APPENDIX A – ADDITIONAL NOTES ON MULTIHULL DESIGN

MULTIHULL STABILITY NOTES

Multihull stability is calculated using exactly the same method as described in Westlawn book 106, "Stability – Part 1," pages 28 through 41 (Module 1). The difference in application is that you need many more closely-spaced heeled buttocks for each heel angle. On a cat, for instance, the heeled buttocks would run through the starboard hull, across the entire width of the bridgedeck, and through the port hull. Of course, you need a larger table or spreadsheet to enter all these heeled buttock measurements in, but the great majority of these heeled buttocks will be between the hulls (thus no hull in the water) and so will measure zero for every station (see fig. 14, next page). The curve of righting arms from your combined stability calculations at several angles should look about as shown in fig. 8, page 19.

It's important to keep in mind that—starting from zero degrees—as heel increases, the windward hull gradually lifts out of the water and the lee hull will gradually become more and more immersed. The buoyancy of in the windward hull will thus decrease and the lee hull increase. At some angle, the windward hull will lift completely out of the water and all the buoyancy will be in the lee hull. This is "flying a hull." At this point, you no longer need the heeled buttocks running from the windward hull across the width of the entire bridgedeck and through the lee hull. You only need heeled buttocks in the lee hull (which must be closely spaced to give you a good heeled center of buoyancy location), see fig. 14 next page.

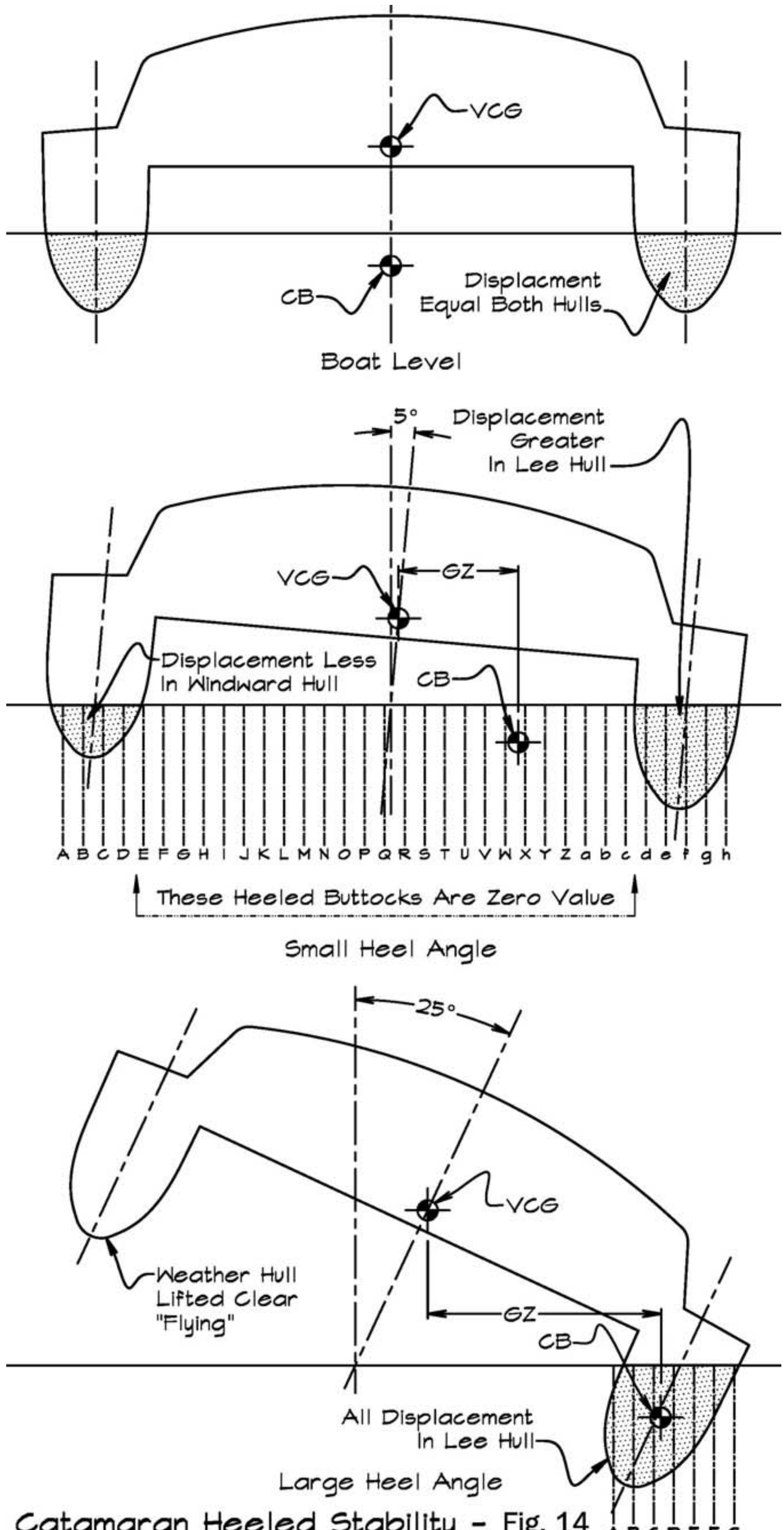
Trimarans are the same as cats in this regard; however, on many tris—at low heel angles—all three hulls will be in the water. Usually, somewhere around 2 to 5 degrees, the windward hull (ama) will lift out and only the main hull (vaka) and lee ama will be in the water. As the tri continues to heel—as with a catamaran—the vaka will lift further out of the water and the lee ama will depress deeper and deeper into the water. Then—as the heel angle increases still more—the vaka itself will lift out completely and all the buoyancy will be in the lee ama alone. This is the condition where a tri is "flying a hull."

Note that if the total buoyancy of the ama, all the way to the sheerline, is less than the displacement of the total boat (less than 100%-bouyancy amas) then—on a catamaran—the lee hull will immerse and the windward hull will not lift completely out of the water unless or until the bridgedeck picks up some of the buoyancy. On tris, with less than 100%-buoyancy amas the lee hull will immerse while the vaka remains in the water (though partially lifted out). This is not acceptable for any sailing cat or for most ordinary power multihulls, but might be acceptable for some specialized power cats and tris with slender wave-piercing amas.

Multihull Preliminary Stability Estimates are Fairly Accurate

Because of multihulls' shape—with separate widely spaced discrete hulls, unlike monohulls—you can make a good estimate of the stability curve of a multihull using common sense and basic math. Stability for multihulls is essentially a function of:

- half beam—from the boat centerline to the centerline of the of the outer hull
- displacement
- heel angle



Catamaran Heeled Stability - Fig. 14

This is what is pictured in Fig. 9, on page 22.

For catamarans you can estimate the righting moments (GZ) as:

GZ = half beam x cos(θ)

Where:
half beam = half the beam from the **boat centerline to the centerline of the outer hull**, ft. or m
θ = heel angle, degrees

Plot at 0 and 11 degrees, and then at 20 degrees, and then at 10 degree increments, from there on, through 90 degrees. Use the following modifier for the zero-degree GZ:

GZ 0° = 0

(Note: Around 11 to 13 degrees is the usual point of max. GZ for catamarans.)

This plots to a the curve below (fig. 15) for a typical catamaran.

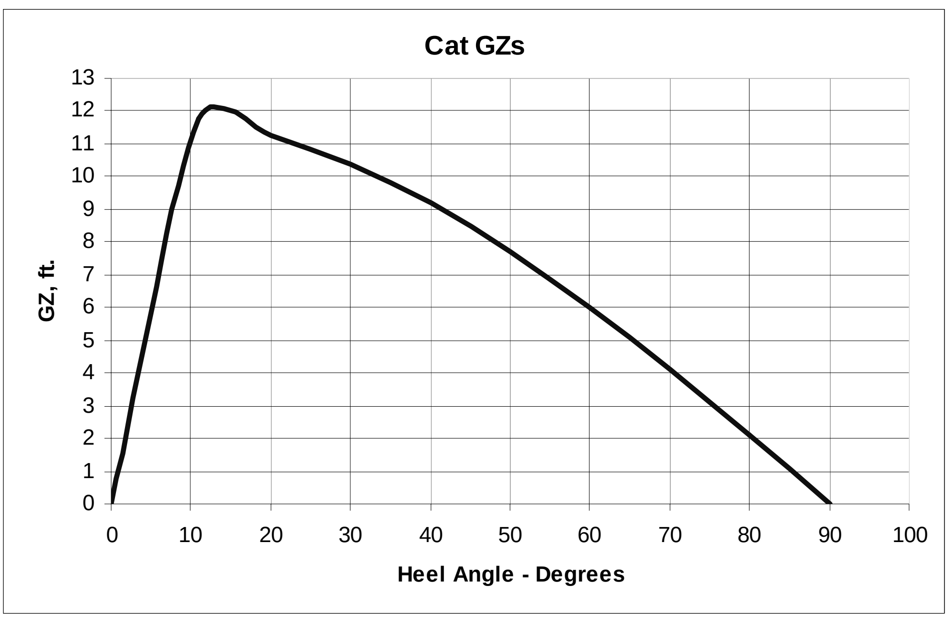


Fig. 15

For mast and rigging calculations, you always us the maximum possible righting moment, which is:

RM = half beam x displacement
(displacement is in pounds or kilograms)

For a tri you can approximate as follows:

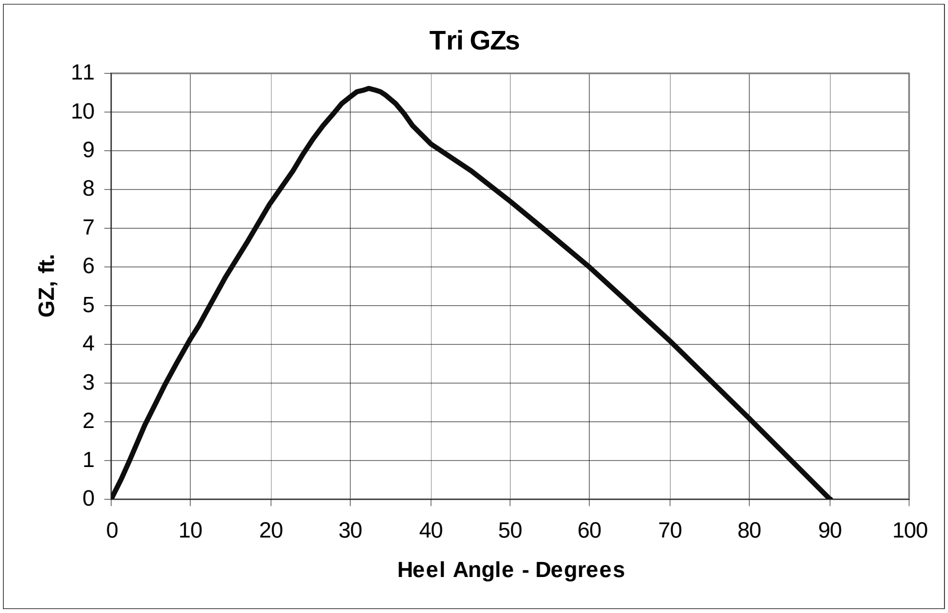


Fig. 16

GZ = half beam x cos(θ)

Plot at 10 degree increments from 0 to 90 degrees. Use the following modifiers for the zero-degree and 10-degree GZs:

GZ 0° = 0
GZ 10° = 0.35 x half beam x cos(θ)

Where:
half beam = half the beam from the **boat centerline to the centerline of the outer hull**, ft. or m
θ = heel angle, degrees

This plots to a the curve above (fig. 16) for a typical trimaran.

For mast and rigging calculations, always use the maximum possible righting moment, which is:

RM = half beam x displacement
(displacement is in pounds or kilograms)

The curves of righting arms above are only approximations but they are close—important for checking your work and for preliminary design. For detailed stability analysis, you should use the full method from Westlawn book 106, “Stability – Part 1,” pages 28 through 41 (Module 1), or your hydrostatics--program stability module.

For most multihull powerboats, which aren’t carrying paying passengers or that don’t have unusual features (such as very narrow overall beam and/or high deck and superstructure), the preliminary estimate above is all that is usually required.

Multihull Sailboat Stability Criteria – Stability Numbers

Don't forget that multihull sailboats must meet the criteria of Bruce number, RPI, stability number, and stability factor. Be sure to refer to the Student Guide 2nd Edition (the SG2) starting on page 101.

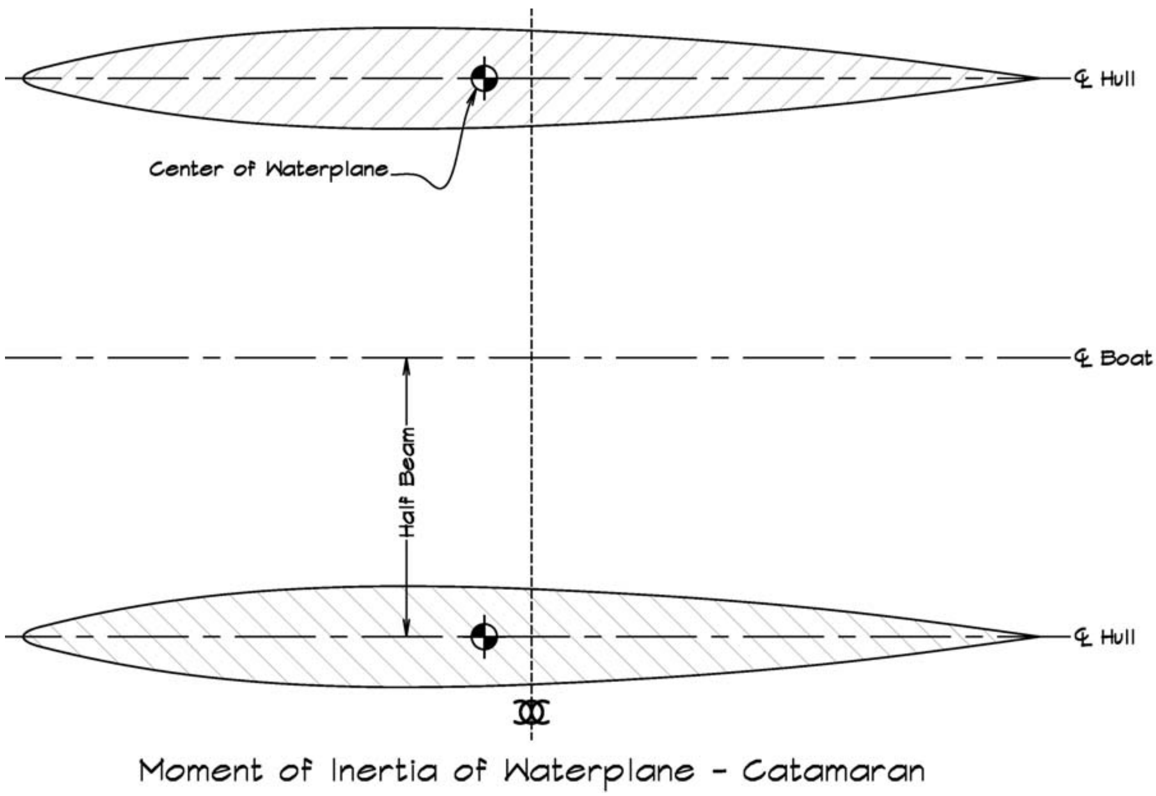


Fig. 17

Multihull Transverse Moment of Inertia of the Waterplane

For catamarans, determining the transverse moment of inertia of the waterplane (It) is quicker and easier than for a monohull. The moment of inertia of a plane area is the "second moment of area." It is the area (in square feet or square inches for small objects, or in square meters or square cm for small objects) times the square of the distance from the centroid of the area (in the same units as the area). Since monohull waterplanes are complex irregular shapes you use the tabular method explained in Westlawn book 106, "Stability – Part 1," page 22 (Module 1) to find the waterplane moment of inertia (It) about the centroid, which is on the boat centerline.

In the case of a catamaran, all you have to do is find the area of the waterplane of one hull and then multiply it by the square of the half beam from boat centerline to the hull centerline, then multiply by two for both hulls, see fig. 17 above.

Itwp = 2 x area one-hull waterplane x half beam^2

Say you have a catamaran with a waterplane area of one hull of 107.94 sq.ft. and a half beam of 11 ft. Then:

$Itwp = 2 \times 107.94$ sq.ft. $\times (11 \text{ ft.})^2 = 26{,}121 \text{ ft.}^4$

or

Say you have a catamaran with a waterplane area of one hull of 10.03 m^2 and a half beam of 3.34 m. Then:

$Itwp = 2 \times 10.03 \text{ m}^2 \times (3.34 \text{ m})^2 = 223.8 \text{ m}^4$

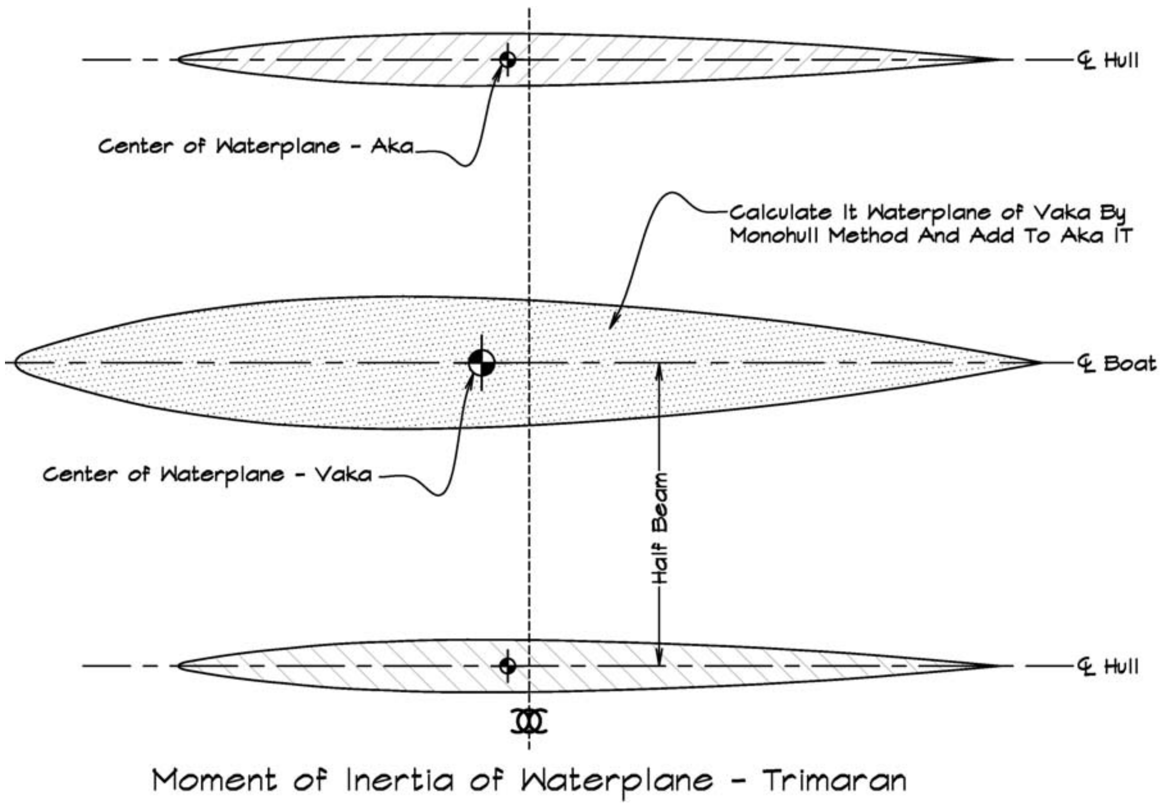


Fig. 18

For a trimaran, the vaka waterplane moment of inertia (It) is calculated using the tabular form exactly as for a standard monohull (see Westlawn book 106, "Stability – Part 1," page 22 – Module 1). The It waterplane of the akas is calculated using the method explained above for a catamaran. Add both the waterplane moments of inertia together to get the total waterplane It for the tri, see fig. 18 above.

<u>Longitudinal Stability (Trim) For Multihulls and Pounds Per Inch</u>

To find the longitudinal trim numbers for a multihull (to determine moment to trim), use the methods for monohulls given in Westlawn book 107, "Stability – Part 2," starting on page 5 (Module 1). Do these calculations for each hull of the multihull and add the results for all hulls to find the total.

HYDROSTATIC NUMBERS AND COEFFICIENTS – MULTIHULL VS MONOHULL

The standard hydrostatic numbers and coefficients for multihulls as opposed to monohulls, are mostly a question of common sense and understanding what the particular number represents. Below is a list of some of the differences:

Disp. =	sum of displacement all hulls
LCB =	same as one hull for catamarans, different for vaka and aka on tris (give both)
VCB =	same as one hull for catamarans, different for vaka and aka on tris (give both)
D/L =	add all hulls' displacements together, but also give individually for each hull or for one aka and the vaka on a tri
Cp =	same as one hull for catamarans, different for vaka and aka on tris (give both)
Cb =	same as one hull for catamarans, different for vaka and aka on tris (give both)
Cm =	give for each hull
WPA =	give for each hull and for all hulls combined
Cwp =	give for each hull
PPI =	total of all hulls combined
MTI =	see discussion of longitudinal stability above
BM =	see discussion of It waterplane above
Itwp =	see discussion of It waterplane above
GM =	see stability discussion above
SW =	give for each hull and total for all hulls

SETTING UP MULTIHULL LINES DRAWINGS

There isn't one right or standard method to set up or layout the hull lines drawing for a multihull. These drawings can be a bit tricky to arrange but it's just common sense. For a catamaran, you need to show only one of the two hulls and half the crossbeam. (If there are only pipe, mast section, or similar tube-type cross beams, you can show only the one hull and just enough of the tube crossbeam to make the attachment location clear.) For a tri, you need to show one outer hull (ama) and the main hull (vaka). You then have to show the crossbeam(s) (amas) clearly and how and where they join, attach to, or blend in with the akas and vaka. Again, there isn't one right way to do this, and sometimes it makes sense to put the aka on one sheet and the vaka and amas together on another sheet (though it is best to fit everything on one sheet if you can).

There is no problem with cutting the lines of cat in half at the boat centerline (in the middle of the crossbeams or bridgedeck). The sections (body plan view) should represent only one half of the boat as usual. Sometimes it makes sense do the forward and after sections (with half the crossbeam or deck included) in two separate section (body-plan) views, but this isn't always necessary. Your goal is to make the drawing clear, businesslike, and readable, with all the information needed to define the geometry. Since there's such a wide variety of types and sizes of multihulls, you must use your creative ability to work out the layout for your drawing to show all that's needed.

HULL MULTIHULL SPEED FORMULAS

Vee-Bottom Planing Multihulls

For vee-bottom planing multihulls (such as pictured on pages 97 and 98 of the SG2), you can estimate speed using the Crouch speed formula:

$$kts = \frac{C}{\sqrt{lb./shp}}$$

or

$$kts = \frac{C}{\sqrt{kg/KWs}}$$

Where:
kts = boat speed, in knots
lb. = displacement, in pounds
shp = total shaft horsepower all engines (about 96% of total rated engine brake horsepower, bhp)
KWs = total shaft kilowatts all engines (about 96% of total rated engine full flywheel kw)
C = Crouch constant
For vee-bottom planing multihulls use:
C = between 210 and 230, with 220 being a good average – English units
C = between 163.8 and 179.4, with 171.6 being a good average – Metric units

“Displacement” Type Slender Multihulls

For slender-hull, “displacement”-type multihulls (such as discussed on pages 97 and 98 of the SG2), you can use Kellsall’s multihull speed formula for a reasonable approximation of speed:

$$kts = \sqrt{\frac{DWL, m \times bhp}{disp., tons}}$$

Where:
kts = boat speed, in knots
DWL, m = waterline length, in meters
(To convert feet to meters divide feet by 3.2808.)
disp., tons = displacement in long tons or metric tons
bhp = total installed engine rated brake horsepower all engines (not shaft horsepower)

Remember, these slender hulls can be driven at well over so-called monohull hull-speed (1.34 x the square root of the waterline length in feet), as long as there is sufficient power installed.