Building Fast Boats That

How do you produce high-performance, composite, offshore powerboats so they hold together in extreme service? A veteran builder describes his practical approach to the problem.

Several thousand of you attended IBEX '97 last February in Fort Lauderdale. IBEX is the now-familiar, easy-to-use acronym for the annual seminar program and trade show sponsored and co-produced by *Professional BoatBuilder* magazine. But with more than four dozen seminars spread across the three-day event, only a small portion of the total attendance at the show is actually present in any given seminar room. And so it was that about 150 people took in Session 801, entitled "Learning from High-Performance Offshore Powerboats." One of the three speakers in that session (the other two being naval architects Don Blount and Dave Shepard) was Val Jenkins, vice-president of manufacturing at Cigarette Racing Team Inc. in North Miami Beach.

Longtime readers of PBB are well aware that Jenkins' name comes up frequently on these pages. That's because he's passionate about boatbuilding, knows a lot, prefers plain language, and is willing to share information. Not incidentally, Cigarette has won manufacturing awards on his watch, including top honors from *Fortune* magazine for building one of the hundred best U.S.-made products.

As moderator of this seminar (there was a question-and-answer period following the individual presentations), here's how I introduced him:

"A native and lifelong resident of South Florida, Val Jenkins has worked local waters as, variously, a diver, guide, commercial fisherman, marine biologist, and professional captain. In the 1970s and early '80s, he developed product and managed production lines at Mako Marine and Blackfin Yachts, respectively, and was among the first to use so-called exotic materials—Kevlar and carbon fiber—in a production setting....At the top end of the muscle-boat market—where Cigarette is a brand name, not a generic classification—the combination of speed and durability remains very difficult to achieve. While it is possible to build a fast boat or a rugged one, the current challenge at every speed shop in the business is to construct a craft that is both."

For those of you who were at IBEX but missed Jenkins in Session 801, what follows is a near-verbatim version of his presentation. And for those of you who have never been to IBEX, what follows is a demonstration in print (though in person is much better) that our sessions deliver plenty of solid technical information without getting academic about it.

—Paul Lazarus, Editor

by Valentine Jenkins

Good morning to all. First, I want to thank the crew at *Professional BoatBuilder* magazine for getting us all together. It's a pleasure for me to see so many people interested in what we have to say. Thanks to all of *you*, too.

I'd like to informally poll the room. Please raise your hands: Boatbuilders. *Offshore* boat builders. *One-hundred-miles-per-hour* boat builders. *Thirty-feet-and-longer* boat builders. Surveyors. Composites industry people.

About myself: I have been in charge of boatbuilding at Cigarette Racing Team for the last 13 years. During this time I've seen offshore pleasure-boat engines grow from 330-horsepower cast-iron automotive conversions, to 1,100-horsepower aluminum 700-cubic-inch supercharged funny-car conversions. And I have struggled to keep the boat equal to the power increases.

Today I'm going to talk about power and structure. Stay with me on the first part.

At Cigarette we use a speed-estimating formula that I got from Harry Schoell [Schoell Marine, Fort Lauderdale, Florida]: Speed equals 225 divided by the square root of the weight divided by the horsepower. "S" is statute miles per hour. "Wt" is the weight of the boat as tested. "Hp" is horsepower; watch out for this one! "225" is an empirical constant based on hundreds of sea trials with weights and horsepower of the same type of boat—that is, similar bottom form, drives, size, and other characteristics. Your boat is probably different. If it's a catamaran-style raceboat, then the constant is 250-plus. Straight inboards, 165.

$$S = \frac{225}{\sqrt{\frac{Wt}{Hp}}}$$

S = Statute miles per hour
Wt = Weight (lbs.) of the boat as tested
Hp = Total engine horsepower
225 = Empirical constant

Trial #1: $$71 = \frac{225}{\sqrt{\frac{10{,}000}{1{,}000}}}$$

Trial #2: $$75 = \frac{225}{\sqrt{\frac{9{,}000}{1{,}000}}}$$

Trial #3: $$74.6 = \frac{225}{\sqrt{\frac{10{,}000}{1{,}100}}}$$

***Figure 1**—Author Jenkins credits designer/builder Harry Schoell (Fort Lauderdale, Florida) as his source for the pragmatic speed-estimating formula above, based on horsepower and boat-weight relationships. See text for a discussion of the three different trial results.*

Take a look at the trial data **[Figure 1]**. Trial #1 is our baseline boat. In Trial #2, we take out 1,000 *lbs*, and in Trial #3, we add 100 *hp*. Trust me, no man alive can tell the difference between Trial #2 [75 mph] and Trial #3 [74.6 mph] by the seat of his pants. It takes a good radar gun.

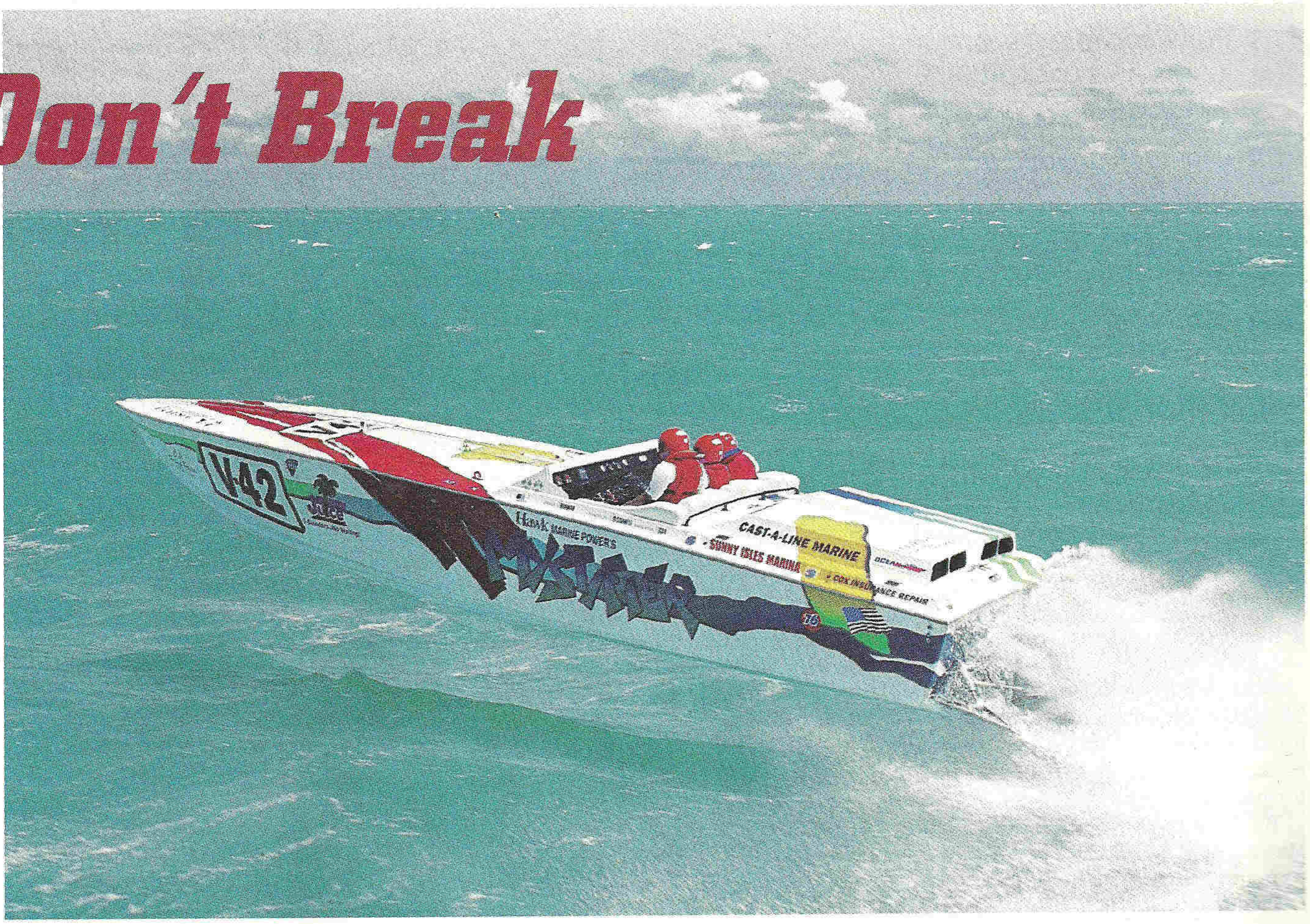
Let's look at the boat: 10,000 pounds, minus 3,000 pounds in engines and drives; 1,000 pounds for 160 gallons of gas; 500 in tanks, plumbing, and toilet; 500 in upholstery, seating, and stereo; 300 for you and your girlfriend or wife; 100 in ice, sodas, and beer. That leaves 4,600 pounds of shell. So, a 1,000-pound reduction in the hull and deck gets you better than a 20% weight savings!

Remember, the mechanicals and people amount can't change much. Think for a moment, though, about what's happening: You want to go faster, hit harder, take bigger risks. But what part of your boat do you want to take out to achieve this 20% weight loss to get a *5%* speed gain? Clearly, the biggest opportunity is to buy more horsepower, not more graphite.

A couple of things to consider. I built a boat once, 42′, carbon fiber to the max, two (no kidding) 1,150 dyno'd horsepower, 588-cubic-inch supercharged engines. Theoretical speed, 110 miles per hour. I saw 96 mph-and-accelerating on the radar gun. The boat was uncontrollable by humans when there was any wind or waves.

Lesson Number One: V-bottoms, with their lack of aerodynamics, need mass to help stability. And the fact is, struc-

Don't Break



CIGARETTE RACING TEAM INC.

ture and strength distributed around the boat help stability.

Lesson Number Two: Speed is useless without control. Better to build a slower boat with more usable speed.

Another item: Consider warranty issues. There is "offshore" use implicit in the term "offshore boat."

All of this leads me to state: *Build it strong, then add power.*

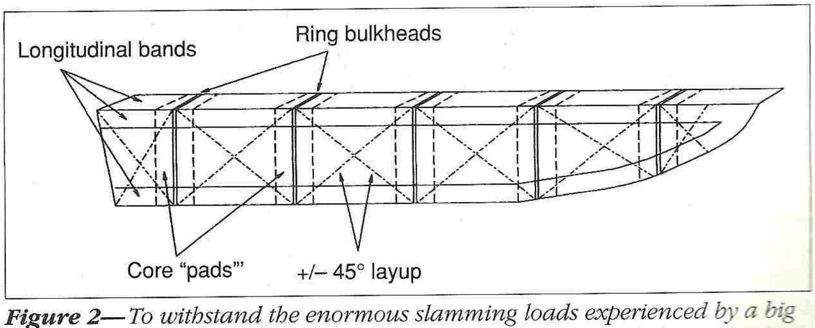


Figure 2—*To withstand the enormous slamming loads experienced by a big raceboat going full bore—like the airborne Cigarette pictured above—Jenkins favors a substantial structural design that he refers to as an "ocean-racing railroad bridge."*

Build it strong how? Boats come in all sizes and shapes, but as a general rule I believe that in smaller boats, *panel* stiffness is key; and as boats get bigger, then *global*, or overall, stiffness becomes more important.

What does this mean? We all know small boats consist of a framework of stringers and bulkheads joined together by skins to form a bottom, sides, and maybe a deck. The stringers that are the load-bearing structure of the boat, and the skins, keep the water out. In this type of construction, the stiffness and strength of the panels *between* the stringers is the place to improve overall structure. In other words, the stringers do the longitudinal work of the structure, while the skins do the side-to-side work.

Now, which is stronger and stiffer—big stringer or little skin?

Using axial fiber and cored construction, it's possible to balance the relative strengths and stiffness of the two structural components. Simply put, use more fiber *across* the boat. This forms a bridge between the strongest structural members in the vessel. Keep that in mind as we consider larger boats. The global situation changes, but the local conditions must always be satisfied.

Some signs of trouble with local stiffness: (1) damage to interior parts of the boat and/or the liner, due to bottom flex; and (2) longitudinal damage to the bottom, usually along the stringers. The simple fix: *more fiber across the boat.* If you think you're close, change the direction of a layer or substitute uniaxial material.

As boats get bigger—at some point based on size and speed and waves and operator—*global bending* begins to play a part. Indeed, it may become the biggest problem we face.

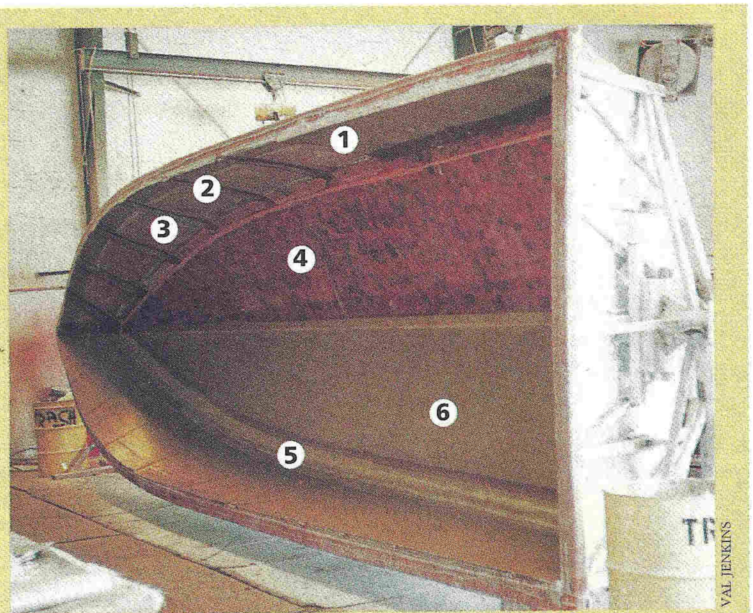
Look at what's happened. In our *small* boat, the short overall length of the stringer system compared to its height gave us a relatively stiff frame to build our boat around. Now we have a bigger boat, with headroom below and a raised helm and other human amenities. But, relatively speaking, what's happened to the stringers? They are *shrinking* as the demands on them to stiffen the whole boat are increasing.

What to do? Let's think a minute.

What's a good example of the global bending problem? A bridge. Picture a bridge made of I-beams. The bottom of the beam is our boat bottom, already pretty strong because of the local loads

1 Fully cored sides around saddle tanks and cockpit
2 Core reinforcement of sheer
3 Core reinforcement for ring bulkheads
4 Core reinforcement of bottom and chine (note putty in chinks)
5 Chine fillet
6 Kevlar over all

A 31′ raceboat hull—caught in mid-construction at the Cigarette Racing Team Inc. plant in North Miami Beach a few years ago—provides some insight into just how serious this company is about structure. Still to come are two stringers on either side of the keel, a series of web frames ("ring bulkheads") every 3′6″, and major bulkheads at the helm and engineroom.



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it has to survive from waves, trailers, and forklifts.

But what about the top of the I-beam? The deck. Except the deck is not perfect for the job; it has holes in it, discontinuities, and it changes shape and height for good reasons.

Back to the bridge analogy. Think about a railroad bridge. The top and bottom are trussed together by the sides.

Picture a boat hull, long and slim, with strong bands of reinforcement up from the chine, down from the sheer, and horizontally inboard from the deck edge. Next, add some ring bulkheads, say, every 42″ along the length of the boat. Lay up some plus-or-minus 45-degree biax material in the skin. Refine the structure by putting some core material between the ring bulkheads and the skin of the sides and deck, say, 12″ wide. What you then have is an *ocean-racing railroad bridge* [see **Figure 2**].

Still, for this thing to work, it is critical that the deck do its job. The deck keeps the sides standing basically vertical to take loads from the bottom. With no deck, the sides would bow in or out and allow the bottom to bend. Also, to some extent, the deck is acting like the top of the I-beam, taking compression and tension and torsion loads as the hull tries to bend over a wave. This means the hull-to-deck joint is very structural in nature.

We're not talking pop-rivets here. We need multiple biax, staggered overlaps, bonding resin, fillets, rolled with a metal roller, edges matted down with ¾-oz mat. The best job you can do.

When a raceboat "stuffs" and the nose breaks off, failure of the hull-to-deck joint is often the cause.

You surveyors in the room should look at the boat's bonding and bulkheads up at the bow, because the stringers have usually died out before they get this far forward, and the sides and the deck are doing all the work. The hull-to-deck joint will show you if there's trouble.

By the way, since length is a big factor, how much length are we talking about? Val's Rule of Thumb: On a 30′ boat, look at bottom panels; 35′ boat, some global; 40′ boat, it's here; 45′ boat, pay close attention. Pay close attention to what? To *global trouble indicators.* Here are the signs:

• *A "kink" in the rubrail* about amidships or a little forward.

• *Stress cracks around the windshield or cockpit.* What's happening here is that the big plane of the forward deck—the top of the I-beam—is suddenly reduced to the width of the gunwale. Where does the load go? Yup—to the inside corner of the cockpit.

• *Transverse damage to the bottom, sides, or deck.* Adding stringers may fix this, but it may also be a sign of bigger things. Anyone remember seeing photographs of Australia's entry in the last *America's* Cup race, when the boat sank with a big tear down her side? In that case, the rig globally bent the hull. How? Because they had repositioned a load on a winch near the hull-to-deck joint, and—Bingo—it failed the joint.

• *Fuel tank problems.* Long tanks may be stiffer than the surrounding boat. This can damage the boat, and flex-fatigue the tank and its mounts. The fix for these troubles is to make the whole boat do the work, not just the bottom.

So, what's next? You build a boat. The bottom panels seem stiff enough. The overall picture is as strong as a railroad bridge. You send it to sea, and things are great—for a while. The boat may outlast its warranty. But what if the warranty is forever?

We need to talk about fatigue. Things that bend, especially bend too far, get tired. But unlike living systems—like George Foreman—boats don't rest and heal after use. And as with Muhammad Ali, the long-term consequences may be bad or terminal.

Now, almost every week a resin salesman approaches me with some wonder goo for 50 cents a pound less than I'm currently paying, which some guy down the street is building beautiful boats out of, with no problem. Good for them. Show me a boat structure, though, with no flex, and I'll show you where you can take weight out and maintain strength. *But it won't be as stiff.*

Remember, flex and amplitude equal fatigue. We know our boat is going to flex. And, if it's going to run fast in rough water, it's going to flex with frequency and amplitude.

So. Job One is to build with materials that have the right physical properties. The resin must stretch more than the reinforcements. The resin must also be tough and have good fatigue properties. To quote Reggie Fountain: "In order to build the finest boat, you have to start with the finest materials." He's right.

Job Two: When a boat is maxed out, secondary bonds will fail before the primary layup. *The best money and effort you can put in your structure is to improve secondary bonds.* Teach your people the best techniques; stress the importance of the work; and Q.C. with religion.

What does this have to do with fatigue? When secondary bonds let go, parts of the structure really start to move—big moves, and often. It adds up to fatigue.

A subset of secondary bonds is *skin-to-core bonds.* This is the number two area to use a good system and reliable Q.C. Think about putty and fatigue. It

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had better be a pretty special putty.

Did anyone in the room hear the presentation by the group from Interplastic Corporation at the '96 MACM [Marine Applications of Composite Materials] Conference in Melbourne, Florida? That technical paper was titled, "Comparison of Fatigue and Static Physical Properties of Plaques Made with Various Resins Constructed Using a Vacuum Infusion Process and Conventional Layup Method." The study confirms my belief that too high a vacuum yields too little resin and leads to a more fragile structure, especially when it may be exposed to a really exceptional hit.

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Cigarette vacuum-bags its sandwich structures, to ensure good secondary bonds. Note the aluminum "king plank" helping to further reinforce this cored deck.

The bottom line for me is that a 60%-fiber-to-40%-resin hand layup well done is tougher than a 70/30 with the same materials using high vacuum.

Finally, after you do all the right things—materials, structure, method, quality control—you have to test. How to test and how much to test is a good question. First of all, *you* can't do it; someone else has to. There is not a person in my entire organization who can willingly get in a boat and dish out the kind of mindless abuse that my customers bring me claiming warranty. Having said that, I figure 200 to 250 hours with teenagers at the wheel is about right. The problems that emerge after this period are probably more fatigue-like in nature and may not appear except only occasionally. That means you have to keep close tabs on your service-and-warranty experience, and think "stiffness." If you see a problem, get to work on it right away. Small signs may be very important, particularly if you've built a lot of boats before the first one comes back.

To reiterate in closing:

You get more speed for less money by increasing horsepower rather than decreasing weight. Weight reduction is limited, but power is unlimited. More horsepower requires more weight and stronger structure. But stronger structure gives you better safety, better warranty, and better control at speed. So:

- Build strong and add power.
- Build the bottom strong enough to survive local loads.
- Build the boat—bottom, sides, and deck—strong enough to survive *global* loads.
- Overbuild with the best fatigue-resisting materials.
- Develop secondary-bond methodology, because the more you change, the more you have to test.
- Relate your warranty experience to your boats, first time and every time.
- Pay close attention to a hurt boat; it's trying to tell you something.

Well, those are some of *my* thoughts on power and structure. I hope I've provoked a few thoughts in *your* minds. Thanks. PBB