The Ship Model Stability Handbook

Please Note:

The formulae used in this booklet (and in the associated software programme ‘Model Stability Calculator) have been based on a number of ‘approximate’ factors and are applicable ONLY to small angles of ‘heel’ (I.e. Less than 15 degrees).

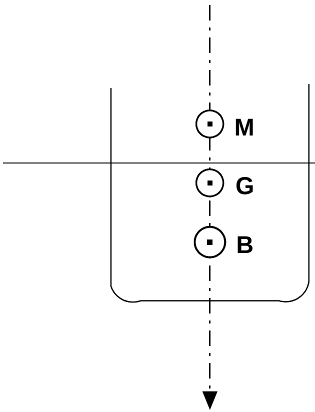
In addition, for simplicities sake, the hull form factors have also been approximated. (Ref. Sir Wm. White - *Manual of Naval Architecture*)

The result of this is that these formulae are best used in a relative fashion, in which case they produce useful results. They have been in use in ship stability calculations since prior to 1942 and I have used them for models since the 1970’s with good results.

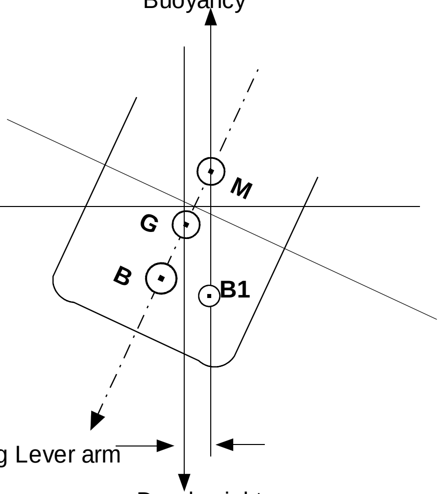
There is an accompanying single sheet instruction set for making a simple Inclinometer that may be used in place of the plumb bob to measure small angles of heel.
If this has become detached, a copy may be obtained from the E.M.B.C Web Site on : http://edinburghmodelboatclub.org

It should be printed full size (on an A4 sheet in portrait orientation) and may then be cut out and used as a template.

M - Metacentric Height
G - Centre of Gravity
B - Centre of Buoyancy

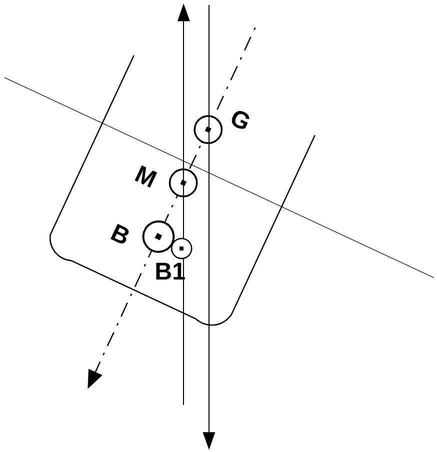


Case 1 - Stable equilibrium



In this case there will be a righting moment that tends to restore the original position.

Case 2 - Unstable Equilibrium

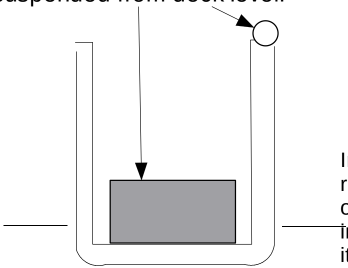


<u>Over she goes !!!!</u>

In this case there is now a tendency for the heeling moment to incline the vessel further away from her original position.

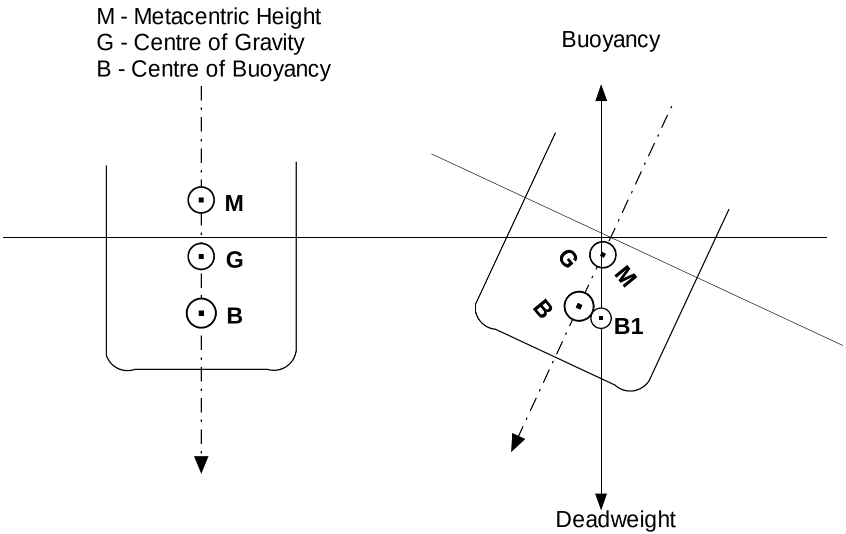
This is what happens if ballast weights are added too high up in the hull or on the deck.

Internal ballast tray suspended from deck level.



In this case, the suspension point, being to the right (or left depending which way the wind blows) of the centre of gravity (G) significantly increases the over turning moment. Even worse, it will RAISE the Centre of Gravity as shown here ....

Case 3 - Neutral Equilibrium
The 'crank' ship



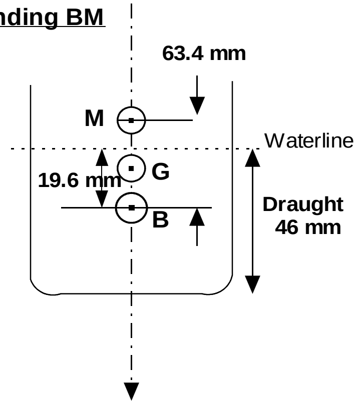
In real life this would be like pumping out ballast to maintain the displacement (draught) after adding cargo into the 'tween decks.

In model terms it equates to placing ballast too high up in the boat OR by adding top weight like fittings, fixtures, guns etc. and reducing the ballast to compensate.

The result is that the buoyancy and the deadweight will both act through G in the line B1M.
There is therefore no lever tending to correct a list, so the vessel may incline either one way or the other.

I call this the 'Flip-Flop' list !! Turn to port (left) and the boat flips to starboard (right) and vice versa.
Sometimes it can even be caused by going ahead then astern even though there is no turning at all. In this case it is caused by the torque of a single prop (or perhaps of a twin prop when one motor is stopped).

Approximate Methods for finding BM



For simplicty we will assume that the hull is of box shape form and we will then use a 'form factor' **k** depending on how fine the hull form is.

The formula for calculating BM (the distance between B and M) is:

$$BM = \mathbf{k} \times \frac{\mathbf{B} \times \mathbf{B}}{\mathbf{D}} \qquad \text{(equation 1)}$$

where **B =** beam and **D** = draught

For all practical purposes, k = 0.09 for most merchant vessel hulls,
and k = 0.08 for full form hulls like tugs.

An example : A launch 760 mm in length and 180 mm beam with a draught of 46 mm.

This would give a $BM = 0.08 \times \frac{180 \times 180}{46} = \mathbf{63.4\ mm}$

The height of the Centre of Buoyancy can be approximated as 0.425 of the mean draught (i.e. draught forward + draught aft /2). For practical purposes take the draught amidships. In this case = 46 mm.
The Centre of Buoyance will therefore be :
46 x 0.425 = **19.6 mm** down from the waterline.

The CofG should lie between B and M (at least we hope so !!)
Question .... how to determine this.
Answer ..... by a series of simple experiments. (unless you are a mathematical fiend in which case I'll give you all the formulae !)

CofG.
The experiment involves consists in heeling the model by moving a weight across the deck and observing the changes in inclination. The model should be in the ballasted condition with batteries etc. installed.

You will need (a) two equal weights and either (b) a plumb line and a 6" rule OR a simple inclinometer.
You also need to weigh the boat. (weigh yourself on the bathroom scales then weigh yourself holding the boat. The difference is the weight of the boat.)

In real life, the plumb line would be hung from a hatch coaming.
In models, even if you have hatches you are not going to be able to easily read off a 6" rule at the bottom of the hold space !!

Either (a) attach the plumb line to the mast or to a fore stay so that it hangs free. Place a 6 inch rule on the deck underneath the bob. OR (b) make up a simple inclinometer (instructions attached) and clip it to a suitable part of the superstructure.

The weights need not be heavy (usually about 1/50 of boat weight).
Take 4 C size torch batteries for example and wrap them in two pairs with elastic bands. (used cells just in case you drop them in the bath!!)
Weigh each pair .... should be the same.
Note the weight.

You will start off with one pair on each side of the deck.
Note the reading of the bob on the rule.
Place both pairs on the same side of the deck.
Note the reading on the rule.

See next page

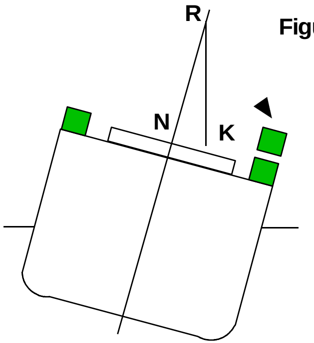


Figure 4a

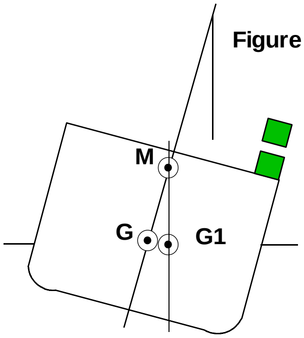


Figure 4b

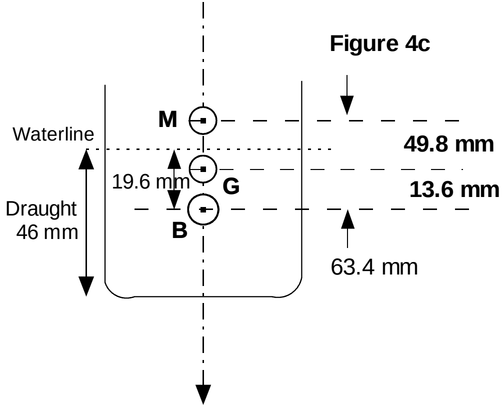


Figure 4c

The diagram above shows what you have just done.
RK represents the plumb line.
N is the position of the plumb bob when the weights are evenly distributed.
K is the position of the plumb bob when both weights are on the right side of the deck.
A is the distance the weights have been moved. Normally this would be the beam of the model minus the width of a weight.

OK .... we have now got all the information we need to do our calculation.

If you look at Figure 4b, you will see that the CofG has been moved from G to G1 by the movement of the weight a distance A across the deck.

The distance GG1 is calculated by the formula $\frac{W \times A}{DW}$ (equation 2)

where W = the healing weight (i.e. 2 x the weight of each pack of batteries)
and A = the distance moved
and DW = the displacement of the model. (the weight)

The distance between G and M is calculated by the formula

$GM = \frac{\text{length of plumb line}}{\text{distance NK}} \times GG1$ (equation 3)

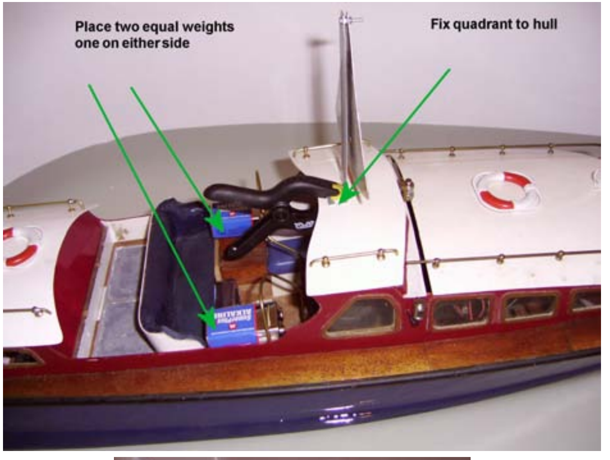
Since we know the position of M from the work we did on page 3, we can easily determine where G lies.

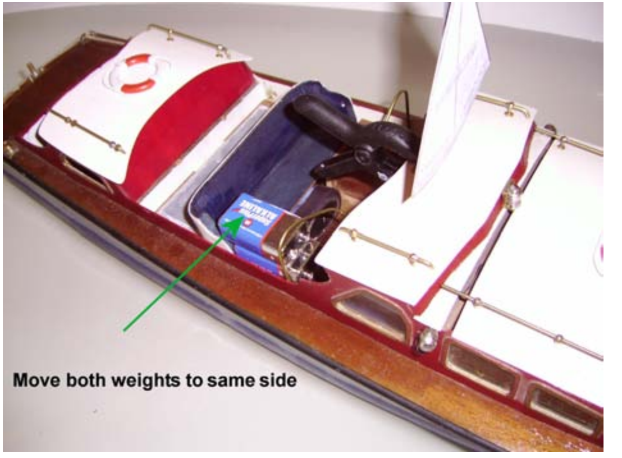
If we take an example :
A Launch 180 mm beam, displacement 7 lbs. (3.14 Kg)
with a plumb line length of 97 mm.
Heeling is done using 2 weights each of 0.1 lb (47 gm).
Distance NK was measured as 7 mm.

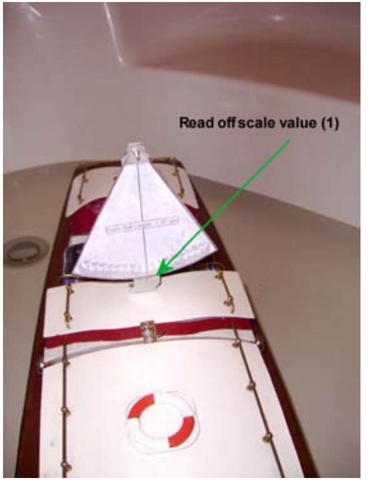
GG1 = (94 x 120) / 3140 = 3.6 mm

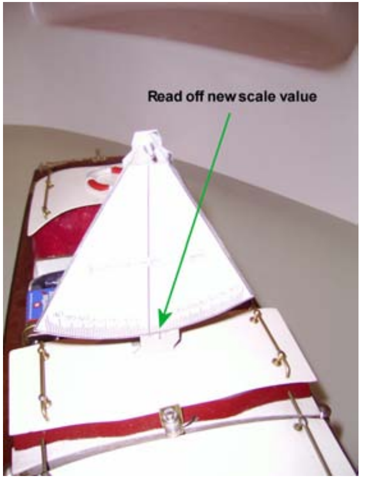
GM = (97 / 7) x 3.6 = 49.8 mm

This model will have a very short and quick roll because of the relatively large distance between the C0fG and the Metacentre but she will certainly never roll over !!


Place two equal weights
one on either side
Fix quadrant to hull


Move both weights to same side


Read off scale value (1)


Read off new scale value

GENERAL HINTS'N'TIPS

If your boat is ballasted down to the correct draught, do NOT add additional ballast to correct trim problems; concentrate on re-distribution of ballast.

NEVER glue ballast in place, at least until after you are certain that the trim and stability are correct. Even then, gluing ballast severely restricts the possibility of future change, especially in the power batteries that are used.

NEVER place ballast under permanently fixed 'floors'; If you have to, then make the floors removable (screwed).

In general ALWAYS use as little ballast as possible. Always try to use 'useful ballast' i.e. Power batteries or auxiliary batteries (receiver etc.).

ALWAYS place the large weights low down on the hull longitudinal centre line (power batteries; ballast weights etc.). Keep the smaller weights available to correct the stability and/or trim.

ALWAYS keep the 'top hamper' weight as low as possible.
If you have heavy superstructure you run the risk of ending up with an unstable boat, or, at best a boat that has 'flip/flop' list properties.
REMEMBER adding weight high up may correct the draught and/or the fore & aft trim BUT it also raises the Centre of Gravity. If this moves above the Metacentre the boat will become unstable and may roll over.

If you use Lead/Acid Gel batteries, make sure that, if possible, the batteries are placed on their longest side. This lowers the centre of gravity of the battery weight and hence has a lesser effect in raising the overall centre of gravity.

It is possible, that by placing the lesser weights to the left and right of the centre line, the roll characteristics of the boat may be improved.

Produced by Iain Moffatt - Pretty Smart Ideas

12th June 2005