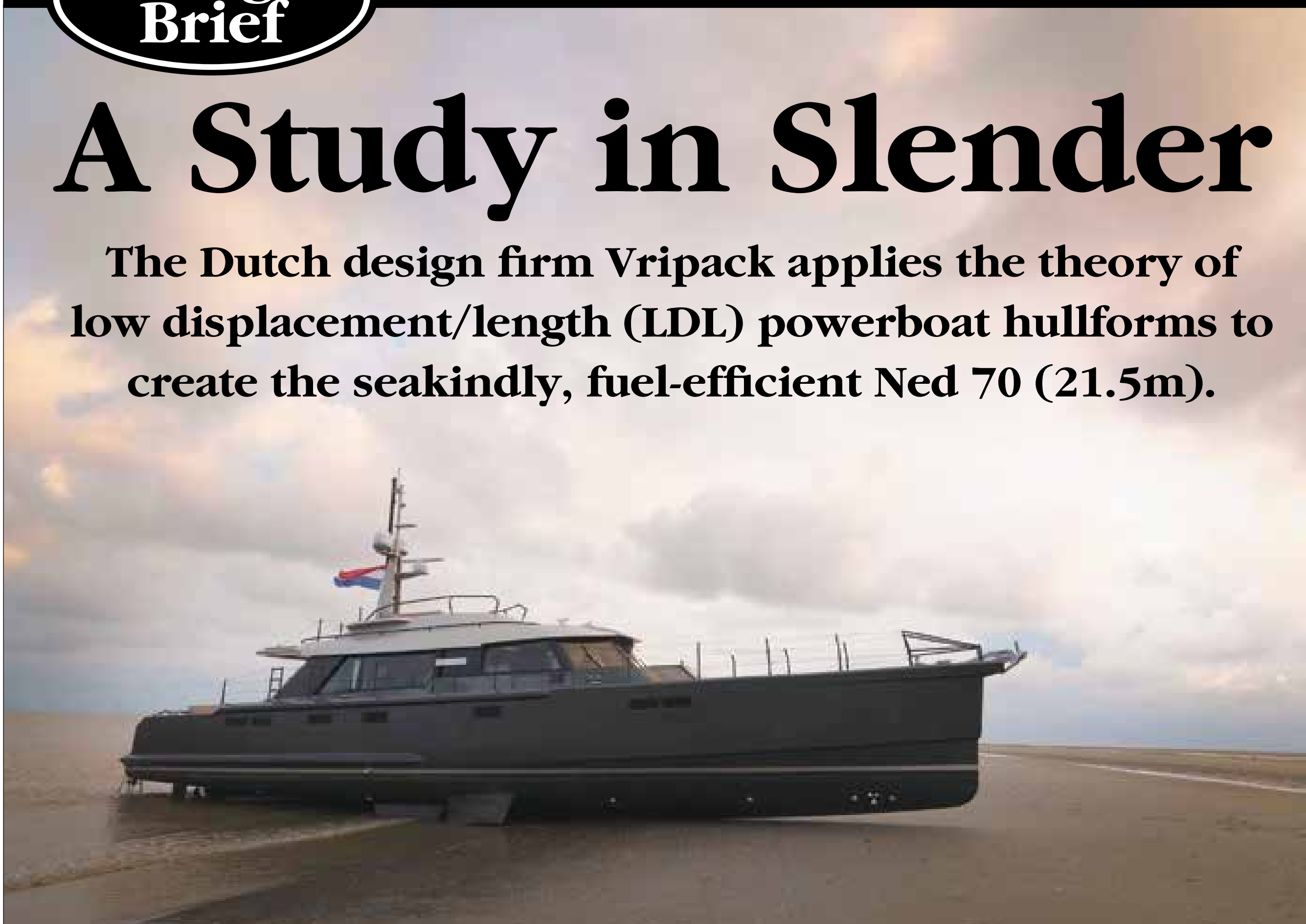
Design Brief

A Study in Slender

The Dutch design firm Vripack applies the theory of low displacement/length (LDL) powerboat hullforms to create the seakindly, fuel-efficient Ned 70 (21.5m).



Text by Albert Abma, Graphics courtesy Vripack

In 2010 an experienced Dutch sailor and boat owner approached our design office, Vripack (Sneek, The Netherlands), to design his new boat. He was a keen solo sailor who also raced in numerous regattas on 40′–60′ (12.2m–18.3m) sailing yachts, but he wanted something he had never owned before—a motoryacht. With young children growing up, the client was looking to share his passion for sailing and adventure with his family. But having been knocked down in his relatively high-performance sailboat in the past, he was looking for a tamer, more stable, self-righting platform for his family, hence a motoryacht design.

In our first conversation the client gave us his basic ideas. Central was his insistence that the new design be efficient in the broadest sense. Not only should it operate with relatively modest fuel consumption, efficiency should also be integrated into building and maintaining the yacht to minimize costs. The intended use of the yacht was specified as "go anywhere at any time," with destinations ranging from Scandinavia to Panama and Fiji. With thin-water cruising grounds closer to home in mind, he also specified draft restrictions and the ability to gracefully ground out on sandbars at low tide while remaining upright. His

Above—*Among other unique requirements, the design brief for the low-displacement Ned 70 (21.5m), designed by Dutch naval architects Vripack, specified that the elegant long-range motoryacht should be able to dry out gracefully on a falling tide.* ***Right***—*The Ned 70's 18′ (5.5m) beam and noticeably fine entry make her easily driven even at high semi-displacement speeds.*

competitive character manifested in the requirement that "the yacht should be capable of overtaking the neighbors," hence the semi-displacement maximum speed specification, so he could also safely outrun a storm.

The client initially suggested an overall length of 65′ (19.8m), which would allow the vessel to be operated and maintained singlehanded. At this preliminary stage he gave little direction about the interior accommodations and layouts, focusing instead on performance requirements and exterior design. With most clients the priorities are the other way around.

After several meetings, we agreed on a simple yet challenging design brief:

- Length: 65′
- Low build cost
- Low operating cost
- Seaworthy
- Comfortable under way
- Capable of cruising at semi-displacement speeds
- Shallow draft and capable of grounding out
- Long cruising range.

At first glance these requirements seem hard to combine in a single yacht, but our designers achieved it, thanks in large part to application of low displacement/length ratio (LDL) principles articulated by naval architect Nigel Irens (see his articles "Powerboats for Sailors," *Professional BoatBuilder* No. 80, and "Craft of Least Resistance," PBB No. 145).

LDL Solution

Our designers' first strategy was to look at a long, slender, lightweight yacht. Slender and lightweight are characteristics at the center of the LDL concept, which depends upon keeping the displacement-to-length ratio (D/L) low.

$$D/L\ ratio = \frac{\Delta}{(0.01 \times LWL)^3}$$

where:

Δ = displacement of the yacht in long tons

LWL = waterline length of the yacht in feet.

How do you recognize an LDL yacht? Physically and aesthetically, LDL yachts are distinguished by long, sleek lines and low profiles. Mathematically, an LDL hull is characterized by the combination of several design ratios, of which a low D/L ratio and a high length-to-beam (L/B) ratio are the most important.

When the D/L ratio is low, the weight per foot of length is also relatively low. In **Figure 1** the blue dots illustrate how the D/L ratio of our Ned 70 compares to some recently delivered, functional motoryachts.

Conversely, a relative high length/beam ratio reduces the resistance of the yacht moving through the water. However, this efficiency is ultimately limited by the need for stability; too extreme a reduction in beam will decrease stability dramatically. But there's more to it than that. The initial stability of any yacht is influenced by two major factors: the form or shape stability (KM) and the center of gravity or weight stability (KG). The form stability is heavily determined by the following calculation for metacentric radius (BM):

$$BM = \frac{LWL \times BWL^3}{\Delta}$$

where:

LWL = length on waterline

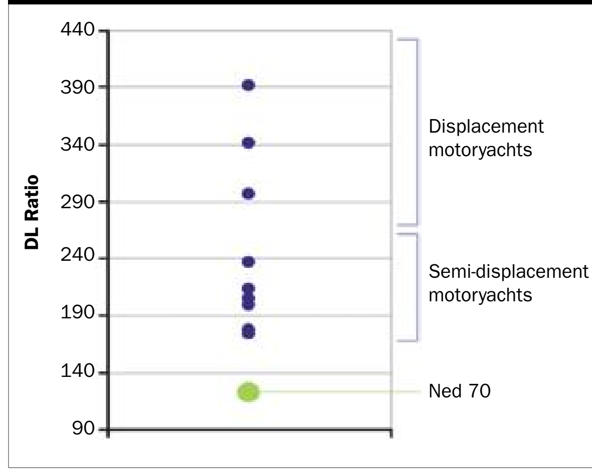
BWL = beam on the waterline

Δ = displacement of the yacht.

In practical terms, this means that to maintain sufficient stability, a heavy boat requires greater beam on the waterline than a lightweight boat of similar length. So the lighter a boat, the leaner it can afford to be. Another factor that contributes to stability without requiring greater beam is a low vertical center of gravity (VCG).

We exploited both these factors in the Ned 70 design, maintaining a relatively modest displacement for its length and a low center of gravity to minimize the beam while still

Figure 1. D/L Ratios



Ned 70 stacks up well against more conventionally efficient semi-displacement powerboats. The specified design goal of minimizing the displacement/length ratio helps the designer keep the overall weight of the vessel low even in the face of temptations to add heavy accommodation or powering options.

Right—*A high length/beam ratio—nearly 4 in the Ned 70—reduces the resistance of the hull moving through the water but is ultimately limited by the need for the stability that beam provides to a hull.* ***Far right***—*Despite her high L/B ratio, the Ned 70 has an enviable stability curve. That's possible because the lighter a boat is and the lower its center of gravity, the better its stability will be, even with a narrow beam.*

Figure 2. L/B Ratios

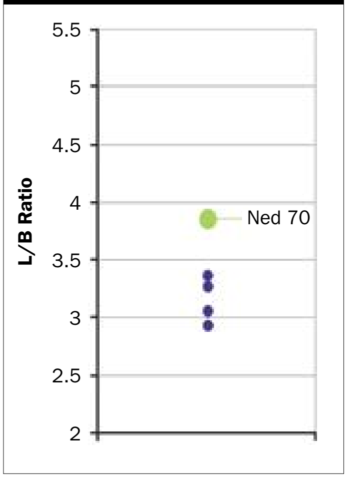
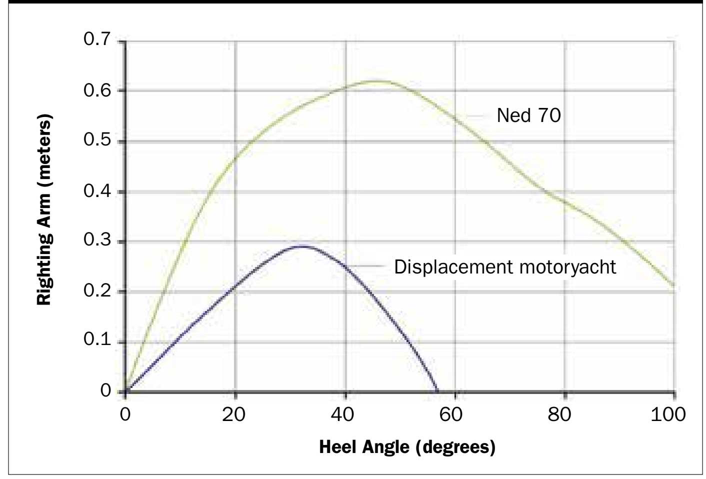


Figure 3. Stability Curve



providing stability for ocean passages. So the Ned 70 is a long and slender yacht, which can clearly be seen in the length-to-beam ratio as indicated in **Figure 2**. But even with this slender hull shape, the stability is still excellent, as illustrated in **Figure 3**.

Minimizing Resistance

Having achieved the desired low D/L ratio at our target length, let's take a look at the intended and unintended consequences for the likely performance and comfort of our design.

To start with, the LDL concept minimizes resistance and hence fuel consumption. The two main components of the hull resistance are the friction resistance and the residual resistance—LDL reduces both.

The friction resistance of the hull is generated by the viscous drag of the underwater surface. It is calculated by multiplying the wetted surface by speed squared:

$$RF = S \times V^2$$

where:
RF = friction resistance
S = wetted surface of the underwater hull
V = boat speed.

So wetted surface is an important factor for friction resistance. Because wetted surface and vessel displacement tend to go up together, limiting displacement to keep the D/L ratio low means that wetted surface and hence frictional resistance can be kept relatively low as well.

Residual resistance comprises wavemaking and form resistances. Of these components, the *wavemaking resistance* increases rapidly with increasing speeds. The magnitude of the wave resistance is related in part to the speed/length ratio.

The relation between the wavemaking resistance and the waterline length is fixed in the Froude number:

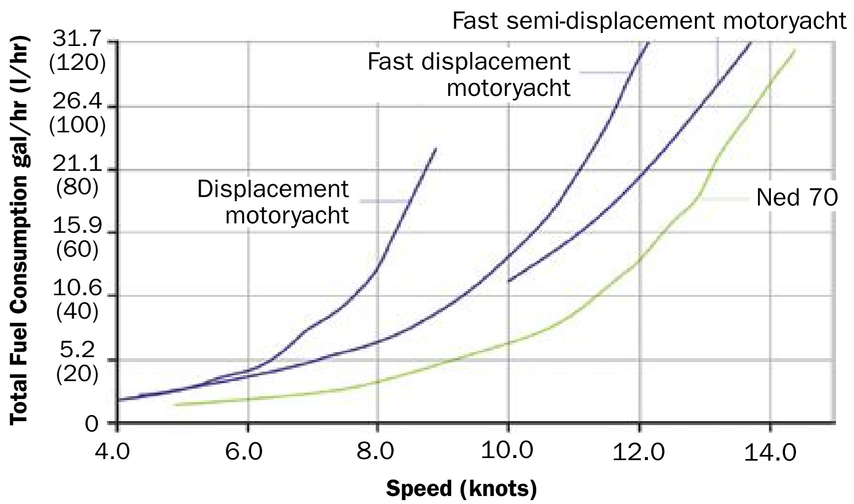
$$FN = \frac{V}{\sqrt{LWL \times G}}$$

where:
FN = dimensionless Froude number
LWL = waterline length in meters
G = gravitation force (9.81m/s^2).

The higher the speed in relation to the waterline length, the higher the wavemaking resistance. The wave resistance is maximum at Froude = 0.500, but for heavy-displacement vessels, Froude = 0.400 is regarded as hull speed and considered the practical

At cruising speed the Ned 70 moves through the water with little fuss. Her Froude number at that speed is just 0.325, which means she expends very little energy to overcome wavemaking resistance.

Figure 4. Fuel Consumption Curves



The low resistance of the LDL hull minimizes power needs at displacement speeds, which starts a virtuous spiral requiring a smaller, lighter-weight propulsion engine and reduced fuel capacity to match the comparatively modest burn rate.

speed limit for the displacement design. Because an LDL boat has a relatively long waterline length, for a given speed the Froude number will be relatively low, and thus the wavemaking resistance will be limited as well.

In addition, wavemaking resistance is inversely related to the length/beam ratio. Because this ratio is increased for LDL yachts, wavemaking resistance is reduced.

For the Ned 70, the Froude number at cruising speed is 0.325, and the L/B is close to 4.

In addition to the wave resistance, for LDL yachts the *form resistance* is reduced as well. The reason for this reduction lies in the stretched lines of the LDL hull shape. When the lines plan of the hull is stretched, which is the case for high L/B and low-D/L-ratio yachts, the curvature of the hull is reduced. This results in less pressure disturbance and a smoother water flow around the hull, which reduces the form resistance.

Because the friction, wave, and form resistances for LDL yachts are limited, the total resistance is reduced significantly as well. This results in lower installed power and less fuel consumption. The reduced resistance of the Ned 70 is shown in **Figure 4**.

Comfort

In designing Ned 70 we discovered that the LDL concept can improve comfort on board when compared to many other hull shapes. This is a distinct advantage, as motion sickness, caused in large part by vertical accelerations while under way, is one of the most important factors contributing to discomfort on yachts.

Low-wetted-surface hulls with relatively round bilges are susceptible to rolling, but such transverse or roll accelerations are easily reduced by means of stabilizers. We designed the Ned 70 with a fin-type stabilizer system mounted next to fixed bilge keels. The latter provide good roll stability themselves, as well as protecting the active stabilizers and acting as legs to keep the boat upright when it grounds out on a falling tide.

While the stabilizers and bilge keels reduce roll, pitching motions are another story. They are most effectively reduced by increasing the overall length and the length/beam ratio of the boat—both are maximized by the LDL concept. **Figure 5** shows the effect of the L/B ratio on pitch accelerations.

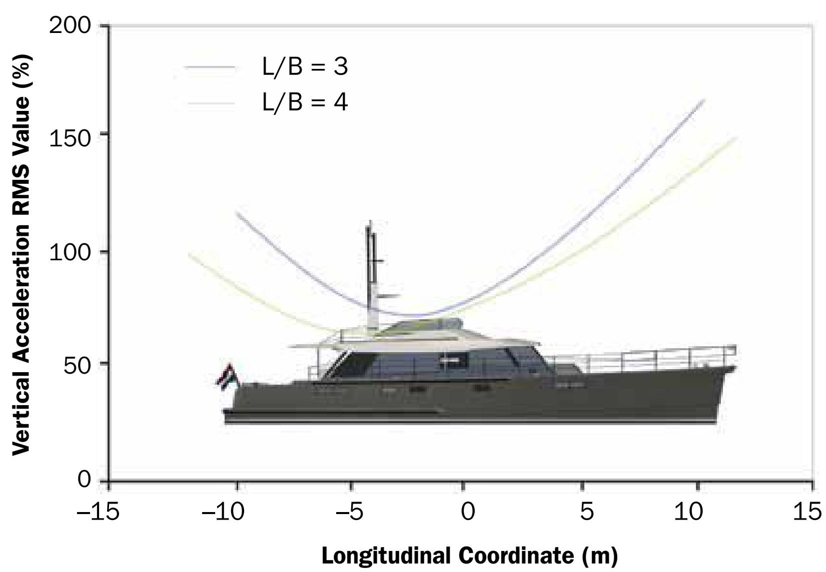
So, considering the described advantages, why aren't more yachts designed according to the LDL principle?

Our answer is focus. Focus on priorities is required of the owner as well as the designer to make the LDL concept a success. The main priorities to adhere to are the weight of the boat and the height of the profile. In practice, these don't have to be sacrificed at the cost of accommodation space or bought at great cost with the introduction of expensive lightweight materials.

As explained in this article, the volume and subsequent shape of the hull are vital to a great LDL design.

Pitching motions in any hull design are best reduced by increasing length and L/B ratio; both are givens in an LDL hull.

Figure 5. Pitch Accelerations



Controlling weight without compromising aesthetics was a challenge for the designer. Here, the anodized aluminum stanchions and lifelines dispense with the need for heavy bulwarks and a wooden caprail, and the lightweight composite Esthec decking replaces traditional heavy teak.

Because volume equals weight, the selection of materials can be viewed as the key to it all.

"Kilos are killing," a saying often used in our naval architecture department, especially applies to the Ned 70 and other fuel-efficient designs. Since she is a one-off, the choice for the main structure was a high-grade marine aluminum alloy called Sealium, made in The Netherlands. Our research and experience have shown that a combination of primary longitudinal stiffening and transverse web frames provides for low panel pressure and thus high-quality, low-weight stiffening. Noise and vibrations are best controlled by the application of mass, so together with a consultant, careful study has gone into selecting the correct materials to minimize those flaws without adding excessive weight.

Another major contributor to vessel weight in conventional construction is the interior carpentry. While lightweight alternatives have been developed to minimize the weight of interior joinery, they tend to be expensive. In the Ned 70, instead of honeycomb-core panels, whitewashed oak liner was glued on a lightweight pressed-wood core, delivering good weight reduction compared to traditional multilayered cores, without breaking the bank. Similarly, we specified a lightweight relatively environmentally benign composite Esthec decking rather than traditional teak.

The Ned 70 was also designed with low-maintenance details, such as the railing. Instead of high-gloss stainless steel or a varnished caprail, lightweight anodized aluminum wire lifelines were fitted between anodized aluminum stanchions.

Finally, all materials were placed in one rather big weight budget database for VCG, LCG, and other calculations. During the build, weight measurements were conducted to track the different weights and monitor any deterioration.

By maintaining their focus the project's owner and designer cultivated the right environment to meet the significant technical and aesthetic challenge of producing an optimal LDL yacht. Reduced to its simplest terms, the solution was found by building the structure of aluminum while limiting the total accommodation volume. The result is deceptively simple and performs to the full satisfaction of the owner, who can sail her from Amsterdam for a weekend trip to his favorite restaurant in Oslo, Norway…and beyond. PBB

About the Author: *Albert Abma is a naval architect at the design office Vripack, in Sneek, The Netherlands.*

One measure of the success of the Ned 70 model is its ease of use. The owner reports that he can comfortably cruise from Amsterdam to Norway and back on a weekend excursion.