SCALING BOAT PLANS

"The basic concept is that you cannot simply take an existing design and scale it up or down without affecting the design in other ways than the linear dimensions. That may seem obvious, but apparently it wasn't obvious to the not insignificant number of people who have attempted to do just this and ended up with boats that were floating disasters. " Thomas Tangvald.

Scaling a boat is a question that routinely reappears on our message board. Let's have a look at what is involved and if you have more questions, please post on our forum.

We will look at several aspects of scaling a boat plan:
- Scaling all dimensions: enlarging or reducing a plan and its dangers.
- Scaling one dimension, usually stretching
- How to do it right, what are the limits?
- How scaling affects the use of existing plans.

Scaling is not as simple as it looks.

There are several very important points to consider when scaling a boat plan. One easy way to understand the problem is to look at a cube. Make its sides two times longer and the surface (hull skin for a boat) is multiplied by 4 and the volume (displacement, flotation) by 8. Surface area increases as the square of any linear scaling, and volume (displacement/mass) increases as the cube.

That by itself creates problems but there is more. "Strength", stability, performance and behavior on the water do not scale in a linear way.

If you scale one of our designs by multiplying all dimensions by 2, the hull will come together nicely but the boat will not float right, not run right and probably fall apart quickly.

For example, let's consider the bottom panels in a fast power boat. The scantlings for those are calculated based on the bottom pressure applied to a certain panel size. That panel is a rectangle between stringers and floor frames.

While scaling, we change the panel span, thickness and the bottom pressure (mass and acceleration), all at a different ratio.

We cannot simply accept a panel that is two times longer and wider and expect it to be stiff enough even with an increase in the bottom thickness. That panel must be recalculated for the new displacement and speed: new size, new scantlings.

To build the scaled boat correctly means adding stringers and floor frames and increasing the bottom thickness.

This is only an example of one of the components that must be recalculated and there are many others. Even hull shape and performance are affected by scaling. For those interested, read this excellent article by a fluids dynamic engineer: http://tangvald.wordpress.com/tag/scaling/ It is about sailboats but applies just as well to power boats.

Scaling one dimension.

Often, the builder wants to scale only the length of the boat. This was done in traditional wooden boat building by changing the spacing of the molds. Since we change only one dimension, we are not confronted with the exponential changes in surfaces and volumes, but we must still consider panel span and linear changes.

A boat hull calculated to be supported by framing every 30" will not be strong enough if there is framing only every 40". We must add frames and move the existing ones. This often requires serious changes in the layout, accommodations and decks.

Other changes will happen: a boat 20% longer will displace 20% more and float higher. It may require changes in hull shape. For example, in a planing power boat, the chine step may be too high and reduce dynamic stability. That displacement change will also move the transom clamp higher and we must cut the motor well differently. The center of planing lift will move, and we may have to move some weights around to adjust the LCG for good performance: console, fuel tank. There is more, those are just some examples of the consequences of scaling.

How to do it right.

As can be seen from the above paragraphs, to scale a boat plan is usually too complicated or will have unintended consequences. Instead of scaling, it is always better to find another boat plan closer to your requirements. However, scaling is possible if kept within reasonable limits. My designs (Mertens-Goossens Yacht Design) can very often be scaled by 5 or 10% without major problems. In many cases, no major changes to the plans are required but consult us anyway. Some boat plans have already been stretched. For example, the DE25 is a stretched DE23 with appropriate changes made to displacement, weight distribution etc. but the frames and bulkheads spacing is at its maximum and that boat cannot be stretched further.

The important point is to scale by only a small factor. For a complete scale in 3D, the length of the boat is multiplied by 1.1 but the surface by 1.1^2 = 1.21 and the volumes by 1.1^3 = 1.33. That means a volume and displacement increase of 33%! A 20% scaling will result in a displacement increase of 73%. That would be a totally different design.

Our TW28 design has been scaled by 10% but that boat uses trim ballast. The builder used heavier scantlings, increased the accommodations and despite that, additional ballast was required to bring her to her lines.

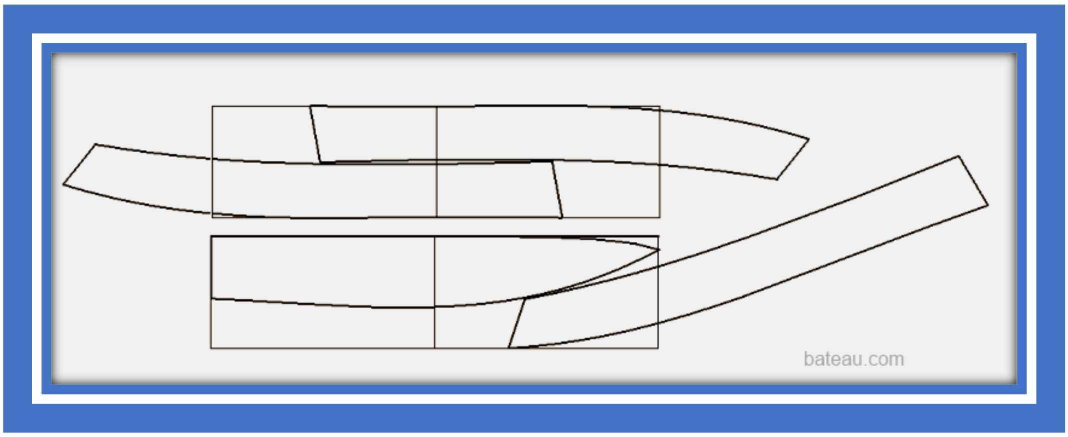
Stay below 10% or better, 5% and in all cases, consult with us.

How does scaling affect the plans.

With our plans, to scale in 1 or 3 dimensions simply requires the use a constant multiplier. For example, to scale a boat plan by 10%, multiply all dimensions by 1.1. This is easily done in decimal units, metric or engineering units (inches decimal) but not in fractional units. For example, a length of 3' 6-1/4" is difficult to multiply by 1.1 but that same length is expressed as 42.25" in engineering units or 1073 mm in metric. Those numbers can be scaled with less risk of error. Order your plans in metric or translate all dimensions to decimal inches. Scantlings should also be scaled: plywood thickness and fiberglass weights. Use common sense or consult the designer.

In some cases, you will move a frame or two. It is often possible to build the boat on a MDF jig properly scaled and then take the new frame dimensions from the assembled hull. Or we, the designers, can provide those dimensions for a small fee.

The scaling will have a major effect on the plywood nesting. Most of our plans are optimized for an economical use of the plywood. During the design, we fine tune the boat dimensions (we scale) to get the most boat out of standard plywood sheets. We show the unrolled hull panels and their layout on the drawings titled "Nesting". Below is an example of plywood nesting for a 17' power boat:



The hull side panels are at the top, the bottom is below it. We show only the hull skin panels but as you can see, to enlarge that boat by only 1" will almost double the amount of plywood required with the added complication of moving the panel splices to the correct place. They can't be at an extreme end. The same nesting problem is repeated for the sole and the framing: the cost of the plywood will almost double.

SCALING BOAT PLANS

In conclusion, scaling is much more difficult than to change some dimensions. It should only be done in small increments and by an experienced builder ready to invest time in that change.

PS: In this file, the words "strong" and "strength" are used as a simplification. For the engineer or yacht designer, there are many different types of strengths to consider.