To return to Steven Callahan's Home Page, click below:
http://www.stevencallahan.net/schome.html

To return to Steven Callahan's ProBoat Articles Page,
which includes links to a number of articles on leading designers, click:
http://www.stevencallahan.net/proboat.html

To return to Steven Callahan's Publications Page
which includes links to both articles and books, click:
http://www.stevencallahan.net/publications.html

OR
You can go directly to the Articles Page,
which links to both the Professional Boatbuilder Articles Page
and other sites containing articles by Steven Callahan,
by clicking:
http://www.stevencallahan.net/articles.html
Or
You can go directly to the Books Page,
which links to books by Steven Callahan and his associates,
plus descriptions and links to books recommended by Steven Callahan,
by clicking:
http://www.stevencallahan.net/books.html

PROFESSIONAL BOATBUILDER

The magazine for those working in design, construction, and repair

NUMBER 74
DECEMBER/JANUARY
2002
$5.95 U.S.

DESIGNER/BUILDER PAUL BIEKER
PROCESS CONTROL
WAVE PIERCERS AND FAST CATS
INTEGRAL TANKS

KELLY O'NEIL

Bieker's Boats

Form flows from function for Seattle-based designer Paul Bieker. No matter what size the boat. Or boat part.

by Steven Callahan

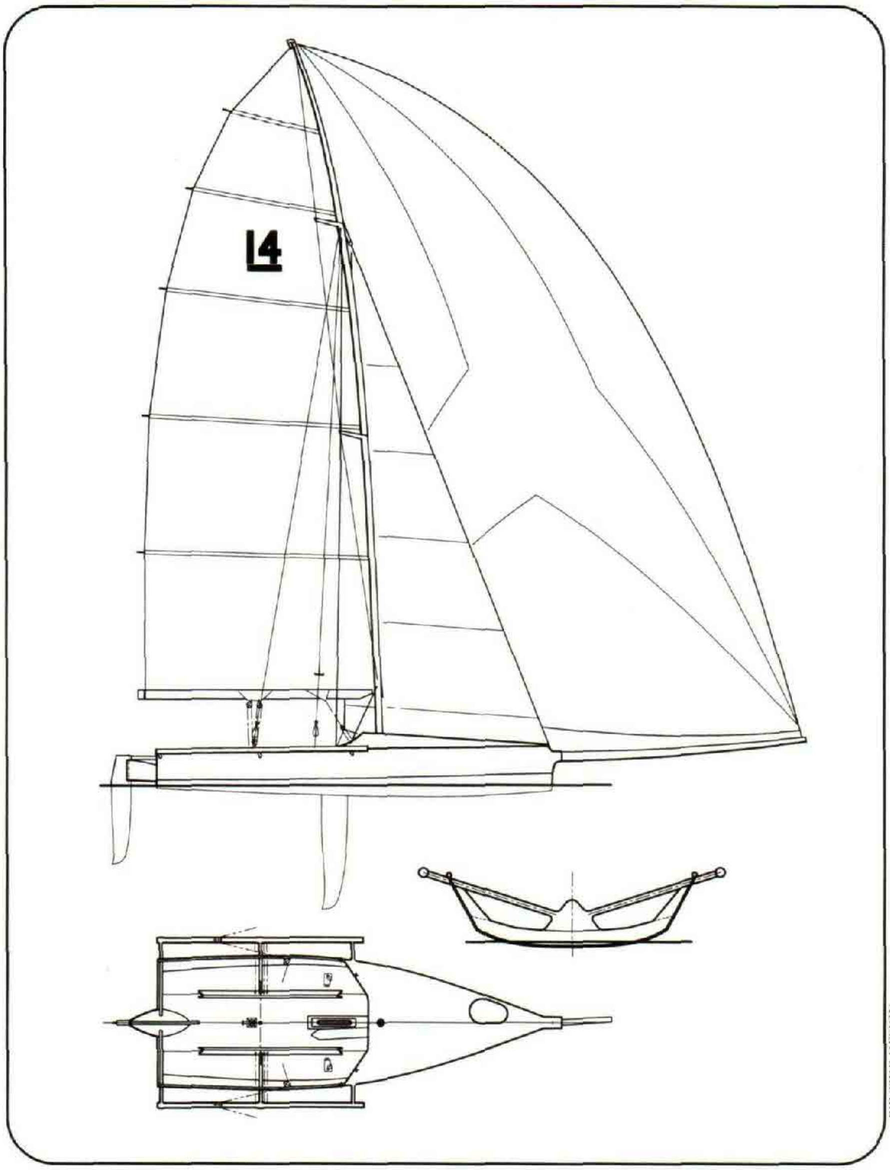
"I want to take things to their logical conclusion, and sometimes that doesn't look like what you're used to seeing." Designer Paul Bieker's statement ideally suits the International 14 (4.2m) racing dinghy, a venerable one-design development class. Despite its short length, a contemporary International 14 can reach speeds exceeding 20 knots, by which time the boat is little more than a rig joined to an underwater foil. Bieker's boats currently dominate this still competitive scene. Right now he is working in Annapolis, Maryland, with Bruce Farr Yacht Design on the Oracle-sponsored *America's* Cup campaign, where Bieker is very much involved with the engineering and finite element analysis (FEA) of the new yacht's structure.

Bieker grew up in Portland, Oregon, sailing big boats. After he graduated high school, his family meandered through the South Pacific for a year and a half on a Swan 48. When others persuaded him that, as he says, "it was more practical to design buildings than boats," Bieker headed for Rhode Island School of Design, but within two years traded the practical for the nautical at the University of California/Berkeley's naval architecture program.

In the mid-1980s, Bieker joined the practice of the late West Coast designer Gary Mull, who was using AutoYacht software to draw hulls. At that time, says Bieker, "you'd put the printout under your vellum and trace it. It was not standard practice to draw a boat by computer."

Soon, however, Bieker moved to Seattle to design ships and other large commercial vessels at Guido Perla and Associates. Ship-design firms of the day were working with UNIX-based systems employing expensive hardware. By contrast, "for a 240' [73.2m] fishing boat, we were writing our own CAD [computer-aided design] programs that ran on PCs

International 14 competition has been virtually owned for the past decade by boats designed (and sometimes built) by naval architect Paul Bieker. His 14s are currently in their third generation, each having numerous iterations. The sail plan and arrangement for a single iteration of a second-generation boat (or "Bieker 2") appear to the right; Bieker 2s were the first 14s to be fitted with racks, among other innovations. Paul Bieker, who also races in these boats, takes them seriously as test platforms for studying the complex hydro- and aerodynamics of high-performance sail. The 14's compact size permits subtle, continuous refinement in hullforms, construction materials and techniques, rigs, and appendages—knowledge that Bieker then applies directly to larger designs, such as the 35-footer on the facing page.



RIP TIDE DESIGN

[personal computers]. We'd design a complex vessel and get a kit cut out so that even a small yard could build a large boat. That sealed my attitude about computers," says Bieker, who has also used ShipCAM but recently switched to Rhinoceros, a modeling program not specifically designed for boats but which he finds especially good for editing surfaces and dealing with the reverse curves, knuckles, and fillets found on his designs. *[As reported in an earlier "Rovings" column in* Professional BoatBuilder, *Rhino is available from Robert McNeel & Associates in Seattle—Ed.]*

For a long time, Bieker played with International 14s on the side, building boats in the evenings, until 1991 when a Bieker-designed 14 took the Nationals. With clients lining up for new Bieker 14s and a boss "who didn't want me to become a part-time employee," Bieker decided to strike out on his own. He's since designed Secondo and third-generation boats—the Bieker 2 and Bieker 3—plus some customized 14s, and has built close to 40 semi-custom 14s himself. His boats won United States and Canadian championships until 1997, when the Northern Hemisphere, Southern Hemisphere, and Australian fleets amalgamated. Bieker recalls the first Worlds in San Francisco in 1997: "Charles Stanley chartered my personal boat, put new sails on it, and won. That was pretty neat because there was a lot of talk beforehand that the Aussies were going to kick our ass. It didn't turn out that way." In fact, at the next Worlds in Melbourne, Australia, Bieker boats

COURTESY PAUL BIEKER

COURTESY PAUL BIEKER

Paul Bieker preps his own International 14—a B-3 named Pell Mell*—prior to a race. The boat features telescoping racks, a compression vang, and nonferrous rigging. Its deck was made with flat stock, the centerline radius formed with epoxy-filled saw kerfs on the inside. His shop is called Bieker Boats; the design office, Rip Tide Design.*

swept 1st through 3rd. A year and a half later they captured eight of the first ten places. And in 2001, his boats captured gold and bronze.

Like Bermuda fitted dinghies, International 14s evolved from harbor tenders. When 14s became a national class in England in the early 1900s, they weighed about 250 lbs (113.4 kg). Two crew hiked out to keep 175 sq ft (16.3 sq m) of sail upright. The class went international in the 1920s. Today, 14s fly upwards of 210 sq ft (19.5 sq m) upwind and weigh about 170 lbs (77.1 kg), but they also fly spinnakers exceeding 500 sq ft (46.4 sq m), set on long bowsprits.

Their crews develop enormous righting moment by hanging on trapezes while standing on racks cantilevered off the boats' sides. Today, a hull might weigh only 135 lbs (61.2 kg) and the mast as little as 15 lbs (6.8 kg). Bieker helped propel 14s literally into the jet age thanks to Boeing Corporation's nearby surplus-sales warehouse, which supplied him with glass-and-carbon-skinned honeycomb panels that cost less than lumber-yard plywood.

Like all designers. Bieker says he was "looking for a silver bullet" when he designed the Bieker 1 comparatively early in his career. "My hull shape was fine-ended with a prismatic coefficient [Cp—the ratio of the boat's volume in its ends to that amidships; a high Cp has full ends, a low Cp fine ends] of about 0.56 for light-to-moderate air speed. I wanted straight waterlines forward for upwind speed and a flat run aft for downwind speed." He discovered, though, that with those constraints, a balanced section-area curve required more rocker forward to balance the straight waterlines, and very curved waterlines aft to balance the straight run. "The boats were untouchable in light airs," says Bieker. "Crews could press the fine entries down to lift the transoms and reduce drag, but in heavier airs, the boats were definitely touchable. As long as you sailed them flat, they were quite fast, but as soon as they tipped a bit and immersed their curved sides, or stuffed the highly rockered forebody into the back of a wave, they became very squirrely. That was a great lesson. A lot of people think that they can capture an ideal if they just push all of the perceived performance-producing characteristics as far as they will go. But there are often a lot of unseen trade-offs."

If you think traditional hydrostatic measures are irrelevant to boats that are usually pictured flying free of the sea, Bieker counters, "Those are photos. Fourteens are actually fairly heavy when you put two 180-pound [81.6 kg] guys into them. You get a displacement-to-length ratio exceeding 100, which is like a keelboat. Or at least, a West Coast keelboat. Also, in few places in the world will you race completely in heavy air. To win a Worlds you can't afford an Achilles heel. There's immense power in not having a weak spot as opposed to having one very strong spot. No matter how good you are, if your boat is a dog in light airs, you're going to pick up a score of 20 or 30 at best on a light-air day, and that's the end of your series." Traditional hydrostatic references remain "totally critical" to Bieker, who also keeps a keen eye on wetted surface. "One thing I learned from 14s is that the section-of-area curve *rules.* especially in medium conditions. Older architects would harp: 'It's all in your section-area curves.' I thought, of all boats, the 14s might not be governed by that, but they still are." Because the C_p is an average between the forebody and afterbody prismatics, only the section-area curve reveals the balance of volumes, and Bieker favors one just slightly hollowed forward.

Bieker explains how he transforms traditional hydrostatics into more dynamic models: "Crews can trim a 14 a lot. In light air they trim bow down, so I look at my light-air prismatic with bow clown, as well as level [a C_p of about 0.6], and heeled. In the 14s, prismatics have been creeping up, primarily for the upwind condition, but there are some tricks you can use to get a higher C_p when you want it and lower when you want it, and to make your hull shape hard or easy to sail downwind, even when planing. No matter what you do, though, a low-prismatic boat is going to be a bear downwind."

For the Bieker 2 and 3 designs, Paul employed shapes that "were as fair as I could make them to meet the section-area curve and rocker that I wanted." He believes that a center of buoyancy (and gravity) just a few percent aft of amidships facilitates handling, which leads to forward sections more V-shaped and deeper than many competitors', though quite similar to designs dating back to Uffa Fox, England's pre-eminent small-craft designer of the last century. Bieker believes the deeper forward sections create smaller bow waves and slam less upwind, though he is careful to employ a well-rounded knuckle between the stem and bottom to eliminate any rudder effect from a sharp, deep forefoot.

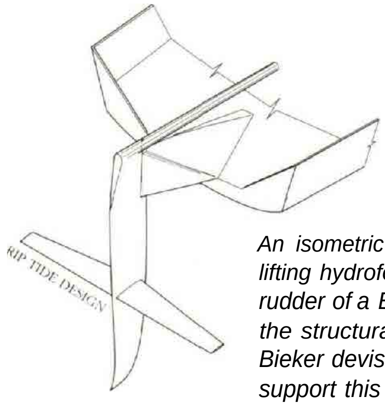
The Bieker 2 was the first 14 with racks. Maximizing stability had long favored increased beam forward where the crew hikes out, but Bieker wanted a finer bow in the topsides, so he decided to "decouple" the hull shape and forward crew's support. The obvious choices were wings, or racks, as found on International Moths or Sydney Harbor 18s, respectively. "Some people objected to the racks," says Bieker. "One rule says that the gunwale has to be a fair and continuous curve, but the racks aren't gunwales, so it was a stretch to make them illegal." For the Bieker 3. he went a step further: "The bottom in the water is roughly the

same, hut I took volume out of the topsides by making the sides more vertical: the bow is narrower up high and the racks stick out relatively more." Although maximum beam is limited to 6' (1.8m) in 14s, rack widths ultimately face practical limitations. In lulls, crews closer to the centerline might simply bend their knees to reduce righting moment by 20% and keep the boat from capsizing to weather. With wide racks, the same crew may need to jump back into a boat, then jump out again in a putt. Racks too wide would exhaust the crew in the puffy conditions in which 14s often sail.

With racks now supporting the back of the boat structurally, sailors really only needed a place to hang the rudder and "corner brackets" to keep the water out during tacks, so Bieker developed a rudder pod and eliminated the transom. To augment control under big asymmetrical chutes. Bieker's pod ties into the hull but extends the rudder mounting well aft, lengthening the blade's lever arm on the centerboard, as well as providing more room for the crew to move aft to keep the bow up. Around the top and bottom of the rudder trunk, Bieker attaches wide carbon flanges that provide enormous stiffness and strength with little weight. "Before 1 came up with that configuration, people were just throwing a lot of material at the problem, but I found you can make these flanges really light and strong," he says. The flanges are quite thick on the nose to carry a long pintle pin that passes through them and a composite gudgeon tube bonded to the pod and spanning the flanges.

All the most recent World champions have been kept on track with Bieker-designed daggerboards and rudders. The tapered laminar-flow foils feature hollowed tail sections and almost-knife-sharp trailing edges. "My theory is that you spend 90 percent of your time going in a straight line." explains Bieker, "so the foils are usually very lightly loaded. It's a laminar-flow section, but it pencils out over a pretty good range of angles of attack. Your maximum lift coefficient may be off 10 to 15 percent less than a standard NACA0012 section, but the rest of the time it reduces drag significantly. At speed, when other sections suffer separation and get unpredictable due to the amount of curvature forward, these foils are rock solid; the faster you go, the better they are. Because of their shape and the fact that they're built from computer-machined tooling, they're the only 14 foils I know of that don't hum at speed." Empirical evidence tells him the foils are maintaining laminar flow at least over the first two-thirds to three-quarters of the sections. Painstaking construction (see the sidebar on page 82) is required to keep the close tolerances and sharp tail, but Bieker thinks it's well worth the trouble. "Ideally, I'd bring all foil trailing edges to zero." he notes.

The last Worlds were won by a Bieker 3 with a new hydrofoil-rudder. "I became interested in it because I wanted to make the water think that the boat was longer—by putting lift into the rudder." Calculations indicated that added drag from a T-foil operating away from the free surface would exceed the reduction of drag on the partially lifted hull. Bieker, however, figured that a foil raised nearer the free surface might gain an advantage from the angle of attack of the water flowing up from the transom. Foils create a lot

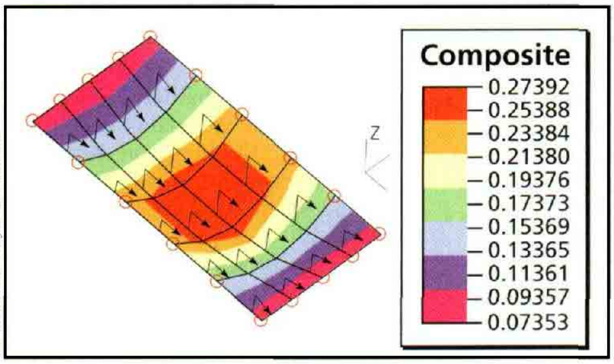


An isometric view of a lifting hydrofoil on the rudder of a B-3. Note the structural pod Bieker devised to support this appendage in an open transom.

of added wetted-surface drag in light airs, and in heavy airs 14s plane anyway, also offering no real advantage. But in most wind conditions that require at least one crew out on the trapeze, the foil promised a boost. Using a friend's molds for a simple, symmetrical NACA0012 section. Bieker built a simple prototype foil the width of the transom—except without the controls (soon to be fitted) that allow the helmsman to adjust the angle of attack. The maiden voyage, in the middle of winter, was cold and windy. "We knew something was going to happen, but weren't sure what," he recalls. The boat seemed fast but the foil was powerful enough to pitchpole the 14 while sailing to weather, and getting back to the dock was an adventure. "The next time, though, we sailed against another boat and we just powered through it like corn through a duck. Downwind in light-to-moderate airs, you can put some load on it and get back in the boat, and even if you don't go any faster you can sail deeper." He laughs, remembering the giddiness of that clay on the sound: "I realized right there on the water with our boat just pasting the other. 'If the wind is anything like this, we're going to win the Worlds!'" Two months later, with the unrefined foil shortened to about two-thirds the transom's width, the boat did win. Bieker's now gearing up to produce a more sophisticated system using an asymmetrical foil.

By the early 1990s, bowsprits and immense asymmetrical chutes set from spinnaker launchers appeared on the racing circuit. Bieker comments. "Sometimes flexing serves a purpose, as in the tip of a mast or in a boom that spills air from the sail in a puff. But when a bowsprit bends upward, the chute luff gets rounder, the draft goes aft, and the angle of attack on the chute gets tighter, so it's all going in the wrong direction." Bieker employed larger-diameter, tapered tubes. (To keep the large apertures from scooping water when the sprits are retracted, he notes, "some guys put toilet plungers over the hole.")

Carbon spars also appeared. When a bendy mast bows in a puff, the hounds descend slightly, loosening the headstay and making the jib fuller. "It's another situation where things are going in the wrong direction," says Bieker. "About four years ago, one innovator in Australia tried a flexible-tip rig, with the lower section locked up by lower diagonal shrouds, which gave him consistent forestay tension. He won the Worlds in it. but the middle of the rig was static. You could make it fast in light air or in heavy airs, but not in both." For the inconsistent conditions around Seattle, Bieker didn't want a rig so "locked up." He tried a pre-bent stick featuring a very stiff lower section, long taper, and swept-back cap shrouds that ran through ears projecting forward from the lower spreaders. Tightening the cap shrouds also pulled back on the middle of the mast. The midsection could bow forward slightly to flatten the



RIP TIDE DESIGN/JAMES BARTICK

Acutely aware of the benefits—and limitations—of finite element analysis, Bieker makes extensive use of FEA in his design and engineering. Here we see a color "map" of panel stresses.

mainsail, hut not so much as to loosen the headstay. "It seems a good rig," he concludes. "The top boats in the last Worlds used that rig."

By capitalizing on his experience designing large commercial vessels, as well as designing *and* building 14s, Paul Bieker has developed a balanced approach to hull engineering that is honed by computer-aided design and finite element analysis. "One of the themes in yacht design for the next decade," he says, "will he that you're really going to have to apply technical tools and numerical data. You're not going to be able to get by with guess-work for most boats. For designing foils I bought a Hanley Innovations program that compares tabular research published by Abbott and Doenhoff, and correlates pretty well with reality. You can change any Reynolds number, thickness, and camber, put a trim tab on it, trip the flow if you think you are getting laminar, and really analyze the foil—all for about 250 bucks,"

When engineering determinate structures for which the load and load paths are well known, Bieker says that "FEA is going to show you stresses pretty close to those you arrived at from hand calculations. In *in*determinate structures, though, there are multiple load paths. Without FEA, you really can't properly analyze complex geometries. A lot has to do with the relative stiffness of structures. If you have a stiff floor next to one more flexible, then you don't know for sure what percentage of load is going through each one, but the stiff one is going to be taking the bulk of the load. What will kill you are geometries that concentrate stress in spots more than you would expect from hand calculations; FEA helps make sure you don't put the carbon in the wrong place—or point it in the wrong direction."

Even FEA remains highly dependent on judgment, Bieker admits. "You can learn much about complex structures from FEA, but the art lies in determining your load criteria, especially without instrumentation. Waves, for example, are difficult to handle. For *America's* Cup boats you measure a lot, and set criteria for what loads and deflections are likely to cause you trouble. But you can't truly model reality; you're simplifying it." He adds that FEA works well for metal structures because welding produces joints that are homogenous with surrounding plates. "But laminated skins are not analogous to welded joints. FEA based on 2-D shells assumes that skins are plates maintaining the strength property of the composite through a joint, as if it meets in an ideal way. hut there's always a weak plane in a structural crossing or connection, and the program knows nothing about things like peeling. You have to he very careful with what's happening around these joints." He adds, "The big thing FEA does show you is the relative importance of structural elements. You can look at a map to see what areas are highly loaded and where the materials are just dead weight. H also gives you a good feel for deflection."

Light displacements and careful detailing help Bieker focus as much on reducing stress as on building to withstand it. He often had to design repairs for commercial fishing boats that had been beaten up by the Bering Sea in winter—and needed to get them back to work within 18 to 24 hours. Big global stresses, he says, sometimes resulted in hull cracks and other "scary stuff." He notes that the solution was





PAUL BIEKER PHOTOS

Stages of a custom International 14 hull under construction in Bieker's shop. ***From the top:*** *Mold stringers in place; structural foam core heat-gunned (and centerline located for a solid-carbon insert at the trunk); applying pre-preg carbon/Nomex flat stock (custom-made by Teklam Industries) to the hull sides; the bottom laminate (one layer each of carbon and glass) goes on; egg-crated carbon/Nomex frames temporarily set in the boat.*

COURTESY PAUL BIEKER

Early in his professional career, Paul Bieker worked on the design, construction, and repair of ships and commercial vessels, such as the F/V Starbound, *a Bering Sea boat.*

often to "address stress concentrations so cracks wouldn't propagate until you could haul the boat to do a proper fix. The solution was to cut structure away rather than reinforce it. An old-timer once told me, 'Stiffness attracts load.' There are situations you get into where the more stiffness you throw at it, the more load it's going to take. That's the paradox of modern design. You can get away with a lot more in a plywood boat than a carbon-fiber one.

"Take the early 14s, for example," he continues. "They were designed for the materials at hand, which meant a lot of framing and thin planking. There's a great deal to be said for that type of single-skin panel, which can move a bit and not fail, because flexing washes out those high instantaneous pressures. That's one unfortunate thing, in my opinion, about the *America's* Cup structural rule: big penalties basically make it onerous to go to single skins. I think it would be a more interesting design problem if they said, 'Thou shalt have an average panel weight greater than x,' and let you do it however you want."

Bieker remains committed to the light weight of cored panels, though, and thinks that failures are more the result of inadequate engineering than inherent flaws with materials. "In a lot of boats, the internal structure is not very well thought out," he says. "Also, I think ABS [American Bureau of Shipping] rules for yachts give just a little too much credit for large panels. The rules allow you to significantly reduce your design pressures as panels get bigger. They presume that smaller panels are more likely to experience large pressure spikes. Still, when the boat slams, the pressure

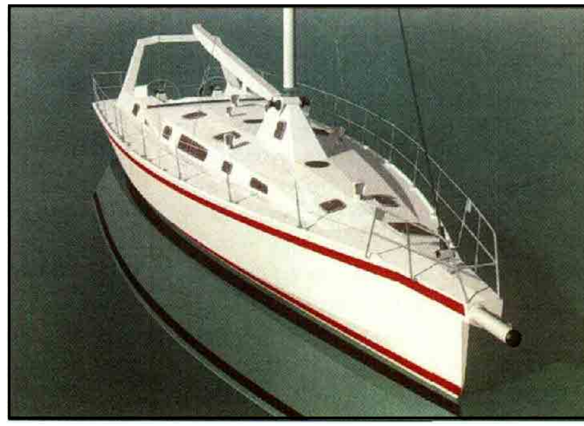
RIP TIDE DESIGN

The sail plan and underwater profile of a Rip Tide 44, Bieker's newest design. He's a firm believer in lightweight, fast, but readily manageable sailing yachts.

map looks uneven, with really big spikes surrounded by areas of lower pressure. It's a statistical thing: the bigger the panel you're looking at, the less likely it is that loads will exceed a large average pressure. But in large monocoque structures, local pressures can be exceedingly high. Panels support those pressures by bending. I think basic engineering would have told you in a lot of cases that you'd get core-shear problems." Since Bieker prefers to split his 14 hulls into small supported panels, FEA is ideally suited to helping him engineer his elegant spiderweb framing set at oblique angles to the centerline, while CAD allows him to provide accurate templates so that even this complex framing simply "egg crates" together.

"I guess I view myself as someone who tries to apply good engineering to accomplish things that might otherwise not have been done," Bieker says. "I see boats as very much related to airplanes, particularly the relationships between drag and weight. Not that I'm Joe Ultralight, you understand. But if there's a lot of weight without purpose, it might as well be put in ballast or removed for reduced displacement." Light displacement is part of Bieker's style, but his engineering expertise and hands-on boatbuilding experience also allow him to mate the theoretically superior with the pragmatically doable. Increasingly, Bieker is applying his style, which has served large commercial vessels and International 14s equally well, to mid-sized watercraft.

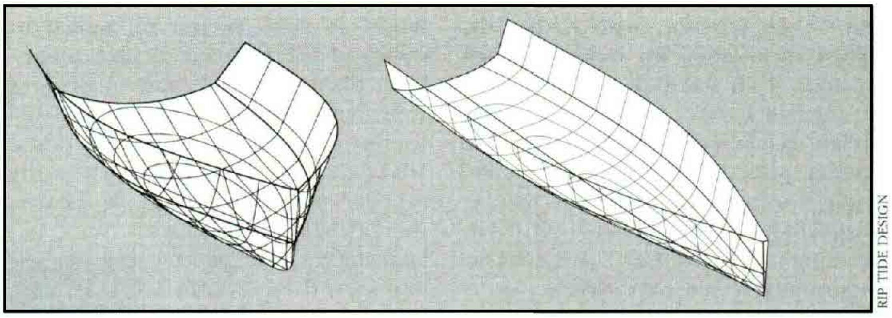
Bieker's first keelboat commission was for a 55' (16.7m) skinny sloop with a notably angular superstructure, a straight sheer, and a near-plumb stem with boxy probiscus. Bieker recalls, "One Seattle yacht designer told me that 'It has a nose like a dogfish shark.' Some people think it's a cool-looking boat because it's quite low in the water and angular. I admit the styling may be over the top. I don't try to make a boat ugly; I do try to make it purposeful without features that lack a reason for being. In this case, the client wanted the biggest boat that could be driven by a sail plan he could handle with his wife and two



A computer rendering, (using Rhino software) of the Rip Tide 55, a fast cruiser. Topsides, deck, superstructure, and much of the interior are built with flat composite panels. The mast steps on a robust pod mounted atop the cabin. This boat's cost-effective construction system was documented in PBB No. 45.

kids. He also wanted an aggressively styled boat."

Freed from traditional constraints for that commission, Bieker mated a smallish sail plan to an easily driven, narrow, balanced hull with deep T-bulb and minimal keel area optimized by a trim tab when set at 5° to 7°. Twin rudders toe out at about 15°. The carbon-skinned, Nomex-cored flat panels that comprise the deck and coachroof and create the boat's angular aesthetic were built efficiently on flat layup tables to eliminate molds. Even the boxy nose provides a very stiff bowsprit and anchor roller that keeps a hanging hook from scarring the topsides. *[For more on the 55 in particular and its type of construction in general, see PBB No. 45. "Boatbuilding with Flat Composite Panels"—Ed]*



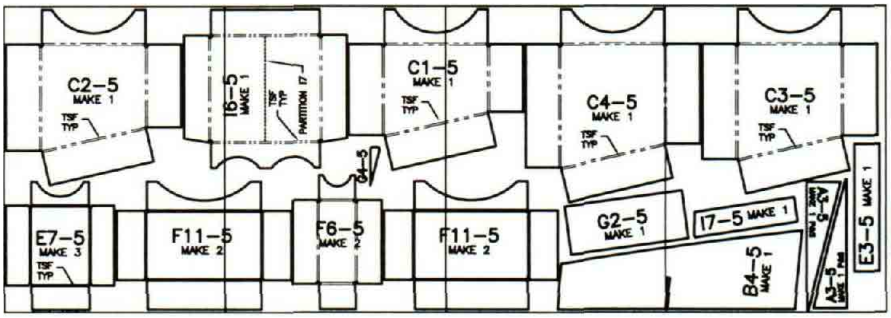
The similarity in basic shape between Bieker's small boats and his larger ones can be clearly seen in perspective drawings of a 55 ***(left)*** *and a B-3 International 14* ***(right).*** *These are chine boats, but the transition is subtle and the bottoms are round.*

Bieker borrowed a page from Open-class raceboats and placed the boom gooseneck on a deck-mounted pod, thereby eliminating shear loads from the boom on the mast section, a common point of failure. With the gooseneck aft, the mainsail foot and leech automatically loosen when the sail is eased. The pod appears stolen from an armored vehicle, but integrates numerous functions. Winches centralize halyard handling for shorthanded sailing. The 55's hydraulic ram perfectly tensions the rig but can be eased alter the crew fixes the position with a ring nut. Internal structural baffles reinforce the cabin edge against diagonal rigging loads and create a giant ventilator for the head below without protruding Dorade vents. The ventilator also creates a miniature "cathedral ceiling" over the WC, where someone sitting might wonder when the mast above, driven by 50,000 lbs (22,679.6 kg) of compression, is going to take a core sample. But the pod's sides actually cany the loads directly to the main bulkhead and to two longitudinal bulkheads flanking the head.

The mast section (fabricated by GMT in Bristol, Rhode Island) is round, as on many 14s. "Elongated mast sections," says Bieker, "make sense when in-line spreaders lend no real fore-and-aft support between the masthead and deck or split lower shrouds. With swept-back spreaders, though, the rig is locked almost as well fore-and-aft as it is side-to-side. Also, round mandrels are a little easier to come by for one-off spars."

The conservative cruising community is unlikely to embrace boats such as the 55, but the Bieker 35 (10.6m) may well lead many performance-oriented cruisers as well as racers in new directions. Bieker designed the water-ballasted 35 much like a 14. To allow builders to launch semi-custom 35s at a cost similar to production boats, only the bottom and coachroof require female molds. The rest is vacuum-bagged on a flat table. Numerically controlled (NC) routers produce mold frames and detail the flat panels to facilitate stitch-and-glue construction. Each topside panel weighs just 70 lbs (31.7 kg); each deck side 40 (18.1 kg). The builder strip-planks the bottom in a female jig then drops in pre-cut sides, bulkheads, and frames, to which the deck panels are attached. The mold retains the hull's shape until completion. All up, the boat weighs 4,700 lbs (2,131 kg) with 2,000 (907.2 kg) of that in the fin and ballast.

Twelve hundred pounds (544.3 kg) of water ballast lend additional stability. Bieker prefers an electrical pump and hand-pump backup for filling the ballast tanks, because a scoop would require eight or more knots of boat speed, which, he says, "would work most of the time, but not all the time, such as when turning upwind." Also, nuisance leaks can develop around scoops unless the inlets run all the way up to the deck. Transfer "valves" are composed of a simple Bieker-designed pinch valve. The crew pulls a line to pinch off a fabricated neoprene tube against a soft pad. It only has to be powered in one direction, unlike ball valves that require force to be opened or closed. To further simplify piping, the tank bottoms rest above the leeward heeled waterline, so they always completely drain by gravity. Almost all of the interior serves structural purposes, but remember: Bieker is a sailor himself, so his solutions often enhance cruisability, too. Over the forward V-berth, instead of a full ring frame, he's specified an arched beam



Flat-panel construction lends itself to nested parts made off the boat, as with any boat built from aluminum, steel, or plywood sheet stock. The drawing above is a computer lofting from a series generated for the Rip Tide 44; it shows interior parts that will be kerfed and folded. The laminate itself consists of Herex foam sandwiched between layers of plain-weave glass.

that stiffens the flat topsides hut tapers to nothing at the berth edge, so it won't dig into sleepers' hips. Twin headstays allow the boat to be worked as a fractional or masthead sloop. The inside stay lives at the mast until needed. Reliable hanked sails remain positively captured by the stays, simplifying handling for shorthanded crews. The bowsprit protrudes about 9' (2.7m). "I figured it had to stick out at least as much as on a 14," says Bieker with a laugh. It fits its hole tightly when extended. Retracted, with the butt reaching back to the main bulkhead, a sleeve slows clown leaks, but a self-draining locker also keeps any water from migrating to the interior.


STEVE CALLAHAN

Detail view up forward in a Rip Tide 35, showing the deck and topsides arch support, and retractable bowsprit. A self-draining locker forward of the bulkhead contains any leaks around the sprit.

Bieker admits that a wide stern going to weather in stiff conditions can drive the bow clown into troughs as big crests pass the boat's voluminous rear, and a chine boat may appear unrefined, but his 35 reveals some real advantages to both. Chines add volume forward so, despite a sharp entry, the static waterline heeled 20° noses the boat clown only ¾" (1.9cm). "Also," he says, "downwind, especially sailing hard, the chines break the water free of the bow. You don't have water sucking up the side of the boat, and you gain a shoulder for the boat to lean against aft. You get some real stability from the chines with 10° of heel, so you can just get up and go." The 35 clocks about seven knots upwind at 27° to 30° apparent, but off the wind, says Bieker, "when it's blowing over about 25. you can go an hour without falling below 16 knots, and we've done 22 in spurts. In the Pacific Cup race to Hawaii in moderate airs, two 35s beat all but one Santa Cruz 50, boat for boat." Still, Bieker emphasizes, "the 35's a really fun boat to cruise. With the sprit and a snuffer, two people can handle the chute, and 12- to 14-knot cruising makes it easy to get from point A to point B."

Bieker's emphasis on the joy of efficiency and not just speed may best be exemplified by his conversion of an Ultimate 30 (9.1m) racing sailboat to a powerboat. "I love pre-World War Two powerboats," he says. "Horsepower was really limited then, so they got as much as they could out of it. The boats were slender and efficient, with nice wakes. They just slid along. The war marked a real shift: within 10 years, powerboats were throwing big wakes as people threw horsepower into them."

Bieker's Ultimate powerboat weighs only about 1,000 lbs (43.6 kg). A four-stroke 40-hp Honda outboard drives her at up to 19 knots; she cruises easily at 15 and gets about eight miles per gallon. Her motion is good in all but quartering seas when, concedes Bieker, "she waddles a bit." It's a condition Bieker

FRED BIEKER PHOTOS

Bieker took a retired racing sailboat of recent vintage (an Ultimate 30) that he'd found as "surplus" and then converted it to power for his own use. The hull is easily driven by a 40-hp four-stroke outboard, making the boat exceptionally fuel-efficient.

believes could be moderated with fins. He loves being able to take friends from Seattle to the San Juan Islands on just six to eight gallons of fuel—"about as much," he says, "as you'd burn in a car and a quarter or less than a moderate-sized powerboat. If your criterion is to spend a certain amount of money to get accommodation, then you won't end up with a boat like this. It's more like a camping vehicle. That appeals to me. It gives up some volume in return for efficiency. Seems a little sad that our recreational pursuits are so wasteful. If there's one part of your life that you might tune a little more to your surroundings, it should be your recreation. When you do, you end up loving your boat and the way it goes through the water."

In the end, says Bieker, "the designer's goal is to understand what the owner is looking for and to create the best solution. I like coming up with a sensible design that I didn't expect. You know, you're your own worst critic, but when you struggle with a problem long enough and something comes to you that is the simplest by far, there's great satisfaction in putting it on paper and seeing it get built. One of life's biggest pleasures is when your mind takes you where you didn't expect to be."

Expect Paul Bieker to bring some daring to the Oracle *America's* Cup campaign. On his 14s, he's now experimenting with composite rigging and multiple headstay locations. He's also intrigued with making vessels globally stiff while more flexible in the microcosm, noting that subtleties in Aleutian kayaks allow them to bend in ways that often produce better performance than more rigid, modern designs. He's fascinated by natural flexible designs—such as fish. He points out that their tails, which lack muscles, twist to enhance efficiency, but he won't yet reveal just how he plans to interpret this natural advantage. He concludes. "If I do 10 boats that really light me up, and each has features that haven't been done before, I'll feel a lot better than if I had designed 100 boats that are mediocre." PBB

About the Author: *Steve Callahan has designed and built multihulls, authored an educational text ou multihull design, written widely on racing designs and personalities, and made many offshore passages. He is a frequent contributor to* Professional BoatBuilder.

STEVE CALLAHAN

The Foils Factory

Russell Brown is perhaps best known for creating a series of wood/epoxy "flying" or Pacific-style proas, one of which he sailed across the Pacific in 2000. But he's also designed and built superbly crafted tooling and components ranging from kayaks and other small craft, to sail slides, hinges, goosenecks, maststeps, and instalment pods, often favoring carbon fiber. When he met Paul Bieker. Brown wanted to build the appendages for Bieker 14s. Judging from the unparalleled competitive achievements of Bieker's boats over the past six years, Brown has clearly succeeded—and all this from a converted chicken barn in Port Townsend, Washington.

For his rudders and boards, Bieker chose a modified Eppler foil section with a complex tapered profile and hollow trailing edge. Brown says, "No matter what tricks I had up my sleeve, I could not possibly build these by hand. The recurve would be very hard to do with hand tools, and the taper would make it impossible." Instead, the process begins with refined aluminum molds produced by Kinetic Research near Seattle, using a computer-driven milling machine. The tooling is very stable and durable, but Brown notes that temperature control is essential to keep the molds from contracting and expanding. He liberally employs heat lamps and therefore suffers, he says, "an astronomical electric bill."

Brown waxes the molds and tapes the perimeter flanges before he applies a kind of gelcoat composed of room-temperature-cure epoxy mixed with graphite powder, applied first with a fine-toothed squeegee, then a roller. After scraping off any excess resin, he cures the gelcoat under a heat lamp for a few hours, then applies a fillet to the leading edge using Cabosil high-density fibers. Following the cure, he lightly sands.

With Gougeon Brothers Pro-Set resin, Brown begins laying in the skins. The first layer is a tightly woven, fine-strand E-glass, followed by woven carbon, both cut to perfectly fit the mold by means of plywood templates. Next comes four (for the rudder) to five (for the centerboard) layers of unidirectional fibers, the lengths staggered to handle the side loads even when a board is not fully deployed. For boards, he adds a thick piece of carbon where it exits the trunk. A beefy piece of carbon cut back slightly from the edges and overlapped by a thick piece of biaxial glass completes the skins. The biax will spread loads from the shear web to the surrounding fibers. Brown then lays down peel-ply and a perforated bleeder cloth.

Resin emerges through the peel ply, but the bleeder slows the travel so more air than resin works its way out. Brown says pre-preg skins would serve even better, but the setup required would be expensive, and judging from the scant amount of resin on the tossed-out peel-ply, he still gets a lean laminate. The vacuum pump runs for eight to ten hours.

The next day, Brown removes the bleeder and peel-ply and sands the skins (he doesn't trust peel-ply alone to leave a bondable surface). He's tried several structural core materials and currently uses a 5.5-lb-density (2.5 kg) Klegecell PVC foam. He's prepared carefully shaped blanks that are kerfed to promote bending. Numerous drilled holes in the kerfs allow resin to thoroughly fill them during layup. He butters the core with filled epoxy, but uses neat resin on the shear web that he inserts. After boards with spruce shear webs broke, Brown turned to select, vertical-grain (and tightly grained) Douglas fir, which has long been air-dried and kept evenly warmed by the shop's woodstove. He completes vacuum-bagging the assembly in the morning, and in the afternoon, carefully begins work with the router to trim all projections flush with the top of the mold, checking them with a straightedge and sometimes removing lumps with a wide chisel. (Since you cannot fix a nicked aluminum mold, you must repair every part you make from a damaged one.) Brown uses a mini-grinder to closely trim the layup that overlaps the perimeter tape. Finally, with an orbital sander, he cleans up all resin around the edge, leaving clean tape.

During the layup, small bubbles often work their way to the edges, and Brown is careful to clean them out and to pack around the perimeter with a thickened putty. To glue the two halves together after he cuts everything flush, Brown mixes a quart and a half of epoxy thickened with microballoons, adds cotton fibers for strength, and applies it with a wide, notch-toothed trowel. Using big C-clamps, he begins clamping in the middle, working his way toward the edges where pins are threaded into the molds for final clamping. The foils cure for a few clays before he pops them in the oven, first at 90°F (22°C), then 100°F and 110°F (37.8°C and 43.3°C) before backing off to 100, each for a couple hours. When the parts emerge, just a paper-thin layer of resin around the edges needs trimming. The edges are impressively straight and the trailing edge almost dangerously sharp, yet it contains carbon all the way to the apex. with woven carbon only 1/8" (.32 cm) inboard. None have broken so far.

Brown makes notes about and numbers each foil so he can keep track of any irregularities in the materials and their effect on the end product. A set of these foils costs on the order of $1,200—not exactly cheap, but considering the care of the layup and the results on the racecourse, inexpensive enough such that demand continues to outstrip supply. He would like to find a way to automate portions of the process—the cutting, kerfing, and drilling of the core blanks, for example—but it is likely that such operations, whether for these foils or other high-quality parts required by the marine industry, will remain labor intensive.

The good news is that, using traditional craftsmanship skills, some of the most sophisticated composite parts in the world can still be made in a simple shop.

—Steve Callahan