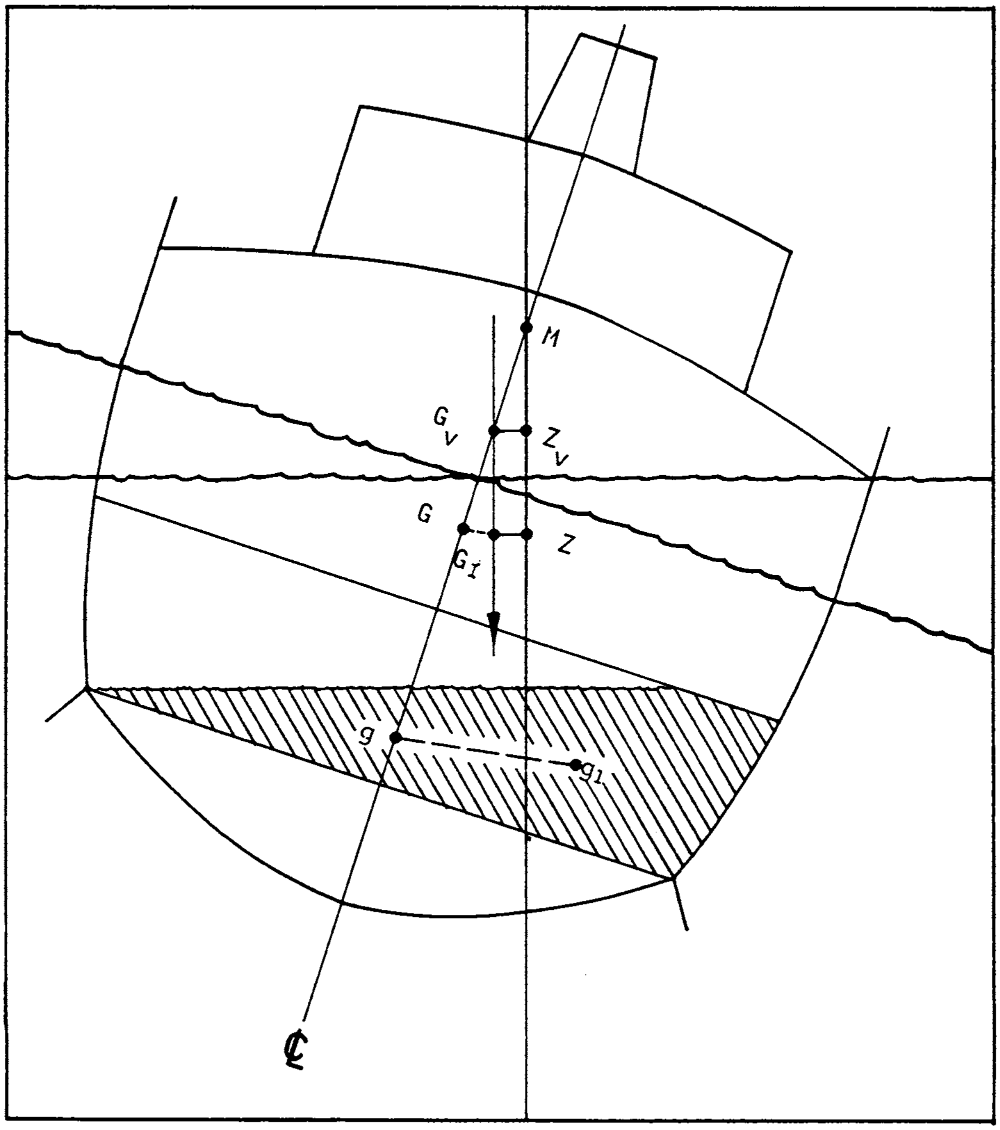


Fig. 3.5(c) Vessel heeled – large free surface – GZ reduced

Dangerous as they may be, fish on deck are not the only danger to stability. Remember all deck cargoes trap water. Timber on deck tends to soak up the water, and the weight of such cargoes can increase by as much as 25%. Perhaps the most dangerous of all deck cargoes are open pipes. It is assumed that they are securely lashed, and so the hazard comes not from the cargo shifting but from the large amounts of water that can become trapped on deck with little chance of it draining away. Usually pipes are stowed fore and aft. This tends to restrict the flow of water to the sides, so that any wave that breaks on deck will not quickly drain away.

As we have already discussed, the addition of any weights on deck (and this includes sea water) has the detrimental effect on the stability of a vessel of not only raising its centre of gravity and reducing the metacentric height (GM) but also of reducing the vessel's free board and hence its reserve buoyancy.

Unit 3.3 Structural Changes

It is important to realise that any structural changes made to a vessel after delivery are going to affect its stability. The designer carefully works out the weight of the vessel with all its appliances, and estimates the final stability of the vessel. When the vessel is built, using a simple inclining experiment, the position of her centre of gravity can be calculated. It is then easy to calculate the GM. Having done this the designer can tell what types of loads the vessel can safely carry. These should never be exceeded.

However, sometimes an owner will have a boat built, using the funds he has available, intending to make modifications if and when he can afford them. These may include items such as: shark winches on deck, ice boxes on deck, a flying bridge, lashing points for additional cray pots, etc. Any structural additions to the vessel must be regarded as weights added. If these are made above the vessel's centre of gravity, they will have the effect of reducing her stability, freeboard and reserve buoyancy.

If the designer was not aware of the proposed changes, they could quite easily result in an unstable vessel under normal conditions of loading. To make such changes, without first establishing the effect they will have on the stability of the vessel, is foolhardy to say the least.

Unit 3.4 Bilging

Bilging is the term used to describe a vessel that is holed below the water line. If she has sufficient transverse watertight bulkheads she will not sink.

Consider the box-shaped vessel in Figure 3.6(a).

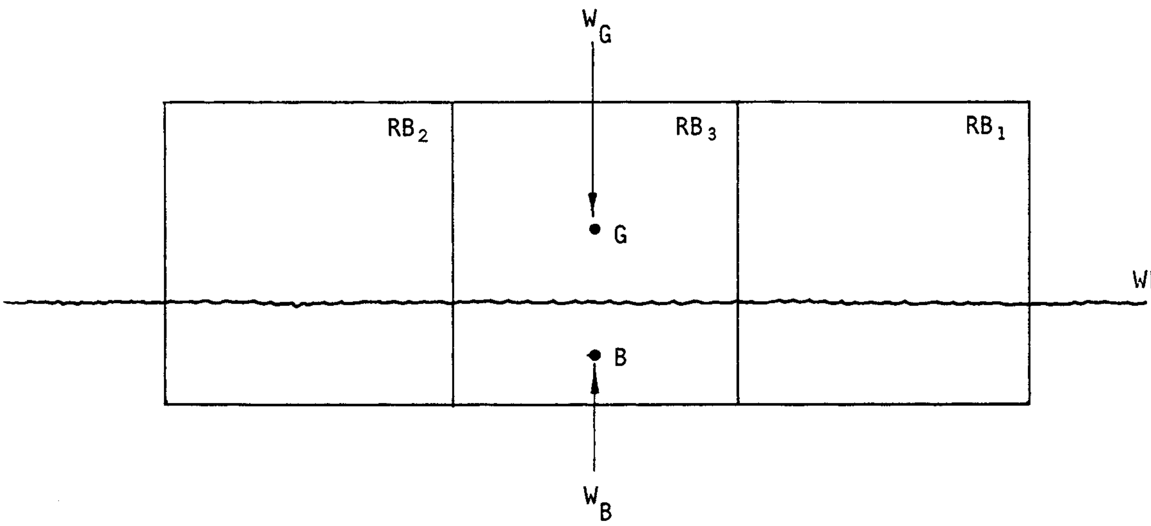


Fig. 3.6(a)

The vessel illustrated has three longitudinal compartments of the same size, separated by two transverse watertight bulkheads. The weight of the vessel (W_G) acts downwards through G. The force of buoyancy (W_B) acts vertically upwards through B.

If she is holed in the amidships compartment to such an extent that the water can flow freely in and out of the compartment she is said to be 'bilged'.

Figure 3.6(b) shows the vessel bilged in that way:

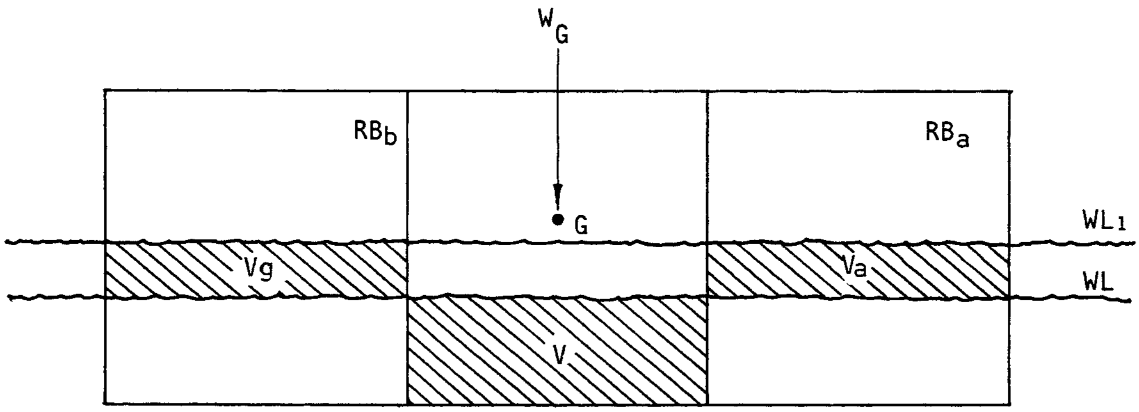


Fig. 3.6(b)

W_G still acts downwards through G. As bilging is the cause of loss of buoyancy only and not an actual addition of weight to the ship, G will not move. The buoyancy provided by the bilged compartment is lost. The draft increases and the vessel floats at the new waterline WL_1. Because all three compartments are the same size the volume of lost buoyancy (v) is replaced equally by the volumes Va and Vg, so that:

$$Va + Vg = V$$

There is no change in trim.

It should be noted that even though the change of draft is the same as if a weight, equivalent to the weight of water flooding the bilged compartment were added, the effect on the vessel's stability is always detrimental. If a weight is added in the position of V, G will be lowered, resulting in an increase of GM. In the case of bilging, however, G is not lowered. Since GM is a function of the area of the intact waterplane, it is reduced when a compartment is bilged. Even more serious is the loss of reserve buoyancy. In Figure 3.6(a) the reserve buoyancy was the entire enclosed volume above the waterline (RB_1 + Rb_2 + RB_3).

In Figure 3.6(b) - after bilging, the reserve buoyancy is only the volumes enclosed by RBa + RBg.

The reserve buoyancy in Figure 3.6(b) after bilging is only two thirds of what it was in Figure 3.6(a) before bilging.

Unit 3.5 Rules for Safe Stability

STUDY pages 20 and 21 in your text.

You have now completed the stability component of this course. For revision you should refer back to your text and READ the entire booklet.

Make sure you fully understand the terms and definitions in the text. Before leaving the text there is one point to cover and that is the limiting curves mentioned on pages 16 and 17.

You should now read these two pages and then the following notes.

(a) It is possible that your state authority may not issue Simplified Stability Information for small vessels.

(b) If your state authority does issue them you are strongly recommended to study them.

This is an extract from the recommendations given in the simplified stability data that is found on Class 2B and 2C vessels of 20 metres and over but less than 35 metres; and on Class 3 vessels - Stability Category K and L of less than 35 metres. STUDY it carefully as it contains valuable information and guidelines.

2 GENERAL

The sheets which follow are general comments to enlarge on good seamanship and house-keeping and issued only to enable the operators to use the stability data to best advantage.

Tank Usage and Slack Tanks

(1) Tanks which are not in use must at all times be full and pressed up, or empty where possible. Remember that slack tanks create free surface and the effect of slack tanks results in actual and often large reductions of stability.

(2) When manipulating tank contents by pumping from one tank to another, make every effort to maintain level trim. Develop a system of tank usage which keeps the trim of the vessel from becoming excessive. Remember that the calculations for stability are accurate only within a small range of trim.

(3) Transference of fuel or fresh water and the ballasting of tanks should only be carried out in favourable weather conditions.

(4) There is in this book a recommended sequence for the use of liquids in tanks, departure from which may be dangerous. These recommendations should be followed unless there are specific reasons at the time for not doing so.

(5) Occasionally, conditions of loading and tank manipulations can lead to trim by the bow. This can be avoided by coordinating the operations; in other words, the effects of loading can be offset by correctly manipulating the contents of the tanks.

(6) Excessive trim by the bow can lead to difficulties in handling the vessel and may result in poor seakeeping.

Water on Decks

Large amounts of water on decks raise the centre of gravity of the vessel and drastically reduce its stability.

(1) Shipping large amounts of water should be avoided by good seamanship.

(2) It is essential to allow quick drainage for any water on decks by keeping the *freeing ports* uncluttered and free from obstructions at all times.

Free Surface Effects

The effect of Free Surface of liquids is to raise the Vertical Centre of Gravity, therefore reducing stability.

(1) On Deck -

Do not allow water to accumulate on *main deck* or *upper deck.*

(2) In Tanks -

The number of slack tanks at any one time should be kept to a minimum. To restrict the amount of Free Surface, it may be necessary to transfer liquids between tanks, bearing in mind the trim required and the weather conditions at the time.

Effect Of Wind and Waves

High speed wind and gusts can cause a considerable angle of heel, especially for vessels with large superstructures, thus reducing the range of stability. The situation can become serious, particularly in heavy and confused seas.

In heavy weather, make sure that all manoeuvres are carried out in accordance with the best practice of seamanship.

Weathertight Integrity

In severe weather, it is the responsibility of the Skipper and Crew to ensure that all hull, deck and superstructure openings are closed and watertight as far as is practicable. In emergency conditions, all openings must be closed, particularly weathertight doors, hatches and ventilation trunks, and only opened at the Skipper's discretion.

General Comments

(1) Always determine the cause of a list or the change of trim of the vessel.

(2) Heavy rolling of the vessel should be regarded as a potential hazard. Oblique seas, particularly from astern, reduce the average stability below that calculated on the sheets in this book.

The most undesirable condition occurs when a wave crest is amidships and when running before a high-following or quartering sea.

Rolling becomes most violent when seas approach the vessel at about 15 degrees abaft the beam.

(3) Fish or cargo shall be properly secured against shifting which could cause dangerous trim or heel of the vessel.

Beam Trawling

(1) Excessive loads may be imposed during beam trawling operations upon the working gear and, through the gear, upon the vessel. The main risks are therefore in failure of gear under load and in reducing the stability of the vessel.

(2) When fishing gear is fast on the bottom and attempts are being made to free it, there is a grave danger of serious personal injury due to gear parting under heavy strain. There is also a potentially more dangerous effect of the fouled gear on the vessel's stability which can lead to the vessel capsizing, thereby putting the lives of all on board at risk. This effect is more prevalent in heavy weather conditions or when strong tidal forces are being experienced. In these conditions, a vessel is particularly vulnerable if it lies beam-on to wind and sea or to the direction in which the tide is running.

(3) When attempting to free fishing gear fouled on the bottom, fishermen should exercise every care and where possible endeavour to free the gear while bow or stern-on to strong tides or heavy weather, or if possible wait for slack water or the weather to abate. Cutting equipment should be readily available to cut loose in an emergency.

(4) The heeling effects imposed upon a vessel when attempts are made to free a fastened trawl have to be withstood by the vessel's transverse stability and the

adverse effects of these heeling forces are minimised if they are *not* applied through the towing block when it is located at the outboard end of the boom.

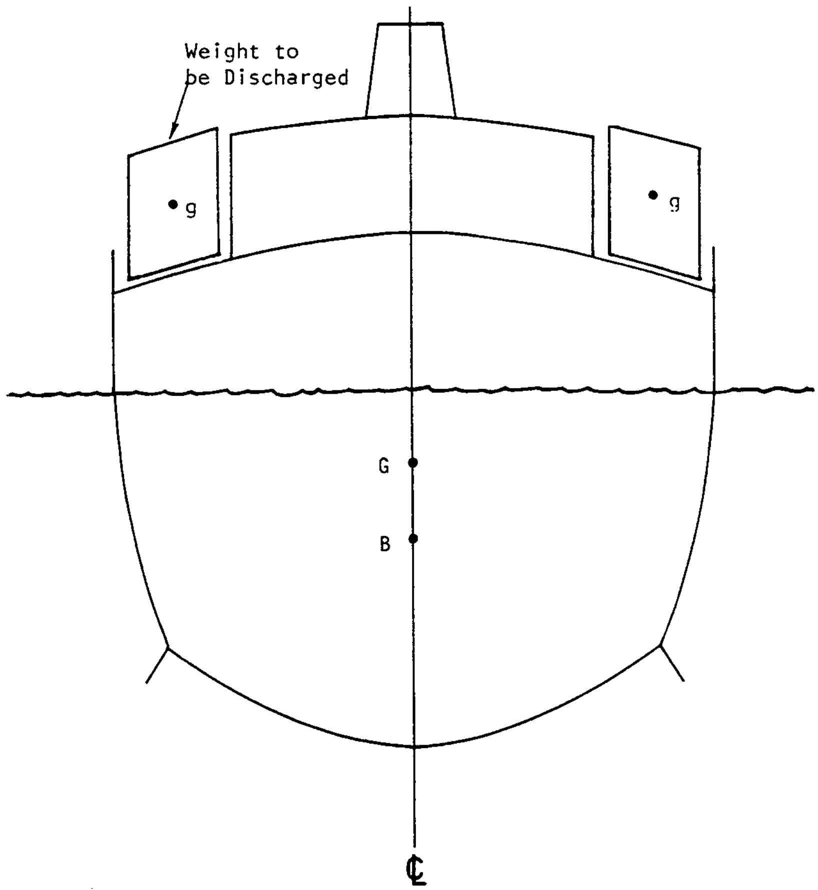
(5) Means should be provided to release the block at the outboard end of the boom, allowing it to drop into the water, or some equally effective method adopted which ensures that the pull in the towing warp is applied close to the vessel's side and as low as practicable when an attempt is being made to haul the warp and clear a fastened net.

(6) Adverse effects similar to those associated with a beam trawl fastened against a sea bed obstruction may arise when the trawl itself is 'sanded-up'.

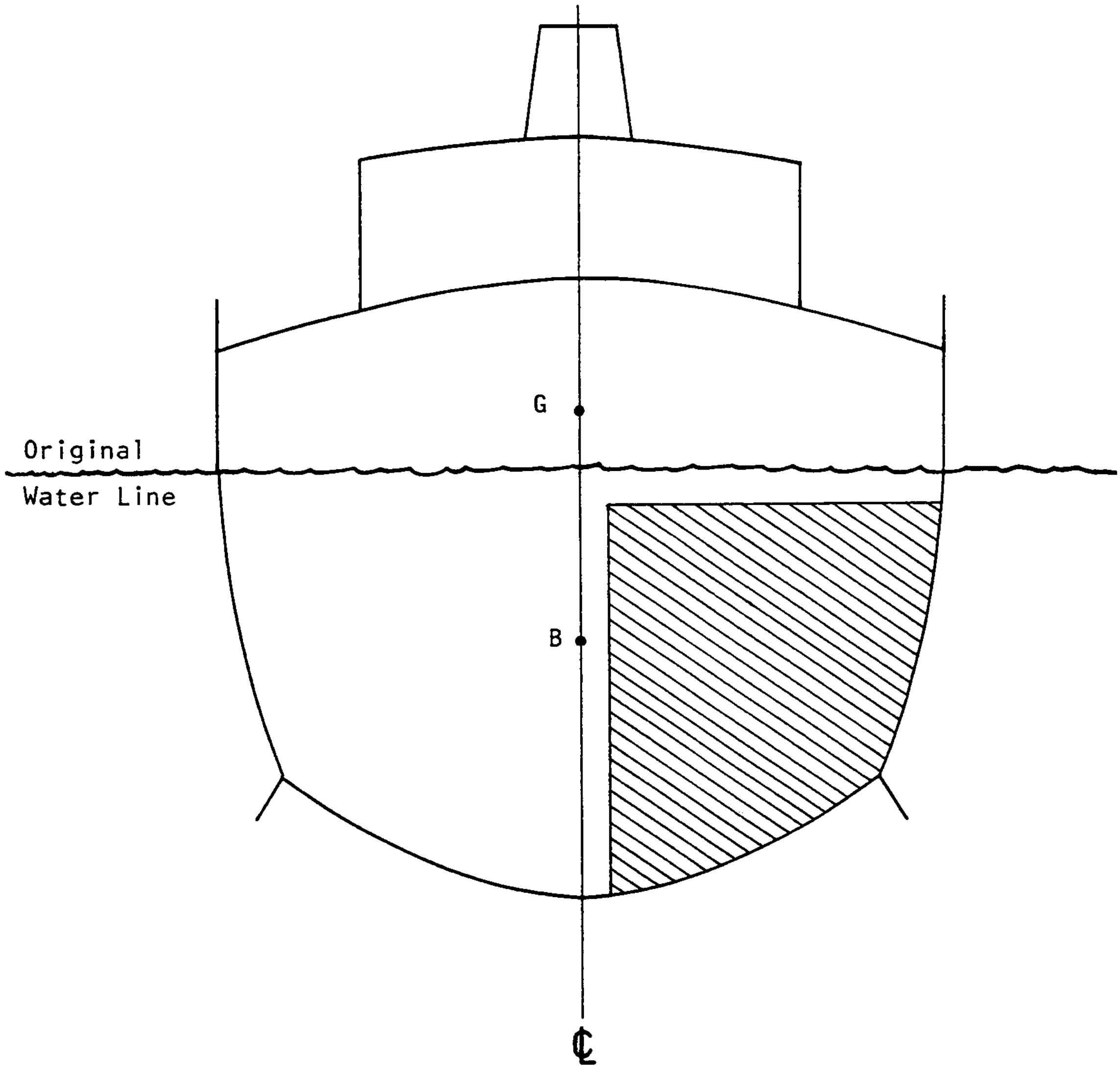
Unit 3.6 Self-test Questions

The answers to these questions are at the end of this Section.

1. Describe the effect of bilging a vessel in a forward compartment. Use a sketch to show the effect it has on trim and reserve buoyancy.
2. What should you do if your nets become fouled while making way?
3. How would you safely carry bulk fish in a hold?
4. What basic precautions would you take when bad weather is expected?
5. What are the problems associated with having a vessel with:
   (a) a large positive trim
   (b) a large negative trim?
6. The vessel drawn below is discharging cargo alongside the wharf. Show what happens when the starboard weight is discharged.



7. A hold is partly filled with a cargo of fish. During the fishing operation the vessel takes a list and a quantity of fish shifts to the port side, so that the surface of the fish remains parallel to the waterline. On the following diagram show the effect on the ship's stability.



ANSWERS TO SELF-TEST QUESTIONS

Unit 3.6

1. The buoyancy provided by the underwater volume of the forward compartment is lost, as is the reserve buoyancy of the enclosed volume above it. The effect on the trim is the same as if a weight is added equal to the weight of water entering the volume of lost buoyancy. The draft increases and the vessel trims by the head. Before bilging, the reserve buoyancy was the entire enclosed volume above the original waterline. After bilging it is the enclosed volume above the new intact water plane area.

2. As discussed in the text on page 12, any suspended weights must be considered to act at the point of suspension. This effectively raises the position of the centre of gravity, thus reducing the GM. For a vessel beam trawling, the extended gear provides a larger lever to heel the ship. If at any stage this heeling lever is greater than the vessel's righting lever, she could capsize. If the nets of a vessel engaged in beam trawling become fouled on the bottom, the momentum of the vessel making way through the water could create massive heeling moments, especially if she is making a turn at the time.

   The first action would be to stop the engines immediately, and then slack away on the trawl winches to lessen the immediate strain. There is the danger of gear parting, and injury to crew, but even this is not as serious as the potential danger of capsizing when the gear is fouled.

3. Ensure that the longitudinal portable divisions are properly installed to prevent the free surface effect of the cargo while being transported. The cargo must not be able to shift.

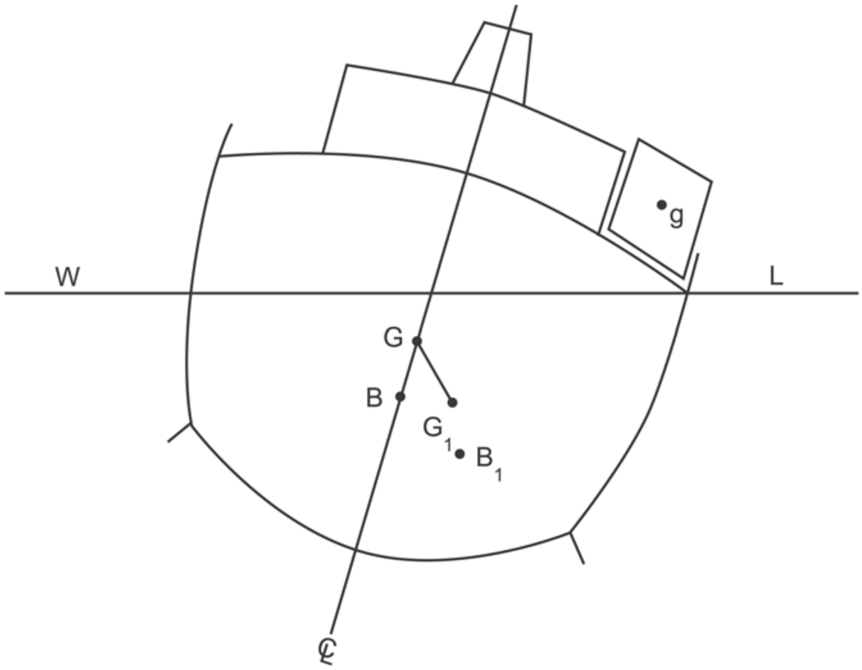
4. All doorways and other openings through which water can enter the hull, or deck houses, accommodation or forecastle, etc. should be suitably closed in adverse weather. All appliances for this purpose should be maintained in good efficient condition. Hatch covers and flush deck scuttles should be kept properly secured. All deadlights and vent covers should be closed. All fishing gear not in use should be stowed and properly secured. All other large weights should be stowed as low as possible.

   All free surfaces should be reduced if possible, and slack tanks avoided. Obviously a safe haven should be sought, to weather out the storm.

5. (a) A vessel with a large positive trim is one which is trimmed by the head. This would result in difficulty in manoeuvring and reduce the vessel's ability to ride over head seas. There is also a reduction in her reserve buoyancy forward and seas coming on deck may overcome her. She would also be very sluggish and slow to respond to the helm.

   (b) A vessel with a large negative trim is one which is trimmed by the stern. Such a vessel will heel over excessively when helm is applied. In a large following sea she will be almost impossible to control and will have a tendency to broach.

6.

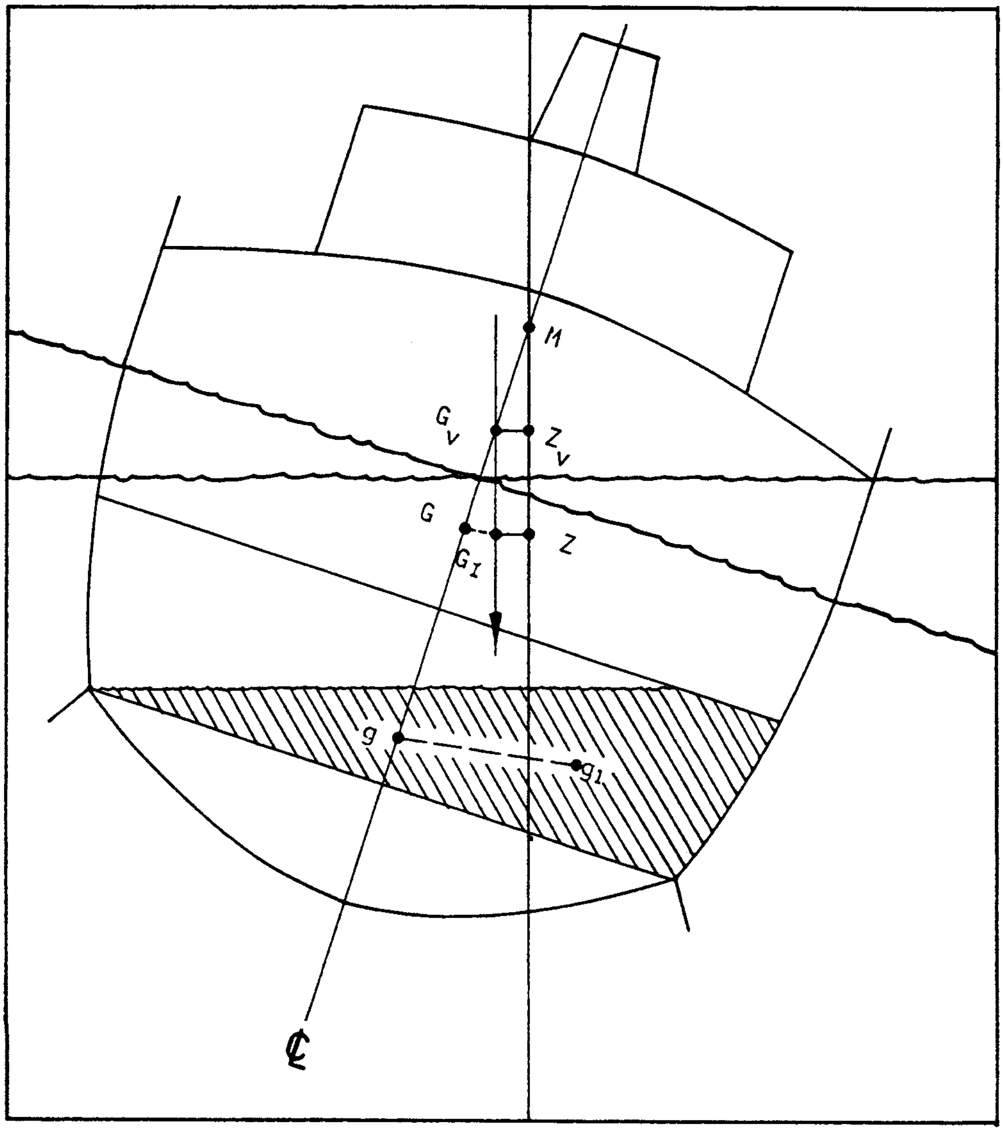


WL moves to WL_2 (the vessel now has more weight on the Port side).

B moves to B_2 (B_2 is now the centre of underwater section).

G moves to G_1 (centre of gravity moves in the opposite direction of the weight which is removed).

7.



g moves to g_1 (new centre of gravity of fish).

B moves to B_1 (new centre of underwater section).

G moves to G_V (the rise in the centre of gravity due to the added shifting weight of the fish).

G_V ●—● Z_V is now the new righting lever.

INTRODUCTION TO SIMPLIFIED STABILITY INFORMATION

The following Section has been included in recognition of the increasing complexity of vessels being skippered by holders of Master Class V certificates of competency.

Study of the following Section will greatly increase your understanding of the subject and help you through your oral exam.

But more than likely the subject matter that follows will relate directly to vessels you may have already served on or will skipper soon.

In particular, make sure you read the Introduction to Twosuch's stability book. Note, especially, the order in which tanks should be used.

Not only will this introduction part tell you how to use the book; it is full of useful information that applies to all vessels.

SECTION 4

TWOSUCH GUIDE NOTES

Every vessel in commercial survey is required to have its own stability information tabulated in a book and held on board the vessel for reference. *Simplified stability information for MV "TWOSUCH"* is an example of the stability book to be carried on MV "TWOSUCH".

The stability book is divided into nine Parts. These are listed in the Contents Page (iii).

Study the relevant Parts in the "TWOSUCH" stability book as you read through this guide. Make notes in the stability book where you feel that you need to.

Unit 4.1

Study Part 1, 'INTRODUCTION'.

The introduction page 1 outlines the purpose of the stability book.

Unit 4.2

Study Part 2, 'GENERAL DATA'.

This Part explains, in a general way, how the vessel's stability is affected by various forces such as wind and waves and conditions - such as having excessive water on decks, slack tanks and beam trawling. Advice is given so that, with these factors in mind, the Master may be able to keep the vessel's stability to a maximum.

The prudent Master would study, and be guided by, these notes.

(Note that the frames are numbered from Aft (No 1) to Frd (No 41).)

Page 4 depicts the dimensions of "TWOSUCH".

Unit 4.3

Study Part 3 'TANK LOCATION'.

On page 5 the tank locations are depicted.

Unit 4.4

Study Part 4, 'SUMMARY OF SPACES'.

The table on page 6 provides us with information about the content of each tank or space, its frame spacing, capacity, vertical centre of gravity (VCG), longitudinal centre of gravity (LCG) and the maximum free surface moment (FS).

If you look from left to right across the top of the table you will see the headings for each column.

SPACE

The names of each space are listed. For example, 'FOR'D F.O P & S: read forward fuel oil tank/s port and starboard.

FRAME No

Between which frames the tank or space is positioned.

NOTE: The frames are numbered from aft.

CONTENT S.G.

The matter contained within the space and its specific gravity. Fresh water does not have a specific gravity listed as it is assumed to be known as 1.000.

The specific gravity of the substance needs to be known so the weight of the substance in the space can be calculated. This has been pre-calculated for you in the TANK DATA tables in the following Part. This is because these tanks have a specific purpose eg fuel oil. Tanks which can be used for liquids of varying densities have the capacity given for FW. The Master will vary the tonnage according to the density of the cargo.

CAPACITY TONNE

Lists the maximum weight in tonnes that a space can hold.

VCG M

Lists the vertical centre of gravity (VCG) of a space in metres away from the keel. VCG is equivalent to KG.

LCG M

Lists the longitudinal centre of gravity (LCG) of a space in metres forward or aft from the centreline of the vessel. A *positive* figure denotes a distance forward of the centreline, a *negative* figure, aft.

MAX FS

Lists the maximum free surface moment for each space. The units for this are tonnes/metres.

NOTE: Regardless of the level of fill of a tank at the vessel's departure, the maximum free surface moment should *always* be used in your calculations.

This is because tanks are rarely filled to 100% capacity and during the voyage it is also expected that the level in the tanks will reduce as the substance is consumed. Therefore, for safety, the maximum free surface moment is always used.

Beneath the table, recommendations are given as to the order in which the tanks should be used in order to keep trim and list to a minimum. Using the tanks in this order ensures maximum stability of the vessel.

Remember that stability is also best maintained when one tank at a time is used so that free surface effect is kept to a minimum.

UNIT 4.5

Study Part 5, 'TANK DATA'.

It is important to note that the tables in Part 4, SUMMARY OF SPACES, gives only the weight, VCG and LCG for a tank or space when 100% full (or empty). The table does not list the weight, VCG, and LCG when the tank is partially full.

As tanks are not always filled to capacity (and once at sea the level will drop as the substance is consumed), we therefore need to calculate the weight, VCG and LCG for various levels of fill in order to calculate the vessel's stability.

On pages 7-11, tank data have been calculated for the various tanks on board MV "TWOSUCH".

The dimensions of each tank are shown in a diagram and the frame numbers. Under frames 29 – 32 (Pg 7) FW Port and Starboard is FSN .65. FSN is Free Surface Number. The units for this are tonnes/metres.

Beneath the diagram is a table which gives the capacity (ie weight) in tonnes, the VCG and the LCG for a given sounding.

For example, if we sounded the port forward fuel oil tank and read 1.2 metres: in order to calculate our final stability we need to find out the weight, VCG and LCG of the fuel oil contained in the tank.

To find this information we need to go to the TANK DATA table for the forward fuel oil tank on page 8.

For example, if sounding was 1.2 m we find this under the column.

SOUNDINGS (m)

If we then look to the right we can see that the capacity would be 1.8 tonnes, the VCG, 0.99 m and the LCG, +3.45 m. This would be entered on the displacement table followed by all the other tanks.

Unit 4.6

Study Part 6 'CALCULATION OF KG AND LCG FOR CONDITIONS OF LOADING IN WHICH THE VESSEL NORMALLY OPERATES'.

On pages 13 – 19 there are several tables listed in which the KG and LCG have been calculated for common conditions of loading.

We need to know the KG and LCG so that we can use this information to look up the 'curve of limiting KG' and the 'curve of limiting LCG' and thus assess whether the vessel has 'safe' or 'unsafe' stability. We will look at this procedure more closely in Unit 4.8.

We will firstly look at the displacement table for '*CONDITION 1 LIGHTSHIP*' on page 12.

Remember that 'Lightship' is the weight of the ship as built. These include its structure and permanent fixtures such as tanks, but does not include items loaded onto the vessel after it was built such as water, provisions and cargo.

The 'Lightship' table can be used to calculate the stability of the vessel where the vessel's loaded condition differs from the common conditions which have already been calculated in the displacement tables on pages 13 - 19.

If you now turn to page 14 '*CONDITION 3 FISHING 20% CATCH 20% FUEL AND WATER*', I will explain the columns and how the figures have been calculated.

Firstly, the title '*FISHING 20% CATCH 20% FUEL AND WATER*' translated means that the table has been calculated assuming the vessel is 'fishing' with 20% capacity catch, 20% fuel and 20% water on board.

The '*MASS TONNES*' (weight) of the item is multiplied by its '*KG*' to give the '*VERTICAL MOMENT*'.

The weight of the item is multiplied by its '*LCG.*' to give the **LONG---AL MOMENT**

The '*FSN*' (Free Surface Numeral) is the free surface moment for the tank or space. Remember that we always use the maximum free surface moment and this is obtained by referring to the 'MAX FS' column in the 'Summary of Spaces' tank values table on page 6.

You will find that the 'MAX FS' figure for the Freshwater Port and Starboard tanks of 0.65 has been doubled in the '*FSN*' column in Condition 3. This is because the 'MAX FS' figure had been calculated for only *one tank* and the '*FSN*' as per condition 3 is for *both tanks*.

NOTE: In your calculations, you must always remember to multiply the 'MAX ' by the number of tanks to give you the '*FSN*'.

In order to calculate the final KG and LCG of the vessel, the weight of the deadweight items (all items included in the '*ITEM*' column) are added to the lightship weight. The total is the vessel's displacement.

The KG is obtained by dividing the total Vertical Moments by the total displacement.

Eg $$\text{KG} = \frac{\text{Sum of Vertical Moments}}{\text{Displacement}}$$

$$\text{KG} = \frac{-141.47}{171.54}$$

$$\text{KG} = 3.40$$

The LCG is obtained the same way.

Eg $$\text{LCG} = \frac{\text{Longitudinal Moments}}{\text{Displacement}}$$

$$\text{LCG} = \frac{-141.47}{171.54}$$

$$\text{LCG} = -0.83$$

NOTE: The KG that we have obtained so far does not allow for the free surface effect of the contents of the tank. In order to better assess the vessel's stability, we must also allow for the free surface effect.

To do this, the total of the free surface moments are divided by the Displacement.

$$\text{Eg} \qquad (\text{Row E}) \;\; \text{FSN} = \frac{\text{FSN (Total free suface moments)}}{\text{Displacement}}$$

$$= \frac{2.36}{171.54}$$

$$= 0.01$$

The FSN must then be added to the KG to obtain the KF_f.

The KG_f is then entered in the 'Curve of Limiting KG' table (page 29) to assess whether the vessel has sufficient stability.

The LCG and displacement is then entered in the 'Curve of limiting LCG' table (page 30) to assess whether the vessel has safe trim.

Unit 4.7

Study Part 7, 'GUIDANCE NOTES FOR THE CALCULATION OF KG AND LCG FOR ANY CONDITION OF LOADING'.

In this Part some of the terminology and calculations used in the stability book are explained.

A worked example of determining KG and LCG for an *uncommon* condition of loading is shown on pages 21 - 27.

Take a photocopy of the 'Lightship Condition' table and work through the example with this guide. (Or, use pencil and work in the actual lightship table in the TWOSUCH booklet.)

Step 1

Enter the weight, KG and the LCG of the items listed in sections 7.2.1 and 7.2.2 (deadweight items) in the Lightship Condition Displacement Table.

Sections 7.3.1 - 7.3.7 explain how the weight, KG and LCG are determined for each item.

Step 2

(a) Multiply the weight of each item by its KG to find the vertical moments.

(b) Total the vertical moments to give you the deadweight vertical moment.

(c) Add the deadweight vertical moment to the lightship vertical moment to give you the *total vertical moment*.

Step 3

(a) Multiply the weight of each item by its LCG to find the longitudinal moments.

(b) Total the longitudinal moments to give you the deadweight longitudinal moment.

(c) Add the deadweight longitudinal moment to the lightship longitudinal moment to give you the total longitudinal moments.

Step 4

(a) Total the weight of the items to give you the deadweight.

(b) Add the deadweight to the lightship weight to give you the displacement.

Step 5

Divide the total vertical moments by the displacement to give you the KG.

Step 6

Divide the total longitudinal moments by the displacement to give you the LCG.

NOTE: In this example they have *not* taken the free surface effect into account. Remember that you should always take the free surface moment into account in your calculations.

Therefore, at the same time as entering the VCG and LCG values you should also enter the maximum (Free Surface) moment taken from the 'Summary Of Spaces' table (page 6). Also remember that the maximum free surface value given in the 'Summary Of Spaces' table is for one tank only. Lastly, total the FSN moments and divide the result by the Displacement. Add the FSN to the KG to find the KG_f.

Now that you have calculated the Displacement, KG (KG_f) and LCG of the loaded vessel the final step is to look at the 'Curve Of Limiting KG' (page 29) and 'Curve Of Limiting LCG' (page 30) to see whether the vessel has 'Safe' or 'Unsafe' stability and safe trim respectively. On page 28 it shows how to enter the displacement, KG and LCG on both graphs. As is shown, MV "TWOSUCH" has sufficient stability and safe trim in this condition of loading.

Unit 4.8

Study parts 8 and 9, 'CURVE OF LIMITING KG' and 'CURVES OF LIMITING LCG'.

These are the graphs for determining 'Safe' or 'Unsafe' stability and trim for MV "TWOSUCH" given the displacement, KG and LCG. The method is depicted on page 28.

HYDROSTATIC PARTICULARS TABLE (Page 32).

In this table you can find certain values given the vessel's *hydrostatic* draft or displacement. These include:

- TPC (Tonnes Per Centimetre immersion) – the amount of weight in tonnes needed to change the vessel's draft by one centimetre.
- MCT (Moment to Change Trim) – the moment required to change trim by one centimetre.
- LCF (Longitudinal Centre of Flotation) – the point around which a vessel trims.
- KM - height of the metacentre above the keel in metres.

The procedure for finding the hydrostatic draft is as follows:

1. Obtain the draft marks forward and aft.
2. Correct them to the 'Baseline' depicted in the 'DRAFT MARK LOCATION' diagram (page 31).

There will be no correction to the aft draft as it is already measured from the baseline. The forward draft will need to have 0.26 m added to correct it to the baseline.

Eg. Assume the drafts:

Forward	=	2.65 m	aft	=	3.10 m
correction	+	0.26	correction		0.00
Corrected draft	F	2.91 m		A	3.10 m

3. Add the F + A drafts and then divide by two to give you the mean draft.

Eg F 2.91
= A 3.10
= 6.01

$$\text{mean draft} = \frac{6.01}{2} = 3.005$$

4. Calculate the total trim by subtracting the lesser from the greater draft.

Eg A 3.10
– F 2.91
Trim = 0.19 (by the stern)

NOTE: Trim is named by the head or the stern, whichever is the greater.

5. Find the LCF for the mean draft in the 'Hydrostatic Particulars' table.

Eg mean draft = 3.005 LCF = –1.015

6. Find the LBP (Length between perpendiculars). Look at the diagram on Page 4.

Eg 10.845
+ 10.845
LBP = 21.690 m

7. Enter the values for the Trim, LCF and LBP in the following formula to find the correction to mean draft required to give you the hydrostatic draft.

Eg

$$= \frac{\text{Trim} \times \text{LCF}}{\text{LBP}}$$

$$= \frac{019 \times -1.015}{21.69}$$

$$\text{Correction} = -0.0089\,\text{m}$$

8. Apply the correction to the mean draft to give you the hydrostatic draft.

Eg	mean draft	3.005 m
	correction	– 0.009 m
	hydrostatic draft =	2.996 m

HOW WELL HAVE YOU UNDERSTOOD WHAT YOU HAVE JUST READ?

The Displacement Tables

The eight tables demonstrate the changing nature of Twosuch's stability as she goes about her work.

Remember that such tables are theoretical and will not cover every condition a vessel may encounter.

As master of a vessel you should be able to immediately recognise a potential condition of loading that could seriously reduce your vessel's stability.

When cargo is put on board, the master should know, or be able to estimate, the weight of the cargo.

The master should also approximate the KG of the weight and be able to enter this information in the displacement table.

Multiplying the tonnes of cargo by the CG of the cargo provides the vertical moment.

It's the sum of all these moments, divided by the weight of what's on board, that tells you your vessel's stability – the KG.

Specific gravity

If different fluid is put into a fuel tank, the contents of the tank will have a different weight.

For instance, when one of the forward double bottom tanks are full of fuel oil with a specific gravity of 0.833, the tank's contents weighs 6.55.

If the tank was filled with salt water (SG: 1.025) it would weigh eight tonnes.

FSN

Once a tank has been drawn from – no matter how much or how little – then the Free Surface Number should be applied.

Unit 4.9

What we have to do now is establish whether the KG Fluid and the LCG as calculated establish that the vessel has adequate stability.

On pages 29 and 30 of the *Simplified Stability* booklet you will find a curve of limiting KG and a curve of limiting LCG. Providing the calculated KG Fluid and LCG fall within the area under, or between, the curves, then the vessel meets the stability requirements.

On page 28 there is an example of how to use the curves for the condition calculated on pages 26 and 27.

Taking the KG Fluid first, it has been calculated that KG_f was 3.22 metres and displacement 195.94 tonnes.

On the KG_f scale, find the KG_f of 3.22 and extend the line across the graph. On the displacement scale, find the displacement of 195.94 and extend a line upwards. Where the two lines intersect is our point of interest.

You can see that this point lies *below* the curve and thus we have adequate stability.

Now try this: On the LCG scale, find the LCG of -0.3 metres and extend a line across the graph. On the displacement scale find the displacement of 195.94 tonnes and extend a line upwards. Where the two lines meet is the point of interest. You can see that this point lies between the two curves and thus the vessel meets the requirement regarding trim.

Unit 4.10

We will now consider a case where the resultant KG Fluid and/or LCG do not meet the requirements, and we shall establish what action to take.

The following information is for an imaginary condition of *M.V. Twosuch.* From this information we will complete a loading summary and then establish if the condition meets the requirements:

- Fresh water port and starboard: sounding of 0.6 metres.
- E.R. wing tanks port and starboard: sounding of 2.0 metres.
- Lube oil tank full.
- Hold half full at aft end: estimated weight 12 tonne.
- Crew, stores and provisions as Condition 3.

ITEM	MASS TONNES	KG	VERTICAL MOMENTS	LG	LONG MOMENTS	PSN
Fresh Water'	0.8	0.85	0.68	+4.74	+3.792	1.3
Engine Room Wings	12.6	2.4	30.24	–4.83	–60.858	0.88
Lube Oil	0.55	2.5	1.38	–7.9	–4.35	0.18
Crew and Effects	1.0	4.0	4.0	+6.0	+6.0	
Stores	2.0	3.0	6.0	–	–	
Provisions	0.4	2.0	0.8	+7.0	+2.8	
Hold	12	2.6	31.2	–1.09	–13.8	

Deadweight	29.35		74.3		–65.696	2.36
Lightship	148.46		516.61		–96.0	
Displacement	177.81	3.323	590.91		–0.91	–161.696

KG FSN	3.31 0.013
KG_f	3.323

Calculations

1. $$KG = \frac{\text{Vertical Moments}}{\text{Displacement}}$$

$$KG = \frac{590.91}{177.81}$$

$$= 3.323$$

2. $$LCG = \frac{\text{Longitudinal Moments}}{\text{Displacement}}$$

$$LCG = \frac{-161.696}{177.81}$$

$$= -0.91$$

3. $$\text{Free Surface Correction} = \frac{FSN}{\text{Displacement}}$$

$$\text{Free Surface Correction} = \frac{2.36}{177.81}$$

$$= 0.013$$

4. Fish Room

The fish room covers frames 14-26 and frames are 0.53 metres apart.

The fish hold is half full and all fish is at aft end.

Capacity of hold is 24 tonnes, therefore there is 12 tonne on board.

As all fish is at aft end, it must be from frames 14-20; that is, 6 frames at 0.53 metres = 3.18 metres from centre of tank.

The Centre of Gravity of fish must therefore be at 1.59 metres from centre of tank.

The LCG of the tank is 0.5 metres forward of amidships; therefore, LCG of fish is 1.59 - 0.5 = 1.09 metres aft of amidships.

CHECKING TO SEE IF VESSEL MEETS REQUIREMENTS:

(a) KG_f: 3.336 metres

Displacement: 177.81 tonnes

From the curve of limiting KG, the vessel's KG_f falls below the curve and thus meets the requirements.

(b) LCG: -0.91

Displacement: 177.81

From the curve of limiting LCG, the vessel's LCG falls below the curves and thus *DOES NOT* meet the requirements.

Before deciding what action to take, let us first try to establish why the vessel does not meet the criteria.

It is the LCG which does not meet the criteria, so the first conclusion that can be made is that the vessel has an excessive trim; as the LCG has a negative value, this excess trim must be by the stern.

If we now consult the system of tank usage on page 6 of the booklet, we can see that we have followed the recommended system; thus the fault does not lie with the tanks. The only other possible fault then is in the method of stowing the fish in the hold.

The problem could possibly be resolved by pumping fuel to other tanks in the vessel; however, if we were to do this we would be working against the recommended system. There is, therefore, no choice but to restow the fish, by one of two possible options:

(a) restow over all the hold

(b) restow in the forward half of the hold.

Being at sea, the most logical way to avoid possible crew injury is to restow over all the hold (option (a)).

ITEM	MASS TONNES	KG	VERTICAL MOMENTS	LG	LONG MOMENTS	FSN
Fresh Water'	0.8	0.85	0.68	+4.74	+3.792	1.3
Engine Room Wings	12.6	2.4	30.24	–4.83	–60.858	0.88
Lube Oil	0.55	2.5	1.38	–7.9	–4.35	0.18
Crew and Effects	1.0	4.0	4.0	+6.0	+6.0	
Stores	2.0	3.0	6.0	–	–	
Provisions	0.4	2.0	0.8	+7.0	+2.8	
Hold	12.0	1.8	21.6	+0.5	+6.0	
Deadweight	29.35		64.7		–46.616	2.36
Lightship	148.46		516.61		–96.0	
Displacement	177.81	3.269	581.31	–0.80	–142.616	

KG FSN	3.269 0.013
KG_f	3.282

We can now check the LCG and KG_f against the limiting curves; you should see that the vessel now meets the requirements.

(It should be noted that, if the vessel is to continue fishing, it is important to complete the summary by considering what would happen if the vessel's winch were to stall or the trawl was to foul suddenly!)

Unit 4.11 Excessive Trim

You should note that, in Unit 4.10, the vessel did not meet the requirements because of an excessive trim. The problem of excessive trim is one which few seamen fully understand.

Most of us appreciate, from experience, that if a vessel is trimmed by the head, then she will be difficult to steer. However, excessive trim by the head also can, and will, result in the vessel burying her bow - shipping vast quantities of water over the fo'c'sle head. This condition is extremely dangerous in moderate-to-rough weather.

The other extreme is what occurred in Unit 4.10 – excessive trim by the stern. A vessel with excessive trim by the stern runs the risk, particularly in quartering or following seas, of putting her stern under the water. There has been, in the last few years, a number of oil rig supply vessels that have foundered due to a combination of excessive stern trim and pipes on deck.

Unit 4.12 Self-test Exercise

1. *M.V. Twosuch* is at the fishing grounds in the following condition:

Fresh Water port and starboard	:	sounding of 0.9 metres
Engine room wing tanks	:	sounding of 1.9 metres
Lube Oil	:	as per Condition 4
Crew and Effects	:	as per Condition 4
Stores	:	as per Condition 4
Provisions	:	as per Condition 4
Hold	:	1/3 full over full area

   Draw up a loading summary and ascertain if *Twosuch* meets the requirements of the KG and LCG limiting curves.

2. *M.V. Twosuch* is at the fishing grounds in Condition No.4, except that she has 50% catch and it is all stowed at the after end of the hatch. The engine room wing tanks have a sounding of 1.6 metres.

   Draw up a loading summary and ascertain if *Twosuch* meets the requirements of the KG and LCG limiting curves. Is there any action you could take to improve the vessel's condition?

Unit 4.13

You should realise that the curves of limiting KGs and LCG is for the static condition only. That is, it is the power exerted by the vessel when it is heeled to an angle. What then happens if the forces causing the vessel to heel are greater than the vessel's ability to return to her original condition?

This could be caused by water being trapped on deck (freeing ports blocked); or the trawl becoming foul and the skipper maintaining full revs - or even excessively large waves breaking on a vessel. Obviously, such conditions cannot be allowed for or else the vessel would never leave port! However, sensible seamanship can avert most of the conditions mentioned.

ANSWERS TO SELF-TEST QUESTIONS

Unit 4.12

1.

ITEM	MASS TONNES	KG	VERTICAL MOMENTS	LG	LONG MOMENTS	FSN
Fresh Water	1.68	1.05	1.68	+4.79	+7.664	1.3
Engine Room Wing Tank	12.0	2.385	28.62	–4.82	–57.84	0.88
Lube Oil	0.10	2.5	0.25	–7.9	–0.79	0.18
Crew and Effects	1.0	4.0	4.0	+6.0	+6.0	
Stores	2.0	3.0	6.0	–	–	
Provisions	0.4	2.0	0.8	+7.0	+2.8	
Hold	8.0	2.067	16.536	+0.5	+4.0	
Deadweight	25.1		57.886		–38.166	2.36
Lightship	148.46		516.61		–96.0	
Displacement	173.56	3.31	574.496	–0.773	–134.166	

KG	3.31
FSN	0.013
KG_f	3.323

* The vessel meets the requirements.

2.

ITEM	MASS TONNES	KG	VERTICAL MOMENTS	LG	LONG MOMENTS	FSN
Fresh Water	1.78	1.26	2.24	+4.88	+8.69	1.3
Engine Room Wings	10.4	2.33	24.232	–4.79	–49.816	0.88
Lube Oil	0.10	2.5	–0.25	–7.9	–0.79	0.18
Crew and Effects	1.0	4.0	4.0	+6.0	+6.0	
Stores	2.0	3.0	6.0	–	–	
Provisions	0.4	2.0	0.8	+7.0	+2.8	
Hold	12.0	2.6	31.2	–1.09	+13.08	
Deadweight	27.68		68.722		–46.196	2.36
Lightship	148.46		516.61		–96.0	
Displacement	176.14	3.323	585.332	–0.807	–142.196	

KG	3.323
FSN	0.01
KG_f	3.333

APPENDIX A

SIMPLIFIED STABILITY INFORMATION

FOR

M.V. “TWOSUCH”

First published 1984

Second edition 1987

Reprinted and reformatted 2001

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W A R N I N G
The contents of this sample book must not be used for determination of stability criteria aboard any vessel in service.
Reference must be made to the vessel's own stability book.

Published by and available from
WestOne Services

Prospect Place West Perth WA 6005
Tel: (08) 9229 5252   Fax: (08) 9229 5292
E-mail: training.pubs@westone.wa.gov.au
Website: www.westone.wa.gov.au

PREFACE

The stability information as presented in this sample book is that which applies to the following categories of vessels:

> Class 2B and 2C vessels of 20 metres and over but less than 35 metres O.A.L.
>
> Class 3 vessels of stability category K and L of less than 35 metres O.A.L.

These categories cover most trading and fishing vessels within the length specifications.

The objective of stability information being presented in this simplified manner, is to enable persons in command of small vessels to ensure that their vessel is in a good stable condition, without the need to have a deep knowledge of stability principles.

The book is presented such that it guides the reader through a full sample loading condition which will then be able to be repeated for any change in distribution.

It must be noted that the stability information and vessel description in this book is given as an example only. Each individual vessel which is required to have stability information presented in this manner will have its own individual stability characteristics.

The publishers acknowledge the Western Australian Department of Marine and Harbours for their kind permission to reproduce the total contents of this book.

VESSEL CLASSIFICATIONS

2B	-	Sea going non-passenger vessel for use in all operational areas up to and including offshore operations.
2C	-	Sea going non-passenger vessel for use in all operational areas up to and including restricted offshore operations.
3 category K	-	Fishing vessels of 25 metres measured length and over.
3 category L	-	Fishing vessels of less than 25 metres in measured length which engage in operations resulting in excessive weights on decks or rigging (e.g. tuna fishing, prawn trawling, beam trawling, single or double boom trawling, large fish tanks on deck etc.)

Note: Crayfishing boats could be considered within class 3 category L under certain loading conditions.

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1. INTRODUCTION

This book is on board for the purpose of enabling the Master and others concerned with the operation of the vessel to determine the measure of stability of the vessel. Curves of limiting KG and LCG are included in the book and subject to the calculated position of KG when plotted on the graph of Limiting KG being below the curve and the calculated LCG when plotted on the graph of Limiting LCG being between the curves the measure of stability of the vessel exceeds the recommended I.M.C.D. criteria.

For your information calculations of KG and LCG for several conditions of loading in which the vessel normally operates have been made. With the exception of condition (7) where the position of the calculated LCG falls outside the curves of limiting LCG all values of KG are below the curve of limiting KG and all values of LCG within the curves of limiting LCG. These calculations show the stability of the vessel in condition I to 6 and 8 to be in excess of the I.M.C.D. recommendations but do not mean it is not possible for the vessel to be capsized.

It is the responsibility of the Master to ensure the vessel is operated in a safe and seamanly manner and that the calculated KG and LCG for any condition of loading can be plotted below the curve of limiting KG or within the curves of limiting LCG. To assist you in the calculation of KG and LCG a worked example is included on pages 20 - 25 of this book. A stamped and approved copy of this book must be on board at all times. Keep this book complete and legible. Should it become lost or unusable, obtain a replacement copy immediately.

2. GENERAL

The sheets which follow are general comments to enlarge on good seamanship and house-keeping and issued only to enable the operators to use the stability data to best advantage.

TANK USAGE AND SLACK TANKS

(1) Tanks which are not in use, must at all times be full and pressed up, or empty where possible. Remember that slack tanks create free surface and the effect of slack tanks results in actual and often large reductions of the stability.

(2) When manipulating tank contents by pumping from one tank to another, make every effort to maintain level trim. Develop a system of tank usage which keeps the trim of the vessel from becoming excessive. Remember that the calculations for stability are accurate only within a small range of trim.

(3) Transference of fuel or fresh water and the ballasting of tanks should only be carried out in favourable weather conditions.

(4) There is in this book a recommended sequence for the use of liquids in tanks, departure from which may be dangerous. These recommendations should be followed unless there are specific reasons at the time for not doing so.

(5) Occasionally conditions of loading and tank manipulations could lead to trim by the bow. This can be avoided by co-ordinating the operations; in other words, the effects of loading can be offset by correctly manipulating the contents of the tanks.

(6) Excessive trim by the bow can lead to difficulties in handling the vessel and may result in poor seakeeping.

WATER ON DECKS

Large amounts of water on-decks raise the centre of gravity of the vessel and drastically reduce its stability.

(1) Shipping large amounts of water should be avoided by good seamanship.

(2) It is essential to allow quick drainage for any water on decks by keeping the *freeing points* uncluttered and free from obstructions at all times.

FREE SURFACE EFFECTS

The effect of Free Surface of liquids is to raise the Vertical Centre of Gravity, therefore reducing stability.

(1) *On Deck*
Do not allow water to accumulate on *main deck* or *upper deck*.

(2) *In Tanks*
The number of slack tanks at any one time should be kept to a minimum. To restrict the amount of Free Surface, it may be necessary to transfer liquids between tanks, bearing in mind the trim required and the weather conditions at the time.

EFFECT OF WIND AND WAVES

High speed wind and gusts, can cause a considerable angle of heel, especially for vessels with large superstructures, thus reducing the range of stability. The situation can become serious, particularly in heavy and confused seas. In heavy weather, make sure that all manoeuvres are carried out in accordance with the best practice of seamanship.

WEATHERTIGHT INTEGRITY

In severe weather, it is the responsibility of the Skipper and Crew to ensure that all hull, deck and superstructure openings are closed watertight as far as is practicable. In emergency conditions, all openings must be closed, particularly weathertight doors, hatches and ventilation trunks, and only opened at the Skipper's discretion.

GENERAL COMMENTS

(1) Always determine the cause of a list or the change of trim of the vessel.

(2) Heavy rolling of the vessel should be regarded as a potential hazard. Oblique seas, particularly from astern, reduce the average stability below that calculated on the sheets in this book.

The most undesirable condition occurs when a wave crest is amid ships and when running before a high-following or quartering sea. Rolling becomes most violent when seas approach the vessel at about 15 degrees abaft the beam.

(3) Fish or cargo shall be properly secured against shifting which could cause dangerous trim or heel of the vessel.

BEAM TRAWLING

(1) Excessive loads may be imposed during beam trawling operations upon the working gear and, through the gear, upon the vessel. The main risks are therefore in failure of gear under load and in reducing the stability of the vessel.

(2) When fishing gear is fast on the bottom and attempts are being made to free it there is grave danger of serious personal injury due to gear parting under heavy strain. There is also a potentially more dangerous effect of the fouled gear on the vessel's stability which can lead to the vessel capsizing, thereby putting the lives of all on board at risk. This effect is more prevalent in heavy weather conditions or when strong tidal forces are being experienced. In these conditions a vessel is particularly vulnerable if it lies beam on to wind and sea or to the direction in which the tide is running.

(3) When attempting to free fishing gear fouled on the bottom, fishermen should exercise every care and where possible endeavour to free the gear while bow or stern on to strong tides or heavy weather or if possible wait for slack water or the weather to abate. Cutting equipment should be readily available to cut gear loose in an emergency.

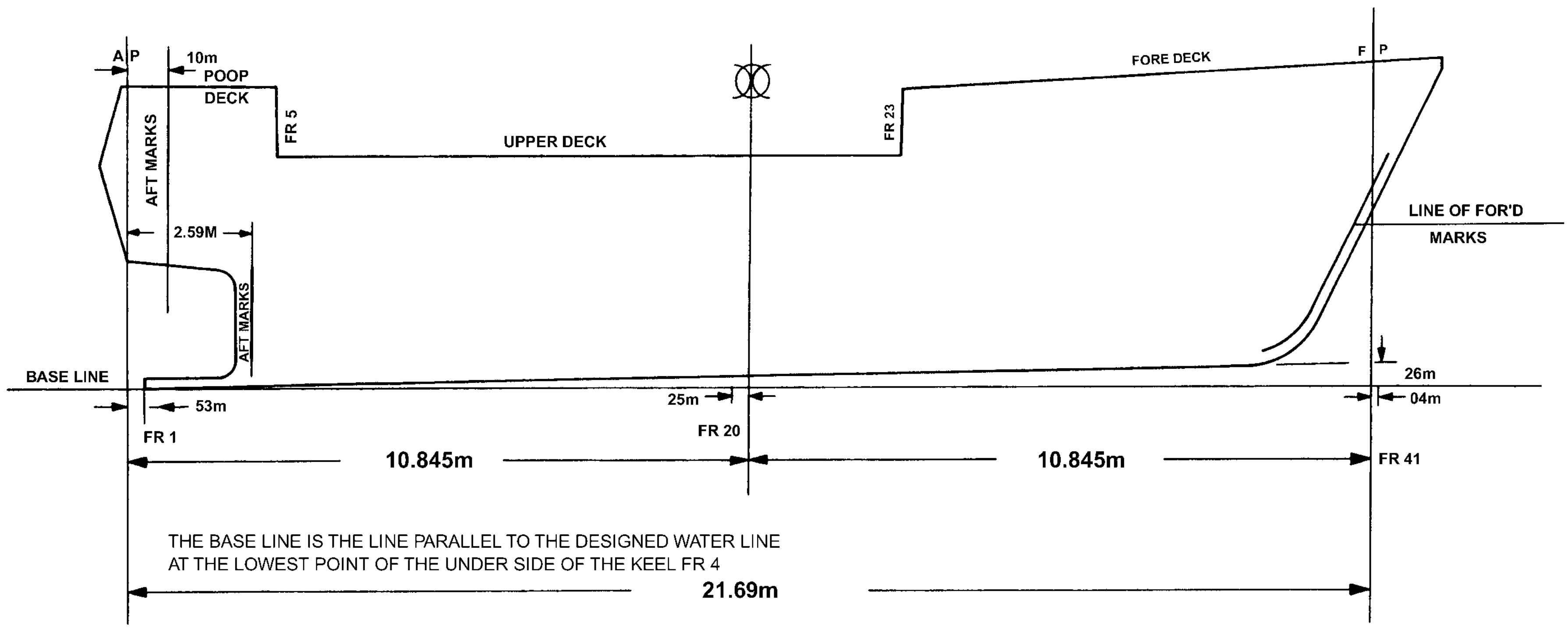
(4) The heeling effects imposed upon a vessel when attempts are made to free a fastened trawl have to be withstood by the vessel's transverse stability and the adverse effects of these heeling forces are minimised if they are not applied through the towing block when it is located at the outboard end of the boom.

(5) Means should be provided to release the block at the outboard end of the boom allowing it to drop into the water, or some equally effective method adopted which ensures that the pull in the towing warp is applied close to the vessel's side and as low as practicable when an attempt is being made to haul the warp and clear a fastened net.

(6) Adverse effects similar to those associated with a beam trawl fastened against a sea bed obstruction may arise when the trawl itself is "sanded-up".

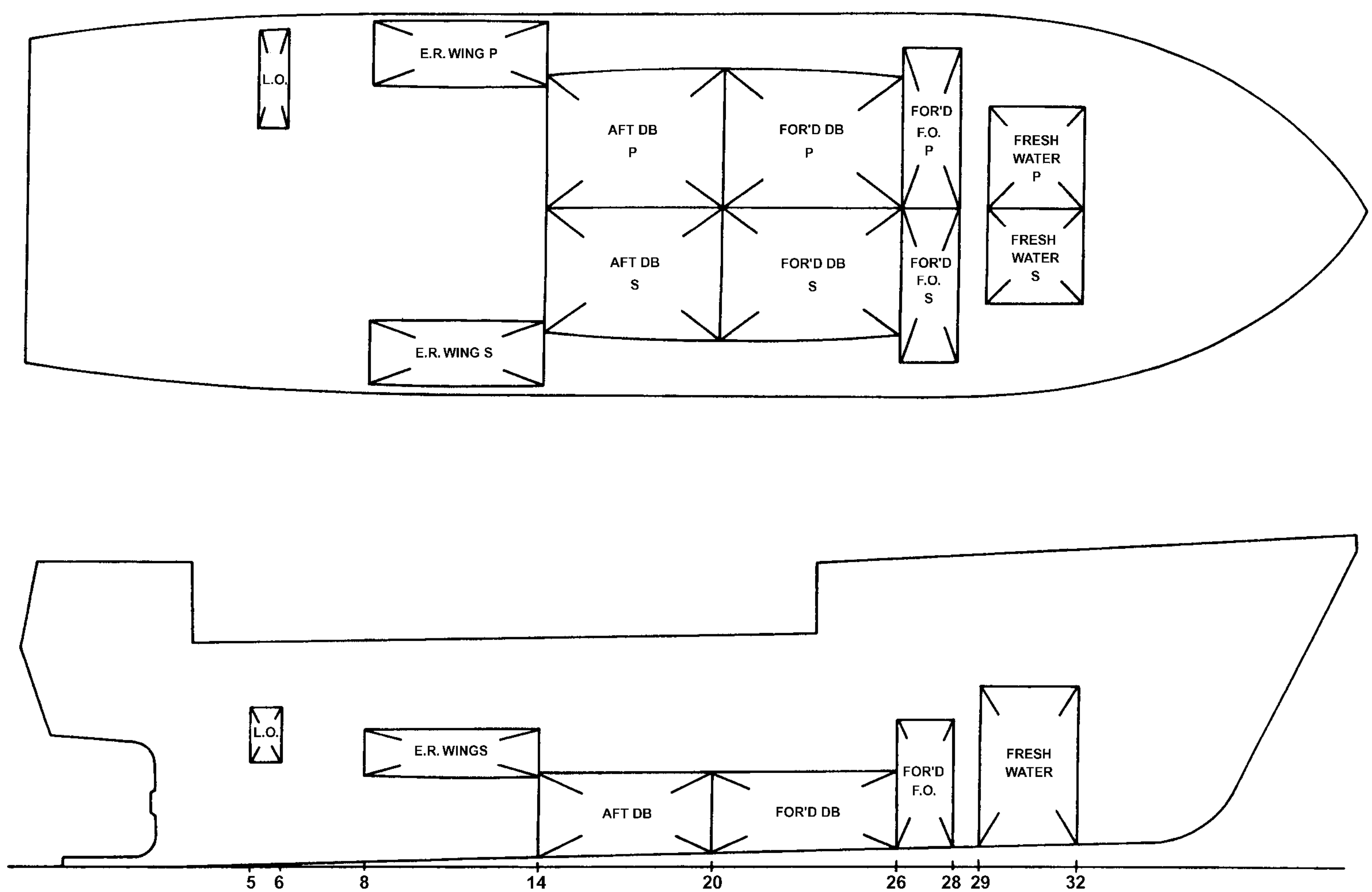
LENGTH O.A.	23.78M
LENGTH B.P.	21.69M
BREADTH MLD.	6.74M
DEPTH MLD.	3.753M
OFFICIAL No	355976

M.V. "TWOSUCH"
SCALE = 1:100
FRAME SPACING 0.53M



3. TANK LOCATION

M.V. "TWOSUCH"
TANK LOCATION
SCALE - 1 : 100



4. SUMMARY OF SPACES

M.V. "TWOSUCH"

VALUES EACH TANK

SPACE	FRAME NO	CONTENT S.G.	CAPACITY TONNE	V.C.G. M	L.C.C. M	MAX. F.S.
FRESH WATER P & S	29 – 32	FRESH WATER	4.40	2.06	+5.05	0.65
FOR'D F.O. P & S	26 – 28	FUEL OIL .833	4.50	1.78	+3.45	2.20
FOR'D D.B. P & S	20 – 26	FUEL OIL .833	6.55	1.17	+1.25	4.14
AFT D.B. P & S	14 – 20	FUEL OIL .833	6.40	1.20	–1.78	4.72
E.R. WING P & S	8 – 14	FUEL OIL .833	6.30	2.40	–4.83	0.44
LUB. OIL	5 – 6	LUB. OIL .833	0.55	2.50	–7.90	0.18
HOLD	14 – 26	FISH 0.5t/M^3	24.00	2.60	+0.50	

It is recommended that tanks be used in the following order:

Fresh Water	*Fuel Oil*
FW Port	Aft DB Std
FW Std	Fwd DB Port
	Fwd DB Std
	Fwd FO Port
	Fwd FO Std
	Aft DB Port
	ER Wing Port

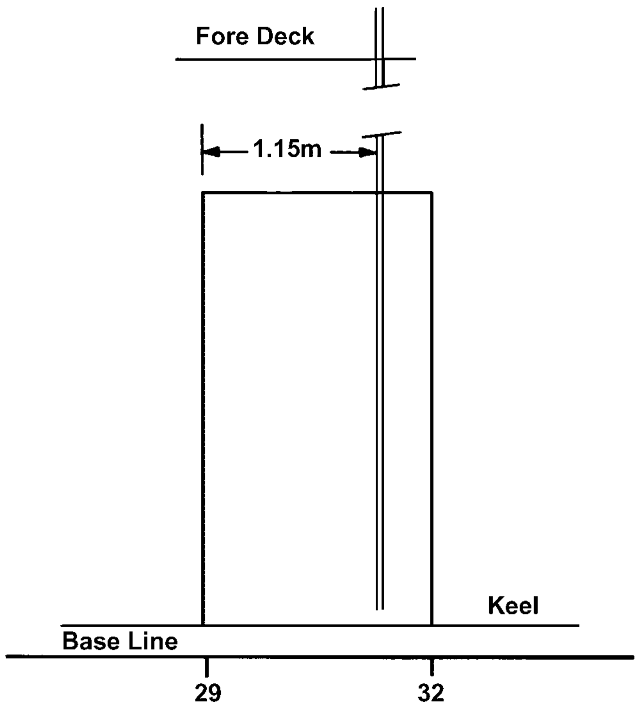
5. TANK DATA

FRESH WATER TANKS

PORT AND STARBOARD

FRAMES 29 - 32

F.S.N. 0.65 Tm



Sounding pipe 0.92 m above fore deck

.07 m p & S of center line

1.15 m for'd F 29

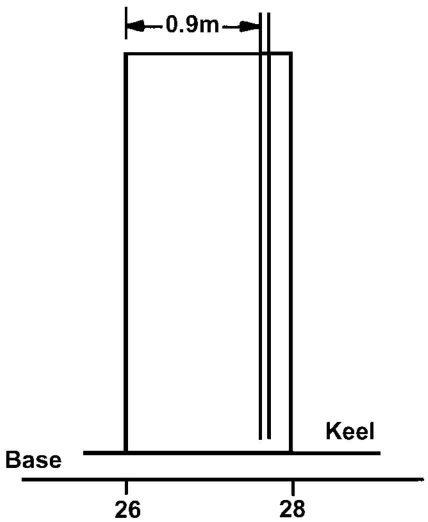
SOUNDINGS (m)	CAPACITY (Tonnes)	V.C.G. (m)	L.C.G. (m)
0.2	0.1	0.65	4.7
0.4	0.2	0.75	4.72
0.6	0.4	0.85	4.74
0.8	0.65	0.95	4.77
1.0	0.95	1.15	4.8
1.2	1.30	1.25	4.82
1.4	1.7	1.35	4.85
1.6	2.1	2.45	4.88
1.8	2.45	1.55	4.91
2.0	2.85	1.65	4.94
2.2	3.2	1.75	4.97
2.4	3.6	1.85	4.99
2.6	4.0	1.95	5.02
2.8	4.4	2.05	5.04
2.82	4.45	2.06	5.05

FORWARD FUEL OIL

PORT AND STARBOARD

FRAMES 26 - 28

FUEL OIL S.G. 0.833 F.S.N. 2.2 Tm



Sounding pipe 0.23 m above tank top

0.20 m p & S of center line

0.90 m for'd FR 26

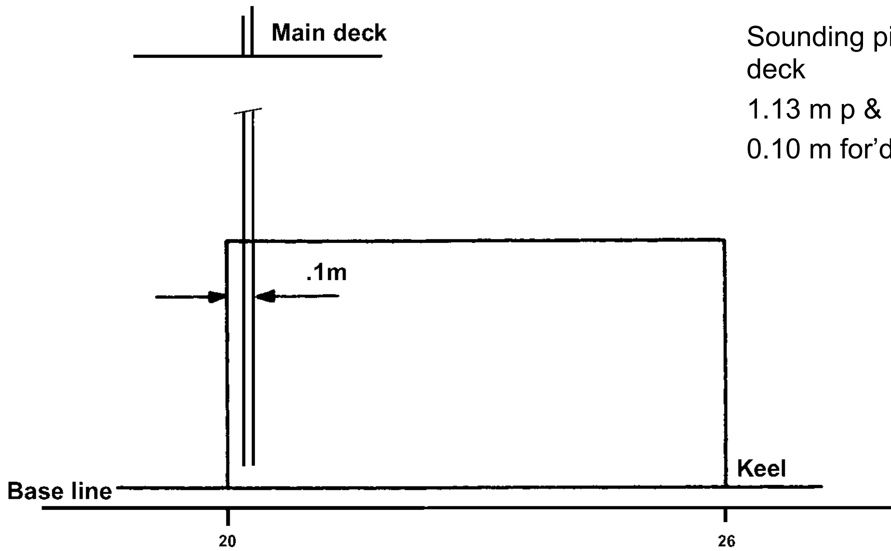
SOUNDINGS (m)	CAPACITY (Tonnes)	V.C.G. (m)	L.C.G. (m)
0.2	0.1	0.2	+3.45
0.4	0.3	0.36	"
0.6	0.6	0.51	"
0.8	0.9	0.67	"
1.0	1.3	1.83	"
1.2	1.8	0.99	"
1.4	2.35	1.15	"
1.6	2.75	1.30	"
1.8	3.25	1.46	"
2.0	3.75	1.52	"
2.2	4.25	1.68	"
2.3	4.5	1.78	"

FORWARD DOUBLE BOTTOM

PORT AND STARBOARD

FRAMES 20 - 26

FUEL OIL S.G. 0.833 F.S.N. 4.14 Tm



Sounding pipe .31 m above main deck

1.13 m p & S of center line

0.10 m for'd FR 20

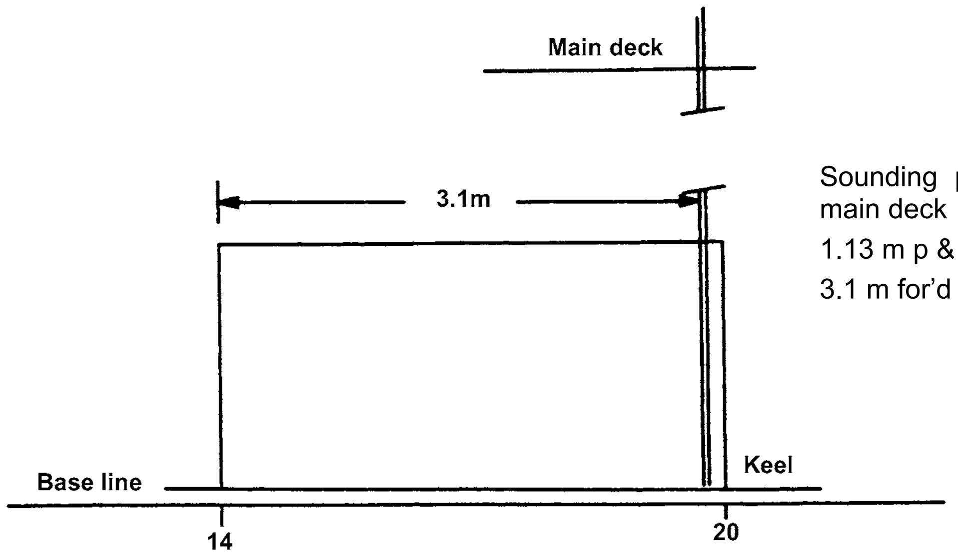
SOUNDINGS (m)	CAPACITY (Tonnes)	V.C.G. (m)	L.C.G. (m)
0.1	1.25	0.50	+1.25
0.2	1.99	0.58	"
0.3	2.63	0.66	"
0.4	3.27	0.74	"
0.5	3.90	0.83	"
0.6	4.54	0.91	"
0.7	5.18	0.99	"
0.8	5.71	1.07	"
0.9	6.35	1.15	"
0.93	6.55	1.17	"

AFTER DOUBLE BOTTOM

PORT AND STARBOARD

FRAME 14 - 20

FUEL OIL S.G. 0.833 F.S.N. 4.72 Tm



Sounding pipe 0.3 m above main deck

1.13 m p & S of center line

3.1 m for'd FR 14

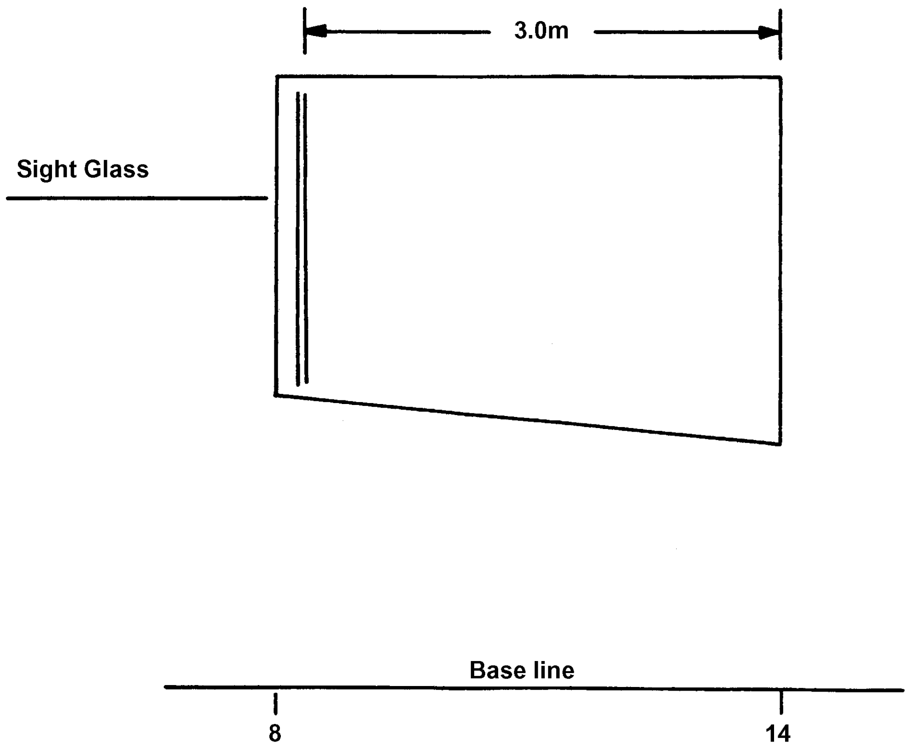
SOUNDINGS (m)	CAPACITY (Tonnes)	V.C.G. (m)	L.C.G. (m)
0.1	1.3	0.65	–1.78
0.2	1.7	0.71	“
0.3	2.0	0.78	“
0.4	2.6	0.84	“
0.5	3.2	0.91	“
0.6	3.8	0.97	“
0.7	4.5	1.04	“
0.8	5.3	1.11	“
0.9	6.1	1.18	“
0.93	6.4	1.20	“

ENGINE ROOM WING TANKS

PORT AND STARBOARD

FRAMES 8 - 14

FUEL OIL S.G. 0.833 F.S.N. 0.44 Tm



SOUNDINGS (m)	CAPACITY (Tonnes)	V.C.G. (m)	L.C.G. (m)
0.2	1.0	4.85	–4.65
0.4	1.7	1.95	–4.67
0.6	2.2	2.05	–4.69
0.8	2.7	2.15	–4.71
1.0	3.4	2.20	–4.73
1.2	4.0	2.25	–4.75
1.4	4.5	2.29	–4.77
1.6	5.2	2.33	–4.79
1.8	5.7	2.37	–4.81
2.0	6.3	2.4	–4.83

6. CALCULATION OF KG AND LCG FOR CONDITIONS OF LOADING IN WHICH VESSEL NORMALLY OPERATES

DISPLACEMENT TABLE

CONDITION 1 **LIGHTSHIP**

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT Tm (3)	L.C.G. FORD/AFT AMIDSHIPS M (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
B Deadweight						
C Lightship	148.46	3.48	516.61	–0.65	–96	–
D Displacement						

E KG	= 3.48 m
F FSN	= 0 m
G KGf	= 3.48 m

DISPLACEMENT TABLE

CONDITION 2

DEPARTURE TO FISHING

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT m (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
Fresh Water	8.9	2.06	18.33	+0.5	+44.95	1.30
For'd FO p & s	9.0	1.78	16.02	+3.45	+31.05	–
For'd D/B FO p & s	13.10	1.17	15.33	+1.25	+16.38	–
Aft B/B FO p & s	12.80	1.20	15.36	–1.78	–22.78	–
E.R. Wings FO p & s	12.60	2.40	20.24	–4.83	–60.86	0.88
Lub. Oil	0.55	2.50	1.38	–7.90	–4.35	–
Crew and Effects	1.00	4.00	4.00	+6.00	+6.00	–
Stores	4.00	3.00	12.00	–	–	–
Provisions	2.00	2.00	4.00	+7.00	+14.00	–
B Deadweight	63.95		116.66		+24.39	2.18
C Lightship	148.46		516.61		–96.00	
D Displacement	212.41	2.98	627.27	–0.337	–71.61	

E KG = 2.98 m	
F FSN = 0.01 m	
G KGf = 2.99 m	

DISPLACEMENT TABLE

CONDITION 3 **FISHING 20% CATCH 20% FUEL AND WATER**

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT m (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
Fresh Water	1.78	1.26	2.24	+4.88	+8.69	1.30
E.R. Wings FO p & s	9.50	2.25	21.37	–4.77	–45.32	0.88
Lub. Oil	0.10	2.5	0.25	–7.9	–0.79	0.18
Crew and Effects	1.00	4.00	4.00	+6.00	+6.00	–
Stores	2.00	3.00	6.00	–	–	–
Provisions	0.40	2.00	0.80	+7.00	+2.8	–
Brine Tank	3.00	4.40	13.20	–5.50	–16.50	–
Cod End Load	0.50	11.40	5.70	–5.50	–2.75	–
Catch	4.80	2.60	12.48	+0.50	+2.40	–
B Deadweight	23.08		66.04		–45.47	2.36
C Lightship	148.46		516.61		–96.00	
D Displacement	171.54	3.40	582.65	– .83	–141.47	

E KG	=	3.40 m
F FSN	=	0.01 m
G KGf	=	3.41 m

DISPLACEMENT TABLE

CONDITION 4 **FISHING 20% CATCH 10% FUEL AND WATER**

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT m (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
Fresh Water	1.78	1.26	2.24	+4.88	+8.69	1.30
E.R. Wings FO p & s	4.75	2.05	9.74	–4.70	–22.33	0.88
Lub. Oil	0.10	0.25	0.25	–7.90	–0.79	0.18
Crew and Effects	1.00	4.00	4.00	+6.00	+6.00	–
Stores	2.00	3.00	6.00	–	–	–
Provisions	0.40	2.00	0.80	+7.00	+2.80	–
Catch	4.80	2.60	12.48	+0.50	+2.40	–
B Deadweight	14.83		35.51		–3.23	2.36
C Lightship	148.46		516.61		–96.00	
D Displacement	163.29	3.38	552.12	–0.61	–99.23	

E KG	=	3.38 m	
F FSN	=	0.01 m	
G KGf	=	3.39 m	

DISPLACEMENT TABLE

CONDITION 5 FISHING 100% CATCH 20% FUEL AND WATER

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT m (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
Fresh Water	1.78	1.26	2.24	+4.88	+8.69	1.30
E.R. Wings FO p & s	9.50	2.25	21.37	–4.77	–45.32	0.88
Lub. Oil	0.10	2.59	0.25	–7.90	–0.79	0.18
Crew and Effects	1.00	4.00	4.00	+6.00	+6.00	–
Stores	2.00	3.00	6.00	–	–	–
Provisions	0.40	2.00	0.80	+7.00	+2.8	–
Catch	24.00	2.60	62.40	+0.50	+12.00	–
B Deadweight	38.78		97.06		–16.62	2.36
C Lightship	148.46		516.61		–96.00	
D Displacement	187.24	3.28	613.67	–0.60	–112.62	

E KG	=	3.28 m	
F FSN	=	0.01 m	
G KGf	=	3.29 m	

DISPLACEMENT TABLE

CONDITION 6 ARRIVAL IN PORT 100% CATCH 20% FUEL AND WATER

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT m (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
Fresh Water	1.78	1.26	2.24	+4.88	+8.69	1.30
E.R. Wings FO p & s	4.75	2.05	9.74	–4.70	–22.33	0.88
Lub. Oil	0.10	2.50	0.25	–7.90	–0.79	0.18
Crew and Effects	1.00	4.00	4.00	+6.00	+6.00	–
Stores	2.00	3.00	6.00	–	–	–
Provisions	0.40	2.00	0.80	+7.00	+2.8	–
Catch	24.00	2.60	62.40	+0.50	+12.00	–
B Deadweight	34.03		85.43		+6.37	2.36
C Lightship	148.46		516.61		–96.00	
D Displacement	182.49	3.30	602.04	–0.45	–89.63	

E KG	= 3.30 m
F FSN	= 0.01 m
G KGf	= 3.31 m

CONDITION 7 **DISPLACEMENT TABLE**

FISHING 20% CATCH 20% WATER AND FUEL WITH STALLED WINCH LOAD

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT m (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
Fresh Water	1.78	1.26	2.24	+4.88	+8.69	1.30
E.R. Wings FO p & s	9.50	2.25	21.37	–4.77	–45.32	0.88
Lub. Oil	0.10	2.50	0.25	–7.90	–0.79	0.18
Crew and Effects	1.00	4.00	4.00	+6.00	+6.00	–
Stores	2.00	3.00	6.00	–	–	–
Provisions	0.40	2.00	0.80	+7.00	+2.80	–
Brine Tank	3.00	4.40	13.20	–5.50	–16.50	–
Catch	4.80	2.60	12.48	+0.50	+2.40	–
Winch Load	2.50	5.50	13.75	–10.50	–26.25	–
B Deadweight	25.08		74.09		+68.97	2.36
C Lightship	148.46		516.61		–96.00	
D Displacement	173.54	3.40	590.70	–0.95	–164.97	

E KG	= 3.40 m
F FSN	= 0.01 m
G KGf	= 3.41 m

DISPLACEMENT TABLE

CONDITION 8 FISHING 20% CATCH 20% FUEL AND WATER, FOULED NET

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT Tm (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONG- -AL MOMENT	F.S.N. (6)
A						
Fresh Water	1.78	1.26	2.24	+4.88	+8.69	1.30
E.R. Wings FO p & s	9.50	2.25	21.37	–4.77	–45.32	0.88
Lub. Oil	0.10	2.50	0.25	–7.90	–0.79	0.18
Crew and Effects	1.00	4.00	4.00	+6.00	+6.00	–
Stores	2.00	3.00	6.00	–	–	–
Provisions	0.40	2.00	0.80	+7.00	+2.80	–
Brine Tank	3.00	4.40	13.20	–5.50	–16.50	–
Catch	4.80	2.60	12.48	+0.50	+2.40	–
Warp Load	0.50	7.00	3.50	–1.00	+0.50	–
B Deadweight	23.08		63.84		–42.22	2.36
C Lightship	148.46		516.61		–96.00	
D Displacement	171.54	3.38	580.45	–0.81	–138.22	

E KG	= 3.38 m
F FSN	= 0.01 m
G KGf	= 3.39 m

7. GUIDANCE NOTES FOR CALCULATION OF KG AND LCG FOR ANY CONDITION OF LOADING

These notes are given in the form of a worked example for an assumed condition of loading.

7.1 DEFINITIONS

7.1.1 *Centre of Gravity*

The centre of gravity is the point through which the total weight of the vessel is assumed to act.

Figure (1) shows position of the centre of gravity with relation to the two references, the base line and amidships.

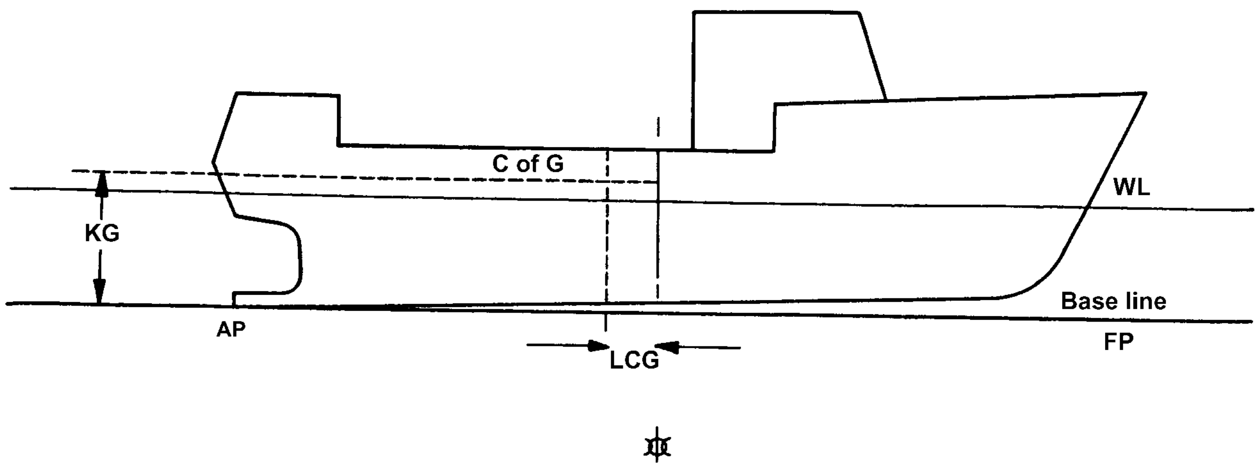


Figure 1

7.1.2 *KG and KG_f*

Vertical Centre of Gravity (KG) is the vertical distance of the centre of gravity from the base line. The base line is the line drawn through the lowest part of the keel parallel to the designed water line as shown above.

KG_f is the Vertical Centre of Gravity corrected for free surface.

7.1.3 *LCG*

Longitudinal Centre of Gravity (LCG) is the horizontal distance of the centre of gravity from amidships. If the LCG is aft of amidships as in the diagram above the value is negative; if forward of amidships the value is positive.

7.1.4 *FSC AND FSM*

Free Surface Correction (FSC) is the measure of the effect on KG of the free surface moment (FSM) of a partially full fuel oil or water tank. It has the effect of raising the position of the centre of gravity and therefore increases the value of KG_f. The limiting KG curve on page 29 includes the effect of the

maximum free surface moment that will be generated when tanks are managed in accordance with the instructions, on page 6. Care must be taken to ensure that the instructions are followed.

7.1.5 *Lightship Weight*

Lightship weight is the weight (tonnes) of the vessel as delivered from the builder's yard, including all fixed ballast and all fixed equipment such as winches, warps on drums, otter boards and nets but excluding variables such as fuel oil, water, crew and effects, provisions, stores, water in brine tanks and the catch.

7.1.6 *Deadweight*

Deadweight is the total weight (tonnes) of the contents of individual fuel and water tanks, crew and effects, stores, provisions, catch, etc. Each of these items has its own weight, vertical centre of gravity (KG) above the base line and longitudinal centre of gravity from amidships (LCG). The values of KG and LCG for tank contents at various soundings are obtained from the tank calibration sheets pages 7-11.

7.1.7 *Displacement*

Displacement is the total of the lightship weight and deadweight.

7.2 ASSUMED CONDITION OF VESSEL

7.2.1 *Fixed and variable Items*

	Weight (tonnes)
Crew and effects	1.50
Provisions	1.0
Stores	3.0
Brine tank	3.0
Catch	12.0
Cod end	0.5

7.2.2 *Tanks*

		Sounding
Fresh water	Port	2.8m
Fresh water	Stbd	1.8m
Fuel oil for'd	Port	1.4m
Fuel oil for'd	Stbd	full
Double bottom for'd	Port	empty
Double bottom for'd	Stbd	empty
Double bottom aft	Port	0.9m
Double bottom aft	Stbd	full
Engine room fuel oil	Port	empty
Engine room fuel oil	Stbd	empty
Engine room lub oil		half full

7.3 WEIGHT, KG AND LCG OF ITEMS

7.3.1 *Crew and Effects*

Take the weight of crew and effects as 0.15 tonnes per crew member. The number of crew on board is taken to be 10, therefore their weight is

0.15 x 10 = 1.5 tonnes

Their position may be taken to be the same as in the standard loading conditions pages 12 - 18, i.e.

KG = 4.0m
LCG = +6.0m

7.3.2 *Provisions*

Estimate the weight of provisions remaining. For this example the weight is taken as 1.0 tonnes.

The centre of gravity may be taken to be the same as in the standard loading conditions i.e.

KG = 2.0m
LCG = +7.0m

7.3.3 *stores*

Estimate the weight of stores remaining. For this example the weight is taken as 3.0 tonnes. From the standard loading conditions we obtain

KG = 3.0m
LCG = 0.0 (i.e. amidships)

7.3.4 *Brine Tank*

Estimate the weight of water in the brine tank, which when full contains 3.0 tonnes of water. Free surface moment is negligible and may be ignored. From the standard loading conditions we obtain

KG = 4. 4m
LCG = –5.5m

Note: If the tank is partially full the KG of the contents should be taken to be at a level of half the depth of brine above the bottom of the tank.

7.3.5 *Catch*

The weight of the catch should be estimated by multiplying the number of boxes by the weight per box. Alternatively, estimate the fraction of the hold volume and multiply the fraction by the total capacity of the hold (24 tonnes) to obtain the mass in tonnes.

If the boxes have been stacked from floor to deckhead in the pens the KG of the catch should be taken as 2.6m. If they are stacked across the floor the KG of the catch will be 1.0m plus half the average height of the stack as shown in Figure 2.

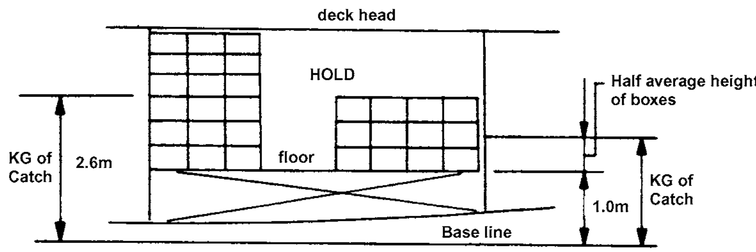


Figure 2

If the hold is filled by filling the centre first and working fore and aft, the LCG of the catch should be taken as +0.5m* as shown in Figure 3. If filled from one end the LCG of the catch will be 0.5m* plus (minus) the distance from the centre of the hold to the centre of the catch if it is stowed forward (aft) as shown in Figure 4.

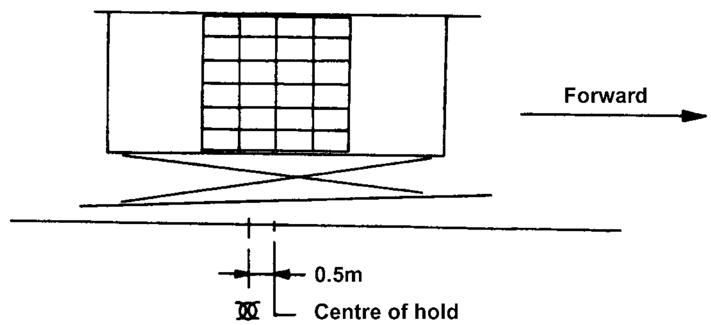


Figure 3

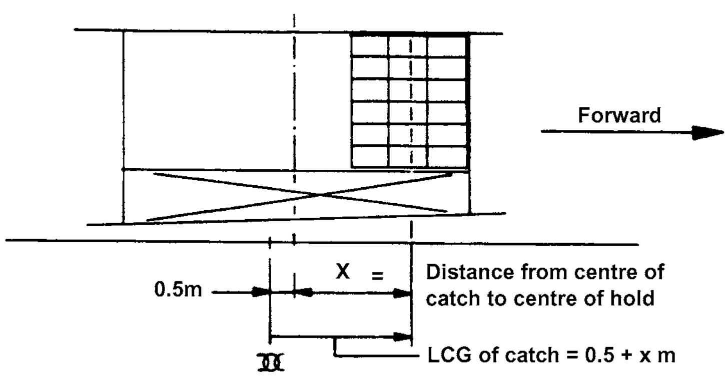


Figure 4

(*+0.5m is the LCG of the centre of the fish hold of this vessel and the actual LCG should be inserted.)

In the example the hold is assumed to be half full stowed floor to deckhead, working from the centre fore and aft so that:

KG	=	2. 6m
LCG	=	+ 0. 5m

7.3.6 *Cod end*

The weight of the catch in the cod end is to be taken as 0.5 tonnes, the KG and LCG is to be taken to be at its point of suspension, i e. the top of the lifting boom as shown, for example, on page 14 giving:

KG	=	11.4m
LCG	=	-5.5m

7.3.7 *Tanks*

Tank calibration tables are given on pages 7 to 11 and a summary table on page 6. Where a tank is full the value in the summary table should be used.

Where a tank is partially full, enter the appropriate table at the measured sounding and read off the values of weight, KG and LCG.

For example:

port fresh water tank (page 7)

sounding	=	2. 8m
weight	=	4.4 tonnes
KG	=	2.05m
LCG	=	+5.05m

double bottom tank aft (page 10)

sounding	=	0. 9m
weight	=	6.1 tonnes
KG	=	1. 18m
LCG	=	-1.78m

To obtain the lub oil tank values, estimate the quantity from the sight glass as a fraction of full and multiply it by the weight of the full tank. In this example

$$\text{weight} = \frac{1}{2} \times 0.55 = 0.28 \text{ tonnes}$$

Take the KG and LCG from the tank summary table

i e.	KG	=	2.50m
	LCG	=	-7.90m

Displacement Table

Enter the values obtained as shown in 7.3.1 to 7.3.6 inclusive in the displacement table.

Enter the values for each full and partially full tank, obtained as shown in 7.3.7 in the same table.

The partially completed table is shown on page 26.

Calculation of Vertical and Longitudinal Moments

For each line, multiply the weight in column (1) by KG in column (2), and enter the resulting vertical moment in column (3). Similarly, multiply the weight by LCG in column (4), and enter the resulting longitudinal moment in column (5).

Calculation of Displacement, KG and LCG of the Vessel

Sum the weights (47.48 tonnes), vertical moment (106.21 tonne-m) and longitudinal moment (+36.18 tonne-m) and enter the results in the appropriate column in the “Deadweight” line (Line B) on page 27.

Take the lightship values of weight (148.46 tonnes), vertical moment (516.61 tonne-m) and longitudinal moment (-96.00 tonne-m) from columns (1), (3) and (5) of page 27 and enter them in the equivalent columns in the displacement tables at line C. Add the values in lines B and C and enter the sums in line D.

The KG (and LCG) of the vessel in the loaded condition is obtained from the values in line D as follows:

$$KG = \frac{\text{Vertical moment (column[3])}}{\text{Displacement (column[1])}} = \frac{622.82}{195.94} = 3.18\text{ m}$$

$$LCG = \frac{\text{Longitudinal moment (column[5])}}{\text{Displacement (column[1])}} = \frac{-59.82}{195.94} = 0.31\text{ m (aft)}$$

Enter these values in columns (2) and (4) respectively. Enter the value of KG (3.18m) also in the first line of the small table below the main displacement table.

DISPLACEMENT TABLE SHOWING WEIGHTS, KG AND LCG

ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT Tm (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONGITUDINAL MOMENT
A					
FW Port	4.4	2.05		+5.05	
FW Stbd	2.45	1.55		+4.91	
FO For'd Port	2.35	1.15		+3.45	
FO For'd Stbd	4.5	1.78		–3.45	
DB Aft Port	6.1	1.18		–1.78	
DB Aft Stbd	6.4	1.2		–1.78	
Lub. Oil	0.28	2.5		–7.9	
Catch	12.00	2.60		+0.5	
Cod End	0.50	11.4		–5.50	
Brine Tank	3.0	4.4		–5.50	
Crew and Effects	1.5	4.0		+0.60	
Provisions	1.0	2.0		+7.0	
Stores	3.0	3.0		0.0	
B Deadweight					
C Lightship					
D Displacement					

E KG = m

COMPLETED DISPLACEMENT TABLE

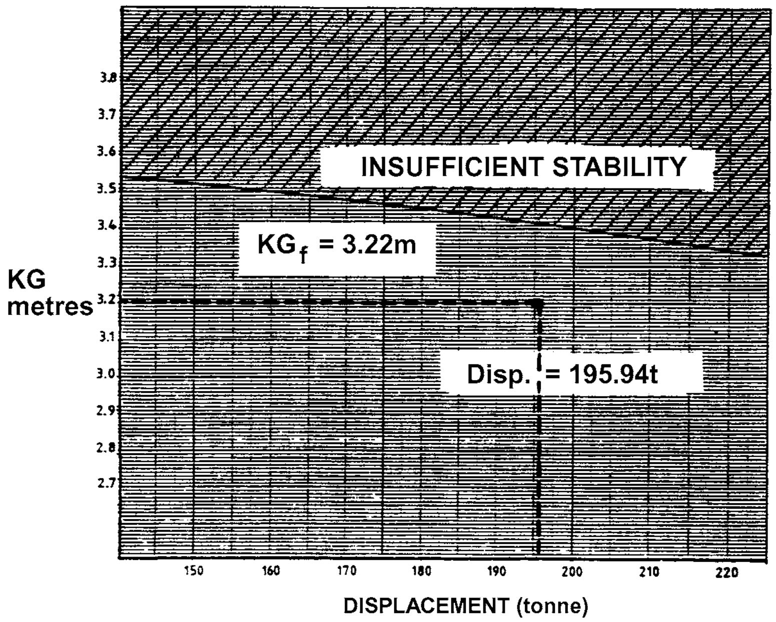
ITEM	MASS TONNES (1)	K.G. m (2)	VERTICAL MOMENT Tm (3)	L.C.G. FORD/AFT AMIDSHIPS m (4)	LONGITUDINAL MOMENT
A					
FW Port	4.4	2.05	9.02	+5.05	+22.22
FW Stbd	2.45	1.55	3.80	+4.91	+12.03
FO For'd Port	2.35	1.15	2.70	+3.45	+8.11
FO For'd Stbd	4.5	1.78	8.01	–3.45	+15.53
DB Aft Port	6.1	1.18	7.20	–1.78	–10.86
DB Aft Stbd	6.4	1.2	7.68	–1.78	–11.39
Lub. Oil	0.28	2.5	0.70	–7.9	–2.21
Catch	12.00	2.60	31.20	+0.5	+6.00
Cod End	0.50	11.4	5.70	–5.50	–2.75
Brine Tank	3.0	4.4	13.20	–5.50	–16.50
Crew and Effects	1.5	4.0	6.00	+0.60	+9.00
Provisions	1.0	2.0	2.00	+7.0	+7.00
Stores	3.0	3.0	9.00	0.0	0.0
B Deadweight	47.48		106.21		+36.18
C Lightship	148.46		516.61		–96.00
D Displacement	196.94	3.18	622.82	–0.31	–59.82

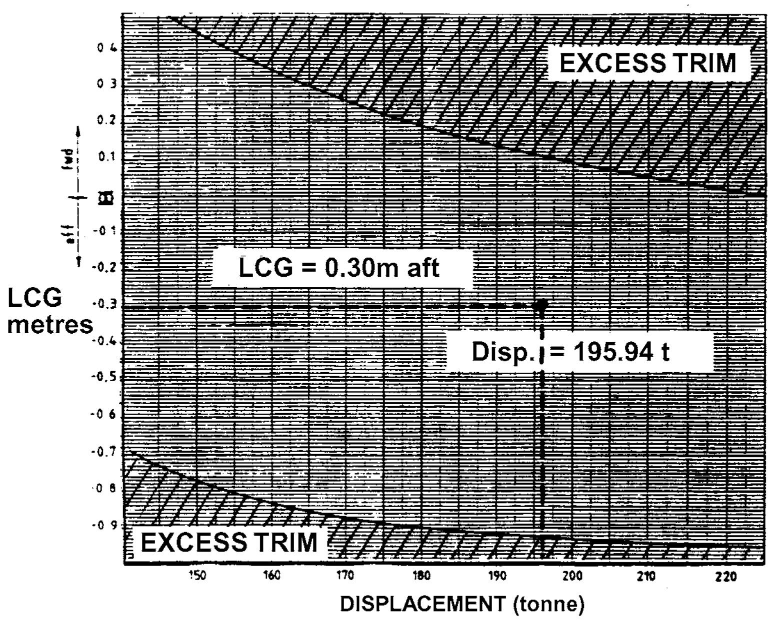
E KG = 3.18 m

COMPARISON WITH STABILITY CRITERIA

The values of KG (and LCG) are compared with the limiting values, as described in Section 2. In this case the KG lies below the curve (and the LCG lies between the curves) see the diagram(s) below. Had KG been above the curve, immediate steps should have been taken to restow movable items lower in the vessel, reduce the number of slack tanks and/or fill empty tanks low down in the vessel. (Similarly, if LCG had not been between the curves, cargo should have been moved, or tank contents redistributed, to obtain a satisfactory value.)

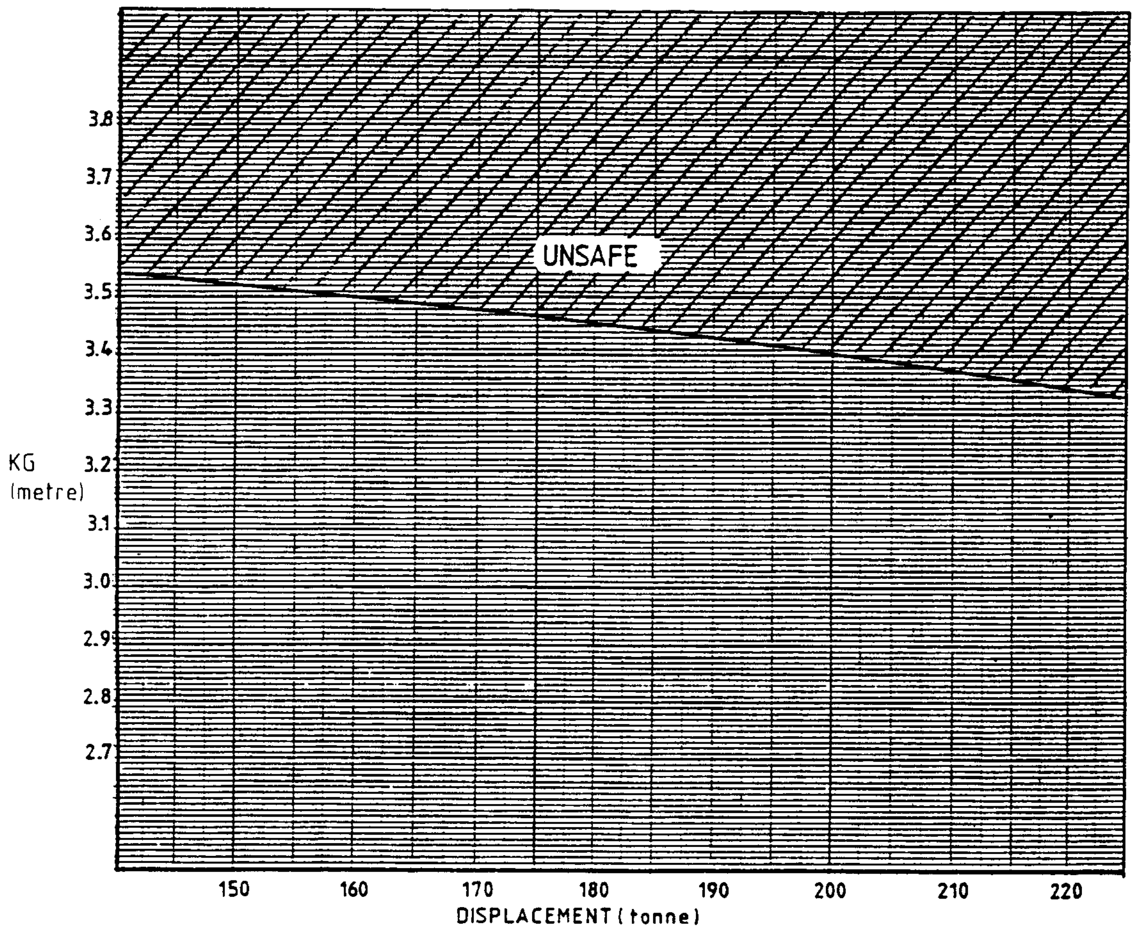
IN NO CIRCUMSTANCES SHOULD THE VESSEL BE OPERATED WHEN THE KG LIES ABOVE THE CURVE ON PAGE 29 (OR THE LCG LIES OUTSIDE THE CURVES ON PAGE 30).





8. CURVE OF LIMITING KG

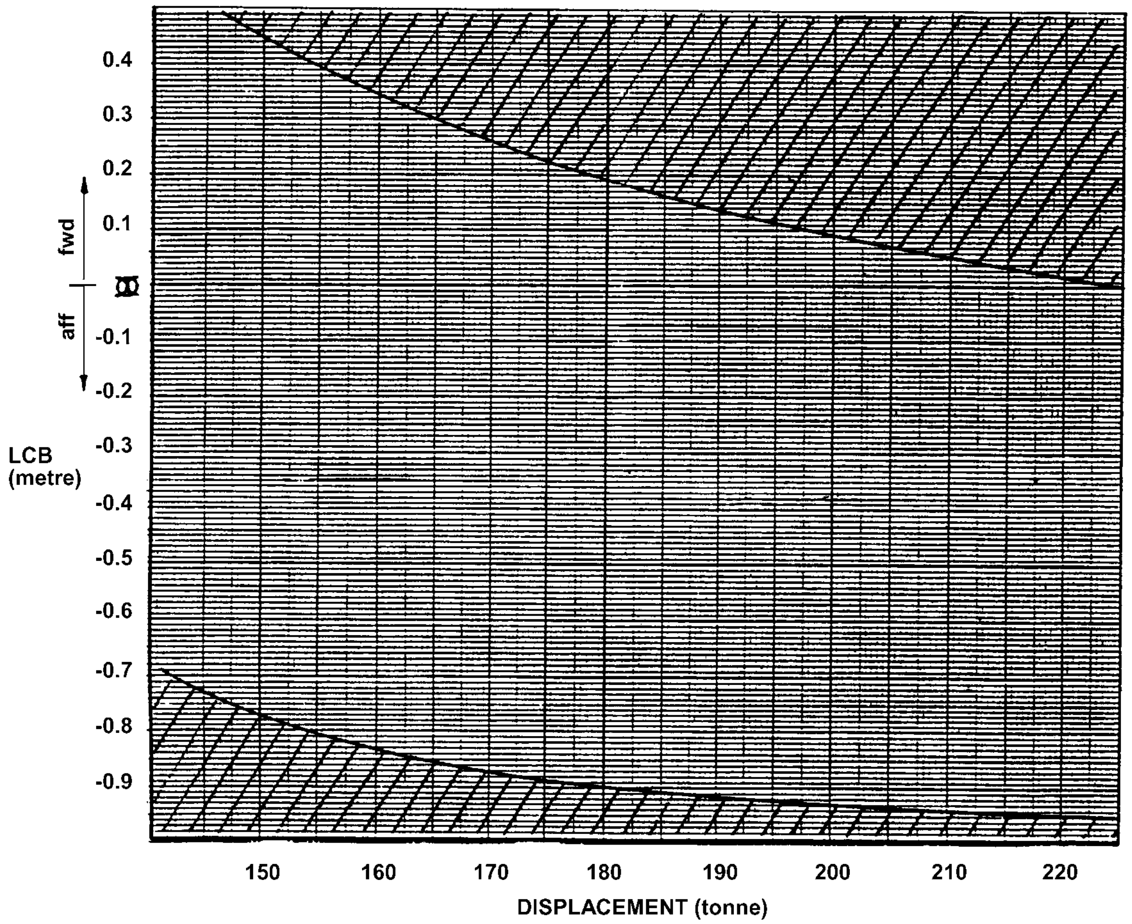
In any condition of loading the KG from line G of the Displacement Table must lie in the area within the curve.



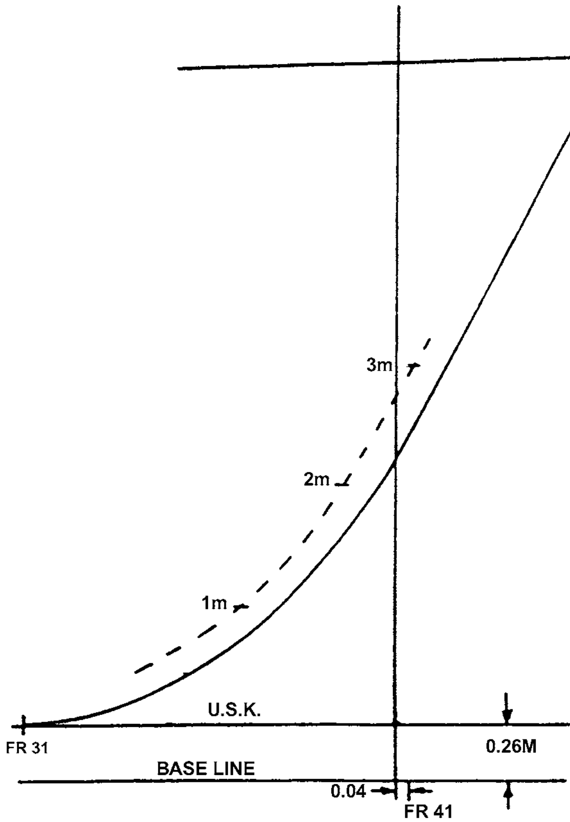
The curve of limiting KG allows for the free surface effect only when the tanks are managed in accordance with the recommended usage.

9 CURVE OF LIMITING LCG

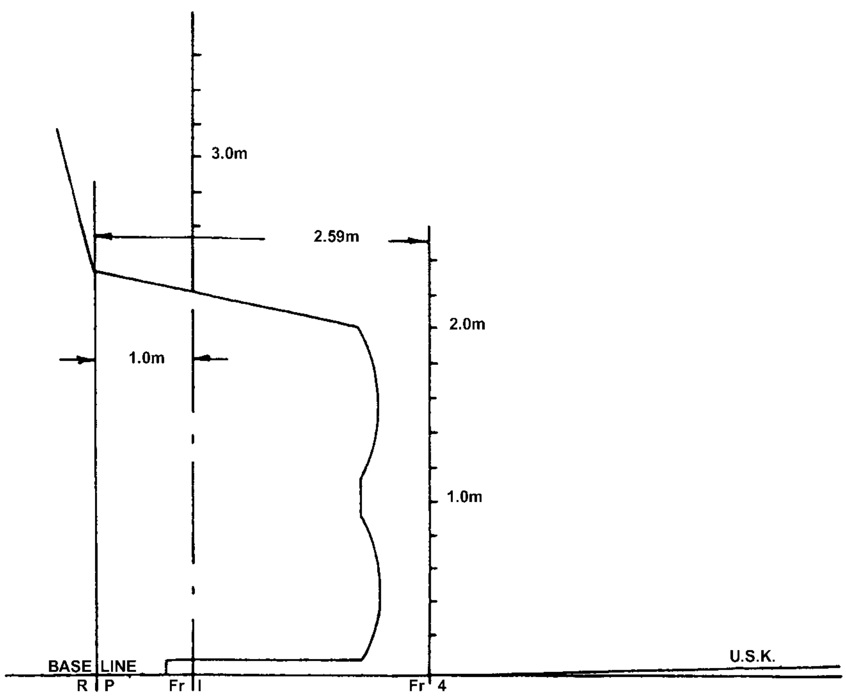
In any condition of loading the LCG from column 4 line D of the Displacement Table must lie in the area within the curves.



DRAFT MARK LOCATION



DRAFT MARK	DRAFT READING	DISTANCE TO F.P. +ve FORD –ve AFT
3.60	3.86	+0.75
3.40	3.66	+0.64
3.20	3.46	+0.53
3.00	3.26	+0.42
2.80	3.06	+0.31
2.60	2.86	+0.20
2.40	2.66	+0.09
2.20	2.46	–0.01
2.00	2.26	–0.14
1.80	2.06	–0.28
1.60	1.86	–0.42
1.40	1.66	–0.42
1.20	1.46	–0.55
1.00	1.26	–0.77
0.80	1.06	–1.00
0.60	0.86	–1.50
0.40	0.66	–1.90
0.20	0.46	–2.56



HYDROSTATIC PARTICULARS

M.V. TWOSUCH

HYDROSTATIC DRAFT (m)	DISPLACEMENT (tonnes)	TPC	MCT 1 cm (t – m)	LCF (m aft 0)	KM (m)
2.00	87.5	0.980	0.885	–0.295	4.47
2.05	93.5	1.000	0.945	–0.380	4.41
2.10	101.0	1.022	1.000	–0.465	4.35
2.15	105.5	1.040	1.060	–0.555	4.29
2.20	111.2	1.062	1.115	–0.650	4.24
2.25	116.8	1.078	1.172	–0.750	4.20
2.30	122.0	1.098	1.235	–0.860	4.15
2.35	127.5	1.115	1.292	–0.955	4.11
2.40	133.2	1.128	1.340	–1.010	4.07
2.45	139.0	1.140	1.380	–1.045	4.03
2.50	145.0	1.150	1.145	–1.065	4.00
2.55	150.5	1.160	1.430	–1.070	3.97
2.60	156.5	1.168	1.438	–1.072	3.94
2.65	162.5	1.172	1.465	–1.065	3.91
2.70	168.0	1.180	1.480	–1.060	3.89
2.75	174.0	1.185	1.500	–1.050	3.87
2.80	180.0	1.190	1.515	–1.042	3.85
2.85	186.0	1.195	1.532	–1.038	3.84
2.90	192.0	1.200	1.550	–1.030	3.82
2.95	198.0	1.208	1.568	–1.022	3.81
3.00	204.0	1.212	1.585	–1.015	3.81
3.05	210.0	1.218	1.605	–1.008	3.80
3.10	216.2	1.220	1.622	–0.995	3.80
3.15	222.2	1.225	1.640	–0.988	3.79
3.20	228.2	1.230	1.660	–0.978	3.79
3.25	324.5	1.240	1.670	–0.968	3.78

LOAD DRAFT 3.00 M

ASSIGNMENTS 1 AND 2

ASSIGNMENT 1 QUESTIONS

These questions test your grasp of the subject matter. It is not an examination so you should look back through the text, the Section notes and your own notes if necessary when answering the questions. An answer that is a direct quotation from your reading is little help to you, so use your own words.

1. (a) Why is the term 'displacement' used to describe the vessel's weight?

   (b) What is the relationship between the loaded displacement and the deadweight?

2. Draw a cross section of a vessel in the upright and the inclined position showing G.B.M.GZ for a vessel with a list and one with a heel.

3. (a) Describe the effect called 'Free Surface Effect'.

   (b) Give 3 causes for free surface effect.

4. Describe with the aid of a sketch stable, unstable and neutral equilibrium.

5. A tank when filled holds 90 tonnes of fresh water.

   Find how many tonnes of oil of RD .9 it can hold?

6. A tank measures 24 × 20 × 8 metres. Find the mass of oil it contains if the RD is .8

7. Define and then explain what is meant by the terms 'Longitudinal' and 'Transverse' with respect to a ship. Use sketches to explain your answer.

8. Explain, using sketches, what happens to the longitudinal and transverse centres of buoyancy when weight is added on deck to the stern of a vessel at sea.

9. Define 'Trim'. Describe the methods which could be used to alter a vessel's trim at sea.

10. What would be the effect of loading weights on deck?

    How would this affect the position of G?

    How would this affect the size of the initial GM?

    How does this affect the size of the righting lever?

    How does this affect the vessel's ability to return to upright after being heeled by an external force?

11. If you discharged three tonnes of cargo and found that the draft had decreased by five centimetres, what would the T.P.C. be?

12 (a) Describe two methods of correcting an angle of loll.

What must you never do?

Why?

What are you ultimately trying to achieve in correcting an angle of loll?

13 What are the two main factors which affect a vessel's roll period?

14. Briefly describe synchronous rolling.

ASSIGNMENT 2 QUESTIONS

These questions test your grasp of the preceding subject matter. It is not an examination so you should look back through the text, the Section notes and your own notes if necessary when answering the questions. An answer that is a direct quotation from your reading is little help to you, so use your own words.

1. Describe, with the aid of sketches, how the stability of a vessel is affected by a partially filled tank. The tank extends the full width of the vessel.

2. Describe how free surface may be reduced by subdividing a compartment. Use clear sketches to show the effects of subdivision.

3. A vessel is bilged in the after port side fuel oil tank, shown by the shaded portions in Figure 1 and Figure 2 (provided at the end of these questions).

   Detach the sketches (Figures 1 and 2) and on them show the following:

   - the new waterlines
   - the reserve buoyancy after bilging.

   With the aid of these sketches describe what happens to the vessel when it is bilged. Pay particular attention to list, trim and stability.

   Discuss also what happens to the positions of G and B.

4. Describe the dangers with respect to stability caused by entrapped water when carrying deck cargoes.

5. Describe the effect Free Water on deck has on the stability of a vessel.

Please use the blank displacement tables provided and submit these with your assignments.

6. Complete a displacement table for Twosuch based on the following information:

   Fresh Water port 1.2 m

   Fresh Water starboard 2.2 m

   Forward Fuel Oil port 2.2 m

   Forward Fuel Oil starboard 2.3 m

   Forward Double Bottom port 0.9 m

   Forward Double Bottom starboard 0.93 m

   After Double Bottom port 0.8 m,

   After Double Bottom starboard 0.9 m

   Engine Room Wing Tank port 2 m

Engine Room Wing Tank starboard 1.8

Lube Oil, Crew and Effects, Stores, and Provisions, as per Condition 2.

What is your vessel's KG, LCG and FSN? Is the vessel in a safe condition of loading?

7. With Lube Oil, Crew and Effects, Stores, and Provisions, as per Condition 3, but with no cod end load, you take the following tan soundings:

   Fresh Water (port and starboard) 1.6 m

   Aft Double Bottom (starboard) empty

   Forward Double Bottom (p&s) 0.9 m

   Aft Double Bottom (port) 0.3 m x/

   Engine Room Wing tanks (p&s) 1.8 m

   What is your vessel's KG, LM and FSN? Is the vessel in a safe condition of loading?

8. Twosuch is in Condition 6 and is alongside and discharging her catch. The hold is half empty with the remaining catch evenly distributed across the length and breadth of the hold.

   What will the catch's KG be at this stage of unloading?

   What will the vessel's KG be at this stage of unloading?

9. Twosuch is in condition 7 with a stalled winch. However:

   The Port Engine Room Wing Tank is empty.

   The Starboard Engine Room Wing Tank sounds 0.8m.

   Her catch is 100 percent.

   What is the vessel's KG, LCG and FSN? Is the vessel in a safe condition of loading?

FOR QUESTION 3

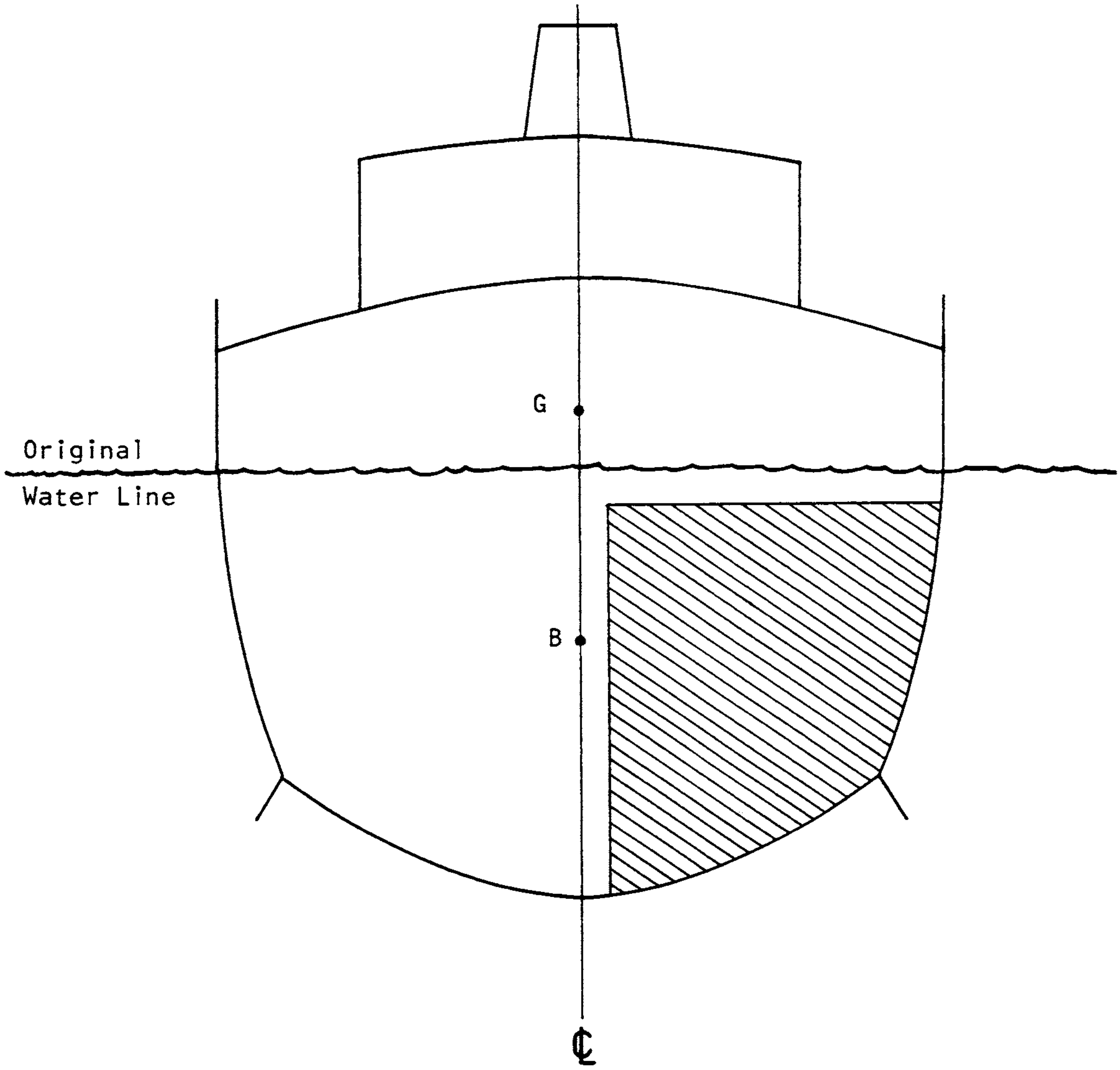


Figure 1

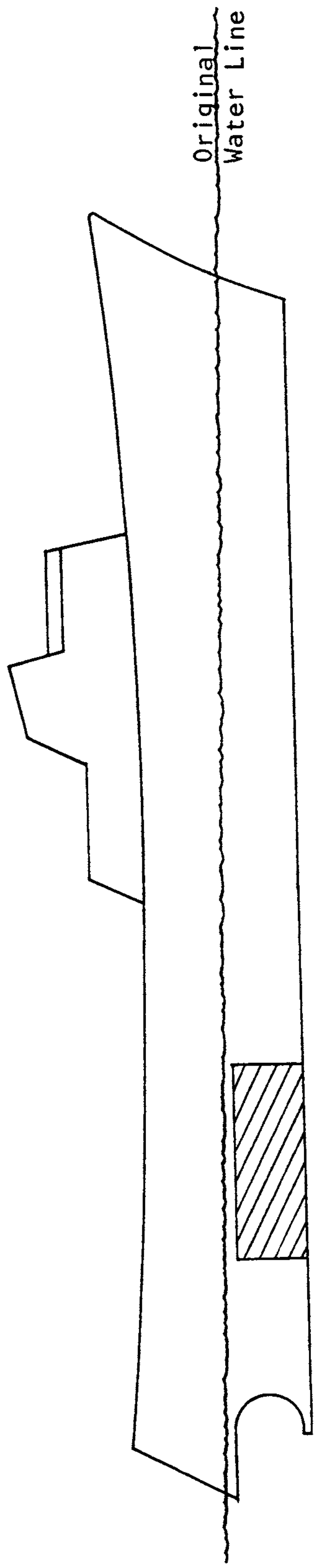


Figure 2

FOR QUESTION 6

ITEM	WEIGHT TONNES	KG M VC6	VERTICAL MOMENT TM	LC6 FORD/AFT AMIDSHIPS M	LONG-AL MOMENT	F.S.N
Fresh water port						
Fresh water s/brd						
Forward fuel oil port						
Forward fuel oil s/brd						
Forward double bottom port						
Forward double bottom s/brd						
After double bottom port						
After double bottom s/brd						
Eng room wing tank port						
Eng room wing tank s/brd						
Lube oil						
Crew and effects						
Stores						
Provisions						
DEADWEIGHT						
LIGHTSHIP	148.46		516.61		-96.00	
DISPLACEMENT						

Kg =   FSN =
KGF =

FOR QUESTION 7

ITEM	WEIGHT TONNES	KG M VC6	VERTICAL MOMENT TM	LC6 FORD/AFT AMIDSHIPS M	LONG-AL MOMENT	F.S.N
Fresh water port						
Fresh water s/brd						
Forward fuel oil port						
Forward fuel oil s/brd						
Forward double bottom port						
Forward double bottom s/brd						
After double bottom port						
After double bottom s/brd						
Eng room wing tank port						
Eng room wing tank s/brd						
Lube oil						
Crew and effects						
Stores						
Provisions						
DEADWEIGHT						
LIGHTSHIP	148.46		516.61		-96.00	
DISPLACEMENT						

Kg = FSN =
KGF =

FOR QUESTION 8

ITEM	WEIGHT TONNES	KG M VC6	VERTICAL MOMENT TM	LC6 FORD/AFT AMIDSHIPS M	LONG-AL MOMENT	F.S.N
Fresh water port						
Fresh water s/brd						
Forward fuel oil port						
Forward fuel oil s/brd						
Forward double bottom port						
Forward double bottom s/brd						
After double bottom port						
After double bottom s/brd						
Eng room wing tank port						
Eng room wing tank s/brd						
Lube oil						
Crew and effects						
Stores						
Provisions						
DEADWEIGHT						
LIGHTSHIP	148.46		516.61		-96.00	
DISPLACEMENT						

Kg = FSN =
KGF =

FOR QUESTION 9

FISHING 20% CATCH 20% WATER AND FUEL WITH STALLED WINCH LOAD

ITEM	WEIGHT TONNES	KG M VC6	VERTICAL MOMENT TM	LC6 FORD/AFT AMIDSHIPS M	LONG-AL MOMENT	F.S.N
Fresh water port						
Fresh water s/brd						
Forward fuel oil port						
Forward fuel oil s/brd						
Forward double bottom port						
Forward double bottom s/brd						
After double bottom port						
After double bottom s/brd						
Eng room wing tank port						
Eng room wing tank s/brd						
Lube oil						
Crew and effects						
Stores						
Provisions						
DEADWEIGHT						
LIGHTSHIP	148.46		516.61		-96.00	
DISPLACEMENT						

Kg =   FSN =
KGF =

Learner's Guide

STABILITY A

Coxswain Level
Master 5 Level

DESCRIPTION

This Maritime resource book contains all the requirements for Stability at the Coxswain, Master 5 and Master 4 levels. It is accordingly divided into three sections. Within each section there are activities for you to work through. The self-test exercises are contained at the end of each short section and are for you to check that you have understood what you have just been studying. At the end of several sections, in the Master 4, are mastery assignments. These are longer and will take some time to work through. The worked answers are given for these. As the final assessment will contain calculations then it is important that they are practised.

CATEGORY

Maritime Studies

Government of Western Australia

West 1

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