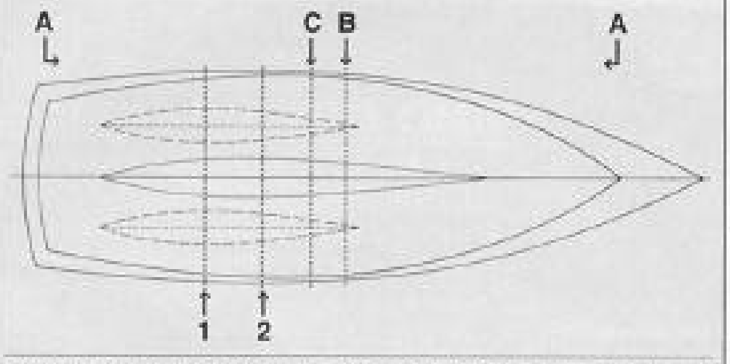
From "Professional Boatbuilder"

Eyeing the Pump Effect

It's high time we paid more attention to reducing wave-making in displacement hulls

by Nils Lucander

Editor's note: *With the goal of stimulating productive thinking and discussion, we have from time to time aired the views of designers who have something different to say about the boats to which they have devoted their professional lives. Art Paine's piece on jettisonable ballast (PBB No. 23) and Stephen Ditmore's article on plumb stems (PBB No. 25) are but two examples. Here, we present a concept integral to the work of industry maverick Nils Lucander, whose design office is in Tacoma, Washington.*



The author has developed two configurations that effectively move a boat's largest sections aft: a single, center-keel version and a twin-after-keel, or three-point, version (dotted "pods"). **A** is the load waterline (same in both versions), **B** is amidships, based on the load waterline (same in both), and **C** is the largest hull section (same in both). The number **1** represents the largest sections of the twin after keels, while **2** indicates the largest section of the hull and after keels combined.

When trying to evaluate the theories, formulas, rules, ratios, and other textbook data used by yacht designers, it soon becomes painfully clear that hardly anything is carved in stone, that nothing is absolute, and that everything is approximate.

Yet, most designers seem to believe that the phenomenon known as wave-making is inescapable and that it limits displacement speeds to the square root of a boat's waterline length multiplied by 1.34. This formula is based on the claim that a boat rides between *transverse* bow and stern waves, and that the distance between these governs the boat's speed. Some professionals state that the rule is just a guideline, but others see it as an ironclad axiom. For example, while one book allows a ratio up to 1.65, another states that any claims of more than 1.34 are false.

Most design literature indicates that wave-making represents from 75% to 85% of resistance, while friction constitutes the balance of 15% to 25%. It's odd, then, that while reducing the weight and wetted surface that comprise friction has drawn extraordinary interest from designers trying to add speed, the far larger problem of wave-making has not been a priority.

When a boat moves through water, the fluid is displaced and, in accordance with physical laws, it goes in the direction of least resistance, which is up. The resulting vertical motion of the water is what I call "the pump effect" and what others refer to as wave-making.

Any hydraulics engineer can tell us that the faster water is "pumped" up, the more power is required. The old "codfish head/mackerel tail" hull forms obviously forced the water up quite fast, pushing it forward of the bow, robbing propulsive power, and producing the detrimental transverse bow wave already mentioned.

However, a boat with a fine or even hollow entry—like that of the 1851 Cup winner *America* and numerous other fast boats from her era—sliced the water, producing a *divergent* bow wave that angled aft at about 35° to the direction of travel *with no apparent effect on speed*. The knife-sharp bows of naval combatants also slice the water without pushing it up and forward as do tankers, bulk carriers, and other blunt-bowed boats.

I began to realize the significance of the water's vertical motion in the mid-1950s and sought to use this knowledge to reduce wave-making in subsequent designs. The first step was to build a series of models (21 in all) and test them for wave-making resistance. The "test facility" was a quiet canal off the Detroit River, where an 8' dinghy with a 1½-hp outboard was fitted with a perfectly balanced 10'-long bar that sat athwartships on the bow. The models, representing various trawler-yacht hulls, were then towed in pairs, and each time, the one that produced more waves and resistance was discarded for firewood.

Three models proved to be nearly equal in wave-making performance. They all had fine entries, and their largest sections were located about 60% aft along the waterline. All three also had box keels, whose largest sections were also positioned some 60% aft along their own lengths. In combination, then, the largest sections in the most successful models were located approximately 65% aft along the hull's waterline.

I then made two additional models based on existing boats that had been built to published designs. These were towed against the three promising prototypes, and the new configuration was confirmed as creating far less resistance and wave-making at moderate speeds (up to the 1.34 formula). This appeared to demonstrate that, by moving the underwater hull geometry further aft, the initial upward motion of the water at the bow was vastly delayed, reducing the power-robbing pump effect.

Full-Scale Evidence

It was not until 1961 that I had a chance to use these findings in the design of a 28' sloop, the *Snapper*. This boat was very heavily built by Cheoy Lee in Hong Kong, and when delivered in 1962, it performed far better than anticipated. Even in light winds, the sloop sailed at almost 7 knots, or about 12% over the hull speed of 6.2 knots. At such speeds, the boat's forward sections sliced the water, and there was no evidence of a 'midships trough or stern wave.

In 1964, I had a chance to do exactly what I wanted with my test results when a customer who didn't know one iota about boats wanted a 50' steel trawler. The hull and keel sections of the resulting *Empress* were close to those of the models. The big box keel, in fact, was so wide near the sternpost that I was able to drop the six-cylinder diesel way down. This resulted in a shaft that angled *up* to the propeller at 3° to the waterline and to the nearly flat run that terminated in the fantail stern.

During sea trials, the bow rose just 3° as the yacht gained speed, making the shaft parallel to the water surface at the vessel's top speed of 10.7 knots—which was more than 20% above the formula-dictated "hull speed" of 8.7 knots. When the boat's interior was completed and all her equipment was installed, displacement increased to slightly more than 60,000 lbs, and top speed dropped to 9.8 knots, which was still 12% over what the formula predicted.

During the testing of full-sized boats like *Empress* and *Snapper*, no discernible waves were produced at speeds up to the maximum dictated by the formula. But, when running at various speeds above that level, the 'midships trough and stern wave indicated a pattern of togetherness. When, at lower speeds, the trough got shallower, the stern wave height was reduced by exactly the same amount. As speeds increased and the trough deepened, the stern wave became higher.

The only logical conclusion is that the 'midships trough and the stern wave are closely related. It now seems clear that the only function of the stern wave is to roll forward and fill the evasive trough. Since the trough does not appear at speeds up to that predicted by the formula, neither does the stern wave. Moreover, the divergent bow wave does not change. All this, of course, is contrary to the many theories formulated during the Froude/Kemp era of well over 100 years ago.

Refining the Concept

Following the launching of *Empress*, I was always looking for ways to delay the upward motion of water even more, thereby reducing the amount of horsepower needed for propulsion, and gaining more displacement speed. In 1973, I produced the first of many so-called "3-Point" designs for trawler-yachts, fishing trawlers, and tugs. In these, I eliminated the center keel aft, substituting twin keels whose alignment permits the vessels to sit on a center keel forward and twin keels aft when beached, hauled, stored, or transported.

On full-displacement versions, the after keels are so husky that engines fit partly inside them, allowing for very short shafts that run parallel to the waterline. The first "3-Point" vessel, built in 1979, is a 52' trawler-yacht presently owned by a charter captain in Florida. The second is an 80' commercial tug launched in 1981. Its largest hull sections were located 62% aft along the waterline, and the twin after keels were positioned still farther aft, at 75% of the tug's waterline length.

When running at a bit more than 13 knots—or 10% higher than the "hull speed" predicted by the formula—this vessel displays no bow or stern wave. And, instead of the customary deep 'midships trough, it shows a shallow wave that actually *adds* to propulsive efficiency. Again, *the key is shifting the underwater hull form geometry further aft, delaying the initial upward motion of the water and minimizing the pump effect.*

Time will tell how far this concept of wave-making reduction can be taken; meanwhile, we can only guess at what new percentages truly represent frictional and wave-making resistance. The correct figures are most certainly not what all the books, papers, and articles call for.