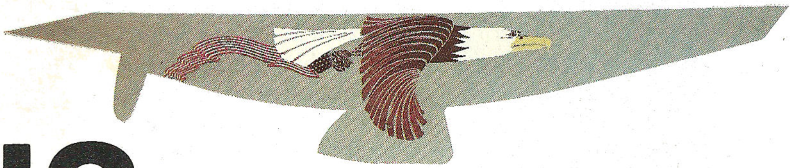
A 12-METER IS BORN

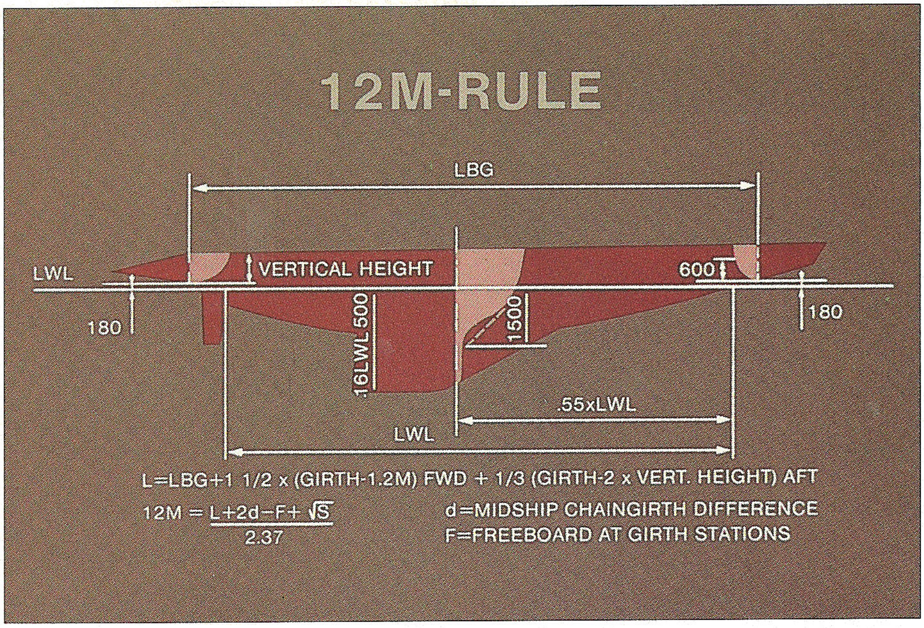


What does a designer do when the 'phone rings and it's a syndicate manager asking him to win the Cup back? Johan Valentijn tells it all.

This article by Johan Valentijn—designer of Eagle *(above) and* Liberty *(right)—combines papers he and his associate Rik Van Hemmen gave before the Westlawn School of Yacht Design and Society of Naval Architects and Marine Engineers, with interviews by Jack Somer,* YACHTING*'s Editor.*

The most difficult choice a designer makes is the size of his Twelve; it's both the first and last thing he thinks of. A boat can be a breakthrough in shape, but it will be slow against the competition if it's the wrong size: meaning waterline length and displacement. Overall length doesn't enter the 12-Meter Rule (see page 81); boats of differing overall length can be identical in rating and performance. In 1983, for example, *Liberty* sailed at 67′ until I observed where her stern wave separated and what her sailing length should be. Then, one sunny day in San Diego, I made some magic-marker lines on her stern and we cut it off with a hacksaw. But her balance wasn't pleasing to my eye—that's im-

Guy Gurney



Johan Valentijn Assoc.

The International 12-Meter Rule is a simple formula disguising complex juggling. Key measurements—Length, Girth Difference, Freeboard and Sail Area—are balanced to make a boat that measures correctly. An increase in one element in the formula's numerator demands a balancing decrease of another. Design strictures include minimum displacement for a given waterline; sail girth measurements.

portant to me—so we cut a bit more off. She sailed the Cup series at about 64½ feet.

The choice of size, of course, is dictated by the weather. In 1983, after having been a challenger twice (with *Australia* and *France 3*), I knew the weather game at Newport: You sail light-air eliminations, then sail for the Cup in a bit more breeze. That's why Dennis Conner and I decided to get *Liberty* her three controversial rating certificates, to give her a wider speed range. In 1987, off Fremantle, the weather pattern is likely to be the opposite: heavy-air eliminations and a light-to-medium Cup series.

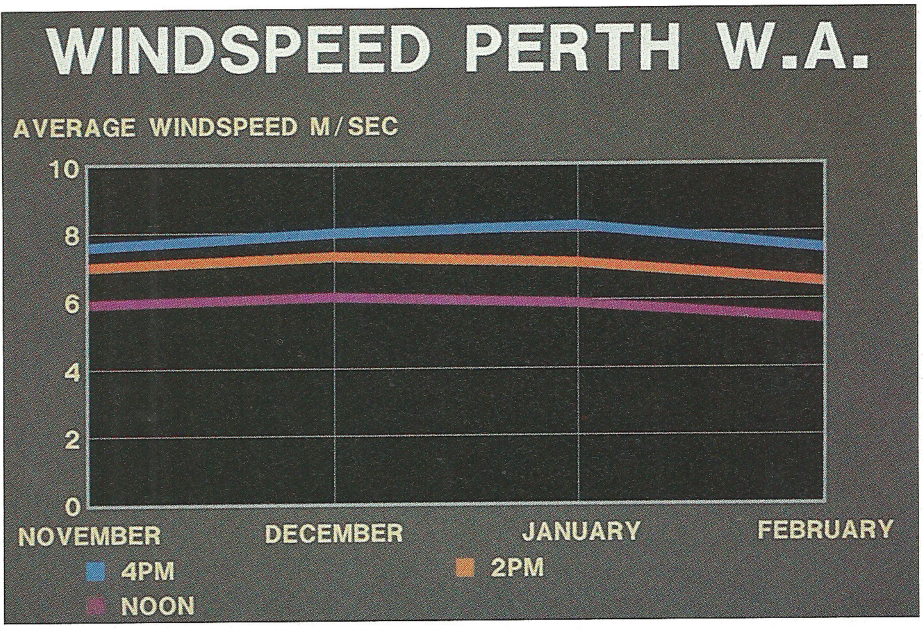
That may surprise some people, but the information from our Fremantle weather buoy showed light air in February 1985; it averaged only eight knots. It might blow 20 knots next year, but I think it will average 16 or 17, and the boats will have to sail well in 10-12 *and* 25 knots (see the weather chart, pg. 82). Even when the Fremantle "Doctor" blows over 20, it's probably only 12 at the start; it builds. The question is: "Do I want to be ahead early and hold my own, or fall behind and have my real speed toward the end?" I like the first choice.

Another new consideration is the course designed by the Royal Perth YC. In Newport, the legs were 4½ miles and there were five buoy roundings; outright speed was important. In 1987 the legs will be 3¼ miles, with seven roundings; good acceleration and maneuverability will play a bigger role in getting ahead early and staying there. Smart tactics may well be more important than speed.

The size of a Twelve can vary all over the lot. Prewar Twelves displaced as much as 74,000 lb.; recently, they've averaged around 56,000 lb. Ben Lexcen brought *Australia II* in at around 53,000 lb., and I took a big gamble with *Magic* at 46,000 lb.—she's the smallest Twelve ever built. In Fremantle you can choose your displacement by throwing darts, but I think all those people who built big boats are wrong.

I didn't always feel that way. When I began developing *Eagle*, I persuaded myself that bigger was going to be better in 1987, based on the overall perception of Fremantle's weather. I didn't analyze our chances in light air. Even when I heard that Dennis's first, big, boat beat *Liberty* only in a breeze, I had second thoughts, but proceeded with a big boat anyway.

We began our research program in late 1984 with drag tests on *Magic*, which we bought at a good price. She was unrigged, like a full-size model, and pushed by her tender to measure her resistance (drag) at various



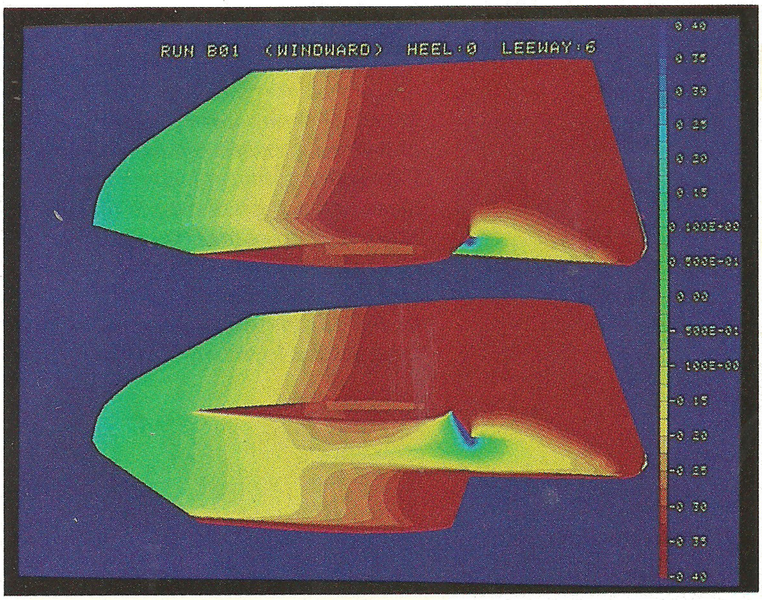
Johan Valentijn Assoc.

The designer's choice of boat size, based on Perth weather studies, will vary widely. Valentijn's study shows that wind increases from November to the end of January, then diminishes in February, during the Cup series. Daily variations show a marked increase between noon and 4 P.M. An all-around 12-Meter will likely perform better than one designed only for the "Doctor," which shows a maximum average of 8 meter/sec., or 15.54 knots.

speeds. Drag was measured by a load cell on the end of a pushing boom that was attached where the mast would be. The data were extremely valuable, though some measurements were compromised by waves, which put the two boats out of phase. We tested her with her original keel and with a modified version of the *Australia II* wing keel. She was also tested for leeway, turning ability and more. Then we rigged her, covered her with strain gauges and instrumentation and, while Rod Davis sailed her, we measured relationships between performance and rig forces, storing data on a 64-channel recorder to correlate it later with model tests and construction studies.

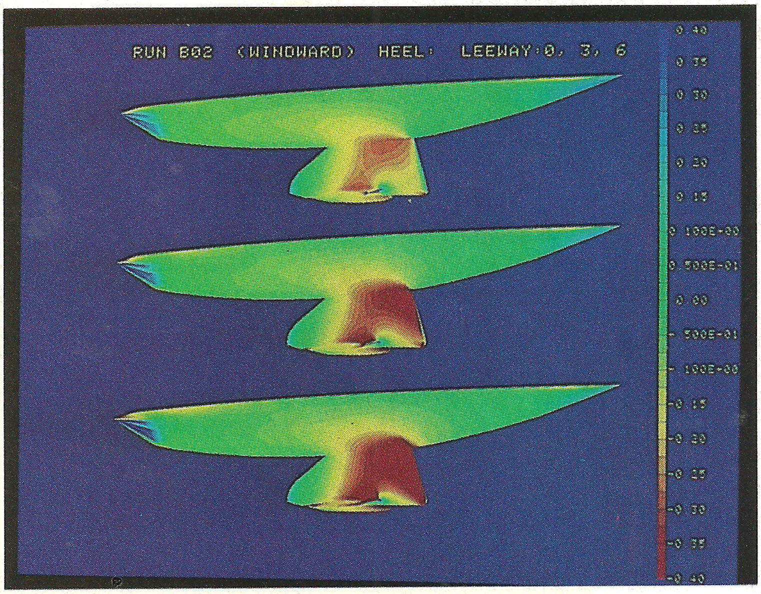
Before we began tank testing, we did a lot of groundwork on computers, which have become an essential ingredient in 12-Meter design. While they have their limitations, computer programs give spectacular results in analyzing hydrodynamic flow and pressure distribution on hulls and keels; these programs are direct transfers from the aerospace industry, and no engineer has contributed more in this area than Joop Slooff of the Netherlands Aerospace Laboratory (NLLR), who is responsible for the rebirth of the wing keel. His "vortex panel" method divides the surface of a boat into small panels, allowing the study of drag and lift at various heel and yaw angles. The results are displayed graphically. Arvel Gentry, of Boeing, used similar aerospace programs for our visual analyses (see pg. 83).

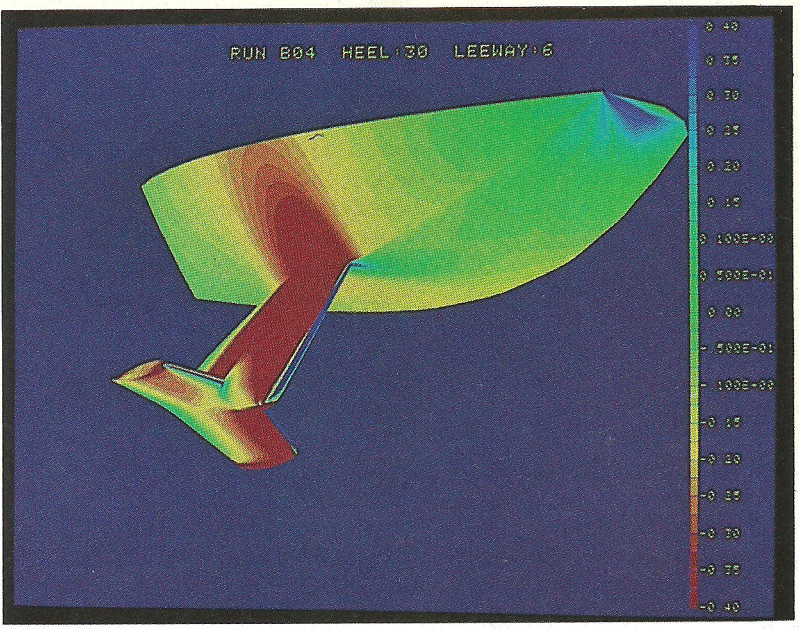
It was my original intention to build *Eagle* in fiberglass, not aluminum, if we could significantly increase hull stiffness. The Todd Shipyard took on the monumental task of building a data base on the loads in a Twelve, aimed at developing glass scantlings that would satisfy Lloyds' requirements. After they did the groundwork of dividing the hull into panels to determine stresses, they exhausted our $50,000 budget. When the Chrysler Corp. offered us the use of its powerful CAD/CAM (Computer-Assisted Design/Manufacturing) technique, we accepted their offer and Todd sent its programs to Chrysler. First we studied loading on keels in order to redesign the hull/keel joint; this is a critical area, since *Australia II*, because inverted keels have attachment areas that are frighteningly small for their loading (see first diagram, pg. 84). Then we picked up where Todd left off, analyzing the deformations on a hull sailing in a breeze; the graphics gave us new insight into both glass and aluminum scantling requirements (see second diagram, pg. 84). We used the studies to



Power of the computer is demonstrated in these pressure distribution studies of a wing keel. The top figure is an upright keel making 6 degrees leeway, viewed from windward; bottom figure is the same keel, heeling 30 degrees. Red indicates areas of negative pressure, which equate to keel lift; blue indicates positive pressure that, on the windward side, diminishes overall lift. Wings extend the lift lower, thus increasing it.

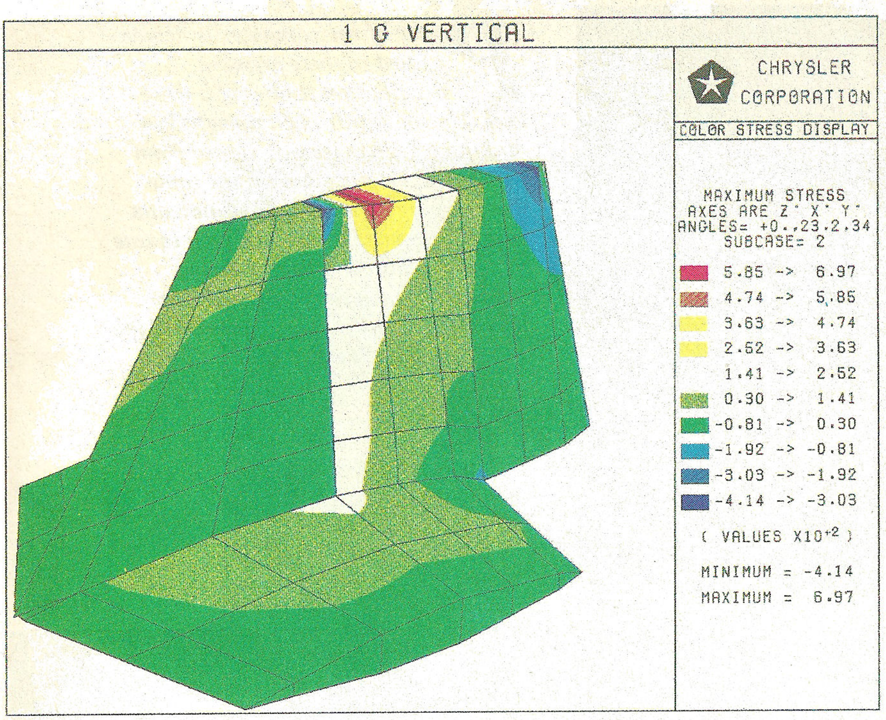
In this computer run, a theoretical hull/keel combination is studied from windward at three leeway angles, to observe lift characteristics. Note that as leeway increases, lift increases—red areas of negative pressure on the windward side spread upward. Lift is concentrated on the keel and on the hull adjacent to it. But at the hull ends, where the bow and stern waves are generated, the windward pressure increases to positive, reducing lift.





The Boeing Co., Arvel Gentry

Arvel Gentry, of Boeing, produced this run—a view from windward, looking aft on a hull/keel combination. Note how the keel effectively spreads lift up onto the hull, and the wings spread lift down the keel. The positive pressure developed on the leeward side is seen as the dark blue area on the keel's leading edge and the light blue area on the hull's leeward side, mirroring the red area. These opposing pressures produce lift.



Chrysler Corp.

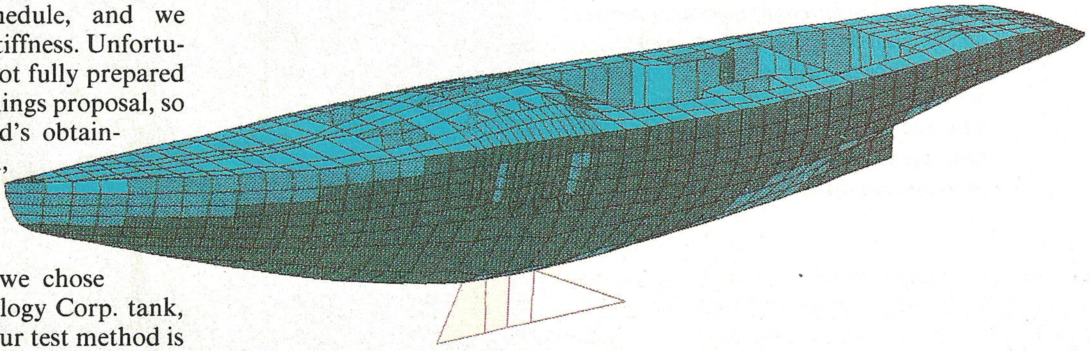
Chrysler's powerful CAD/CAM computer programs were applied to analyzing stresses in a 12-Meter, as a means to improve scantlings in both alloy and fiberglass. This display shows distribution of loads in a theoretical wing keel (cast in theoretical lead). High stress area (the red at the keel top) indicates that keel bolts directly above the keel's center of gravity are taking a disproportionate loading. Trim tab is relatively free of stress.

develop a much improved fiberglass laminate layup schedule, and we achieved the added stiffness. Unfortunately, Lloyds was not fully prepared to approve our scantlings proposal, so despite New Zealand's obtaining Lloyds' approval, we have just abandoned the idea of a fiberglass 12-Meter.

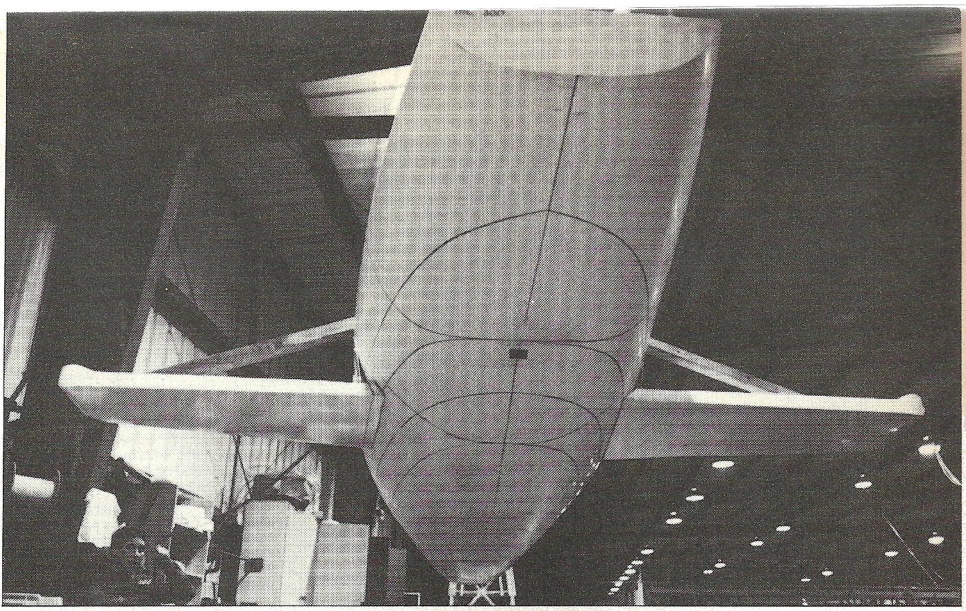
For tank testing we chose the Offshore Technology Corp. tank, in Escondido, Cal. Our test method is a bit different from others. Some designers seek to measure VMG (upwind speed) in heeled condition. That's fine. But I believe in a simple principle: If a model is good upright (downwind) you can always get it to go fast heeled (upwind); if it doesn't test well upright, throw it away.

Models are dragged through the tank to derive their upright resistance curve—water resistance vs. speed—at various speeds; that's standard. They are also inclined at various heel angles (10, 20, 30 degrees) and dragged at leeway angles in two-degree increments. The computer then calculates, for a given heel angle, aerodynamic forces from the sail plan and matches them with hull forces that produce a theoretical equilibrium between hull and sails; this iteration process establishes the hull's performance numbers: boat speed, leeway angle and VMG. We generally test in smooth water; again, if a model is slow in smooth water, why expect it to have speed in waves? We did most of our rough-water testing with a *Liberty* model, in the full spectrum of waves found in Fremantle. Testing in waves, however, gave us little more than work we'd done by computer; by dropping it from our program we saved tank time. At $3-4,000 per day for a tank, that eased budget pressures.

In truth, we could easily have spent millions in the tank and still be there, without a finished boat. In six weeks of tests, spread over nearly a year, we did about 1,500 runs and evaluated about 20 model configurations, many of them radical: Some had planing wings, bulbous bows and unusual bustles. And our models were built in modular form: Bows, sterns and keels could be interchanged—bolted together—to form new models, which



Extraordinary view of a 12-Meter hull, under full press of sail, combines real strain-gauge data with a computer-drawn model. This view shows how a hull distorts: Windward chain plates pull the sheer up and suck topsides in; the deck buckles out; the foredeck compensates by buckling in. A large afterdeck hump appears at the runner attachment point. Ribs and frames show actual construction. Vertical scale is greatly exaggerated.



Johan Valentijn

Since Ben Lexcen's wing keel received full sanction, 12-Meter design has a no-holds-barred aspect. Valentijn tested a hull with wave-suppressing wings at the waterline (right); he says they would fit the Rule. They might help the hull plane in a strong breeze, but their true purpose is to hold down the quarter wave and fool the hull into thinking it's longer, thus giving it higher speed potential. This hull was also tested with a bulbous bow.

we tested for specific qualities (see photos, right). We tried not to test a model with more than one new element. Often, we ran only partial tests, whose results were run through the computer to extrapolate a lot of information with a minimum of tank time. That's where the data from full-size *Magic* tests were applied.

The computer is a magnificent tool in 12-Meter design. You can test a 1/3 model of a specific-size boat, then scale it up or down. But there are risks. For example, when you scale a model down by computer it gets too narrow under the Rule; you have to make it mathematically beamier. You probably can scale a minimum-beam Twelve down about five percent, with little risk. More than that and you're no longer comparing apples to apples. Scaling up is less of a problem as beam increases according to the Rule. Though it's good to make models close to the size of boat they represent, I like to build them the same size, say 60,000 lb., with only shapes that differ. Then I'm comparing apples that can be scaled up or down for comparison. If you make a separate model for each boat, you'll be making models forever.

Model testing is very valuable, but it is also a very dangerous area: Results, good or bad, are subject to interpretation; tank-test accuracy is always questionable. We're all trying to

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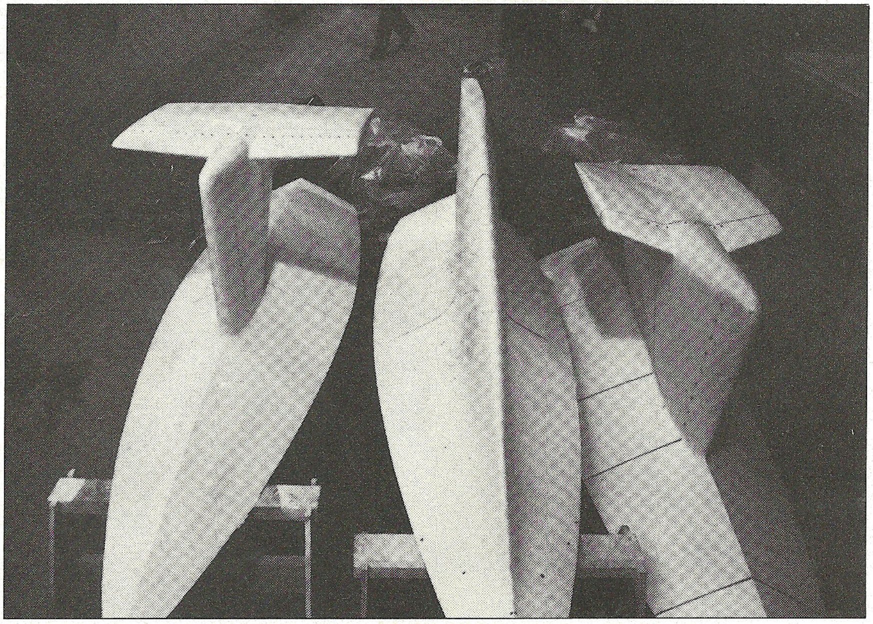

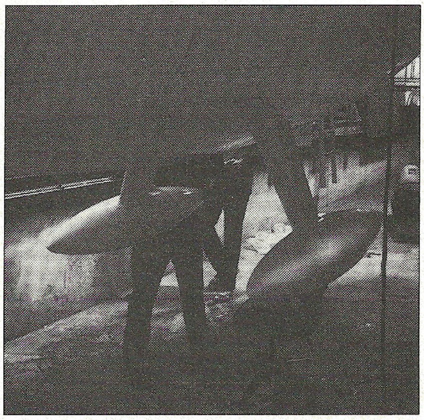

Valentijn saved considerable tank time by building hull modules that combined to produce new boats (above). One of his radical experiments included a twin-keel model whose stability was achieved by large lead torpedoes fixed to the ends of two very high aspect ratio fins (left). The fins, including trim tabs, were expected to develop lift equal to that of a single, larger keel, and were turned relative to the hull to produce a better angle of attack.

squeeze a mere 1/4 percent speed improvement out of our designs, but if you get only 1/4 percent gain from a model, throw it away: The measurement error is probably larger than the gain! I'm always present at tank tests, therefore, to study the water flow around my models. I can observe odd things that don't show in the numbers; they can be more important in judging a hull's potential.

The margin of error in today's tanks is about one or two percent. In a four-hour race a two-percent speed gain means about five minutes saved. I've heard some designers claim that their models have shown two- to five-minute gains. That's barely within the accuracy of the tank. There's the scary part of this exercise: Those boats could be five minutes faster, or five minutes slower! Until you put the boat in the water, you can't really know.

Our model testing for 1987 began in December 1984. Curiously, after two other syndicates had spent time there, we found the OTC tank completely out of calibration; we had to recalibrate it to gain confidence in the numbers. That discovery was made by my associate Francis Clauser, PhD, a retired aerodynamicist and former professor at Cal Tech (whose credentials include major aircraft development for McDonnell Douglas). He became our tank watchdog, to assure the best results.

First we tested 1/3-size models of *Liberty* and *Magic* (with original and wing keels) to fill out the data base for comparison to the full-size *Magic* tests. The wing keel was derived from *Australia II*. I bought it from Joop Slooff. Slooff still claims it's his design, so I sent him a check and he sent me the plans. I understand that other syndicates claim to have *AII*'s keel; we had an exclusive with NLLR, so who knows what they bought?

In April 1985 we tested our first new model, of a very big boat: It had 70-odd thousand pounds displacement. That expanded the data base to a full range of boats—with *Liberty* in the middle and *Magic* on the light end—that we could scale up and down like yo-yos, in 1,000-lb. increments. The new boat had a dramatically different shape. Its buoyancy distribution was radical: It had an extremely fine bow for quite a length, then a very full stern. I cut the bustle away, like *AII*, then packed a lot of displacement around Station 6, rather far aft. That gave her a sharp pinch before the bustle. She didn't test very well; I knew it within minutes, not from the numbers but from watching the model go through the water. It had enormous separated flow, which sparked our later experiments in separation control.

We then tested a new keel on the *Magic* model that seemed very good, so we put the keel on another new model. As I said, we always tested unknowns in conjunction with knowns.

By midsummer 1985 rumors were flying that one or two big new Twelves were slow. I became more concerned about being wrong to go with a big boat. We studied the weather again. We made some more computer runs, scaling designs up, down and sideways. We created about 10 tons of paperwork.

In July we tested three new models, more like my past boats, to satisfy my gut feeling. They were medium size, but had very different shapes, prismatics and buoyancy configurations. One showed promise, but had a dramatic displacement penalty. The Rule says that for a given waterline, a Twelve should have a certain displacement. If you make the displacement lighter, you have to give up something: sail area. In 1983 *Magic* had a huge penalty; we had to give up about four feet of boom.

The *Eagle* syndicate had planned to start building in August 1985, but decided to delay construction until October, so we tried one more model. This one was conceived by Clauser and designed specifically to delay separation of laminar flow; it was based on a mathematical model with parabolic sections. As we had done on some prior tests, we used liquid dyes squirting from the hull to see where the laminar flow became turbulent. This model showed some promise, but wasn't good enough to build.

Finally, I learned so much from test observations that our boat, *Eagle*, is actually none of the boats we tested. It may sound strange that, after all the money we spent on testing, we'd build a boat "on spec," but it's true. Testing gives you only the basic numbers, but a designer's instinct has to put its two cents in. *Liberty* and *Magic* in their final form were never tested as models either. I know that we lost the Cup in 1983. But I have to believe that the design of a Twelve is only about 10 or 20 percent of a syndicate's total effort; *Liberty* was competitive. That doesn't mean that I didn't make mistakes, but I think I sorted them out before she hit the line.

So, when it came time to loft and build at Williams & Manchester, in Newport, R.I., I took a year's worth of work and let it all sink in. That's the way I operate. I just sit at my desk, or walk, or drive my car. I just mull it all over at odd times of day or night. I give in to my instincts and let the numbers take care of themselves. I remember the tank tests, and what the waves told me.

I drew *Eagle*'s lines. She has a small, heavy keel; she will accelerate and turn easily. She's a good light-to-medium boat, and she'll hang in there in a breeze. Maybe I'm wrong, but I don't think it's going to blow 25 knots out there every day. I see a 50-50 chance of a 16-knot average breeze, with more light air than heavy.

If it does blow very hard in November and December, however, we'll be out by Christmas. ☐