

STABILITY – WHAT IS IT AND HOW DOES IT WORK?



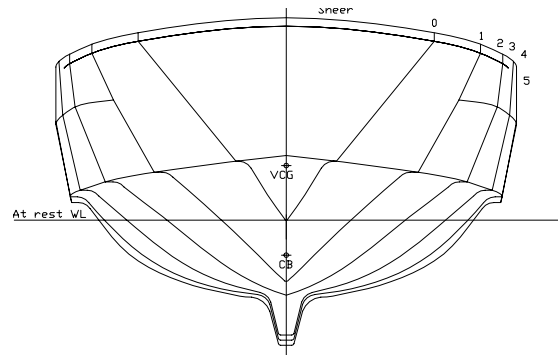
“Eastland”
disaster,
July 1915

Stability is the ability of a vessel to return to a previous position. Positive stability would then be to return to upright and negative stability would be to overturn. Stability in it's most basic form is the relationship between the center of all floatation in your hull (center of buoyancy, or CB) and the center of all weight (vertical center of gravity, or VCG). In other words, the downward pull of Gravity and the uplifting force of Buoyancy. These are the primary characters in this scene and all others play minor roles. Once you understand how their relationship works, understanding stability becomes a simple matter.

Static stability

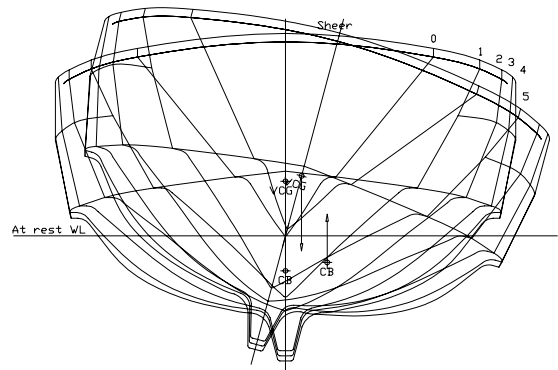
This is stability at rest without active external forces at work. The VCG for all intended purposes is a fixed point in space and is a reflection of the placement of major weights within the boat affected in part by the amount of superstructure and number of decks.

The shape of the hull determines the CB, which is not fixed. It moves around to balance the loads and keep the forces in equilibrium. The shape of the hull has a major effect on the path that the CB will take as the vessel heels or trims. At rest the CB and the VCG align vertically. If they are not vertically aligned then the vessel will change trim or list until they do come into alignment. Then all the forces are equalized and the vessel becomes stable.



Form stability (effects of section shape)

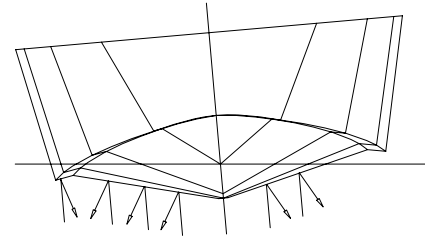
As the boat heels, sides of the boat previously above water are immersed and bottom sections previously underwater are now exposed, and the CB is on the move. The battle has begun. As forces are applied to the vessel changing it's attitude in relation to the surface of the water. This causes the CB to move, creating the forces to bring the vessel into equilibrium. If the CB can not create enough counterforce to right the vessel then it will be over turned.



The amount of counterforce can be determined mathematically from the designer's drawings and verified on the finished boat with an inclining experiment. How are these calculations performed, you ask? Someone needs to do a weight calculation, which accounts for every item on the entire boat right down to the weight of the paint and screws, and also accounts for their position in the vessel both vertically and fore and aft. Usually transverse measurements are considered less critical as most boats are very symmetrical. Knowing where the VCG is (remember, this is a fixed position) we can now go on to look at where the CB moves for each angle of heel. This is also calculated, but in a far more complex manner and is best done by an experienced Naval Architect (and their computer). Both hull form, and ballast if any, have a major role to play out in this scene. Both will have a major effect on stability, but more on that later.

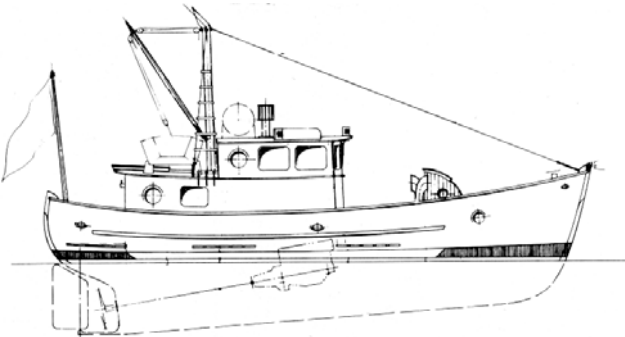
Dynamic stability

Once a vessel is under way the effects of wave train, bottom pressure and change of trim can add or detract from the amount of stability. Many planing hulls become more stable at speed due to the change in pressure distribution across the hull bottom. Because of the V-bottom and the spray rails outboard, unequal pressure builds up on the lower side in a turn. This pressure restores the vessel to upright when the heeling forces of the turn are over.



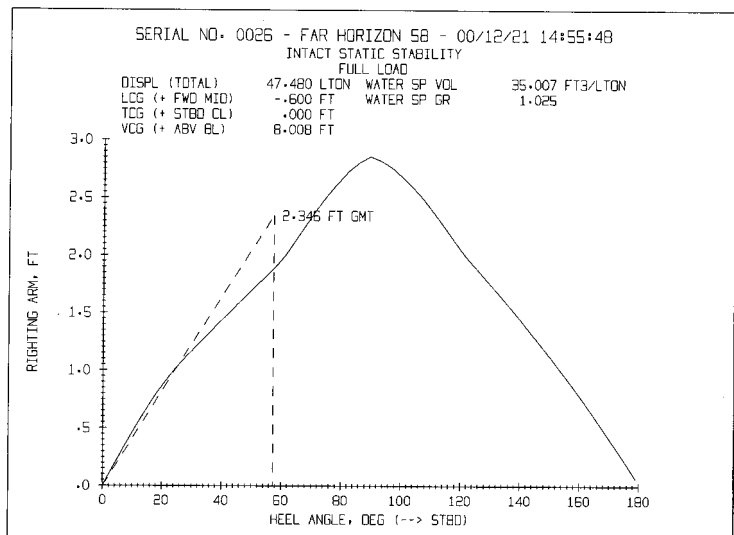
Some double-ended vessels become less stable at hull speed because of the wave hollow amidship. With only the fine forward and after sections floating the boat and the Midship section mostly unsupported there is little width to provide stability. This can also be a problem to any vessel in short steep seas.

Active and passive stabilizer systems give the impression of increasing stability; however they actually act to reduce roll. In fact, active stabilizers are only effective when underway.



Amounts of stability required

The Coast Guard sets minimum standards of stability for various types of commercial craft but no such standard is set for yachts. Fishing vessel standards can be used as a guide as they have similar characteristics and are a similar size to many offshore cruising powerboats. However, these are minimums and do not address comfort. And even comfort is subject to personal interpretation. A serious offshore vessel will be tender initially and will tend to have a long easy rolling motion which will not knock crew nor gear off the deck. For many pleasure boaters this amount of



roll and length of time (period of roll) is alarmingly long.

If a boat is very stable at the dock (great as a liveaboard), or in flat water, it can have a very quick motion at sea. A case in point is a very successful 110 ft motoryacht that does harbor charters seating 95 for dinner cruises. When taken to sea it has such a quick motion in a seaway that the crew have to go around on their hands and knees to keep from getting knocked off their feet; and this is at 8 knots.

Stepping aboard a 60 footer that noticeably settles under your weight (low GM) does not instill confidence. Having it heel under the press of a strong breeze will only erode that confidence further; yet it can have an excellent sea motion and be extremely comfortable once you get your sea legs.

For the general boating public there has to be a middle ground. Few boaters spend all their time at sea and just as few plan to spend all their aboard time at the dock (although sometimes it works out that way!). A compromise must be struck: one that provides stability for dockside comfort moving around the vessel and a suitable motion for safe operation in some kind of seaway. The proportion of compromise depends on the purpose of the vessel and the market segment that it is appealing to. What is the intended use of the vessel and what level of experience will the purchaser have?

Let's look at the effects various elements of design have on the stability characteristics of a vessel.

Ballast

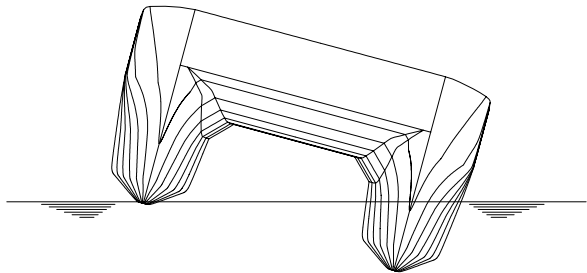
Generally when people think of stability and ways to increase it they think of adding ballast. Generally this will help - but not in all cases. If ballast reduces the freeboard to the degree that the deck edge enters the water at a much lower angle of heel, then the overall stability is drastically reduced. Again, it is the relationship between the hull form and the overall center of weight that tells the story. Removing top weight from as high up as possible will have a greater effect than adding ballast low down.

Also, ballast will not do much to increase initial stability (stability at very low angles of heel). It's real forté is at higher angles of heel. Once the heel angle starts to reach or exceed 45 degrees ballast comes into it's own. Although this may provide real peace of mind, it does little to improve a day to day comfort situation.

Beam

Wide beam will produce high initial stability (and low ultimate stability). It is great for liveaboard space and comfort at the dock but taken to extremes it will produce an uncomfortable motion in a seaway. The combination of extremely wide beam and low freeboard in a monohull can be dangerous, as the high initial stability reaches it's peak at a very low angle of heel. Once overturned the vessel becomes very stable inverted and has no desire to return to upright.

A catamaran is a classic example of wide beam and no ballast taken to extremes. The interior volume and low heel angles make these vessels very comfortable to liveaboard. On the other hand, if one hull ever leaves the water the chances of seeing it re-enter the water upright is slim to none. To compensate for this, specific hull forms have been developed which allow high immersion of one hull before the other hull leaves



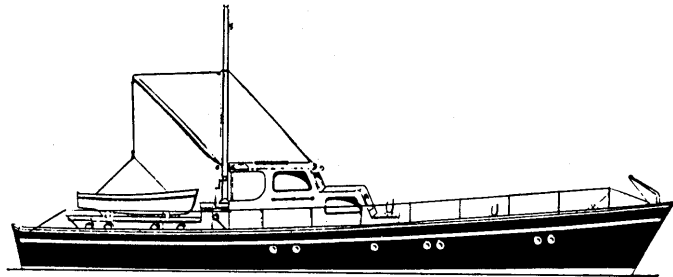
the water. This means a higher angle of heel can be achieved before total loss of stability. Also, scale comes into effect and once the vessels reach a reasonable size it becomes impossible short of a Tsunami to overturn them.

Inertia

One of the ways to improve the motion of an existing vessel is to alter the amount of inertia. If you have a boat with a quick motion and want to slow it down try moving major weights horizontally outboard from the centerline. This will increase the inertia and dampen out the motion. By moving the weight horizontally rather than vertically you do not affect the overall stability. If your vessel has a slow roll that you would like quickened, try moving heavy weights inboard or down as this will reduce the inertia and/or increase the stability. For a quick demo on inertia try spinning around on a swivel chair and bring your arms or legs in and out.

Superstructure

Generally stability increases in strength until 45-60 degrees of heel (occasionally as high as 90 degrees) and then slowly diminishes to nothing at 90-120 degrees, (the critical angle or ultimate angle). Rarely, the ultimate angle goes all the way to 180 degrees, making the boat self-righting. Once the deck edge immerses the shape and size of the superstructure becomes a major player in shaping the course the CB will take. For this reason it is important that the house be well constructed and that there are few openings for water to enter. If there are wide side decks then the house will enter the water later reducing it's effect on the stability curve. If the vessel is flush decked with little in the way of a house then all stability must be gained from the hull form.



Windage

The very area of a large superstructure can act as a sail, heeling the boat to some degree. If the stability is reasonable then this should not be a problem. In fact, in some boats this press of wind actually acts to dampen rolling motions further producing an even more comfortable ride. Unfortunately, it is not a sail area that can be reduced as the wind pipes up.



Waves

All vessels will suffer from loss of stability on a wave face. If the waves are short and steep, as in a shelving area, the situation becomes worse. With the majority of the vessel sup-

ported by the buoyant ends there is little waterline width. As the vessel heels the midsection falls into the trough. This can induce deep rolling motions and even cause capsizing.

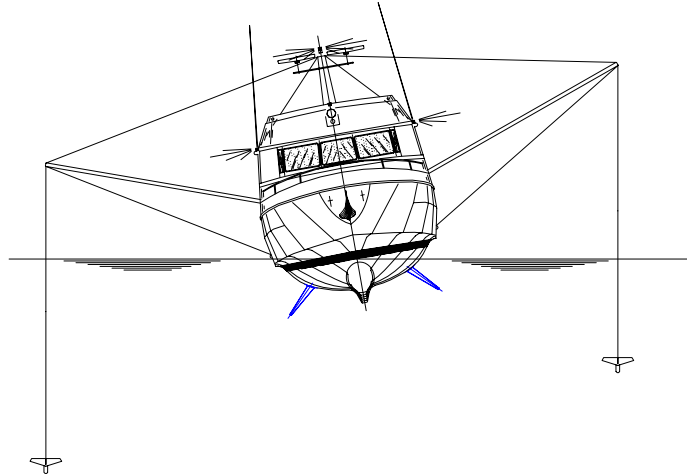
Even a beam sea can create serious problems if the wave train coincides with the vessel's natural rolling motion. Luckily a small change in direction or speed is all that is required to avert a progressively worsening situation.

Active stabilizers

These stabilizers are usually gyro controlled and hydraulically activated fins which are placed amidship. Their dynamic forces return the vessel to upright when a heeling force is detected. They can even compensate for a list. Generally, they dampen rolling motions more than 80%, however they do not increase the vessel's actual stability. Unfortunately, they are not considered workable at speeds below 8 knots through the water. Their forces and effectiveness diminish as speeds drop until at anchor or at the dock they provide no real effectiveness.

Passive stabilizers

These passive systems vary from Paravanes to Fixed Bilge Keels to anti-rolling ballast tanks. Their primary feature is that they have few to no moving parts and are mechanically simple and therefore very reliable. They are not as effective in dampening roll underway as an active system but do tend to be better roll dampeners at low speed and at anchor. They will do nothing to increase stability but will dampen the forces acting on your vessel.



Downflooding points

All of the stability in the world will be of no use if there are openings in your hull or superstructure that will let water in to flood your boat. Items such as engine room intakes placed low in the hull sides and leading directly into the engine room are a classic problem. Even if the boat has a good range of stability, what good will it do when water is pouring in a large open vent? It is like having a gaping hole in your boat waiting to gulp up water.

Openings for interior ventilation also need to be placed carefully. Non-watertight hatches to hull compartments need to be checked so water cannot enter at low angles of heel.

The effects of uncontained water inside a boat are unbelievable! Water always runs to the low side, making matters worse and it is surprising



how much water weighs. As the vessel rolls, the water shifts from side to side, producing a pendulum effect which increases the rolling even further.

Even uncontained water on deck has the effect of raising the VCG and reducing stability. Large freeing ports (drainage openings) in the bulwark are necessary in order to get the water off the boat fast, before the next wave adds further to the burden on deck.

Of course, once a hull has been damaged and water is pouring in, there is little that can be done if there are no watertight subdivisions in your boat. Commercial vessels not only are required to have watertight bulkheads but must be designed to remain afloat and stable with one and sometimes even two compartments completely flooded.

Numbers for number crunchers

Hard and fast numbers are usually misleading, because there are so many variables that effect stability. In addition few of the thousands of small craft are designed by a Naval Architect so in many cases these stability numbers are just not known.

Having said that, for a mono-hull yacht that is expected to do extended coastal cruising, open ocean cruising, or any vessel that is expected to be caught out in really bad weather you should look for the following;

- a minimum range of stability to 90° of heel and over 120° preferred
- a maximum righting moment (GZ) that occurs after 30° and preferably after 50°
- and a GM of at least 2 feet and preferably between 3 feet and 5 feet

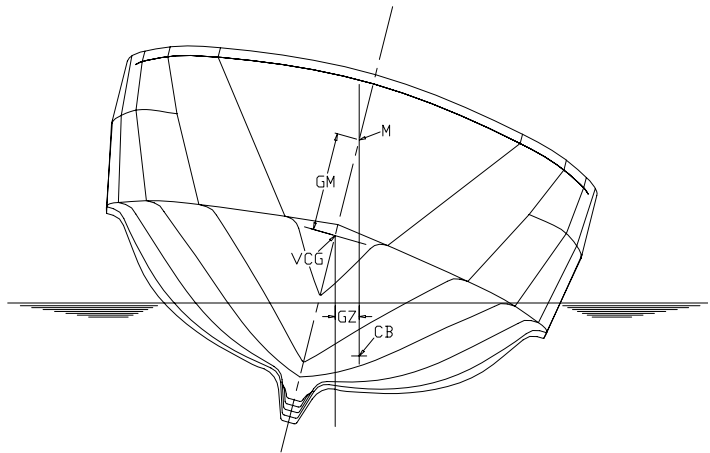
GM is the most valuable number to consider, as it tells you the initial stability; the stability that you will notice day to day. GM is actually the measurement between the VCG and the Metacenter (M—the point at which a vertical line taken from the heeled CB crosses the vessel's centreline) as shown in this diagram.

Low GM means the boat may be a bit tender to walk around on and heel a few degrees under wind pressure. However, there may be a good overall range of stability, which you can check by looking at the Critical Angle or Ultimate Stability.

If it has a higher GM then more than likely there will be sufficient initial stability, and possibly too much, however Ultimate Stability may be low. The boat will have a quick jerky motion in a seaway but be very stable at the dock.

Good stability doesn't 'just happen'

Good stability can be, and should be, achieved during the design stage. Careful placement of heavy items down low, and knowledgeable design of a hull form and superstructure that takes stability characteristics into account will produce a sound vessel with a good solid feel to it. Attention to the numbers that determine the vessel's final characteristics will produce a successful yacht long before the boat is launched.



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