PROFESSIONAL BOATBUILDER

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

NUMBER 64
APRIL/MAY 2000
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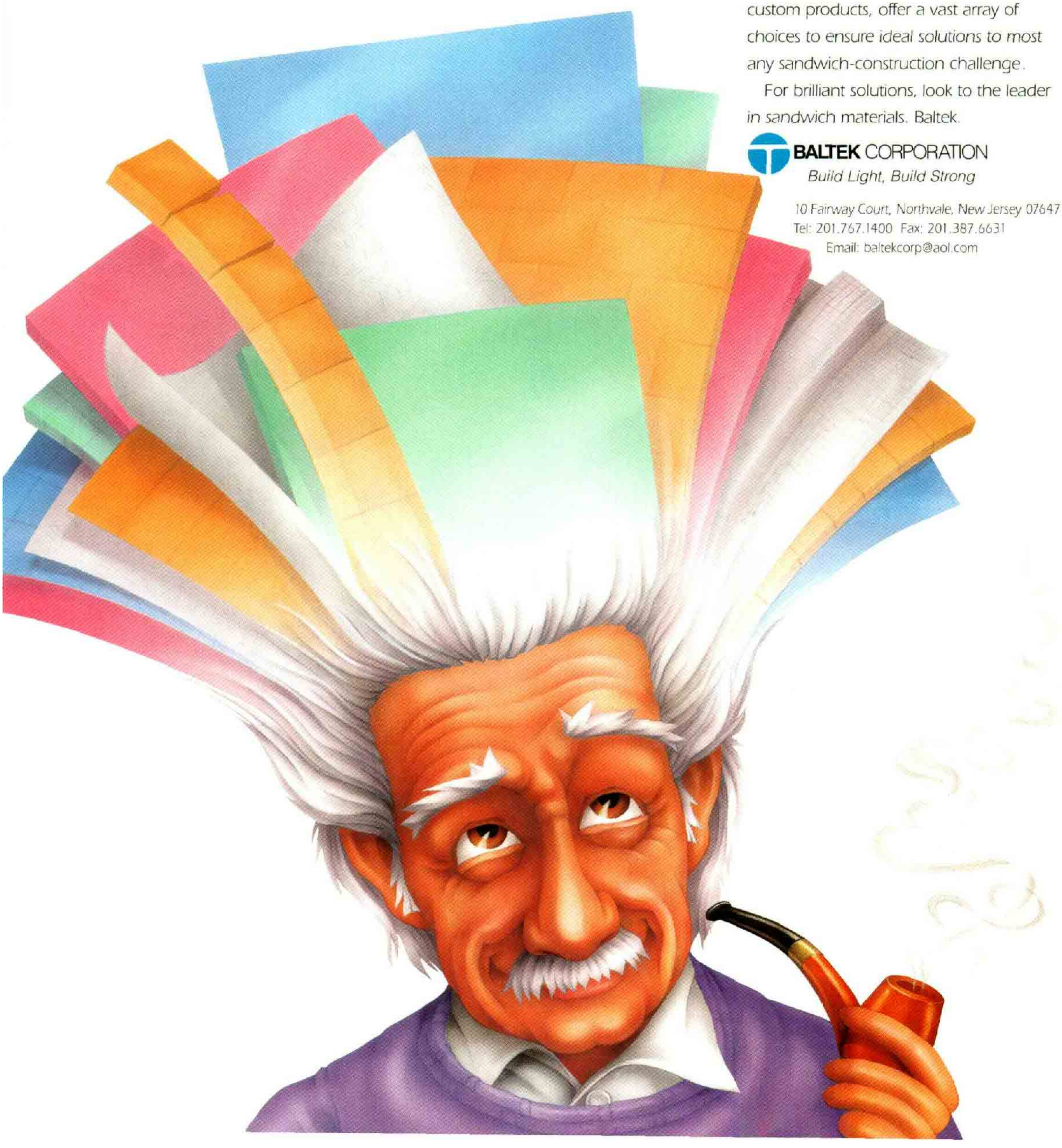
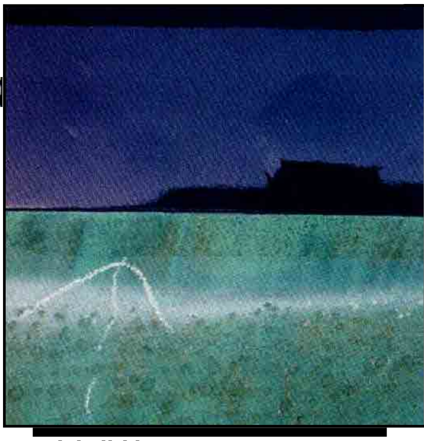
SEATTLE'S VIC FRANCK YARD
LOW-TEMP PRE-PREGS
GROUPE FINOT
WEIGHT MANAGEMENT FOR MOTORYACHTS



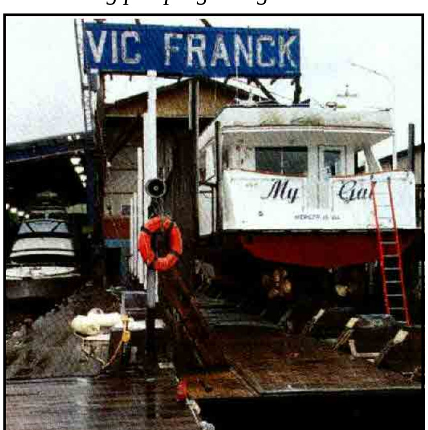


BRUCE PFUND

Dark-bull blisters. Page 22.

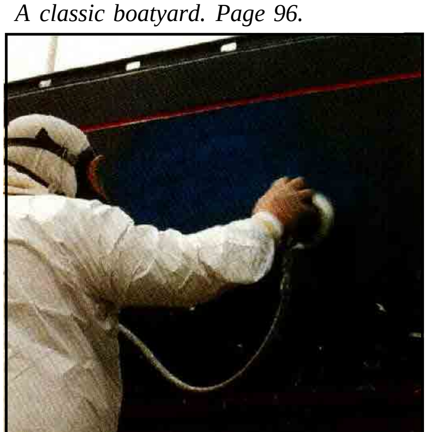
SP SYSTEMS

Producing pre-pregs. Page 82.



GREG GILBERT

A classic boatyard. Page 96.



BILLY BLACK

Choosing repair jobs. Page 112.

FEATURES

DEPARTMENTS

READER SERVICES

On the cover: A crew member at the Vic Franck Boat Co. (Seattle, Washington) mills some stock on the yard's big, smooth-running bandsaw, acquired from Boeing more than a half-century ago. Story on page 96. *Photograph by Greg Gilbert.*

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PROFESSIONAL BOATBUILDER MAGAZINE

Industrial Evolution

Pre-preg technology first migrated to the marine industry in the 1980s from aerospace, where it was developed for building strong lightweight structures. In recent years, the introduction of low-temperature pre-pregs has removed the need for an autoclave or elaborate oven to cure the material. But there remains much room for improvement in streamlining the numerous steps that go into making a pre-preg part, from small-scale samples to debulking to core application to carefully controlled curing—to name just a few. Note the schematic drawings in our article on pre-pregs ("Builders Wanted," page 82), which depict some of the steps for laminating a typical sandwich structure.

Those drawings were made by Susan Robitaille of YLA (Benicia, California), a pre-preg manufacturer. "I wish it didn't seem so complicated," she said to me recently. "The process is really quite easy and forgiving." Rob Turner of Turner Yachts (St. Catharines, Ontario) is not so sure. Since switching to pre-pregs last year, Turner has been struck by the dearth of practical information on this technology, a discovery shared by Steve Lee and Lynn Bowser of Westerly Marine (Costa Mesa, California). Apart from the learning curve required for pre-preg construction, all three veteran builders have had to reckon with the relatively slow pace of boatbuilding imposed by the pre-pregs themselves. "When it comes to pre-pregs," Turner told me, "advancement in materials has outpaced advancement in processing."

Eric Goetz's custom boat shop in Bristol. Rhode Island, began working with pre-pregs in 1992. His crew has long since grown comfortable with the medium, and is by now adept at it. But, for the technology as a whole to evolve, many more shops besides Goetz and Turner and Westerly—operations we're covering in *Professional BoatBuilder*—must take up pre-preg construction and experiment with ways and means of fabricating large structures efficiently. There are signs that such change may be on its way: a handful of production builders in the United Kingdom and the United States are employing pre-preg parts in their boats. And currently, as added incentive, the cost of basic carbon fiber/epoxy pre-preg is lower than the price of the component materials sold separately.

"Complex" and "labor intensive" are two reasons often cited by boatbuilders who choose to steer well clear of pre-preg construction. Interestingly, many of these same builders view traditional wood construction in much the same light. And yet, a four-man crew at the famed Beetle facility in New Bedford, Massachusetts, in the early 20th century was able to turn out a 28' whaleboat in just 48 hours of shop time, start to finish. Anyone who's done conventional wooden boat building with solid lumber will appreciate this feat, made possible by practiced hands, plenty of patterns and jigs, precision machine tools, and above all, the industrial genius to put these elements together in a building process faster than any of its antecedents.

A similar breakthrough in productivity will have to occur with pre-pregs for these materials to gain widespread adoption. No one can predict just what that pre-preg breakthrough, or series of them, might be. But I *am* hopeful it will happen.

Enjoy the issue.

Paul Lazarus

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Photo of Club 420
Courtesy of Vanguard Sailboats

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LETTERS, ETC.

Structural Standards for Recreational Boats

To the Editor:

Robert Schofield's article "Structural Standards for Recreational Boats" (PBB No. 63, page 38) contains errors that could possibly lead some people to misinterpret the U.S. Coast Guard's regulations for commercial Small Passenger Vessels (SPVs). He states that "for a commercial vessel carrying more than 12 passengers, the USCG Subchapter-T or -S regulations govern the design and construction of the boat's structures."

If one were to check the Code of Federal Regulations, he or she would find that Title 46, Subchapter T, Parts 175-185 are for SPVs less than 100GT (gross tons) carrying more than six passengers, of which only one may be for hire. SPVs are broken into two classes under Subchapter T. One is for vessels less than 65' in length, known as T-S; the other is for vessels 65' or greater, known as T-L.

I don't know where the author came up with Subchapter S. This Subchapter is where all the stability regulations are located, except for SPVs—their requirements are found in their related subchapters.

The confusion may come from the fact that there is an additional SPV subchapter: Title 46, Subchapter K, Parts 114—122. This Subchapter is for commercial SPVs less than 100GT carrying more than 150 passengers, of which only one may be for hire, or the vessel has overnight accommodations for more than 49 persons.

Other than the misinterpretation of the correct regulatory sites, and the 12-passenger vs. 6-passenger requirement, I found the article to be constructive and informative. The oversights between 6 and 12 passengers has been cause for concern in the past. A lot of work and diplomacy are needed to ensure that we meet the safety concerns of the boating public.

Jim Bower, CWO4
Senior Marine Inspector
Marine Safety Detached Duty Office
U.S. Coast Guard

Rob Schofield responds:

Chief Bower is correct—"S" was a typo; I should have written "K." Principally, the article deals in structural matters, for which the 12- to 149-passenger limits for Subchapter T governs. The "six packs" (6- to 12-passenger vessels) are not subject to the same USCG structural design review as larger vessels.

Subdivision, stability, and safety equipment are another matter, however, and Chief Bower is right when he outlines the respective rules for T-S and T-K.

Young America

To the Editor:

Russell Bowler, vice president of Farr Yacht Design, and I were disappointed when we read Brooks Townes' "Rovings" item on the failure of USA-53 ("Broken Boat," PBB No. 63, page 10). It was highly speculative and not typical of the high-quality articles we have become accustomed to finding in your magazine.

I also want to correct the article for pointing out Bruce Farr as the designer. Farr Yacht Design was the principal designer for *Young America* and worked as part of a much larger design team. Furthermore, Bruce Farr was not the structural engineer for USA-53; Russell Bowler and several other *Young America* team members were responsible for the structural design.

Amy Fazekas
Farr Yacht Design, Ltd.
Annapolis, Maryland

For more on this, see "Oops" in Rovings on page 15—Ed.

Fire Protection in Marine Composites

To the Editor:

While reading Eric Greene's interesting article, "Fire Protection in Marine Composites" (PBB No. 62, page 78), it struck me that I once read about ceramic coatings developed for NASA's extensive and expensive steel structures at the Kennedy Space Center in Cape Canaveral, Florida. The coatings were created to work as anti-corrosion protection against the relentless salt and air at the Kennedy complex.

Ceramics, as we all know, are applied just about anywhere and everywhere that people engage in the battle against fire and heat. Power plants are researching ceramic coatings for diesel and gas engines to enable higher thermodynamic efficiencies. In his article, Mr. Greene doesn't mention various ceramic developments for structural steel members. I wonder if some of NASA's anticorrosive paints could also be employed as thermo-retardants?

Stephen Kittredge
Innovations PDC
Portland, Maine

Eric Greene responds:

Usman Sorathia, head of the Fire Protection and Sea Survival Branch at the Naval Surface Warfare Center, Carderock Division, has evaluated ceramic coatings as fire-protection systems for composites for the U.S. Navy, and although results to date haven't been promising, I wouldn't rule out future developments in formulations that may perform better. For burn-through protection, ceramic coatings are traditionally too heavy to build up the thickness required to protect composite skin. Ceramics also tend to be brittle; this may not be compatible with composite structures, which tend to flex more than steel.

That said, ceramics may *indeed* find a role in limiting flame spread, and may enable a material to qualify as "fire restrictive," as per the International Maritime Organization's (IMO) High Speed Craft Code. The trick will be in getting good bond strength and sufficient burn-through resistance to pass the International Standards Organization (ISO) 9705 Room/Corner Test.

The marine industry continually benefits from aerospace technology transfer. Our challenge typically involves scaling up the size of the structure and scaling down the costs.

Designing for an Electrical Emergency

To the Editor:

As an electrical-system designer, I read Charles Husick's article with great interest ("Designing for an Electrical Emergency," PBB No. 62, page 7). It's not often that we see, in print, meaningful advice on yacht and boat *systems*, as opposed to construction.

No doubt others have commented on what we might call "slip-ups" in the diagrams that accompanied Charles's article. I'm sure they are due to the transposition from copy to printing press, and I wouldn't want to insult him by highlighting them.

The article was obviously written with smaller boats in mind (12V batteries), but the principles apply to larger vessels with 24V systems. I agree absolutely with the scheme proposed—with one small exception. The diagram shows the engine start batteries linked to the main bus, parallel to the house batteries. If this is indeed how Charles drew it, I have reservations about that.

In the first instance, prolonged use without charging would drain not only the house battery set, but also the engine start batteries, thus compromising engine startup.

When starting an engine, the electrical interference from the starter motors would be superimposed onto the domestic supply and the navigation/communication bus.

The volt-dip that occurs when the engine starter motor is first energized may show on the house supply, particularly if all batteries are low on charge.

I normally separate starting batteries from the house supply, but include emergency link switches. These would allow the two engine batteries to be switched in parallel, so that one backs up the other. Then there would be another switch between each engine battery and the house battery, to use as the last resort. This latter switch would normally be a "press and hold, spring release" type to avoid permanent paralleling.

In the case of electronic engine controls, a constant backup of supply can be obtained by supplying the power via diodes from both the engine start battery and the house battery.

The large sportfishing boat mentioned in the article that lost power to the engine-control system highlights the fact that where electronic controls are installed, there ought to be a purely mechanical stop control at the helm, operated by pull-wire as an override. On the 100' boats that I've been involved with, however, the length of run for a mechanical-wire stop system has been just too great, so it wasn't fitted.

My final observations relate to the number of buses Charles shows in his diagram. On each new-build I've been involved with, there has always been a struggle to obtain the space required for electrical distribution panels. Owners and designers have a misguided idea that all space within the hull is available for human occupation, but they also insist on lighting, air conditioning, telephones, hi-fi systems, and the like. When we get the room to install the panels where the poor crew can access them, we then have a fight to obtain the space to run the cables to and from them, because bulkheads and headliners need to be fitted tight up to frames. Anyone else recognize this problem? I could go on, but I'll spare you.

Eric W. Perryman
Freelance Electrical Design Engineer
(ex-Camper & Nicholsons Yachts, Ltd.)
Emsworth, Hampshire
United Kingdom

Chuck Husick responds:

The proposed system will work regardless of whether the voltage is 12V DC or 24V DC. I did not intend to show the engine start batteries as they appear in the diagram; they were to be isolated, with manual paralleling switches to use when, and if, necessary. Clearly, paralleling the start batteries would defeat much of the value of the system in ensuring reliable power delivery.

In my opinion, powering the engine controls from two separate batteries via diodes is a good idea, but perhaps not quite as bulletproof as my proposal, because the system I suggest forces a test of the back-up power source on each start-up cycle, much as the fire protection circuits in an aircraft are checked for voltage and continuity each time the master power switch is closed. I agree completely that a mechanical fuel cutoff, or other means for shutting down the engine must be provided. There are many ways to accomplish this.

In my opinion, the proposed bus system need not occupy more space than most conventional arrangements. There don't need to be more circuit breakers than are ordinarily used. What's important is the way in which the various buses are tied into the main battery buses.

The Dreaded Itch

To the Editor:

I'm sure that many of your readers who work with fiberglass would be most interested in learning about worker safety, health, and the dreaded fiberglass itch. What are some of the causes, health hazards, strategies for prevention, cures, and safety and protective equipment regarding this irritating phenomenon?

What, technically, causes the itching sensation on a microscopic level? What are some of the long-term or cumulative health effects from skin contact or inhalation? Are there any comparisons between glass, Kevlar, or carbon fibers and the carcinogenic asbestos fibers? Is it possible for one's skin or respiratory system to become sensitized over time? And, what happens to those resin-coated slivers that eventually disappear into fingers and hands after handling laminate parts before they're ground? I suspect the body breaks down these little chemically coated intruders. Surely the absorption of these chemicals can't be good for you. What price does the body pay over time?

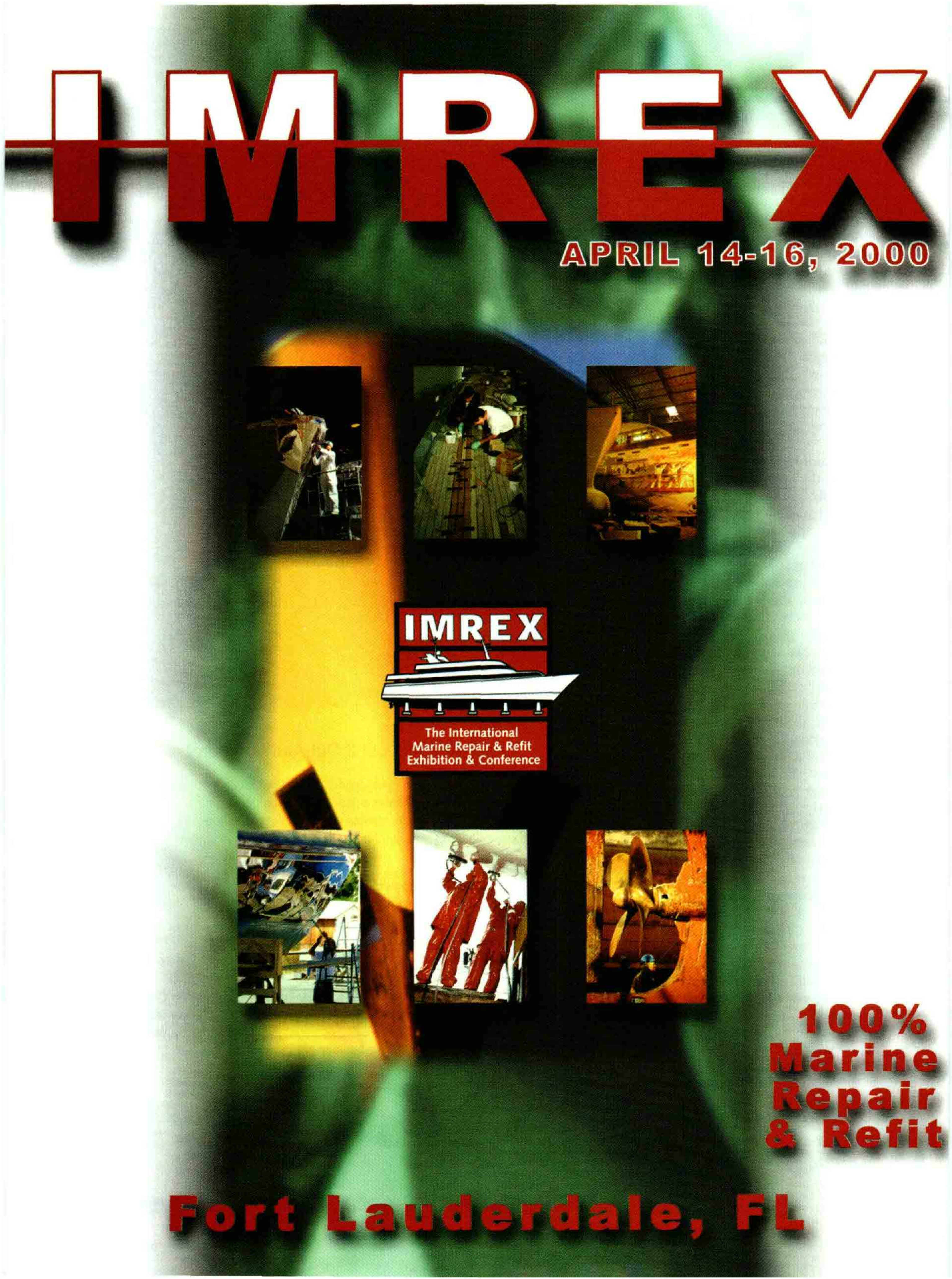
What are the health effects of resin-vapor inhalation and resin absorption through unprotected skin, such as when doing layup work without gloves or respirator? On one occasion some years ago, after laying up without respirator or gloves, my entire body smelled so strongly of resin that upon arriving home, my girlfriend (who usually commented on the odor) complained she could actually smell resin on my breath and accused me of "now drinking the stuff!" What happens here? Is it possible to absorb resin through the skin, and for lungs to become so saturated with vapors that one would exhale them for a period of time afterward?

Let's talk about protective clothing and safety equipment. What do other technicians wear when grinding fiberglass and laying up? What protective equipment do manufacturers have available? Personally, I've found a reasonably effective clothing combination for grinding: disposable Tyvek-type coveralls with wrist and ankle elastics, and rubber gloves. Because my brow, my neck, and the section under my eyes are especially sensitive, I use a full-coverage sandblaster's-style Tyvek hood with a clear lens and bib collar, which can be supplied with filtered shop air. Of course, convenience, portability, practicality, ergonomics, and impaired vision clue to scratched or dusty lenses are continual problems with this type of equipment.

Finally, I wonder about different methods for curing the itch: showering, scrubbing, steam bath, sauna, and vigorous exercise. For myself, sweating seems to be the only cure, but our cooler northern climate is not necessarily conducive to working up a sweat. I've discovered that even after several days, and showers, I can still be carrying around the potential for a faceful of itch.

Paul Dean
Dean Designs
Vancouver, British Columbia
Canada

PBB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IMREX SEMINAR PROGRAM

FRIDAY, APRIL 14

9:30 - 11:00 a.m.

101 Using Sub-contractors
James C. Merrill, Michael Moore, Susan Engle

102 Preventive Maintenance Training for Crew
Bruce Pfund

103 Eliminating Structure-borne Noise in a Workboat Refit
Marcus Murray, Owner/Operator Representative

11:15 a.m. - 12:45 p.m.

201 Sound Insulation: Methods & Materials
Eric Fiske, Rives Potts

202 Case History: *Avalon 109'* Interior Refit
Ron Holland

203 Software: Tools for Repair & Refit Success
Bruce Hays, Rolf Oetter

3:00 - 4:30 p.m.

301 Refitting Sailboats with Carbon Masts
Ben Sprague

302 Managing a Paint Job
Michael Bach, Ian MacDonald

303 Transom Extensions: More than Cosmetic Surgery
Andre Cocquyt, Cortland Steck

SATURDAY, APRIL 15

9:30 - 11:00 a.m.

401 Managing Composite Construction for Repair & Refit
Dana Greenwood, Mike Taylor

402 Estimating The Cost of Repair and Refit
Laury Deschamps, David King

403 Lightweight Interiors
Andre Cocquyt, Paul Bennett

11:15 a.m. - 12:45 p.m.

501 The MCA's Effect on U.S. Yachts
Anna Bradley, Derek Novak

502 Corrosion Prevention and Solutions
Ward Eshleman

503 The Boatyard Experience
Jim Bronstien

3:00 - 4:30 p.m.

601 Yacht Classification Societies and The MCA
Derek Novak, Anna Bradley

602 Hull Extensions: What Happens Below the Waterline
Walter Hahn

603 Refitting for Speed
Rick Hyer

SUNDAY, APRIL 16

9:30 - 11:00 a.m.

701 Change Orders and Contracts
Fred Kirtland

702 Ensuring Repower Performance from Concept to Delivery
Donald McPherson, Brian King

703 Yacht and Megayacht Surveyors: Are Specialists Required?
Bruce Pfund, Ron Reisner, Mike Taylor

11:15 a.m. - 12:45 p.m.

801 Computerized Monitoring & Control Systems
David Leone, Chuck DeAngelo

802 'Base-lining' the Modern Yacht
Bruce Pfund, Val Jenkins

803 Teak Deck Replacement
Joseph Filipowski

3:00 - 4:30 p.m.

901 Avoiding Fairing Problems
Ken Hickling

902 Case Study: Extension & Structural Refit of a 60' Motoryacht
Kin Biddick

903 Steel, Aluminum and Structural Integrity
Merrill-Stevens Dry Dock Company

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Saturday, April 15	10:00 a.m. - 5:00 p.m.
Sunday, April 16	10:00 a.m. - 4:00 p.m.

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- ☐ **F**. Project manager
- ☐ **G**. Naval architect or yacht designer
- ☐ **H**. Interior decorator
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2. If you have answered A - E above, please indicate:

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- ☐ **C.** Year of yacht or ship construction: ____________
- ☐ **D.** Construction material (steel, etc.): ____________
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Friday, April 14	9:30 a.m. - 11:00 a.m.	101	102	103
	11:15 a.m. - 12:45 p.m.	201	202	203
	3:00 p.m. - 4:30 p.m.	301	302	303
Saturday, April 15	9:30 a.m. - 11:00 a.m.	401	402	403
	11:15 a.m. - 12:45 p.m.	501	502	503
	3:00 p.m. - 4:30 p.m.	601	602	603
Sunday, April 16	9:30 a.m. - 11:00 a.m.	701	702	703
	11:15 a.m. - 12:45 p.m.	801	802	803
	3:00 p.m. - 4:30 p.m.	901	902	903

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ROVINGS

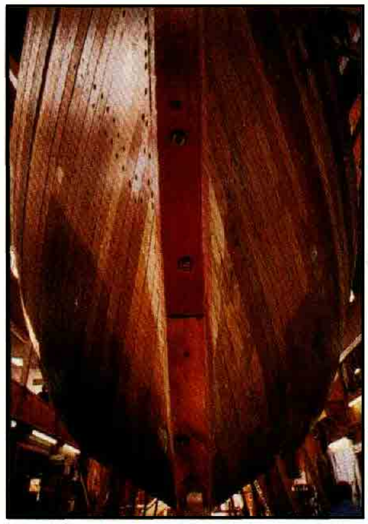
by Brooks Townes

Exceptional Project

The 81' *Amistad*, the first large new vessel ever built at Mystic Seaport Museum in Connecticut, will soon be headed for sea. This *Amistad* is not quite a replica of the original slave ship of the same name, believed to have been built in Cuba. The *Amistad* story, you may recall, was made famous to the general public-only recently by movie director Steven Spielberg. But to faithfully recreate a tops'l schooner from an 1839 slave mutiny would have rendered it fairly useless as an educational sailing craft, owing to modern U.S. Coast Guard regulations.

The museum-built boat was constructed *by* some of the test traditional-vessel restorers in the country, under the direction of shipwright Roger Hambidge. The design came from Andrew Davis and Peter Bourdreaus of Tri-Coastal Marine, a group that's carved quite a niche for itself in old-vessel restorations and upgrades. On a purpleheart keel measuring 50' x 14" and carrying 44,000 lbs of scarfed-in cast-lead ballast, *Amistad* (meaning "friendship" in Spanish) has live-oak frames molded 9" at the keel tapering to 4½" at the deck. White-oak planking 2½" thick was used below the waterline and longleaf yellow pine above, all bronze-fastened.

The old slaver will be a centerpiece during the beginning of a big push by Mystic Seaport to gain wider exposure for U.S. maritime history through a program called "Voyages: Stories of America and the Sea," scheduled to begin in mid-June, with many new-Museum displays. The museum expects heightened interest in its program due to a slew of sailing events scheduled for this summer. One of these is "Operation Sail 2000," featuring most of the world's remaining square-riggers and large schooners sailing into New York Harbor on July 4. Mystic's *Amistad* will be among them.



MYSTIC SEAPORT MUSEUM

Mystic (Connecticut) Seaport's shipyard crew did themselves proud, building a near-replica of the 81' Amistad, *a circa-1830s tops'l schooner. An historic slave-mutiny aboard the original vessel was the subject of a recent Steven Spielberg movie.*

Mystic Seaport Museum, 75 Greenmanville Ave., P.O. Box 6000, Mystic, CT 06355-0990 USA, tel. 888-9SEAPORT, Web site <www.mysticseaport.org>.

Winging it

Australia's Incat continues to surprise. There are some 90 big Incat wave-piercing ferries out there, ranging in size from 74m (242.7') to 96m (315'), speeding around nearly every part of the watery world (see Rovings, PBB No. 53, page 13). Incat brags that its advanced computerized design-process technology is the same used by DaimlerChrysler and BMW. Then there's the wing-craft, one of Incat's latest experiments.

Incat has been working quietly on this almost-flying boat. The idea is to eventually build large high-speed wing ferries where passengers, vehicles, and freight ride *inside* a huge swept-back airfoil spanning three narrow displacement hulls—a kind of high-powered semi-flying trimaran.

Incat Chairman Robert Clifford reported on a test run he made this winter aboard a scaled-down prototype. Its hulls are staggered like wheels on a tricycle, each hull being 6m (19.7') long. The prototype's wing is some 20m (65.6'), the whole thing powered by large outboards. When Clifford took her out this time,

INCAT AUSTRALIA

Next-generation Incat ferries may look like this scale-model being tested by company chairman Robert Clifford, who reports high speeds and good maneuverability from the unusual swept-wing design.

CMVDR/HALIFAX

The towing tank and related services (model building, performance analysis) at Halifax, Nova Scotia's Center for Marine Vessel Development and Research are, says Canada's trade commissioner, "priced for the small-boat building industry."

she'd been newly fitted with ailerons, end-plates on the wingtips, spray deflectors, and weight was re-distributed. It seems, judging by his report in a company newsletter, he had quite a ride. In previous trials, the experimental prototype reached 49 knots. Clifford said he was "startled to immediately experience a marked jump, first, in low-speed performance.

"Then, at around 30 knots, the craft lifted evenly and the center hull was touching the water only intermittently. The bows of the side hulls were dry for at least one third of their length...With full power on, I cranked on the steering to make a 30-degree turn, the craft probably doing in excess of 45 knots. The G-force was substantial, but the craft was level fore and aft and athwartships. The starboard hull on the inside of the turn was reported to be prop-riding."

With the helm centered, Clifford noted a "sharp increase in speed"—to more than 60 knots. "The experience was exhilarating, very smooth and quiet...The hulls were virtually not touching the water," he said, adding. "Never before has a heavy displacement high-speed craft traveled so fast with so little power."

Clifford said he prefers to call the wing "swept back and skewed" rather than a delta wing. In answer to Rovings' questions, Judy Benson. Incat's public relations person, quoted Clifford as predicting that "the first full-scale unit should carry about 200 passengers, followed by a larger version for 600 passengers and 200 cars, this to be followed by a 1.000+ passenger version that could take more than 1,000 tons of cargo long distances."

On commercial runs, the wing should cruise at 80 to 100 knots. Clifford said. The commercial applications would be varied and worldwide, "but only where the operator or passengers are prepared to pay a premium for that speed," Benson told us.

"The craft uses Wing-in-Ground-Effect principles," she said, "although you need to understand that at all times the craft is effectively a ship and not an aircraft. Note that the eventual full-sized vessel would be powered by waterjets; to be effective, a waterjet must have a continual flow-through of water, so the hulls must stay in contact with the water. The wing shape assists the goal of speed with economy of power.

"The development of this project will be gradual. Much research and development is still to be completed. Robert Clifford has projected it will be three years before the first version, with five years between upgrades," she said. Full size wing-craft are to be powered by gas turbines running advanced waterjets.

As we learn more about this, we'll pass it on.

Incat Australia Pty. Ltd., 18 Bender Dr., Hobart, Tasmania 7009 Australia, tel. +61 3 62 730 677, fax +61 3 62 730 932, Web site <www.incat.com.au>.

Tank Tows

As more and more designers and builders use model-towing tanks, there's one in Halifax, Nova Scotia, that has not received much publicity. It is the Center for Marine Vessel Development and Research (CMVDR), affiliated with Dalhousie University. This facility was not included in our list of towing tanks, published last year (See "Model Testing—Part 2," PBB No. 56, page 26).

CMVDR offers modern equipment for determining accurate scale weights and balances, and "a strong capability in the computer simulation and analysis of boat performance," said Canada's Trade Commissioner Mark Fletcher, adding that the Halifax tank is "priced for the small-boat building industry." The center's staff, directed by Dr. Charles Hsiung, will build models as well as test and analyze them.

Center for Marine Vessel Development and Research, P.O. Box 1000, Halifax, Nova Scotia B3J 2X4 Canada, tel. 902-494-3918, fax 902-423-9734, e-mail <cmvdr@dal.ca>.

Panel Testing

Gougeon Brothers Inc. has earned ASTM (American Society for Testing and Materials) approval for the device it developed to conduct structural tests on composite panels. Called a "Hydromat," it accurately simulates

GOUGEON BROTHERS INC.

Epoxy resin manufacturer Gougeon Brothers Inc. has won ASTM approval of its Hydromat device. The apparatus' structural tests of composite panels closely simulate dynamic loads in marine conditions.

the loads to which a hull is subjected when traveling through water, and has been in use for some time. What's news is the ASTM approval, giving the device and its tests more credence.

Gougeon's apparatus applies water to sample hull panels, either single-skin or cored, replicating loads and bending forces more realistically than simple bending tests.

The tool was invented by Gougeon engineer Bill Bertelsen. It's a self-contained pressure bladder made of two *24"* squares of industrial belting sealed at the edges to hold water. The bladder is pressed against a similar-sized test panel, causing it to bulge, while sensors measure deflection and contact pressure. The device can repeatedly load a panel to determine fatigue resistance, and is good for testing panels from ¼" to 2.5" thick. (For a detailed look at the Hydromat, see "Rethinking Composites Testing," PBB No. 34, page 42.)

Gougeon Brothers Inc., P.O. Box 908, Bay City, MI 48707 USA, tel. 517-684-7286, fax 517-684-1374, Web site <www.westsystem.com>.

Florida builder Kick Dec KY/S commissioned to build a special edition ofbis stock 24-footer, designed and molded by Paul Morgan. The deluxe version ofDee's Marinetech commercial and sportfisherman is powered with twin Yanmar turbodiesels. andfinished with plenty ofteak and custom-made hardware.

Boulevardier's Boat

You see them cruising slowly through Fort Lauderdale nights in Ferrari 308s and out in San Francisco on Ducati bikes. In L.A., they favor Corvettes, stopping at cafes for cappuccinos. Now apparently *boulevardiers* are on the water. Maybe they have been for a while and we didn't notice. Anyway, Marinetech Inc., of Florida, is building a boulevardier's boat—though it looks rather sensible and conservative.

Normally a builder of a few stout straightforward $40,000 FRP fishing boats each year, Marinetech's Rick Dee recently finished custom-building a rich man's plaything costing three to four times that. "The owner's a diver, fisherman, and restaurant-goer in Bermuda with several places he travels to by boat," Dee said. "It took us six months to take what he had in mind and make it work for day or night cruising, fishing, diving, water-skiing, and entertaining. There are no real accommodations below in this 24-footer, except a head and place to change, but this is totally custom, from a one-off mold for the interior and deck."

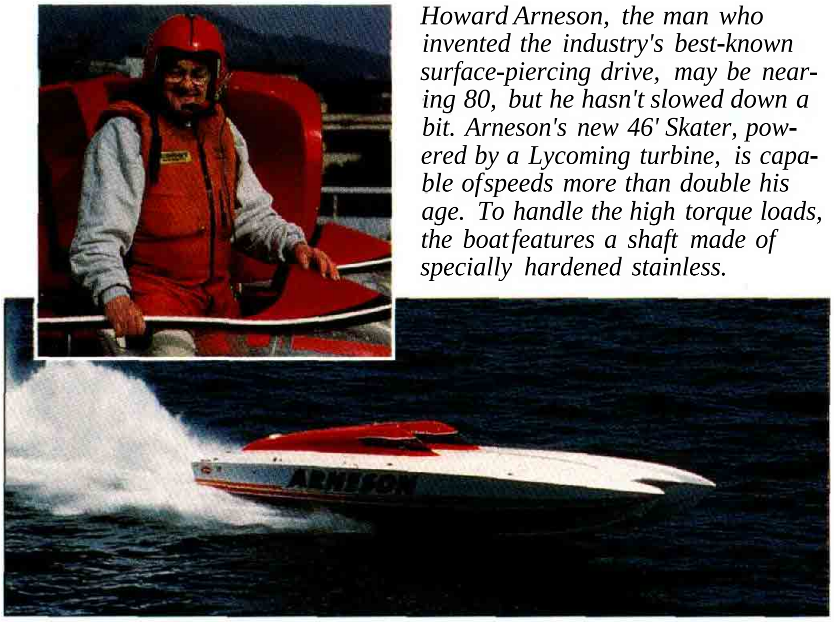
Only the solid-layup hull is Marinetech's standard part, a good-looking traditional Florida saltwater fishboat model, molded by Paul Morgan of Naples, Florida, who designed the hull several years ago. "It just works really well," Dee said. "It's comfortable, dry, stable, and smooth riding."

With the new fancy boat, Dee said, "you lose sight of what you're doing after about eight months on a job like this until somebody comes along and says, 'What are you *doing!?* That's outrageous!'" He still sounded amazed by the job as the project neared completion.

What Dee has done is give his boulevardier a custom vertical-grain Burmese teak deck, all custom-cast and polished (not chromed) brass or bronze hardware, and one of VDO's new 4" all-in-one cluster gauges from Germany set in a carbon fiber dash that hydraulically lowers into a trick console. There's a one-scoop raw-water pickup that feeds a single sea-chest serving twin 250-hp, 6-cyl Yanmar turbodiesels. For shelter, the boat sports a custom aluminum Bimini top 11' long, fitted with a control station. There are underwater lights aft below the swim platform, and 4" straight-pipe exhausts; people are sure to hear Dee's client arriving, and they'll see his wake when he leaves.

For flat-panel parts, Dee favored Mantex composite sheets instead of epoxied and/or glassed plywood. Mantex comes in 4' x 8' sheets in a variety of thicknesses; a *½"* sheet costs $150—not bad. Dee figures, when you factor the cost of materials and labor to coat plywood. Mantex, used by airplane and truck builders, is made with foamed resin containing fiberglass hairs. Dee says he's found Mantex has the same density as wood. "You can screw into it, glass to it—whatever you'd normally do with plywood—and it doesn't rot or absorb water. I use it for lots of things. Other than the deck and steering wheel, the only wood in the boat is close-grain Norwegian spruce inside the engine stringers. This spruce is so dense it'll burn out a drill bit if you're not careful."

Dee is a clever guy always ready to custom design and fabricate. He builds his own flush-mounted underwater lights that require just a 5" hole. They are sealed from the outside and allow bulbs to be changed from inside the boat. "We've also mounted underwater cameras in hulls, the lens surrounded by infrared LED lights, which are great for several feet in clear water, for seeing reefs at night, or, mounted in the transom, for watching a fighting fish underwater as



Howard Arneson, the man who invented the industry's best-known surface-piercing drive, may be nearing 80, but he hasn't slowed down a bit. Arneson's new 46' Skater, powered by a Lycoming turbine, is capable of speeds more than double his age. To handle the high torque loads, the boat features a shaft made of specially hardened stainless.

it nears the boat. I've also made hydraulic transoms for dive boats: push a button and the transom folds out to become a swim platform."

The Mantex panels Dee uses come from AVMAR Acoustic Design, a Florida outfit manufacturing a variety of composite products that seem like bright ideas. Among them are "Acoustiboard," "Acoustiwall," and "Acoustideck"—laminated panels that combine structural polyester foam with closed-cell acoustic foam for bulkheads and decks to control vibration, noise, and temperature transfer. The company also makes frameless window systems (laminated or tempered, flat or curved), cored structural fabrications, and electrical membrane switches.

Marinetech Inc., 5750 N.E. 7th Ave., Boca Raton, FL 33487 USA, tel./fax 561-997-6254, e-mail <marinetec@hotmail.com>, Web site www.marinetech.com. AVMAR Acoustic Design Inc., 1786 N.W. Madrid Way, Boca Raton, FL 33432 USA, tel. 561-361-7062, fax 561-361-7063, e-mail <rasimmonsl@aol.com>.

Speed Thrills

Howard Arneson at 78 is as irrepressible as a five-year-old. He still delights in cooking over the water at 175 mph in his latest offshore racing boat, a big gas-turbine-powered catamaran. The Arneson surface-drive inventor has long been a common sight blasting around San Francisco Bay and out the Golden Gate in one or another of the 17 raceboats he's conjured up or acquired over the years.

Arneson's latest is a "Skater"—the name for a line of highly regarded, high-performance boats built by Douglas Marine in Michigan. Douglas' Peter Hledin said his shop has delivered several boats to Arnie; this one, measuring 46' x 11', was built of vacuum-bagged S-glass, carbon, Kevlar, and epoxy over balsa cores. It weighs more than 10,000 lbs empty (it carries 1,000 gallons of fuel) and is powered by a 4,500 hp Lycoming turbine, similar to a Chinook helicopter's engine. A press release from Carpenter Specialty Alloys—fabricators of Arneson's new high-strength stainless steel prop shaft—landed on your Rovings writer's desk and brought up the indelible memory of a ride with Arneson. Years ago, my wife and I stopped by a funky oyster shack on the Petaluma River north of San Francisco, and there at the dock was Arneson with an earlier, open-cockpit fast cat. While I scrutinized the boat, he walked up and chatted.

"Wanna take a ride?" he asked. Is a snake's ass close to ground? Of course we did! Minutes later, in helmets and goggles, my wife and I were idling out of a slough toward the river with Arneson at the helm. Upon reaching the river, the big cat surged onto plane and we were off, running 120 mph down this curving river maybe 30 yards wide. It felt more like a powerful race car than any boat, the ride jiggly and purposeful over a solid wind-chop, but it wasn't harsh. Then we made a U-turn in mid-river at 60 mph, the big cat remaining as flat as road-kill—no sliding, no fuss. Arnie shot us upriver again at 120 mph, and the ride was over too soon, but it was clear his composite cat handled predictably. It seemed as reliable as a daily-driver car.

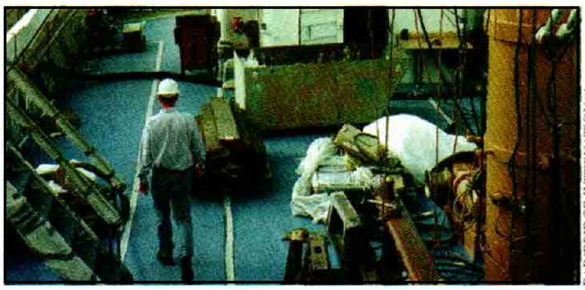
This latest Arneson boat also accelerates *right now*, maybe quicker. It's a single-screw boat, which means tremendous running gear loads, and that's how Carpenter's alloys came into the picture. Arneson's first shaft for this Skater sheared off and went to the bottom with the prop. It was made of 17Cr-4Ni precipitation-hardened stainless, finished to 2.5" in the center and tapering to 1 7/8" at the ends. Zeiger Industries in Ohio made Arnie a new one of custom 465 stainless from Carpenter, good for an ultimate tensile strength of some 260 ksi.

Arneson Industries, 47 Mill St., San Rafael, CA 94901 USA, tel. 415-485-0788, fax 415-485-1293. Douglas Marine Corp., 6780 Enterprise Dr., Douglas, MI 49406 USA, tel. 616-857-4308, fax 616-857-1606. Zeiger Industries, 4704 Wiseland Ave. S.E., Canton, OH 44707 USA, tel. 330-484-4413, fax 330-484-0267. Carpenter Specialty Alloys, P.O. Box 14662, Reading, PA 19612-4662 USA, tel. 610-208-2197.

Temporary Protection

There's nothing very sexy about deck covers and bubble-wrap, but a picture of an entire destroyer deck, or the teak deck of the U.S. Coast Guard's barque *Eagle* covered in blue, does tend to catch the eye. What all that blue is, is a product called


CENTURY



BAINBRIDGE INTERNATIONAL

The blue decking material on these two different vessels is a product line made by Bainbridge. The flame-retardant temporary protective coverings have earned testimonials from a number of top yacht yards and shipyards, and comes in many forms for the variety of applications required by a typical large-scale construction or repair project.

"cover(**guard**." Yes, that's how it's spelled: lower case, left parenthesis, half bold. Bainbridge International sells cover(**guard** as a "flame-retardant protection system" to take the place of cardboard, plain old polypro sheets, or heavy paper taped down in often-futile attempts to keep decks clean while workers are clomping all around and dropping tools. Bainbridge lists a who's-who of yacht yards using its materials, including Palmer Johnson, Hatteras, Broward Marine, Derecktor Gunnell, and Westport Shipyard.

The stuff comes in sheets, in tapes, adhesive-backed or not, and in various thicknesses with or without a diamond-plate nonskid pattern molded in. A new fire-curtain cover(**guard** for flame and smoke control, or for wrapping areas for welding, is also available, as is scaffold draping for containing paint, bead- or sandblasting, or welding spatter. Variations are made for covering bulkheads and fixtures. It's neat stuff, some of it similar to self-adhering products from other manufacturers such as 3M (see "Tools of the Trade," PBB No. 29, page 58).

Bainbridge International, 255 Revere St., Canton, MA 02021-2960 USA, tel. 781-821-2600, fax 781-821-2609, Web site <www.covergard.com>.

Oops!

The item in last issue's Rovings about the *America's* Cup boat *Young America* folding during trials was printed by mistake. A second, more up-to-date version of that item was ready to go to press—then got left out in a last-minute production rush. It doesn't much matter now since that story has kept on developing. For a fuller analysis, *Professional BoatBuilder* is scheduling an article in an upcoming issue covering what happened to *Young America* during the blustery elimination races for this year's *A*-Cup.

Meanwhile, since *America's* Cup boats are so full of leading-edge technology, plenty of people are dissecting the raceboats' structural successes and failures. One is Alex Kozloff, consultant on composites in marine applications and a lecturer in the University of California at Los Angeles' Engineering Short Course on Honeycomb Sandwich Structures. Kozloff will take up *Young America's* mishap in a May 16-19 course in Los Angeles.

UCLA Engineering Extension, 10995 Le Conte Ave., Los Angeles, CA 90024 USA, tel. 310-825-5050, e-mail <mhenness@unex.ucla.edu>.

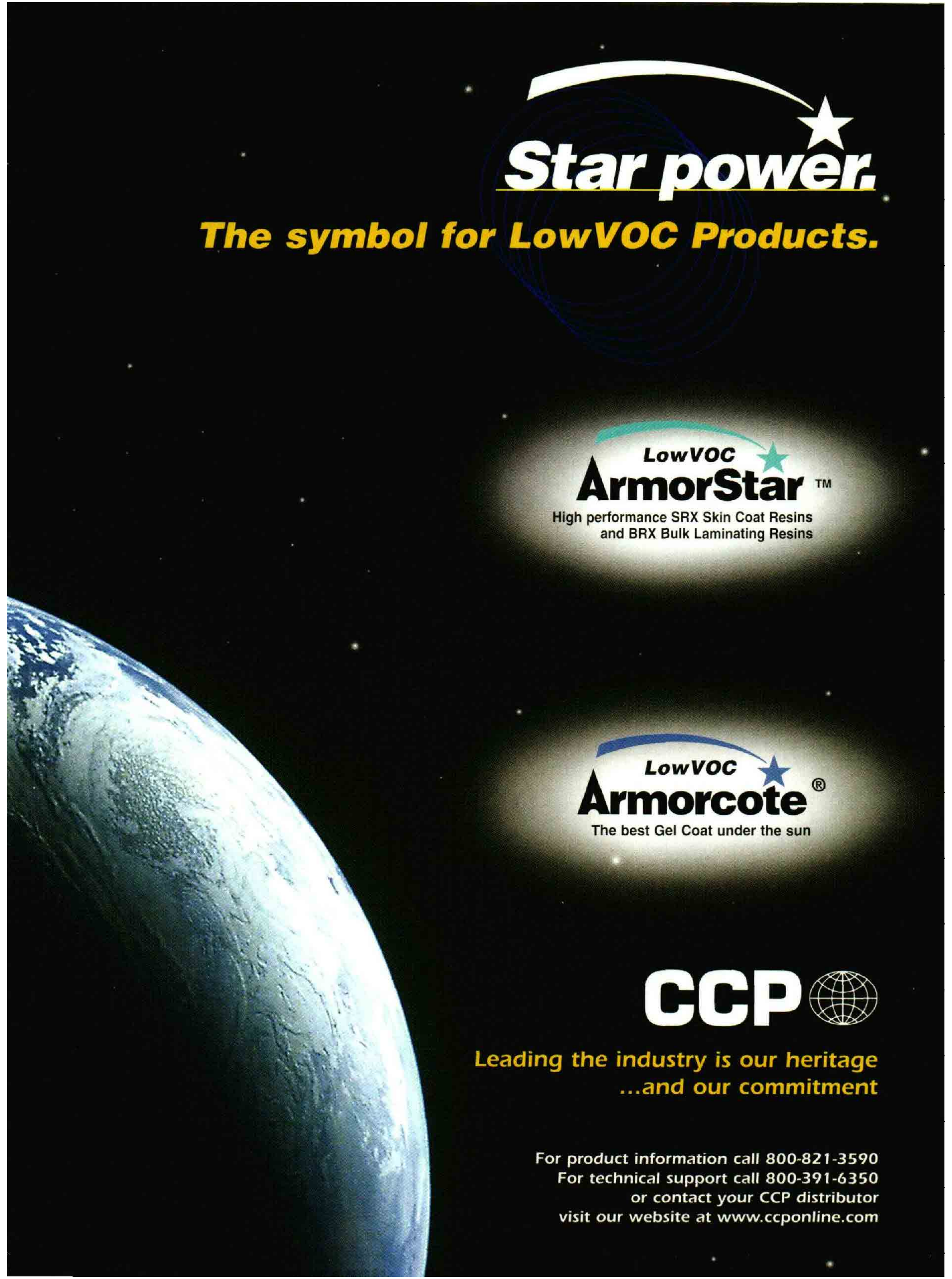
A Hard Row

Tori Murden of Louisville, Kentucky, is the first American and first woman ever to row across the Atlantic alone. She left the Canary Islands last September 13 and arrived in Guadaloupe December 3. It was her second attempt: in June '98, she had set off from Cape Hatteras, North Carolina, eastbound across and she made it to within 900 miles of France when she was bashed unmercifully by Hurricane Danielle. Her 23' boat capsized 11 times in 12 hours and pitchpoled once.

"The wind howled like a train whistle," she wrote after her first attempt. "The periodic silences were worse...Head over heels, heels over head; wood, fiberglass, flesh and bone, all interacted in unnatural ways. As the violent motion slowed, the whistle of the wind would tell me that I had a few seconds to sort things out before the next onslaught...Am I on the ceiling or on the floor?" At last, 91 days out, she hesitated, then activated her EPIRB. She and her boat were soon plucked aboard the freighter *Independent Spirit.*

Murden isn't one to quit. She earned an undergraduate degree from Smith College, a masters from Harvard, and a law degree from Louisville. She was the first woman to climb Lewis Nunatuk in Antarctica, and the first woman and first American to ski to the geographic South Pole. So another attempt across the Atlantic seemed in order—with a new boat. And that's how she came to talk with yacht designer and PBB contributor Eric Sponberg.

Her old boat, *American Pearl*, had been shipped back to the United States pretty beat up—not from the sea, but from rough handling by freight movers. At 23'4" long and 6'3" wide, it weighs about 980 lbs empty.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ERIC SPONBERG

Marathon rowing demands a strong back, a strong will, and a strong boat. Tori Murden could account for the first two: Newport-based naval architect Eric Sponberg helped with the third. He lightened and modified Murden's existing boat, enabling her to become the first American and first woman to row across the Atlantic alone.

A new boat could be lighter (maybe 600 lbs empty, 1,800 loaded) and designed with more consideration for the tumbling it and its 6'-tall skipper would likely get. It would be of modern composites. Sponberg hypothesized, and he made a sketch of a 24-footer.

Designing an ocean marathon rowboat presents interesting problems: Cross-ocean rowers must take advantage of winds and currents, because a lot of intercontinental rowing is, as one expert once put it, "enhanced drifting." If trade winds and easier calm-water rowing are what you want, then high and shallow are good attributes in a hullform. But it will be prone to roll early and return upright late. A deep hullform and light weight are somewhat conflicting requirements, but that type of boat, fitted with turtleback ends for shelter and buoyancy, should more easily right itself. Sponberg leaned toward a compromise shape on the deep side.

But, as it turned out, there wasn't time enough to build a new boat: another woman was set to row the Atlantic and Murden was determined to be first. "Tori phones me and says, 'Please come to Louisville and tell us how to fix this boat,'" Sponberg said. "I get off the plane and she and her boyfriend stick a big powered cutting-wheel in my hand and say, 'Here, get to work!'" For starters, the designer-turned-rebuilder made the daggerboard narrower and deeper. "We weighed everything we cut off. We also used foam core for all the new pieces."

Sponberg couldn't do much about hull shape and draft, but he did help the boat shed weight, found 4" more headroom for Murden inside the ends, and he got rid of web framing that had given her many bruises. The rest is now, as they say, history. For more on Murden's feat and on the general boom in open-water rowing, check out the Web site <www.openwater.com>.

Eric Sponberg Yacht Design Inc., P.O. Box 661, Newport, RI 02840 USA, tel. 401-849-7730, fax 401-849-7898, e-mail <ewsponberg @cs.com>.

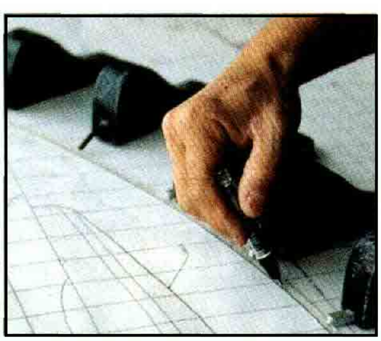
Better Than Studyhall

Kids can win something with their boat drawings now. When I was a kid and drew boats in homeroom and Studyhall, all I got was glared at by the teacher. Now there are contests for kids drawing good boats.

One that sounds interesting is sponsored by the Marine Design Resource Alliance, a trade group of interior designers, marine fabric makers, and adhesive purveyors, among others. Your crotchety Rovings writer admits he's wondered about this group that says it aims to help "grow boating," but the Alliance appears to have some worthwhile activities.

Consider, for example, this contest called "Draw Kids Into Boating." It's reportedly the third such free contest sponsored by the Alliance. American kids in grades four through six are encouraged to draw "boats of the future." The drawings "are judged by professional boat designers to pick one winner and four runners-up from each school. Each winner gets a radio-controlled model speedboat." One national winner gets the Grand Prize—a real boat, motor, and trailer. Winners are to be announced at IMTEC (International Marine Trades and Exhibit Conference) in Orlando, Florida, next August. Deadline for entering this year's contest is May 1. Tell your kid's teacher to contact:

Joe Taylor Ford, Marine Design



Know a kid who loves boats? A design contest specifically for grade-schoolers, sponsored by the Marine Design Resource Alliance, has appealing prizes—and a May 1 entry deadline. See the item at right for details.

Resource Alliance, Emerson Falls Business Park, St. Johnsbury, VT 05819 USA, tel. 802-748-4472, fax 802-748-1939.

Design Lite?

It you're not a kid but want a better idea of yacht design principles, then Westlawn School of Yacht Design has a new course-offering it calls "Yacht Design Lite." Sounds like a new beer, but Westlawn has proven its worth over the years with a list of notable graduates. This particular course is for "marine industry personnel who need to understand the principles, but do not aspire to become yacht designers," said Westlawn's Jim Backus.

Design Lite "covers fundamentals from a production company perspective through the study of subjects including hydrostatics, stability, resistance, hull lines, arrangements, systems and equipment, and fundamentals of fiberglass design."

There aren't many drawing assignments, so individuals not blessed with great drafting or drawing ability can handle the lessons. The whole course can be completed in less than a year. Backus said, and anyone who then takes the full Westlawn program will get credit for success in Design Lite.

Westlawn School of Yacht Design, 733 Summer St., Stamford, CT 06901 USA, tel. 203-359-1500, Web site <www.westlawn.org>.

MILES THOMPSON

This clever and classy new four-way batch hardware makes it possible—at last—to take best advantage down below of the day's weather.

Any Which Way

Designer E. Barton Chapin III and naval architect Jay Paris have conceived skylight hatch hardware that allows hatch covers to be opened in four directions, yet tightly seal down over sill hardware that sure looks watertight. There is no hinge; the entire frame acts like one. The hatch is fitted with an elegant mechanical leg, or prop, that's reportedly easy to operate, and that holds the hatch open to any angle in all four directions, or fully closed and locked. The hatch cover and prop can also quickly be removed entirely for loading or unloading large objects through the opening, and the whole system can be fitted to any size hatch. Though we've no first-hand experience with this rig built by Lone Star Maritime, for anybody who's suffered with leaky skylights and hatches that never seem to open the way you need them to, this thing looks pretty good.

Lone Star Maritime Inc., 2121 Edwards St., P.O. Box 7692, Houston, TX 77007 USA, tel. 713-866-8517, fax 713-868-2441.

Three-Dot Journalism

This must be a good book because my San Diego pal Joe Ditler says it is. Joe, one of the brains at the excellent San Diego Maritime Museum, is pretty sharp—and he's fussy. The book is *Primitive Benchmark* by San Diego naval architect Jerry Selness. Joe says it "advances understanding of sailboat speed...and transcends all previous sailing assumptions and conclusions with a new mathematical-physical theory. It's not exactly light bedtime reading." And it's apparently not for the mathematically challenged, either. "But for the really serious." he says, "it's valuable." Windward Enterprises, P.O. Box 928188, San Diego, CA 92192 USA, tel. 619-225-1707, Web site <www.wegt.com>.

• • •

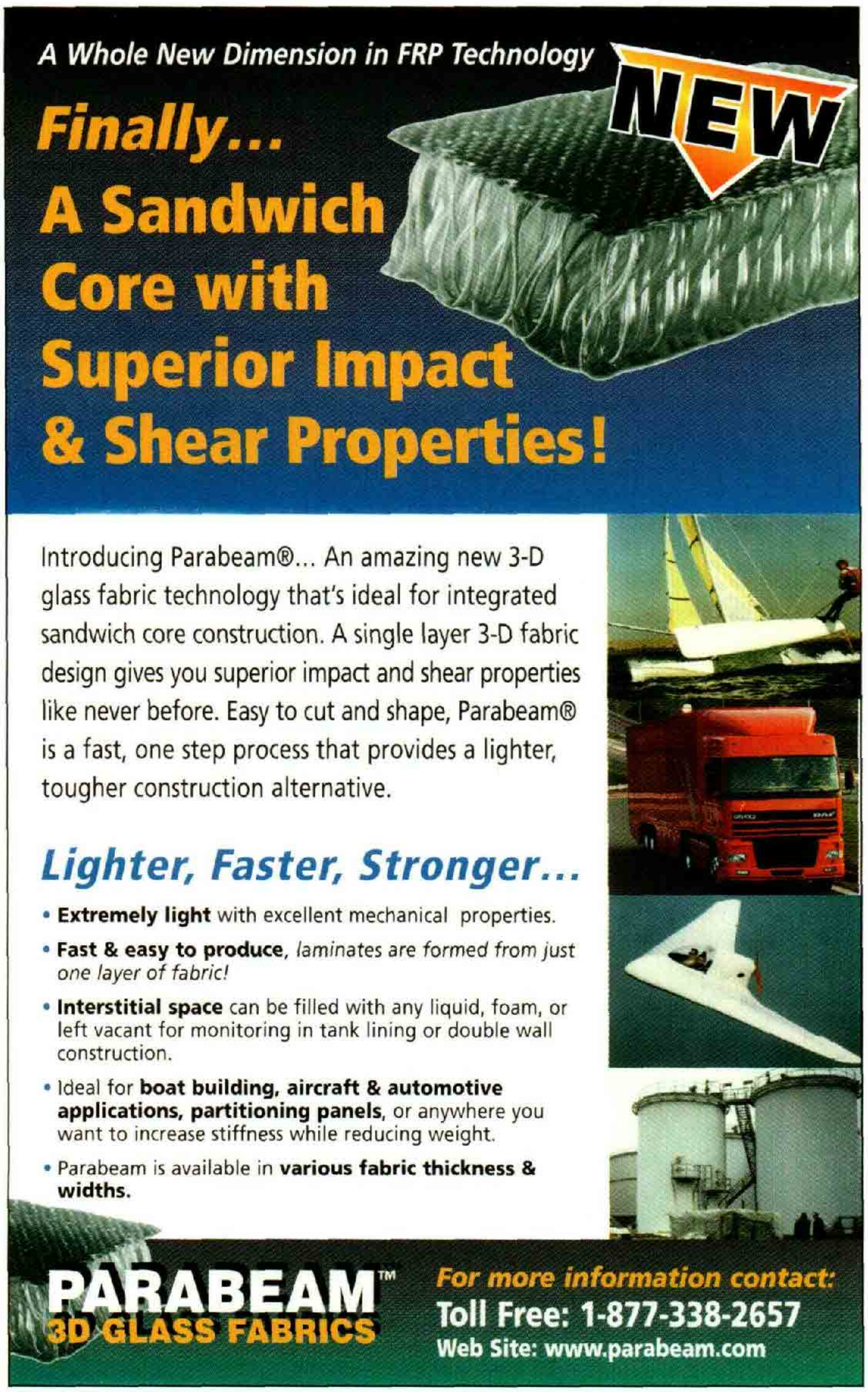
Ribbed 2000, a boat show devoted to rigid hull Inflatables, will be held May 12—14 in England in conjunction with the Royal Institute of Naval Architects' conference on surveillance, pilot, and rescue craft at the Royal Southampton Yacht Club. That's close to Ocean Village, where Ribbed 2000 will be held. RIB Exhibitions Ltd., The Rib Suite, Hunters Lodge, Kentisbeare, Devon EX15 2DY, UK, tel. +44 1884 266100, fax +44 1884266101. The Royal Institute of Naval Architects, 10 Upper Belgrave St., London SW1X 8BQ, UK, tel. +44 171 235 4622, fax +44 171 259 5912.

• • •

SPAR Associates Inc. (927 West St., Annapolis, MD 21401 USA, tel. 410-263-5893) has released a new computer program "for integrated management of boatyard job planning and resource management." A Windows-based system, the software is called PERCEPTION, Version 6.2.

PBB

In last issue's Rovings, we mentioned the "Hydraulic Mini Jack," but failed to list the manufacturer's address: SPX Power Team Corporation, 2121 West Bridge St., Owatonna, MN 55060 USA, tel. 800-541-1418, fax 800-288-7031, Web site <www.powerteam.com>. Our apologies for the omission. —*Ed.*



Why Some Dark Boats Blister

Unexpected FRP failures occur due to high temperatures generated by solar gain on dark-colored exterior surfaces. Here are three perspectives on why.

EDITOR'S NOTE: The phenomenon of dark-colored hulls blistering has long been observed, but there is still controversy over the reasons behind it. Here, we present the opinions of three marine-industry professionals: a boatbuilder, a resin manufacturer, and a marine surveyor, all of whom have first-hand experience with this problem. Jim Gardiner, founder and president of Consolidated Yacht Corporation, offers a case study of a blister-repair job his shop performed on a dark-colored sailboat hull. Joe Parker, technical advisor for PRO-SET laminating resin from Gougeon Brothers Inc., translates complex data on heat distortion temperature and glass transition temperature into useful information for boatbuilders. And *Professional BoatBuilder's* technical editor Bruce Pfund, a marine surveyor and composites specialist, offers some practical, shop-floor suggestions on post-curing, and on repairing hulls that have experienced print-through.

Heat Deflection Temperature or Heat Distortion Temperature (HDT)
Some manufacturers quote HDT in addition to glass transition temperature (Tg). The method of test is defined in ASTM D-648 (Test Method for Deflection Temperature of Plastics Under Flexural Load). It is widely used and measures the temperature at which a standard bar of the cast resin system, which is under a defined load, undergoes an arbitrary deflection. The test provides a means of comparing the temperature resistance of resin materials. HDT is a useful guide to developing an optimum cure cycle, and in general indicates the extent of cross-linking. Typically, Tg values are higher temperatures than HDT.

Glass Transition Temperature (Tg)
has several definitions:

- A wide range of materials exhibit glass transition temperatures, such as the temperature at which a material changes from being rigid and brittle to becoming rubbery and flexible with a considerable reduction in mechanical properties.
- The temperature at which increased molecular mobility results in significant changes in the properties of a cured resin system.

Excerpted from Care and Repair of Advanced Composites *by Keith B. Armstrong and Richard T. Barrett, published by Society of Automotive Engineers (Warrendale, Pennsylvania), 1997.*

by Jim Gardiner

At my boatyard in Florida, it's been interesting to note that almost all dark-colored boats with blistering problems come from the northern United States, Canada, and Europe. The builders there naturally have less experience with the tropical sun and high ambient temperatures common in the South, and also may have used ambient room-temperature cures that produce relatively low *beat deflection temperature* (HDT) values in the matrix resin of the final composite laminates. Post-cured resins and resins cured at higher temperatures achieve higher HDT values and are more suitable for building dark-colored boats for tropical conditions.

In 1991. we performed a blister repair on a dark-blue 52' sailing yacht. The boat had a foam-cored hull and epoxy resin, which had a low heat-distortion temperature of 120°F (49°C) when fully cured.

This was a problem. The maximum in-service temperature of this boat's outer laminate on a hot sunny clay could be as high as 190°F to 200°F (88°C to 93°C). Thus, the matrix resin of this composite had almost definitely experienced temperatures above its HDT and maybe even its *glass transition temperature (Tg).*

What Happens When You Exceed Tg?

Exceeding Tg temporarily creates a soft and rubbery resin as long as it stays too hot, resulting in a loss of both modulus (stiffness) and strength in the composite (resin and fibers combined). In tension, the fibers contribute the majority of the strength, so it's not considerably reduced. In compression, however, exceeding Tg is more critical

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***Above**—In the same ambient temperature, a dark hull will sustain higher surface temperatures than a lighter-colored hull, which is clearly illustrated by this dark-blue boottop that—once exposed to high temperatures—heated up enough to bubble, while the lighter-colored topsides did not.*

by Joe Parker

Much of the confusion surrounding the thermal performance of polymer composites in the marine industry is caused by inconsistent thermal-property reports from one resin supplier to another. When reviewing material specifications, you should know which test method has been used, and you need to know exactly what the cure and conditioning schedules are for a particular test specimen; they have a major effect on the results.

On a resin data sheet, most suppliers will report a heat deflection temperature (HDT) that has been determined either on an FRP laminate or on an unreinforced, neat-resin sample, tested at either 264 psi or 66 psi. Because the test is based on a specified load standard and the fibers are carrying that applied load, the fiber-reinforced sample will provide much higher results than the neat-resin sample. Also, if the 66 psi results are compared with 264 psi results in a neat-resin sample, there will be a difference in reported HDT.

Another thermal property regularly identified on a resin data sheet is glass transition temperature (Tg). This too can be very confusing because there are several ways to determine Tg. The most common methods are: Dynamic Mechanical Analysis (DMA), Differential Scanning Calorimetry (DSC), and Thermal Mechanical Analysis (TMA). They produce varied results; generally, the highest are with DMA, followed by DSC, and TMA. At times, fabricators will compare the ultimate Tg of one resin that has been determined by TMA, with the Tg of another resin that has been determined by DSC.

More importantly, the ASTM (American Society for Testing of Materials) standards commonly cited for testing Tg require that the sample be exposed to an elevated-temperature cure to remove the effects of the thermal

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by Bruce Pfund

There are two types of post-cure cycles for composite parts. Room-temperature gel and cure, followed by a controlled post-cure cycle, go a long way toward producing a part that is both dimensionally stable, and free from print-through and other problems caused by resin softening. Uncontrolled post-curing is precisely what causes print-through and dimensional instability, and it must be avoided at all costs.

A controlled post-cure cycle takes place inside an oven, or at least in a closed room of some sort. The rate of heating—known as the "ramp rate"—is rather gentle, perhaps 8°F to 10°F per hour. One reason for this slow heating rate is simply that most boatshops have only modest heat sources. Nevertheless, even when massive amounts of BTUs are available, as in the autoclaves used to cure and post-cure aircraft and aerospace parts, the heating rate remains quite conservative.

Why? Because the goal of the controlled post-cure is to gradually "drive" the glass transition temperature (Tg) and the heat distortion temperature (HDT) to their ultimate values, but without exceeding the values that an incompletely cured part possesses. Exceed the HDT or Tg of the incompletely cured part during post-cure, and the part will change shape, print-through, or even sag between supports or internal framing—just what the builder is trying to avoid by a controlled post-cure. Post-cure temperatures at any point of the cycle should always lag behind the part's current Tg and HDT by a minimum of 5°F to 8°F. if not more.

The ramp rate can be particularly tricky to control when the part is first placed in the oven. It's not like baking brownies; preheating the post-cure oven is not recommended. Good air circulation is critical for even heat

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CONSOLIDATED YACHT CORPORATION

In order to perform blister repairs on this 52' foam-cored sailboat, Jim Gardiner's shop had to remove the entire exterior laminate. The original epoxy laminating resin had a heat deflection temperature (HDT) of 120°F, but since the boat was painted dark blue and was located in a tropical climate, the outer skin of the hull reached temperatures as high as 200°F, causing it to blister.

because the *resin* contributes most of the strength. To explain in more detail, most compressive failures occur via a shear mode, such as buckling. Here, the fibers provide the majority of the strength, but only up to the point where the resin can maintain the fibers in column. A soft matrix lessens the degree of support *and* the compressive strength—by a significant amount. The effect is the same on the composite's shear properties, where again, the matrix resin dominates. Although the fibers have been oriented to handle in-plane loading, there are usually no fibers running in the thickness direction. Thus, only the matrix resin resists primary shearing within the composite.

In general, when a laminate's temperature exceeds the matrix resin's HDT, the effects are the same as exceeding Tg, except that the property loss may not be as severe. Exceeding HDT means that you have taken the resin to a point where it will deflect, or move. Exceeding Tg means that the resin has passed a threshold where every increase in temperature will result in a significant drop in properties. But, clue to individual differences in resin chemistry and the additional reduction in composite properties if water enters into a laminate, the best rule for hull laminates is to keep the composite part well below the matrix resin's Tg *and* HDT.

Effect of Color Choice on Surface Temperature Under Sunlight*

Panel Color	Surface Temperature (°F) Unbacked	Foam Backed
White	120	127
Light Blue	127	137
Medium Blue	137	157
Dark Blue	144	174
Medium Red	128	142
Dark Red	137	169
Black	148	173

* These panels were exposed to outdoor sunlight with unrestricted ventilation of 100°F air. Excerpted from *The Cook Book*, published by Cook Composites and Polymers Co. (Kansas City, Missouri), 1990.

Adding in Thermal Expansion

As stated earlier, temperatures on the outer skin of a dark boat in tropical climates can easily reach 190°F (88°C). The top of the composite hull discussed here had most definitely seen temperatures close to this. Because the composite was constructed and cured at room temperature, the temperature differential between cure and in-service conditions was around 120°F (49°C). This would have generated an appreciable level of thermal expansion in the composite.

Since the laminate was basically isotropic (fibers oriented in all directions: 0°, 90°, and ±45°), the expansion was similar in all directions along the plane. Expansion of a laminate against itself caused the fibers to go into compression—greatest in the longest ply orientation, or the bow-to-stern, direction. As a laminate expands against itself, it will eventually deflect out of plane, since it is bound by rigid connections. Although the strength in the fiber direction of the hull laminate of the case boat in our shop was quite high—the fiber strength was many times that of the resin—the stress generated from a small variation in the fiber angle would have quickly overloaded the matrix.

Now include the loss of shear strength in the matrix resin once Tg has been exceeded. The small compressive stress produced by the thermal expansion described above can exert enough shear stress to result in a shear failure in the adhesion of the laminate to the core, especially where there is less than optimum bonding. Remember, heating rates will vary through the material stack's thickness, especially at the bond line between the conducting laminate and insulating core.

In my opinion, the large variation in reinforcement-fiber direction causes a high shear to develop through the laminate thickness. The thermal expansion of the laminate against itself causes in-plane compression and shear stress. The result is an upheaval of the outer skin caused by the movement of the softened matrix resin, leaving mounded-up blisters on the outer surface that signal bonding defects.

Weak Spots

We were able to see this connection between bonding defects and blisters in dark-hulled boats on a blister repair we performed on a 90' composite sailboat made in northern Europe. This boat was built on a male mold using foam core and an orthophthalic resin, and was also painted dark blue. The first three boats in the production series were painted white and had vinyl ester resin. The orthophthalic resin used on this fourth, dark-hulled boat had a potential to achieve only a 140°F (60°C) HDT, according to published data.

Beneath every one of the blisters on this boat, there was an area that looked like tan putty (core-bonding putty) on the surface of the foam. The shear stresses concentrated on these weak spots. Regardless of whether the putty on the foam surface was from bleeder holes while vacuum bagging, or surface defects on the foam core that were glazed and puttied before laminating the outer skin, the putty had very poor adhesion to the foam and released from it easily. Quite often, if a foam is not hot-coated first, it will suck the

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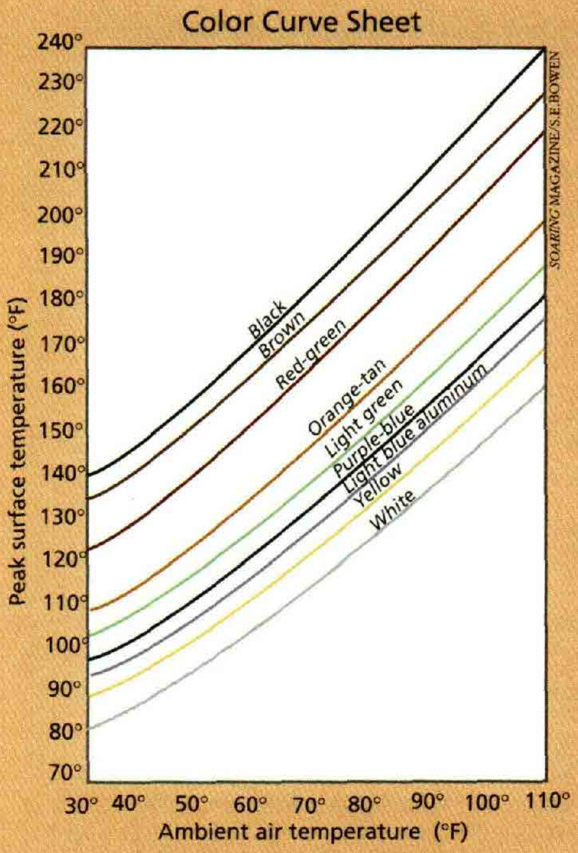

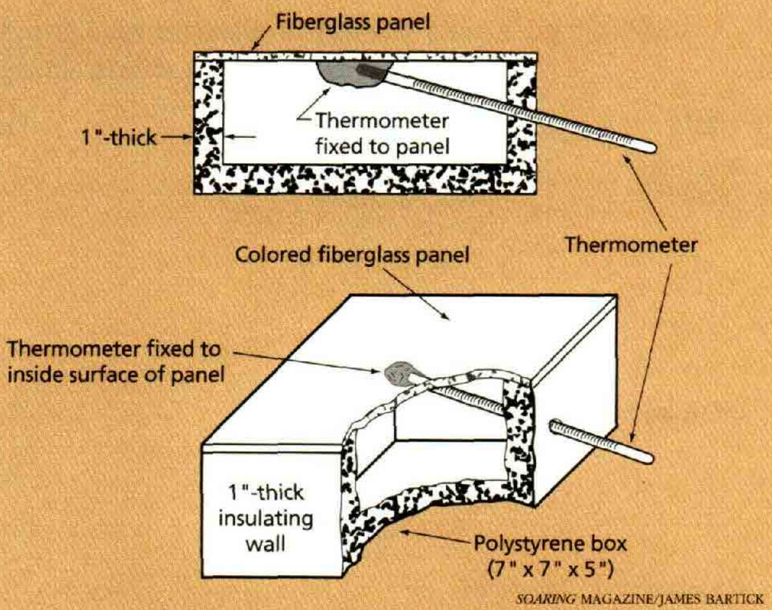

To determine the temperature rise on the skin surface of sailplanes, different-colored fiberglass panels were attached to polystyrene boxes, with the tip of a mercury thermometer bonded to the underside of each painted panel ***(above).*** *These boxes were placed in the sun on days having clear skies and calm air. The results, plotted as curves* ***(left),*** *represent the highest recorded temperatures, based on a broad ambient temperature range of 30°F to 110°F.*

Traditionally, glass sailplanes have been produced with a white finish only, and even the limited use of colored trim has been a rare factory option. There are some apparently valid reasons for staying with white.... However, the main thrust in this report will investigate the temperature rise at the skin surface of a colored sailplane resulting from direct exposure to sunlight....

An experimental program was conducted involving thousands of temperature readings with dozens of colored samples. Testing was conducted in New Jersey during the years 1972 to 1974. To closely simulate conditions that might exist on the skin surface of a real sailplane, samples were prepared from polystyrene boxes measuring 7"x 7"x 5" on the outside dimensions with 1" thick sides. One face of each box was removed and replaced with a colored fiberglass panel. A number of these test samples were prepared using different colors and shades in addition to black and white. A mercury thermometer was placed with the tip bonded to the underside of each painted fiberglass panel.... Test samples were mounted in a simple frame with the colored surfaces aimed squarely at the sun. This frame was continuously tilted and turned to follow the sun across the sky.... Ambient air temperature and surface temperature of all samples were continuously recorded until a peak was reached for existing conditions.... Test requirements called for a very clear sky without the slightest cloud formation or haze.... Tests were conducted only in very calm air *[i.e., worst-case conditions—Ed.].*

After two years of testing, significant data was sorted out and plotted on the curve sheet to develop temperature rise curves for each color and for black and white. Referring to these curves, note that the baseline represents ambient temperature. As might be expected, the curves are bounded on the top by black and on the bottom by white. These finished curves are simply a graphical presentation of the highest temperatures recorded for each color based on a broad ambient temperature range from 30°F to 110°F [-15°C to 29°C]....

The curves clearly indicated a black sailplane could achieve a surface temperature of 115°F to 120°F [29°C to 35°C] above ambient air. For example, on a day with a temperature of 90°F to 95°F [18°C to 21°C] in the shade, it is conceivable that the skin surface of a black sailplane could reach the temperature of boiling water.... The curve sheet also indicates an all-white sailplane could attain a peak temperature of 45°F to 50°F [7°C to 10°C] above ambient—about 70°F [21°C] lower than the corresponding figure for black. Looking at the color curves, we see that brown shows a decided tendency to absorb heat—not too different from black. Colors like red and green should be avoided if moderately high surface temperatures are objectionable. Orange and tan fall near the middle of the range and...the coolest colors are pink, yellow, and light blue, along with all pastel shades....

The reader should treat the values given in this report as an approximation—an indication—of what might be expected.... For every color, there are countless shades and hues, all with different capacities to absorb or reflect solar energy, and it is entirely possible that the position of two adjacent colors on the curve sheet could be interchanged simply by deepening one while adding white to lighten the other.... However, the numbers that appear on the curve sheet clearly suggest that in some parts of the country, with certain colors, overheating from sunlight could present a serious problem.

Excerpted from "Why Is White So Sacred? Energy Absorption and Color in *Fiberglass,*"SOARING magazine. September 1975.

Listing of Some Common Resins and their Heat Deflection Temperature (HDT) and Glass Transition Temperature (Tg) Values

Mfr.	Product	Type	HDT	Tg
Gougeon Bros.*	**PRO-SET 145 resin with 229 hardener**	Epoxy		
	16 hrs @ RT + 8 hrs @ 130°F (54°C)		160°F (71°C)	163°F (73°C)
	16 hrs @ RT + 8 hrs @ 150°F (66°C)		169°F (76°C)	175°F (79°C)
	16 hrs @ RT + 8 hrs @ 170°F (77°C)		185°F (85°C)	187°F (86°C)
Interplastic**	**CORVE 81172**	Vinyl Ester	210°F (99°C)	261°F (127°C)
	T704-673	Iso	210°F (99°C)	228°F (109°C)
	T520-703	Ortho	165°F (74°C)	183°F (84°C)

Manufacturers' Comments:

*Tg values were determined with the DSC (Differential Scanning Calorimetry) method. Test specimens were neat resin without fiber.

**Tg values are typically found using clear castings that have been cured as follows: 4-hour ramp up to 250°F (121°C); 2 hours @ 250°F; and then 2-hour cool-down to room temperature.

Tg values were determined with the TMA (Thermal Mechanical Analysis) method and will vary according to resin type, formulation (i.e., styrene content), and the resin's molecular weight. Standard cure schedule for test samples: 1 hour @ 140°F (60°C); 1 hour @ 158°F (70°C); 1 hour @ 176°F (80°C); 1 hour @ 194°F (90°C); and then 5 hours @ 212°F (100°C). The goal is to ensure that the resin is completely cured. Tg and HDT values are typically derived using clear castings, since fiber content and air voids significantly affect test results of laminate samples. Note that clear-casting samples with air bubbles will break right where the bubble is.

resin from a putty, leaving it resin-starved, unbonded, and a weak link in the overall composite laminate.

On this dark-hulled 90' boat, there were literally hundreds of defects, 2" in diameter and larger, caused by the thermal stress of the solar heat generated on the blue exterior, and by poor putty adhesion to the foam core. The core bonding practices used in the first three boats may not have caused blisters, but when combined with a lower-HDT resin, a dark-blue hull, and a tropical service environment, they produced disastrous results.

Causes of Defects in Foam Core and Outer Skin Bonding

- Air voids.
- Foam-cell closure caused by any material (dust, air, grease, putty) that prevents resin from bonding the entire surface of each cell to the underside of the laminate.
- Mixing resin systems; for example, using epoxy putty to bond core to a vinyl ester laminate. The result is basically the same as waxing the area that is to be bonded.
- Dust from the shop.
- Dust from sanding the foam.
- Oil and grease from air tools.
- Putty used for filling cracks in foam or for large joint fillets, and smeared on the surface of the foam.

Foam Cores and HDT

One additional note of interest in this case was that the boat's name, which was painted in white on the transom, was visible on the foam core once the exterior laminate had been removed. The name appeared in the natural foam color, which stood out from the brown that the rest of the foam had been "cooked" to beneath the dark-blue skin. Foam core also has an HDT value, since it's typically a polymer that has been frothed into a foam. Thus, if the foam within a cored laminate reaches a high-enough temperature, it will also be affected. The most well-known effect is core print-through or "checkerboarding." The easiest way to see this is to take a piece of structural foam core, and put it in an oven that has been heated to a temperature above the foam's HDT. The foam will shrink. Print-through results from this shrinkage in the core combined with softening in the surface skin's matrix resin when the whole laminate is heated beyond its HDT. Once overheated, and cooled in this configuration, the checkerboarding becomes a permanent cosmetic feature. PBB

About the Author: *Jim Gardiner is the founder and president of Consolidated Yacht Corporation, which has recently relocated to Miami, Florida.*

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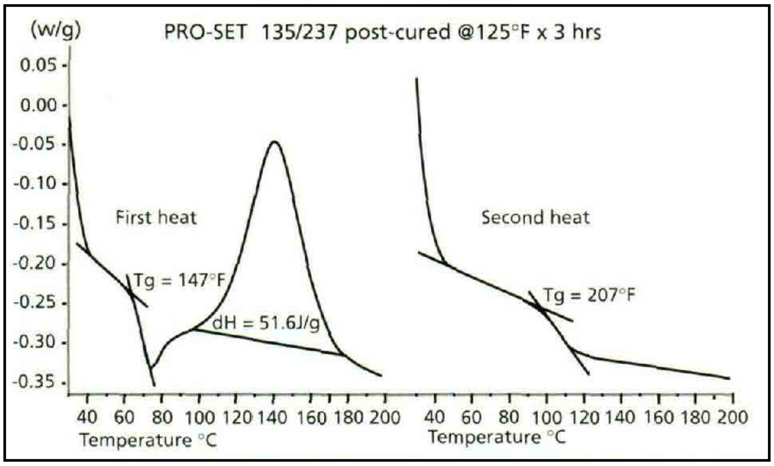

*Differential Scanning Calorimetry (DSC) is one of the more common ways to determine glass transition temperature (Tg). A tiny sample of cured polymer is gradually heated from room temperature, and the rate and amount of absorbed heat energy is plotted on a graph **(far left).** An absorption-rate shin is considered the onset of 1st Tg (in this case 147°F), and there is a physical change in the characteristics of the specimen from hard and glossy to soft and rubbery. If the sample releases heat during this process, there is unreacted polymer and additional cure is occurring. The procedure is repeated on the same sample to calculate the ultimate Tg **(near left),** which for this sample is 207°F. A sample's cure schedule prior to the DSC test has a significant impact on the 1st heat Tg, but very little bearing on the ultimate Tg. As the properties data sheet for PRO-SET 135 Resin and 237 Hardener indicates **(below),** the ultimate Tg does not change based on the post-cure schedule, but the 1st heat Tg is considerably different. As the post-cure temperature increases, less and less unreacted polymer remains.*

history, or cure profile. The resultant information is really of very little use to the boatbuilder because this sample-has, in effect, been post-cured at an extreme temperature, usually 200°C (392°F). The data recorded from the test is the ultimate Tg that this particular resin system can reach. So, by pre-conditioning the sample before determining the Tg, the data point most important to boatbuilders has been eliminated.

Here is how we determine a resin's Tg at Gougeon Brothers, using a Mettler-brand DSC:

We place a tiny sample (typically 20mg) of a cured polymer in a crucible within the machine. During the course of the machine's cycle, we increase the temperature inside a miniature furnace from room temperature to 200°C (392°F) at 10°C (50°F) per minute. According to ASTM standards, this first cycle should not be recorded, because its purpose is to negate the effects of the cure history of the sample. But, we record and plot the results of that cycle; what happens during this part of the test is exactly what happens when a boat is exposed to its working environment. We understand that a boat will not be exposed to a cure of 200°C (392°F) prior to entering service.

As the temperature increases, we plot the amount and rate of heat energy absorbed by the sample for the entire cycle. At some point, the sample begins to absorb heat energy at a different rate. The inflection (change in slope) of the energy-absorbed curve is the onset of Tg, or *1st beat Tg,* which indicates a change in the physical characteristics of the specimen from a hard, glassy solid to a softer, more rubbery solid. During the first cycle, the sample may begin to release heat, indicating that additional cure is taking place. By measuring the amount of energy released, it's possible to determine the degree of cure. The sample is cooled back to room temperature, and then exposed to a second cycle.

By comparing the first cycle with the second cycle, we can calculate the amount of unreacted polymer. Again, in the beginning, the sample absorbs energy at a given rate, then the absorption rate changes and, later in the cycle, the sample may release energy. The inflection of the energy-absorption curve determines ultimate Tg, or *2nd heal Tg.* Here's the big question: When you read a data sheet and the Tg is identified, is it the Tg from a sample with a specified cure (1st heat Tg), or the ultimate Tg (2nd heat Tg), which has been determined after a conditioning

"Parker" continues on page 30

PRO-SET 135 Resin/237 Hardener		Cure Schedule				
Physical Properties	Test Method	Room-Temp.* Cure	RT* x 15 hrs+ 125°F x 8 hrs	RT x 15 hrs+ 140°F x 8 hrs	Rt x15 hrs+ 180°F x 4 hrs	RT x 15 hrs+ 180°F x 8 hrs
Hardness (Shore D)	ASTM D-2240		85	86	85	85
Compression Yield (psi)	ASTM D-695		17,024	16,825	16,497	16,729
Tensile Strength (psi)	ASTM D-638		8,816	9,933	11,550	10,874
Tensile Elongation (psi)	ASTM D-638		4.1	4.6	6.1	5.7
Tensile Modulus (psi)	ASTM D-638	Post-cure Required	5,30E+05	5.10E+05	5.00E+05	5.10E+05
Flexural Strength (psi)	ASTM D-790		15,711	20,710	20,549	19,096
Flexural Modulus (psi)	ASTM D-790		5.44E+05	5,40E+05	5.55R+05	5.10E+05
Heat Deflection Temperature (°F)	ASTM D-648		141	172	174	196
First Heat Tg (°F) **		147	176	178	189	
Ultimate Tg–second heat (°F)**			207	207	207	207
Izod Impact (ft lbs/in.)	ASTM D-256		0.48	1.03	1.07	0.83

* Room temperature (70°F-75°F) Test specimens were neat epoxy (without fiber reinforcement) Typical values; not to be construed as specification.
** Determined using a Differential Scanning Calorimeter (DSC). Value reported is the onset of the glass transition.

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"Parker" continues from page 28

If a part is within 20°F of its rated heat deflection temperature (HDT), the resin does get soft—especially if it's undercured—and print-through and distortion can occur. Note, in this case, the print of both reinforcing fabric and core blocks.

cycle? These results can be very different from one another.

The sample's cure schedule prior to the test has a significant impact on the 1st heat Tg. But, the pre-test cure schedule has very little bearing on the ultimate Tg, because the sample has been post-cured at 200°C (392°F) in the first cycle of the test. To show this relationship, refer to the properties data sheet for PRO-SET 135 Resin and 237 Hardener on page 58. The ultimate Tg doesn't change based on the post-cure schedule, but the 1st heat Tg is considerably different in a 52°C (125°F) eight-hour cure than in a post-cure of 82°C (180°F) for eight hours.

With proper post-cure, can the ultimate Tg be reached in the first heat scan? By looking at this data sheet, we can guess that with a post-cure greater than 82°C (180°F) for more than 8 hours, a 1st heat Tg equivalent to ultimate Tg can be achieved. It demonstrates that less and less unreacted polymer is left as the post-cure temperature increases. This is real information that the builder can understand. But more importantly, it accurately indicates how a resin system will respond to the temperatures a boat hull or deck will see in service. There are many who would have you believe that the ultimate Tg is the important factor when choosing or comparing resin systems. In reality, the most important consideration is the *achievable* thermal properties (1st heat Tg at a specified cure), not the ultimate thermal properties (2nd heat Tg).

Once a laminate is heated to near the 1st heat Tg, distortion and print-through begin. As the temperature remains at, or above, 1st heat Tg, additional cure takes place in the resin matrix, causing more shrinkage and surface-profile change. While at, or above, the 1st heat Tg, the strength and stiffness of the composite decreases. The only good news here is that the Tg increases because the part is being post-cured by the sun. Each time the laminate is heated, additional cure takes place, pushing the Tg higher and higher until, eventually, cure is complete.

Here's a practical example of thermal properties: my wife and I recently purchased a 30-year-old FRP sailboat. The boat had been painted several times in its lifetime, so it had been sanded a number of times, and had a very smooth surface. The boat spent a good part of its life in the Caribbean, and had always been white. Last winter we painted the hull a dark green. A couple of weeks after the boat was launched, the hull began to distort and print. There is now woven-roving pattern all over the boat; every bulkhead, knee, and other internal structure telegraphed to the outside of the hull. The only place that still looks good is under the counter near the transom, which was not exposed to direct sunlight. This happened in *Michigan.* In the summer, temperatures were never higher than about 32°C (90°F). Even though some would say it couldn't happen because the Tg of a polyester resin is high enough to prevent print-through, it *did* happen. And I am sure I know why.

I was aboard the boat most of the month of July, when this was going on. I can tell you the surface of the hull never got to a temperature that was too hot to lay my hand on it. That means the surface temperature could not have been above about 60°C (140°F). The 1st heat Tg of the resin system had to be about 57°C to 60°C (135°F to 140°F), and once the surface temperature approached the 1st heat Tg, additional cure in the resin system took place. This continued cure resulted in resin shrinkage, causing roving print to appear. I also believe some creep took place while the boat was warm, which probably caused structural members to telegraph to the surface.

I did expect a little bit of this to happen since 1 knew the surface temperature would be higher than it had ever been, but I certainly did not expect it to this degree. Because this happened so dramatically, and because we have the ability to do the testing here, we took the time to determine the Tg of our boat after 30 years. I removed a couple of chips from resin-rich areas on the inside of the boat and was disappointed to learn that the 1st heat Tg and the ultimate Tg matched at 57°C (135°F). The resin system in the boat has fully cured at this point, and unfortunately, has a rather low Tg. This means that if the boat remains a dark color, it will probably print each time it's faired and painted. I will sand and paint the boat again, but following the suggestions of others. I will use a thicker layer of fairing, post-cure the fairing, and try to create a barrier between the laminate and the surface to prevent recurrence of significant print.

The thermal properties I've described here are true for all thermosetting plastics commonly used in the marine industry. So, the next time you're discussing the thermal performance of a resin system, ask about the cure schedule of the sample, and ask for 1st heat Tg as well as ultimate Tg. Make sure you know if the HDT is determined with a neat-resin sample or a laminate, and whether the load was 66 psi or 264 psi. This information will provide a much clearer picture of thermal properties of a particular resin system. PBB

***About the Author:** Joe Parker is the technical advisor for PRO-SET laminating resin at Gougeon Brothers Inc. (Bay City, Michigan).*

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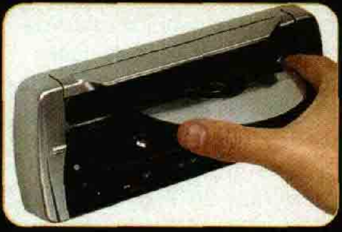

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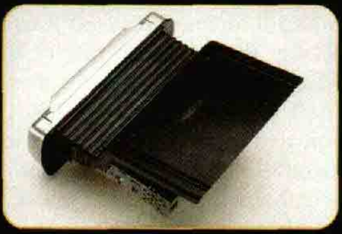

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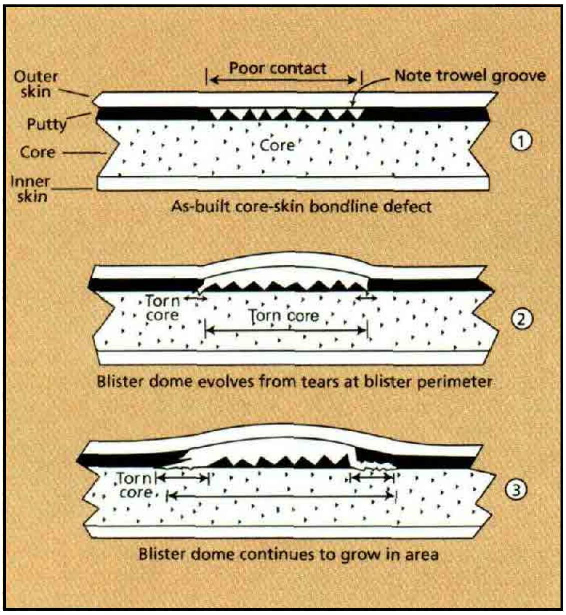
"Pfund" continues from page 23



***Lett**—The anatomy and evolution of a blister dome.*
***Above**—Construction defects play a role in blisters that occur when a part is exposed to high temperatures. Air trapped between a cored hull's outer skin and the face of the core material heats up with the skin, expanding and forcing the outer laminate into a blister dome. As the part cools, that dome shape becomes a permanent feature. A core-to-skin interface experiences many different types of stresses as part of its normal load cycle. Compression, tension, and shear are all expected, but a poor core-to-skin bond can lead to blister-dome growth due to peel forces in high surface temperatures.*

absorption. "Freestanding" post-cures, in which the part has already been de-molded, are simplest, because both the inside and outside skins of the part can be bathed in circulating hot air. In-the-mold post-curing is far more complex, because the mold, whether male or female, insulates the side of the part that's in contact with it.

A Dark-Colored Part in the Sun

Now, imagine what happens to a dark-colored, undercured part the first time it's rolled out of the shop and into the sunlight. With its surface perpendicular to the sun's rays, the part's surface temperature might rise from the ambient shop temperature of 80°F to over 160°F in as little as one hour. That's a ramp rate of 80°F per hour—and a sure-fire prescription for cosmetic, if not structural, problems.

If you doubt me on this, check out a dark-colored part on a day with clouds and intermittent sun. This test will work in the winter in Florida, or from spring to fall in northern regions. With good calluses on your hands, 130°F is about the upper limit of comfort for resting your hand on a surface. When the sun comes out from behind the clouds, a dark-colored part will get uncomfortably hot to the touch in less than 30 minutes.

So, when a new part emerges from the shop into the sunlight, it could be in for one heck of a thermal shock on the first sunny day of its life outside. Remember, though, that it's not going to be heated up at a uniform rate, as it would be in a proper post-cure oven. Overhangs and shadows will cause radically different heating rates, with perhaps 30°F to 50°F temperature differences just on one side of the boat. Depending upon how the hull is oriented to the sun, heating rates for the port and starboard sides may be very different, especially if one side of the hull stays in the shade all day, while the other side gets toasted.

Resin Properties vs. Temperature

A resin's properties don't change suddenly when its HDT or Tg is exceeded. Softening occurs quite gradually, and well before the HDT or Tg is reached.

I spoke to Jack Brand, president of Spectralab (Pinellas Park, Florida), about standardized tests used to evaluate resin thermal performance. He said, "ASTM D-648 is the standard test for determining a resin's HDT. It's a three-point flexural bending test. A bar of cured, unreinforced resin is set on two pivot points 4" apart, and loaded midway between those two supports at either 66 or 264 psi while it is heated. The HDT is measured when that beam has deflected 1mm." In other words, the beam has already bent when the HDT is established.

Adjusting for the mixed measurement systems, I calculated that with a span of 4" (101.6mm), the deflection is .04"(1mm) when the HDT has been reached. That sounds quite a bit like the "L over 100" rule for composite panel deflection for boat design, doesn't it? If a panel measuring 100" between supports deflects 1" or more, trouble's likely.

The test demonstrates that resin does get soft before it reaches its rated HDT, especially if it's undercured—which may explain why some boatbuilders have complained to me, "This problem can't be happening because of the resin's high HDT." If the part's within 20°F of its rated HDT, print-through and distortion *can* occur.

A related phenomenon specific to polymeric materials is long-term "creep." When a part deflects at loads or temperatures well below its rated performance, it's often creep related. Poppets pushing up into a cored hull over a period of a few weeks or months, when no problems were noticed after the first few days of storage, is a classic example of long-term creep.

Construction Defects and Heating: A Bad Combination

As Jim Gardiner notes in his article, construction defects can also play a big role in problems that occur when a part—even one that's thoroughly and correctly cured—is exposed to high temperature. Imagine an area of air trapped between a cored hull's outer skin and the outer face of the core material. That air will heat up as the skin does, expanding and forcing the outer laminate into a blister dome. As the part cools down, that dome shape will become a permanent feature.

Blister domes, however, are not always static features, but will sometimes expand over time with multiple heating

cycles. Opening up such a dome may reveal two very different problems. The original air inclusion will probably show a shiny surface, or uncompressed trowel marks where the core and skin never bonded. Around the perimeter of the "neverbond," however, a ring of torn foam may be visible.

What causes the foam to fail? A core-to-skin interface experiences many different types of stresses as part of its normal load cycle. Compression, tension, and shear are all to be expected. Peel, however, does not normally occur in service. But, that's exactly what happens at the edges of an area where core and skin have not been properly bonded. The air inside the blister dome expands as the laminate warms up; the dome tries to rise; and tremendous peel loads are generated around the dome's perimeter—even when the boat's at the dock or in storage on dry land. Combined with the long-term creep phenomenon (which also affects foam core materials, not just laminating resins), a poor core-to-skin bond is a prescription for blister-dome growth in high-temperature conditions.

Repairing Print-Through

In my experiences with state-of-cure testing to investigate print-through problems, I have been surprised by the low "fully cured" Tg and HDT properties of some general-purpose polyester boatbuilding resins commonly used in the 70s and '80s. Tg's of under 150°F—sometimes barely 135°F—were not unusual. It's important to note that I determined these properties by having testing performed on skin coupons. Resin manufacturers, by contrast, test "neat," or unreinforced, samples, in conformance with ASTM test standards. To minimize the directional effects from fiber reinforcement in the samples, the test lab selected and cleaved the omnidirectionally reinforced skincoat layer from the holesaw coupon for testing. Since the fibers reinforcing the skincoat beam made it stiffer, the true HDT of the resin itself was probably lower than the number I got by having the skincoat tested.

In some hulls I have investigated, the texture of the chopped fiberglass in the skincoat has printed-through not one, but two LPU paint jobs that included multiple primer layers. In some cases, the original gelcoat thickness had been considerably reduced when the hull was prepped for the first paint job. That made the printing slightly more understandable. However, other hulls with print-through have had normal gelcoat thicknesses of 0.014" to 0.018".

I think that part of the problem in these unusual cases of recurring print-through may be the dramatically different thermal expansion rates for polyester resin and fiberglass filaments. Resin expands approximately 50 times faster than fiberglass filaments. If the resin moves around a lot when its Tg is exceeded, but the fiberglass filaments move approximately 50 times less, print-through is a logical result.

What's the cure for this nasty situation? Extra layers of primer or fairing putty seem to help. I've seen some hulls that have had lots of print showing, except where minor dings or scrapes had been sanded and faired, then primed and painted. In other areas, the print was reduced where the primer layers were thickest. The extra layers of material between the original hull exterior and the paint seemed to mask the print quite nicely. I learned this by drilling lots of holesaw coupons and then measuring the thicknesses of the coating layers.

In cases where this problem is severe—typically on dark-colored hulls—my current recommendation is to prep, prime, paint, and then post-cure a small section of the hull—at least one square yard. Warm it to a realistic service temperature—perhaps 180°F for a few hours—six or eight times, and then check for print-through. If it still prints, add more primer. If necessary, apply fairing compounds and longboard, then prime and paint. This type of "patch" testing is not cheap, but it's preferable to repainting the whole boat for an unhappy owner. There are just too many mysterious factors affecting print-through in these cases to recommend anything but a very conservative course of action.

A Note on Manufacturers' Data

During a class on composites I recently taught, my students and I looked up a product data sheet (PDS) for a typical general-purpose polyester boatbuilding resin, specified for use "in sprayup or hand-layup techniques." It listed the standard series of ASTM mechanical and physical test results; among them, an HDT at 264 psi for a bar of cured resin. The published temperature of about 162°F looked just fine—unless you checked the fine print at the bottom of the page, where it said, "Resin cured by adding 1% benzoyl peroxide."

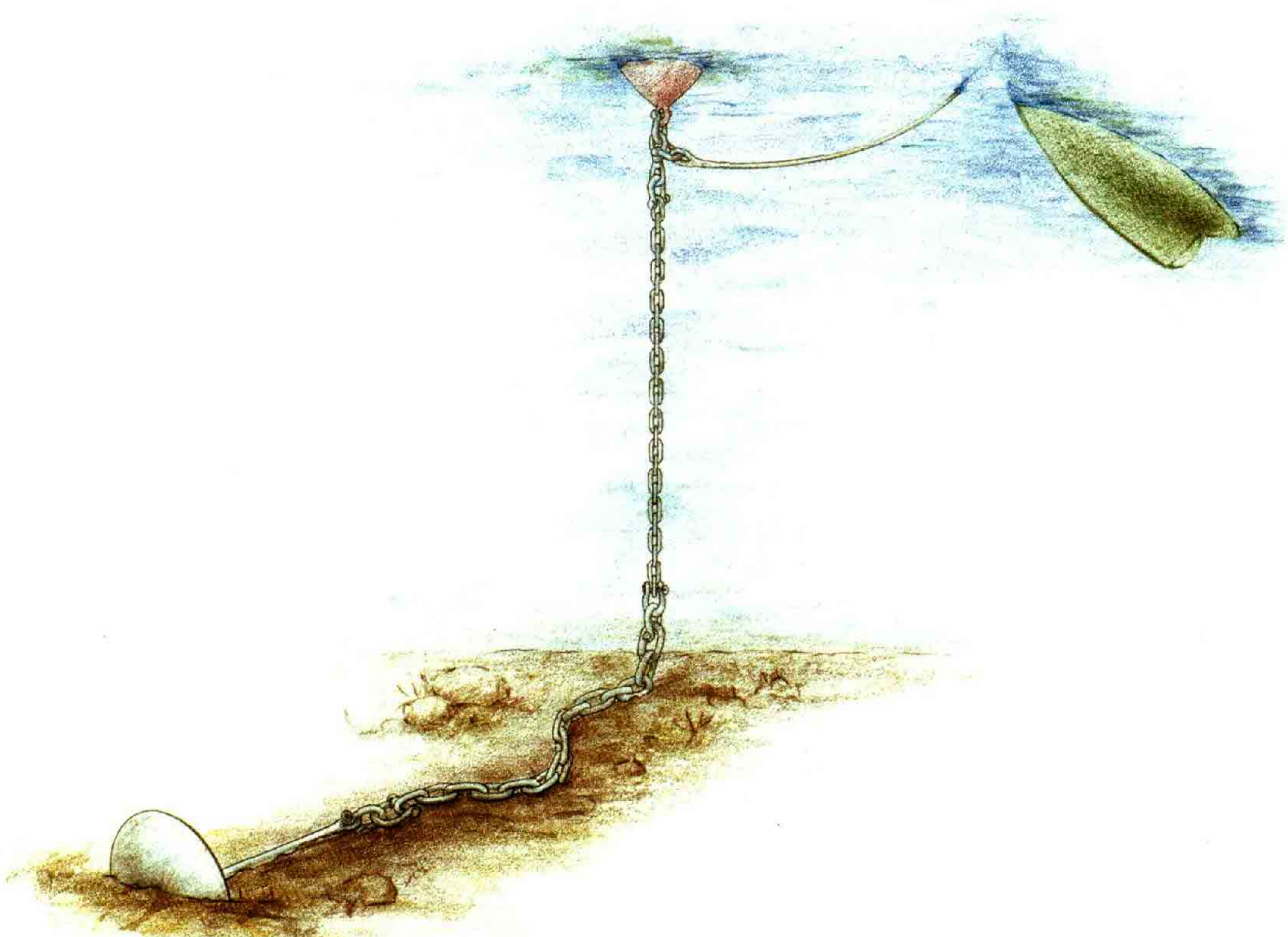
Do you cure your resin with BPO? I doubt it. Methyl ethyl ketone peroxide (MEKP) is a far more common boatshop catalyst. The next sentence in the PDS, though, was the kicker. It read, "Gelation is carried out at 180°F, followed by a 1 hour bake at 240°F to complete the cure. (I'm assuming gelation occured in a water bath.)

So, you don't use BPO catalyst. You don't heat your shop to 180°F while the crew laminates and the resin gels. And I sure hope you don't post-cure the boat for an hour at 240°F. What, then, does the elaborate PDS tell you about how that particular resin is going to behave in your shop? Exactly nothing. The only way to get that information is to run your own tests, in your shop. Make a few castings, or coupons, of varying thicknesses, say 1/8" and ¼"—the old-fashioned "coffee-can lid" test—and then send them to the lab after a few days.

Ideally, you should understand the resin's HDT properties around the time the part is de-molded. If your demold cycle is a week, call the lab a week or so in advance of de-molding and book a slot in their test schedule. FedEx them the coupons so their tests will occur at roughly the same "gel time to heat" interval your products see if they get rolled out of the shop and into the sun soon after de-molding. If that scenario doesn't apply to your shop, the timing of the lab testing becomes less critical, but the information you are seeking remains the same: "What is the real-world HDT of my resin, catalyzed and cured the way we do it in my shop?"

Don't forget that these factors may change quite a bit from July to January. Varying shop temperatures and catalyst levels have a big effect on how rapidly a resin cures and develops its ultimate room-temperature-cure HDT, and may also affect the ramp rate and soak times appropriate for a controlled post-cure cycle. PBB

***About the Author:** As "Bruce Pfund/Special Projects L.L.C.," Bruce consults on composite processes and stir-revs marine composite structures. He is the technical editor of* Professional BoatBuilder.



CALCULATING THE LOAD

There's plenty of conflicting information in circulation about estimating loads on mooring systems and ground tackle. The author tried to reconcile the numbers—and came up with a few of his own.

by Nigel Calder

Over the years, I have seen a number of differing opinions on how to size moorings and ground tackle for boats. Not all of these make sense to me. Nor is it surprising that there's some confusion on this subject, because the data on which most suggestions are made is itself pretty confusing, particularly from the perspective of a non-engineer. It occurred to me that by reviewing existing data I might produce some common-sense recommendations. The following is what I came up with.

Defining the Load

The loads on moorings and ground tackle are a function of:

- the windage of a boat;
- the extent to which the boat *shears* (weaves) around on the mooring or at anchor (the more it swings out of line with the wind, the greater the windage);
- the impact of any current on the boat;
- the boat's weight;
- the sea state in which the tackle is deployed; and
- the extent to which the mooring or ground tackle cushions shock loads. (The two key factors here are *scope*—the relationship of rode length to water depth—and *rode material,* such as chain or nvlon line.)

By far the most significant factor, especially at higher wind speeds, is windage. The load resulting from windage increases with the square of the wind speed, which is to say that if the wind speed doubles, the wind-induced load increases by four.

By making certain assumptions about windage in relation to boat length and beam, the wind load at different wind speeds can be readily calculated for "generic" boat lengths and beams. These numbers can then be adjusted on the assumption that a boat on a mooring or at anchor may shear away from the wind, from one side to another, by as much as 30°. Some assumptions can also be made

ILLUSTRATION BY KATHY BRAY

The elements of a mooring system ***(facing page).*** *This detailed example shows a recommended chain, shackle, and swivel arrangement secured to a mushroom anchor. For heavy-weather conditions, such as when Hurricane Bob hit Rhode Island in 1991* ***(right),*** *the author suggests using a polyester (Dacron) snubber to bring the loads of the nylon pennant on board. Research shows that continual stretching and contracting generates heat in the nylon and can melt the fibers from within.*

BILLY BLACK

relating boat length and beam to immersed volume and, thus, the maximum likely impact of tidal streams and currents on the anchoring load (as you can see. this is getting pretty fuzzy).

Next we introduce some waves. This is where things start to get really complex. As a boat pitches up and down it can impart snatching, or jerking, loads to a mooring or anchor rode. These loads can be in excess of the wind- and current-generated loads. The extent of this is related to the amount of scope, and the elasticity of the rode.

At different times, various people and organizations have attempted to quantify all these factors to derive tables showing the likely loads on moorings, ground tackle, and associated hardware. The most widely known and applied of these tables is published by the American Boat and Yacht Council (ABYC). Entitled "Design Loads for Sizing Deck Hardware," it indicates the load effects of wind, current, and wave action. These loads have been calculated for four different wind speeds—15 knots. 30 knots, 42 knots, and 60 knots **(Figure 1).**

Note that this is a conservative table with substantial built-in safety margins, which is to say that in most circumstances, *it considerably overstates the loads that will be experienced by mooring tackle, ground tackle, and deck hardware.* If windage alone

FIGURE 1: DESIGN LOADS FOR SIZING MOORING AND GROUND TACKLE

Boat Length (LOA)—ft	Boat Beam (Bmax)—ft		Load on Tackle and Hardware—lbs			
	Sail	Power	15 knots	30 knots	42 knots	60 knots
10	4	5	40	160	320	640
15	5	6	60	250	500	1,000
20	7	8	90	360	720	1,440
25	8	9	125	490	980	1,660
30	9	11	175	700	1,400	2,800
35	10	13	225	900	1,800	3,600
40	11	14	300	1,200	2,400	4,800
50	13	16	400	1,600	3,200	6,400
60	15	18	500	2,000	4,000	8,000

Adapted from a table courtesy of the American Boat & Yacht Council (ABYC).

When purchasing moorings, ground tackle, and associated hardware, it's necessary to know the likely loads on the system. Find the potential loads at different wind speeds by reading horizontally across this table—the numbers already reflect wind, current, and wave action. For example, the tackle and hardware for a 50' sailboat in a 30-knot wind will need to withstand 1,600 lbs of load.

FIGURE 2:
WORKING LOAD LIMITS FOR MOORING AND GROUND TACKLE COMPONENTS

NOMINAL SIZE (chain) DIAMETER (rope)—inches	WORKING LOAD LIMIT (WLL)—LBS				
	Nylon		Galvanized Chain		Anchor Shackles
	3-strand	Double Braid	Proof Coil (BBB)	High-Test	
1/4	186	208	1,300	2,600	1,000
5/16	287	326	1,900	3,900	1,500
3/8	405	463	2,650	5,400	2,000
7/16	550	–	3,500	7,200	3,000
1/2	709	816	4,500	9,200	4,000
5/8	1,114	1,275	6,900	11,500	6,500
3/4	1,598	1,813	9,750	16,200	9,500
7/8	2,160	2,063	11,375	–	12,000
1	2,795	3,153	13,950	–	15,000

Adapted from a table courtesy of ABYC.

After finding the likely loads on a mooring system (from Figure 1), choose components with equivalent, or higher, working load limits (WLL). For example, according to this table, a 50' sailboat that sustains 1,600 lbs of load on a mooring requires ¾" nylon, 5/16" proof coil or ¼" high-test chain, and 5/16" anchor shackles. Note that proof coil and BBB chain are not the same, but for the purposes of matching the components in a system, they're close enough.

were used to calculate loads, the numbers would he approximately 25% of those in this table. Consequently, if the table is used to size tackle, it will provide a significant margin for dealing with dynamic (surge) loads and other complicating factors.

A boat's length and beam is entered in Figure 1, using whichever gives the highest numbers. As far as anchoring is concerned, a weekend sailor who never goes to sea if strong winds are forecast is going to need very different ground tackle than an around-the-world cruiser who may, at some point, be faced with violent winds and seas while at anchor. Clearly, the ground tackle and associated fittings must be matched to the intended use and area of operation. Nevertheless, no boat should have its ground tackle sized according to the 15-knot column. A day sailor who never strays far from home might use the 30-knot column. A cruising sailor, whether coastal or offshore, should use the 42-knot column. In the case of a long-distance cruising boat, this column should serve as a *minimum* starting point; a more conservative approach would be to take the potential loads at 60 knots.

When it comes to moorings, similar considerations apply: a mooring in a protected cove that never sees any significant wave action will be subjected to vastly different loads than one in an exposed bay where the fetch allows seas to build up in certain conditions. It the ability to stand up to hurricane-force winds is required, the 60-knot column should serve as a starting point.

Matching the Components

We need to size mooring and anchor pennants, and rodes and shackles, to meet the kinds of loads we might see—making sure that all the components in the system match one another. Unfortunately, at this point we step into a minefield. We can start to negotiate a path through it with another table developed by the ABYC **(Figure 2)**

On the surface of things, if we have a rope and chain mooring system or rode, we simply make sure the working load limits (WLL) of the various pieces are matched, and are at least as high as the number we extracted from Figure 1. But let's consider my 40' Pacific Seacraft, for which I prefer a mooring or anchoring system that withstands wind speeds of up to 42 knots, and for which I use a combination of chain and rope. Figure 1 tells us that at 42 knots we should anticipate loads of up to 2,400 lbs (at 60 knots, these loads rise to 4,800 lbs). Figure 2 tells us we can use either 3/8" proof coil or BUB chain, or else ¼" high-test, with a 7/16' shackle. We will need 1" nylon line.

What's wrong with this picture? First, although a conservative person might use a 1" nylon pennant in a mooring system, no one in their right mind will use a 1" nylon rode for anchoring a 40' boat—5/8" is more likely, or possibly ¾". Second, ¼" high-test chain has an inside diameter (inside link width) of 0.4" while a "A" shackle has a pin diameter of ½ " ; the pin won't fit. How do we reconcile these things?

The first thing to note is that Figure 2 gives *working load limits*, not breaking strengths. The WLL is defined as a percentage of breaking strength. Different WLLs are used for the different components covered by this table, reflecting the different properties of these components (such as nylon rope as opposed to chain)

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FIGURE 3:
MODIFIED WORKING LOAD LIMITS FOR MOORING AND GROUND TACKLE COMPONENTS

NOMINAL SIZE (chain)/ DIAMETER (rope)— inches	*MODIFIED* WORKING LOAD LIMIT (WLL)—LBS				
	Nylon		Galvanized Chain		Shackles
	3-strand	Double Braid	Proof Coil (BBB)	High-Test	(weldless, drop forged)
1/4	–	–	1,300 (.43)	1,950 (.4)	1,250
5/16	–	–	1,900 (.50)	2,925 (.48)	1,875
3/8	–	–	2,650 (.62)	4,050 (.57)	2,500
7/16	–	–	3,500 (.75)	5,400 (.65)	3,750
1/2	1,500	1,700	4,500 (.81)	6,900 (.74)	5,000
9/16	1,880	–	5,500 (.84)	–	–
5/8	2,440	2,700	6,900 (1.01)	8,625 (.82)	8,125
3/4	3,340	3,880	10,600 (1.10)	12,150 (1.02)	11,875
7/8	4,700	–	–	–	15,000 (1)
1	5,880	6,800	–	–	18,750

(Use at Your Own Risk)

Chain and pin diameters—in inches—are in parentheses.

The modified nylon WLLs are based on high-quality nylon rope, such as New England Rope (Fall River, Massachusetts); ***they will need to be downgraded for lower-quality rope.*** The modified nylon WLLs assume dynamic (stretching) loads, but not shock loads.

For practical marine application and for the purpose of this article, the author modified Figure 2 to come up with this table. It shows less conservative numbers for shackles and nylon, while increasing the safety margin for the high-test chain. Proof coil (BBB) remains the same. Note that internal chain and pin diameters—in inches—are in parentheses.

but *also reflecting other considerations not necessarily related to functionality in a mooring or anchoring system* (i.e., legal considerations, use in other applications, and so on). For example:

• Nylon rope may have a WLL of anywhere from 5% to 25% of its breaking strength, depending on the application. The numbers in the ABYC table come from the Cordage Institute (an industry-wide organization based in Wayne, Pennsylvania), which uses an extremely conservative WLL of around 10% of minimum tensile strength of generic nylon rope. *Minimum tensile strength* is generally somewhere between 80% to 90% of the average breaking strength of a rope. In other words, 10% of minimum tensile strength is just 8% to 9% of average breaking strength. What's more, the generic nylon rope used to calculate these numbers has a breaking strength below that of most nylon rope sold for mooring and anchoring applications, further lowering the WLL number.

• Proof coil and BBB chain have a WLL that is 25% of their breaking strength.

• High-test chain has a WLL that is one third of its breaking strength.

• Shackles are commonly given a WLL of 20% of their breaking strength, reflecting the fact that they may also be used in lifting applications with wire rope, which in turn has a WLL of 20% of its breaking strength.

I'm going to stick my neck out here and propose that in practice it's reasonable to assume a WLL of 25% of *minimum tensile strength* for nylon rode (20% to 22.5% of average breaking strength), or 20% of average breaking strength (if average breaking strength is the only number available), and a common WLL of 25% of breaking strength for proof coil chain, high-test chain, and anchor shackles. In my modified table, I show no nylon-line sizes below ½" because mooring pennants and rodes smaller than this are uncomfortable to handle, and because the strength of smaller pennants and rodes is disproportionately affected by the kind of damage that can be expected. Two other key pieces of information in the mooring and ground-tackle puzzle are included in my table. These are the inside diameter of chain links, and the diameter of shackle pins. We end up with **Figure 3.**

Now the different pieces start to fit together somewhat better. For the 2,400-lb load on our Pacific Seacraft 40 we can still use 3/8" proof coil chain (WLL of 2,650 lbs), but we have to go up a size to 5/16" for the high-test chain (*modified* WLL of 2,925 lbs). This high-test chain has an inside diameter of 0.48" which will accept the 7/16" pin (0.4375") of a 3/8" shackle (*modified* WLL of 2,500 lbs). The shackle is the weak link. To be on the safe side, I would prefer to use the next shackle size (7/16", with a *modified* WLL of 3,750 lbs), but it won't fit the high-test chain (the shackle has a ½"pin).

I might be tempted to use a stainless-steel shackle, because these have a much higher WLL for the same size

as a galvanized anchor shackle, but this would be a mistake. Typically, stainless-steel shackles are rated at up to 50% of breaking strength, so the extra strength may be illusory and, in fact, *the shackle may be weaker.* In addition, the stainless steel may cause galvanic corrosion with the chain. The way to use a larger shackle is to have the manufacturer weld an oversized link at the ends of the chain (this is commonly done) before purchasing it. If you already have the chain without this link, and you're using high-test chain, you should use the largest galvanized shackle that will fit, and recognize that this is likely to be the weak link in the system. However you do it, *any shackle used in a mooring or ground-tackle system should be specifically manufactured for this purpose, and stamped with its WLL. All other shackles are suspect.*

If I have a nylon pennant on my mooring system, or a combined rope/chain anchor rode, then 5⁄8″ three-strand nylon with a *modified* WLL of 2,440 lbs fits nicely. Nevertheless, bearing in mind the risk of abrasion as the boat surges around its mooring, and given the relatively short length of any pennant, I might use ¾" line, with a *modified* WLL of 3340 lbs.

If 60-knot winds are a consideration, the anticipated ground-tackle load goes up to 4,800 lbs, which can be met with ½″ proof coil or BBB chain (with a WLL of 4,500 lbs, both are a little undersized), or 7⁄16″ high-test chain (*modified* WLL of 5,400 lbs), connected with a ½″ shackle (*modified* WLL of 5,000 lbs), which has a pin size of 0.625" (fitting the 0.65" link width of the high-test chain). The *modified* table tells me I should use a 7⁄8", three-strand nylon rode, which I would certainly use on a mooring (maybe even 1"), but I believe I would use the V line for anchoring, knowing that I had reduced my safety margin, simply because the 7⁄8' would be extremely heavy and bulky to handle. I know that doesn't sound like a very good reason to use the smaller size line, but at some point pragmatism has to win out over theory!

Some Caveats

Now for some caveats. Bear in mind that the numbers given in my modified table are based on new rope from a quality manufacturer. This rope is made from fibers manufactured by Allied Signal (Petersburg, Virginia) that not only have a high tensile strength to start with, they have also been treated with a Marine Overlay Finish (MOF—Allied calls its product SeaGard). The MOF significantly reduces the strength nylon loses when it's wet (approximately 10%), and also reduces damage from abrasion. Other rope may not have as high initial strength, or as good performance in service.

The modified nylon WLLs that I'm proposing are based on the assumption that there are no shock loads. This is a reasonable assumption when at anchor. Even if a boat is bucking up and down wildly, the combined effect of any catenary in the anchor rode and the inherent stretch of a

Calculating the Effect of Shock Loads

In a mooring or anchoring situation it's not possible (without sophisticated equipment) to quantify shock loading and its effect on any given rode. But, understanding what could be done with these numbers if they were available helps illustrate what is happening to the line, which in turn helps provide an understanding of how to mitigate potential damage. I will take a look at this topic using Yalon as an example—a double-braided nylon line made by Yale Cordage (Biddeford, Maine).

The first step in a shock-loading calculation is to work out how much energy the line is being asked to absorb:

Work done (in ft-lbs) = the weight (in lbs) x the drop (in ft).

Let's assume a 24,000-lb boat at anchor jerked through 3' and then brought up short: Work done (ft-lbs) =

24,000 x 3 = 72,000 ft-lbs.

This assumes a worst case in which the boat builds up as much momentum as if in a free fall, which is unlikely, but never mind.

Assume we have 150' of 5/8" Yalon rode let out. Yale Cordage's data sheet for this line indicates a *working energy absorption* capacity of 910 ft-lbs per lb of line, and a weight of 13 lbs per 100' of line.

We have 150' of rode out = 13.0 x 1.5 = 19.5 lbs of line. This line must absorb 72,000 ft-lbs of energy = 72,000/719.5 = 3,692 ft-lbs per lb of rode.

If we look at the energy absorption graph for Yalon (available from the manufacturer), we find that the line has been loaded to 60% of its breaking strength. Since the average breaking strength of 5/8" Yalon is 17,000 lbs (according to the data sheet), this computes to an actual load on the rode of 17,000 x 0.6 - 10,200 lbs. That is three times the *working load limit* (WLL) given by Yale Cordage for this rope—some degree of the rode's integrity has been *permanently* compromised,

Let's say we are at anchor and we let out another 100' of rode. Two things immediately happen. A shock load is less likely in the first place. But let's assume we have the same shock load. There is now more line absorbing the shock:

250' of rode = 13.0 x 2.5 = 32.5 lbs of line. Each lb is absorbing 72,000/32.5 = 2,215 ft-lbs of energy.

This is about 41% of the breaking strength of the line, which in turn translates to an actual load on the rode of about 6,970 lbs. Although the rode is still stressed to two times its WLL, the simple act of letting out more line has reduced the load by 32%. The amount of rode, and its scope, in any particular mooring or anchoring situation is a significant factor in the extent to which the tackle gets shock-loaded.

Now let's say, instead, that the nylon line is a relatively short pennant in a mooring system. Not only is wave action more likely to impart a shock load, but for any given size of line, the short length of line will mean that the line itself is less able to absorb and dissipate the shock. Clearly, moorings in areas subjected to significant wave action have to be designed with as much scope as possible, and then put together using extremely conservative WLL numbers. —*Nigel Calder* nylon rode will significantly cushion the load. Given that Figure 1 was developed *taking these kinds of dynamic loads into account*, it seems reasonable to assume that the ground tackle at any given wind speed (such as 30 knots, 42 knots, or 60 knots) will not he subjected to greater dynamic loads than those in the table. Such an assumption, however, may not be valid with a mooring because moorings are commonly given substantially less scope than anchor rodes. It must be realized that the less the scope, the less valid is the assumption regarding the mitigation of shock loads. If shock loads are likely, the nylon pennant and the rest of the components in the mooring system will have to be beefed up.

Note that when you're caught out in a rough anchorage, the simple act of letting out more rode, or increasing scope, will not only significantly increase the holding power of an anchor, but it will also significantly reduce the shock loading on the rode. (Obviously, this is not an option on a mooring.)

What happens if the loads on a nylon pennant or rode periodically exceed 25% of minimum tensile strength? That's a gray area, and it's difficult to get hard and fast data. The Oil Companies International Marine Forum (OCIMF). however, has developed data on nylon lines that are used to secure oil tankers to single-point moorings. The lines are progressively stressed (not shock loaded) to 50% of breaking strength for 1,000 cycles, then 60% of breaking strength for another 1,000 cycles, then 70% of breaking strength, and so on until failure occurs. Most fail at the 60% loading level. Clearly, any pennant or rode sized at 25% of the WLL as I have suggested has a safety margin built in, but at some point between this and 60% of breaking strength, permanent damage (however minimal) occurs at each load cycle, which ultimately leads to failure. The industry specialists that I have talked to seem to think that this point occurs at around 30% of minimum tensile strength.

Finally, it should be noted that if any nylon line under load breaks, *it can spring back (snapback) with enough force to break limbs and tear eyes out of their sockets.* Always exercise extreme caution when in the vicinity of a highly loaded nylon line.

A Workable Approach

1 believe that the approach to mooring and ground-tackle sizing described above represents the best use of available data from a commonsense perspective. As far as anchoring is concerned, it mirrors the approach learned through trial and error by many experienced cruisers. This gives me a high level of confidence when recommending it to others. It would be interesting, though, to hear from any engineers who might have a different perspective.

For more information on the various ways to anchor a mooring system, sec PBB No. 30. page 8—Ed.

About the Author: *Nigel Calder is a contributing editor of* Professional Boatbuilder.

Chafe Prevention

In practice, the number one enemy of nylon pennants and rodes, both on a mooring and at anchor, is chafe, rather than load. In order to minimize the chances of chafe underwater any mooring or anchor should be given a substantial chain lead so that the nylon does not drag across the bottom every time the boat swings (a chain lead will, in any case, be needed with an anchor to hold the anchor's shank down and help it to set). With moorings, the chain lead often comes all the way to the main buoy.

When anchoring, ideally the chain lead will be at least as long as the boat, with maybe a small float where the nylon rode is attached. This will keep the nylon off the bottom at that point A modest load on the line will then keep the entire rode clear of the bottom. In reality, a chain lead of from 8' to 20' is more common, without the float, but this still works well in most cases. Problems arise when a boat swings and the rode fouls a rock or coral head; unfortunately, there's not much that can protect against this.

On deck, chafe is mitigated by providing chafe guards at all points of contact between a nylon pennant or rode, and the boat Traditionally, chafe protection has been provided by wrapping a piece of cloth around the rode and tying it on. *In all but an* extreme *blow,* a far more effective approach is to use a length of hose. Slit it down one side so that it can be slipped over the rode. Then, tie it securely in place (it helps to have a hole drilled in both ends of the hose for a lashing). In a prolonged blow, the chafe protection will need regular inspection.

When it comes to *an extreme blow,* Massachusetts Institute of Technology (MIT) and BOAT/US researched nylon mooring pennants that failed during hurricanes Bob and Gloria.Their study suggests that a primary cause of failure is heat generated in the pennants as they stretch and contract over the relatively tight bend that occurs where a pennant (or rode) comes over a bow roller or chock. Many of the failed pennants had melted strands in the *interior* of the lines (the heat was generated by the fibers working—stretching and contracting—rather than by chafe). Researchers speculated that the heat *buildup is exacerbated when a* hose provides chafe *protection* because the hose traps the heat while at the same time preventing cooling from the wind and wind-driven spray.

This raises an interesting idea, which is that in extreme conditions it is *almost certainly preferable to add a polyester (Dacron) snubber to a nylon pennant or rode.* The polyester snubber is attached to the pennant or rode in such a way that the polyester brings the mooring or anchoring load on board. Where the snubber contacts the boat (at the bow roller or fairlead), the polyester is protected against chafe with a length of hose. The nylon pennant or rode up to the snubber provides the necessary shock absorption for the boat, while the polyester snubber on account of its low stretch, will not suffer from the same heat buildup and melting problems as nylon.

—N.C

Power Cats and the LCG

An overweight multihull with trim problems is not easy to fix.

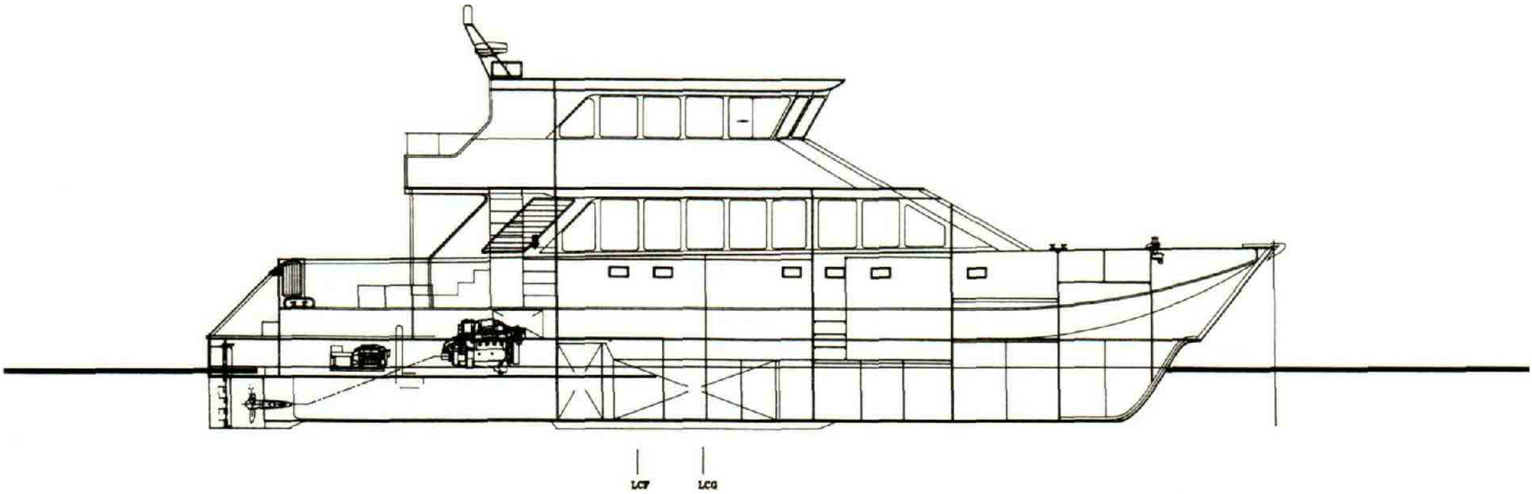
Text and illustration by Malcolm Tennant

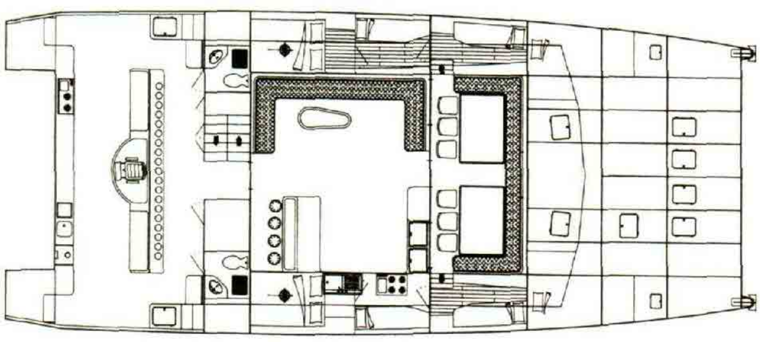
Some keelboat designers and builders take a rather cavalier approach toward mass and longitudinal center of gravity (LCG) calculations. In many ways this is quite understandable. By adding and subtracting ballast, the displacement of most monohulls can be adjusted relatively easily after the vessel is built. (This excludes high-tech boats, such as *America's* Cup competitors, which have ballast ratios of around 80% and ballast concentrated in the keel bulb.) The LCG position can be changed by moving the ballast fore-and-aft to affect trim; the keel can be repositioned; and the mast can often be moved—admittedly all a bit drastic and undesirable. But post-hoc solutions to a trim, or an overweight, problem are possible. In fact, these things may often be done so the vessel will achieve a more favorable rating for racing.

Multihull-sailboat designers, on the other hand, don't have any of these luxuries. They may be able to move some fluid tanks around a bit, but this is only a partial solution, since the tanks change weight as they consume the fluid and they constantly need to be topped off to maintain trim. There is no ballast; there is no keel; and the mast stays right where it is, unless you're willing to tear out the structure the mast rests on and rebuild a major part of the internal framework. To compound this problem, the difference between the light-ship condition and the full-load displacement can be as high as 30% or more; so mass calculations that are not precise can result in a major trim problem.

An overweight vessel also affects the safety factors calculated into the rig and structure. Loads on rig and structure are calculated for the full-load situation, and with a particular safety factor appropriate to the vessel's intended use. If the vessel is heavier than the designed full-load displacement, then such things as the righting moment and transverse bending moments are higher, which erodes the safety factors in the structural calculations. Unless the overload situation is extreme, it's unlikely it will lead to immediate rig or structural failure. But it will almost certainly mean that the rig will need replacing earlier than would otherwise have been the case, and some structural problems, such as cracking, may occur with age.

Power-monohull designers are in a similar situation. They don't really want to add ballast to correct a trim





LOA	19.95m	65.5′
LWL	17.85m	58.6′
BOA	8.5m	27.9′
Light-load displ.	17,794 kg	39,230 lbs
Half-load displ.	23,057 kg	50,830 lbs
Full-load displ.	28,320 kg	62,340 lbs
Prismatic	0.67 (at ½ load)	0.67
Power	2 x 254 kW	2 x 340 hp
Speed	23 knots	23 knots

A little extra weight doesn't necessarily affect the performance of a displacement power cat. But, if the weight affects the longitudinal center of gravity (LCG), then it affects the trim, and that *affects the performance. Even relatively small shifts in the LCG can cause trim problems. With its fine hulls and narrow waterplanes, this catamaran designed by the author* ***(facing page and above)*** *is especially susceptible to changes in longitudinal trim. He argues that any increase in weight, or shift in the designed LCG, during construction can be disastrous.*

problem if they can help it; this could exacerbate an already existing weight problem.

Power-multihull designers, however, must treat the mass estimates and the calculation of the LCG position as the proverbial Holy Grail. If the vessel is a planing power cat, then the mass estimate and the LCG position are critical. The planing catamaran tends to have a smaller planing surface and higher bottom-loading than the equivalent monohull. Because it almost certainly has more skin area, it also tends to weigh more than the monohull, unless it's built out of advanced composites. If it's overweight and the LCG is in the wrong position, affecting the trim, then there's going to be a major problem getting it to plane. It may, in fact, end up as a rather inefficient displacement boat. *[There are also critical factors in dynamic instability. For more on this, see PBB No. 31, page 20—Ed.]*

You may think that because weight, per se, is not the same problem from a performance point of view for a displacement catamaran, the mass and LCG calculations would not seem so critical. Wrong! The displacement cat usually has finer hulls than a planing cat (and much finer than a monohull), which gives it a higher hull speed. This makes it more susceptible to changes in longitudinal trim because of the narrower waterplane. It's basically the difference between a plank floating on its edge or on its flat. If weight is added to the end of the plank floating edgewise, then it will "dip" a lot more than the plank floating on its flat with the same added weight. So the position of the LCG relative to the longitudinal center of buoyancy (LCB) and the longitudinal center of flotation (LCF) is crucial, since relatively small shifts in the position of the LCG can cause serious trim problems. What this means in practice is that it's very difficult to keep a power cat in level trim in all conditions from light-ship, through half-load, to full-load displacement; this is especially true of the displacement cat. On vessels with a substantial difference between the light-ship and full-load conditions (such as those craft with transoceanic or long-range capabilities), it's common to arrange a fuel-transfer system to keep the craft in trim as the fuel and water loads change. More seriously, it also means that any increase in weight or shift in the designed LCG position during construction can be disastrous.

An increase in weight may have very little influence on the performance of a displacement power cat (one of our ferry designs, for example, performs with 150 people much the same as when it's empty). This is because the major determiners of hull speed, such as the prismatic coefficient and the ratio between the waterline-length and waterline-beam, are little affected by any immersion.

If the extra weight affects the trim, however, then it adversely affects the performance. Stern-clown trim can often reduce speed by a knot or two, but more important, the weight increase may also compromise the performance of the vessel by lowering the height of the wingdeck off the water, causing the waves to hit the wing in milder conditions than might have been the case if the vessel were at its correct displacement. And, in similar fashion to the sailing catamaran, the structural integrity is compromised because the loadings on the structure are higher than those in the original structural calculations. This lower wingdeck height severely disturbs passenger comfort—their peace of mind notwithstanding—since waves thump more frequently on the wingdeck.

Weight should be concentrated toward the center of the vessel to minimize the pitching effects on a slim-waterplane catamaran.

Weight also increases the longitudinal rotational moments of inertia of the craft, particularly if the added weight has been distributed toward the ends of the vessel. The bows are slower to rise to wave action, which further increases the likelihood of wave impact on the wing, particularly at the leading edge. When the bows come back down again, the wingdeck will hit the water harder. Even in normal conditions, weight should be concentrated toward the center of the vessel as much as possible to minimize the pitching effects that are more evident on the slim-waterplane catamaran.

To counter wingdeck impact, some designers place a vestigial third hull in the center of the wing, up forward—similar to the center "hull" on a wave-piercing catamaran, though somewhat smaller. This obviously costs more to construct than the flat wing, but may be a way of minimizing the impact of the additional weight that always seems to sneak in. It doesn't do any harm to have extra length of empty boat at the ends and to keep the wingdeck as short as possible, and as far back *from* the bow as practicable. If I can, I prefer to bring the wingdeck up to gunwale level some distance back from the bow; the area forward of this is then left open. A "pickle-fork" bow, with perhaps a trampoline or a forward deck from gunwale to gunwale at sheer height, is fitted. This forward deck is well off the water (right up at gunwale height) and the central anti-slamming nacelle is brought forward under this area. I

A Cautionary Tale

My assistant and I performed nearly three weeks of calculations on a comprehensive spreadsheet to get the mass and LCG estimates as precise as possible on a 19.6m (6-13') power catamaran designed for strip-plank/ply/foam/fiberglass composite construction. In fact, it was probably the most careful mass estimate we had ever done.

When the vessel was launched, it appeared to be floating over its lines. We took measurements from the waterline, and the computer confirmed that in light-ship condition the boat was 27% heavier than the weight estimates. So what had gone wrong?

I had only visited the vessel once in the early stages of its construction because it was being built at a considerable distance from my home base. Somebody told the owners that extra weight did not have an adverse effect on displacement power catamarans. That was correct with regard to speed, but they seemed to be totally unaware of the negative effects on vessel trim—despite my earlier emphasis on weight when discussing the design with them,

So where had all this extra weight come from? Unbeknownst to us, the builder had substituted 150kg/m^3 (9.37 lb/ft^3) end-grain balsa for the specified 60kg/m^3 (3.75 lb/ft^3) PVC foam in the core of the ply/foam/ply structures of the wingdeck, bulkheads, and cabintop. The area involved was several hundred square meters. The exterior sheathing glass was 750g/m^2 (22 oz/yd^2), instead of the specified 300g/m- (8 oz/yd^2). Factoring in the resin, this is a significant increase in weight. The plywood specified for the interior cabinetry was 4mm to 5mm (.16" to .2"); actual ply in a lot of places was 12mm (.5"). Was the builder the source of the problem? He certainly contributed, and commented that none of the increases in weight was very much. But if you say that 200 times, the result represents a significant increase.

The owners also had the builder move the rather large galley some 2m (6.60 forward and they installed commercial/hotel appliances rather than the domestic units we had allowed for. To compensate for the resulting bow-clown trim, the builder put 500kgs (1,100 lbs) of batteries aft. This may have corrected the bow-down trim, but it magnified the longitudinal moment of inertia already initiated by the forward galley.

What could we have done? The owners weren't willing to pay for supervision, but we should have insisted on being informed—in writing—of any design changes. We should also have insisted that the vessel be built on load cells, or at least weighed several times. If these things had taken place we might have been able to notice the problem earlier. Isn't hindsight wonderful?

—*Malcolm Tennant*

cany the nacelle right aft through the underside of the wingdeck where it becomes a very convenient duct for pipes, holding tanks, etc. On my more recent rough-water performance designs, I have used a "double arch," which has a cross section similar to (but smaller than) those those employed on some early wave-piercing catamarans. All these approaches minimize slamming should it occur. Keeping the vessel in level trim with the wing at the designed height, however, is the real name of the game.

It has also been suggested that the "unknown-items factor" should be increased to compensate for any possible added weight. This "fudge" factor allows for the weight of those small things that are difficult to estimate, such as bolts, screws, clips, hinges, and the like. If this factor is assessed with any precision, it will increase the design cost considerably because of the amount of time involved. The unknown-items factor is usually expressed as a percentage of the structural weight, or light-ship displacement.

To some extent, an increase in the unknown-items factor can be justified as compensation, but there are a few problems associated with this approach. First, it degrades the accuracy of the whole weight-estimating process and makes it more and more of a guess. If the factor is too big, then there isn't much of a reason to even estimate the weight; you may as well just stay with the original "best guess" established at the beginning of the design process, which is based on previous experience. If you don't have a lot of experience, then you would just have to accept all the uncertainty that goes with it, particularly if you haven't designed a similar vessel before. The basic assumption about all the small items that make up the factor is that they're evenly distributed around the structure of the vessel and, therefore, do not affect the LCG position, only the weight. But. if major items are added to or moved around the vessel after the weight estimates are completed, then they can have a marked effect on the LCG position.

Power-multihull designers must make sure that the mass and LCG calculations are as precise and comprehensive as possible. Impress upon clients, in the strongest possible terms, that they must tell you everything they're going to have on the boat, even if they're not going to fit it at the moment. (I have a checklist these days to help with this.) A client can't keep adding equipment to the boat after the design stage is finished. This is a major problem with catamarans of all types because of the amount of interior volume that's generally available. Unfortunately, the volume of space doesn't equate to large load-carrying capability, and owners must be restrained from filling up every available space, particularly with heavy items.

Assuming that the owner can be kept under control, then there's the question of possible differences between the builder and the designer. How do you ensure that the builder is working to the same weights as the designer? This isn't too much of a problem with alloy [aluminum] construction. Because the plating is produced under tightly controlled conditions, you can rely on its being a particular weight per square meter within very close tolerances, and this makes the mass estimates relatively easy, aside from the question of filler. But in the case of a composite craft, whether it's wood, foam, fiberglass, balsa, or various combinations of these, the construction material isn't manufactured in a factory—it's made on site. Designers use particular fiber-to-resin ratios, thicknesses of plywood, weights of fiberglass, etc., for their mass estimates. These should be based on actual achievable, as-built-in-a-yard weights, not laboratory perfection. But if the builder is not achieving the same weights per square meter as the designer intends—or the builder changes the material—then things can get seriously out of whack very quickly. The solutions to this problem are twofold. One, the designer can get actual, as-built weights from the builder. Unfortunately, this only works with the second boat from a particular builder, and doesn't necessarily work for all of them since laminate-weight variations can be as high as 25% from builder to builder; even with individual laminators at a given shop applying open-mold, hand-layup techniques. Second, some builders institute careful quality-control procedures covering the laminating techniques and the fiber-to-resin ratios to ensure that they're getting the correct weight estimates. SCRIMP (Seemann Composites Resin Infusion Molding Process), pre-preg fabrics, and wet-out machines may offer better control over fiber-to-resin ratios, at least for a primary structure.

Communication between the designer and builder concerning the actual weights is crucial. And this is no less true for a wood/epoxy composite boat. [See the sidebar on page 49.1 To this end. it's advantageous for the designer to supervise construction and be aware of any problems as soon as they become evident. In fact, designers who supervise construction should be constantly on the lookout for any deviation from the plan that's going to have a deleterious effect on the mass of the vessel. The builder can also construct the boat on load cells, or at least weigh the vessel at particular intervals, allowing the builder and designer to monitor the vessel weight and the LCG position as construction progresses. At a particular stage of assembly, if weight is high and the LCG is not where it should be, then it may be possible to take corrective measures. If all weighing happens at the end of construction, then it may be far too late and the unhappy owner is left with a boat that doesn't perform as expected, and with a set of problems (hat will be expensive to remedy. *[For more on the topic of weight management see "Controlling Weights in Large FRP Yachts" on page 52 ofthis issue—Ed.]* PBB

***About the Author:** A multihull designer with over 30 years' experience, Malcolm Tennant's articles have appeared in several marine publications. He is based in Auckland, New Zealand.*

CONTROLLING WEIGHT

DELTA MARINE INDUSTRIES

An accurate weight study—often considered the most tedious job in yacht design—can make or break a large yacht project.

by Jay N. Miner

***Editor's Note:** Author Jay Miner is the chief naval architect at Delta Marine Industries (Seattle, Washington). Since 1968, Delta has built high-quality fiberglass commercial vessels and. in 1985, began building luxury FRP motoryachts. The author originally offered the following material as a 1996 IBEX West presentation, and subsequently published it in the April 1998 issue of* Marine Technology.*

The subject of vessel weights and weight estimating brings to mind my own experience over 20 years ago as a junior naval architect in a Seattle design office. One of the first assignments given to me was a weight estimate. Viewed by many as sheer drudgery, the weight estimate is actually one of the most important engineering tasks in new-vessel design from the standpoint of safety and performance. In yacht-construction contracts, it's more the rule than the exception to have penalties assessed for failing to meet maximum draft and minimum speed thresholds—both of which depend on an accurate weight study.

The paradox of the weight estimate is that the person who is least equipped to perform the work—that is, the least experienced—is frequently

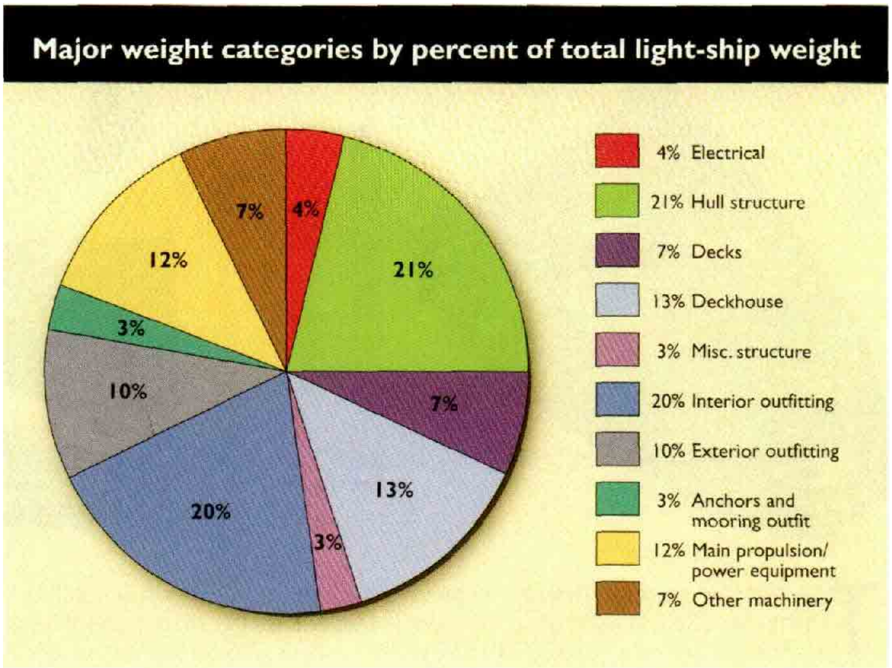
* The original version of this article, including the chart on page 53, was published as "Weight Control and Monitoring in Fiberglass Yacht Construction," by Jay N. Miner, in *Marine Technology,* Vol. 35, No. 2, April 1998, pp. 110-118. Reprinted with permission of The Society of Naval Architects and Marine Engineers (SNAME), 601 Pavonia Ave., Jersey City, NJ 07306, USA. Material originally appearing in SNAME publications cannot be reprinted without obtaining written permission from the Society.

IN LARGE FRP YACHTS

the one who gets the assignment, because senior engineers will avoid it by giving it to subordinates. Delegating the job, however, doesn't mean that we can abdicate our responsibility to guide those whose willingness to perform it doesn't entirely compensate for their lack of experience. That said, a good weight estimator should: appreciate the importance of the task; be familiar with the production environment; be detail oriented; and be allowed enough time to do the job right.

Most of what I'll discuss here is based on my experience as an engineer working in direct support of a production environment, rather than as an independent designer. There are some inherent advantages to working in close association with the production facility: it allows for real-time verification of data, and a more intimate appreciation of the details that sometimes get lost when you don't see them every day.

Although 1 would like to make some suggestions for reducing light-ship vessel weight, most of what I have to say is more about the methodology of determining goals, tracking the progress to those goals, and ultimately meeting them. When it comes to building the lightest possible large composite yacht, there may be builders out there who have taken greater strides than we have. The key for all of us should be to develop a rational basis to determine the amount of effort required to meet the specific project goals, and what the associated cost will be.



DELTA MARINE INDUSTRIES/SNAME

Known for building solid, oceangoing luxury motoryachts. Delta Marine has taken a conservative but thorough approach to reducing weight in its vessels. Facing page— Lady Linda *is an example of Delta's 124' shallow-draft series.* ***Above****—A representative sample ofthe weight breakdown ofa Delta motoryacht. Since the largest amount ofweight is in the hull structure, the best opportunities for reuniting weight are probably in that area.*

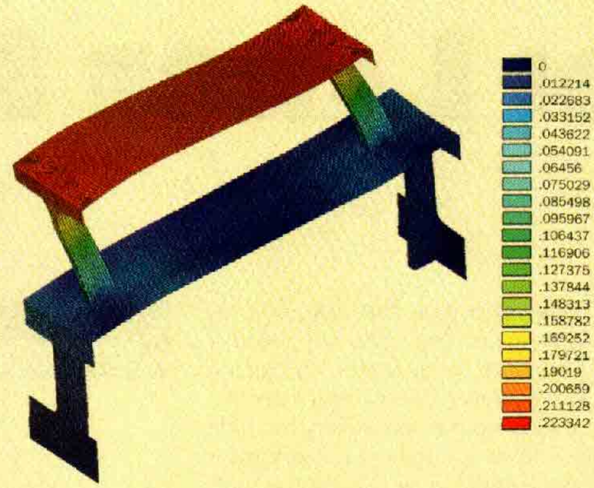
Weight Estimates in the Preliminary Design Process

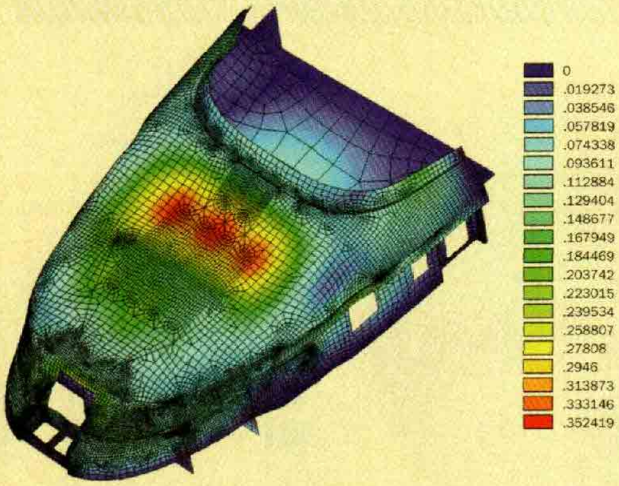
Weight estimates are an important tool in the preliminary design process, as you are developing performance goals and the principal characteristics of the vessel. Obviously, accurate data will give you more confidence in the predictions you make early in the design phase. Much of what we do in our office is to develop proposals based on parent hullforms. This is a natural for us, since we have been building primarily from fixed hull tooling that can be lengthened or widened from project to project, but is similar enough to lend itself to parametric manipulation. Our goal is to get a large enough empirical database to be able to dial in a vessel weight on a given proposal with a minimum of time required. Compiling this kind of data would be more difficult for a builder doing two or three custom yachts a year than for a production facility delivering many copies of a variety of models over the same period of time.

Define Your Format

The first step in a weight estimate is to choose a format and terminology. You can't keep track of anything if you don't know what it's called and what box it belongs in. To the best of my knowledge, there is no common standard lor weight estimates that applies specifically to yachts. There certainly are formats available for commercial vessels, such as the Maritime Administration (MARAD) system; and the U.S. Navy has its own numbering system for weight groups. Typically, large design offices have an established standard. At Delta, we decided to develop our own standard, based on the MARAD categories. We eliminated some inappropriate sections such as boiler foundations, riveting, and wooden hatch covers: and expanded others which, in yachts, represent a significant amount of weight. We developed the groups around the unique characteristics of composite construction, as well as the

PHOTOS AND DRAWINGS: DELTA MARINE INDUSTRIES





The price of very lightweight, high-modulus reinforcements has been coming down in recent years, and Delta Marine is one of a number of large-yacht builders who are taking advantage of the increasing affordability of these materials. Pictured above are two projects now underway at Delta in which the primary reinforcement is carbon fiber—24-oz double bias and 20-oz unidirectional—in a vinyl ester resin system.

Aerie **(below, right),** whose styling was done by Jonathan Barnett (Seattle, Washington), is the newest in a series of shallow-draft 124' tri-deck motoryachts. It's the first project at Delta to include all-carbon-fiber deckbeams. The bimini top will be constructed of carbon fiber skins and a foam core for additional weight savings in the most critical region.

Also under construction is *Gran Finale* **(top, left),** the first of the new Delta 147' tri-deck series, in collaboration with J.C. Espinosa (Stuart, Florida). The boat's design concept called for a skylounge with a 360-degree view, leaving little structural support for the large windows and curved sliding door. The solution to this engineering challenge is a prefabricated one-piece carbon fiber racking beam, which will extend through two deck levels and span beam-to-beam in the main saloon and upper lounge.

Virtually all structure on Delta projects, in addition to being checked against the standard regulatory-body requirements, is analyzed by finite element modeling (FEM). There are many FEM programs available; we have found ANSYS to be very adaptable to composite construction. The figure at **top, right** is a finite element model of the racking frame for *Gran Finale* showing exaggerated deflections under applied lateral loading. At **lower left** is an image of the main cabin front and coach roof for *Aerie* showing the finite element modeling of the carbon fiber reinforced structure under a simulated load. The accompanying legend in both drawings shows deflections in inches.

The combination of affordable, high-modulus reinforcements and FEM has allowed Delta to design and build lightweight *and* reliable structures. —*Jay Miner*

sequence in which our vessels are put together. The latter was particularly important to us, since we wanted to be able to verify our predictions as we went along by weighing each component as it was loaded or assembled.

Once the weight-category standard is established, the next step is to create an organized format for tracking your entries. This is commonly done on a computer spreadsheet.

Choose Realistic Weight Targets

It's not always easy to persuade a potential client to have reasonable expectations for a new project—as evidenced by some of the bid specifications floating around the industry for operating profiles difficult to accomplish in monohull designs. As the average vessel size continues to increase, we're seeing a demand for vessels in the 150' range with target drafts matching a client's present 110' yacht. Owners also ask for transoceanic capability, and a cruise speed approaching 20 knots. These requirements are at least on the edge of what is possible employing conventional hull configurations and construction methods. No designer or builder wants to be in the position of telling prospective clients that they can't have what they are asking for, but sometimes that's the right answer.

Beware of the trap of putting yourself in a position you can't support technically. As an independent designer, you have an implied obligation to work with the builder to determine which construction methods match the yard's skills and equipment, as well as to view the client's budget with the same level of concern that he or she does. As an in-house engineer, you are *compelled* to do these things.

At Delta, we have been lucky to have clients whose demands tend to fall in line with our perspectives, which may be more conservative than those of some other builders. Integrity and oceanworthiness of the vessel are our primary requirements. Speed, although a consideration, is not always the driving criterion. Still, since most of what we deliver has been going to south Florida, and the Bahamas are still on the cruising itinerary, draft remains an issue. This is one of the main reasons I think that we're seeing greater beam-to-length ratios in the newer vessels. Another reason is the demand for more accommodations within the same overall length, as dock space becomes increasingly limited for vessels over 100'. The majority of yacht owners would rather have the convenience of being able to moor their vessel at the quay than have to commute by tender from an anchorage.

For those who are just beginning to develop a set of data for vessel size, displacement, power, and speed, a word of caution: view the figures published in consumer magazines with a healthy dose of skepticism. There are numerous opportunities for you to gather bad information. Some of it may be the result of a simple misinterpretation between publisher and designer; and sometimes I believe it's an intentional red herring—many architects and designers may be reluctant to disclose too much free information to their competition. At any rate, if the published figures indicate a "tonnage" figure without a qualifier, you should be cautious. I've seen many people in the yachting industry who should know better (although typically not designers or engineers), confuse a vessel's gross tonnage on its U.S. Coast Guard certificate with a displacement weight. I've had numerous calls from people wanting to know what the "tonnage" of a specific Delta vessel was. If the call was from a shipyard getting ready to do a drydocking. they were usually looking for a weight to make certain their lift could handle the load. If the call was from a captain looking to upgrade a Coast Guard license, the caller needed the gross tonnage figure, which is essentially a volume measurement and has no direct relationship to the vessel's weight.

A good source of weight and performance numbers is engine distributors, who have a great deal of sea-trial data. Although this information is often proprietary, you may be able to convince them to share some of it by suggesting that they first delete the identity of the vessel and builder. Still, use this data with caution, since many sea trials are run before the vessel is 100% complete. Consider the well-publicized example some years ago of a 115' U.S.-built yacht. The project was a landmark for its builder, and the press was plentiful. I learned some time later that the trials were run before any of the interior was installed, and that the final speed of the vessel was notably less than the number that was splashed about marine magazines for six months.

Select Weight Margins Based on Your Level of Ignorance

We have found that the biggest unknown in the weight-estimating game in custom motoryachts is the client's propensity to add to the project, up to and even following launch day. We've seen projects start with the driving premise of simplicity. Somewhere along the line this philosophy gets replaced with, "This is the last yacht I'm going to build and I always wanted 'X.'"

Beware of statements similar to the following:

Broker: *"I've worked with this client for years and can tell you exactly what he will want..."*

Client: *"I don't want to make a statement. I want a very simple interior."*

Client's spouse: *"I'm going to do the interior design."*

In one extreme example a number of years ago. a 100'-plus yacht from a U.S. yard came in nearly one-third over original target weight at launch. The naval architect caught most of the blame, although the client was primarily responsible for making significant additions to the vessel long after the engineering was "finished."

I highly recommend identifying as much of the equipment list and basic outfit as possible at the time of contract. That way, there is a benchmark to refer to when weight is added. All the change orders my company writes include three questions:

- How much does the change cost?
- How much does it delay the delivery?
- How much does it weigh?

Every change order signed does not necessarily result in a delay or weight change (or even a cost change. for that matter), but at least such a document will prevent misunderstandings later. At the end of the project it's a simple matter to "weigh" all of the change orders and add the sum to the contract light-ship pound-per-inch immersion to determine the adjustment to the contract draft. While we haven't seen a number arise from this method that amounted to more than a half-inch of additional draft, formalizing the process in this way keeps the subject of weight in the client's mind when changes are being discussed.

In an ideal world, every pound could be accounted for and loaded into a spreadsheet, but some margin would still be necessary to ensure that the final weight comes in as expected. In our office, we like to see 5% or less as a margin in any category by the end of the process. Ultimately, you must decide how much to "keep in the pocket" for the unknown or unanticipated. Large composite yachts seem to have an exasperating ability to generate pounds where you would least expect it. If you don't adequately protect yourself from these uncertainties, you might find yourself facing a hefty penalty and an unhappy customer at the end of the project.

Also consider allowing a margin for the vertical center of gravity (VCG). My observation is that for normal length-to-beam ratios, a conventional yacht form provides a fairly safe range of intact stability characteristics. Nevertheless, an early check for stability is imperative. Given the implications of marginal stability, I recommend that you allow yourself some buffer here as well—3" of VCG in reserve is probably a reasonable figure. Use more if you are uncertain about the design tangibles. As in all vessels, when weight increases, it inevitably seems to migrate up rather than down. When choosing targets for vessel VCG at the beginning of a project, you can practically assume 90% of the distance from the rabbet line to the main deck. This has been a good rule of thumb for us for normal profiles and configurations.

Eventually, if you are diligent and develop a large enough database, you will be able to make fairly quick and accurate weight predictions for similar vessels using parametric methods.

Foster a Cooperative Attitude Between Designer and Builder

An education process between design/engineering and production is critical to attaining weight goals. The design group needs to understand the shop's preferred production methods and materials, and production needs to recognize the importance of the procedures and goals established at the beginning of the project. Your numbers must be accurate enough to allow you to answer questions from production such as this, from the carpentry foreman: "Yes, I *can* build this cabinetry out of ½" plywood, but ¾" is a lot easier. Does it *really* matter?"

We've discovered that once the production people become part of a team approach to saving weight, they are enthusiastic supporters of the program and frequently will come up with innovations for how to build something lighter.

We have found it quite useful to make up samples of structure in-house to verify weights against a manufacturer's published figures for various materials. Perhaps not surprisingly, the published figures can vary significantly from the actual samples—frequently because of differences in the glass-to-resin ratio of a laminate. This variation is akin to the mill-tolerance concerns with metal vessels, but perhaps more extreme in terms of percentage variation. Our samples are built in our own glass shop against a backer of waxed plastic laminate. Standard lengths or square footages are cut and weighed on a very accurate digital scale and labeled accordingly.

Draft Restrictions and Hull Design

If you are starting from scratch and developing a set of lines (particularly if you are going to make a reusable female tool), bear in mind the inherent advantages of putting ample beam into the design:

1. The hull might be stretched at

some point. What started life as a 100' yacht may be 106' before it hits the water.

2. More beam means bigger waterplane, which means higher tons per inch, if you are fighting a draft restriction.

3. More beam also means better stability when the 100' raised pilothouse becomes a stretch tri-deck.

4. Your competition is building a wider hull and the client's interior designer likes the added space to work with.

Of course, the down side to greater beam is the implication of lower speed if the proportions are not appropriate to the power available.

Partial tunnels are a common feature in shallow-draft vessels. Properly designed, tunnels aren't necessarily a detriment to performance. It's easier to reduce draft by locating the propellers up into the hull a little and bringing up the keel drag a few inches, than to find another 16,000 lbs to eliminate in order to meet a contract target.

Recordkeeping

Once the contract is signed and the targets established, the work goes to the second phase. It's imperative to review weight as construction progresses. In our shop, we weigh individual fiberglass parts as they are built and assembled. Similarly, we verify weights of mechanical components against manufacturers' figures, and weigh a representative number of interior cabinets to verify the predicted figures on a square-footage basis. The idea here is to avoid surprises and delays. We weigh parts that can fit on a 48" x 48" footprint and that weigh in the range of 10 lbs to perhaps 1,000 lbs on a digital platform floor scale. As components are loaded aboard the vessel, production people record the weights, which are later collected by the weight engineer. For heavier items, we have a digital scale that can be suspended from the hook of a portable crane, and has a capacity to 10,000 lbs.

We also own load cells, which we periodically use to verify the total weight of the vessel during various stages of construction. We can then compare these weights to the predicted figures for the same level of completion. Our system consists of eight load cells rated at 200,000 lbs each, accurate to plus or minus 10 lbs, and represents an investment of about $12,000. This may seem like a lot of money, but compared to the ramifications of an overweight vessel it's a good value. One draft or speed penalty would buy this much equipment several times over.

Typically, we weigh our vessels at certain milestones of assembly and outfitting:

- hull with all fiberglass bulkheads, tanks, web frames, and shell stiffeners installed;
- vessel main deck and first-tier superstructure assembled, boat deck loaded, main machinery installed;
- boat completely stacked up to flybridge level, main machinery installed, secondary mechanical systems underway, joinery rough-in underway;

- boat fully assembled, machinery complete, joinery rough-in complete, finish of interior underway, fairing and painting underway.
- After launch, vessel weight is verified by flotation waterline, checked against computer hydrostatics, and corrected via deadweight survey.

The beauty of ongoing weight monitoring during construction is that it doesn't really matter exactly what the level of completion may be. so long as all of the components can be identified and included in the running summary. Another benefit is a better idea of how the categories should be split once the light-ship weight is determined after launch. It's one thing to know how much the total vessel weighs completed. It's much more useful to have an accurate idea of what percentage of that total weight was joinery, or air-conditioning equipment, or stainless steel railings, etc. This is the only way you will be able to use this information for accurate parametric predictions for future designs.

Opportunities to Remove Weight

Delta has historically been known for its heavy-duty commercial vessels and trawler-style yachts. The latter craft were our entry into the yacht business, and we still build them. As our product line has expanded, however, the demand for stricter control over weight and draft has increased. The majority of hulls now in production in our shop are semi-displacement shallower-draft projects based on a single-chine bottom shape. When we built the tooling for the first of these hulls in 1992, we knew we needed a different approach to weights in general. Where we once had the license to simply make it strong and let the draft increase a little if necessary, we were now in the realm of tight constraints. All builders of 100'-plus fiberglass yachts are constantly dealing with these same issues.

SUGGESTIONS FOR HULL WEIGHT SAVINGS

If you look at the sample weight breakdown of the various major categories shown on the pie chart on page 53, you can see the largest amount of weight is in the hull structure, and the best opportunities to remove weight are probably in that area. I've listed below a variety of ways to extract pounds from structural weight.

1. The easiest pound to get out of a vessel is the one that was never needed in the first place. Good engineering up front eliminates the second-guessing that otherwise may take place on the shop floor when parts are being hud up. Lab-testing of shop-built laminates yields real-world numbers, which will give you greater confidence in your engineering than would a manufacturer's figures. Your test results may fall on either side of the published numbers. It's best to know what you're really getting on a day-to-clay basis in production, and select your laminates accordingly.

2. Cored structure is usually lighter than solid laminate for similar applications. Foams will generally produce lighter structures than balsa, since you

have to allow about 0.4 lb per square foot for both sides for resin soakage into the balsa—assuming you are not using a precoated product. (If you are using an ultralight balsa core with a manufacturer-applied surface treatment, the difference will be much less.) But remember the greater shear modulus afforded by balsa in long spans, especially on decks. Lower shear modulus will result in more material being used in a foam-cored deck to meet the same span-to-deflection ratio. Thick cores allow larger panel spans, and the labor costs are reduced because less framing is required. It takes no more labor to install a 1" core than a ½" core.

3. Make your parts as large as possible. The weight of secondary bonds can add up. A main deck built in two pieces rather than four, for example, could result in saving a significant percentage of the total weight of the part.

4. Avoid redundant structure where possible, but prepare for the unexpected bulkhead relocations clue to late-breaking arrangement changes.

5. Deep beams are more effective than shallow ones, where headroom permits.

6. Lightweight cores work in most places. However, labor hours are increased if you have to use compression sleeves for bolted installations.

7. Long spans in decks can get heavy in a hurry because of deflection-critical design. Large open areas, endemic to the yacht industry, are a challenge to design and build. Sell interior designers on the beauty of stanchions and columns.

Note that the figures published in the American Bureau of Shipping (ABS) *Guide to Building and Classing Motor Pleasure Yachts* may be inadequate for large spans. My conversations with other naval architects confirm this opinion, and many of them exceed the inertia figures published by ABS.

8. Use unidirectional reinforcements and other high-modulus materials where appropriate. For standard E-glass, the cost premium paid for unidirectional roving is small compared to the benefits (see sidebar on page 54).

9. Fairing compound acids pounds, and doesn't contribute anything to the structure. Wherever possible, filler materials should be used on the tooling, and not on the part.

SUGGESTIONS FOR MECHANICAL WEIGHT SAVINGS

Although this weight group makes up a smaller percentage of the overall light-ship weight, you can still pare it clown.

1. The first and most obvious consideration is the engine and the horsepower delivered per pound of weight. Your options are improving all the time, as more manufacturers offer high-performance packages. The challenge is to reach a balance between reliability and performance. We have

found that clients are sometimes more willing to accept the higher horsepower-to-weight-ratio engine when it's included in an extended-warranty package.

2. Specify aluminum rather than steel foundations and engine rails.

3. Where appropriate, plastic, rather than metal, pipe will save significant weight.

4. Aluminum or composite housings on engineroom blowers are available.

5. Select aluminum housings for reduction gears rather than steel or cast iron.

SUGGESTIONS FOR INTERIOR WEIGHT SAVINGS

1. Watch the small furniture, lockers, shower stalls, etc. They can get heavy quickly. A few years ago we checked some of the parts we were building for fixed seating and found that we could easily cut the weight in half and still build them plenty solid.

2. Our old method of building interiors employed a double-sheathed interior system. By converting largely to single sheathing of interior bulkheads or lightweight overlays, we have removed redundant labor and weight.

3. Cut out the backs of cabinetry. Use ½" instead of ½" stock where you can. Don't double-box the built-ins. This approach is more cost-effective than building with lightweight cored panels; we met our most restrictive project goals to date with selective use of those materials by paying careful attention along the way to everything that went aboard the vessel. Depending on cost and goals, the lighter-weight cores are certainly an option. Just make sure you do the cost-benefit analysis. How many dollars do you want to spend to remove the next pound?

4. We have built interior and exterior doors with heat-cured epoxy prepregs, and are considering these materials for other applications.

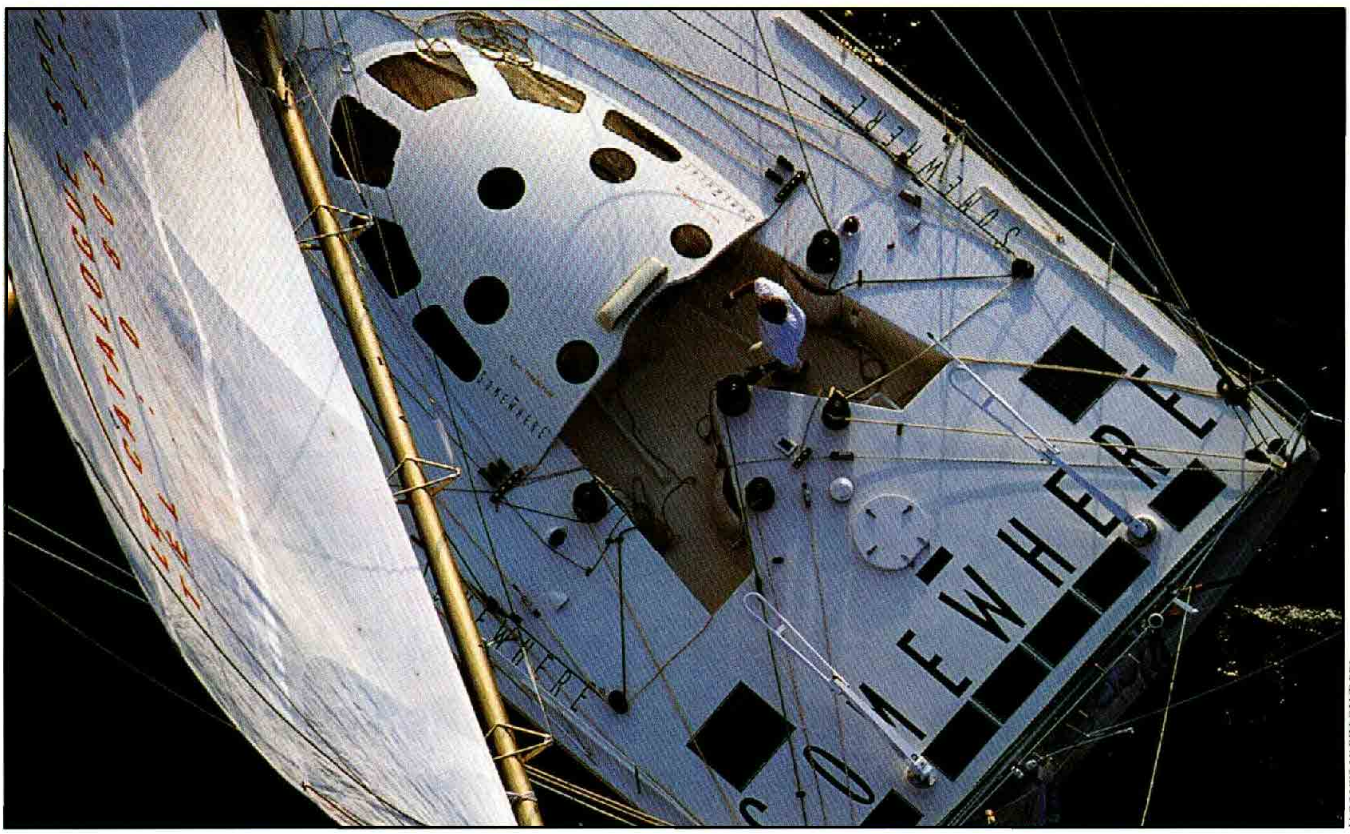
The biggest pitfall in weight estimating is not dedicating sufficient attention and resources to the task. The best intentions at the beginning of a project can get derailed if there is no clear priority to maintain an ongoing and thorough effort. It's a danger to relax too early in the project, because that's when the weight can creep aboard. Most production people will, if left to their own judgment, build components much heavier than engineering requirements dictate.

Weight estimates are frequently the least conspicuous part of a vessel design—until the launch. Then all eyes are fixed on the waterline at the moment *just before* the vessel floats free. It's easier to appear confident at that point when you've done a thorough job ahead of time. PBB

***About the Author:** Jay Miner is a licensed professional engineer. He joined Delta Marine Industries in 1987, and has been the company's chief navel architecht since 1989.*

The firm whose controversial, wide-bodied sailboat designs now dominate the field of shorthanded distance racing, continues to develop high-speed monohulls—for cruisers and racers alike.

Groupe Finot



JACQUES VAPILLON/DPPI

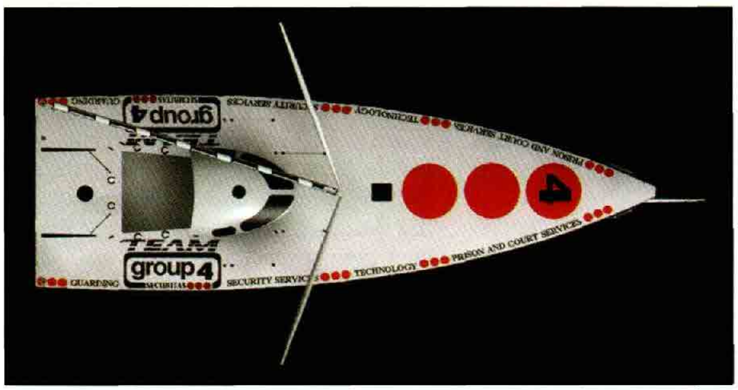
by Steven Callahan

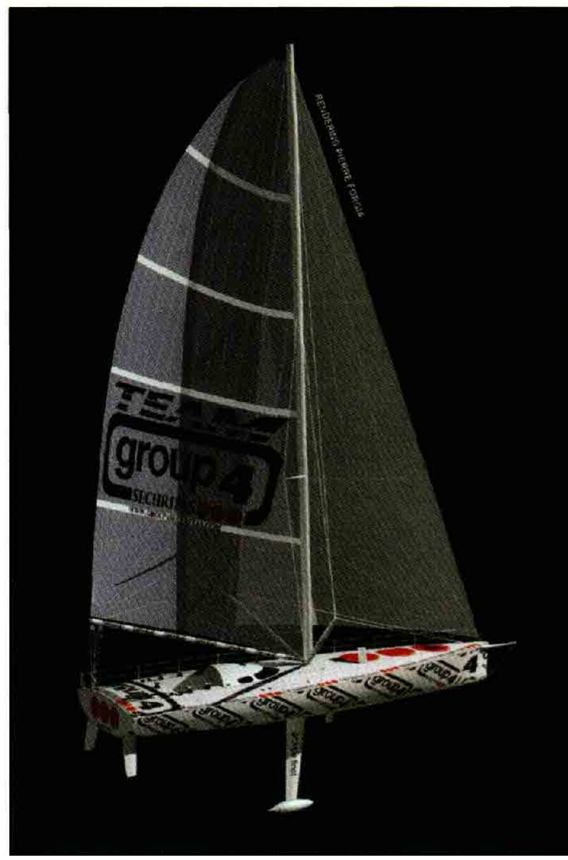
Jean-Marie Finot might just be the world's most controversial sailboat designer. Even as his speedsters dominate long-distance, shorthanded races and continue to influence the realm of cruisers, he battles the critics over issues of safety and the public's tendency to oversimplify complex design issues.

"I am not interested in boat design," says Finot. "The boat is not the objective. The objective is to create something harmonious with the sea, the wind, your crew, and you." The harmony in his head, however, is based on a hissing wake winding out astern at 20-plus knots, and the rolling thunder of big waves offshore. Although his 145-plus designs have spawned more than 27,000 boats built in a half-dozen countries, it is the so-called Finot skimming dish, sled, monomaran, or aircraft carrier—an ultralight racer featuring a beam a third its length, and a broad, chopped-off stern—that has become his trademark as well as the cross he has sometimes had to bear.

In the 1960s, when modern long-distance shorthanded sailboat racing began, few people imagined single-handed skippers effectively driving boats longer than about 40' or averaging more than about 150 miles a day. (Even large yachts rarely exceeded 250.) No one envisioned lone sailors piloting Finot 60-footers around the globe, routinely doing in excess of 350 miles in 24 hours while the boats remain amazingly well-behaved (usually), even when sliding clown enormous seas in the Southern Ocean.

There's no dark secret to gaining





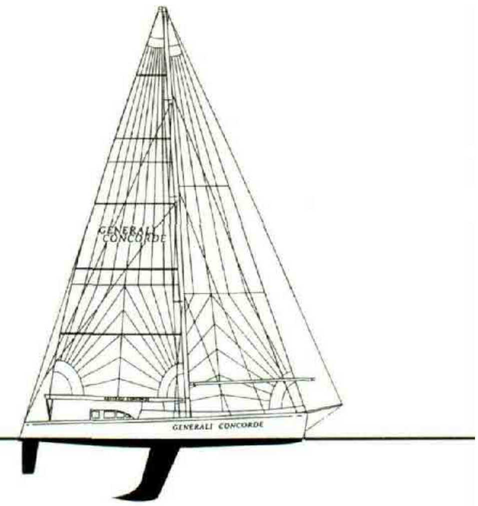
RENDERINGS, PIERRE FORGIA/GROUPE FINOT; PHOTO, JACQUES VAPILLON/PIXSAIL.COM

***Facing page**—*Somewhere *displays two distinctive features associated with Finot-designed Open-class 60 (18.28m) solo ocean racers: an aircraft canopy-like deckhouse, on an aircraft carrier-like deck.* ***Above**—Four views of the virtual* Team Group 4, *a recent Open 60, invite close study. At upper right, is a photo of the real thing. After winning the first leg of the 1998/99 Around Alone Race,* Team Group *4 had an unlucky grounding off New Zealand, compromising her carbon hull-to-keel-blade connection; the boat was pulled from the race. (For a technical discussion of the damage, see "Working with Carbon Fiber," PBB No. 61, page 34.)*

performance: increase power, decrease drag, or both. Starting early in the 20th century, offshore-sailboat designers began improving rigs and then lowering centers of gravity by using external ballast and deeper keels. They reduced drag by sculpting narrow hulls, or they added sail-carrying power by increasing beam, but until recently, they could only marginally decrease weight. In fact, boats like *America's* Cup 12-Meter yachts employed *more* weight to capture more ultimate stability. Until the 1960s, few offshore boats were light enough to escape the limits of their gravity waves, which bind hulls in displacement mode to a narrow range of hull speeds.

Since the 1960s, the quickening pace of change in offshore sailboat

Seven *years, seven representative raceboats. The Finot Open-60s profiled on these two pages chart an evolution in design, rigging, and construction. Keel migration aft, for example, is barely noticeable, except for* PRB, *where the shift is quite evident. Hers, however, is a less aft-oriented rig; instead, more emphasis has been placed on the daggerboards forward. The first boat in this series is aluminum, while the later boats were built in advanced composites, reducing weight by nearly half.*



DRAWINGS COURTESY OF GROUPE FINOT

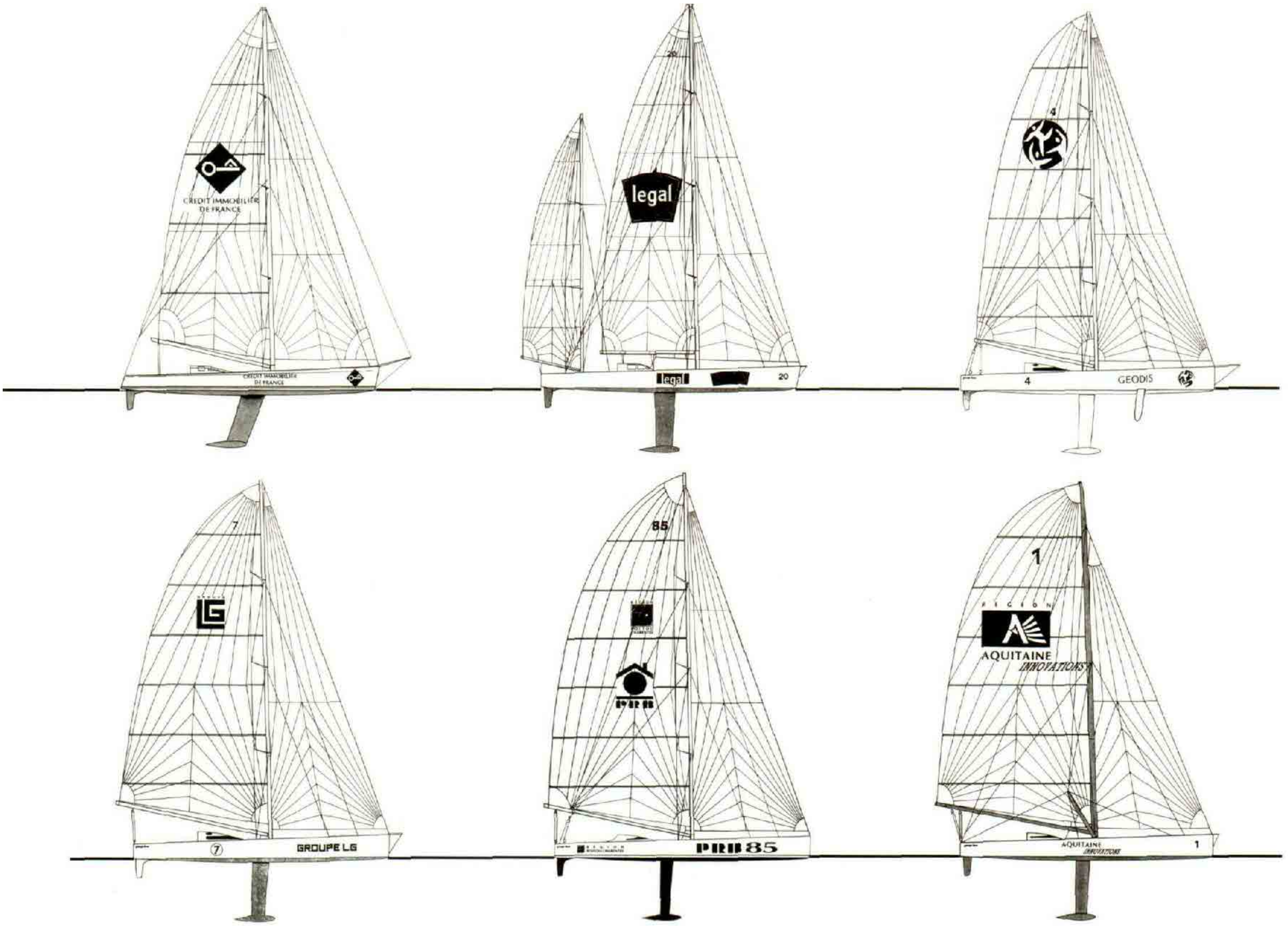
construction has fostered parallel advances in design. For example, in the United States, Alan Gurney's cold-molded 73' *Windward Passage* ("the big dinghy"), with a beam of more than 19', set records around the world. Bill Lapworth's light but narrower glass boats, like the Cal 40, balanced upwind power with low drag, and surfed prodigiously to become a production classic. Bill Lee and other West Coast designers followed suit in the 1970s with cored-glass, slim-waisted, ultralight displacement boats (ULDBs) that sacrificed upwind stiffness but shattered downwind records as they raced far offshore to places like Hawaii. New Zealand's Bruce Farr, among others, morph'd extreme dinghy designs like the Sydney Harbor 18s into IOR (International Offshore Rule) winners. These sharp-bowed yet very wide, shallow hulls, with their broad sterns and with big crews camped out on the windward rail, sailed upright while carrying generous sail both upwind and when surfing and planing off the wind. The IOR model, though, proved a poor package for cruising or shorthanded offshore racing. When overpowered and well heeled, these designs showed little forgiveness; their triangular plan-forms nosed down, ventilating their rudders and often causing the boats to spin out of control. More importantly, though very stiff at small angles of heel, these designs lacked a large range of stability. Indeed, the trend among racing yachts toward big beam, light displacement, and a shallow hull with a high center of gravity was widely held responsible for the numerous knockdowns and capsizes in the disastrous 1979 Fastnet Race, in which 24 boats were abandoned and 15 sailors died.

From France, Jean-Marie Finot had been lending a more measured influence. After two years under the wing of Philippe Harle, one of France's most prolific boat designers, Finot made a name for himself with *Ecume de Mer,* winner of the 1970 and 72 Quarter Ton Cups (she then spent five years circumnavigating), followed by *Revolution,* which won RORC championships in 1976, '77, 78, and 79. *Revolution* showed that even back then, Finot thought outside the box. Whereas the early IOR greatly encouraged pinched sterns and bulbous protrusions, called bustles, around the rudders, Finot's design featured smooth lines and a broad transom.

Finot recognized that light weight, broad beam, and a shallow hull were not technical problems per se. The problem was with a handicapping rule that *penalized* a light shallow hull having a low center of gravity (giving it an improved range of stability), and, in general, hull shapes offering better overall handling characteristics. Finot, who had closely studied hull shapes, derived formulas for attaining good balance; though the "hips" of his boats have grown broader in the years since, Finot's vessels have also earned a reputation for remaining so easy to handle that 60-footers are fitted with tillers that usually require only fingertip control.

Finot's goal has always been straightforward: to design boats that are, in his words, "happy in all conditions." The then-new "Open" development rules provided Finot with a perfect opportunity to realize his dreams. Dreading any repeat of negative results caused by previous handicapping systems, the organizers of shorthanded offshore races decided to divide boats into classes determined only by overall length, thereby allowing designers to explore widely divergent paths to victory.

In most of those early races, monohulls competed directly against multihulls. The latter type benefited from low-drag, skinny, lightweight hulls that were incredibly stiff, allowing them to carry lots of sail even in high winds. Their rigs' power also benefited from stiffness. Since lift is perpendicular to a foil, one component of a heeled sail's thrust pushes the boat down into the water, increasing dynamic displacement and drag. More air also slips up and over the sail's head, decreasing the sail's power. A deep keel may lend a great deal of stability as a boat heels, but it won't add much stability at the low heel angles at which a boat most efficiently sails. So the only way to gain comparable power in a monohull was through beam, light construction, and movable ballast, which significantly lengthens the righting arm even at zero degrees of heel. Overcanvassed 19th-century "sandbaggers," with length/beam ratios of 3, and narrow racing log-canoes of the same period, whose crews hiked out on boards, were among the earliest boats to exploit movable ballast, but they almost always sailed in displacement mode. Then in the mid-1960s legendary French offshore sailor Eric Tabarly commissioned the design of a shallow-bodied 35' raceboat with a novel system of water ballast that could be

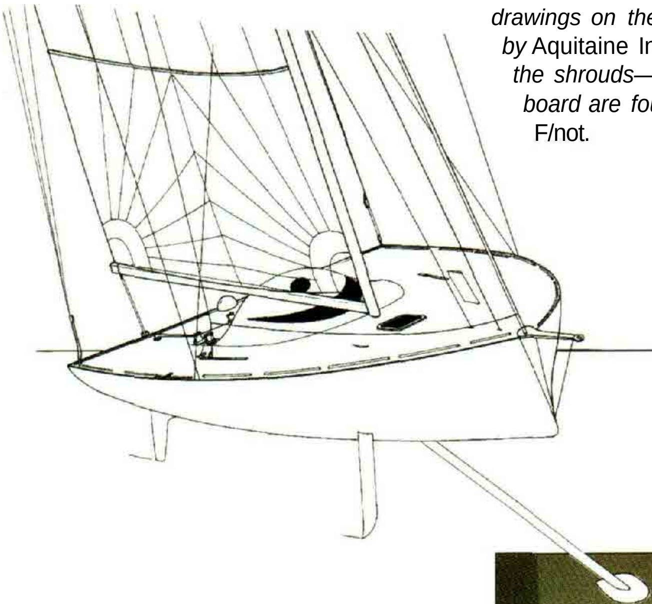


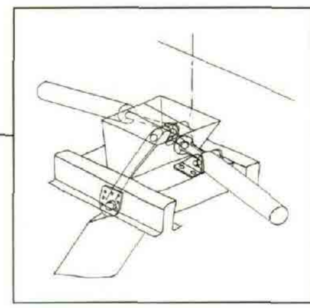
	Générali Concorde	Groupe Sceta**	Café Legal***	Geodis	Groupe LG	PRB	Aquitaine Innovations
Year built	1989	1990	1991	1993	1995	1996	1996
Length	18.28m						
Beam	5.80m	5.80m	5.80m	5.75m	5.75m	5.70m	5.85m
Draft	3.80m	4.25m	3.92m	4.12m	4.12m	4.18m	4.15m
Displ.*	14 tons	11 tons	11.5 tons	9.3 tons	8.9 tons	9.5 tons	8.5 tons
Mast	25.50m	25.50m	25.50m ketch	25m	25m	25m	25m wing (40 cm)
Total sail area	$220m^2$	$240m^2$	$261m^2$	$265m^2$	$285m^2$	$270m^2$	$304m^2$
Mainsail	$104m^2$	$135m^2$	$112m^2$	$155m^2$	$170m^2$	$160m^2$	$190m^2$
Genoa	$116m^2$	$105m^2$	$9m^2$	$110m^2$	$110m^2$	$110m^2$	$114m^2$
Spinnaker	$300m^2$ and $350m^2$ entered according to the configurations						
Materials	aluminum	E-glass/ PVC foam	S-glass/ PVC foam; deck: carbon/PVC	carbon/ Nomex	carbon/ Nomex	carbon/ Nomex	carbon/ Nomex
Builder	Le Guen Hemidy	Pinta	CDK Composites	JMV/MAG	JMV/MAG	Pinta	Thierry Eluere/ Composites Aquitaine

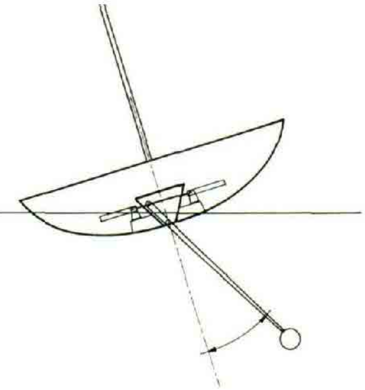
* The last four boats have essentially the same hull weight; the difference is in the ballast and equipment

*** Credit Immobilier de France*   **** Baggages Supérior*

Below we see PRB's *swing keel, and a detail drawing of its mechanism. The two drawings on the left at the bottom of the page illustrate the unusual "Tirant" rig worn by* Aquitaine Innovations, *among other boats. It was conceived by* F/not *to spread the shrouds—much* as *they might be with a multihull. Conferring at the drawing board are founder Jean-Marie* F/not, *left, and Pascal Conq, his partner in Groupe* F/not.



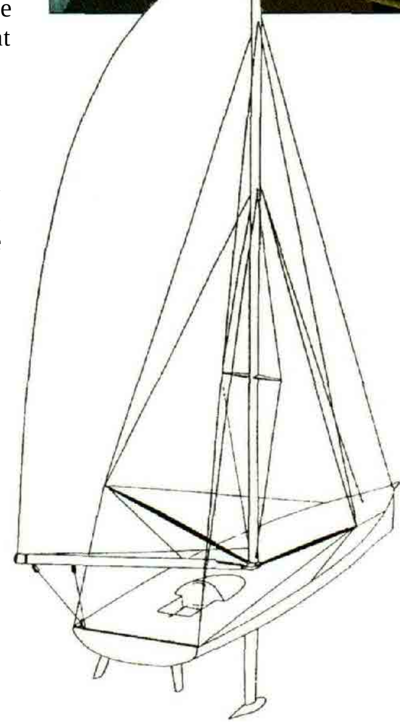


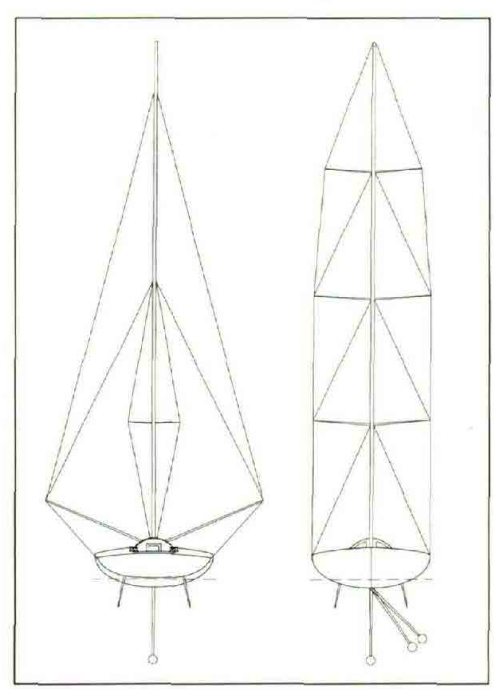


dumped when not needed yet easily picked up again. Tabarly's *Pen Duick V* easily won the Singlehanded Transpacific Race.

By the early 1980s, the "Open" rules for both the MiniTransat singlehanded transatlantic and the BOC singlehanded circumnavigation races (already limited to monohulls) had closed significantly. Organizers feared that too much water ballast might help capsize a boat caught aback. After the 1979 MiniTransat and the '83 BOC, they limited water ballast, which had to be carried within the hull; in the BOC, to an amount that would heel the boat at rest no more than 10°. Designers immediately rec ognized that the wider the hull, the more form stability it possessed to resist heeling from the movable bal last. They could tuck ballast tank under the deck edges of very wide hulls—the farther from the centerline, the more foot-pounds of righting moment they would gain to hold up increasingly large sail plans. The net effect of the rule was to increase beam and power while eliminating narrow, self-righting designs with external ballast systems.

In view of the IOR experience, however, throughout the 1980s most designers of offshore racers feared extreme beam. Since singlehanded sailors had to trust self-steering in truly horrendous conditions,





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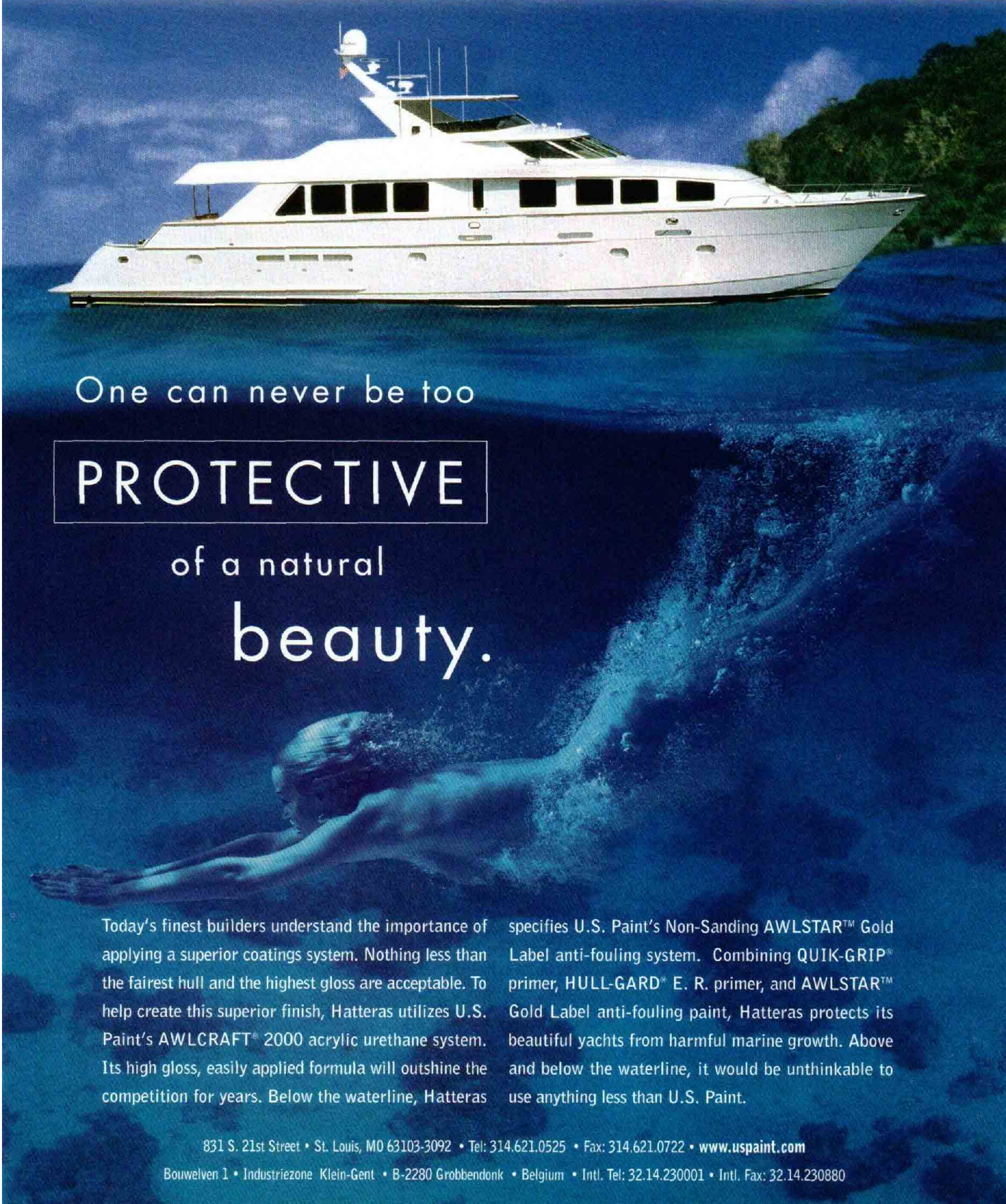
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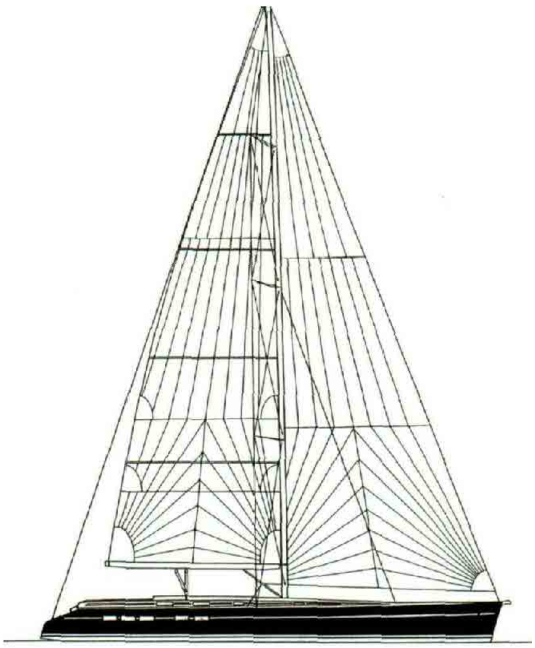

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Designed as a fast offshore cruiser, the Cigale 18 is a semi-production 60-footer being built by the Alubat Shipyard in France. The low-profile deck is deceiving: down below, accommodations are fairly generous. While Finot's big raceboats may get a lot of press, the firm's design work for production builders has been a staple of the business for years.

they needed easily handled boats that also were capable of sailing efficiently to weather offshore. This enticed designers of the period to draw narrower boats. But not Finot.

With a maximum length of 6.5m (21.30, MiniTransat boats had always been little more than decked-over dinghies. As early as 1979, those boats with beams a third or more of their length clearly claimed the advantage, especially during the second, downwind leg from the Canary Islands to the Caribbean, when they were doing 180- to 220-mile days. Such speed more than made up for any upwind shortcomings, but even upwind they could carry so much sail they remained very fast, if wet, while bashing into waves. When well heeled-out, one of their double rudders, like those found on traditional Great Lakes racing scows, remained in the water at a near-ideal angle and kept the boats under control. Finot carefully observed the field, beginning in 1977, when his *Reve De Mer* finished second. By the time he produced a winner 12 years later, which he followed with wins in '91 and '95, he'd merged all the successful trends with his own refined hullform. He scaled it up to 60' with *Generali Concorde* for the 1989-90 Vendee Globe (6th place) and then *Groupe Sceta* for the 1990-91 BOC (1st place; *Generali Concorde* 2nd), quickly solidifying his lead. Since then, Finot's lead has only stretched as his boats won the 1992-93 and 1996-97 Vendee Globe races and the BOC/Around Alone in 1994-95 and 1998-99, as well as the 1991 and '95 MiniTransats. His Open 50 designs have been just as successful, placing first and second in the 1998-99 Around Alone.

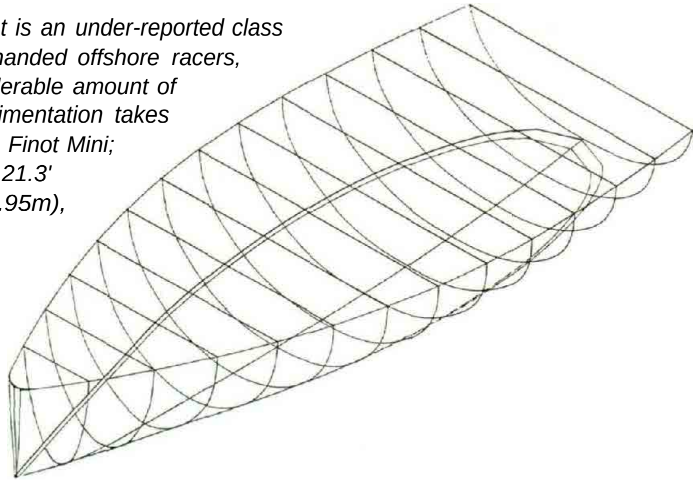
Designer Olin Stephens has long criticized light, beamy IOR boats, insisting that sailing hull shapes must be balanced from end to end. Finot actually agrees with Stephens, but typically re-examines the underlying truths behind such rules of thumb. He discovered early on that good balance does not require pinched ends or heavier displacement. While perpetually sketching hull shapes, centers of forces, and graphs and vectors as he talks, Finot concludes, "Triangular shapes are not good, and immersed banana shapes are not good except for turning." He balances his hulls by using firm forward shoulders—again, like lake scows. These hulls roll out evenly, the heeled centerline remaining nearly parallel with the upright one. American designer Rodger Martin recalls his surprise upon seeing a Finot boat sailing upwind for the first time: "The bow didn't roll down," he says. "It actually lifted!" Martin began developing related shapes for his own Open designs.

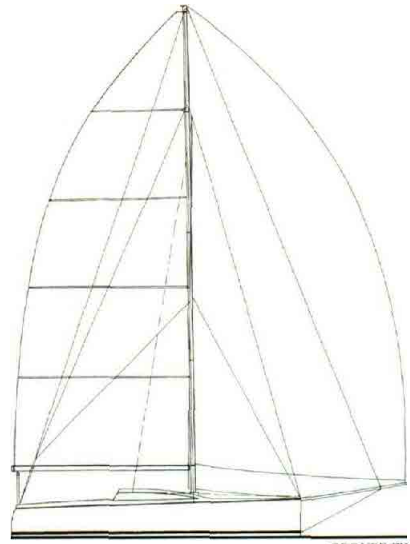
Finot boats have also re-emphasized the importance of sail forces in the balance equation. A stiff boat keeps the rig more centered over the hull, decreasing the turning lever arm between the rig's center of force and the center of lateral resistance. By the late 1980s, Finot had got the proportions of his winners so right that they have not had to change much since. In his Open 60s, for example, a beam of 5.7m to 5.85m (18.7' to 19.2') remains more or less constant. Mast heights reach about 25m (82'). This





The MiniTransat is an under-reported class of small singlehanded offshore racers, where a considerable amount of technical experimentation takes place. Here's a Finot Mini; she measures 21.3' (6.5m) x 9.7'(2.95m), and draws 6.5' (2m). Note the dinghy hullform.

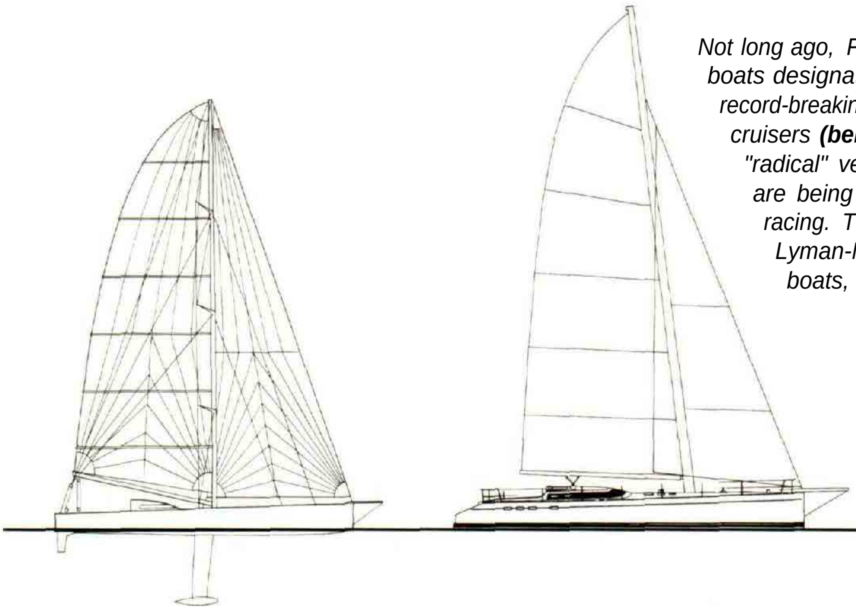


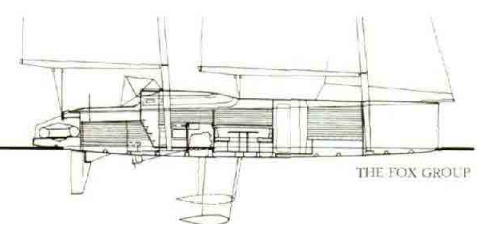


GROUPE FINOT

envelope's seemingly consistent size, though, masks its significant evolution.

Composite-built boats in the Whitbread and other major offshore races have a history of delamination and shear failures. Finot knew that he would have to confront the huge beating that his broad, flattish panels would take offshore. So Finot's first Open 60, *Generali Concorde.* launched in 1989, was built of aluminum. Still, Finot soon recognized that only composite construction could appreciably lighten his hulls. *Groupe Sceta,* Finot's first Open 60 built of polyester and glass, suffered delamination in some large panels in the first leg of the 1990-91 BOC; but repaired, she carried on to win. Pascal Conq, Finot's right-hand man since 1985 and now his design partner in what is called Groupe Finot, explains that it was hard to tell what caused the delam problem with *Groupe Sceta,* though it appeared to be due





Not long ago, Finot was commissioned to develop a family of boats designated The Fox, all based on Finot's successful, record-breaking Open 50. There are ketch- and sloop-rigged cruisers ***(below),*** *with alternate layouts. And there are "radical" versions that share the same profile* ***(left)*** *and are being marketed for fast daysailing and/or offshore racing. Two U.S. builders—TPI (Rhode Island) and Lyman-Morse (Maine)—have teamed to produce these boats, utilizing SCRIMP technology.*

to outgassing from the foam core. The next Finot raceboat. *Baggages Superior,* was built with epoxy and higher-quality glass; she suffered no problems going around the world to win the 1992-93 Vendee Globe. Even so. says Conq, "We later found a 'bubble' in the engine compartment, so we decided to do something about it."

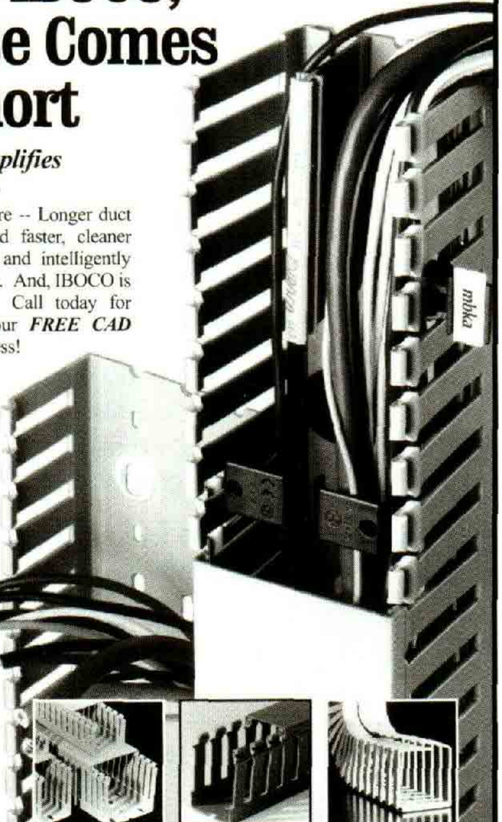
The Finot office has always been very computer-oriented, and uses finite element analysis for engineering high-load areas and details, as on masts. But Finot himself takes a multi-pronged approach to the general engineering of his hulls. "Our number one obsession is to make sure the boat is strong enough," says Finot. "We looked first at 'old' regulations like Lloyd's to figure out the size of stringers, frames, and skins. We could then calculate the pressures those are built to handle. Next, we looked at our boats as built. If a stringer broke, we asked what it took to break it. But we also consider the speed of the boat and the wave and calculate the energy it takes to slow or stop the boat. Say the boat is going 12 knots and the wave 30 knots and the boat slows to six; that energy forces water away from the hull, and we can calculate that."

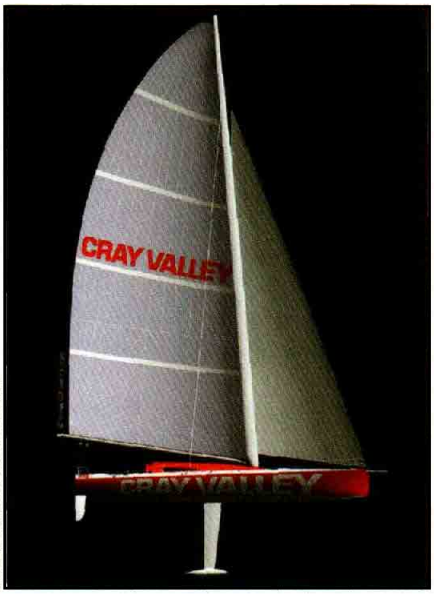
A typical Groupe Finot hull is divided into 30 or more panels composed of five or six basic laminates. Photos of a Finot model being tank-tested for surfing and planing, show sheets of light spray near the bow; these shift suddenly to a massive solid bow wave concentrated just forward of the keel. That's where, Finot notes, "the keel and rig tend to twist the hull and pull the boat into a banana shape. It is also where the hull panels become significantly bigger, fuller, and flatter." Experience indicated that the panels most highly stressed withstood a head of seven meters or more, "but to me it still was not enough," notes Finot. "We design for a *working pressure* of 15 meters, and *failure* at 30 to 40 meters, or about 30 tons per square meter of hull. For that kind of load it's difficult to design a sandwich structure that won't fail in shear. So, since the 1994-95 BOC, we've been using core materials only aft and in the deck, and pre-preg carbon single skins with stringers forward." Discounting lost spars and a ruptured keel joint (after grounding at full speed—boats with deep narrow fins are designed to survive a grounding at up to 10 knots, but not 20), Finot's raceboats have suffered no significant structural failures. It is a remarkable record.

For cruising boats, too, Finot now believes that single skins—beneath the waterline, at least—provide superior shear strength and longevity, since they eliminate any possibility of water entering the core. "It requires a little more material and may be a bit heavier," he says, "but a solid skin of carbon is about half the weight of solid glass, and *stringered* carbon is close to the weight of cored glass or carbon. It just takes more time to build." He thinks it's also safer for groundings or collisions, because single-skin carbon is more flexible than a cored layup, so it better absorbs spike loads. And, the skin is thicker than a skin on a core. "Also," he notes, "when failures occur within a cored laminate, you can't see them. With a single skin, you'll see a broken stringer, and you fix it."

Finot has honed aircraft-style stringer/skin construction by alleviating stress risers and eliminating secondary bonds. "We round the stringers on top and place little fillets in the corners," he explains. "We also use more flexible resins in the fillets, and we put the stringers in when we cook the hull, so they become part of the primary bond."

Thanks to composites, Open 60 displacements have plummeted from 14 tons to 8.5. Finot could save still more weight, but he chooses instead to balance several factors. These include the need to increase power while minimizing wetted surface. Finot keels have deepened from 3.8m (12.50 to 4.18m (13.7'). Increased ballast now is carried in highly refined T-bulbs having hollowed tail sections. With the launch of *PRB* in 1996, Finot chose to begin offering





PIERRE FORGIA/GROUPE FINOT

JACQUES VAPILLON/PIXSAIL.COM

swinging keels in lieu of water ballast. The swinging keel allows the center of gravity to shift to weather at low heel angles, just like water ballast; but, driven by hydraulic rams, the swinging keel is quick, relatively simple, and keeps the boat lighter, which is a distinct benefit when reaching or sailing upwind. Of course, once the keel is hitched up to weather, it makes a very poor lateral-lift device, so Finot employs secondary daggerboards (as do other designers). Recent victories with these boats have proven the effectiveness of this approach, but victory comes at the

CCP Cray Valley, *an Open 50, set a Newport-to-Bermuda record prior to winning Class II in the 1998/99 Around Alone Race. Her hull and deck were SCRIMPed by Maine builder North End Composites. The boat as built has a smaller deckhouse than is shown in the Finot rendering.*

GROUPE FINOT

The South 35 is Finot's newest production racer/cruiser. Construction is carbon pre-preg; the builder, Aerodyne Technology in South Africa. She measures 34.4' (10.5m) by 11.5' (3.52m). Groupe Finot's name for the rig is the "C. Wing.

price of an extra $100.000 to $200,000 for the additional complexity.

The rig revolution also has yielded enormous speed enhancement. Increased stability and carbon masts have allowed Finot to boost raw sail power as areas increased from 220 square meters (2.367 sq ft) to 304 (3,271 sq ft). Rigs have moved aft. too. With small headsails and large, heavily roached mains'ls set on booms overhanging the sterns, sail pressures do not depress the bows as much, allowing Finot to continue to test just how sharp he can make his hull entries to improve upwind work. Keels, too, have migrated aft, to balance the rigs. And forward daggerboards on boats with swinging keels help keep the bows from blowing off on some headings.

With apparent winds often in the 30- to 40-knot range offshore, the aerodynamics for both reducing drag and maximizing lift become increasingly important. Finot was an early proponent of carbon fiber, which decreases a spar's sectional weight and frontal area, correspondingly decreasing pitching inertia and parasitic drag from windage and turbulence. Also, by 1991, departing again from the route taken by most of his contemporaries, he returned to non-overlapping working jibs. Taking advantage of the boat's wide beam, Finot rigs—with their very long spreaders—suffered smaller compression forces, keeping them slim and light.

The great efficiency of wing masts held much appeal for Finot, but how to get one light enough for a monohull? What if he widened the staying base even more, as on a multihull, by using a pair of boom-like spreaders splayed out from a deck-mounted maststep? Says Conq of what he and Finot call their "Tirant" (meaning push and pull) rig: "The weight of the rig is a little greater, but it's centered lower, so the heeling moment is the same. We needed to acid no weight to the keel or anywhere else, and we gained a wing. There's much less drag and it makes the forward 25 percent of the sail much more usable."

Unfortunately, the first Tirant-rigged boat dismasted in the Transatlantic Cate Race. Finot and Cone) found that pre-tensioning the shrouds and controlling the stretch of the running backstays was critical. "There was a miscommunication about the modulus for the Vectran backstays," says Finot. "The running backstay stretched too much, so all the force came on the primary rigging. Now we use PBO-fiber backstays." (Made by Toyobo, a Japanese manufacturer, "PBO" is an acronym for the lengthy chemical name describing this new cordage, which is about 50% stronger for its weight than Vectran.) Beneath the mast, a hydraulic mast jack pre-tensions each rod under the Tirant. Load cells with a readout at the chart table let the skipper check levels: mainsheet, 3-3.5 tons; lower shrouds. 7-11 tons; mast compression, 20-25 tons. By the 1998-99 Around Alone, Tirant-equipped boats were reliable enough to dominate the race, Canting

RENDERINGS: PIERRE FORGIA/GROUPE FINOT

such rigs could allow a boat to develop even more horsepower by keeping the mast upright when the boat heels: Finot has designed one, but says that at this stage it remains too complicated for his taste. Besides, they are currently forbidden by the rules.

Finot boats have shown such consistent superior speed that in the 1998-99 Around Alone, half the fleet was conceived on Finot's board, and most of the competing boats looked like Finot clones. Groupe Finot designs finished first and second in Class I (Open 60s, and the only two boats *to* finish) and Class II (Open 50s). Strange then that the editors of a prominent sailing magazine recently plastered the word "unacceptable" across a photo of a Finot speedster. Of course, that boat was upside down at the time. Still, why should we be surprised when grand prix racers of any ilk, from cars to powerboats, push the limits and a goodly number crash? And why would the media blame Finot for the capsize, rather than a rule that encourages monomarans that remain just as content upside down as they do right-side up? Finot himself seems rather perplexed by it all.

This type of raceboat should be assessed as a hybrid craft, because it is more closely related to a catamaran than to a 12-Meter, both in terms of performance and stability characteristics. Like a cat, these very wide, extremely stiff hulls develop enormous righting moment (RM) at low angles of heel (Finot's reach maximum RM at about 50°), so they are highly

JACQUES VAPILLON/PIXSAIL.COM

Despite an excellent race record, PRB's *terminal capsize in the last Around Alone caused many members of the international racing community to question the dynamic stability of* Groupe Finot's *big, wide, shallow hulls. Called upon to explain the circumstances of that particular event, Finot's Pascal Conq insists that newer* F/not *raceboats will self-right if flipped.*

resistant to knockdowns or capsize. But, acknowledges Finot, "that also makes them less forgiving." The RM quickly declines after the maximum is reached. Once inverted, the boats become stable rafts; like multihulls, they have not sunk but protected their crews within the hulls, sometimes for days, before rescue. Granted, those within the racing community already opposed to multihulls and light monohulls have always been critical of these craft, but after a number of Finot boats capsized and refused to re-right during the last Vendee and Around Alone, even Finot fans were beginning to wonder about the Groupe Finot approach.

Finot argues that the complex issue of safety cannot be summed up as simply as his critics would have the public believe. He stresses structural integrity as the primary safety feature. Finot believes that sailing upright also is more restful for the crew and safer. He adds, "I think that speed is a huge security factor. Even against the wind, it's an advantage. Given better weather information and the ability to sail 400 miles a day, you gain a lot of choices of where to go in relation to a storm system." Moreover, Finot feels that certain criticisms are apples-to-oranges comparisons. "One race such as Around Alone," he says, "is equal in miles to a typical family cruising for their whole lives. It's not fair to compare traditional cruising vessels sailing in the summer to high-performance boats racing in the Southern Ocean. In the winter each year, not many people go out cruising, but every year one or two traditional boats go down. If you compare traditional boats sailing the same amount of miles in winter—or even the number of failures of 'conventional' boats in the most recent Sydney-Hobart Race [the fleet was swept by a gale with monstrous seas]—to the Open 60s, I think you'll find proportionally more accidents with traditional boats."

Despite this reasoning, Finot hardly discounts stability, which he ranks second in importance to structural integrity. In fact, he declines to design multihulls precisely because of stability concerns. In the final analysis, Finot is determined to create boats that can perform like multihulls but are self-righting.

Deep bulb-keels have helped to deliver static stability ranges of up to 120° in Open-class designs, and that is surprising, given the proportions of these boats. But Finot argues that rules of thumb and hydrostatic figures only through 180° are not very useful. He thinks dynamically. He considers the ratio between the total energy under the positive righting curve and the energy in the capsize force of the wave. He also understands that the boat itself may *add to* capsize energy, as when veteran singlehander Isabelle Autissier jibed her Finot-designed 60 in the 1998-99 Around Alone. That jibe added significant centrifugal force to the capsize moment. It also put her boat's canted keel on the wrong side, aiding the capsize. Once flipped, the keel then rested to weather, helping to resist re-righting.

Clearly, boats like those that Finot designs, with their immense catamaran-like righting moments, will capsize infrequently. But he is still determined to design boats that are unwilling to remain upside down. For each boat in every conceivable condition—with mast and without (masts are usually sealed and buoyant, helping to resist capsize and thus promote re-righting); with and without water ballast; with keel canted or upright—he plots righting curves throughout 360°. The asymmetry of forces offered by factors such as water ballast reduces the negative energy on one side of the curve, so a Finot boat probably will re-right by continuing its roll through 360°. Although the positive stability energy of *Fila,* a Finot Open 60, is *60* times her negative energy, when she capsized in the mid-Atlantic the boat took 6.5 minutes to re-right. It took that long, says Pascal Conq, because first, the keel had to swing to leeward; second, since the rig was broken, *Fila's* skipper had to get all that gear into a position that would permit the boat to re-right; and third, he had to maneuver the boat 90° to the waves. (Conq points out that for boats built before *Fila.* a dismasting during capsize might cause the hull to remain inverted permanently if waves are not large enough to tip the vessel at least 20°.)

Fila was re-righted and went on to win the 1998-99 Around Alone. "But," says Conq, "we don't want to hear anything more about capsizes." The goal now at Groupe Finot is nothing less than to reduce the negative energy on one side of the righting curve to zero. To do this. Finot and

Conq are designing decks with greater camber, and bubble coach roofs with greater volume. Also, some raceboats currently carry inflatable bags on the sterns. Once activated, this equipment raises the capsized boat's center of gravity and reduces re-righting resistance from the broad beam; re-righting is facilitated around the narrower bow. And, if the boat retains its watertight mast, then so much the better.

Finot is fairly pleased with the technical progress in offshore racing-boat design during the past 30 years. "It used to be that up to 9 knots of wind, the boat remained 'asleep,' and it might remain 'happy' to about 30 knots. Now, with a more stable boat, you can put up more sail and keep sail up longer, so the boat is in harmony with the sea from 4 to 40 knots," he says. Has this expansion of the performance envelope done much, though, for cruisers? After all, in an Open 60 you don't even have enough headroom to stand inside, except under the tiny coach-roof blister. And just what are the differences between racers and cruisers? "No difference," Finot replies. "A cruising boat is not a racing boat, but the crew faces the same problems. Even when sailing with your family, very often you must handle the boat alone."

The many cruisers Finot has designed for production builders like Beneteau show some influence from his raceboats, but newer designs, such as the aluminum Cigale and Levrier product lines from Alubat Shipyard in Les Sables D'Olonne, France, and the all-carbon sport cruiser, the South 35, built by Aerodyne Technology in Cape Town, South Africa, are close cousins to Finot's Open designs. Given similar hullforms, these new cruisers feature greater relative freeboard, which earns them enormous interior volume for accommodations, and extends the range of their static positive stability to 130° or more. They carry water ballast tanks, but the tanks are placed lower in the hulls to add to the range of stability. The bulbs on their keels do not extend forward of the fin (so they won't snag debris), demanding a different bulb shape, but these fins are still pretty deep. Other fast-cruiser designs still on the Groupe Finot drawing board display *lifting* keels. Finot's trademarked "C. Wing" rig—an option on the South 35—is clearly a departure, but may foreshadow upcoming Open 60 designs. "Once we did the Tirant rig we knew we'd try to find another, simpler solution as soon as possible," says Conq. The C. Wing, a lightly stayed carbon wing mast, eliminates spreaders, which often restrain a mainsail from being let out enough for perfect trim, and which claw at long battens and sails that are eased for reefing.

Although the public has been gradually lured into the benefits of wide, lighter boats, many yachtsmen still view such boats as being too radical, and Finot continues to battle long-held myths. He acknowledges that if you were to spend all your time sailing upwind, heavier narrower hulls might be more comfortable. "But I don't do that," he says, noting that cruisers usually prefer offwind courses to bashing to weather. "Even upwind in light airs, our boats have no problem because there are no waves. In heavy airs, you have more stability and the waves are farther apart, so again you have no problem. The only problem is in moderate airs in a chop. If it's less comfortable then, at least it will be so for less time. Off the wind, our boats don't heel or roll as much."

When confronted with the old saw that loading up a light hull hampers its performance more than it would a heavy one, Finot laughs. "I agree! With a heavy boat loaded you slow from 4 knots to 3.9; with a light boat you go from 6 to 5.5!" He points out that a beamy hull makes a bigger footprint on the water than a narrow one, increasing its pounds-per-inch immersion, so a given load depresses the wide hull less. Like cruising-multihull designers, Finot, for structural and hydrodynamic purposes, designs boats with the fully loaded condition in mind. Take the South 35 as an example. Finot allows for a working payload of one ton and a maximum of two. Says Conq: "Putting additional weight in is usually *not* catastrophic. But taking too much weight out is terrible, because the boat gets tender."

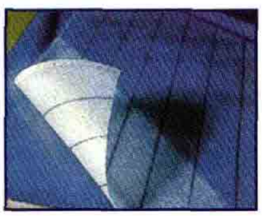
For Finot, development of monohulls is far from over. "Since people like Van de Stadt, Harle, and in my generation, Dufour, began drawing what I consider 'modern' designs three decades ago, speed has gone up by 30% to 50%, and the window of performance has widened." Continued refinement, he adds, "will make it possible to improve cruising boats by another 30%."

Finot's success is due not just to designing boats with great speed potential, but also ones that are practical. Says Conq: "We're trying to be as simple as we can because we like simple things, and we know that it's not easy to design simple things that work. We don't want to hide behind something complicated just to pretend it's something good." Thanks to the many offshore miles logged by Finot boats, the interiors and deck layouts of a Finot *cruiser* are roomy *and* highly pragmatic. This has led to an austere aesthetic package as modern as an aircraft. "We take a lot of time to find the lines and shapes that we like to look at but that also work with our aims," says Conq. "We don't look at aesthetics first. If a solution brings something untraditional, even if it hurts a bit aesthetically, we're not against it. We think it's nice because it functions."

The Groupe Finot aesthetic may never appeal to traditionalists, but to those who love the act of sailing and want to increase their range. Finot designs are becoming increasingly attractive. Aboard a Finot Open 50 a couple years ago, our small, relaxed crew slipped along faster than the light-to-moderate breeze, and outpaced a fully crewed *America's* Cup boat...to weather! Now *that* is a thing of beauty. PBB

***About the Author:** Steve Callahan began Open-style racing in 1977 and has since crossed the Atlantic twice in Open-style boats. He's written widely on adventure-racing designs and personalities.*

Builders Wanted



Long-awaited low-temperature-curing pre-pregs are here. And they're nearly as convenient as packaged frozen food. What's needed are more boatbuilders working with this technology to make it less exotic, less expensive, and—ultimately—more efficient.

I'm not too proud to admit that I frequently fix a mid-week supper starting with a frozen package called Create-a-Meal, or some similar product line. The manufacturer supplies ready-made pasta, vegetables, and sauce, all contained in a sealed bag; I supply the olive oil, meat or poultry, milk, and any optional fixings for enhancing the dish, as suggested on the bag. Only two things are required of me: that I have the necessary equipment (refrigerator/freezer, stove, skillet) for storage and cooking; and that I follow the printed directions.

I won't belabor the analogy, or oversimplify the complexity of what might be called Create-a-Part composite boatbuilding. Nevertheless, there are clear similarities here: the pre-preg manufacturer supplies frozen, factory-made, pre-impregnated fiber or fabric reinforcement, layered neatly in a box, and perhaps other essentials such as co-curing adhesive film; the builder provides materials storage and processing gear, typically refrigeration, a vacuum-bag system, process controls, and a shop-made oven. *Professional BoatBuilder* covered the recent conversion of two North American boatshops to low-temp pre-preg construction: Westerly Marine in Costa Mesa, California (PBB No. 6l, page 52), and Turner Yachts in St. Catharines, Ontario (PBB No. 63, page 151). These articles demonstrate the doability of pre-preg technology, as the magazine seeks to demystify it. In the coming months, PBB will continue to follow the step-by-step construction of the 66' Tripp-designed pre-preg carbon-fiber cruiser/racer at the Turner shop.

Meanwhile, in the spirit of *Star Wars* (a film series that did not begin at the beginning), we hereby present an article that probably should have run before either of the two cited above—but didn't. It's basically a summary of a 90-minute seminar on low-temp pre-pregs, that was intended as an introduction to this technology for other builders considering either adopting it outright (like Turner), or adding it to a shop-floor mix of conventional and advanced by Paul Lazarus

ALL PHOTOS SP SYSTEMS

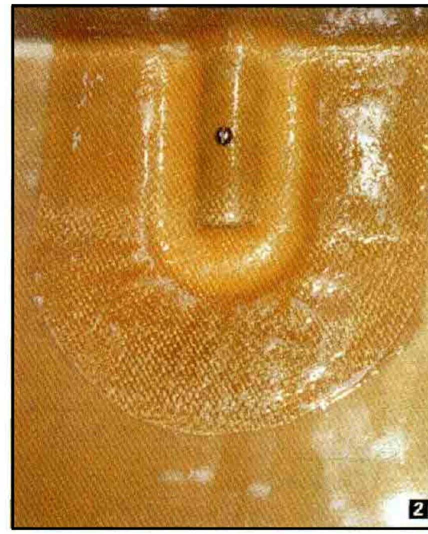
fabrication methods (as is the case with Westerly). This particular session was on the program at IBEX '99 in Fort Lauderdale, Florida, and the three speakers were Lou Dorworth, chief technical instructor in advanced-composites repair and construction at Abaris Training (Reno, Nevada); Susan Robitaille, director of research and development at YLA Inc. (Benecia, California), manufacturer of pre-pregs and other advanced composites; and David Cripps, then head of the technical management of new products and currently marketing director at SP Systems (Isle of Wight, England), which manufactures and supplies a wide range of composite materials for the marine and other industries.

Lou Dorworth, Abaris Training

Dorworth led off, his role being to offer an overview of the technology. He was direct. "Pre-pregs are not a passing fad," Dorworth said, and he speaks from experience. Although his own background is in building advanced-composite structures for aircraft and aerospace companies, at Abaris Dorworth teaches people sent to the school from a broad spectrum of unrelated industries. "In medical equipment, for example," said Dorworth, "pre-pregs are used in the manufacture of prosthetic devices and orthopedic braces, among other items. In sporting goods, we now see them in everything from golf clubs to snowboards. In motorsports, they comprise the chassis and body parts for Indy and Formula-One race cars. In infrastructure, civil engineers are specifying pre-pregs to retrofit highway bridge columns for earthquake protection. Pre-pregs have, of course, long been the material of choice for spacecraft and aircraft structures. And in the marine industry, pre-pregs are routinely going into mast-and-boom construction, racing hulls and decks, sonar housings and radomes, and small parts."

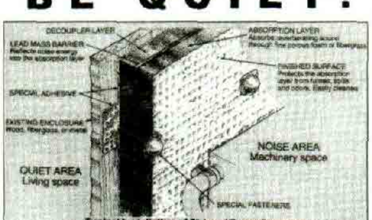
The appeal of low-temp pre-pregs in particular, he noted, "is that the sub-200°F (93°C) curing range is readily achievable in makeshift ovens or

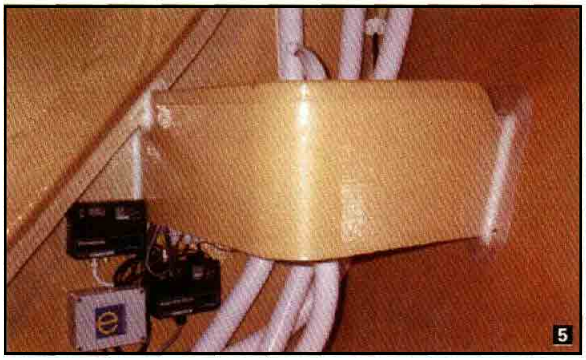
Unlike conventional wet layup or even wet-preg construction, in composite boatbuilding with pre-impregnated reinforcements the laminate skin is already made, having been manufactured by an outside source, a so-called pre-pregger. When that source is a reliable one, the skin-laminating process takes place under conditions much more precisely controlled than is possible in a boatshop environment. On these two pages we see snapshots of different pre-pregs being made at SP Systems' facility on England's Isle of Wight. 1. Carbon fibers are assembled into a sheet prior to wetout with an epoxy film. 2. One of SP's hot-melt production lines running unidirectional glass. (The hot-melt lamination process is explained in detail in the text.) 3. Electronic programming assures the accuracy of the resin film, which controls a pre-preg's resin content. 4. Hot-melt filming of SP's SE 84, a low-temperature-curing pre-preg; in this case, for a run of narrow unidirectional tapes. 5. SP uses beta-ray gauging to control film thickness. ***Inset, facing page***—*A finished product: SE 84 in woven-glass form, one of numerous possible pre-pregs.*



tents." Low-temp pre-pregs also mean that high-temperature plugs or molds are not required. "This gives you a much wider range of tooling-material options," he said. Further, the low curing temperatures afford better dimensional control of the part. "There's less shrinkage of the matrix resin," he said, "and, based on the lower temperatures needed, there will be less dimensional change as a result of minimal thermal expansion of the plug." Another advantage is reduced void content. "Compared to a wet layup, low-temp pre-pregs can reduce void content—which adversely affects a composite part's mechanical properties—by more than half. Where a wet layup might have a 7% void content in the part, pre-pregs generally yield less than 3%. And when applying material," he continued, "you get much less fiber distortion. The carrier film, or backing, on a pre-preg aids in maintaining better control of fiber loading and orientation."

Dorworth asked rhetorically, "Is there a lower overall cost? You can certainly realize some labor savings by virtue of pre-pregs' elimination of





PHOTOS COURTESY OF ERIC GOETZ

The Goetz shop in Bristol, Rhode Island, was cold-molding in the early 1970s, then evolved through cored cold-molding and wet-pregs before switching to pre-pregs by the early '90s. These photos are of Idler, a *Nelson/Marek-designed IMS 50, beautifully built last year with low-temperature-curing YLA pre-pregs.* ***1.*** Idler's *Kevlar deck and superstructure, displaying sharp definition at the intersection of the deck and house.* ***2.*** *A stanchion support.* ***3.*** *Detail showing the cockpit side/sole intersection. 4. The industrially finished navigation station—"left natural," in the words of custom builder Eric Goetz. 5. Interior, in the head area.*

resin mixing, hot-coating, and other procedures common to conventional construction. Plus, you potentially-lower your raw-material cost, because you can optimize the structural design with pre-pregs."

Those are the advantages. The *dis*-advantages to these materials, he said, are several. "They require frozen storage and special handling. We recommend they be kept below 0°F (-17°C). And then you have to allow sufficient time to bring materials *out of* frozen storage. They must be stored and thawed in proper packaging in order

PHOTOS COURTESY OF ERIC GOETZ

to avoid condensation and still maintain adequate out-time for building the part." Some pre-pregs, he said, "have a short shelf-life and out-time. This leads to another perceived disadvantage to pre-pregs: the need to monitor and record those out-times, so you know exactly where you are in the usable life of the product." Finally, Dorworth noted that large parts must be laid up in a series of carefully orchestrated steps—involving vacuum-bagging at each stage and all the work it entails—in order to debulk the various layers and consolidate the laminate. "Many production builders," he said, "are not accustomed to the number of steps involved in the layup of a large, cored, pre-preg part."

Because Dorworth routinely deals with advanced composites peculiar to different fields, he is more familiar than most people with the many types of pre-pregs available. There are, for instance, at least three forms of unidirectional pre-preg: uni tapes, fiber tows ("tow-pregs"), and fabrics containing more than 80% warp yarns. There are bi-directional forms: so-called balanced fabrics, and biaxial stitched products, usually 0°/90° or ±45°. "Multi-axial stitched and braided products are available from some pre-preggers," he added.

There is also a wealth of fiber

Two more recent projects at Goetz. ***1.*** *Detent detail on the hull bottom of* Starlight, *a 101' motoryacht designed by C. Raymond Hunt Associates (Boston, Massachusetts). Goetz fabricated the composite parts; Derecktor Shipyard (Mamaroneck, New York) did the finish work, completed in February.* ***2. & 3.*** *Laminating* Starlight's *hull. Note the absence of respirators and space suits, and the overall cleanliness of the operation.* ***4.*** *Prepping the hull tool for the 80' maxi* Pyewacket *prior to lamination. Goetz delivered this boat in January '99.*

options: E-glass and S-glass, aramid (Kevlar), carbon, and polyethylene (Spectra). As for matrix resins, Dorworth said that "epoxy resin formulations offer the widest range of process capabilities, as well as superior structural properties over conventional polyester or vinyl ester wet layup systems." And he mentioned in passing that polycyanates are available from some pre-preg manufacturers as a low-temp *initial* cure system. "But they require elevated post-cures for high temperature resistance and to achieve good structural properties. And they're very, very expensive. Limited use, at best, in marine applications," he said.

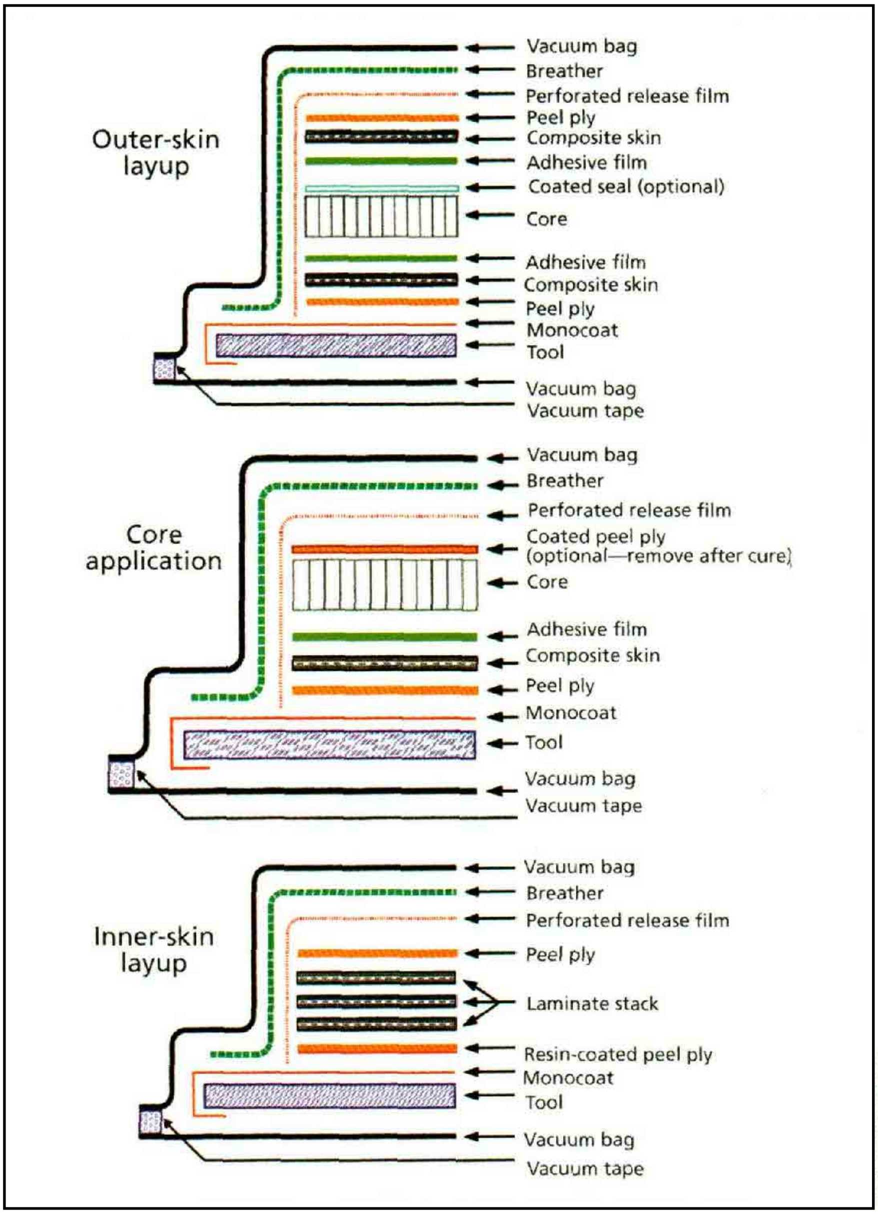
Knowing that pre-pregs comprise only one element in a sandwich structure, Dorworth stressed that there are other, fully compatible, low-temp-curing materials available to make the processing job go easier. For example, there are special "core splice adhesives" for bonding honeycomb core assemblies and for making honeycomb core repairs. And there are syntactic films, which can be used either as a surface layer or as a thin, lightweight, core layer.

Dorworth then ran through the list of essential equipment and supplies: freezer and refrigerated storage; a shop-made oven (the most rudimentary setup consisting of a temporary tent and portable space heaters); a vacuum pump and a full complement of bagging materials (peel ply, perforated release film, bleeder/breathers, bagging film, sealant tape, vacuum hoses, and ports). In terms of tooling requirements. Dorworth said that the mold or plug must be capable of maintaining vacuum when bagged, and withstanding elevated temperatures "once you're into the cure cycles." Mold sealers and release systems are needed, and he added that there are now water-based release systems that give off no VOCs.

Finally, Dorworth mentioned more than a half-dozen manufacturers of low-temperature-curing pre-pregs in the United States and United Kingdom, so no boatbuilder need feel that sources are limited. It's a growing and competitive market, he said. (The companies named by Dorworth appear on page 95.)

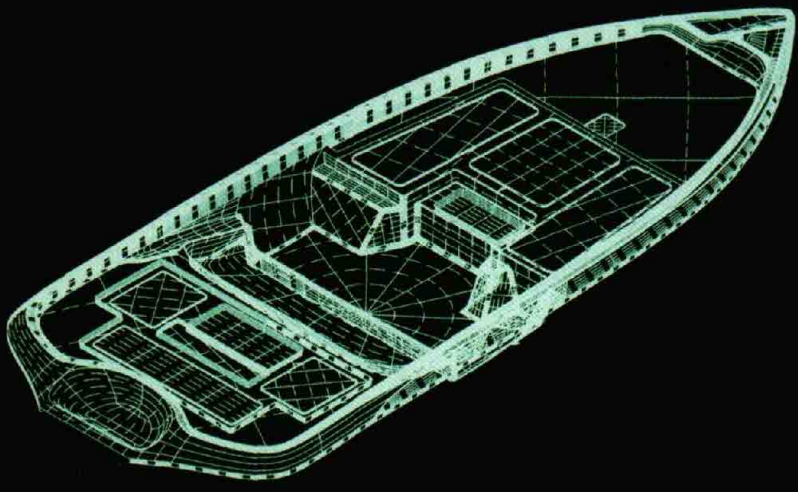
Susan Robitaille, YLA

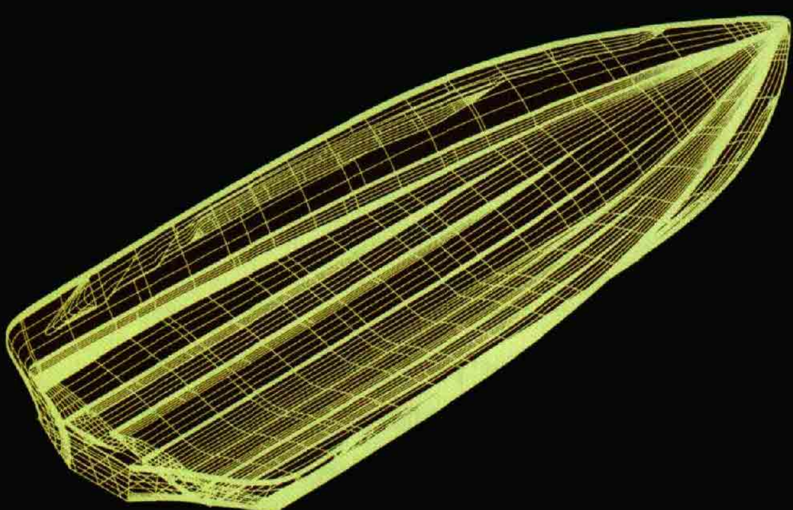
Robitaille spoke next. She focused on boatbuilding with pre-pregs, a process, she said, predicated on a good working relationship between the pre-preg manufacturer and the builder. "The builder is the expert on how to build boats," Robitaille said, "but the pre-preg manufacturer is the expert on their materials. The selection of materials and the in-service performance of those materials is structure- and process-specific. Success with pre-pregs depends on the way the material will be processed in the shop, and there are many factors to take into account, including the type of core, the type of adhesive, the type of core splice, and the target weight of the structure. Our job as supplier," she continued, "is to indicate the properties of our materials, and assist in the selection of suitable products that give you 'traceability' throughout construction. And to provide processing information and recommendations when applicable. This team relationship is critical to reducing the risk and cost of building with pre-pregs."



These schematics, read from bottom to top, reveal one reason that many boatbuilders—custom and production alike—remain reluctant to adopt pre-preg sandwich construction: lots of layers of process and laminate materials, and therefore lots of building steps out on the shop floor, along with solid waste. With practice, though, comes crew efficiency in time-and-motion, along with certain economies in controlling the amount of "vacuum consumables" required for any pre-preg project.

That said, Robitaille detailed how builder and supplier get started. "First, we help develop data for the design. And then we work closely with you. the builder, to develop the in-shop process." In PBB's recent articles on pre-preg construction, readers may recall that both Westerly Marine and Turner Yachts prepared laminate samples in the shop, off the actual tooling. Those samples were processed and monitored exactly the way the actual boat part would be, but at a small scale: that is, they were laid up. bagged, and cured just as the full-size part would be fabricated—same kind of bleeder, same kind of bag, same ramping up of temperatures, and same dwell time—in effect, a miniaturized boat part, made in the shop exactly as the full-scale version would be. Every step was documented, every procedure trialed, and all the data recorded. The reason for this precise simulation is that structural properties required for a particular boat design must be developed with laminate samples that are cured as





closely as possible to those specified for the boat—*in the shop environment.* For both of the shops we covered, YLA happened to be the pre-preg source. Other (though not necessarily all) pre-preg manufacturers operate closely with their customers to select a suitable reinforcement and refine a process appropriate to the boat and the shop building it. As Robitaille pointed out, the degree of cooperation between builder and supplier goes well beyond the technical support most boatbuilders are accustomed to in non-pre-preg composite construction.

Okay. Pre-preg systems, said Robitaille, are picked for the following reasons. "We're looking for the lowest cure temperature possible—typically, in the 175°F (80°C) to 250°F (120°C) range. We're selecting for glass transition temperature and heat distortion temperature. *[These values are referred to symbolically as Tg and HDT, respectively. For a more complete discussion of their significance in composite boatbuilding, particularly with regard to dark surfaces, see the article on page 22 in this issue—Ed.]*

"We're selecting for cure-temperature heating requirements," continued Robitaille, "usually a ramp rate of 0.5°F per minute. We're looking at resin-viscosity profiles; that is, temperature versus flow. We're going to take into account the specified core type, so we can determine adhesive requirements and the weight of that adhesive." And then there are the many physical elements of the processing itself—the bagging gear and the oven.

Returning to cure requirements, Robitaille posed a frequently asked question: What happens if the resin is undercured? "If the HDT is lower than it should be because the resin is undercured, then the finished product may be brittle," she said. "There could be microcracking. and a real potential for composite damage. Mechanical properties will be poor."

To avoid this outcome, she said, "you need to fully understand temperature controls. You gain this knowledge by installing thermocouples and by systematically logging the data, either manually or by computer. You must know the temperature of the mold, the ambient temperature, and the temperature of the part. On a 40' hull, for example, we recommend no fewer than 20 thermocouples. Once spread out, they'll reveal the coldest spot on the hull, and you start timing the cure from the thermocouple reading that's 'lagging.'"

As for the oven, Robitaille realizes it varies from shop to shop. Regardless of design, though, Robitaille stresses the following criteria. "It should be a well-insulated, heat-tolerant box with at least one door panel. This box should be capable of heating the mold and the pre-preg layup at a *minimum* heating ramp-rate of 0.5°F per minute. It's helpful if the floor of the oven can be insulated; since boatshop ovens tend to be portable, some builders lay down insulation on the floor just before heating.

"There should be good airflow within this box," she continued. "You need easy circulation to even out the heating rate and prevent cold spots; remember, we don't want the pre-

preg to be undercured. Heating units are best positioned *outside* the oven, with heat directed into the oven through ducts in the walls. That way, adjustments can be made, and heaters can be added or removed while you monitor the cure." She emphasized that the builder should always test the heat-up rate with the mold and thermocouples in place—*before* committing the pre-preg materials.

Turning next to vacuum requirements, Robitaille reminded builders that "good vacuum pressure is important to compact and consolidate the laminate, and to lower the void content." Though not required for all pre-preg systems, a "full" vacuum, she said, would mean "26-plus inches of mercury. You check the integrity of the bag with a valve/gauge shutoff. No matter what system you employ, it should be able to hold a vacuum for several minutes with minimal change—a maximum drop of 5" of mercury in 15 minutes." She cautioned against employing highly elastic bagging materials, and to beware of "bridging" the vacuum bag over corners and radii in the part.

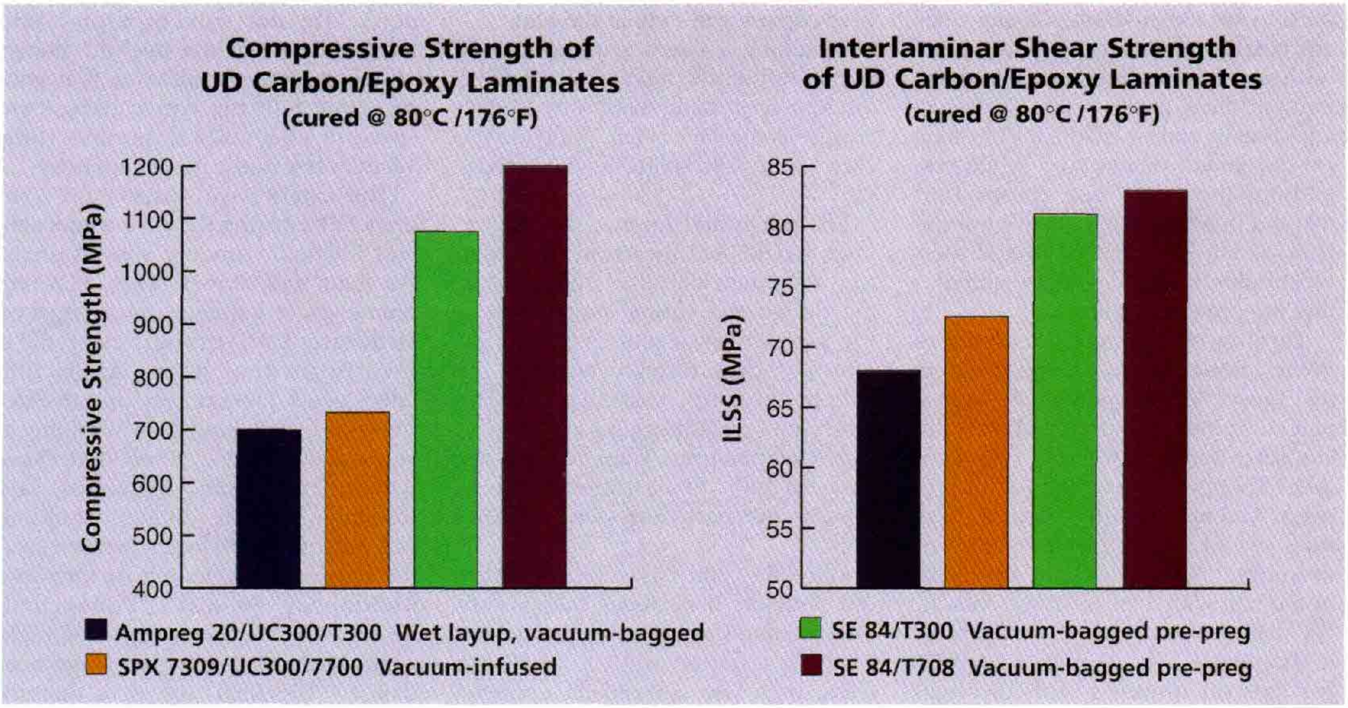
Assuming a cored part on a male mold, Robitaille next reviewed the discrete processing steps involved in laying up the inner skin, applying the core, and finally laying up the exterior skin.

For the initial layup, she began, "You would seal the mold, and then run a vacuum check of the mold at the designated curing temperature—for a short test-cycle. Apply mold release. Apply resin-coated peel-ply and/or 'tacking resin.' Lay up the laminate, debulking as needed at room temperature. Then reapply the vacuum bag. place thermocouples around the part, and cure the first skin."

Once the skin has cured, the core can be fitted. If it's foam, then you fit and vacuum-form the core, and hold it under vacuum until cool. If it's balsa, then you cut and fit, applying core splice between panels. With honeycomb, you form and cut and apply core splice. Note that the peel-ply remains on the surface of the first skin until just prior to bonding the core. "Do not solvent-wipe," said Robitaille. When the peel-ply comes off, a "supported" adhesive film goes on. Now refit the core, "using core splice or edge filler as needed," then vacuum-bag and cure the adhesive.

The exterior-skin installation commences by fairing the core as needed, and filling or sanding spliced areas. For foam and Nomex cores, YLA recommends re-bagging the unfinished structure and "drying" it at 80°C (175°F) for four hours. Apply film adhesive to the core. Lay up the exterior skin, debulking it by vacuum at room temperature, if needed. Note that for honeycomb structures, said Robitaille, "we recommend holding full vacuum for 48 hours before cure," the reason being to release pressure buildup in the sealed honeycomb cells." (Not all pre-preggers, though, agree with this particular recommendation.) The final step is to thermocouple the structure and cure it according to the supplier's directions.

"And there you have it," Robitaille concluded. "Remove the vacuum 'consumables,' remove the oven (or the



DAVID CRIPPS/SP AND OLGA LANGE

The graphs above demonstrate just two of the persuasive strength properties obtainable with low-temp pre-pregs, compared to other vacuum-assisted fabrication processes. To remove any suspicion that the data is skewed, note that the different building methods shown employ epoxies from the same source (SP Systems).

part from the oven), and you've got a hull or deck or small part with low void content and excellent mechanical properties—a pre-preg structure to be proud of."

(Refer to the illustrations on page 88 for a schematic representation of the principal layup steps described by Susan Robitaille.)

David Cripps, SP Systems

In conventional contact molding or resin infusion or even wet-preg construction, it is the builder who applies resin to reinforcement to create a laminate skin. But since a pre-preg is. by definition, a skin prepared by an "outside" source, any boatbuilder considering this technology should be aware of the process of making the pre-preg itself. David Cripps completed our IBEX seminar by first explaining the principal methods for manufacturing the material, and the implications each method holds.

There are two primary technical issues in impregnation, said Cripps: the high viscosity of the resin system; and the fact that the resin system is pre-catalyzed. One manufacturing method is the "solvent tower" process. The catalyzed resin is dissolved in a solvent—typically, methyl ethyl ketone or acetone. The fabric is passed through this solvented resin bath. Nip rolls and the solvent-to-resin ratio control the resin content. Then the material is heated in a drying tower to remove the solvent.

Some of the finer points within the solvent-tower process are: heating zones to "stage" the resin; venting or incinerating the solvent; and interleaving the material with carrier films, enabling it to be wound up for storage.

"The advantages of the solvent-tower process," said Cripps, "are that it is fast and simple. You can use very high viscosity resins. And it provides reasonable—but only moderate—control of the fabric-to-resin ratio."

The disadvantages, he continued, are several. "The fabric needs to be stable; that means, for example, you cannot make unidirectional tape from pure fibers. Second, solvent entrapment limits fabric thickness, meaning you can't easily make heavyweight pre-pregs that are free of residual solvent. And third, this process is environmentally unacceptable in some regions. So although the boatbuilder may opt for pre-pregs to help lower his emissions, there are still emissions occurring *elsewhere* due to the pre-preg manufacturing process."

An alternative manufacturing method is the "hot-melt" process. Here, catalyzed resin is heated, and then coated onto release paper; fiber or fabric is pressed into the resin film; and impregnation occurs under high pressure and some heat. The impregnated material is then wound up for storage. Cripps enumerated the advantages of the hot-melt process: "You get a very accurate resin content. You can make UD tapes from pure fiber. You can customize the level of impregnation. There are no solvents to entrap. And the process is environmentally clean."

Although SP makes most of its pre-pregs by the hot-melt method, the process is not without its own set of disadvantages. "Accurate control of the resin-film thickness," said Cripps. "requires expensive online scanning gauges. The impregnation process demands heavy-duty machinery. And it can be difficult to fully impregnate thick fabrics with the high-viscosity resins used."

Speaking of resins, Cripps reminded his audience that, although epoxies

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are probably best suited to boatbuilding with pre-pregs, other resin types *are* available, the best known in marine circles being styrenated resins and phenolics. (Cyanate ester, silicone, bismaleimide, and polyimide resins are also found in pre-pregs.) In the epoxies, there are two categories of "standard"-cure pre-pregs: those that cure at 350°F (180°C), and those at 250°F (120°C). Cripps showed those numbers to better contrast them with the four categories of *low-temperature-curing* pre-pregs: 190°F to 250°F (90°C to 120°C); 175°F to 190°F (80°C to 90°C); 160°F to 175°F (70°C to 80°C); and those that cure below 160°F.

At this point, Cripps took the opportunity to address the persistent question of wet-pregs vs. pre-pregs. Where YLA is strictly a pre-preg source (and a supplier of related process materials), SP sells a full line of composite materials for making wet-pregs, in addition to an array of pre-preg products. Why should a boatbuilder commit to the extra expense, and some would say the extra trouble, of a pre-preg system? "There are persuasive reasons for learning pre-preg construction," said Cripps. "In terms of materials handling on the shop floor, pre-pregs offer improved worker health and safety. There is less mess and clean-up to contend with. And unlike wet-pregs, where the meter is running once you've wet out the reinforcement, you get very long working times with pre-pregs—*weeks*, if not months, as opposed to the hours or at most a day or two with wet-preg systems. Pre-pregs also eliminate the possibility of incorrect mix ratios when catalyzing the resin."

End properties, too, he pointed out, are measurably higher with pre-pregs. "Superior mechanical properties—specifically, interlaminar shear strength and compressive strength," Cripps said. "And superior thermal properties," he added. Those mechanical properties, argues Cripps, are a function of the higher-viscosity, higher-molecular-weight components used in pre-pregs. Indeed, compressive strengths obtainable with new low-temp pre-pregs rival those achieved by curing a typical aerospace pre-preg at 120°C (248°F). *[See graphs on page 92, comparing three distinct modes of composite construction, all using SP epoxies. See PBB No. 55, page 61, for a different perspective on the wet-preg vs. pre-preg question, written by Richard Downs-Honey of High Modulus, an Auckland, New Zealand, firm that provides composite materials and engineering to the marine industry—Ed.]*

Low-temp pre-pregs, said Cripps, offer yet another advantage, even over "standard" pre-pregs: the former can be used with some foam cores, such as SAN foam, making them economical for large sandwich structures. (In the exhibition hall at this same IBEX, boatbuilder Henry Elliot, who authored the PBB article on Turner Yachts, built a composite canoe using low-temp pre-pregs and an Airex core.) Still one more feature of low-temp pre-pregs not yet touched upon in this seminar, is that they can be supplied as *collimated* unidirectionals, where unidirectional fibers are simply held together in a continuous sheet by the resin system. The advantages of this type of material, said Cripps, are the following: "The weaving, or stitching, process is removed, thereby removing that expense; the fibers remain completely straight; there is no parasitic material holding the fibers together; heavyweight fiber tows can be used, which further reduces material cost; and we can achieve very high fiber fractions."

These pre-pregs lend themselves to large, flat structures, such as interior panels and bulkheads, which can be economically produced in the boatshop on dedicated vacuum tables. "Heating elements in the tabletop minimize the area that needs to be heated to cure the component," Cripps said. "It gives you a self-contained pre-preg curing system."

Today, he concluded, "almost all top-level racing yachts are constructed with pre-pregs, and more and more commercial craft, such as patrol boats, are beginning to use them. Other industry sectors, such as wind-turbine blade manufacturers, are adopting epoxy pre-pregs, spurred on by the desire to eliminate styrene from the workplace and to build bigger blades. It is the continuing development of ever-heavier, lower-curing pre-impregnated fabrics—together with lower-cost processing techniques—that will enable these already successful materials to be more widely used for ever-larger composite structures." PBB

***About the Author:** Paul Lazarus is the editor of* Professional BoatBuilder.

Lou Dorworth's List of Low-temp Pre-preg Manufacturers

The Advanced Composites Group Inc.
5350 S. 129th E. Ave.
Tulsa, OK 74134
tel. 918-252-3922
fax 918-252-7371

Airtech International Inc.
2542 E. Del Arno Blvd.
Carson, CA 90749
tel. 310-603-9683
fax 310-603-9040

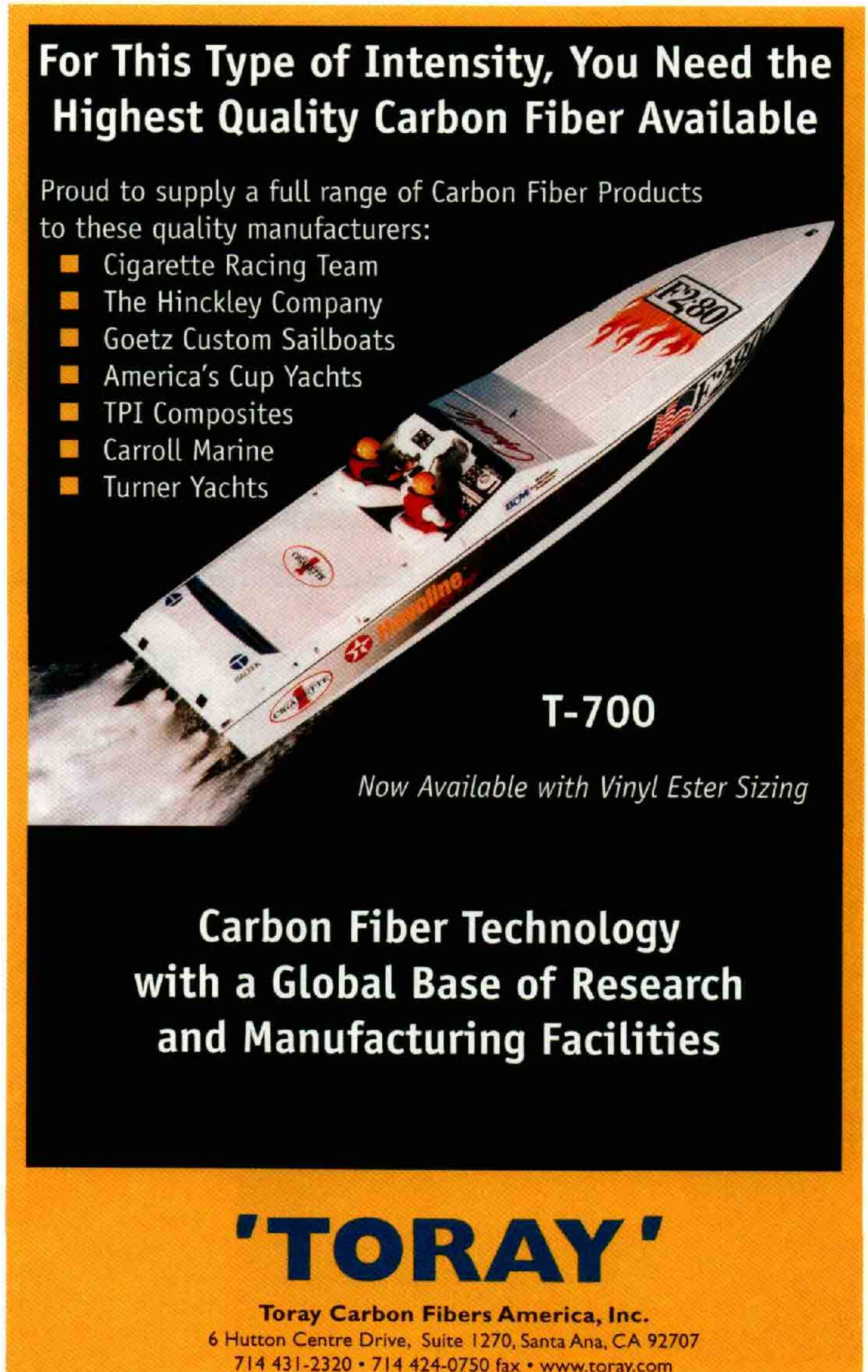
Bryte Technologies Inc.
2025 O'Toole Ave.
San Jose, CA 95131
tel. 408-434-9809
fax 408-434-9811

Cytec/Fiberite Inc.
1300 Revolution St.
Havre de Grace, MD 21078
tel. 410-939-1910
fax 410-939-8100

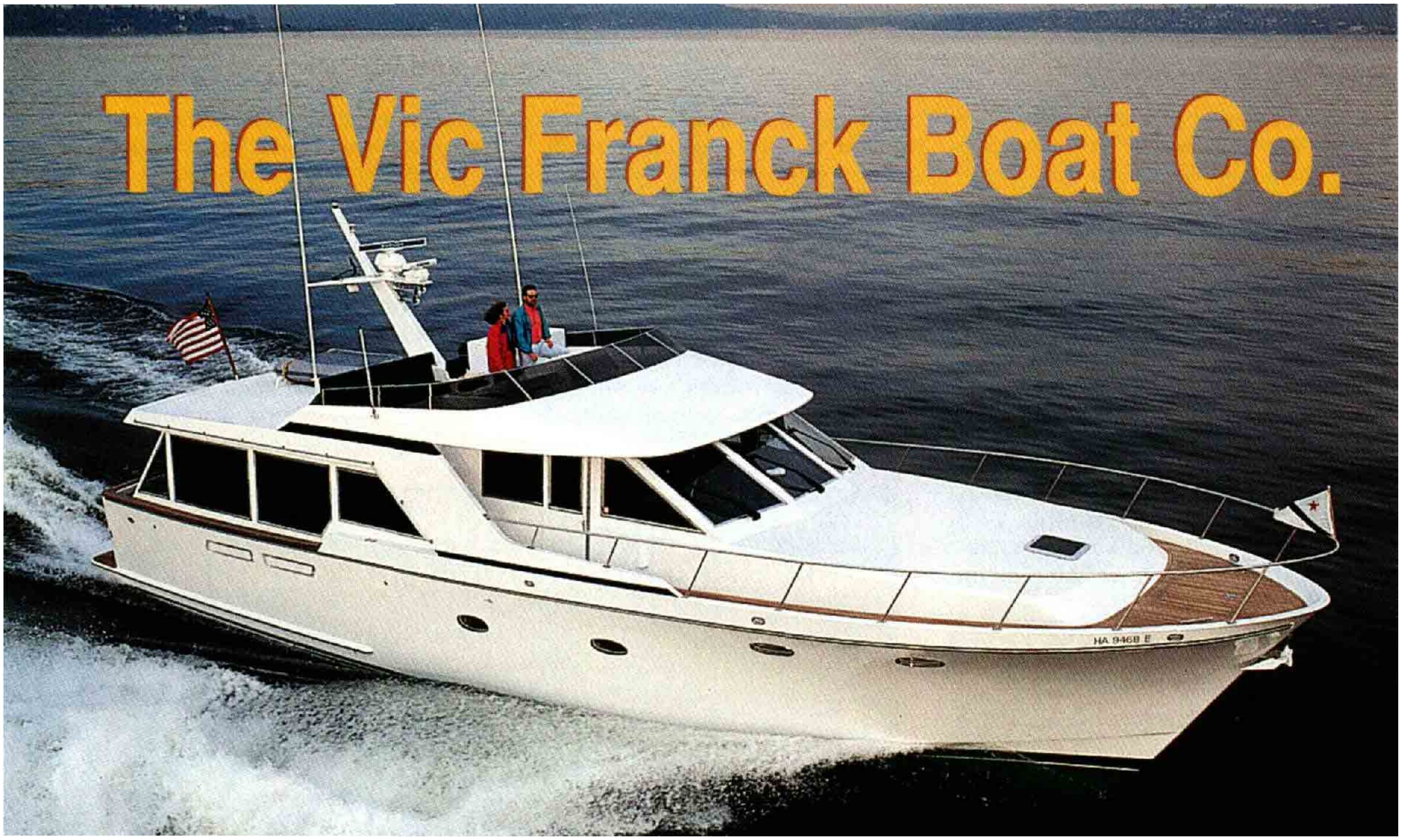
Newport Adhesives & Composites Inc.
1822 Reynolds Ave.
Irvine, California 92714
tel. 714-253-5680
fax 714-253-5692

SP Systems Ltd.
St. Cross Business Park
Newport, Isle of Wight, England
P030 5WU
tel. +44 1983 828000
fax +44 1983 828100

YLA Inc.
2970 Bay Vista Ct.
Benicia, CA 94510
tel. 707-747-2750
fax 707-747-4841



The Vic Franck Boat Co.



NEIL RABINOWITZ

With a rich history of building wooden fishing boats and yachts, this small Seattle yard has made a successful transition to high-end, lightweight composite motoryachts, by Brooks Townes

NEIL RABINOWITZ

The sweet-pungent smell of newly sawn yellow cedar drifted up past the crew with the saws. They were cutting through a 15" x 15" square timber 20' long and many decades old. "God, that's what this shop used to smell like instead of styrene and acetone," said Dan Franck, breathing nostalgia. The cedar was still perfect. It probably pained the men to cut it, but it had to go: The Vic Franck's Boat Company shop was being modified again to accommodate building a new boat.

Franck's is set entirely over the water and measures just 100' by little more than 200'. There's really no room to expand, yet the boats built here keep getting bigger, more complex, more expensive—in this case, and of composites instead of wood.

Vic Franck's has to be one of America's oldest continuously operating boatyards; certainly one of few its age still owned and operated by the founder's family, still doing business in its original location—in this case, the north shore of Seattle's urban Lake Union.

The area isn't the commercial waterfront it was when the yard first opened in 1927. Expanding here is out of the question. The yard is hemmed in tightly now by yacht brokers, fancy restaurants, coffee houses, offices, and of course (this being Seattle) by a big computer company. Dan Franck, the founder's grandson, is in charge, and rebuffs astounding offers for the property almost weekly.

GREG GILBERT

***Above**—Founded in 1927 on Seattle's Lake Union waterfront, the Vic Franck Boat Company is a family-owned and -operated business that runs on ingenuity, WWII-vintage machinery, and fine craftsmanship. Pictured here are current owner Dan Franck (right) and shop foreman Ray Young. Above them hangs the original transom of the Olin Stephens-designed 52' yawl* Dorade *(built by a New York yard in 1930), which came into the Franck yard for repair in the early 1960s.* ***Facing page, top**—*Bavaria, *a 65' Ed Monk Jr.-designed motoryacht. Franck's normally purchases its composite hulls elsewhere:* Bavaria's *hull, however, is a one-off molded by the Franck crew in a throwaway female mold.* ***Bottom**—*Bavaria's *interior shows off the Franck carpenters' joinery skills.*

There are no intentions to sell or move what is now a Seattle waterfront institution. The property is paid for, and to the boatbuilders, the place is like a good old pair of boots—broken-in and comfortable. They're used to it. It works well. Why mess with a good thing?

The project Vic Franck's was preparing for during my visit last fall would be the yard's 251st new boat. It's probably just out of the mold as you read this—a 78' fiberglass long-range motoryacht with a 21'4" beam and a draft of 6'6", a bulbous bow, and an interior fancy enough for *Showboats* magazine. The hull was being molded two hours away at Northern Marine in Anacortes, Washington, because Franck's doesn't mold its own hulls. There's no room. Also, the people here don't want to be *that* involved in fiberglass. The boat will be fully custom—the only kind Franck's does. Though the hull is being laid up in the mold Northern uses for its 76-footer, few would ever guess, the mold was so drastically-modified for Franck's customer. *[For more on Northern Marine, see "The Making of a Passagemaker," PBB No. 57, page 123—Ed.]*

Thoroughly modern, this yacht is in some ways typical of the boats built here since Vic Franck started the yard. All have been strong, sensible, and up to date for their eras, and most assuredly well-crafted. Repair and maintenance work has always been a big part of Franck's business, and it still is, but the yard has never gone for long without a new custom boat project, or two or three.

"Franck's is known for building some of the finest boats around. In terms of quality of workmanship, they've always been right up there with the best. They've concentrated on the high end of the client list and kept a reputation for doing first-class work," said retired Northwest boatbuilder and history buff Jan Nielsen. He said what just about everyone else in the know says about Vic Franck's.

"A lot of guys work there because they want to work *only* there. The Francks have always treated them well. Some guys have left, gone elsewhere, and couldn't wait to return to Franck's, it's such a good shop to work in. I don't think the philosophical differences are there between the journeymen and front office like in a lot of places. You just don't hear of stuff going weird there."

From outside on Northlake Way, the front of Vic Franck's looks ordinary—a well-painted wooden building little more than one story tall and with parking out front. Inside, the offices seem unremarkable—except maybe for Dan's. The day I visited, it was jammed with boat cushions wrapped in plastic, place settings, table lamps, galley paraphernalia, and boat "jewelry" of all sorts, all of it stacked high, the pile threatening to topple and *bury* the unwary. That stuff would soon go aboard a new yacht, but for now Dan's small office was also a storeroom. He didn't appear to mind.

There was just enough room on Dan's conference table for a large pile of sepia-toned photos of early Franck boats, and an unrolled set of freshly computer-generated profile and plan-view drawings of the new 78-footer. The old and the new side-by-side was a striking contrast which, I discovered, is an attractive recurring theme throughout Vic Franck's.

When I arrived, Dan was just getting off the phone and motioned me in. He had been talking about propulsion for the new boat, debating whether it should be a six-cylinder Cummins rated at 525 hp at 2,100 rpm, or maybe a Cat of similar wallop. "For long passagemaking, according to tank testing on this hull, we need 100 hp to go 7 knots, then the next 400 hp gains us another 3 knots, so most of the time you're going to go 7 or 8 knots and just be sipping fuel," he said, his mind still on the topic of his phone call. "We'll need to work the engine some, so we'll get the pitch just right and watch our pyrometer and have it at the right operating temperature...."

He had been discussing with his client, a local businessman, the merits of installing a Hundested variable-pitch propeller in the 78-footer—a nice but pricey piece of gear. "Not really that expensive," Dan said. "You know, you start taking off the gearbox and its shaft and prop and you've removed about $30,000 worth of hardware—more than half the expense of the variable-pitch prop is gone already, so that makes it about a $20,000 option and the benefits are tremendous." That's what the client chose, I later learned. Somehow it wasn't surprising.

"Our customers have always been our good friends because we build their prized posessions," Franck enjoyed noting, and this is a yard where satisfied customers really are its biggest advertisers. Said Steve Bunnell in a '93 issue of *Northwest Yachting,* "The Franck yard does the job right the first time. They offer no excuses for their work, there are no coverups. They've been in business for a long, long time and they know the correct way to complete a job." None of that seems to have changed.

It's how Vic Franck's has avoided the kinds of conflict so common among buyers and builders in these litigious days, the kinds of messes that have bankrupted several yards recently. "All of our customers are either repeat, or else our trusted friends have referred them. And, we turn down a lot of business," Dan said. He can afford to be careful, but he envies his dad and grandfather for having run the yard when a man's word was his bond and a handshake was all a guy needed. "My father rarely signed contracts and there was seldom a problem. Now lawyers draw up agreements that are 30 pages long."

The custom boats built here over the years are amazingly varied and represent the work of some of the Northwest's top designers—Ben Seaborn, Bill Garden, Ed Monk Sr., Ed Monk Jr., Jack Sarin, plus Sparkman & Stephens, and Dan himself, his father, and grandfather. Scores of examples

"Vic Franck" continues on page 104

A Seattle Waterfront Institution

VIC FRANCK BOAT COMPANY

Built of wood, the 59' motoryacht Zest was launched in 1964.

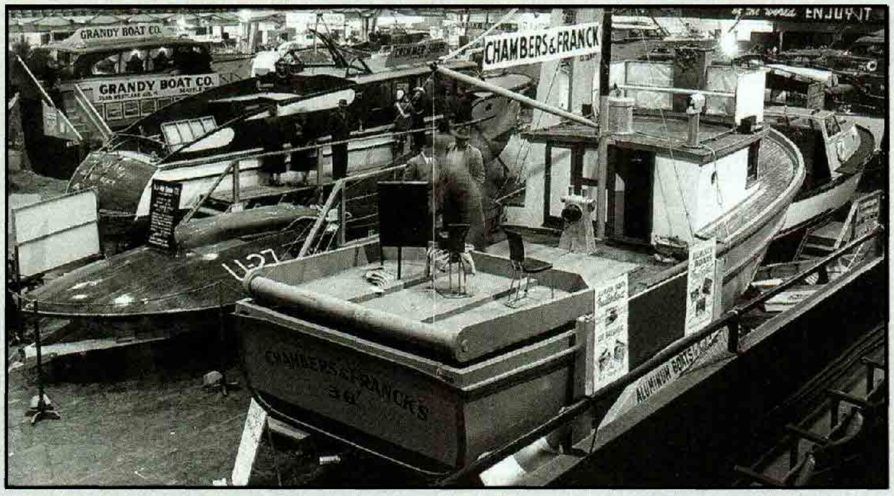
Victor Arthur Franck grew up a farmer's kid on San Juan Island in Puget Sound. The boats and ships he watched sail by as a boy were a whole lot more interesting than any farm, and when Franck, born in 1894, was 18, he built out in the family barn his first boat—a narrow, canoe-sterned 35-footer with a deckhouse. It was powered by "probably something he salvaged from something else," said Dan Franck, Vic's grandson, guessing it was an East Hope make-and-break.

Soon after he launched his vessel, Vic Franck left the farm for a job at Seattle's Moran Shipyard, where he realized he cared about boats, not ships. He quit Moran for a job running a small boatyard back on San Juan Island, but soon enough migrated to the mainland, and worked in a cabinetmaker's shop south of Seattle. "He thought that was pretty boring," said Dan, and by then it was the Roaring Twenties. There was a lot of money around. Franck figured to get his share by indulging his passion—building and repairing boats in a shop of his own.

"One day Grandfather took the Interurban train to work at the cabinet shop down in Kent Valley, which was unusual," Dan said. "Grandmother asked what had happened to the car. He told her he'd sold it for the down payment on the yard."

Franck built his yard in 1927 over the water on pilings along a 100' stretch of Lake Union shoreline, where it remains. The neighbors then were lumber mills, tugboat companies, other boatworks, and a huge industrial gas refinery. It was an ideal spot on fresh water, protected from harsh weather and big tides. It was—and is—just a mile or two across the lake to downtown Seattle, to banks and wealthy customers' offices, and it's handy to Lake Washington by a canal to the east and to Puget Sound via canal and locks to the west.

About the same time Franck built his yard, boatbuilding contemporaries and friends Norman J. Blanchard and



VIC FRANCK BOAT COMPANY

A 36' power seiner on display at the 1950 Seattle boat show. After the death of Vic Franck in 1938, his wife Ruth ran the business. In the "unliberated" climate of the 1940s, she was obliged to take on partners in order to get bank credit; hence the name "Chambers" on the banner. Note the boat to the left: the Ted Jones-designed Unlimited hydroplane Slo-Mo-Shun IV, *built by Franck's neighbor, Jensen Motor-Boat Co. Fifty years ago, it was the world's fastest boat.*

Anchor Jensen, Northwest legends now, were building up their own businesses nearby.

Like his friends, Franck maintained and repaired boats for his bread and butter, and designed and built fishboats and yachts for the gravy. A favorite small yacht in that Gatsby era for the merely well-off (as opposed to the filthy rich) was the Lake Union "Dreamboat," an elegant plumb-stemmed, raised-deck motor cruiser, usually between 30' and 40' long. A typical Vic Franck Dreamboat of the late '20s—he built a dozen of them—sold for $3,000, including a full tank of gas, tools, linens, dishes, and silverware. Franck also reportedly built rum runners, but we don't know what those cost.

Of all the local-legend boatbuilders on the lake from that period, only Vic Franck's still builds yachts. Jensen's, perhaps best known for building the world's fastest boat 50 years ago—the late Ted Jones' Unlimited hydroplane *Slo-mo-shun IV*—still repairs boats in the Lake Union yard, but it's no longer a beehive of activity. Like Vic Franck's, Jensen's has managed to fend off Seattle's aggressive "gentrification," and the two yards are near neighbors. A man with a good arm could hit Jensen's shop roof with a half-inch nut thrown from Franck's dock. The nut would now have to fly past a boutique or two.

The Great Depression arrived two years after Franck opened his place. He survived doing repairs and maintenance mainly, undoubtedly helped by his fast-established reputation for integrity and top-quality work. "People had too much invested in their boats to just let them go." Dan Franck said. "They had to keep them up." Also. America then was not yet a throw-away society.

There was a silver lining to the lack of new-boat commissions in the '30s: Franck had time to design, refine, and build a revolutionary yacht for himself—a twin-screw motoryacht with a flying bridge, two steering stations, and an autopilot. He named her *Silverheels* after a pair of his wife's shoes. *Silverheels* was reportedly the first of its type built on the West Coast, and she worked well.

Vic Franck had barely begun to enjoy his new yacht when in 1937 his yard burned. The flames destroyed *Silverheels* too, and Vic went into deep shock. "He died a year later, almost to the day, of a heart attack. Grandfather never really got over the fire," Dan said. "My grandmother believed that's what killed him—the loss of his boat and damage to the yard." He was only 45.

"There was some speculation at Grandmother's funeral last year over whether there'd be a Vic Franck's Boat Company now if grandfather hadn't died when he did following the fire," Dan said. Would he have thrown in the towel? Vic's wife, Ruth, was not about to. The crew was like her family—a family of some of the area's finest, most loyal craftsmen—and she knew the business.

Ruth was the hard-nosed Franck on many decisions, and she'd handled the paperwork from the start—but right away she had one big problem: Seattle was not a "liberated" town 60 years ago. Bankers scoffed at the notion of a woman running a boatyard. None would extend her credit. None would accept that she really understood the operation. Ruth's solution was to form a series of partnerships on paper with trusted foremen. They would go with her when "man talk" was required.

Vic Franck's Boat Company thrived, and much later, when her son Vic Franck took over, his mother continued doing the books until 1977. when three generations of Francks worked there at once. Ruth died at the age of 101 a year ago last February. "Her goal was to make it to her next birthday this March," Dan said. "She wanted to have lived in three centuries—and she was sharp as a tack to the end."

An example: The wooden 65' *Navita*, a Blanchard-built motorsailer, was in for extensive work. Ruth was approaching 100. "The masts were out, *Navita's* teak decks were getting caulked, the house was wooded—the whole thing looked like a big dust mote," Dan recalled. "Most of the stern was taken apart; the name was nowhere to be seen. When Ruth walked past the shop, she looked in and said 'Gee, that boat hasn't been in here in for 35 years!'" Curious, Dan looked it up: It had indeed been 35 years.

Ruth was the boss during World War II. "During those years almost all the boatbuilders became Navy contractors," said Dan. He recalled from family talk that "No one had time to track costs, so there was an allowance given the builders for supplies and to pay their crews, and you were allowed a percentage of profit." By the end of the war, Vic Franck's had built seven 65' water taxis and several freight scows and patrol boats for the Navy, and the government went over the accounting. "My grandmother had clone so well we had to return some

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of the profits," Dan said. Franck's had been too efficient, spending less time building the boats to Navy specs than other yards, hence the government felt this yard had "earned" less.

When the younger Vic Franck came home from the Navy after the war in 1946 and re-joined the business, the yard was building and repairing several types of commercial fishboats. The government had begun allowing powered vessels into Alaska's Bristol Bay gillnet salmon fishery and Franck's soon had orders for some 30 Bristol Bay boats with engines. These (roughly) 32-footers were canoe-sterned, similar to their sailing predecessors. "Every boatbuilder in the Northwest, it seemed, was building for Bristol Bay," Dan said.

Franck's mostly built commercial boats for several years—carvel-planked fishing seiners, trollers, and gillnetters—though the repair end of the business always remained important. In the 1950s the tax code changed: fishermen were encouraged to depreciate and write off their old boats and replace them more often. A lot of fishermen went slack on their maintenance, anticipating their next boat, which could be built quick-and-dirty since it needn't last long. At Franck's, they couldn't bring themselves to build throwaway boats, so they switched to mainly building yachts.

Dan Franck never intended to enter the family business. When he was young, he studied residential and commercial architecture at the University of Washington. "After I read *The Fountainhead,* I wanted to be the next Howard Roark or Frank Lloyd Wright. Of course, that didn't happen." Dan worked at the yard through high school and college, sweeping out the shops after classes. "I'd come in around 4:30 p.m. after everybody went home. I'd sweep up, then do my homework in the office. After college in 1975, there weren't many opportunities for

PHOTOS VIC FRANCK BOAT COMPANY

After WWII, the government began allowing powered vessels of a limited size into Alaska's Bristol Bay gillnet salmon fishery, and Franck's built some 30 of these. The yard continued to build commercial boats for the next several years, three of which are shown here. In the 1950s, a change in the tax code encouraged the building of quick-and-dirty fishing boats. Unwilling to compromise quality, Franck's switched to building mainly yachts. ***Far left****—A 34' beach seiner, with the 25-year-old Vic Franck at the helm. The photo was taken in 1950.*
Middle*—Built in the early '50s,* Beticia *was rigged for halibut fishing.*
Left*—An early Bristol Bay gillnetter, with founder Vic Franck at the helm.*

what I wanted to do so I came to work here while I tried to find my niche in architecture."

He found the family business could be interesting. "That's when we did the designs for one of my dad's boats named *Viboco* on a 53' glass hull from Hoquiam Boat Shop (Hoquiam, Washington). The next boat I did on my own was the 50-footer *Fast Break* for Bruce Nordstrom [of the department store family]. I found that satisfied my creative urge, and I started doing a lot of our design work, trying to get potential customers hooked." When Vic Franck suffered a stroke in 1984, Dan took on more responsibility. "Dad still worked here, but he took more and more time off. Lately he's been spending most of his time in Palm Springs."

Dan is the Franck-in-charge now, and one could get the idea that Dan's dad was smart like a fox, stroke or not. First you give the kid money to sweep up, see—that gets him in the shop. Later you let him design a few things and gain some satisfaction, and show him how the business works, and before you know it, you're laying back in Palm Springs and the kid's doing all the work. Pretty good! Whether or not Vic Franck had a twinkle in his eye watching his son get hooked on the boat business, it's clear Dan Franck has as fine a grasp on it as the Francks who started the yard and ran it so well for so long.

Dan has no intention of retiring anytime soon, and his son, Jason, 19, is getting involved in the business now. Dan swears he hasn't pressured the boy nor been grooming him, but there's no mistaking his pleasure when he says, "Jason's already very good at handling the customers and that's a big part of this business—and not easy, especially when you consider that some of the customers are high-powered people with big egos."

— *Brooks Townes*

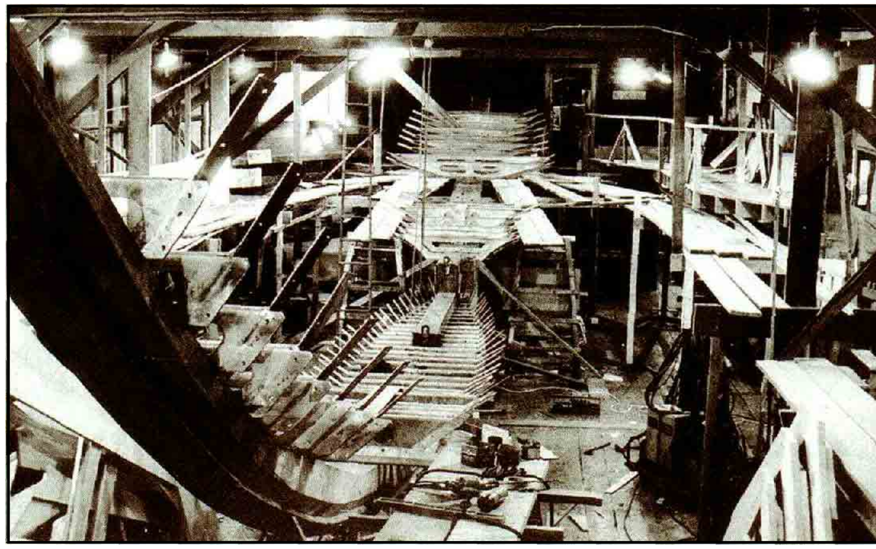
"Vic Franck" continues from page 98

were pictured in the pile of photos on Dan's table, including the standout-beautiful motorsailer *Tatoosh,* an 80' ketch designed by Seaborn and built for a member of the Boeing Aircraft family.

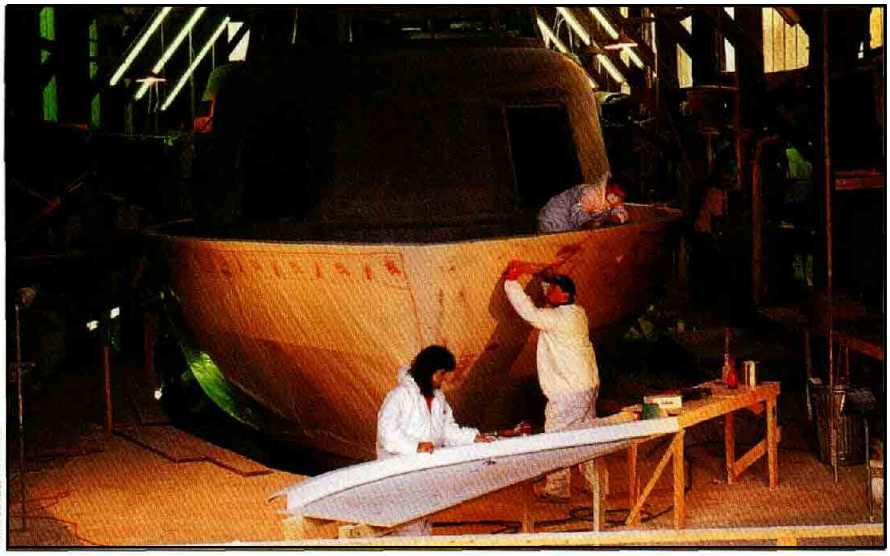
Tatoosh—and the earlier, smaller, Seaborn-designed 51' *Sea Fever,* launched in 1955—illustrate a few of the reasons for the yard's longevity: the ability to adapt, and an early acceptance of various kinds of "composites." Though a traditional boatbuilder with its shops on the shore. Vic Franck's has never been stuck in the mud. In *Tatoosh,* much of the backbone and all the floors are silicon bronze, fabricated at the Boeing Aircraft plant across town. Her masthead fitting is silicon bronze—another Boeing fabrication; and to raise and lower the centerboard, Franck's installed a cable-and-winch rig—a brand-new bomb lifting mechanism Boeing built for B-52s.

Sea Fever was one of the earliest strip-planked boats on the West Coast. Seaborn and Vic Franck's gave her a flat sheer, reverse transom, and a trim tab on her fin keel, which was cutting-edge in her clay. In the same era, Franck's was building several of Bill Garden's far more traditional, full-keel sailboat designs (some of which appear to have been later copied by Far Eastern yards that did not always pay royalties). Whoever designed them, "all the Franck-built sailboats of those years display cockpits and interiors that are dazzling testaments to wood artisans," said Brunell.

Those "dazzling testaments" came from Franck's 3,000-sq-ft joinery shop directly behind Dan's office. The shop is open along one side at deck height to most of the boats Franck's builds in the adjacent main construction bay.



VIC FRANCK BOAT COMPANY



NEIL RABINOWITZ

***Facing page**—The keel, stem, and silicon bronze floors and frame attachments for the 80' sailing yacht* Tatoosh, *built in 1961.* Tatoosh was *the last boat from Seattle designer Ben Seaborn, who died during construction. Sparkman & Stephens finished the design.*
***Left**—A 90' motoryacht under construction, designed by Seattle designer Jack Sarin. The composite hull is from Heisley Marine, formerly of Portland, Oregon.*

Timber floors and walls are dark with age, and a gang of cast iron shop tools, showing well-earned patinas, dominate the room. It could he part of a boatbuilding museum, were it not for the work in progress. The only modern things in there, it seemed, were new-boat parts and a large, expandable, aluminum flat-table for laying up composite bulkheads and cabin soles (Franck's cores are primarily Nida-Core or Tricel). Almost hidden behind a wall in the far corner last fall was the fiberglass shop. It was about to be greatly expanded.

"Most of our boats now are designed to go fast, so we're very weight conscious," explained Dan. That means more cored bulkheads and cabinets; veneers over foam or honeycomb, and thin granite or marble laminated countertops. "We face the same quandary other builders do when customers want trendy countertops of heavy stone but still want their big boats to go fast. One recently wanted marble counters but could not be talked into paying the cost of thin marble over aluminum honeycomb. That's a lot more expensive than using solid rock due to the labor involved: You've got to hide the raw honeycomb edges with machined-ancl-bonded matched marble caps to make it look solid." Dan's solution: he talked the client into lightweight marble tile. "People want all that heavy material. It's tough to keep them reigned in."

Despite modernization for working with new materials, the joinery shop's most prominent feature will likely remain its large Turner ship's saw (see the photo on the cover of ths issue). The Turner has a 36" throat, the tilt of its wheels and blade still smoothly controlled by compressed air. It was built in the 1930s or before and acquired from the Boeing Aircraft shop across town "after Boeing stopped making airplane parts and patterns of wood," Dan said. That was sometime in the 1940s, he guessed. His father, Vic Franck, bought or bartered for the saw before Dan's time, yet it is in perfect adjustment and still in use—but no longer for big curved timbers with changing bevels. "It's really handy for its throat and big table, for making temporary molds and cutting other wide stock.

"These old cast iron pieces of machinery, you can't beat them," Dan continued. "We're going to keep them. It's interesting: You can still get parts for them. I'll tell you, I'd much rather rebuild our old tools than buy the stuff that's replacing them. You just can't top the accuracy and solidity of a big cast machine—a big joiner or planer of cast parts, rather than the stamped stuff we see these days. When we're working on a big wood project, we have one guy who just goes around oiling and adjusting them all the time."

Dan described, perhaps with a note of sadness, how the great old joinery area was shrinking, because more and more space is needed for modern composite work. What do Vic Franck's traditional craftsmen think of that? "Nobody really likes it."

Change is nothing new here, though: the joinery shop also used to be the lofting floor, and a baseline can still be seen running the length of the place. "We last lofted something in 1977," Dan recalled. "I remember because I helped with it. We lofted a 75' hull and built the plug clown at

PHOTOS VIC FRANCK BOAT COMPANY

Franck's has a long tradition of taking care of the boats it builds. ***Left***—*The 80', William Garden-designed* Kakki M, *launched in 1960, on a christening cruise on Lake Washington.* ***Facing page***—*At 104',* Dorothea *is the largest vessel Franck's has built to date. Also a Garden design, she was built in 1967. This photo was taken just before she went to the yard for a year-long refit in 1995.*

Delta Marine [Seattle, Washington]. Then we pulled a mold off our plug to provide us with hulls. The mold is still active down at Delta. We haven't used it for a number of years because our clients keep wanting one-offs."

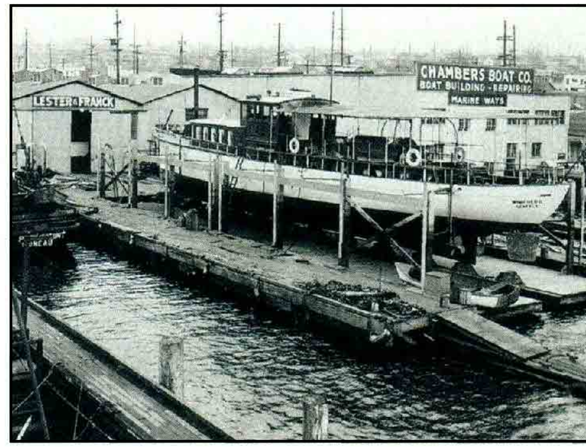
The new 78-footer's hull now being laid up at Northern Marine is a highly modified version of Northern's semi-stock 76' hull. For some of its big one-off parts, Franck's now turns to Janicki Machine Design, an hour's drive north in Sedro Woolley, Washington. A 104-footer, the biggest Franck boat ever, completely filled the building bay. Smaller parts—even complex shapes for flying bridges and the like—are molded in-house over temporary forms, which is likely all the glasswork most of Franck's crew really wants to be around.

Much of the rest of Vic Franck's yard is as big a step back in time as the woodshop. It's built on several levels to make the most of the small space. Rough wooden stairs connect one level with another, and going down, then up, we went into the machine shop. It, too, was crowded with heavy iron machine tools of a certain vintage. Charred timbers salvaged from the fire of '37 (see the sidebar on page 106) are visible in the machine shop, confirming suspicions that little is ever wasted in this place. Dan blamed the help: "My foremen won't let me throw anything away."

The yard's storerooms seem like caves carved out of the earth under the street. They are jammed with hardware, some of it ancient. A friend of mine, an old boat-nut, said he came here as a last resort a while ago looking for some historic piece of

Far right—*The first boat hauled on the yard's new drydock, circa 1948. The PVC pipes (in the recent photo, right) cover worm gears that were surplus Sherman Tank drives used vertically instead of horizontally, as they would have been in the tanks to drive the tracks. The gearing to make them work is a pair of old Model-A Ford gearboxes. Total lift is about 10'. The two docks, each 50' long, can be used separately, or raised together.*


GREG GILBERT



VIC FRANCK BOAT COMPANY

boat hardware. Franck's had it: "It's a good bet the yard will have a never-used whatever-it-is—probably cast 50 years ago. It'll be tucked away in the back somewhere, maybe next to tins of Stockholm tar. but somebody there'll go straight to it."

"The yard's character is actually a selling point for some customers." Dan said. "A lot of them like this. They're comfortable here. One day we had Wolter Huisman, a Dutch builder of large yachts, come by. We were working on one of his smaller boats and he stopped by to see it. He looked around and said, *'This* is a boatyard!'" *[For more on the Royal Huisman Shipyard, see "Production Thinking. Custom Building. " PBR No.45, page 47—Ed.]*

Our tour took us out onto the docks, two of which extend inside the largest building, where in-the-water work can continue under cover on two or three 50'-plus boats at a time—important in Rainytown. This structure, and a large in-the-water paint shop, are new metal buildings. They replace a pair of older sheds collapsed by heavy snow two years ago. Between them are Franck's dry-docks—really mechanical liftdocks and monuments to the kind of ingenuity that seems to run in the Franck family.

Raised together, the two docks work as one 100' drydock with cradle rails leading into the large main new-boat building bay, where a cable winch and donkey engine live. The two liftdocks, each 50' long, can be used separately. I guess I should not have been surprised at the way they're raised and lowered. "The gearing to make them work is a pair of old Model-A Ford gearboxes," Dan said. "They drive gear assemblies that were surplus Sherman Tank drives used vertically, instead of horizontally as they would be in the tanks to drive the tracks. It just screws up and down; it's all mechanical," and good for about a 10' lift. They were installed in the 1940s by Dan's dad.

VIC FRANCK BOAT COMPANY

Launched in 1970, this is one of the first pleasure boats built with turbine engines. Two Pratt and Whitney JP-6 turbines give the 58-footer a 34-knot cruising speed.

The drydock has allowed Vic Franck's to survive some slow times. "During the late 70s and early '80s when boat buyers evaporated, we didn't do a hell of a lot. We kept going because of our customer base. We were working on a lot of our older wooden boats, doing maintenance and repair. They were lean years, but we never had to lay our best guys off. We never went below about 15 people, and that's one nice thing about this place. It's an old physical plant but it's paid for. The last time we ran the figures, we could afford to go down to about eight people and still keep the doors open."

Franck's employs some 30 union craftsmen at the moment, and "I'd say half of them have been here at least 20 years." Dan noted. "The foreman. Ray Young, has been here 37 years."

Many employees over the decades have been recruited from the Edison Boat Building School, now a part of Seattle's community college system. Edison was originally next door to Vic Franck's. One of the partners that Ruth Franck took on to please long-ago bankers (see sidebar on page 98) was Jim Chambers, Edison's first instructor. Among his first students was William Garden—the same Garden who later designed many of the boats Franck's built. Meanwhile, the school and Vic Franck's have kept close ties: Some of Franck's journeymen are instructors there, and the best students at Edison often go to


GREG GILBERT

Shipwright Brady McCormick reefs the oakum out of a seam in My Gal, *built at Franck's in 1967, before removing a plank.*

work at Franck's—where they're likely to stay a long time.

"I got a visit from one of the Edison teachers and we were talking about the switch from wood to composite construction," recalled Dan. "They're still trying to teach the old wood boatbuilding skills because there remain some wooden boats around that need to be repaired, but they're teaching laminating and molding, too."

You get the feeling the owners and employees of this place really do make up an extended family—those are not just words or a wish as in so many modern corporations. There's a wholesome kind of comradely as old-fashioned as the tools in the shops. None of the crew has ever gotten rich here, Dan says, but his grandmother was known for advancing employees money to buy houses.

In addition to the joiners, shipwrights, and machinists, Franck's has a full paint crew, welders, hydraulics mechanics, and electricians—all known to be stellar craftsmen. The yard does its own electronics installations; owners and crews farm out as little as possible, except for jobs like engine rebuilds. Anything a customer finds not quite right, the yard quietly fixes. It also fixes a lot of "repairs" done elsewhere. Franck's policies and reputation mean there's generally a customer waiting list.

Some credit Vic Franck's with building the forerunners of the Ocean Alexander-style motoryacht—a comfortable cruiser good for running the inside passage to Alaska. Dan said that might be: Franck's has built numerous boats drawn by Ed

Monk—both Junior and Senior (Ed Monk Jr. designs Ocean Alexanders now)—creators of many popular Northwest boats; but Dan said he thought a big change had come years ago when his father and Bill Garden did a 58-footer for a Michigan customer.

"The customer said, 'I'm going to send out this shore boat that's not available on the West Coast, something to run around in,' and it was a 13' Boston Whaler. I was seven years old. I'd always had some sort of skiff with a little motor, but now I had a sled with a 55-hp Johnson. My friends and I were going like the wind. We could water ski with it. Then Dad tried to tow it and couldn't make it do right, so Garden and Dad came up with with an arrangement to carry the Whaler up on the main cabin roof [of the 58-footer]. That was one of the very first applications where you had a tender up on a relatively small boat.

"It kind of did evolve into the forms you see that Ed Monk designed and propagated with the Ocean Alexander series and Tollycraft. I don't know that Vic Franck's can take total credit. Certainly Tolly Tollefson gets credit in there too."

Some of Franck's boats are pictured on these pages. More of the many that Bill Garden designed and Franck built are featured in the two volumes of *Yacht Designs by Bill Garden* (International Marine/McGraw-Hill), and still more Franck boats, like as not built for the Northwest's most prominent yachtsmen, are in the popular book on fancy interiors, *Down Below Aboard the World's Classic Yachts* (Chronicle Books).

The new Vic Franck boat may well turn up in glossy books too, and it may be at the front of a trend: Said Dan, "What we're seeing is a guy who wants to go cruising long-range but we don't have to make his boat a caricature of a commercial vessel. On the 78-footer, we've been working with designer Tom Henderson of Seattle. The parameter is, the client is an avid sports fisherman," Dan said. "If he had his way, he'd have strictly a fishboat. His background is in the tuna and whaling industries in the Azores, which has influenced his choices. This boat has a clipper bow. [The mold at Northern is modified for extra beam and the clipper bow, yet retains the bulb below the waterline.]

"Where Northern's boat would have a split-level fisherman-style house, we have a full deckhouse and flybridge, then as you go aft, below the main deck it turns into a yacht with a European transom—an open transom and staircases coming down from the aft deck to an open fish-fighting stern and fighting chair."

If you want to know which way the finest yachts, short of "superyachts," are evolving, it seems like a good idea to keep an eye on Vic Franck's. That should be easy in the Northwest. This yard is likely to be here for several more decades. PBB

***About the Author:** A veteran sailor and former boatyard manager, Brooks Townes has been writing about boats for three decades. He writes the Rovings column for* Professional BoatBuilder.

Boatyard Repair Strategies

To run a successful repair yard, you've got to pick the right jobs and the right boat owners.

by Bruce Pfund

Repair-project customers have already, in effect, selected you if you're being asked to comment or quote on a project. The biggest favor you can do for both your boatyard and your potential customer—turning down a job—may sound bad for your business reputation and for the bottom line. If, however, declining a job prevents an unhappy customer, cost and delivery-date overruns, and associated problems that affect the level of service your *other* customers receive, walking away from a juicy contract opportunity can be money in the bank.

Carefully selecting your jobs sounds basic—but that doesn't mean it's easy. Your decision depends on a wide range of variables that involve almost every aspect of your business.

- Whom do you hire and train?
- How many employees do you need?
- What equipment and tools do you need?
- Can you work outside, or inside only?
- Should you do the projects yourself, or outsource them?
- What are the insurance angles?
- What are the environmental and regulatory considerations involved?
- What's the potential for profits?
- Is there potential for business growth?

Survival, according to the small boatyard owners and operators I spoke to, depends on finding niches where you can do quality work, get your price, and avoid problems and dissatisfied customers. Evaluating these kinds of possibilities requires a keen sense of customer expectations for boatyard work, and a clear understanding of what's practical for your crew to undertake. According to George Cochran, manager at Brewer's Cowesett Boatyard (Warwick, Rhode Island), "We like to do jobs here at the yard that the owners see, projects that reward them for all the money they spent. Gelcoat-blister repair projects are profitable for us, but expensive and decidedly unglamorous for the boat owner. Gelcoat repairs or paint jobs are there for the world to

Continues on page 114

Above—*In a large repair job such as this one on a hurricane-damaged sailboat, it's best to have a written contract with the boat owner that clearly spells out the scope of work. Beware of owners who ask you to "bury the deductible" on an insurance job.*

Gelcoat Repair

Modern additives and techniques can turn this once-difficult job into a specialized profit center for many repair yards.

"Crossover" jobs—those outside your specific area of expertise—become attractive when your regular workload gets light, or if you're looking to expand into an unfilled niche in a local market. Cosmetic gelcoat repair can be just such a project. I'm not talking about re-gelcoating over large-area structural repairs, but about repairs to little hickeys—the kind of damage that drives compulsive boat-owners nutty. It seems that dents and dings are just an inevitable part of boating. Until relatively recently, cosmetic gelcoat repair was a fussy, difficult job—one that required artisanal skills to do well. Today, however, with new technology I'll describe below, gelcoat repair is an attractive and profitable job that can be a good fit in many boatyards, large and small.

Repairs to composite laminates and coatings are perhaps the jobs most subject to "project creep" in a modern recreational boat. Systems and drive-train repairs have their purchasing, installing, and billing mysteries too, but at least the components are usually discrete items, rather than indefinite amounts of fairing putty, resin from a 55-gallon drum, or fabric off a 25-yard roll. Because of this inherent vagueness, it's critical to select composite repair jobs whose type and scope are appropriate for your boatyard.

Years ago, I was tasked with learning how to "patch match" gelcoat colors. I don't know why I write "learning," because that makes it sound as if I had an instructor. In fact, the boss just left me alone with a cratered boat, a quart of white gelcoat, six tubes of different coloring agents, and said, "You figure it out." Well, I did figure it out, but what a lot of wasted time! More than one patch that looked fine the summer I applied it looked yellow and downright terrible just one season later, and had to be re-done—at no

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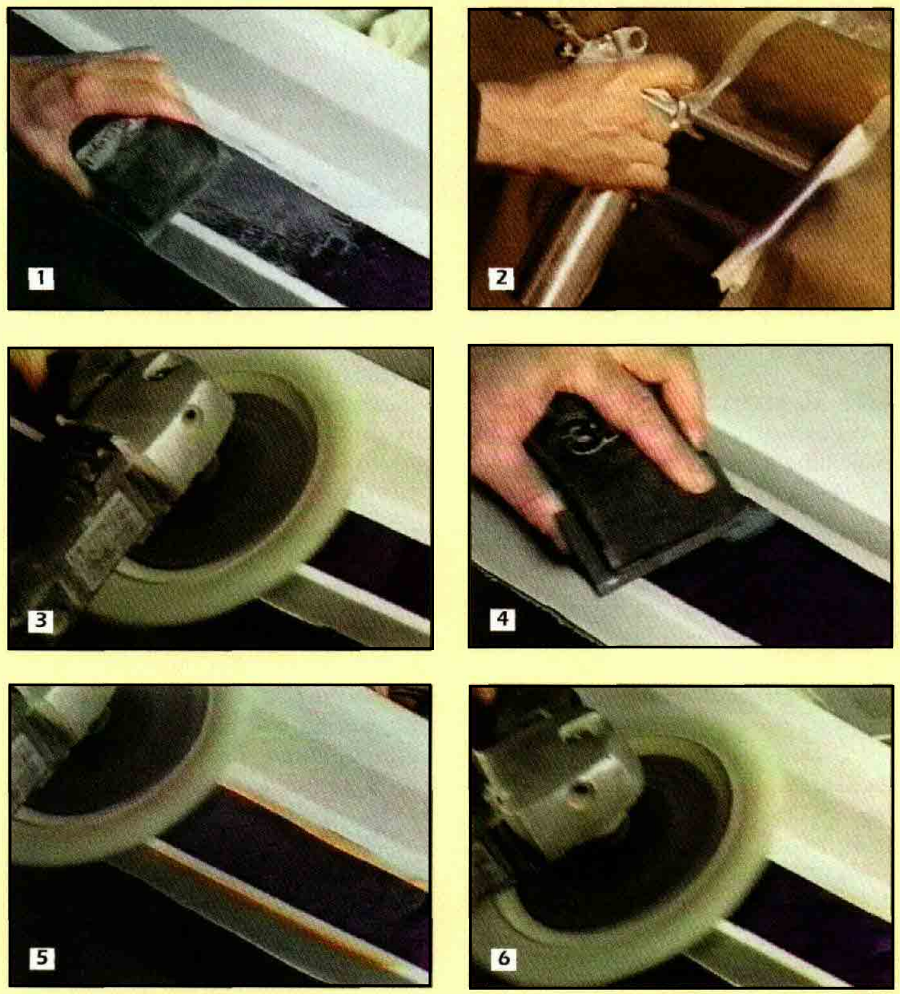


The images above, captured from Cook Composites and Polymers Co.'s video entitled "The Best Patch of All," show the steps involved in performing a repair to a minor gelcoat defect, as pictured in the top photo. **1.** Sand the area around the damaged gelcoat with a medium-grit paper. This step is essential for getting the repair gelcoat to adhere to the surface. **2.** Mask thoroughly. Prepare for lots of overspray, particularly if you are working outdoors. Square corners in the tape job may require a bit more careful perimeter sanding and buffing than radiused corners or an oval-shaped area. The small touch-up gun shown here is ideal for little repair projects, and not too expensive. **3.** After the patch has cured for at least an hour, heating it up with an aggressive "burn" with the polishing bonnet will drive the cure through to completion, while highlighting any air bubbles entrapped in the repair gelcoat layer. Be careful: too much heat will strip the "green" gelcoat right off. **4.** Hand-sand the patch with 400-grit, then 600-grit paper. **5.** Buff the repair with a 1,700-3,000-rpm machine and coarse buffing compound. Use plenty of compound to keep the area cool. Take extra care at the edges of the repair gelcoat to blend it into the existing gelcoat. Be sure to mask off to protect the rest of the boat from spatter. **6.** Buff with a polishing wax.

Continues from page 112

JONATHAN KLOPMAN

A carpenter at Pilot's Point Marina (Westbrook, Connecticut) planes a teak margin strake for a new teak deck on a Swan sailboat. Pilot's Point invested in sending its yard manager to the manufacturer, Nautor, to develop a repair spec for teak replacement decking. The results have paid off in a slick system that minimizes the holes drilled into the deck, does not depend on vacuum bagging, and allows for fast and easy finishing of the strake nib ends.

see, and the owner gets lots of visual satisfaction for the bucks. Happy customers squawk less about paying big bills."

The Seasonal Challenge

Let's start off with geography in evaluating a yard's repair-project strategy. Is the operation year-round in a warm region; or a seasonal one, in a less hospitable climate? There's a basic "busy almost all the time" versus "off-season" workload juggling act for Northern yards of which many Southern operations may be blissfully unaware. Southern yards have slow periods too, but at least they can still perform outdoor work. Finding the right project to fill yard buildings and to get the crew through the winter is an important goal for many yards. That can create problems. In seasonal yards, it's not uncommon to reduce the yard personnel count during colder months. Fall decommissioning, however, is a labor-intensive process that coincides with the disappearance of the college- and high-school-age labor pool; suddenly your skilled, year-round "project-grade" workers are out moving blocking and boat stands. Who will work on the big project during that period?

Continues from page 113

charge to the boat owner. I got my paycheck that week, but the boatyard took the economic hit for the re-work.

Although small-scale gelcoat repairs are still tricky, the toughest part—color matching by eye—has become far simpler. Computerized color matching and "patching aid" additives have truly revolutionized gelcoat repair. Combined with good workmanship and the right tools, your yard can produce results that are essentially invisible. Color matching is almost a no-brainer these days. Send off a sample chip from a faded hull, and you'll get custom-blended "faded" gelcoat to match, not the bright new color you'd receive if you just called the manufacturer and matched the product code and color number for the original gelcoat. It's important, though, to buff the area before pulling a chip for color matching, because you will no doubt have to buff to blend in the repair with the surrounding original gelcoat.

Gelcoat is an air-inhibited material, meant for contact-molding in female tooling. It won't air-cure to a tack-free, sandable, or buffable surface without some extra tweaks. Gelcoat also has some "thin-film-cure" problems. I can remember heating styrene and paraffin wax in a coffee can on an electric stove, then adding the mixture to gelcoat to make a formula that would air-dry to a hard, sandable surface—without needing a layer of polyvinyl alcohol (PVA) sprayed over it to prevent air inhibition. Those days, thank goodness, are over. I won't embarrass myself by describing how I measured cobalt naphthenate promoter (often necessary to get a thin layer of gelcoat to air-cure adequately, even at high catalyst levels) while formulating my own repair gelcoat. Today's patching additives take care of both surface and thin-film-cure problems quite effectively.

How Much Repair Gelcoat Do You Need?

Minimum orders for custom-blended gelcoat may seem excessive; some vendors' minimum is a pint, others a quart. If all you need is two tablespoons, it may seem silly to buy that much, but it's not. Buy a quart, and resign yourself to throwing away 75% or more of it. Your customer will be glad to pay for it, because the job will look so good.

When catalyzing a small quantity of repair gelcoat, do you use a scale, or do you catalyze "by eye"? If ever there was an application where exact catalyzation was critical, repair gelcoating is it. MEKP catalyst is dispersed in a liquid vehicle—commonly di-allyl or di-methyl phthalate, which are plasticizers. So, if you add too much, the cured resin will be soft and overplasticized. It'll gum up sandpaper, and won't buff up to the gloss of the surrounding area. Undercatalyze, and you'll experience similar "gumming" problems with sanding and buffing.

How, then, do you accurately measure 1.5% to 2.5% catalyst by weight for two tablespoons (10 to 20 grams) of gelcoat? Unless you've got a triple beam balance accurate to 0.1 gram, you don't have a prayer. Catalyze a larger quantity—say, a 100-gram "Dixie Cup"-sized mass—and the accuracy of your scale can drop to 1

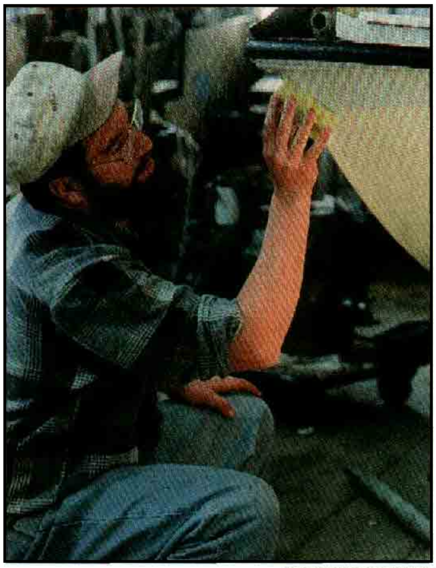
Even summer jobs can be troublesome. Let's say a boat owner asks a New England boatyard in July, "How about installing a new engine, RO desalinator, and then fairing and painting the bottom on my 50-footer before we head down the Intracoastal Waterway in mid-October?" It may sound like an attractive project, but with the yard crew leaving in early September and customers suddenly screaming to be hauled and winterized, can you handle the last-minute pressures of completing the job? It's easy to say yes in June, but what if the boat's torn apart, the new engine is delayed, and it's September 25? In other words, beware of projects that can potentially span more than one business season.

Why Me?

Near where I live is a lovely little postage stamp of a marina on the upper reaches of a local navigable river. They have a 48' x 20' soft-sided building for year-round projects that can only be completed under cover. The yard owner, while considering a fairing project on a mid-sized racing sailboat, called me to talk about farming out the job. "I'm reluctant to do this job," he told me, "because of a bad time we had with a 50-footer that spent the winter here being faired and modified a few years ago.

"I wondered at the time why this owner brought his boat all the way up the river to see me, at my tiny little yard, when there were so many big operators closer to where he kept the boat. Sure, I'd been highly recommended by a broker he knew, but I still found myself wondering 'Why me?' We initially decided that the owner had come to us because we were much cheaper than the other quotes he'd received. Hmm...why was that?"

He continued, "We later wondered, had we been selected because of our small size to be deliberately screwed? He sure could not have gotten away with what he did to us at a bigger yard. They would have had him locked up with a written contract. We worked our hearts out, but the project went over time and over budget. The scope of services never seemed to stop expanding—until the first check


JONATHAN KLOPMAN

A worker at Cloutman Marine Services (Marblehead, Massachusetts) blends and wet-sands a gelcoat repair. The yard found that switching to superior tools, materials, and abrasive products has not only improved job quality, but also efficiency.

gram, because you will be adding 1.5 to 2.5 grams. Interpolating the half-gram increment is simply a matter of counting drops as the scale reading changes. Ten drops per gram, 15 drops equals 1.5 grams. This type of scale costs about $100 for an electronic version, and in my opinion it's an absolute must-have item for gelcoat repair. You'll throw out most of the gelcoat when you've finished the repair, but think of it as an investment in doing a top-quality job. If you catalyzed in tablespoon-sized batches you might have to do the job five or six times before getting it right—ultimately using the same amount of gelcoat, but far less profitably or effectively.

Mixing and Applying the Gelcoat

I believe it's best to follow the rules that apply to gelcoating in a production-building context. The first rule is, *never* mix anything other than approved catalyst or patching-aid additives into the gelcoat. If you're brush-applying gelcoat (which I don't recommend if you are seriously trying for a high-quality patch), subsurface pinholes and air entrapment—exposed once you start sanding the brushed repair—will be a problem. These faults are common in brushed gelcoat because the coating layer is too thick. In a production setting, gelcoat is applied in three passes with spray equipment, with a short interval between each application. Entrapped air bubbles must weave their way between pigment flakes as they rise to the surface, and this takes a while, even in a thin layer. In a thick layer, the gelcoat will gel before air release is complete. The result is porosity and pinholes in the gelcoat.

Spraying the repair gelcoat—which in my opinion is the right way—has its own set of challenges. During new-boat production, gelcoat is atomized in high-pressure airless pump and spray equipment. A repair yard, however, may only have compressed air at 110 psi and a spray gun intended for paint. In this setup, gelcoat will just spit and sputter out of the gun, regardless of whether the gun is configured for pressure or siphon operation. The situation is worse if you're trying to apply the gelcoat from a little disposable sprayer powered by an aerosol can of compressed gas. It's a great tool for small-scale, lower-viscosity paint-patch spraying, but it lacks the necessary oomph to atomize high-viscosity gelcoat.

Heating the gelcoat and/or the spray gear to improve viscosity is tricky; the risk is premature gel or too fast a cure. It may also be tempting to dilute the gelcoat to make it easier to spray. Styrene and acetone are two diluents usually found in most boatshops. Don't use them! Acetone makes the gelcoat porous as it evaporates; and styrene dooms the gelcoat to rapid yellowing once exposed to sunlight. I've also heard of stove alcohol or paint thinner being used to thin gelcoat. These simply don't work. Never dilute a gelcoat with anything other than an approved patching aid from the same formulator that made the gelcoat; don't mix and match gelcoat and patch-additive brands, either.

Once you have diluted the gelcoat

Continues on page 120


JONATHAN KLOPMAN

A fiberglass technician at Pilot's Point glasses in a foam-cored coaming on a custom 42' yacht.

bounced. Neither the owner nor my business was happy at the end.

"Never again. I think we should stick to what we do best, where we understand the costs and time aspects, and where we have a clear understanding of what our profit will probably be. I ask myself 'Why me?' a lot more often now when I'm evaluating a job. My taxes and overhead on the building are really minimal. Given a choice between an empty building over the winter, or having a nasty low-profit or zero-profit project in it, I'd take an empty building any day."

Don't Play "Bury the Deductible"

Remember, as this gentleman pointed out, you won't be dealing with just the boat during a repair or refit project; you'll have to deal with its owner, too. Perhaps you've got a well-trained eye for evaluating repair projects, but what about evaluating boat owners? Are there any clues that can help you decide with whom you want to do business?

According to George Cochran, certain comments from boat owners put him on high alert. "When an owner asks me to 'bury the deductible' in an insurance repair project," he told me, "I'm immediately concerned. Is he too strapped for cash to pay the deductible out of pocket, or is he just a crook? Either way, we don't need the business. I'll stand right up and tell customers that the deductible issue is between them and the underwriter. The underwriters cut the check to them, not to us. The owner's got to pay the deductible—our of his or her pocket. We simply won't get involved in any financial games.

"It's interesting," Cochran continued, "that word about our policy in this regard seems to have reached the surveyors and the insurance underwriters and agencies. Perhaps it's happened through the surveyors' network. Although it has cost us a few jobs—ones that we didn't want under the conditions the owners proposed—we've gained respect among surveyors and insurance companies, and I think that's far more important than profits from one or two borderline repair projects. We only want to do top-quality work for top-quality customers."

Gordon Reed, former manager of Robinhood Marine (Arrowsic, Maine), has an efficient-sounding method for handling these awkward requests. Now a private marine consultant. Reed told me. "I'd say to the boat owner. 'Let's fill out a work order for your repairs.' I'd dig out a form and start by writing down their name, address, phone number, insurance company, and claim number. Then, while I read aloud what I was writing, I'd start on the repair specifications. 'Vessel owner has asked me to fraudulently increase the bill for this project by the amount of his insurance deductible in repairing the following damage.' I usually didn't have to write much more," Reed noted. "And it was funny, we didn't get many of the jobs that started out that way. That was fine by me," he added, "because once you become a parry to fraud, the owner's got lots of leverage over you. You're a crook too at that point."

Project Creep

Honest owners with deep pockets and good intentions can still become problems, especially in a small yard where business is conducted with a handshake and a direct look in the eye, rather than with formal paperwork. An honest owner might ask, "How about varnishing the handrails on the cabintop—and billing me, of course—while you're replacing and varnishing the damaged toerail for my insurance job?" Next thing you know, it's "Please sand and varnish the undamaged toerail too, and the spars, and how about a little glass work on the foredeck?"

As long as you've got open time in your shop and with your crew, it's a great and completely legitimate project. Without the paperwork from your cost estimates, and even more paper from the owner authorizing those extra "little" labor-intensive projects, settling the bill may be an ugly experience. The late Eugene O'Brien—a former Rhode Island boatyard owner who came to work at the yard that employed me as a teenager—once told me, "The owner sees the bill and wonders why the boat doesn't look or work better. The boatyard sees the bill and wonders why the boat still floats."

Some amount of paperwork, it seems, is a necessary evil in the modern boatyard, especially in a small one. The small-yard operators I interviewed for this article all confessed they fell short in this regard. It's much more enjoyable to work on a boat


BILLY BLACK

Repairing grounding damage to an internal-ballast keel.

than to write contracts...until there's a project-scope or payment problem. Then all that painful paperwork for price quotes and signed owner approvals for "extras" suddenly becomes a blessing.

Calling for Help

Says John Hall, owner of The Frank Hall Boatyard (Avondale, Rhode Island), "One thing boatyards often fail to do—and I'm guilty of this—is to call our vendors and suppliers. They're there to help us use their materials correctly, and their advice is free. They'll even make house calls. I've also found that calling other boatyards or specialists to get advice on a particular project or problem can really be a big help. Sometimes a job that seems small is actually far bigger and more complicated than you originally thought, and speaking with someone you trust who has already done a similar job can really help out, especially when you're a small operation like we are."

As president of the American Boatbuilders and Repairers Association (ABBRA) in 1996, Hall played a big part in establishing a variety of ABBRA-sponsored training programs, including the one-week schools on laminate and gelcoat repairs that ABBRA puts on in cooperation with the New England Institute of Technology (Warwick, Rhode Island). "Spending money on training your employees is a cost that comes right off the bottom line," Hall told me, "hut losses from nightmare jobs, large or small, hit the bottom line, too. The great thing about education is that you'll end up making money from it in the future, plus you'll get happier workers, and satisfied boat owners. The quality of the work your trained employees can produce will be better, and, they'll only have to do the job once.

"Capturing certain skills in-house makes sense," Hall continued, "but outsourcing makes sense, too—although it does come with its own set of potential snags. For example, you send out an engine for core replacement and general reconditioning, to an outfit that claims to offer a good warranty. You install it, and perhaps it doesn't start, or smokes like mad if it does. You make a warranty call to request that one of their technicians come down to the boat for a visit. Perhaps the reply to that request is, 'We don't do that. Take it out and send it back to us for diagnosis.' Who pays for the remove-and-replace labor, the shipping, loss of boat use by the owner, and so forth?"

Whether done in-house or outsourced, boat repair of any sort is a tricky business, especially lately. According to Hall, "Boat owners are far smarter these days than they were 10 or 20 years ago. Consumer magazines are highly technical now, and many boat owners are close to being experts about their boats—in some cases more expert than the young kids whom we often task with projects in boatyards. It's not that the kids aren't smart, it's just that they aren't old enough to have read as much, or gained lots of experience. That's why I think specialized schooling is so important," Hall told me. "It's a chance for boatyard workers to get smart fast, and I think it's perhaps the best money boatyard management can spend. Think of it as an investment."

✦

Project creep, repair re-work, crooked boat owners, bounced checks—the boatyard managers I spoke with made the boat repair business sound like a minefield. I think they're right. George Cochran told me, "You've got to be a good businessman, constantly cautious and vigilant, and not just good with boats, to run a boatyard. A screwing can come at you from almost any angle."

I heard lots of horror stories during interviews for this article, and without exception the boatyard folks confessed that they'd experienced a slight twinge of anxiety at the start of a questionable project, but had ignored it and forged ahead into troubled waters. Ignore those twinges at your peril. Selecting the right projects and the right owners is important, but what I heard was that avoiding the wrong projects and the wrong owners is equally, if not more, important. PBB

***About the Author:** As "Bruce Pfund/ Special Projects L.L.C.," Bruce consults on composite processes and surveys marine composite structures. He is the technical editor of* Professional BoatBuilder.

Continues from page 115

with a suitable patching agent and properly catalyzed it, you should be able to spray from a wide range of small-scale patch or "detail" guns—perhaps a simple airbrush rig—and get good atomization. A skilled operator can even produce excellent results with an old-fashioned cup gun. Just follow the same procedures as for gelcoating a new part. Spray the gelcoat in three passes, and check the total wet-film thickness with a mil gauge to confirm that you've applied the recommended amount—usually 18 to 25 mils.

Before you spray, practice *off the part* on a piece of window glass or Formica-covered plywood. That will allow you to adjust the gun's spray pattern, learn its delivery rate, and use up some of the approximately 75% of the catalyzed gelcoat that you will eventually throw away anyway.

Remember, the air you use to atomize the gelcoat must be spotlessly clean and dry. Your best efforts to gelcoat will be haunted by fisheyes and mysterious "crawl" problems if you don't use clean air. If you're working inside a shop, be sure to drain the water traps and check the filter elements in the compressor before you hook up the air supply hose to the spray gun.

I suggest that you turn the pressure regulator at the air system "drop" clown to zero, put a male nipple in the quick-disconnect fitting at the gun end of the hose, and then gradually increase the air pressure to about 60 psi while letting the air hose discharge into a clean white rag. Let it blow for at least a minute, shut it off, and then check the rag. Any sign of moisture or oil means contamination.

It only gets tougher if you are working out in the yard, with air supplied from a portable compressor. Once again, run the test described above. Consider dedicating a few pieces of equipment to repair-gelcoat spraying: a hose used *only* for supplying air to the gelcoat repair gun: and a set of board-mounted filters and water separator/coalescers (in addition to those at the drop or on the portable compressor) marked "GELCOATING ONLY!!!" These extra measures may cost $100-$ 150, but the yard will recover that in just a few successful projects.

Masking, Sanding, and Buffing

Mask off the areas surrounding the patch site to avoid overspray when spraying repair gelcoat. After the gelcoat has gelled and the first round of masking materials is removed, it's a good idea to re-mask for the sanding steps. One slip, and you can run sanding scratches out into the undamaged region around the repair area.

Buffing any gelcoat, let alone repair gelcoat, deserves a full article. For the moment, let me suggest that you use a buffing "system" that offers multiple grits. Be sure to have plenty of clean bonnets in stock so that you really stop using a coarse cutting compound when you switch to a finer one. Since buffing machines tend to fling around rubbing compounds, careful masking off of surrounding areas of the boat is once again a prudent idea.

—Bruce Pfund

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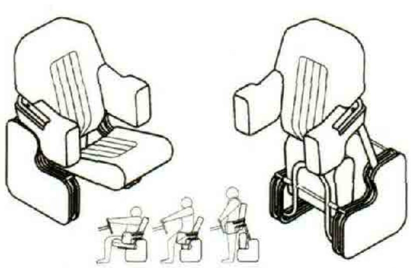

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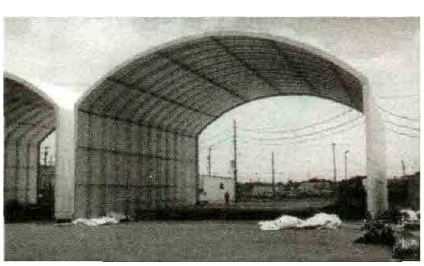

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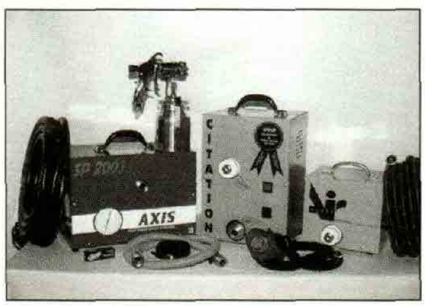

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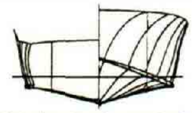

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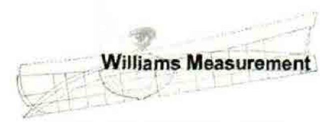

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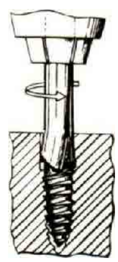

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SEASONAL MARINE MECHANICS needed May through August, annually, at Martha's Vineyard Shipyard, a full service boatyard. Must have experience with outboard, inboard/outboard, and small diesel engine repairs, as well as service and repair skills on all boat systems for sail and power boats up to 50'. Good wages and overtime. Apply to P.O. Box 1119, Vineyard Haven, MA 02568, fax 508-693-4100, <ship yard@vineyard.net>.

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White Bluff, TN 37187
Fax # (615) 797–4889
www.ebbtideboats.com

ENTHUSIASTIC, TRAINED, entry-level boatbuilders and craftsmen available. Contact NorthWest School of Wooden BoatBuilding, 251 Otto St. 251P, Port Townsend, WA 98368. 360-385-4948.

YACHT CARPENTER/BOATBUILDER. Position open immediately for an individual well-versed in fine yacht work in wood and fiberglass at C.W. Hood Yachts, Inc. Massachusetts location, competitive pay. Call for an interview, 781-586-1660 or fax qualifications to 781-586-1676.

WESTPORT SHIPYARD, INC. Looking for a challenging job with great pay and benefits? Join our team of professionals, building world-class yachts. Department head, mechanical: supervise plumbing, electrical, and metal fabrication departments. This is an administrative position. The right candidate must be skilled in all departments. Also accepting resumes from highly skilled individuals in marine trades. Westport Shipyard offers a complete benefit package. P.O. Box 308, Westport, WA 98595. Fax 360-268-1900, e-mail <humanres@westportshipyard.com>.

MARINE DESIGN/DRAFTSMEN. Looking for small-town U.S.A., to raise your children where there are good schools, low crime rate, excellent doctors and hospital, friendly folks, and plenty of outdoor recreation (fishing, hunting, hiking, etc.)? SeaArk Marine, Inc. (southeast Arkansas boat manufacturer) is located in just such an area, and is seeking mechanical/structural draftsmen with AutoCAD experience. Interested? Great! Fax resume or inquiries to 870-460-3105, or email <gayr@ipa.net>. EEOE/AA.

YACHT DESIGN company, based in the south of France, looking for both an entry-level naval architect and an interior designer. Skilled in CAD. Please send resume to Catherine Cuenot, Blubay Yachts, S.A., 68 rue d'Antibes, 06400 Cannes, France. Fax +33-4-9706-5497; e-mail <cc@blubay.com>.

MARINE MECHANIC. Martha's Vineyard Shipyard seeks applicants for a year-round marine mechanic. Must have experience with small diesel, outboard, and inboard/outboard engine repairs, as well as service and repair skills on all boat systems for sail and power boats up to 50'. Excellent pay and benefits. Six days per week, April to August; weekdays rest of year. Apply to Box 1119, Vineyard Haven, MA 02568.

SAILBOAT OUTFITTER in northwest seeks highly skilled rigger with extensive experience rigging and outfitting cruising sailboats. Must be proficient with AC and DC systems and gear. Job offers excellent wage and benefits to right person. Please call or fax resume to Todd Rickard. Seattle, WA, 206-730-9016. fax 206-283-0391.

HUCKINS YACHT CORPORATION, 70 years of custom boatbuilding, seeking designer/draftsman with hands-on experience in yacht construction to head up new project. Please fax resume to 904-388-2281, or mail to 3482 Lakeshore Blvd., Jacksonville, FL 32210.

TAMPA BAY AREA performance sportfisherman builder has immediate opening for experienced lead marine carpenter/cabinetmaker due to expanding product line to 80'. Must have quality cabinetry experience, be able to read prints, and have organizational skills. Please respond to Ron Rookstool, Plant Manager, Roscioli International, 6111 21st St. East, Bradenton, FL 34203. Fax 941-753-2646.

SKILLED TRADESPEOPLE, Gratitude Marina/ Osprey Point, Inc. Full-service boatyard with two marinas and the area's largest new boat-commissioning yard. Immediate, secure, long-term employment opportunities for the following tradespeople: riggers, mechanic (diesel experience required), installers (electronics, mechanical, and electrical). Multi-skilled trades experience a plus. Top industry wages and benefits; training and educational benefits as well. Excellent working environment, great staff, beautiful pastoral setting, good schools, great lifestyle. Send resume and detailed employment history to: Attn: Douglas Megargee, Gratitude Marina, 5924 Lawton Ave., Rock Hall, MD 21661. Phone 1-800-622-7011, fax 410-639-2854, e-mail <gmarina@dmv.com>.

MARINE MECHANICS. We are currently looking for two full-time mechanics: one experienced in troubleshooting, maintenance, and servicing smaller diesel and gas engines; the second experienced in all mechanical, electrical, and plumbing systems typically found on 40'-60' yachts. Salary commensurate with experience. Please send resume to Marblehead Trading Co., 89 Front St.. Marblehead, MA 01945, or fax 781-631-0542.

SEA RAY BOATS, INC., Industrial Designer. Requires a BA degree in industrial design or transportation design with formalized training in computer design. One year work experience and Alias software preferred. Individual will create and develop concepts and specifications that optimize the function, value, and appearance of Sea Ray boats; generate a broad variety of conceptual design alternatives through the use of preliminary sketches, accommodation plans, and renderings using Alias software and manual media. Fax resume to Human Resources, FL, 407-453-5609.

PRESTIGIOUS FLORIDA BUILDER of quality performance sportfishing vessels, 58-86', has an immediate opening for an experienced marine engineer in its Gulf Coast manufacturing plant. Experience with high-horsepower diesel propulsion systems, multiple- voltage electrical systems, and other yacht-related design disciplines a must. AutoCad software proficiency also a requirement. This is a position of responsibility in a quality-focused organization. Please send employment history and salary requirements to Roscioli International, Inc., 6111 21st St. East, Bradenton, FL 34203.

EXPERIENCED BOATBUILDERS. San Juan Composites, a growing high-tech marine company located in Anacortes, WA, at the gateway to the San Juan Islands, is recruiting quality, conscientious team members. Current openings include laminators, carpenters, paint/fairing, mechanical, and electrical. If you are a dependable hard worker looking for a position with an organization that values its team members, contact San Juan Composites at 502 34th St., Anacortes, WA 98221. 360-299-3790, fax 360-299-2747.

ALDEN YACHTS, PORTSMOUTH, RHODE ISLAND, builders of semi-custom 40'-76' sail and power yachts, seeks experienced crew for all departments; in particular, lead mechanic, finish carpenter, FRP small mold tool maker, paint and varnish shop. Excellent rates are commensurate with skill, bonus scheme, health and dental benefit package, and 401(k) plan. Portsmouth has excellent public schooling and environment for families. Applications by letter with resume or call production manager, 401-683-4200, fax 401-683-3668, e-mail, <graemejwsmith@excite.com>.

SILVERTON MARINE CORPORATION is looking for a Mechanical Systems Engineer. Experience in the boatbuilding industry is preferred. Candidate will be responsible for all underwater hardware, tanks, engines, propellers, shafting, etc. for fiberglass yachts from 30' to 45'. Experience with Pro Engineer or 3D modeling. Familiarity with USCG, NMMA, & ABYC regulations. Contact Walt Sharp at 856-825-4117 or e-mail to <wyacht@jaguarsystems.com>.

WHY WAIT UNTIL YOU RETIRE to relocate to beautiful Camden, Maine? Make the move to quality at Wayfarer Marine. We are currently looking for experienced marine craftsmen at our internationally known, full-service yard. We have upcoming openings for mechanics, riggers, and an electronics supervisor. Competitive wages and benefits. Please visit our website at <www.wayfarermarine.com> to see our yard and current and past projects. Please send resume to Wayfarer Marine Corporation, P.O. Box 677, Camden, ME 04843.

PRESERVATION SHIPYARD, a young, dynamic, custom boatbuilder, producing yachts and commercial vessels to 60', using modern wood/epoxy composite structures, seeks apprentice to journeyman level, versatile boatbuilders with systems, mechanical, or general boatbuilding skills. Build a great future with us! Phone 978-469-1929 or fax resume to 978-469-1962.

RIVOLTA MARINE. INC. is looking for team players with experience and talent to participate in the building of custom high-tech yachts. We are seeking individuals for the following positions: shop foreman, lamination, carpentry, and finishing. We offer complete benefit plans and a comfortable working environment in our air-conditioned shipyard. For more details, please contact Rivolta Marine, Inc., 13340 Reeder Rd., Palmetto, FL 34221; 941-729-6927, fax 941-729-7384, e-mail <yachtshere@aol.com>. We look forward to hearing from you.

SMALL EXPANDING BOATYARD in midcoast Maine seeking experienced marine diesel mechanic and boatbuilder. Mechanic must be motivated person with varied experience in marine systems and installations. Boatbuilder should be experienced in custom construction in wood, glass, and composites. Competitive compensation. We are not a marina, but an involved service and new construction facility. Send resume to Tenants Harbor Boat Yard, P.O. Box 382, Tenants Harbor, ME 04860. Telephone 207-372-8997, fax 207-372-0573.

DESIGN PROFESSIONAL. Keen-sailing Englishman. Twenty years design and prototype experience from automotive to sports equipment. Marine last five: Performance Cruising, Maryland, prototype Gemini 34' sailing catamaran; Robb Ladd Design, Maryland, fast cruising interior, cabinetry, and systems; Trinity Yachts, Los Angeles, 95'-212' custom yachts, interior/exterior planning, 3D design, detailing, surface modeling, graphics. Elegant, practical, and enthusiastic designs. Prefer home-based work from Los Angeles via Internet, but you tell me. UK, +44-1323-873-882, or <ladybird@seaford68.freeserve.co.uk>.

FIBERGLASS BOAT MANUFACTURING. Positions open in gelcoating, $40-100,000; also upholstery supervisor. Excellent benefits, good wages, cheap housing, and good schools. Send or fax your resume to Advantage Boats, 1000 N. Lake Havasu Ave., Lake Havasu City, AZ 86403. Phone 520-680-2628 or fax 520-680-1150. See our website, <www.advantageboats.com>, e-mail address <advantag@ctaz.com>.

PALM BEACH, FLORIDA. Long-established, full-service boatyard has opening for an experienced, knowledgeable person to take charge of purchasing, inventory control, and customer service. We offer an excellent employment package, including health care, 401(k), and vacations. Send/fax resume to E&H Boat Works. Inc., 2180 Idlewild Rd., Palm Beach Gardens. FL 33410, 561-622-8550, fax 561-627-4231, e-mail <ehboat@flinet.com>.

NEW ZEALAND. RAE LINE BOATS, in the garden city of Christchurch, is a licensed builder of Sea Ray boats, supplying the Australasian market. We seek experienced lead persons in the following areas: laminating, assembly, and fiberglass/gelcoat repairers. New Zealand has it all. Here in Christchurch we are no more than one hour's drive to the ski fields, sea, lakes, and national parks. Top industry wages for those with the ability to perform. Fax resume to +64-3-312-6526, e-mail <raelineltd@xtra.co.nz>.

LAMINATION FOREMAN. A leading motoryacht manufacturer in the Northeast has an immediate opening for an experienced fiberglass foreman. Must be proficient in gelcoat, vacuum-bagging, hand layup, etc. Must also be a self-starter with excellent personal communication capabilities, leadership ability, scheduling experience, and good recordkeeping skills. Our backlog is expanding and our company is doubling in size to meet the market requirements. This challenging position is a great opportunity for the right person. Excellent salary and benefit package. Send resume and salary requirements to Bob D'Ascoli, Albin Manufacturing, Inc., 226 West Shore Rd., Portsmouth, RI 02871.

INTERMARINE SAVANNAH is a rapidly expanding company specializing in new yacht construction as well as repair and refit work. We have immediate openings for the following crafts: pipefitters/welders, electricians, machinists, millworkers, cabinetmakers, plumbers, shipfitters, and SM/HVAC. Intermarine Savannah offers excellent benefits, including medical/dental insurance, 401(k), pension, paid holidays, vacation, company-paid life insurance, and many others. Interested individuals should fax or send a resume to 301 N. Lathrop Ave., Savannah, GA 31415; fax 912-239-1288. For inquiries, call 912-239-1139.

DESIGNER, Boston. North Shore design firm is seeking a self-motivated individual fluent in CAD with three to five years experience in the marine field. The position offers opportunities working in all aspects of the design of high-performance motoryachts built both here and abroad. Send resume to Zurn Yacht Design, P.O. Box 110, Marblehead, MA 01945, or <dz@zurnyachts.com>.

PALMER JOHNSON SAVANNAH INC. is now hiring for immediate employment! We are currently hiring experienced yacht-refitting craftsmen in the following trades: topcoat painters, prep painters, mechanics, welders, upholstery and canvas, carpet installers, furniture builders, master cabinet builders, outfitters, machinists, electricians, and seamstresses. Full benefit package. Pay based on experience. Send resume today to be part of our winning team! Palmer Johnson Savannah, Inc., Karan Resler, P.O. Box 5860. Savannah, GA 31414.

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BENNETT BROTHERS YACHTS in Wilmington, North Carolina, has immediate opportunities for skilled craftsmen in the following areas: paint, mechanical and electrical, rigging, carpentry, and lofting. Excellent benefits and pay based on experience. Come see our new facilities on the Cape Fear River in historic downtown Wilmington! Be part of our extraordinary team and enjoy outstanding climate in one of the fastest-growing areas in the country. Call Paul Bennett at 910-772-9277 for details.

EMPLOYMENT OPPORTUNITIES exist with builder of top-quality, composite, 100-150' super-yachts in sunny Florida. We are looking for a few self-motivated yacht builders and design engineers with a minimum of five years experience in the following disciplines: structural composites, yacht mechanical and electrical systems, custom yacht production engineering. Microstation CAD, Autoship, and Excel experience a plus. Experienced custom-furniture builders and high-tech composite laminators needed. Please submit resume with salary requirements to Human Resources, Trident Shipworks, Inc., 5251 W. Tyson Ave., Tampa, FL 33611. EOE. DFWP.

DRAFTSPERSON. Established interior yacht design firm now accepting applications for an upcoming permanent staff position. Superior quality millwork drawings required. General arrangements, sections, details required, along with free-hand conceptual drawings and AutoCAD renderings. Only experienced need apply. Confidential applications must include resume, professional references, salary requirements, and an exemplary sampling of AutoCAD work product. P.O. Box 39614. Ft. Lauderdale, *FL* 33339-9614.

SOUTHERN FLORIDA'S premier yacht service facility is seeking skilled, motivated professionals to fill positions as service managers, custom yacht builders and cabinetmakers, marine painters, and fiberglass technicians. Competitive salaries and excellent benefits, plus a great location! Rybovich Spencer, 4200 No. Flagler Dr., West Palm Beach, FL 33407. 561-840-8113. fax 561-844-8393. <www.rybovich.com:>. E-mail <service@rybovich.com>.

FAIRVIEW MARINA is a full-service repair yard, servicing both power and sail, from 30'-60'. Conveniently located, we are between Baltimore and Annapolis, Maryland. Presently, we have positions available for paint prep and topcoat application technicians. Positions in our custom and mechanical shops are also available. If you are motivated and have high standards, we offer part-time and year round employment with competitive wages and benefits. Send your resume to Rock Creek Management. 1575 Fairview Beach Rd., Pasadena. MD 21122: 410-437-3400.

NORTHCOAST YACHTS. INC.. is seeking to fill permanent, full-time positions in all disciplines of custom FRP yacht construction: carpenters, cabinetmakers, mold makers, mechanics, electricians, FRP laminators, painters/finishers. Northcoast Yachts builds large, custom, composite fiberglass motoryachts in Tacoma, Washington. Dedicated professionals are sought at all levels, from lead persons to entry level. Exceptional wage packages are based on experience. Send or fax resume: Northcoast Yachts, Inc., 401 Alexander Ave., Bldg. 407, Tacoma, WA 98421, fax 253-272 0306.

YACHT DESIGNER AND BOATBUILDER, currently designing very large power yachts for a French naval architect, would like to join sailboat design team. Previous sailboat design experience. Profound knowledge of 2D and 3D CAD Microstation J, MultiSurf, Prolines. GHS, NavCAD, PaintShop Pro, and Microsoft Office Suite. Graduate of Southampton Institute of Higher Education and the Landing School. Certified boatbuilder. Multilingual (German, French, English, and some Italian). Good communicator; willing to relocate. Please leave a message, tel/fax +49-7021-44371, e-mail <K.v.B.@gmx.net>.

AMERICAN CUSTOM YACHTS is looking for yacht-quality craftsmen in search of occupational challenges with one of the leading producers of custom sportfishermen. We are presently looking for craftsmen qualified in the following fields: mechanical fabricators, systems mechanics, service and repair carpenters, new hull construction carpenters, welders, painters, laminators. Minimum three years' marine experience required. Gain employment in one of the most desirable areas in Florida. Attractive benefits package. For information, call 561-221-9100: fax 561-288-4993. Located Stuart, Florida.

SANTA CRUZ YACHTS, Soquel, California, is now hiring boatbuilding professionals for all areas of operation. Positions are available for fiberglass laminators, woodworkers, electricians, plumber/systems installers, purchasing agents, mechanical installers, and deck hardware installers. The right candidate has a mini mum of five years experience, is capable of working in a high-quality, production atmosphere, is a self-starter, and wants to work as part of a team. If you do not have a strong work ethic and a dedication to quality, do not apply. Excellent pay and benefits for the right individuals. Call CA, 831-475-9627. or fax resume to 831-475-0867.

AUSTRALIAN PROFESSIONAL ENGINEER; composites, FEA, production management, structural design, carbon fiber, MMCs, non-linear analysis. Registered mast engineer, seeks technical challenges and employment anywhere on the planet. Multi skilled, hands-on, lateral thinker. What more do you need? 42 years old, enthusiastic. See <www.lusas.com/case/solarig.html> for work example. Please contact Peter Schwarzel, phone/fax +61-7-5545-2984, <carbonworks@winshop.com.au> for resume or any further questions.

PROMINENT PORTLAND, OREGON AREA full-service boatyard is seeking a shop foreman. Must have excellent supervisory skills and good knowledge of all phases of recreational boat repair. Company also produces several custom new boats annually. Experience with wood/epoxy/foam core and exotic composites a plus. Resume with salary requirements to P.O. Box 307, Vancouver, WA 98666.

MARYLAND'S EASTERN SHORE. Haven Harbour Marina and Yacht Services is looking for experienced yacht repair specialists: painters, fiberglass repair, installers, carpenters, mechanics. Qualified applicants will receive the top salary and benefits offered by our industry. Paid vacation, family health insurance, 401(k), life insurance, sick pay, all pre-tax Section 125 benefits. Send resume to Jonathan Jones. Haven Harbour Marina, 20880 Rock Hall Ave., Rock Hall, MD 21661, or call 800-506-6697. E-mail <havenhbr@friend.ly.net>. Look us up on the Internet, <www.havenharbour.com>.

SERVICE MANAGER, Maryland, Chesapeake Bay full-service yacht repair yard. Qualified applicant should have previous experience with all aspects of yacht building and repair. Strong customer service skills, communication skills, and a computer background required. Excellent benefits package and profit sharing available. For confidential consideration, send resume to PBB Classified Advertiser #M, P.O. Box 78, Brooklin. ME 04616.

TAMPA BAY AREA performance sportfisherman builder has immediate opening for experienced lead marine electrician due to expanding product line to 80'. Must have 120/240VAC and 12/24VDC experience, be able to read schematics, and have organizational skills. Please respond to Ron Rookstool, Plant Manager, Roscioli International, 6111 21st St. East, Bradenton, FL 34203. Fax 941-753-2646.

HINES-FARLEY YACHTS, woodcraftsman and electrical positions available. Custom yacht builder is seeking applicants for experienced wood craftsman for fine furniture building, using veneers and laminates. Also seeking an experienced mechanical and electrical supervisor. VA, 757-484-5702. fax 757-484-4458.

SALMON RIVER BOATWORKS is looking for a few good people. We build custom Downeast pleasure and work boats from 22' to 30'. Immediate openings for carpenters, systems technicians, and fiberglass specialists. We also operate a full service boatyard with 65 slips and indoor/outdoor storage for 200-plus boats. Our facility is located in Haddam, Connecticut, on the Connecticut River, 18 miles from Long Island Sound. If you are a motivated team player and want to know more, give us a call at 860-345-4330; ask for Scott or Elliott.

CAD OPERATOR NEEDED for fast-paced design/tooling firm. Must have marine design experience with CAD background, unigraphics helpful. Fax resumes to 941-283-3332. or e-mail them to <Margie@marineconcepts.com>.

MARINE MECHANIC WANTED. Experienced inboard/outboard, Mercury outdrives, Volvo, OMC certification. Self motivated. Reliable benefits and salary depending on experience. Fax resumes to CA, 916-777-6782.

PROFESSIONAL BOATBUILDER MAGAZINE

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PARTING SHOT

Trimming the Product-Safety Standards Bureaucracy

by Peter Randall

Some product-safety regulations are good and effective; others aren't. Some of the good ones incorporate existing industry standards—the UL Marine listing, for example—by referencing them. That way, a designer or boatbuilder needs only to see a label to be assured that the regulations have been satisfied. To the regulated, it appears to be less paperwork. Sounds like a great idea, doesn't it? Instead of the bureaucrats developing rules in a semi-vacuum, the parties involved get together to develop consensus standards that are presumably better, up-to-date, and agreeable to all. Unfortunately, it doesn't always work this way.

I recently heard a U.S. Coast Guard official tell a group revising a venerable marine electrical engineering standard that the Coast Guard "has a mandate to reduce the volume of regulations by adopting industry-developed standards...If you do a good job, this [standard] will replace Subchapter J...of the Code of Federal Regulations."

I've worked with Subchapter J and this particular engineering standard for over 20 years—some of those years as a Coast Guard marine inspector. Today, I use both of them for inspecting vessel design and construction. I once worked in the same office as the gentleman quoted above, under the same federal mandate to reduce regulations. One of the things I've learned is that the well-intentioned incorporation-by-reference scheme can sometimes result in even more bureaucracy than the regulations it replaces. Here's what happens.

You open the recently updated regulations to find out what is required. In the front, you find a listing of standards that are incorporated by reference—American Bureau of Shipping, the Institute of Electrical and Electronics Engineers, American Society for Testing and Materials, International Electrotechnical Commission, etc. The regulation says, "The widgets shall meet ABC." So you contact the organization that publishes ABC to get a copy of the standard. They tell you they'll send it to you for a fee (usually steep), and you'll get it in a few weeks. When it arrives, you find that it adopts standard XYZ. So you call and order XYZ. And so on. Finally, several weeks and several hundred dollars later, you've assembled everything. You start to read through your new standards library and quickly conclude that you either need to buy a handbook from the organization, or hire a consultant to explain what all this paperwork really says and what you have to do. So your conscientious effort to look up a few pages of information has led you on a long, circuitous, sometimes costly journey through several new bureaucratic landscapes that you never knew existed. You also may find that the new regulation incorporates a standard that has changed, or inadvertently references provisions in XYZ that the Coast Guard never intended.

Many product-safety regulations incorporate existing industry standards by referencing them. But, does that really reduce the volume of regulations?

Unfortunately, the Coast Guard's own field offices frequently can't afford to keep their libraries of adopted standards complete or up-to-date. Many of the Coast Guard marine inspectors I've known have never read some of the standards they're supposed to enforce, let alone understood them. The Coast Guard sometimes issues free guidance circulars (NVICs) to try to clarify the intent, but these take time to develop and usually can't keep pace with the updates.

Consensus standards can work very well. There's little doubt that people are safer as a result of them. There's also little doubt that the public would prefer to see the Coast Guard expend its limited resources in areas other than the bureaucracy needed to develop and maintain the huge quantity of *minimal* regulatory standards that are *necessary.* But this hidden catch *must* be addressed, as the same process and problem exist throughout the regulatory community.

First, just about everyone in the marine industry has a computer and is on the World Wide Web. Regulators (federal, state, classification society, etc.) who have already been paid to develop a regulation should post the standards they adopt on the Internet *for free.* Not only would the regulations be more useable in the future, but the public would actually get to look at the standard before it becomes a de facto regulation. It's a dirty little secret of the regulatory business that the public rarely has adequate opportunity to read the adopted standards before the final regulation is issued.

Second, regulators should work with standards-development organizations to make sure the manufacturer or service provider is required to certify that the product or service meets the standards. This points the liability gun in the right direction.

Third, if the first two things can't be done, then the regulatory body should require the product or service to be tested and certified by a third party (e.g., Underwriters Laboratories). Manufacturers don't particularly like this and say that it adds to overhead, price, and the time it takes to get new products to market, but the end result is a better product and honest market competition.

As for me, I'll keep my 20-plus-year-old copy of Subchapter J and the old electrical standard handy, just in case I need to try to figure out what the new improved regulations are trying to say.

PBB

***About the Author:** Peter Randall is senior electrical engineer at Elliot Bay Design Group in Seattle, Washington.*

The opinions expressed in "Parting Shot" are the author's and not necessarily those of Professional BoatBuilder. *We welcome contributions to the column from anyone in the marine industry. Write to Editor,* Professional BoatBuilder, *P.O. Box 78. Brooklin, ME 04616.*