Water Awareness and Charge Certificate Manual

Module 14: Stability

Current Document Revision Number: 1.1
Revision Date: 13 January 2018

Module Contents

Module Title	Comments	Rev No	Revision Date
Module 14: Stability	Initial Release	1.0	18 Sep 2009
Module 14: Stability	Outcomes Added	1.1	13 Jan 2018

Outcomes

After completing this module, the certificate holder will:

- Be able to define the terms "Centre of Buoyancy", "Centre for Gravity", "List" and "Loll"
- Be able to explain the danger of free surface liquids

1 Stability

Stability is the resistance to capsizing and a stable vessel that has been pushed from its upright position by an external force, such as the wind or waves, should return to the upright position. If the vessel does not return upright, it is unstable. A well designed vessel has adequate stability build into it. However, any changes made to the vessel, or any changes made to her loading, will upset that stability - perhaps to the extent of making the vessel dangerous.

We must be able to recognise the signs of impending instability of the vessel, and we must know the measures needed to correct this. In the long term this may involve consultations with a surveyor or a naval architect, but in an emergency at sea more immediate measures may have to be taken and these will only be safe and effective if we have a basic understanding of the fundamental forces that govern a vessel's stability.

The two forces governing vessel stability are buoyancy, provided by the water, and gravity.

1.1 The Centre of Buoyancy

As a vessel is lowered into the water it appears to lose weight. The water is exerting an upward thrust on the hull, called buoyancy. When the vessel is floating free in the water, this upward thrust is equal in value to the weight of the vessel and everything aboard it.

Buoyancy acts over the entire submerged surface of the hull. The centre of its force is called the centre of buoyancy (B) and through this point the force of buoyancy always acts directly upwards. The centre of buoyancy is always at the geometric centre of the boa's underwater volume. When the vessel is on an even keel, this is on the centreline.

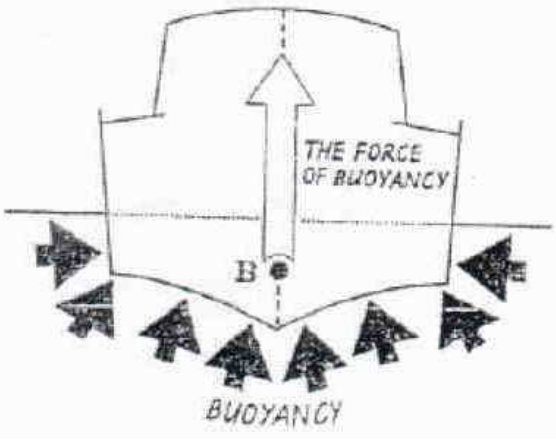

Figure 1: Buoyancy force

1.2 Rolling

If the vessel rolls, the centre of buoyancy will take up a new position to port or starboard of the centreline, but always at the centre of the underwater portion of the hull with the force of buoyancy acting directly upwards.

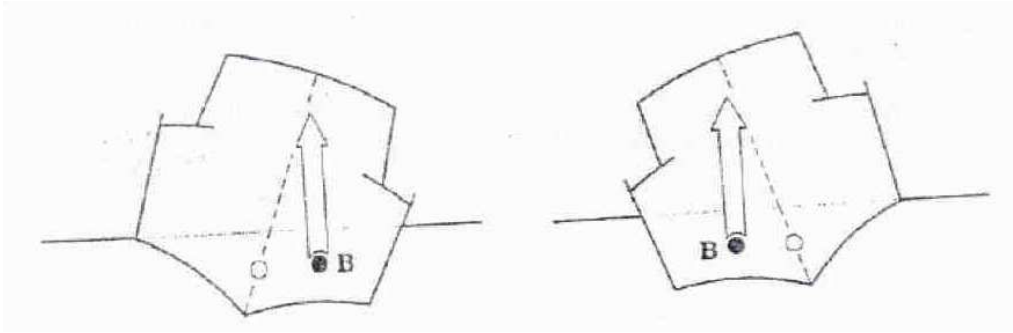

Figure 2: Centre of Bouyancy

1.3 The Centre of Gravity

Gravity is the force that give everything weight. If it were possible to suspend a vessel so that it balanced perfectly in all direction, the point of suspension would be its centre of gravity (G). Thus the whole weight of the vessel, and everything aboard it, is considered to act through this point vertically downwards. A well designed vessel has its centre of gravity as low as possible. Heavy weights, such as the engine and storage tanks, are placed in the bottom of the vessel to help achieve this.

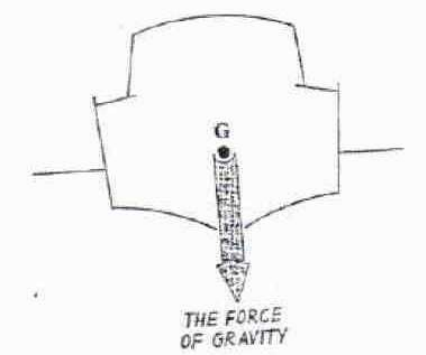

Figure 3: Centre of gravity

1.4 Movement of weights

If any weight is moved within the vessel, the balance is upset, and therefore the centre of gravity must also move to maintain its position at the centre of balance.
If a weight is moved horizontally across the vessel, the centre of gravity will also more horizontally in the same direction. If a weight is moved vertically, the centre of gravity will also move vertically in the same direction. The distance moved by the centre of gravity will depend on the amount of weight shifted ~ the heavier the weight, and the further it is moved, the further the centre of gravity will shift.

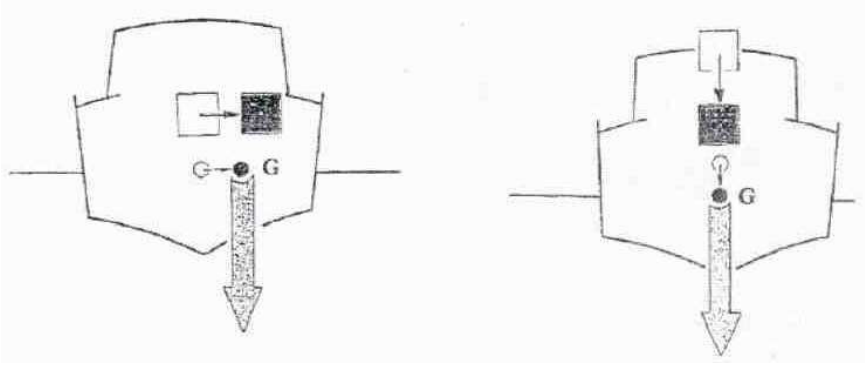

Figure 4: Movement of weights

1.5 Addition or Removal of Weights

If a weight is added to the vessel, the centre of gravity will move directly towards the added weight. If a weight is removed, the centre of gravity will move directly away from the former position of that weight.
The distance the centre of gravity will shift will be proportional to the amount of weight added or removed, and its distance from the vessel's original centre of gravity.

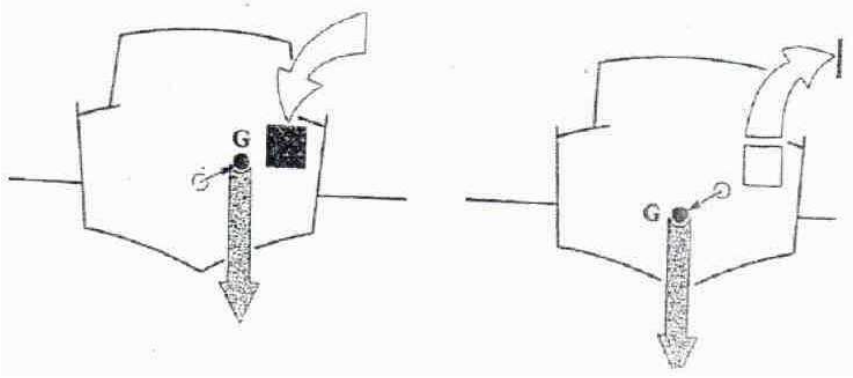

Figure 5: Adding and removing weights

1.6 Interaction between Gravity and Buoyancy

When a vessel is heeled over by the effects of wind and sea, it will try, if it is stable, to return to an upright attitude. This is brought about by an interaction between the forces of gravity and buoyancy.

In a stable vessel, which has evenly stowed weights within the vessel, the centres of gravity and buoyancy are on the centre line, and the vessel rests in an upright position. This is because the forces of gravity and buoyancy are acting in opposite directions but in the same vertical line.

If the vessel is now heeled by the wind, there is an immediate change to the shape of the hull's underwater portion. Since the centre of buoyancy is always at the centre of the underwater volume of the hull, it will move to take up a new position further towards the lower side of the vessel. The forces of gravity and buoyancy now form a couple, acting to return the vessel to an upright attitude.

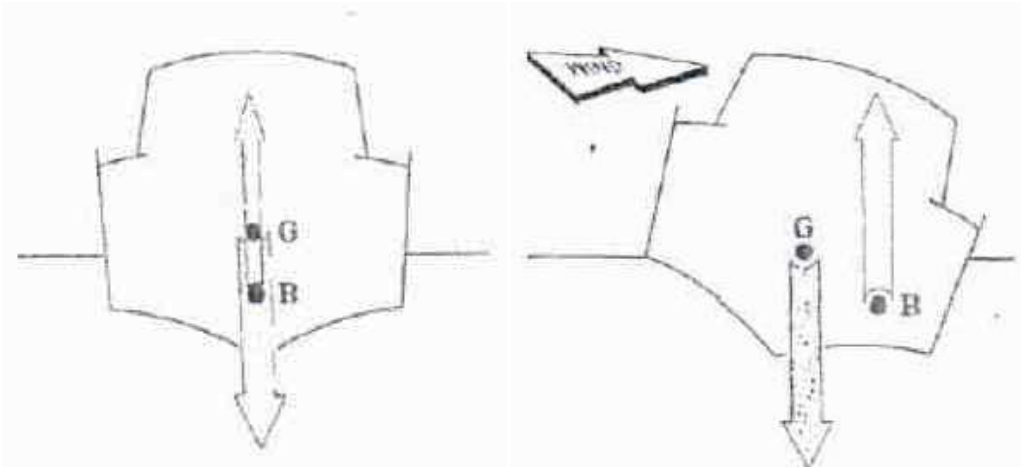

Figure 6: Interaction between buoyancy and gravity

1.7 List

An athwart ship change in the vessel's attitude caused by the wind is called heel, but if the vessel leans to one side because of an uneven distribution of weight aboard, the vessel is said to have a list.

If, for example, a weight is moved across to the starboard side of the vessel, the centre f gravity will also move to starboard. The two forces of buoyancy and gravity have now been put out of balance, and the resulting couple tips the vessel to starboard.

As the vessel tips, the underwater shape changes, and the centre of buoyancy will move over to starboard to assume its now position at the centre of this shape.

The centres of gravity and buoyancy are now both to starboard of the centreline, with their forces acting in the same vertical line. No righting couple is formed, and the vessel will therefore rest in this attitude, listed to starboard.

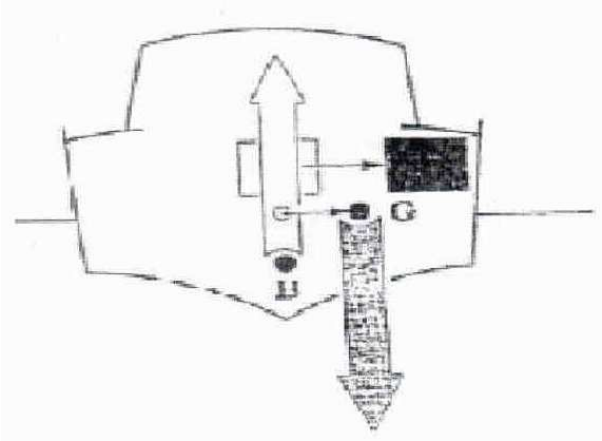

Figure 7: Listing

1.8 Stiffness and Tenderness

The height of the centre of gravity within the vessel can be gauged by the manner in which the vessel rights itself. If the centre of gravity is low, the forces of gravity and buoyancy exert a large righting couple to return the vessel upright. A vessel in this condition is very stable and returns to the upright position rapidly. This vessel is said to be stiff.
If top weight on the vessel raises the centre of gravity, the righting couple trying to return the vessel to the upright is reduced. A vessel in this condition is not so stable and returns more slowly to the upright position. This vessel is said to be tender. The stiffness or tenderness of a vessel is usually indicated by the way in which it rolls. A stiff vessel rolls quickly, almost uncomfortably, as it tries to keep upright. A tender vessel has a much slower period of roll - if it is very tender it may "hang" at the extreme of the roll before swinging back.

1.9 Loll

A situation may arise in which the centre of gravity is at a height where the forces of gravity and buoyancy neither return the vessel to the upright nor cause it to roll further. In this condition the vessel has no righting couple. It will therefore flop over and take up an angle of loll.
This vessel is now at neutral equilibrium, a dangerous situation because it could capsize very easily. The immediate remedy is to lower the vessel's centre of gravity. It is important that any action taken to correct loll is taken at once, and that the corrective action is safe.
Do not mistake loll for list. List can be corrected by placing weight on the opposite side of the vessel, but loll must never be corrected in this way. Placing a weight on the higher side of the vessel will raise the centre of gravity further, and create an unstable situation. The vessel will simply flop over in the opposite direction and capsize.
If the vessel should ever develop a lean to one side for no apparent reason, and adopt a sluggish, rolling motion, suspect loll. Act quickly to lower the vessel's centre of gravity. This can be done by reducing top weight and increasing bottom weight or by restowing weight from the top of the vessel into the bottom of the vessel.

1.10 Loose Water (Free Surface)

A particular hazard to a vessel's stability is any water within the vessel that is able to move around. As the water moves from side to side with the rolling motion of the vessel it has the effect of reducing the vessel's ability to right itself.

If water in the bottom of the vessel is unable to move, the vessel's centre of gravity will not move as the vessel rolls. The righting couple is large enough to return the vessel quickly to the upright.

If the water in the bottom of the vessel is able to move, it will move towards the low side. Because weight has shifted within the vessel, the vessel's centre of gravity will shift, also towards the low side. The righting couple is now considerably smaller perhaps non-existent.

Loose water or fuel in storage tanks will cause a similar reduction in stability. Movement within tanks can be reduced by fitting baffles, otherwise ensure that tanks are kept fully