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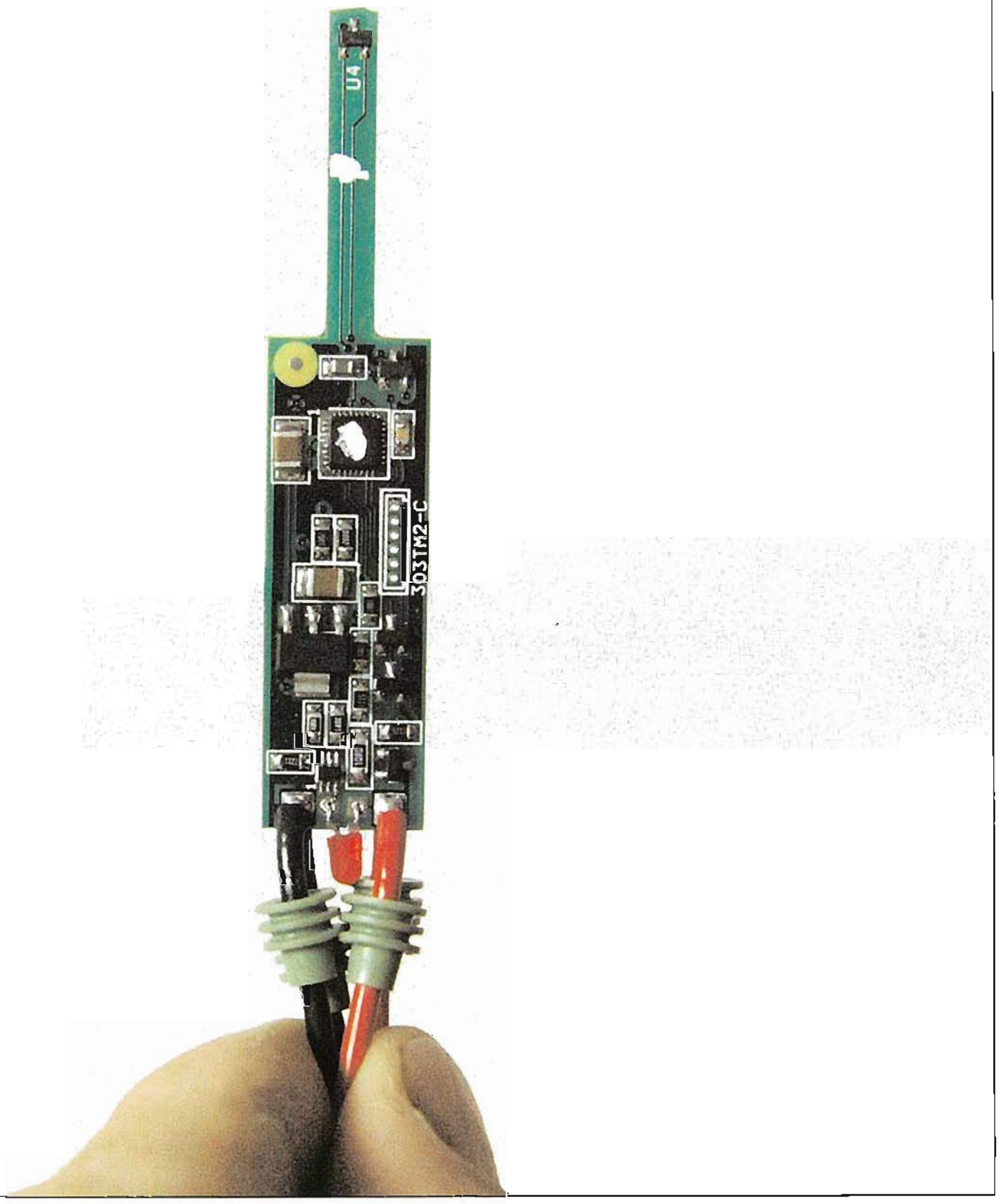

The magazine for those working in design, construction, and repair

NUMBER 98
DECEMBER/JANUARY
2006
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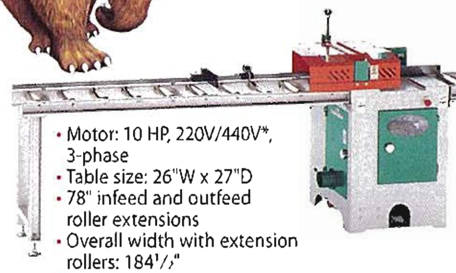

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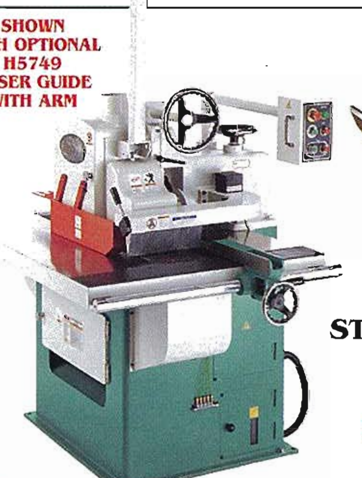

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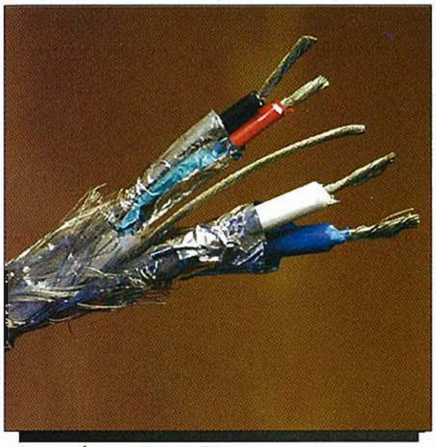
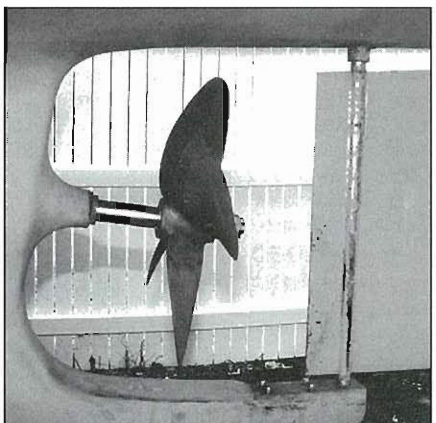
J BOATS

J Is for Johnstone. Page 28.



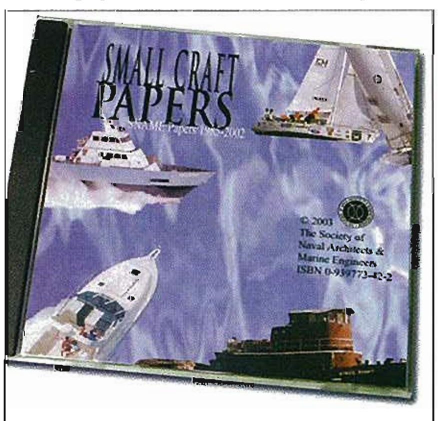
NIGEL CALDER

Networking. Page 50.



DAVE GERR

Steering System Fundamentals. Page 76.



SNAME's Small Craft Papers. *Page 22.*

FEATURES

DEPARTMENTS

READER SERVICES

On the cover: A new-generation tank-level probe. The circuit board shown is ED&D's so-called "core"—a transceiver that will ultimately be reduced to a chip. Story (on networking), page 50.
Photograph by Nigel Calder.

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PROFESSIONAL BOATBUILDER MAGAZINE

Operating Systems

The late Robert Noyce, co-inventor of the computer chip, waited not just years but decades for people to appreciate the potential applications of miniaturized circuitry. In some respects, he'd still be waiting for widespread computerization *aboard boats*. Nevertheless, as contributing editor Nigel Calder's articles on networking ship's systems make clear ("Networking—Part 1," in PBB No. 97, and Part 2 on page 50), the newest generation of boats and yachts is well on its way to fully integrating computer technology throughout the vessel.

Why the seemingly slow response in the marine sector? After all, other major modes of transport—aircraft and automobiles—have, by comparison, long been extensively computer-equipped. The explanation may be that, first, the slow rate of computerization in boats is a measure of the severity of the marine environment; second (and this is a function of the first), the marine industry as a whole, through its designers and builders, tends to resist rapid changes in methods and materials; and third, in relative terms both the commercial and recreational segments of the boat business represent only a small market. (An order of magnitude smaller than, say, the potato-chip market.)

Correct me if I'm wrong, but the advent of digitally controlled systems *on the water* probably dates to the U.S. Navy's introduction of the *Spruance*-class destroyer, in 1975. Still, only the destroyer's weapons system was digital. Thirty years later, in 2005–06, digital technology is now the next new thing aboard sophisticated small craft (that includes large yachts), controlling the propulsion and other mechanical systems, and the electrical system and electronics gear. We are indeed on the verge of great change.

Unfortunately, all this significant technical development in the boat biz comes at a cost, the price being a throwback, however temporary, to the type of competition that end users find confusing and frustrating. Nigel describes, in great detail, competing protocols in today's marine networking market. Such protocols are fundamental to the modern machine age—namely, the ability of one computer, or chip, or device to read the data, or messages, of another and thus communicate. The warfare we're witnessing between vendors, large and small, of marine networking technology is reminiscent of earlier battles in the computer age, some of which are not yet resolved: the struggle, for example, between Microsoft and Apple over operating systems and therefore platform preference; or the formerly fierce competition among once-numerous tech companies promoting their word-processing programs; or, similarly, the race between developers of different types of hull-design software.

Nigel suggests one approach that may ultimately win out: not a single networking standard, though that would be ideal; rather, a tiered solution in which two different controller area networks, or CANs, control whole blocks of ship's systems while a third network—the more familiar Ethernet—operates a separate cluster, with each of these three variants specializing in the territories (electronics, propulsion, navigation) whence they come. An interesting idea.

Even so, safety at sea further suggests that standards may need to be written to ensure that networked craft—of whatever configuration—do not suffer potentially dangerous system crashes due to software failures, or inherent incompatibility.

Enjoy the issue.

Paul Lazarus

LETTERS, ETC.

Keels and Rudders: Engineering and Construction

To the Editor:

I enjoyed Eric Sponberg's excellent article on keel and rudder engineering and construction (PBB No. 96, page 72). Some additional information on keelbolts might be of interest.

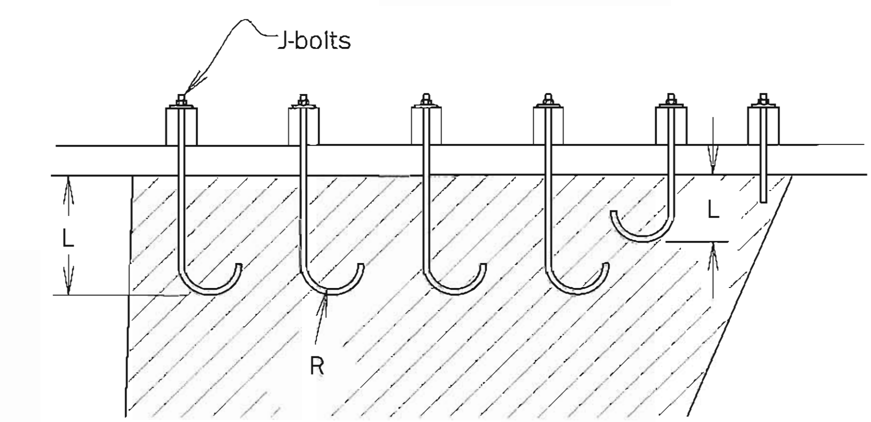
Drilling and tapping of lead for lag bolts is excellent. This was used on traditional boats, where the aspect ratio of the lead ballast itself was fairly low. Such fastening is suited only for ballast lead that has an aspect ratio of 0.5 or less. The lead should be alloyed with at least 3% antimony, for a minimum tensile strength of 4,700 psi (32 MPa). Five percent antimony is optimum, with a tensile strength of 6,300 psi (43 MPa) and an elongation of 29%. Above 5% antimony, the elongation begins to drop. Above 10% antimony, the tensile strength also begins to drop. For the depth of the drilled-and-tapped bolt holes, eight times bolt diameter is good up to ballast aspect ratios of about 0.35. From 0.35 to 0.5, use 10 times bolt diameter.

For deeper-ballast fins (aspect ratio over 0.5), J-bolts are required. The rule of thumb for proportioning J-bolts is:

The total vertical bury of the J-bolts into the keel (L) should be between 12 and 20 times bolt diameter, and the radius (R) of the U should be five times bolt diameter, but not less than 2½" (6cm)—see illustration.

For very high aspect keels (aspect ratio over 1.2), then the bronze or stainless weldments Sponberg describes so well are required. This distributes the large loads far better than simple J-bolts. Of course—though not usually required—it doesn't hurt to have such bolt "trees" or armatures on lower-aspect keels: *stronger is always better.*

Dave Gerr
New York, New York



Keelbolts

Wet Balsa Core

To the Editor:

I commend Rick Strand for sticking to the title of his article "Wet Balsa Core" (PBB No. 96, page 16) and not pursuing the global problem of *all* wet-core materials. His only reference to wet foam core is to a study being undertaken to quantify results from testing similar to that conducted on wet balsa core.

Most internationally accepted rules for structural scantlings provide different factors for allowable core shear stress based on survivability criteria and ultimate elongation at failure (toughness). Regardless of what you use for a starting point with the mechanical properties of any core, the basic safety factors are the same. All sandwich panels are (or should be) designed with the same factors of safety. If a sandwich panel is designed and built to minimum core and skin thicknesses, which is normally the goal of any design optimization, then any reduction in the mechanical strength of either component (core or skin) would naturally reduce the original design safety factors. Design safety factors help define long-term survivability of a given structure. Historical data and laboratory test data (from the U.S. Navy, Interplastic Corporation, and DJA/Sigma Labs, to name three separate sources) have demonstrated that 25% stress levels provide long-term strength and stiffness retention—and that raising the allowed stress to a 35% level causes fatigue life values to drop like a stone.

Calculations based on the property of core shear strength are generally used to determine the minimum core thickness allowed. Since we are trying to optimize the design and we don't want to spend any more money than is absolutely necessary, we would choose the thinnest skins and core that meet the shear and deflection criteria for the design application. To lose 20% of the core shear strength—a figure cited by Mr. Strand in connection with wet balsa core—could very well lead to early failure of the structure.

Many builders prefer thicker skins on either side of a thin core. The core will certainly add stiffness to the structure, but at the same time thick skins also impart higher core shear stresses than will a thin-skinned, thick-cored design. When the ratio of the sum of the thickness of the two skins compared to the thickness of the core (2t/c) nears 0.5 or greater, much higher stress is developed in the core than necessary, which can be reduced only through increased core thickness, reduction of load, or additional internal stiffeners. In other words, it's an example of a design that has not been optimized.

Core shear and core compressive moduli also play a much larger role in the design of a panel than is inferred

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by this article. Core shear and core compressive moduli help determine the limiting buckling stress on the compression-side skin. Since both sides of a panel are subjected to alternating tension and compression stresses during cyclic bending, the critical stress area is generally where the panel is being wrapped around a bulkhead or frame in a high loading condition. First failure of sandwich panels often comes with buckling failure: the skin bending on the core. Losing 25% of the shear modulus and nearly 30% of the compressive modulus due to balsa core with high moisture content would adversely limit the allowable buckling performance of the structure. This significant loss of mechanical properties occurs at the fiber saturation point of the balsa core.

If you were able to examine a balsa core at the fiber saturation point, or FSP, before decay has set in, it may feel damp, but it could have the appearance of normal (dry) balsa core. In my opinion, if the core is wet to the point of fiber saturation, that means moisture has reached the bondline on both sides, where your chance of finding a bondline void is much higher—especially when the core has not been properly vacuum-bagged or infused in place.

Mr. Strand states that the freeze/thaw samples his study group made took only a few days to reach 280%–290% moisture content by weight—good evidence that water saturates a balsa core at a fairly rapid rate, regardless of exposure to cross-grain, kerfs, or end-grain. At a saturation level of 290%, I would certainly like to see the results of the mechanical testing, if they can even be accomplished.

I like to think that we build boats to last a lifetime. Many builders have long understood the importance of proper core returns, elimination of voids (particularly along the edges of a cored section), and the elimination of all through-penetrations into a cored area. Vessels built with that understanding do not have the problems described in Mr. Strand's article. I recently sold a 1965 41′ [12.5m] Hatteras (HIN #53) that had balsa decks, hull sides, and superstructure. I had owned the boat for more than 27 years without any problems with wet core. His article also implies that hardware penetrations into cored areas will eventually leak in "a couple of years of use and no maintenance." Is it a currently accepted practice to remove and re-bed hardware every year or six months to ensure that the core remains sealed? Or is it the builder's responsibility to do the proper job in the first place and build longevity into the design?

Mr. Strand's article basically takes the stance that: in the event of water intrusion into a balsa-cored structure, only decayed core material need be removed and the point of water ingress sealed; the remaining wet core still has a majority of its original strength and stiffness; and, since the moisture will eventually dissipate through the rest of the core material, all is well with this universe. I disagree. If we take the case of a leaky deck fitting, the decayed core gets replaced and the area is sealed so that no more water or air can enter locally. But what happens to other air vent sites or electrical runs that have been cut through the deck and are not exposed to high moisture areas or moisture ingress, but to air? I believe that air will continue to circulate through the kerf system, providing spores and oxygen to the wet core that are necessary for decay.

I have a difficult time understanding how water—with air and microscopic spores—can travel through the kerf system of a hull side, through an unsealed portlight cutout, and then, when the visible decay is removed and the area resealed, no more damage will occur. There is still air in that kerf system. High moisture will accumulate at the lowest point—perhaps along a line-bubble at the core edge at the chine; an optimum breeding ground will therefore still exist within the hull side shell. Maybe the decay needs more air than what is in the kerfs in order to exist, but I would argue that there is more than enough air to allow other pockets of decay to form, which may not be readily accessible when the site of ingress is repaired.

So: How much moisture can be left in a balsa-cored structure? That's the big question! As reported in the article, balsa core is originally shipped from the manufacturer with approximately 12% moisture by weight, whereas spores need a minimum of 20% moisture to flourish. The U.S. Department of Agriculture's Forest Products Laboratory [Madison, Wisconsin] says that the optimum moisture content for decay is the FSP, 28%. The American Plywood Association [Tacoma, Washington] puts the threshold for the use of wet-wood mechanical properties at 16%. Where, then, is the cutoff point? Do we really want to design boats with wet-wood properties? Do we really want wet wood of any type left in a structural part of the vessel? We already know that's not a good thing with plywood stringers.

I would be most interested in a long-term study that analyzes the effects wet balsa core has on the mechanical properties of the core in a sealed environment (no new air or moisture). I, too, have had very little success in drying out wet balsa-cored boats and have often found that, when an owner of one of these affected boats is faced with a choice between many months of attempted drying processes, or the much shorter time frame of rapid amputation coupled with a rapid recovery period, that owner will usually choose the method that can put him back on the water more quickly.

David E. Jones, N.A.
D.E. Jones & Associates
St. Petersburg, Florida

To the Editor:

I consider Mr. Strand's article a "puff piece" for the marine industry—something they can direct irate buyers to and show them that wet balsa cores are acceptable.

We have been involved with a number of soaked balsa-cored vessels. Over the long term, the balsa

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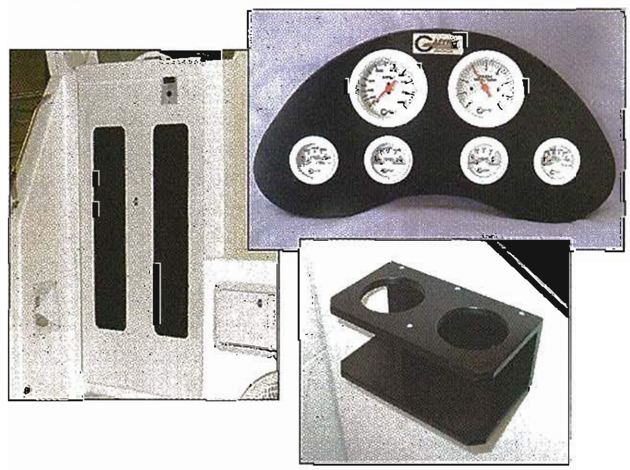

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turns to "mush," and strength is compromised. Additionally, Mr. Strand makes no mention of the *extra weight* of the saturated core. One soaked boat we dealt with had developed a noticeable list because only one side of the bottom was saturated.

Hell, if soaked balsa core is so wonderful, why not *pre-saturate* it at the factory? This would eliminate two problems: listing, and degraded performance as the boat grows ever-heavier after delivery.

Tom Fexas
Tom Fexas Yacht Design Inc.
Stuart, Florida

Rick Strand responds:

Picking a generalized fatigue limit for all marine construction is lazy but cost effective. It negates the expense of doing the required testing. A handful of fatigue tests on specific material types does not extend to all types in a blanket fashion. Doing this places the industry in a position where the builder cannot capitalize on the benefits of improved materials and manufacturing technologies. I have not seen any fatigue data produced exclusively for core materials. I would not accept sandwich cyclic loading as a method to generate such information, due to the large error introduced by multiple materials, system mechanics, and test fixtures/setups.

Buckling of facings should always be checked when we engineer sandwich composites. Our article dealt specifically with 9-lb-density (144 kg/m^3) balsa core. If we maintain facing-safety-factor levels at 2.0 to 3.0, our maximum operational stresses are well below their critical buckling stress on 9-lb balsa. Using lower density cores or very high strength facings will create buckling concerns.

Our freeze/thaw samples had the direct end-grain of the balsa exposed to the water source. That is why the moisture uptake was so rapid. We note that an exposure perpendicular to the grain has and always will take significantly longer by multiple orders of magnitude.

With respect to drying, the kerf networks in the majority of wet balsa I have reviewed (more than 600 samples) close from swelling after they are wet, thus shutting off airflow. This is one reason why wet balsa is difficult to dry. Airflow through the kerfs is greatly reduced. When wet core is discovered, all local fittings should be corrected and resealed, not just the "leaker." This assures that air does not get to the damp core from other locations.

We were clear in the article that the 20% reduction in shear strength held constant up to 100% moisture by weight. We were clear that according to information from both the U.S. Department of Agriculture's Forest Products Laboratory and the American Plywood Association, almost no further loss in properties beyond fiber saturation point occurs, meaning that fully saturated wood does not lose more strength or stiffness beyond FSP. All the same principles apply for stringer plywood. Whether it is structural or acts as a form for composite overlay makes a huge difference. Yes, engine mounts require special considerations. Not all wet plywood needs to be removed.

Finally, the sarcasm of Mr. Fexas' letter demonstrates the lack of objectivity that has helped produce the strong negative charge of the wet core issue. I've seen both mush and listing vessels. Most involve severe cases. Again, not all wet core is acceptable. The article provides many of the tools necessary to distinguish the good from the bad and the ugly.

Ground Faults Revisited

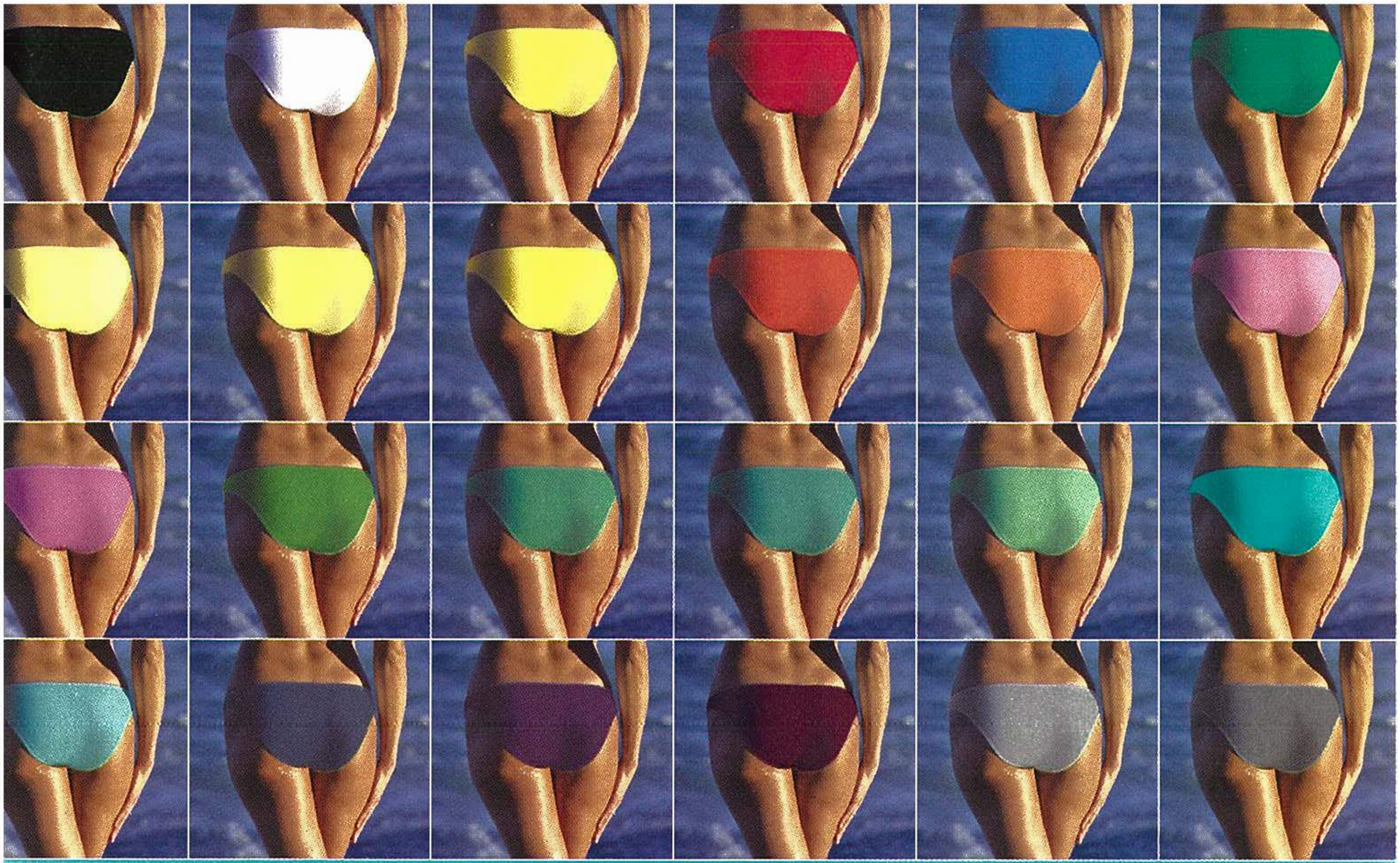
To the Editor:

As a regular reader of this magazine, I cannot deny that Ed Sherman's article "Ground Faults Revisited" (PBB No. 94, page 84), with his tragic story of the loss of a human life due to an electric fault on board, hasn't affected me. Through my work as professor at the European Design Institute (Rome, Italy) and my work at the Cantalupi Electric Systems Company (Viareggio), I am involved in managing the design and installation of electrical systems for yachts; the primary aim of my activity is electrical safety on board.

Regarding residual current: Any difference in current (also called "non-zero sum") between the hot and neutral conductors is always a big problem in electrical systems installed on boats, mainly caused by the presence of water (seawater or moisture) and salt deposits (that are current conductors). The residual current is easily measured with a clamp-type ammeter, by enclosing all the charged wires but leaving out the ground conductor. When the sum of the charged wires to a piece of electrical equipment or of powered blocks of systems is not zero, the remaining current returns through a different path. Frequently this alternative return path is the grounding connection; thus the green/yellow wire becomes electrically charged, and therefore could, in some circumstances, shock personnel who touch grounded components, such as a ground-connected equipment case.

That potentially dangerous fault situation can be solved by installing GFCI protection devices (ground fault current interrupters or differential breakers, as they are called in Europe). Unfortunately, electricians here remain divided on their use. Some installers still think that GFCIs are not fully compatible with the marine environment, because moisture and water may produce current dispersion (low-level fault currents), thereby tripping the supply breaker and stopping operation of the involved faulty device. So what is better: protection, or continuous operation of the devices? For that question the only good answer is to consider the protection of personnel as the first priority, by way of the devices. Both the distribution and the protection systems should be optimized for the possibility of having devices out of service. A rule of thumb here is to fit all the end-user devices (all the equipment that can be directly accessible to personnel) with GFCIs, so that if, for example, an installed washing machine is producing residual current, then its protection breaker trips, disconnecting it from the power supply line.

Other equipment not in direct contact with personnel should be



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fitted with a GFP (ground fault protector), a less sensitive differential device. In this way, with a properly planned grounding system, safety will still be assured—along with uninterrupted operation of the equipment. Direct contacts between one of the supply hot wires and ground (or any metallic part of the chassis or adjacent part) will obviously trip the GFP-driven supply breaker.

In addition, a permanent ground fault controller has to be installed, which indicates the state of the ground potential. In certain cases, such as isolated distribution systems (no ground-connected neutral), the installation of a ground fault or isolation controller is mandatory (according to IEC rules). This device should provide an indication of the state of the grounding system and of any residual currents flowing. Fitted with a settable alarm level, such a unit is useful for monitoring the loss of isolation of the installed devices. Thus, the loss of isolation of a blower (which may occur, say, by seawater dripping on it) will be shown by the isolation controller before the GFP trips, disconnecting the blower.

A similar case occurred not long ago on a motoryacht that called us for an inspection: the captain of the boat reported a surprising phenomenon regarding the aft swim ladder attached to the gangway. It so happened that seawater around the two vertical support holders of the ladder released bubbles as though it were steaming. My first thought was that it must be corrosion, but we found a permanent DC voltage charge on the ladder; it acted like an electrode in an electrolysis cell. What was happening? The motoryacht was fitted with a doorbell at the gangway. This removable push button was connected to the boat though a male/female connector, placed on the lower side of the gangway. Because of its incorrect positioning, the connector became immersed in seawater whenever the mobile ladder/gangway was deployed. Therefore, due to sea water and salt deposits, the 24VDC supply powering the doorbell charged the ladder and closed the contact for the bell, keeping it always on. As if all this wasn't enough, a second problem occurred: The captain, hearing the bell always on, instead of interrupting the circuit and looking for the fault, cut the wires to the bell. Everything then worked fine—except for the doorbell and the strange "boiling" of the water around the ladder. We simply installed a new connector, moving it to a safe position, and all equipment again worked correctly.

Another important component, as

you know, is the isolation transformer that should be connected between the marina power system and the onboard distribution net for the shore power connection. In this way, the onboard electrical system will become fully isolated and independent from the marina's power. Accordingly, alternative reclosure paths for all the currents (including dispersion, or fault, currents) will be normally limited to the boat's area.

Horia Marinescu
Technical Manager
Cantalupi Electric Systems
Viareggio, Italy

Ed Sherman responds:

I agree with all of Mr. Marinescu's comments regarding my article. Personnel safety should always be the paramount concern. Generally, onboard personnel safety has been the primary focus, but in light of the increasing number of in-the-water deaths associated with fault current leakage through the bottoms of boats, I feel that the European whole-boat fault current protection concept is the safest way to go. Isolation transformers are a great possible solution, but not appropriate for smaller boats that still have AC service on board. Until lighter, smaller isolation transformers are available, it's just too difficult to find a place to fit the transformers on many boats.

As regards GFCIs versus GFPs, or RCDs, I agree with those who contend that the 5-mA trip rate for whole-boat protection is not feasible, considering the inherent leakage of some AC devices typically found on boats. The best overall layout would have a 30-mA whole-boat device installed, adding 5-mA devices to service AC receptacles in heads, galleys, machinery spaces, and on weather decks, as required by the present ABYC E-11 Standard. In monitoring existing installations all over North America, I have never seen a boat—and this includes vessels up to the 100'/30.5m class—that has inherent leakages even beginning to approach the 30-mA level, *unless* there was a bona fide AC electrical problem on board that needed repair or service. A 30-mA RCD would have saved young Lucas Ritz's life, and others'. This is the best, most cost-effective method to enhance the safety of personnel on board and in the water around docks at marinas. PBB

Correction

In the *Fairweather* sidebar for "Lyman-Morse," PBB No. 97, page 90, the location of Composite Solutions (which supplied *Fairweather*'s carbon rig) should be Hingham, Massachusetts. We regret the error—*Ed.*

Compiled by Dan Spurr

It's Not About the Boat

"On a clear morning in March 2003 we carefully hoisted the first Pacific 22 fiberglass hull from the mold. It hung there suspended in the air before us like a little jewel. The lapstrake hull lines were fair and smooth. The perfect reflections were everything we had worked so hard to attain. What I saw hanging in front of me were two stories coming back together. One had started in the early 1960s, when Chris-Craft was building this same hull design out of lapstrake plywood, and offering it as their Cavalier Division's Cutlass and Dory models. Overall, Chris-Craft's Cutlass production run lasted 13 years, into 1977, when the company introduced this time-proven, dory-type hullform as the fiberglass 22′ [6.7m] Tournament Fisherman model.

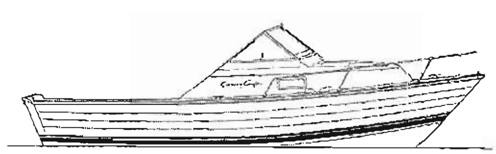
"The other story is a little more personal. Also suspended before me was something my father and I had talked about for many years: replicating our own '66 wooden Cutlass into a modern fiberglass hull, and then topping it off with a classic mahogany-and-teak deck and house, finished bright."

So begins Wayne Mooers' account of the origins of the Pacific 22 Series he is building, based on the original Chris-Craft lines, and of a special friendship between a father and son. "It was not so much about building a boat," he continued. "I came to realize it was more about holding onto something for us to dream about and always look forward to—the boat we were going to build someday. But more importantly, as the years went by, it was another good reason for my 85-year-old father and I to get together on the water, or in the shop, work with our family tools and keep that 'someday' sparkle in my father's eye."

Two years into their part-time boatbuilding project the elder Mooers passed away, but not before calling his son Wayne to his side and making him promise to complete their boat. The first completed Pacific 22 Cruiser is appropriately named *Some Day*, and represents a fine example of blending wood and composites into an attractive boat.

An old Chris-Craft sales brochure reads: "In 1964, Chris-Craft's Cavalier Division introduced the 22′ Cutlass and open-decked Dory models as modernized versions of classic surfboat designs. The Dory and Cutlass share a fast seaworthy hull, sweeping sheer, full lapstrake sides, and a convex bottom of tough, marine-grade plywood." The brochure shows the original blue-gray hull and white deck of a Cutlass—outfitted with riggers and fishing rods—and two guys and a gal aboard, rounding Fort Lauderdale's Light House Point, heading into the Atlantic.

Chris-Craft's R.C. Anderson drew the hull lines in 1964 at the company's Pompano Beach, Florida, facility. Over the next 13 years, 906 Cutlass, Dory, and Fisherman 22′ models were built in both wood and fiberglass. Also built, between 1966 and 1968, were 220 units of the 26′/7.9m



MARINERS' MUSEUM/NEWPORT NEWS, VIRGINIA

WAYNE MOOERS

W. SANKEY

***Top right**—Waterline profile drawing of the original Chris-Craft 22′ (6.7m) lapstrake-plywood Cutlass. The hullform is a dory derivative.*
***Far right**—Wayne Mooers (in light-blue shirt), a marine manufacturers' rep, collaborated with his father to create a new, composite rendition of the Cutlass. Next to him is Jason Neri, who worked on the fiberglass tooling, taken off a wooden plug Mooers built. In the mold is Oscar Loera, who, Mooers says, "made it all shine."*
***Right**—The first Pacific 22, christened* Some Day, *marries a composite hull with a wood deck, superstructure, and interior.*

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THRUSTERS | ANCHORING SYSTEMS | MARINE LIGHTING | MARINE WIPERS | CUSTOM EQUIPMENT version of the Cutlass, based on the same lines. Mooers believes that the eye-pleasing Cutlass hull—and the type of rough-water use for which it was originally intended—is still in demand today. Line drawings were obtained from the Mariners' Museum in Newport News, Virginia, which owns the Chris-Craft archive of boat plans *(to 1980; see PBB No. 80 for more on the museum's Chris-Craft collection—Ed.)*.

There are many things to admire about the original design, Mooers says, starting with the lapstrake construction, which generates strength from the overlapping strakes. The boat's sheerline rises from 28"/71cm of freeboard aft to 43"/109cm at the bow. Running into or with the seas, the Cutlass' "bow-up" design offers a safe, controllable, dry ride, while the low freeboard aft provides a comfortable deck height to fish or operate from.

Regarding the design and engineering of his new Pacific 22 Series, Mooers says, "We left the original hull lines and rounded transom alone. Why mess with something that is perfect? The Cutlass hull flares from the chine up, and this, combined with the 'relief' of the individual strakes, makes it an ideal shape to release from a fiberglass mold. But we did modify the bottom and running gear, to improve tracking and steering. Three bronze fins were designed into the bottom, and the propeller area was updated to enhance performance and minimize wake turbulence. Now, like a modern tournament ski-boat, the Pacific 22 will turn inside her own length."


WAYNE MOOERS

G. FITZSIMMONS

Right—*Ralph Mooers helped his son Wayne get their Pacific 22 project going, but didn't live to see its completion. He died in 2001 at age 88, three years before the launch of hull #1,* Some Day.
Below—*Three bronze "performance fins" were designed into the hull bottom, and the propeller area was updated so that the boat makes minimal wake and can turn in its own length.*

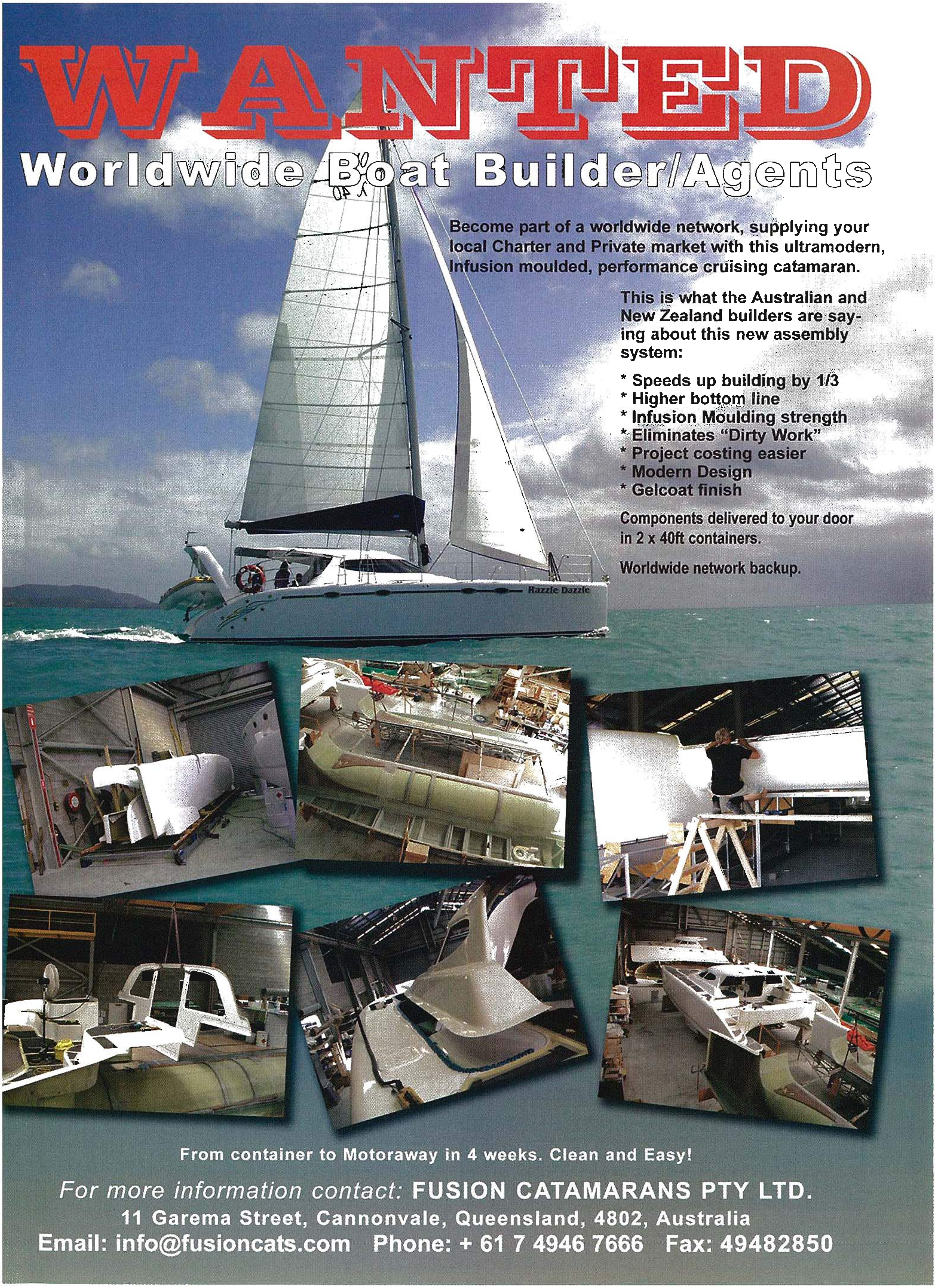
A one-piece, full-length composite stringer grid forms the backbone of the Pacific 22, and distributes the direct-drive, centerline-engine torque and weight. Stringers are bonded into the hand-laid hull while still in the mold. Then, for additional stiffening and for sound insulation and hull flotation, the area beneath the stringers and composite sole is filled with foam.

Mooers: "We knew from the beginning we did not want to build another white fiberglass boat. The plan was to create a very carefully done fiberglass hull, and then blend in the warmth and beauty of classic teak and mahogany for topsides and interior components. Not a boat for everybody, but a semicustom little yacht. A boat that, when you idle into the yacht club, you get a smile and a little respect!"

The original Cutlass design had a 20° wedge-shaped house that ended at about amidships at the helmsman's chest height. This afforded excellent stand-up-driving visibility, hold-on security, and operator mobility—but compromised accommodations below. In 1977, Chris-Craft's fiberglass Corsair Division introduced a Cutlass Cuddy model. That superstructure stretched farther into the foredeck, and had a high aluminum-framed windscreen. Mooers says he and his father thought the house too large for the original '64 hull lines; the company, they felt, was succumbing to market demand for more interior space.

Nevertheless, Mooers says that Corsair Cuddy model influenced his Pacific 22 Cruiser version; the difference, he says, is that his 22 "lowers the house and windscreen profile" so that it's more in keeping with the original 1960s hull lines. On *Some Day*, mahogany sheer clamps and deckbeams were secured to the fiberglass hull. The construction process from there up utilized traditional wooden boat construction techniques. For function and beauty, teak decks were installed in the forward and aft deck areas, with varnished-mahogany margin and covering boards framing the teak.

Some Day's house was cold-molded to a thickness of ⅝" (16mm) with diagonally opposed mahogany veneers set in epoxy and formed over a male mold. Lightweight and strong, the varnished house sides feature a final outside skin that starts with a book-matched joint on the house front's centerline. Then the mahogany grain pattern rolls around the forward radius of the house sides into a sweeping horizontal pattern aft. Similarly, the mahogany windscreen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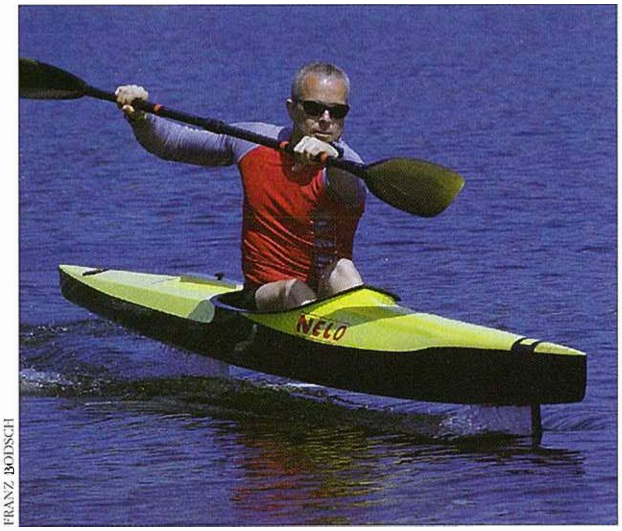
FRANZ BODSCH

Norwegian Einar Rasmussen has invented a hydrofoil kayak that is breaking paddle-power speed records. To get the boat up on its foils, a 4- to 8-second burst of effort is required, but Rasmussen hopes to reduce that time with further design improvements.

incorporates some interesting joinery details to produce the relaxed compound angles necessary to attain the desired strength and visual design elements.

Mooers describes the power plant: "The original '60s-era Cutlass came with an optional 327-cid engine that pushed the boats to a catalog-listed speed of 38 miles per hour [61 kmh]. The 1977-era Corsair boats came with a smaller 302/307-cid engine; it compromised the boat's get-up-and-go performance. Our Pacific 22 Cruiser, at 3,200 lbs [1,450 kg] total weight, is powered with a 350-cid Chevy-based engine turning a 13″ x 13″ [33cm x 33cm] four-blade prop. Speed exceeds 40 mph [64 kph]; it cruises very comfortably, quietly, and smoothly at 25 mph [40 kmh]. The boat is designed to accept either gasoline or diesel power."

Thus the two stories do come together. *Some Day* was launched in May 2004, three years to the day after Mooers' father died. Wayne Mooers made good on his promise. In August 2004, *Some Day* was formally introduced at the 32nd Annual Concours d'Elegance at Lake Tahoe. Mooers wrote, "We joined in the grand finale exit parade, following an Italian Riva and a San Juan 38 out of the show. The audience on the breakwater cheered, and the crews on the boats lining the channel waved and blew their horns as the varnished classic powerboats paraded out of the harbor. The 'someday' my father and I dreamed about was finally here."

Pacific Marine Manufacturing, 3368 McGraw Lane, Lafayette, CA 94549 USA, tel. 925-284-4855, on the Web at www.pacificmarinemfg.com. Sales: Sierra Boat Co. Inc. P.O. Box 69, Carnelian Bay, CA 96140 USA, tel. 530-546-2551, fax 530-546-7321.

Hydrofoil Kayak

If foils can reduce drag and resistance, improve fuel efficiency, and increase speed on multihulls, then why not on other lightweight craft? Even kayaks. In terms of the latter, the trick is providing the motive power to get the hull up out of the water. According to Einar Rasmussen, inventor of the Flyak, "a certain level of fitness" is required to achieve the sprint necessary to get the boat up on its foils—four to eight seconds' worth of sprint effort, he says. But he's working to reduce that effort.

Rasmussen's goal of making the Flyak the fastest human-powered boat is lofty, and apparently achievable. "We know that a top-level kayaker can reach a speed of 20 kmh [12.4 mph]. A four-man kayak (K4) has a maximum speed of about 25 kmh [15.5 mph]. A two-dimensional optimal wing profile has a lift/drag coefficient up to 120. A sailplane (glider) has a lift/drag coefficient up to 50; a World War II fighter plane, the Spitfire, has a lift/drag coefficient of about 16. If we—with the Flyak—reach a lift/drag coefficient higher than 13, it should be possible to beat the K4 on top speed."

Rasmussen's goal is to beat a rowing eight over 2,000m (6,561′), and he's pretty darn sure he can do it.

Flyak, on the Web at www.foilkayak.com.

Awlbrite Quik-Fil Clear

Before we go any further describing this new product from Awlgrip, what do you suppose the label would look like if the name on the can was spelled Awlbright Quick-Fill Clear? Would correct spelling look weird, or what?

Hey, that's marketing for you. Many people today

Awlgrip recently introduced Quik-Fil Clear, a fast-drying wood sealer for conventional atomized spray application. It can be overcoated with any of Awlgrip's finish paint and varnish systems.

don't know how to spell anyway.

Now, down to business. The parent company (Netherlands-based Akzo Nobel) claims Awlbrite Quik-Fil was developed in response to requests from builders and boatyards for a faster, more efficient wood sealer and build coat. Awlgrip's is said to be fast drying and possess excellent adhesion. Spray application (conventional atomized air) is recommended, though it is possible to brush on as well (in which case, reduce 25%–50% with T0001 or T0003). Quik-Fil is dry to the touch after 30 minutes and can be sanded after three hours at 75°F (25°C). It is mixed at a ratio of 1:1 base to converter, and has a pot life of three hours. Quick-Fil can be overcoated with any of Awlgrip's paint and varnish systems: Awlbrite Clear Gloss, Semi-gloss, Awlgrip, Awlcraft 2000 topcoat, Awlspar Classic varnish, and Awlspar High Solids varnish. Recommended wet-film thickness is 3 to 3½ mils (80 to 90 microns) per coat by either spray or brush; dry film thickness should be 1 to 1½ mils (30 to 40 microns).

Note that Quik-Fil Clear is made specifically for the trade (as distinct from the consumer market); applicators should exercise great care in its application—meaning, be sure to suit up for this stuff. The best personal protective gear is in order, particularly if the product will be applied in the close quarters of accommodation spaces down below.

Awlgrip, 2270 Morris Ave., Union, NJ 07083 USA, tel. 908–686–1300, fax 908–686–8545, on the Web at www.awlgrip.com.

German-Made Fuel Cell for Yachts

Slowly but surely, alternative energy sources are finding their way into the marine industry. The German firm Smart Fuel Cell AG develops, builds, and markets direct methanol fuel cells, or DMFC, as finished products. Headed by Manfred Stefener, SFC started, appropriately enough, at the turn of the 21st century. One year later, pilot production of its first fuel-cell model, the A25, was under way for use in various applications: transportation, environmental technology, camping, and water sports. In January 2002, the company exhibited the world's first prototype of a miniaturized DMFC at the Hydrogen Fair in Hamburg. In 2003, the A25 was approved by the German Technical Inspection Authority's product service, which meant this portable system was meeting the highest safety requirements of the day. In 2004, the SFC A50 was exhibited at the Caravan Show in Düsseldorf as a viable alternative power supply for RVs.

Specially tailored for the energy requirements on sailboats, the new marine fuel cell MFC 100 is marketed by Max Power, a subsidiary of the Navimo Group, which specializes in bow thrusters. At Amsterdam's Marine Equipment Trade Show in November 2004, this fuel-cell model was awarded one of the coveted DAME prizes for innovative products. As a battery charger, it silently and cleanly feeds up to 100 amp-hours of charge into onboard batteries, every day. Average fuel consumption is around 1.3 liters (1.4 quarts) of methanol per kWh. The unit's

Above—*The German company Smart Fuel Cell AG developed the A25, the world's first prototype of a miniaturized direct methanol fuel cell, or DMFC, exhibited at the 2001 Hydrogen Fair in Hamburg. Two years later the company introduced the commercially viable SFC A50, shown.*
Below—*The MFC 100, tailored for energy requirements on sailboats, will feed 100 amp-hours into a battery bank every 24 hours. Average fuel consumption is around 1.3 liters (1.4 quarts) of methanol per kWh. It's marketed by Max Power in France, and won a DAME prize for innovation at METS 2004, in Amsterdam.*

housing is corrosion-resistant aluminum, and all fasteners are stainless steel. Charging current reaches 4 amps at 12 volts. At 50 watts of power, the MFC 100 is capable of 1,200 watt-hours per day, given optimum conditions; also, the unit can operate at up to 30° of heel. Compact (15″ x 6″ x 10″/38cm x 15cm x 25cm) and light (15 lbs/6.8 kg), it is suitable for even the smallest cruising boats. Noise emission is about 47 dBA.

Basic fuel-cell technology was described in detail in PBB No. 69 (page 38). In brief, a fuel cell converts

PROFESSIONAL BOATBUILDER MAGAZINE

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D) Free distribution by mail, carrier, or other means: sample, complimentary, and other free copies: 4,319
E) Total distribution: 30,719
F) Copies not distributed:
1) Office use, left over, unaccounted, spoiled after printing and returns from news agents: 901
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Carl Cramer, Publisher
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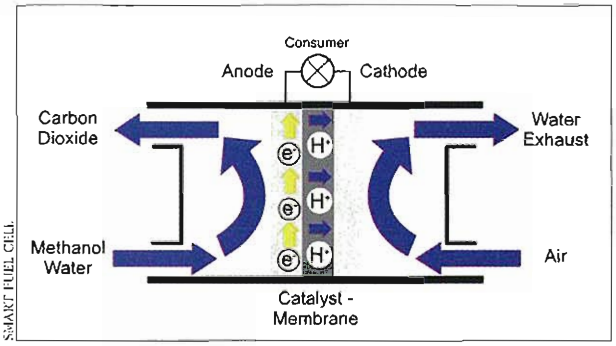


SMART FUEL CELL

On the anode side of a direct methanol fuel cell, a methanol-water mixture is supplied to the cell by the internal fluid-management system. The cathode side is supplied with air, and connected to the anode through a conventional electrical circuit. Methanol, in contact with the platinum catalyst, is converted into carbon dioxide (waste), protons, and electrons. The electrons circulate from the anode side to the cathode via the electrical connection, while protons pass through the membrane that divides the cell. On the cathode side, protons, electrons, and oxygen react to form pure water (for the record: $2\ CH_3OH + 3\ O_2 \rightarrow 4\ H_2O + 2\ CO_2$*). Due to heating of the cell in operation, the water is emitted as water vapor, the other by-product being a small amount of carbon dioxide; by way of comparison, the overall amount of these by-products is equivalent to the respiratory exhalation of a small child while playing.*

—J.-Y.P.

chemical energy directly into electricity. The technology has long been found in the aerospace industry; for more down-to-earth applications, however, the high operating temperatures, pressurized hydrogen, and cost of this equipment presented difficult technical and economic challenges. SFC's product line is based on DMFC technology (see accompanying diagram), which offers reliability, security, and efficiency.

Note that, ordinarily, hydrogen is stored in heavy, bulky metal-hydride canisters that are expensive to manufacture and refill. The contents last only a short time; also, due to potential hazards, transporting hydrogen is subject to very strict regulations. For those reasons, SFC engineers chose methanol, because it can be distributed in safe and easy-to-handle fuel cans. The fuel cartridges are shippable anywhere via air freight, and changed in seconds, allowing for near-continuous operation. They are equipped with a safety valve that prevents spillage and protects the end-user from direct contact with the liquid. Since it is a naturally occurring compound, methanol is an environmentally friendly product: water soluble and biodegradable, with no unpleasant fumes.

Price in France for an MFC 100 is about €5,500.

Smart Fuel Cell AG, Eugen Saenger Ring 4, 85649

Brunnthal Nord, Germany, tel. +49 89 607 454 60, on the Web at www.smartfuelcell.de. Max Power, 10 Allee F. Coli, Mandelieu Technology Center, 06210 Cannes-Mandelieu, France, tel. +33 4 92 19 60 60, on the Web at www.max-power.com.

—Jean-Yves Poirier

High-Performance Yacht Design Conference

New Zealand is establishing itself internationally not only as a builder of yachts, but as a fountainhead of new ideas and technologies. In addition to mounting its annual Yacht Vision symposium, this small South Pacific country will host, next February 14–16, the second annual High-Performance Yacht Design conference. The first conference, held in December 2002 in Auckland, drew 140 delegates from 14 countries.

The upcoming conference is timed so that attendees can get a look at the arriving Volvo Ocean Race fleet. (The new 70'/21.3m boats, fitted with canting keels, are very fast.) As for the purpose of the conference, it's "to showcase the latest developments in yacht research from around the globe." Papers are being solicited from naval architects, engineers, designers, and researchers addressing "the current state of high-performance yacht and power craft technology."

Areas of interest include:

- performance prediction and measurement
- wind-tunnel and towing-tank technology
- regulations and rating rules
- computational methods
- materials and construction
- hull and appendage design.

The conference's "international technical review panel" boasts numerous PhDs from New Zealand and elsewhere, as well as High Modulus (Auckland) managing director Richard Downs-Honey, sailing science expert Jim Teeters of the United States, the Wolfson Unit's Ian Campbell of England, and *America*'s Cup technical specialist Giovanni Belgrano, currently with Emirates Team New Zealand.

This panel has already selected the first group of abstracts. To get your creative and intellectual powers flowing, here are the titles of a few papers they've accepted: "High-Performance Large-Yacht Construction Using Product Data Models," by Rolf Oetters of Albacore Research Ltd, and Chris Barry of Davis & Company Ltd; "Practical Aspects of Design, Construction, and Analysis of Canting Keels," by Liz Tier, Merfyn Owen, and Tim Sadler of Owen Clarke Design; and "A CFD Validation Test Case—Wind Tunnel Tests of a Winglet Keel," by Sofia Werner and Lars Larsen of Chalmers University of Technology, and Björn Regnström of Flowtech International AB.

For information on the submission of late abstracts, write technical@hpyd.org.nz. And for more information on the conference itself, go to www.hpyd.org.nz. PBB

Mining the Archives

Absent the publication of a long-awaited technical text devoted to small craft, the Society of Naval Architects and Marine Engineers issues a compact disc of previously published papers.

by Dudley Dawson

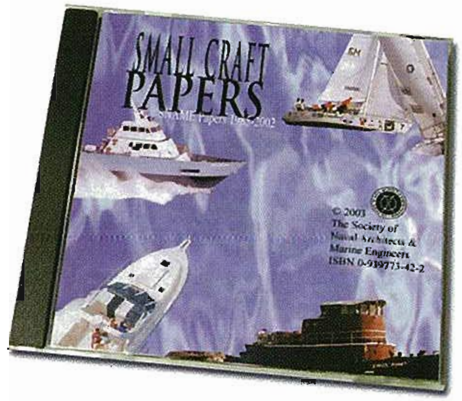
When I joined SNAME in 1968 as a student member, there was talk of the Jersey City, New Jersey–based Society publishing a small craft companion volume to its design bible, *Principles of Naval Architecture*, better known as the "PNA."

When I was working for Jack Hargrave in 1978, designing yachts and small commercial craft, there was talk of the Society publishing a small craft companion to the PNA.

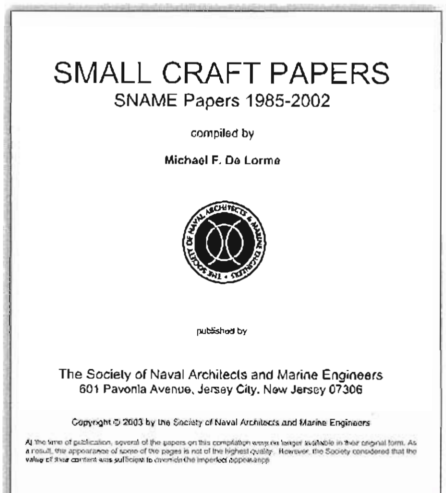
When I joined Hatteras Yachts in 1988, there was talk of the Society publishing a small craft companion to the PNA.

And somewhere around 1998, in a Society Section meeting in Miami, where it was announced that the Society was planning to publish a small craft companion to the PNA, Lester Rosenblatt, a former Society president, stood in the audience and addressed the book project's latest editor: "Your enthusiasm is admirable. But what makes you think you'll succeed where everyone else has failed for the last 30 years?"

Rosenblatt's question was embarrassing, even if to the point. That particular iteration of the SNAME book project foundered a little over a year later, sunk as it was by a conundrum peculiar to the small craft industry. Forgive me for generalizing, but those who have the practical knowledge and experience to write such a volume—practicing designers—can't afford the time; and those who do have the time and resources—bureaucrats and academicians—don't have the practical knowledge and experience. The problem has no easy solution, and thus the result, time and again, is a book that never materializes.



Only a few months later, the SNAME book project's most recent demise happened to be the topic of conversation among a clutch of naval architects—Dean Schleicher, Lou Codega, and me, to name three—as we walked from the Fort Lauderdale Convention Center to Joe's Bel-Air Diner for lunch during that year's IBEX show. (The annual International BoatBuilders' Exhibition & Conference is now held in Miami Beach. And the landmark diner is gone.) Dean's wife, Christine, a Webb Institute–educated naval architect, had been the book's designated editor and the target of Rosenblatt's skewer. She'd actually brought the project closer to fruition than any of her similarly



SMALL CRAFT PAPERS
SNAME Papers 1985-2002

compiled by

Michael F. De Lorme

published by

The Society of Naval Architects and Marine Engineers
601 Pavonia Avenue, Jersey City, New Jersey 07306

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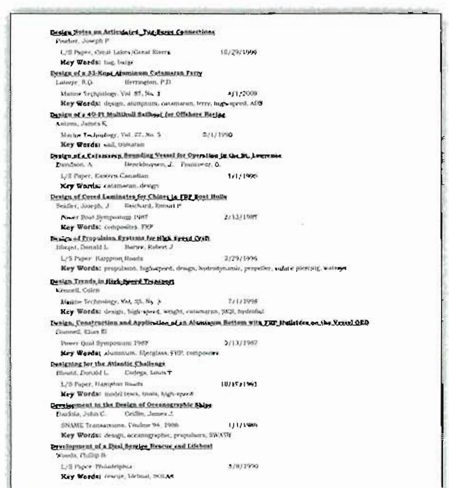
At the time of publication, several of the papers on this compilation were no longer available in their original form. As a result, the appearance of some of the pages is not of the highest quality. However, the Society considered that the value of their content was sufficient to override the imperfect appearance.

Keywords

12-meter
ABS
acoustic
aerodynamic
aluminum
Americans with Disabilities Act
ADA
America's cup
anti-roll tank
appendages
azimuth
barge
bollard pull
boundary layer
buoy tender
capsize
carbon fiber
catamaran
cavitation
computational fluid dynamics
CFD
coefficients
collision
composite
construction
contrarotate
corrosion
cycloidal
damage
design
diesel
ducted
dynamic
electric
fatigue
feathering
ferry
fiberglass
FRP
finite element
fire
fishing
flap
Flettner
head sea
heave
high-speed
hull
human factor
hydrodynamic
IMO
intact stability
keel
kevlar
laminate
life boat
lobster
machinery
male mold
Marine Spill Response Corporation
mast
mechanical properties
model tests
motion
natural frequency
noise
oceanographic
oil
paddle wheel
paravane
passenger
patrol
pitch
planning
plating
power
propeller
propulsion
propulsor
rescue
resistance
roll
rudder
sail
sailing school
sea trials
seakeeping
SES
shaft
skin friction
small craft
solar
SOLAS
spar
stability
sportfish
steel
stern
strength
structure
supply
surface piercing
SWATH
tank
titanium
transom stern
trawler
trimaran
tug
tunnel
turning
U.S. Coast Guard
vibration
wake
waterjet
wave
wedge
weight
weld
winglet
work
yacht



Design Notes on Articulated Tug-Barge Connections
Design of a 33-Knot Aluminum Catamaran Ferry
Design of a 40-Ft Multihull Sailboat for Offshore Racing
Design of a Catamaran Sounding Vessel for Operation in the St. Lawrence
Design of Cored Laminates for Chines in FRP Boat Hulls
Design of Propulsion Systems for High Speed Craft
Design Trends in High-Speed Transport
Design, Construction and Application of an Aluminum Bottom with FRP Insulation on the Vessel ORD
Designing for the Atlantic Challenge
Development in the Design of Oceanographic Ships
Development of a Dual Service Rescue and Lifeboat

Top—When you order SNAME's compilation of small craft papers, the CD comes packaged in a jewel case. ***Left****—The title page for the collection, printed out.* ***Middle****—Keywords are provided, for searches by subject area.* ***Right****—The searchable index has active links that quickly bring up a full copy of the selected paper, for viewing on-screen or for printing.*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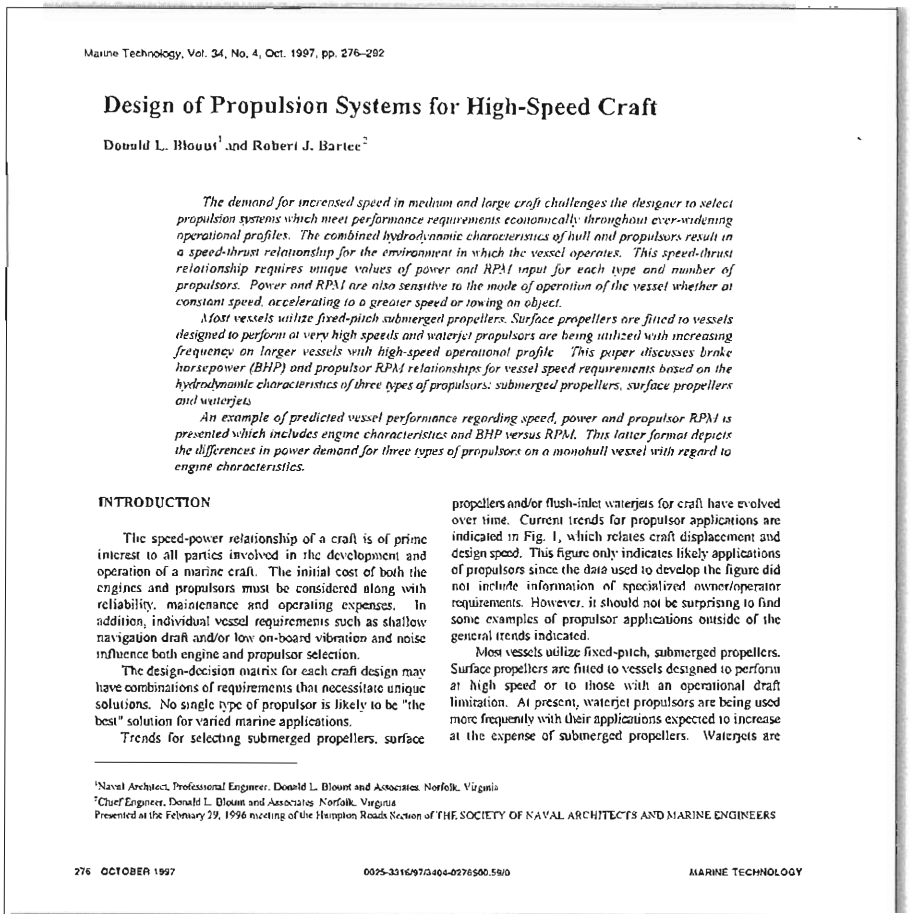
designated predecessors; practical obstacles, however, had once again proven insurmountable.

As our group neared Joe's, someone remarked that if we couldn't have the book, then the next best thing would be a compilation of the references that we all seem to use on a regular basis. You know the ones: many are out of print and all are difficult to find—the handful of useful pages from books by Skene, Levi, Fox, DuCane, Chapelle, and Lord; limited-distribution research papers by Blount, Koelbel, and others; and most of all, arcane SNAME papers, little jewels that were published as local Section papers with a print run of 50 copies or so.

Well, Codega was apparently listening, because here's the good news—no, *excellent* news—and it comes from SNAME, where Codega heads the Power/Planing Craft Panel under Alan Gilbert's chairmanship of the Small Craft Committee. That committee's members selected more than 300 small craft papers from the years 1985 to 2002 and, through the efforts of Michael De Lorme of SNAME, compiled them onto a single CD, *Small Craft Papers*, sorted in such a way that each fell into one or more "subject" categories.

The papers were scanned and stored in PDF format so they can be read on a computer screen and printed out as desired. The CD is searchable, at least to a limited extent, by various keywords. Papers were selected not just from the Society's annual *Transactions*, but also from research reports, regional symposia, and local Section presentations, making it likely that there are useful papers you didn't know existed and had no other way of finding.

Since the CD does not list hardware or software requirements, I tried the disc—as a test—on several personal computers around my office, including one long since retired from active service. The CD functioned as well on the oldest machine as on the newer, more powerful ones. The only requirement, it seemed, was a CD drive. I searched for papers I considered important or significant, and found them to be there without exception, provided they fell within the specified years. I searched subject categories of special interest, and again found the milestone papers, along with many that were new to me. In short, my initial foray into this product was a tremendously satisfying experience from a professional standpoint.



Marine Technology, Vol. 34, No. 4, Oct. 1997, pp. 276–292

Design of Propulsion Systems for High-Speed Craft

Donald L. Blount[1] and Robert J. Bartee[2]

The demand for increased speed in medium and large craft challenges the designer to select propulsion systems which meet performance requirements economically throughout ever-widening operational profiles. The combined hydrodynamic characteristics of hull and propulsors result in a speed-thrust relationship for the environment in which the vessel operates. This speed-thrust relationship requires unique values of power and RPM input for each type and number of propulsors. Power and RPM are also sensitive to the mode of operation of the vessel whether at constant speed, accelerating to a greater speed or towing an object.

Most vessels utilize fixed-pitch submerged propellers. Surface propellers are fitted to vessels designed to perform at very high speeds and waterjet propulsors are being utilized with increasing frequency on larger vessels with high-speed operational profile. This paper discusses brake horsepower (BHP) and propulsor RPM relationships for vessel speed requirements based on the hydrodynamic characteristics of three types of propulsors: submerged propellers, surface propellers and waterjets.

An example of predicted vessel performance regarding speed, power and propulsor RPM is presented which includes engine characteristics and BHP versus RPM. This latter format depicts the differences in power demand for three types of propulsors on a monohull vessel with regard to engine characteristics.

INTRODUCTION

The speed-power relationship of a craft is of prime interest to all parties involved in the development and operation of a marine craft. The initial cost of both the engines and propulsors must be considered along with reliability, maintenance and operating expenses. In addition, individual vessel requirements such as shallow navigation draft and/or low on-board vibration and noise influence both engine and propulsor selection.

The design-decision matrix for each craft design may have combinations of requirements that necessitate unique solutions. No single type of propulsor is likely to be "the best" solution for varied marine applications.

Trends for selecting submerged propellers, surface propellers and/or flush-inlet waterjets for craft have evolved over time. Current trends for propulsor applications are indicated in Fig. 1, which relates craft displacement and design speed. This figure only indicates likely applications of propulsors since the data used to develop the figure did not include information of specialized owner/operator requirements. However, it should not be surprising to find some examples of propulsor applications outside of the general trends indicated.

Most vessels utilize fixed-pitch, submerged propellers. Surface propellers are fitted to vessels designed to perform at high speed or to those with an operational draft limitation. At present, waterjet propulsors are being used more frequently with their applications expected to increase at the expense of submerged propellers. Waterjets are

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[2]Chief Engineer, Donald L. Blount and Associates, Norfolk, Virginia

Presented at the February 29, 1996 meeting of the Hampton Roads Section of THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

276 OCTOBER 1997 0025-3316/97/3404-0276$00.59/0 MARINE TECHNOLOGY

Here we have, as a sample selection, the first page of a paper by D. Blount and R. Bartee. The format is standard for a technical monograph. Among other readily identifiable features: an italicized abstract, or synopsis, summarizing the paper in shortest form; footnotes identifying the authors, and indicating when and where their paper was originally presented.

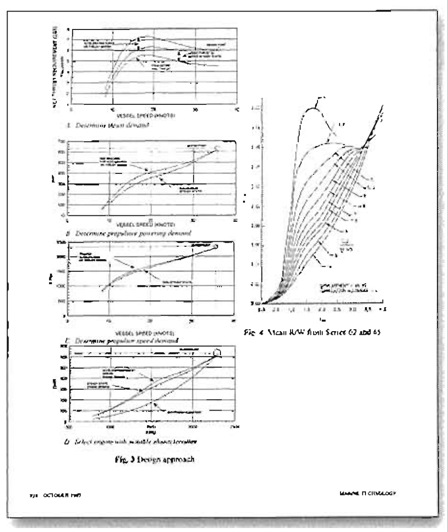
The CD is a terrific first step and a very welcome addition to the library of small craft literature, so I don't want to make too much of its shortcomings. We can dream, though, can't we? In the best of worlds, the body of each paper's text would be searchable; not just its title, author, subject, and date. In addition, I'd love to see active links on the references cited at the end of many of the papers, and on keywords within the text.

Moreover, it would be great to see a second CD, this one going from 1985 *backward*, to earlier years. There are numerous older SNAME small craft papers that have never been supplanted by later editions; the ocean hasn't changed much in the past few millennia, so most of the science remains valid. Alan Gilbert and Lou Codega indicated to me that just such a complementary CD was planned, and that their understanding of SNAME's original intent was for the proceeds from the first CD to help fund development of the second. That seems a fair and logical idea, but unfortunately, SNAME's management remembers the deal a little differently. I spoke directly to Phil Kimball, SNAME's executive director, about the situation. He indicated that any net

proceeds from sales of the *Small Craft Papers* CD—i.e., any money left over after paying the costs of developing, manufacturing, and selling the first CD—would be earmarked for "future development." Of what? Not a follow-on CD, but of (you guessed it) a small craft companion volume to the PNA. When I served as a Section officer for SNAME, projects were funded based on their technical merit and on their potential benefit to the industry, not on their ability to be self-funding or profitable.

As I considered what a wonderful reference tool this SNAME CD is, I couldn't help but wish that there were more such works, from outside the Society. SNAME, after all, does not have a monopoly on small craft references. One of the best sources of more recent vintage, in my opinion, is the magazine you hold in your hands at this moment and the dozens of issues that preceded it. Indeed, a few years ago, there was a short-lived CD compilation of back issues of *Professional BoatBuilder*, which was withdrawn from market due to certain copyright disputes at the time. In its place is a search engine on *Professional BoatBuilder*'s Web site, www.proboat.com. But it's not the same thing.

I for one hope the legal dispute can be resolved, because in some ways, *Professional BoatBuilder* is responsible for a decline in the number of small craft papers published by SNAME. Many authors, myself included, prefer the looser format and broader audience this magazine brings them. In addition, the success of the IBEX seminar program seems to have contributed to lagging interest in the heretofore excellent Power Craft Symposia that were a long-



Graphs from the Blount/Bartee paper. Recent papers that were created electronically have excellent graphics, whereas older papers had their text and illustrations scanned—not redrawn—for the CD, and thus their image quality varies from good to fair. Many of the SNAME papers, including this one, have extensive bibliographies. Although there are no active links, a substantial portion of those referenced papers is also on this CD.

standing staple of SNAME's Southeast Section.

To encourage candid and open presentations and discussion, IBEX sessions, unlike SNAME presentations, are not recorded or published, and thus there is no record of the proceedings—other than speaker handouts and occasional subsequent articles based on selected sessions. There are people in the industry who would prefer a more formal set of published material upon completion of the IBEX conferences, especially those who are unable to attend in person. Others value the open exchanges that might not occur were comments being recorded. It's another of those questions for which I don't have the answer.

Inasmuch as I've raised the matter of SNAME papers versus *Professsional BoatBuilder* articles, I must mention a key difference between the two. SNAME papers are peer-reviewed by a "papers committee" before they reach print or become oral presentation; both written and oral discussions of papers presented at the Society's annual meeting are appended to the papers once they're published in the Society's *Transactions*. It is a difference of which *Professional BoatBuilder*'s editor, Paul Lazarus, is well aware. To help assure validity and fairness in the magazine, he relies on his technical and contributing editors and others when he has any doubt about an article. Nevertheless, the vitality of the magazine's "Letters, Etc." pages is proof that no matter how careful you are, there will always be honest disagreements.

In summary, the SNAME *Small Craft Papers* CD is a must-buy. At $100 ($75 for SNAME members, $35 for SNAME student members) for a compilation of more than 300 small-craft reference papers, it's a no-brainer purchase. Certainly every marine design office and small craft builder should have a copy. I'll go further than that: every designer, surveyor, shop foreman, and repair yard supervisor should have a personal copy for ready reference. Buy the CD from SNAME (tel. 800–798–2188, fax 201–798–4975, or on the Web at www.sname.org), and if you find it useful, make a point of telling the Society you want more. Getting both the PNA companion book and a second CD would be nice, but if a choice must be made, history indicates a second CD is a more realistic goal. An e-mail with your thoughts and suggestions can be sent to SNAME executive director Phil Kimball (pkimball@sname.org); a copy to *Professional BoatBuilder* (paul.lazarus@proboat.com) would be welcome. PBB

About the Author: Naval architect Dudley Dawson, PE, is president of Dawson Marine Group Inc., technical editor of *Yachting* magazine, and a contributing editor of *Professional BoatBuilder*.

J Is for Johnstone

Having failed to persuade one American conglomerate to manufacture the performance keelboat they had in mind, brothers Rod and Bob Johnstone went into business for themselves—as a company called J Boats. It's become one of the great international success stories in modern production boatbuilding.

by Dan Spurr

You can count them on your fingers, the number of large production sailboat builders still around since the 1970s. Let's see: There's Catalina Yachts (Woodland Hills, California), Hunter Marine (Alachua, Florida), and...mmm...how about Newport, Rhode Island–based J Boats? Okay, J Boats isn't *that* big, but since the first J/24 one-design keelboat splashed in 1976, the company has sold *12,000* boats, ranging in length from the J/22 (22.5'/6.86m) to the new carbon/epoxy J/65 (64.5'/19.66m) currently under construction at Pearson Composites in Warren, Rhode Island.

It's been a team effort, to be sure, and here, "team" means family: brothers Rod and Bob Johnstone, Rod's sons Jeff and Alan, and their cousin Jim Johnstone. Bob's sons Stuart and Drake (who, with Jeff, also founded J World Sailing School) have matriculated through the office and are still on the board. A third son, Peter, founded Johnstone One-Design, which in 1989 introduced the first production boat with an asymmetric spinnaker and retractable sprit. More recently, Peter founded the Gunboat line of performance cruising catamarans, being built in South Africa. Sailing runs deep with this clan.

Luck? There's usually a little in every success story. But this is more a story about identifying (and in some cases, creating) a market, designing a product for it, and then finding creative ways to sell it. In brief, what the Johnstones do is design and build boats they themselves would like to sail (forget the handicap rules; just make it fun), and develop a dealer network that can sell them.

The Idea

Rod Johnstone always wanted to design boats, and his roundabout road to success began in 1961 when he enrolled in the small-craft program offered by what was then called the Westlawn School of Yacht Design. At the time, Rod was a schoolteacher in Millbrook, New York. To get closer to boats, in 1962 he moved to Stonington, Connecticut, to run the brokerage at Dodson Boatyard, before moving on to submarine builder Electric Boat Co., in nearby Groton, where he planned the enginerooms in 637-class nuclear subs. After five years at Electric Boat, he quit and started a sailing school on the Connecticut River.

In 1970 the boating newspaper *Soundings* was seven years old, based in Essex, on the river, in the same general vicinity. Rod met with *Soundings* editor Keith Taylor and owner Jack Turner, and joined the paper as an ad salesman.

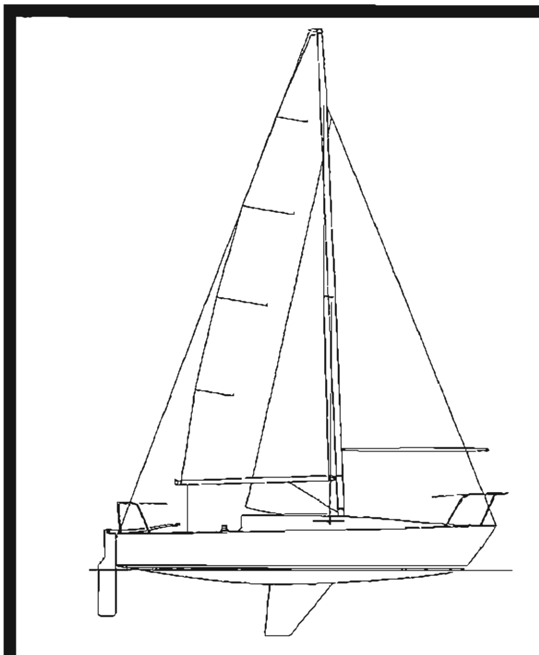
Rod says of Turner, who passed away last spring, "He knew when I went to work for him that I wanted to design boats. So every opportunity that came up—like starting a design-review section—I got to do it. I basically justified my existence there by selling advertising. I covered all the sailboat racing events because I was the only one on the staff who knew anything about sailboat racing. I worked for him for six-and-a-half years."

During those years, Rod's brother Bob was working for Quaker Oats as head of market strategy and analysis. One of Bob's responsibilities was to evaluate products the company might want to acquire. Given his own long-standing interest in sailing, Bob took a close look at sailboats. He divided that market into three groups: low cost, middle ground, and high end. The low-cost segment, he says, succeeds when you've got sufficient distribution through mass merchandisers, and when there is a sufficient number of potential customers who make purchase decisions based on price. The problem is, with only 6% of the United States populace involved in the sport of sailing, there are no *affordable* mass media with which to reach the remaining 94%.

Then there's the middle ground. According to Bob, successfully selling to that segment depends on styling and new models every year, which, in turn, require volume sales to cover tooling costs. The approach he eventually settled on—Bob characterizes it as a high-end/best-brand approach—made sense to him because aficionados of any sport gravitate toward the more expensive products, whether those products be sailboats, skis, or tennis rackets. And, he could reach the aficionados through magazines like *SAIL* and *One-Design & Offshore*

J BOATS (BOTH)

Left—*The J/24 is a hugely successful one-design keelboat class, numbering more than 5,200 worldwide. Rod Johnstone designed and built the prototype in his Connecticut garage, launching her in 1976.*
Opposite page—*Left to right, Jim, Bob, Rod, Jeff, and Alan, all Johnstones. Though other family members have worked for the Newport, Rhode Island–based company, and serve on the board of directors, these five are the current active management team.*



J/24

LOA . . . . 24.0′ (7.32m)
LWL . . . . 20.0′ (6.10m)
Beam . . . . 8.9′ (2.71m)
Draft . . . . 4.0′ (1.22m)
Displ. . . . . 3,100 lbs (1,406 kg)
100% SA . . . . 261 sq ft (24.25m^2)
Engine . . . . Outboard 4 hp

Yachtsman (now *Sailing World*).

"It also seems," he says, "that if you've got a top-of-the-line product, you're less subject to swings in the market; your customers are more committed to a sailing lifestyle. The last thing they're going to give up is their boat. They'll give up the house first, or cut back on something else. It seemed to be a better long-term strategy to be on that side of the business. I put together a recommended recreational products group for Quaker, which included Hobie Cat, Ericson, North Sails, Laser, and Fiberglas Evercoat. What I was thinking of was a franchise/retail operation with all these major brands tied in to it. I was thinking about the sport and how one might develop a strategy to market it. But I couldn't persuade them to do it."

So Bob left Quaker Oats and became vice-president of sales and marketing at AMF, a recreational-products conglomerate then building a few brands of small sailboats, most notably the Sunfish. Market research suggested a larger boat for Sunfish sailors to move up to, between 20′ and 30′ (6.1m and 9.1m). "They had the Sunfish," Bob says, "but most markets are cold water; even in Long Island Sound you freeze to death after an hour in a swimsuit. You've got all these people into sailing, but what are they going to get into next—a slug like an O'Day 25? There was nothing out there. Maybe the Bill Lee–designed Santa Cruz 27, but its sales were limited because there was no professional dealer network associated with it. So I went to AMF and told them this market was wide open to sell into, with a performance sailboat between 20 and 30 feet."

In making his pitch, Bob likened sailing to skiing. Jean-Claude Killy was then the world's best ski racer, and at every opportunity, he showed off his skis with the Rossignol logo, the company sponsoring him. No one was doing this in sailing, Bob told management. "Cal and Ericson would do it for a while, and win races, but then the dealers would get hold of the designs and load them down with a lot of cruising amenities. And the next thing you know, the boats wouldn't perform."

Bob supported his argument with market research showing that half the people interested in buying a boat between 20′ and 30′ would buy the hypothetical AMF 7.2 or the Farr-designed Quarter Ton champ *45 Degrees South*, rather than the popular Catalina 22, Paceship 23, or other trailer-sailers of the day. The picture he presented of the AMF 7.2 actually was brother Rod's garage-built 24-footer (7.3m) called *Ragtime*.

In spite of the strong indicators of success, AMF wouldn't bite. *Ragtime*, like Canadian builder George Hinterhoeller's similarly sized Shark, was hot right out of the box. But AMF declined on two counts: Rod wasn't an established designer; and it would be a conflict of interest. Bob and management went back and forth over other designers, and he suggested a sail-off to see which boat AMF should back. Ted Hood and Gary Mull designs were contemplated. But, in the end, Bob concluded, "They just didn't

J BOATS

Jeff Johnstone says that one key to a model's long-term success is the creation of one-design owners' associations, which manage race events and foster camaraderie. He spends about a third of his time working with the various owner groups, much of it involving rules. Large numbers of J owners participate in regattas such as Key West and Block Island Race Weeks.

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(Part 1)

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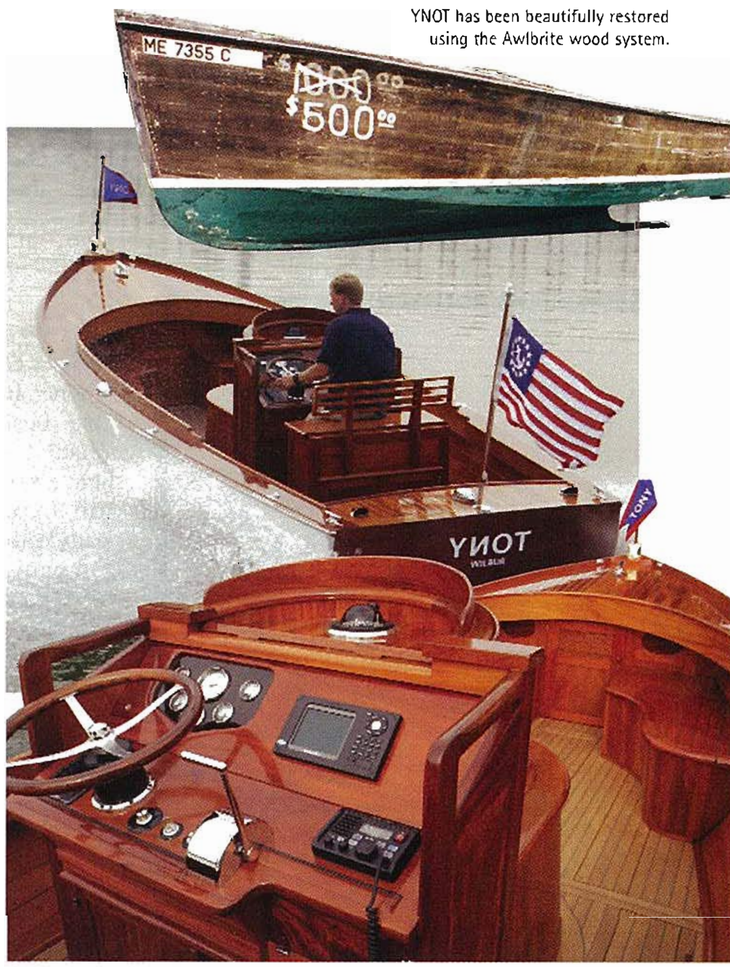

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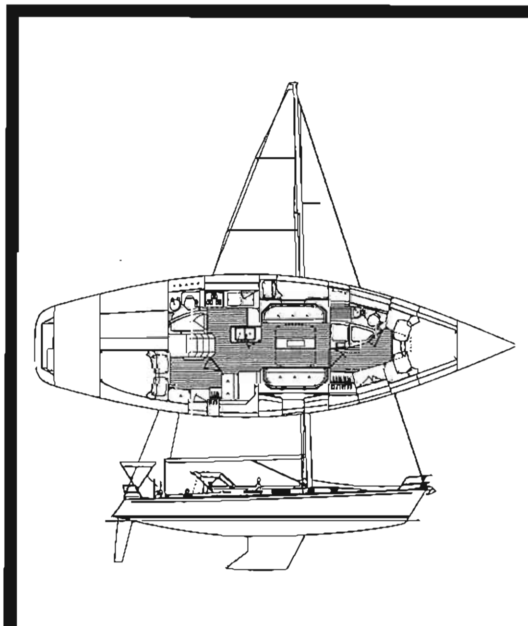
want to do new products." Frustrated, Bob resigned and threw in with Rod to form J Boats in February of 1977. Rod contributed the design; Bob contributed the sum of $20,000, along with assuming the full-time presidency until the business could be considered established. Though Bob was and still is the marketing ace, Rod could claim crucial connections for the brothers' startup—namely, to *Soundings* owner Jack Turner and to Everett Pearson, president of Tillotson-Pearson Incorporated in Warren, Rhode Island, whom Rod had been calling on since 1971 to sell display advertising in *Soundings*. *[Tillotson-Pearson Incorporated later became TPI, which recently reorganized to create Pearson Composites, the principal manufacturer of J Boats' product line—Ed.]*

Rod: "When I finally got around to launching *Ragtime*, Jack Turner was there at the launching. He supported me when I was building the boat, giving me time off. And in the fall of '76, when I decided to start the company, he gave me three full pages of advertising in consecutive issues of *Soundings*."

While Turner was the catalyst, Everett Pearson's enthusiasm for the project and his well-honed composite boatbuilding skills are what made it happen. After inspecting Rod's prototype, Pearson knew exactly how he wanted to build the boat, and was able to put it in production quickly. Pearson determined that he could produce a high-performance sailboat at a reasonable price, using a modern laminate schedule consisting of end-grain balsa core in the hull and deck, protected by a vinyl ester skincoat.

The combination of publicity in *Soundings*, innovative boatbuilding at Tillotson-Pearson, and the remarkable racing record amassed by *Ragtime* the previous summer served to jump-start the fledgling company, and generated the first batch of orders for the J/24—most of them sight unseen.

Thirty years and more than 5,200 units later, the J/24 remains one of the boating world's all-time great success stories.



J/46

LOA . . . . 46.0' (14.02m)
LWL . . . . 40.5' (12.34m)
Beam . . . . 13.8' (4.21m)
Draft . . . . 6.2' (1.89m)
Displ. . . . . 4,400 lbs (10,432 kg)
100% SA . . . . . . 1,021 sq ft (95m^2)
Engine . . . . 76 hp

You've Still Got to Sell 'Em

What Bob brought to the table, besides $20,000, was: consumer-product management expertise and production experience from 17 years with the Quaker Oats Company; familiarity with the dynamics of boat-dealer networks, courtesy of AMF; and his contacts with the top sailors in the country as an officer of the U.S. Olympic Committee. He knew which dealers around the country were good, and which were not so good. Plus, he knew who the best sailors were, and he targeted them, many of whom were (and still are) sailmakers. His first ad was a letter to them, saying, in effect: Do yourself and your customers a favor and get one of these boats. And by the way, come to Key West this January for the first one-design race regatta for the J/24.

Bob scheduled the J/24 racing to immediately follow the Fort Lauderdale–Key West Race, a major SORC event featuring large yachts, and persuaded the sponsors to "leave the tent up." The boating press gave the Johnstones' comparatively smaller affair good coverage, and the J/24 was on its way. That happens also to have been the genesis of Key West Race Week. What it meant, in basic terms, was this: For 10 grand a guy could buy a boat, put a crew together, and get a taste of big-keelboat racing.

Meanwhile, across the Atlantic, the Johnstones licensed a builder in England. At the 1978 London Boat Show, 32 J/24s were sold. Marine journalist Jack Knights described the boat, in print, as "a Laser with a lid"—it was a catchy phrase that signaled acceptance, making the J/24 cool.

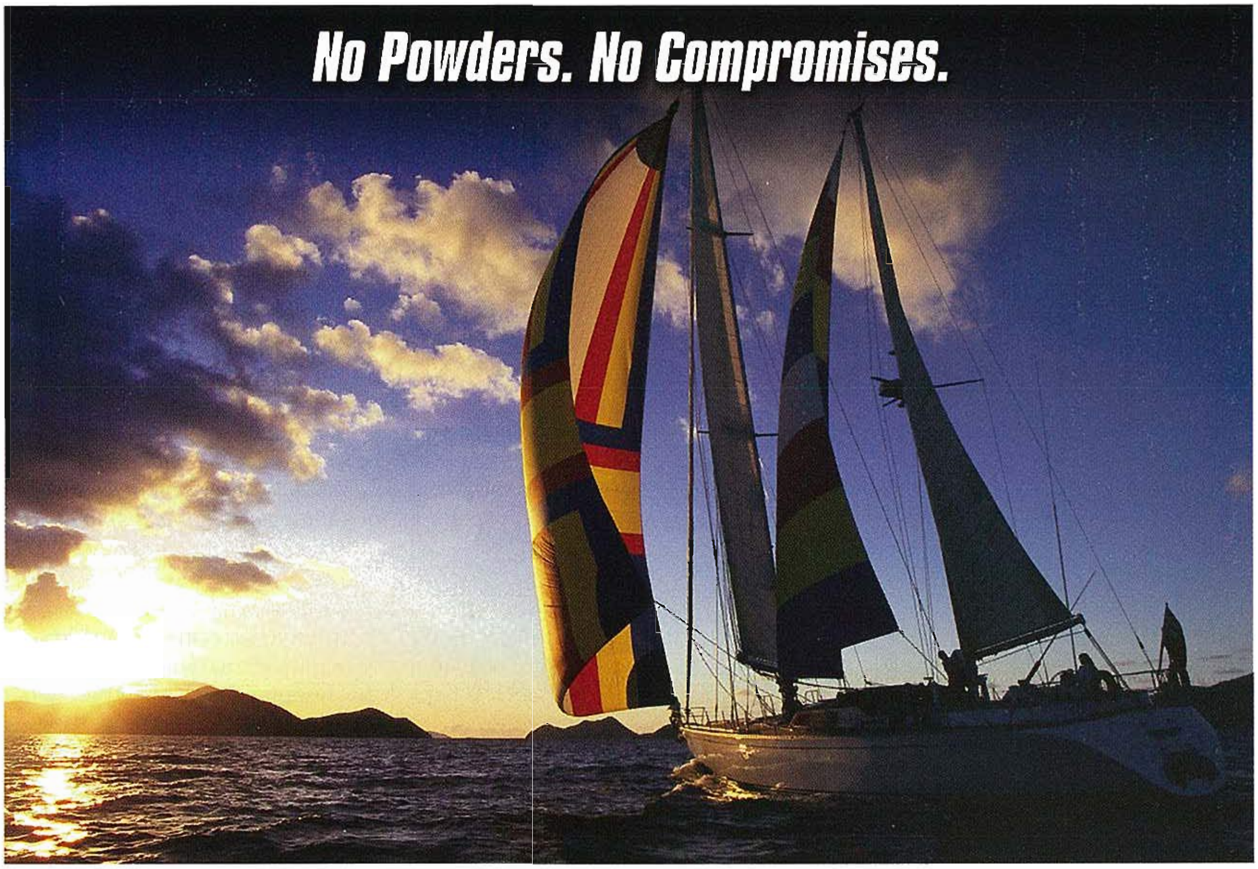
Other construction licenses went to Japan, Argentina, Brazil, and Italy.

The next challenge for Bob and Rod was figuring out a follow-up model. J/24 customers began telling the company that while they loved their boats, a larger boat would be ideal—one with standing headroom they could cruise with the family, in addition to the Wednesday-night beer-can races. Thus was born the J/30 (29.83', 9.09m).

"My role," says Bob, "has primarily been identifying the market niche. What is the boat we should come up with next? Rod's job has been to make sure it floats on its lines and sails well. These days, all the aspects of each boat go back and forth among all of us Johnstones. One of us might say, the sheer doesn't look right, or, the cabin trunk doesn't look right. In which case, we rework the plug and change it. Likewise, we sit at the helm; if it seems to someone that the cabin trunk kind of sticks out, we'll shave it down. Or maybe the sheeting angle doesn't feel right." (In truth, the Johnstone clan is doing less tinkering now—thanks to 3D modeling. More on that later.)

Bob usually takes home hull #1 of any model, and sails it. That way, he can tweak what can still be tweaked and make sure all the needed changes occur on hull #2—which enters the marketplace—rather than get delayed to hull #10 (an all-too-familiar scenario at many boat companies).

When asked how much input dealers have on future designs, Bob



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J BOATS (BOTH)

Left—*The design of most J Boats begins with Rod Johnstone; the J/32, though, was designed entirely by his son Alan. Its varnished interior has 6'3" (1.9m) headroom.* ***Right***—*The J/160 is one of several J Boat models intended more for cruising than racing. It features a three-cabin layout, a 7' (2.1m) retractable carbon fiber sprit for setting asymmetrical spinnakers, and can make upwind VMGs of 6.1 knots with a small jib.*

answers, "We like to get dealer input, but we also take it with a grain of salt, since dealers tend to look backward at what's worked in the past, rather than look forward and try to anticipate the next new, successful product."

By way of an example, Bob cites the company's introduction of the retractable sprit for asymmetrical spinnakers. "The J/105 came out of son Peter's one-design 14' [4.3m] dinghy, which has a retractable sprit," he says. "I reasoned, hey, if it makes going downwind easier on a 14-foot racer, why wouldn't it make an even greater contribution to the ease of sailing downwind on a bigger boat? No way dealers would have come up with that. In fact, most of them, as well as some of our TPI/J Boat team, thought the idea was nuts. So integrating that detail was a bit of a battle." *[Modern retractable sprits originated with the French singlehanded entries in Open Class monohulls at competitions such as the BOC Challenge round-the-world race—Ed.]*

The J/105 is 34.5' (10.5m) overall and sells new for around $160,000 all up; used, the price runs between $100,000 and $150,000. And the boat doesn't even have standing headroom. But that's not what J Boats is selling. What the company *is* selling is simplicity and speed. As the late, great English designer/racer Uffa Fox once said, "If you want to stand up, go on deck."

Ask Rod how much attention he pays to IMS and other rating rules, and he answers, "Zero. When you're torquing the boat to a rule, I think all you can do is make the boat less than what it could have been. What's the sense of that? Those rules come and go. But, unlike a car, the boat's not going to fall apart in 10 years. Somebody is going to be stuck with it."

Today, the president of J Boats is 45-year-old Jeff Johnstone. Key to selling Js, he says, are the following points:

• *Plenty of information.* J Boat buyers tend to do a lot of research, even years' worth, and the more they do, the better a J Boat looks. Design and construction details—explaining critical data such as displacement/length and sail area/displacement ratios, or explaining the SCRIMP infusion process—find their way into J Boat sales brochures and advertisements.

• *An on-the-water experience.* This might occur on someone else's boat, or a dealer's boat, or a demo at a boat show. "If you can get that person off a crowded dock," says Jeff, "and onto a J for just 30 minutes, then you've created an everlasting impression. Getting people on the water is really important."

• *The thinking behind the design.* "A lot of what we do, from a marketing standpoint, is educational," Jeff says. "You need to get to the root of what a particular design is all about."

• *Class associations.* These serve the same purpose as the popular rendezvous concept—that is, they generate camaraderie among owners by bringing them together. When Jeff spots a critical mass of J Boat owners in a given geographical area, he suggests they form a group, and he's there to help. With J Boat owners, such gatherings are usually to race, but sometimes the focus is on a cruise, or other times just comparing gadgets, or exchanging notes on troubleshooting or on upgrades the owners have made. For racing, Jeff says, "We'll provide a framework of rules limiting modifications to the boats. At the same time, we'll encourage amenities for cruising and daysailing." Jeff or a company staffer serves on the local executive committee until the boat owners can run the organization themselves. Then the J Boat person backs out, though someone from the company is always standing by for support.

• *Strong dealers.* A good case study is Maryland dealer Paul Mikulski, whose business is called J Port Annapolis. Here's what Mikulski instituted not long ago: He leased a dock with slips, negotiated favorable rates for 20 of his clients, offered training via a J World school, and ongoing access through the J Port Sailing Club. Ten club members share access time on each boat for the season. A J/80 (26.25', 8m), on this basis, runs about $2,500 per person a season—less than the cost of owning your own boat.

"Wonder why a dealer would want to focus on *activities* other than selling boats?" Jeff Johnstone asks,

Shown: 2003 Sea Ray 480 Sedan Bridge.
Courtesy: Marine Max, Somers Point, N.J.

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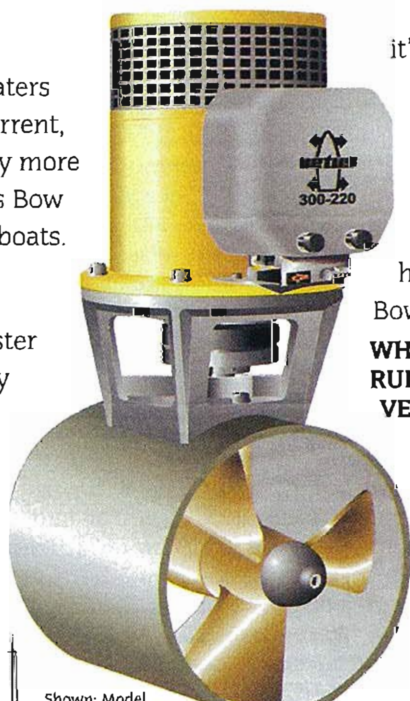

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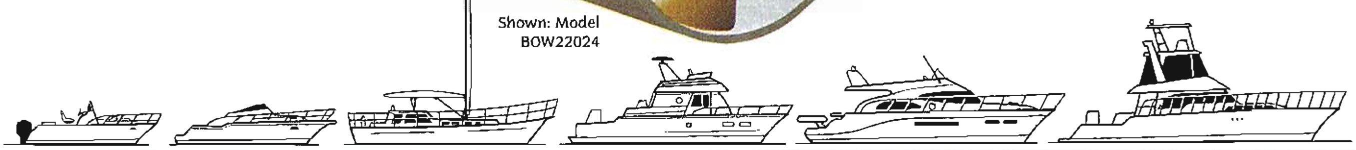

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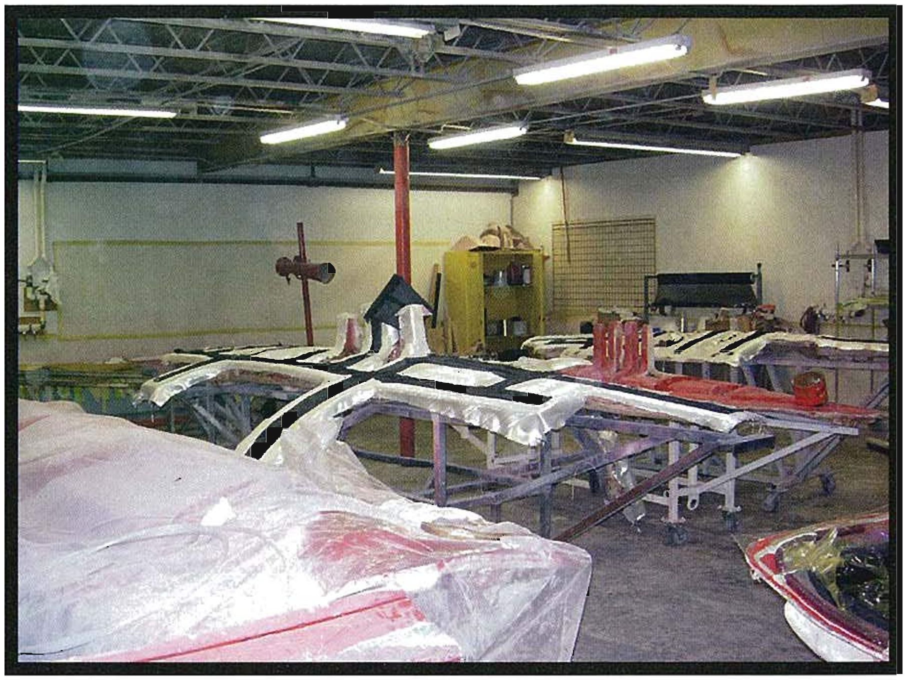
Grid molds readied for infusion by the SCRIMP process at Pearson Composites (Warren, Rhode Island), principal (but not sole) builder of the J Boat product line. In the center of the room, two J/109 grid molds have reinforcement fabric and the SCRIMP resin distribution medium (black) in place. Following infusion and cure, and prior to installing the grid unit in the hull, the glass around the edge of the mold will be trimmed to the desired flange width of 2"–3" (51mm–102mm). Vertical members of the first two molds are the keel floors. Three grid molds are inverted, so that the underside surface that interfaces with the hull is visible.



rhetorically. "Well, it's easy. The customer falls in love with the boat, and pretty soon he or she says, 'It would be nice to take this out whenever I want.'"

To which Mikulski would add, "Energy breeds energy." He's shaken up the traditional dealer model, what with school, time-share, charters, club, and Friday-night cookouts. Johnstone: "You get J World students just coming off the boats talking to prospective owners walking up and down the dock, and you've got this whole exciting environment. So the dealer spends very little time selling boats. The boats sell themselves." And, he might further add, J Boat owners sell the boats to others.

Jeff Johnstone says he spends 30% of his time on class-association business. That's because 40% of sales are to current J Boat owners and another 20%–30% are to people who have sailed on someone else's J. Jeff: "I think if you brought in an MBA, he'd ask why we spend so much time on activities that don't directly relate to sales. Advertising and boat shows are the sizzle, but they represent a smaller percentage of our sales."

A major event in the marketing program is the midwinter rendezvous at the manufacturing operation in Rhode Island, which attracts from 350 to 400 owners. Key suppliers and guest speakers are brought in. Last year, a weather specialist talked to the group about cold fronts. Another speaker talked about sailing his J/46 (46', 14.02m) to the Arctic. Pearson personnel put on a SCRIMP demonstration (that acronym has, by now, supplanted the original wording: Seemann Composites Resin Infusion Molding Process), and other Pearson employees taught a class on engine maintenance. So owners actually learn something at this gathering, and when it comes time to buy a new boat, hey, those Johnstone boys seem like really straight shooters.

As with most contemporary businesses, J Boats relies heavily on the Web to reach customers and to stay in touch with them. The class associations and owner forums are all run on the Web. And for prospective buyers, this medium affords J Boats, and its customers, a great way to conduct research. As noted earlier, the Johnstones believe that owners of Js do several years' worth of research before buying. Which is why, says Jeff, more than 2,000 pages of information are to be found on the J Boat Web site. "It's so detailed," he says, "the factory uses it as a starting point for the bill of materials."

Jeff reiterates uncle Bob's emphasis on the importance of dealers, of which there are 45 in North America. "Our job," Jeff says, "is to supply the sales network with as much information as possible. We know it takes time, a lot of time, to work with a customer. We could never be both dealer and builder."

Most J Boat dealers are not multiline dealers. Eighty percent or more carry only J Boats, though some of these might have a powerboat brand as well. The Johnstones like dealers who are themselves active in sailing or in the local marine trades. Four or five dealers, Jeff says, have been commodores of their yacht clubs. What is important here is that they're living their clients' lifestyle. "When we're looking for a dealer," Jeff says, "we're looking for someone who's made a personal investment in the sport. We're much more likely to go with a person who opens a small office, who's been involved in junior sailing, run a race committee, or would be considered a knowledgeable resource in his home territory—as opposed to going with the guy who owns the chandlery."

J Boats does not have a stocking requirement for its dealers, but fully expects a dealer in an important market area to have product. "We like our dealers to be focused," Jeff says, implying that they get more than a little coaching from headquarters.

Overseas

Bob Johnstone recognized opportunities in Europe early on, in 1979, and though some of J Boats' licensed builders overseas have come and gone, that overseas presence has nevertheless proven to be a nice counterweight to swings in the North American economy. In 1991–92, for

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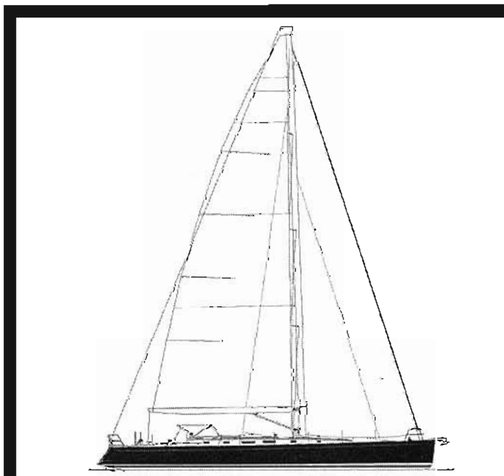
Right—*The grid for a J/42 has been infused along with the hull, the mold removed, and the hull sanded. Exposed areas of the bilge have been gelcoated, and the limber and plumbing penetrations installed.* ***Far right***—*A J/105 hull and grid getting infused under the green bag; feed lines extend down from the sheer. The uniform reddish color, from Norax-dyed catalyst, indicates that infusion is complete. Longitudinal black stripes are sections of infusion medium containing the resin feed lines.*

J BOATS (BOTH)

example, thanks to Stu Johnstone moving abroad to set up J Europe, 25%–30% of TPI's production went to Europe. Today, J Europe builds as many boats—the J/80, J/92, J/105, J/109, J/120, and J/133—as TPI's successor, Pearson Composites, builds in Rhode Island.



J/65

LOA	64.5′ (19.66m)
LWL	57.0′ (17.37m)
Beam	16.0′ (4.88m)
Standard Draft	9.0′ (2.74m)
Displ.	50,000 lbs (22,683 kg)
100% SA	1,819 sq ft (169m^2)
Engine	125 hp

But it was up and down, those 14 years. Jeff Johnstone: "When the U.S. dollar got strong, the margin evaporated, and our dealers over there had nothing to sell." In 1994, J Boats licensed its first full-line builder in Europe, J Composite. That operation has now moved, along with J Composite general manager Didier LeMoal, to King Cat, a Swiss-owned yard in Les Sable d'Olonne, France. The firm's three owners are sailors and build primarily J Boats. The J/109 (35.25′, 10.74m) was tooled at King Cat, and the boat debuted there in 2001.

"As it turns out," says Jeff, "we're now *importing* all of the J/80s, even though it's going somewhat against the exchange rate. The factory here was backed up, so we've been importing two boats every six weeks."

The next, larger model, the J/133 (43′, 13.12m), was tooled in Rhode Island and then shipped to France. "The ability to tool up in North America or Europe, or simultaneously," Jeff says, "has certainly put us in a stronger position if one side of the Atlantic is weak versus the other."

Ten years ago, the strategic plan called for a third builder in the Pacific Rim, but that market couldn't sustain a full-time builder; there are inactive J/24 licensees in Japan and Australia. The company was counting on better sales in Australia and New Zealand. Instead, boats bound for that part of the world are shipped from both the U.S. and France through dealers in the Pacific Rim.

Largest Build Yet and Model Turnover

The company's current major project is the J/65—its 15th model in active production, 36th overall, and biggest build to date. Two of these boats were under construction in Rhode Island as of this writing, with the first scheduled for sea trials in September. The new design is the result of several J owners wanting bigger boats, with aspirations toward a possible circumnavigation. The project has made Jeff Johnstone both excited and cautious. On one hand, the two owners wanted virtually the same interior in the middle of the boat, thereby simplifying each project; and, with two orders under way, the company is halfway to the four or five units needed to amortize the cost of tooling. On the other hand, Jeff can readily cite industry horror stories in which big projects have put builders out of business—"owing to poor builder management, a difficult client, or trying economic times. It's a whole new level of risk."

The J/65 is a joint venture between J Boats and Pearson Composites, and together the two companies decided

PAUL FUCHS

The J/65 was developed at the behest of several J owners who wanted larger boats—for possible circumnavigations. Hull #1 launched last fall in San Diego, California, and hull #2 is expected to be completed in early 2006. For the 65—a joint project between J Boats and Pearson Composites—independent project manager David Lake was brought in to oversee construction.

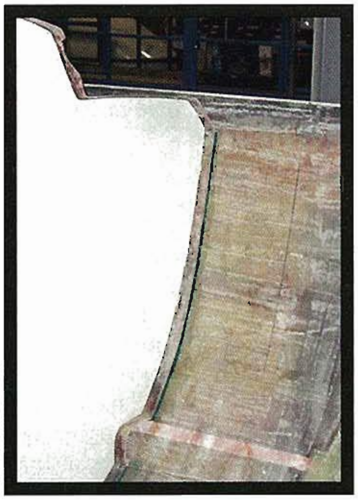
DAN SPURR

J/65 hulls are SCRIMP'd with Baltek SuperLite S56 balsa core and vinyl ester resin, and later stiffened with floors and longitudinal foam stringers.

to bring in an independent project manager: David Lake. The factory SCRIMP'd the hull and deck, but other jobs, including electrical design and some interior modules, have been subcontracted. Jeff says the goal is to create a new standard of woodwork and finish for J Boats.

Jeff is adamant that the two big boats not jeopardize the rest of the product line, which is the company's bread and butter. As many veteran boat manufacturers know too well, timing the introduction of a new model and ceasing production of old ones is a science unto itself. The average life span of a J Boat model is 7½ years—twice the longevity of what Jeff refers to as a "mass-produced" boat. "When the price of an existing model reaches nearly double of that of an older (used) sistership, then new-boat demand usually fizzles and it's time to consider retiring the model. But we've never retired a boat unless we haven't built it in a year, and are rarely quick to reintroduce a new model of the same size, in the interests of preserving both the resale value of the retiring model and the goodwill of the owners."

Sometimes a model can realize a second life. The J/44 (44.75', 13.64m), new in 1989, was retired prematurely in 1993, because the ill-conceived federal luxury tax of the period cut demand by 80% in 1991. But then, in 1998, when the company saw that



DAN SPURR (BOTH)

Left—*Bulkheads are trimmed of excess material in way of tabbing to the hull.*
Right—*In a J/133, carbon anchors for rigging tie-rods are robustly laminated to the hull. Local reinforcement (darker area surrounding the buttress) can be clearly seen. There is a section of Penske Extreme 2000 aft of the buttress, ready to receive a through-hull fitting (either a shower sump pump or electric bilge-pump discharge). The join of the buttress flange—secured with vinyl ester resin and biaxial E-glass tapes—is a secondary bond denoted by its light-green color, due to catalyst dye. (Since the resin/catalyst system is naturally clear, a dye indicates whether the resin has been catalyzed.) The horizontal red stripe is a 2"-wide (51mm) copper SSB ground plane extending around the entire inside of the hull. The whitish surface finish is from prep-sanding the hull prior to tabbing-in joinerwork and bulkheads, and for gelcoating.*

customers were willing to pay nearly twice the original price on the used-boat market for a J/44 outfitted for cruising (genset, air-conditioning, shoal keel), that model was retooled as the J/46—with certain tweaks: a 2'/0.6m hull extension, a carbon rig, a low-VCG keel, and a full suite of marine systems, including genset. J/44s were last selling in the low- to mid-$200,000 range; the J/46, when introduced in 1999, was going out the door for prices in the mid-$400,000 to low-$500,000 range.

The Role of Design

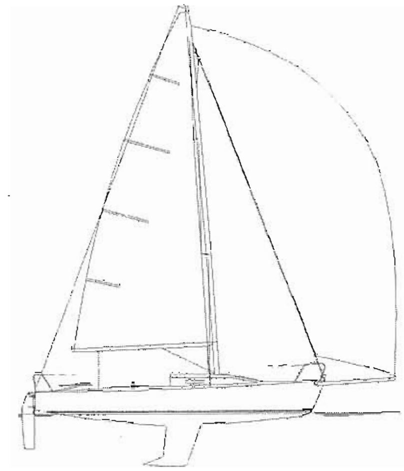
Al Johnstone, 42, son of Rod, is vice-president of design. His training has included studies at Westlawn, and apprenticeship to his father. "My responsibility," he explains, "is to take what Rod comes up with for the hull and then add the details. I spec out what the dealers need." We should note that

Al's done two complete designs himself, the J/32 and J/109.

Certain features serve as guiding criteria for J Boats, and distinguish the designs. First, the boats must sail well and be relatively easy to handle. As noted earlier, little if any attention is paid to rating rules, though the J/41 was an exception, designed as it was to IOR III. And the J/109 at least paid respects to the once-popular IMS. Rod says there's pressure to look at the rules if only to maintain J Boats' high-performance image. But doing so runs counter to his instincts. Given the company's success creating class organizations, the Johnstones are more interested in one-design racing and in performance cruising. Sail plans tend to favor large mainsails and smaller headsails, so tacking doesn't require inordinate amounts of energy, grinding away on sheet winches. Again, using themselves as market guides, the Johnstones design boats they'd like to sail themselves. "The one thing we share in common," Al says of his cousins and uncles, "is that we all have relatively large families and we like to go sailing with family. When it comes to doing grand prix racing, ours may not be an ideal boat, but we'll go at it the best we can. There are compromises in there that reflect where we come from."

Rod adds: "Simplicity and efficiency are critical to what we try to do. We're trying to design a boat that regular sailors like to sail, a boat they can aspire to own and is not out of financial reach. Except for the 22 and 24, most of our boats have been in the 30' to 40' [9.1m to 12.2m] range. That's the most popular range."

The Johnstones also favor boats that are fairly simple to build, so the molds are not unduly complicated. "Some of the bigger boats have winch moldings and similar details," Rod says, "but I've always been a fanatic about weight—not about keeping weight out of the structure, but about *not* putting stuff on the boat that adds



J/80

LOA . . . . . . 26.3' (8.0m)
LWL . . . . . . 22.0' (6.71m)
Beam . . . . . 8.3' (2.51m)
Draft . . . . . . 4.9' (1.49m)
Displ. . . . . . 2,900 lbs (1,315 kg)
100% SA . . . 338 sq ft (31.4 m²)
Engine . . . . Long-shaft outboard

J BOATS

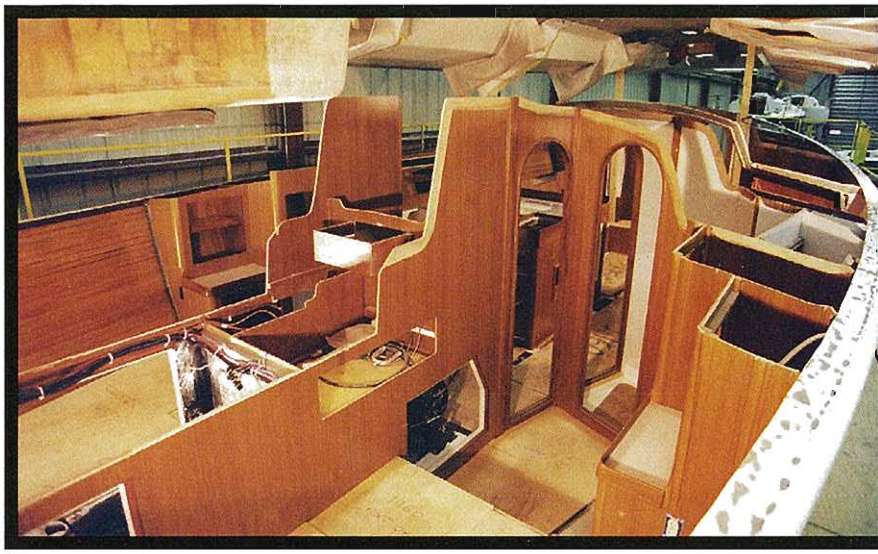
At the Pearson plant, J Boat hulls ride on wheeled cradles from one area to the next. The Pearson operation—same building, new owners—split off from the more familiar TPI, which continues to build industrial parts.

weight unnecessarily. With a fiberglass molding, every time you go around a corner, you add weight. You look at our decks; they tend to have fewer molded corners."

For structure and engineering, Al collaborates with the builder. "Their responsibility," Al says, "is to engineer the structure of the boat. As designers, we're involved in that process—deciding from a price/value standpoint the materials we want to use. And that depends on the priorities of the project."

Al works closely with engineer Clive Dent at Pearson Composites, systems engineer James Doe, and various laminate engineers—always with the objective, Al says, of "optimizing SCRIMP for weight and cost."

Al also works with naval architect Paul Fuchs, formerly with Tripp Design (East Norwalk, Connecticut), now running his own design studio in Connecticut. He takes Al's 3D-modeling files and renders them in Rhino. This has reduced the time it takes to develop new models. The J/133 was tooled and in production just 14 months after the first napkin sketch. Much of the savings, Jeff Johnstone says, is in the interior. With 3D modeling, it is no longer necessary to install a prospective piece of furniture, take it out, make patterns, stick it back in,



J BOATS

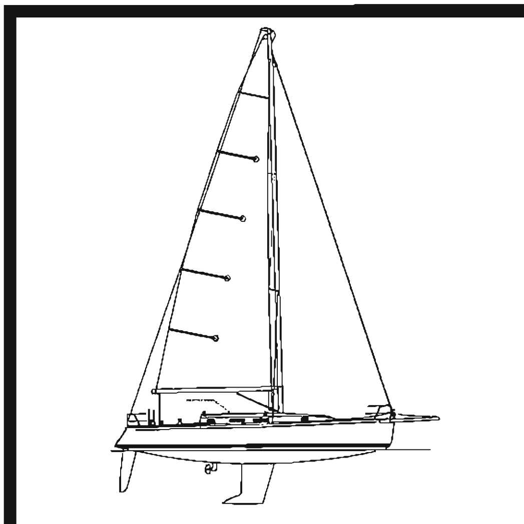
Bulkheads are installed prior to the hull receiving the deck assembly. Here, a J/160, with its deck suspended directly above, is displayed for attendees (J owners and prospects) at J Boats' annual Midwinter Rendezvous.

and so on. Everything is precise and known, right down to the thickness of the laminate. This process enables Pearson Composites to subcontract some of that woodwork to East Coast Interiors in Dartmouth, Massachusetts (see PBB No. 97, page 20), a talented cabinet-shop that makes galley and fore-peak modules for the J/133 and J/65, and builds the entire interior for the MJM 34z Downeast-style express cruiser for Bob Johnstone's other boat company, in Boston, as well as steering wheels for Edson International (New Bedford, Massachusetts) and various parts for business aircraft.

Prior to 3D modeling, Al says, "*everything* was done with mock-ups. Interiors and decks. You put the hardware on and moved it around until it was right. Very labor intensive, and there was much less forethought, really, to details. Now, all the ergonomics are worked out in 3D."

Jim Johnstone, 35, is first cousin to Jeff and Al, and he handles sales. That means he's the principal liaison between dealer and manufacturer, assigning hull numbers and performing his own production checks in the plant. During a recent plant tour with Jim, I watched as shop-floor personnel turned out one J/109 and two J/100s in the course of one week.

Tooling for a new J Boat model begins at DLBA Robotics in Chesapeake, Virginia, or at King Cat in France. DLBA has tooled the last three Js—on budget, on time. This shop



J/133

LOA	43.0' (13.11m)
LWL	37.8' (11.52m)
Beam	12.78' (3.90m)
Standard Draft	7.50' (2.29m)
Displ.	17,900 lbs (8,119 kg)
100% SA	964 sq ft (89.6m^2)
Engine	56 hp

delivers to Pearson Composites plugs that are fair to 150-grit. Next, a firm called All Paint (Bristol, Rhode Island) does the final fairing before Pearson makes the molds.

Materials for each line on the shop floor are color-coded. The purchase of a robotic diamond-cutter has reduced cutting time of reinforcements for a J/105 kit from three days to 45 minutes. The Ferro gelcoat for deck nonskid is sprayed rather than brushed. Penske fiberglass/foam board is now the Johnstones' backing material of choice for winches, through-hulls, cleats, and other hardware. Vinyl ester resin is in the hull skincoat and the only resin in the J/100 deck and for secondary bonding throughout the product line. Templates are used to locate deck hardware. Decks are prewired with B&G 15-conductor wire between the sea hood and nav station, which Jim Johnstone says reduces electronics install-time by four hours.

Though late in the day, the Pearson plant is bustling. There are two J/46s on the floor, one going to the United Kingdom and therefore requiring CE certification. Pedrick-designed Navy 44s (13.41m)—the newest generation of training sloops for the U.S. Naval Academy in Annapolis, Maryland—will be built here soon. But for now, the focus is on the two J/65s, which are mostly carbon, except for a small amount of glass for better adhesion of gelcoat and to improve secondary bonding. Reinforcements were supplied by Saertex Wagener (Saerbeck, Germany). Stringers are foam. The hulls are cored with Baltek SuperLite S56 end-grain balsa, the decks with Corecell A500 foam. The hulls are infused (via SCRIMP) in one shot; the stringers are done afterward. Lock-

DAN SPURR

A J/109 deck—fitted with winches, steering pedestal, and other hardware—awaits installation. Pearson Composites turns out about one per week of this model, and more of smaller J Boats, such as the tiller-steered J/100.

down flooring sits on an aluminum grid and is all removable. Installation of marine systems in the first boat is well under way, and they're complex, including as they do hydraulically operated bow thruster, vang, backstay adjuster, and mainsheet winches. In the center of the dinette is a large transformer. The Grunert refrigeration has both AC and DC compressors.

It is clear that David Lake is correct when he says, "We're building a J yacht, not a J boat." A semicustom offering with a configuration limited only by the hull, deck, and structural bulkheads, the J/65 is a fairly radical departure from the small stock boats on which the company has made its name and fortune—and no minor reputation. Little wonder, then, that the Johnstones are counting the days until hull #1 splashes.

It's all about market niches. Few in the marine industry have been as good, uncannily good, as the Johnstones at identifying and supplying those niches. And when you can use yourself as the market test, what could be simpler—and more fun? PBB

About the Author: *Dan Spurr is* Professional BoatBuilder's *editor-at-large.*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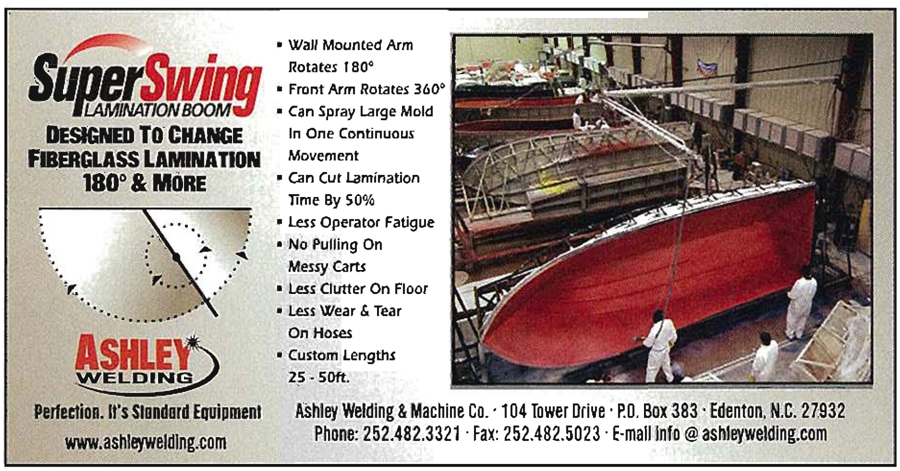
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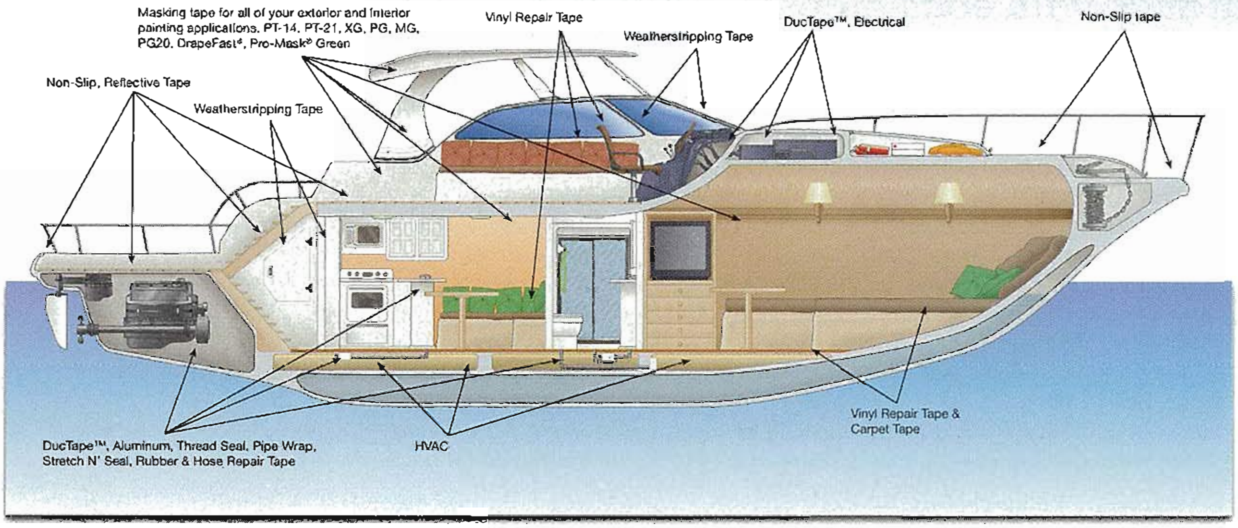

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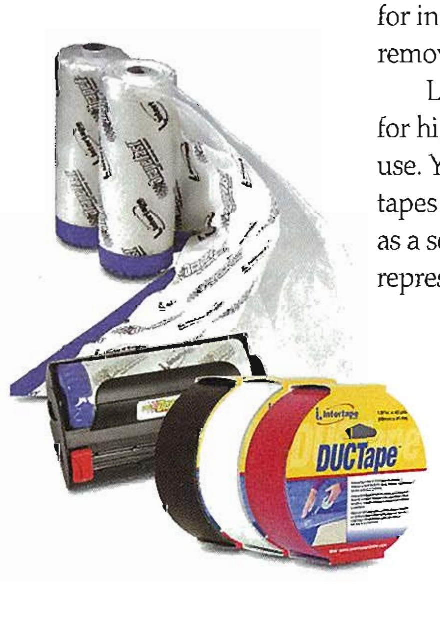

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Networking —Part 2

In theory, the concept of a "three-cable boat" should simplify marine-systems installations and monitoring. In reality, builders and boat owners now face a new complexity: different protocols at variance with each other.

Part 1 of this three-part series looked at the emergence of whole-boat networking systems for integrating engine monitoring and control, navigational electronics, and power distribution. These systems have the potential to dramatically reduce the amount of wiring in boats, moving toward what I call a "three-cable boat."

To get a better sense of how the available systems differ, and of their benefits and drawbacks, we'll consider them in more detail in Part 3. There, we'll look at how these networking systems are being applied to general-purpose boat wiring—what's known as a "distributed-power system." But before doing this it will be useful to have an understanding of how they work.

The two networking systems that presently have the highest visibility—SmartCraft and NMEA 2000—are both based on the Controller Area Network (CAN) protocol, which has come out of the automotive industry but is also now widely used in industrial controls. So, it makes sense to start by discussing CAN.

Before we begin, I wish to state that I have at one time or another been hired as a consultant by several of the companies mentioned in this series; however, I have no ongoing arrangement with any of them.

For a list of companies mentioned in the article, see the source list on pages 74–75.

Text and photographs by Nigel Calder

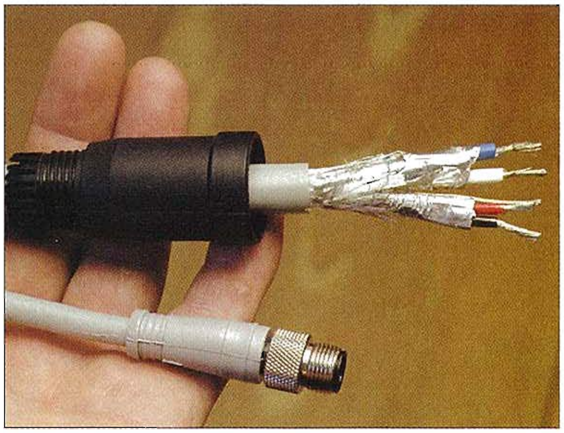
(except where noted)

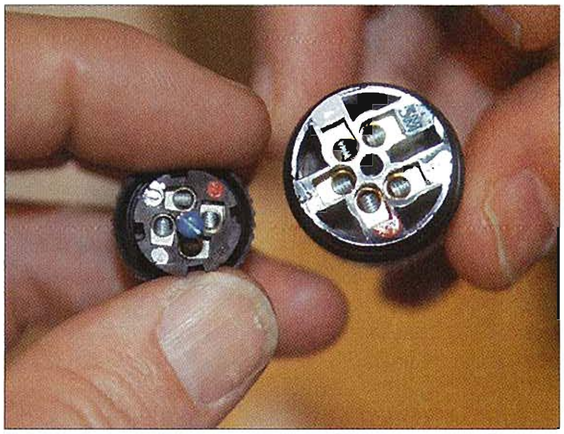
Core CAN Concepts

CAN defines a message-sending pipeline and the mechanisms to be used to transport messages through it. It does not say what those messages will be. Every device, or *node*, connected to a CAN-based system (commonly referred to as a CANbus) must include a *transceiver* for transmitting and receiving the CAN-based messages, and a *link controller* for translating those messages into and out of an appropriate format for the device. The two processes are often conflated, and the hardware—a small microprocessor—that performs them is referred to as either a *transceiver* or *chip* (also known as an *Applications Specific Integrated Circuit*, or ASIC).

The contents of the messages on any CAN system are customized for the specific purposes of that system, which makes the CAN approach extremely flexible. Engine manufacturers can design a system in which the messages relate to engine performance, such as rpm, temperature and pressure measurements, and exhaust analysis; in industrial controls, different messages will be used—a grain-elevator system, for example, would include information on how full the hoppers are, the state of the elevators, etc.

For the marine world, MotoTron (among other companies), a subsidiary of the Brunswick Corporation tasked with developing and managing SmartCraft, has devised a set of messages that relate primarily to engine operations; and the National Marine Electronics Association, the creator of NMEA 2000, has devised a set of messages that relate primarily to marine electronics (latitude and longitude, heading, depth, etc.). *[For background on SmartCraft and NMEA 2000, see Part 1 in PBB No. 97—Ed.]* Other companies—notably EmpirBus and Moritz Aerospace—have developed messages relating to power distribution on boats. All these systems have the capability to be expanded, and are being expanded, with new messages as new types of equipment and functions are supported or developed. Various engine manufacturers also have proprietary, CAN-based systems for electronically controlled engines, most of which now include throttle control and transmission shifting, with Volvo Penta's approach including an interface with some autopilots. As far as I know, though, there are no plans to extend any of these into whole-boat applications.





Left—*In networking, heavy or light cable and connectors are necessary, depending on the amperage requirements of the devices to be connected to a given system.* ***Below***—*Note the relative difference in the heavy and light connectors used with the two different sizes of NMEA 2000 cable.*

Addresses

Unlike some other networking protocols, CAN-based messages need not contain the address of the sending node (although the NMEA version does include an addressing system), and need not be addressed to a particular station or device. Instead, the content of a message—wind speed, water temperature, revolutions per minute—is given an identifier that is unique within the system. All devices then send their information to all nodes on the system. Each node "decides" on the basis of the identifier whether or not the information is relevant to that particular node, and thus whether or not to process the message. This decision is programmed into the transceiver chip; in the NMEA version, if the message is addressed to a specific device, all devices—other than the device to which it is addressed—will ignore it.

In a message-based system of this kind, every node must have the chip needed to send and receive signals. No central controller, or *master*, is needed (a *masterless* system), so the failure of any node or device will not crash the system. In fact, one of the requirements of NMEA 2000 is that any node can fail in just about any way without adversely affecting the system. A corollary to this is that equipment can be added to and removed from the system at any time without shutting down the system, and without having to reconfigure it every time it's booted up. If there have been any changes since the last time it was powered up, the addressing system is used to assign a new address to all nodes. This is known as *automatic dynamic addressing*.

CAN Kingdom

The basic CAN approach described above is sometimes modified to include a master, resulting in what is known as CAN Kingdom. Here, there *is* a central controller, which acts as a system "king" to allow or disallow access to the system; there is no automatic dynamic addressing. SmartCraft takes this approach, designating the engine as the main controller of the system. If some component in the system causes trouble, it can be shut down without affecting the engine, which is, in essence, treated as the most important piece of equipment on the boat. If the master crashes, the engine crashes, although it can still be configured to operate in a fail-safe, "limp home" mode.

Phil Gaynor, business manager for MotoTron, writes, "Safety-critical systems for throttle/shift/steering must have 100% redundancy and fail-safe allowances. This is the primary reason SmartCraft exists." The Brunswick Corporation/MotoTron uses the king approach as a mechanism to maintain control over all non-engine-related devices that will be put on the SmartCraft bus(es). With respect to NMEA 2000, he comments, "There are a lot of unanswered questions about merging critical safety systems with an 'all-purpose network.'" Advocates of NMEA 2000 challenge the notion that the king approach provides greater security for engine controls, as well as the implied assumption that the broader-based NMEA 2000 provides any less security for mission-critical functions.

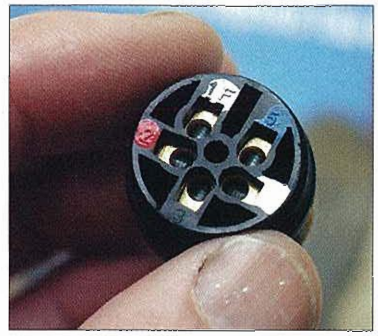
There is not yet enough real-world data to see how these differences in philosophy play out in practice, and in fact whether there is anything at all to be concerned about.

Collisions and Errors

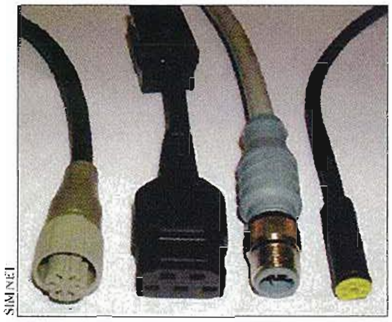
What happens if two nodes transmit information simultaneously, leading to a "collision"? CAN's response is an approach known as *Carrier Sense, Multiple Access with Collision Detection* (CSMA/CD) combined with *nondestructive bitwise arbitration*.

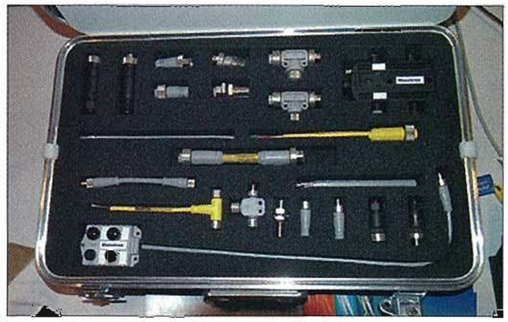
The way this works is as follows. All messages within any given system are assigned a priority. When two collide, the higher-priority message gets through with no delay (as opposed to Ethernet, for example, on which both messages get delayed). The lower-priority message does not get lost, as can happen on other kinds of networks such as Ethernet. Instead, the message gets put in a queue and waits its turn. CAN's ability to guarantee

Top left—A section of the heavy NMEA 2000 cable, which can carry up to 8 amps, is readied for the installation of a connector. *Top right*—A closer view of the connector shows where the five distinct small cables attach that together make up the larger package. *Below left*—Four competing cable and connector options currently available are, from left: NavNet, SeaTalk2, NMEA 2000, and SimNet. *Below right*—A Maretron NMEA 2000 cable kit includes an array of Ts and connectors for installation.



SIMNET





that the highest-priority messages (throttle, gear-shifting, and steering commands) get through in real time—that is, immediately—is critical to the safety of a vessel and its crew. It is one of the main reasons NMEA, Brunswick Corporation, and others have settled on CAN.

CAN also has built into it a number of error checks that enable faulty messages to be rapidly recognized and sidelined, and that also prevent a node that may be outputting a stream of junk—from fouling up the system. It is, in short, an extremely reliable and robust messaging protocol that has proven itself over many years in the automotive and industrial fields.

The Physical Layer: NMEA 2000

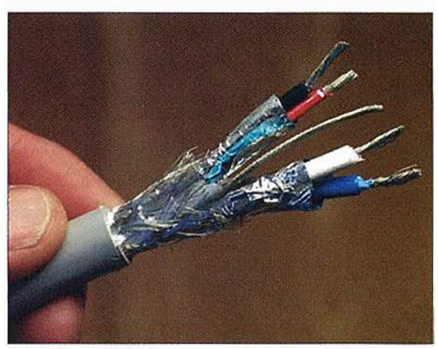
Of course, the CAN system is not of much use if the cabling and connectors—the physical layer through which messages are transmitted—fail to provide an adequate framework to carry the messages. One of the problems with NMEA 0183 (NMEA's earlier messaging protocol) has been that NMEA only *recommended* a particular physical layer instead of *requiring* it. Device manufacturers and installers can use less-robust approaches than those recommended and still claim NMEA 0183 compliance.

The NMEA 2000 standard *requires* a very specific physical layer comprising an extremely sturdy cable that is fully shielded against electrical interference, with cabling and connectors that are waterproof—they can be submerged in bilgewater and still work. These components have been developed for industrial controls and come out of a widely used CAN-based system known as DeviceNet. Two cable sizes are specified: NMEA 2000 heavy cable and NMEA 2000 light cable. Even the light cable is built to the same rugged standards; essentially, all that changes is the size of the wires within the cables, and the size of the connectors.

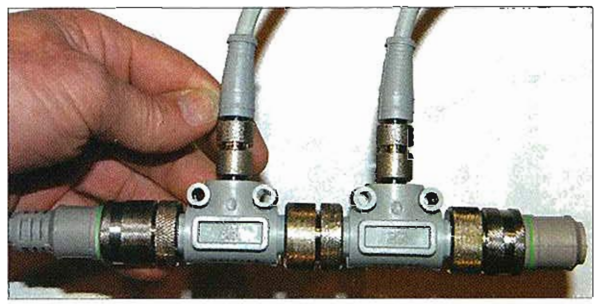
An NMEA 2000 cable contains a negative and a positive power cable, two data cables, and a ground cable—five cables in all. The NMEA 2000 heavy cable has AWG 16 power cables, which can carry up to 8 amps, and AWG 18 signal cables; the light cable has AWG 22 power cables, which can carry up to 4 amps, and AWG 24 signal cables. Power is supplied to the power cables from the boat's batteries or from a dedicated power supply, and connected into the network cable via a *Powertap T*. If required for redundancy, power can be taken from two or more different sources, using blocking diodes to keep the sources isolated from one another.

Those devices that require less than 1 amp to operate, such as a depth-sounder, can be powered directly from the power cables within the NMEA 2000 cable. The NMEA cable would be the only cable connected to the device. Those that require more than 1 amp, such as radar, are powered from separate power cables. In this case, there would be the usual negative and positive power feeds to the device, plus the NMEA 2000 cable. A basic NMEA 2000 chip draws 15 mA to 20 mA; display screens draw more power. The 8-amp and 4-amp limits of the heavy and light cables result in a limit to the number of physical connections that can be made to a bus. This limit will vary according to the power draw of the various devices.

When installing an NMEA 2000 system, a cable called the *backbone* or *trunk* is run through the boat to all locations at which devices will be plugged into the system. At both ends of this cable there is a terminating



NMEA 2000 heavy cable is really a bundle of five smaller cables: two for data, two for power, and one ground wire.



Top—*A T fitting in light cable,* ***left****, compared to one in heavy cable,* ***right****. Both examples shown terminate with a resistor on the right-hand side.*
Below left—*A heavy connecting terminal being made up along with a heavy T.*
Below right—*Getting progressively more complicated, a heavy cable steps down to light cables at two Ts, and ends with a terminating resistor at right.*

resistor—a piece of hardware needed to stop signals "reflecting" back onto the network. Wherever a device is to be attached, a "T" is inserted into the backbone and a cable known as a *drop cable* is run to the device. The drop cable and its device constitute a *node.* The Ts and all other pieces of hardware inserted into the backbone, as well as the drop cable, must be NMEA certified, although the means of connecting the drop cable to its device is left up to the device manufacturer.

Every device is individually wired to the backbone with no daisy-chaining (connecting in series) of devices, so they can be added or removed without affecting any other device on the network. Where a number of devices connect to the backbone in close proximity to one another, a *multiport box* can be used to consolidate the connections into a single drop cable onto the backbone.

NMEA 2000 requires that communication can still continue, albeit at a degraded level, with no permanent damage done, with either of the two signal wires broken, and either signal wire shorted to the power supply or to ground. In other words, any device can be miswired in any conceivable way for any length of time without causing permanent damage to the system or any device on it, although this may well render the network inoperative until the fault is corrected.

The NMEA 2000 physical layer is expensive. The T required for every drop onto the NMEA 2000 heavy cable costs more than certain sensors or pieces of equipment that someone may want to add to the system! This high cost is a bone of contention with many device manufacturers, and a source of hot debate within NMEA. It has led to several manufacturers developing their own physical layer, which is not NMEA certified, and then providing access to the NMEA 2000 bus via a single NMEA 2000–certified "gateway" of some kind. Discussion persists within the NMEA over whether or not to certify, and under what circumstances, a less-expensive physical layer.

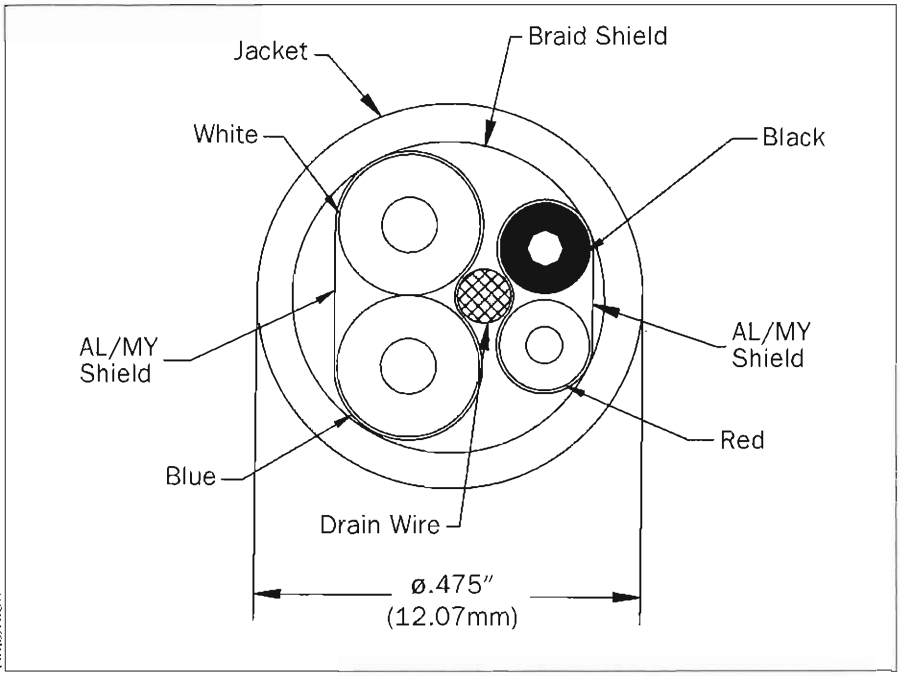
The Physical Layer: SmartCraft

As you would expect, the physical layer for SmartCraft has many similarities to that of NMEA 2000, including: the linear layout; the resistors at each end; the limit on the number of physical connections that results from the size of the power cables and the power demands of connected devices; and others. The big difference lies in the fact that SmartCraft is designed around three data buses, "X," "P," and "V" (as opposed to the single data bus in the NMEA 2000 cable), with a different core function for each bus, sometimes resulting in different information running on each.

CAN X is a bus reserved exclusively for safety-critical systems, such as throttle and transmission shifting, with access tightly controlled by MotoTron (it is essentially reserved for Mercury Marine and Cummins MerCruiser Diesel). It entered production in 2004 as the control system for Mercury's fully electronic Verado and MerCruiser DTS engine platforms. CAN P carries propulsion and extensive system-diagnostics data, and also acts as a fully redundant bus to CAN X, providing a backup for mission-critical data transfers. CAN V is reserved for all other vessel devices, such as generators, switching systems, and bilge systems. It began to carry its first generator and system diagnostic data in May 2005. It is the bus most suited for a distributed power system, but is the least developed at present and has yet to be deployed for distributed power.

The triple-bus design of SmartCraft is intended to separate the vessel into its major functional areas and to preserve bus integrity through division. One defective bus will not bring down the others. SmartCraft buses can be combined at the helm and elsewhere, so devices such as displays or switches can have access to all the information and control on the boat.

Typically, the physical layer may contain only one of the three buses (CAN X in engine applications, or CAN V for distributed power) or perhaps



MARETRON

Inside a section of NMEA 2000 cable, we find ample shielding to prevent radio frequency interference. The blue and white data cables are wrapped together in an individual Mylar shield. The same is true for the red and black power cables, while the ground wire remains uninsulated. The entire package is enclosed in large braided shield and finally a waterproof jacket.

two (CAN X and CAN P), but almost never all three. The buses are likely to be routed together from the engine-room to the helm, but then separated to suit specific installation criteria. Each bus consists of a twisted pair of cables. The physical layer also includes a set of power cables (positive and negative) and a switched power lead for powering devices from the keyswitch. As with NMEA 2000, power for SmartCraft buses can be supplied from multiple, isolated sources via blocking diodes, with those devices that draw less than 1 amp operating directly off the network power supply. In some cases, there also is an uninterrupted power supply (hardwired to the batteries, to maintain memory functions when a system is shut down), and ignition cables. The standard SmartCraft engine connector ends up with 14 pins, including connections for redundant power and data cables.

Shielding and Grounding

NMEA 2000 positive and negative power cables are wrapped in a shield, as are the two data (signal) cables. The fifth (ground) cable is laid in separately, and then another shield (made of Mylar), and a braided shield, surround the cable as a whole. That's a lot of shielding! There is considerably less shielding with the SmartCraft physical layer, and less expensive, automotive-like connectors. As such, the installation is less costly than that for NMEA 2000, and less robust.

NMEA's focus on shielding for radio frequency interference (RFI) is a reflection of the fact that NMEA 2000 has come out of the navigational side of the marine industry, where RFI is a big issue, and the device manufacturer has limited control over the installation. The backbone, for example, may be run close to a "noisy" fluorescent light or CRT display screen. By contrast, SmartCraft has come out of the engine side of the industry, where the manufacturer has a high degree of control over the bus and its installation, and where RFI is less of an issue.

As noted above, MotoTron/Brunswick is maintaining a tight control over CAN X and CAN P, but will have a different level of control over CAN V when it is extended to distributed power systems, which will require the bus to be run all over the boat. It remains to be seen whether this results in problems. If it does, the triple-bus nature of SmartCraft will keep problems on CAN V from disrupting the CAN X and CAN P buses.

Shielding is another of those issues on which strong opinions are expressed by the advocates for the differing network approaches. Once again, there is not yet enough real-world data to see how these differences play out in practice, and in fact, whether there is anything to be concerned about.

With all networked systems, single-point grounding on the network side is necessary to prevent "ground loops" that could destroy the integrity of the system, causing messages to get lost. On those devices that require more power to operate than can be pulled from the network backbone—a radar, for example—and that therefore require an additional power supply to the device, for safety reasons it is essential to isolate the grounded (negative) side of this power supply from the network ground. If this is not done and the main power ground to the device gets broken externally, the full operating current of the device will run to ground down the data ground. The relatively high current flow will likely melt the small grounding cable in the network cable, disabling the system and possibly starting a fire. Ground isolation can be achieved within devices either via an optical isolator (with an OEM cost of $1.50 to $9.00, depending on the required level of robustness) or at a lower cost through "current loop isolation." This added layer of complexity and expense is another bone of contention for some manufacturers.

Practical Limitations

The data-carrying capacity of any network is a function of such things as the length of the network, the speed of data transmission, the number of nodes on the bus, and the message structure.

The longer a data cable, the longer the time it takes for data to travel from one end to the other, and therefore the longer another device must wait to get its data transmitted down the bus. The NMEA has determined that a backbone cable length of 200m (656′) is adequate for marine purposes. SmartCraft currently limits bus length to 40m (131′), but is extending this to 70m (230′), and could, in all probability, handle 200m, depending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on the bus loads and/or whether the information is safety critical. (The 40m comes from the J1939 standard from which SmartCraft and NMEA 2000 are derived, which in turn has come from the automotive industry where long cable runs simply do not occur.)

CAN-based equipment is nominally designed to operate at data rates of 1 megabit (Mb) per second, but on a 200m backbone this drops to 250 kilobits (Kb) per second—the designed speed of NMEA 2000 and SmartCraft. This is still 50 times faster than NMEA 0183. Where NMEA 0183 can deliver 6 to 8 messages a second at 4.8 Kb per second, NMEA 2000 can deliver 300 to 400 messages at 250 Kb per second. However, the greater the number of nodes on a bus, the lower the message rate will be. The SmartCraft people use this fact to argue in favor of breaking up the messages and putting them on more than one bus. The response from the NMEA 2000 advocates is that it is irrelevant, because the NMEA 2000 bus has plenty of capacity.

Data (messages) on CAN-based systems are transmitted using a 29-bit identifier. The way this is configured effectively limits the number of functional connections to a network to 252, meaning 252 devices can be uniquely addressed on the network, although the physical layer can support a maximum of only 50 electrical connections to the bus (see above). One physical connection, however, can support multiple addresses to multiple logical devices. For example, an autopilot may integrate a GPS, heading sensor, fluxgate compass, and other devices, all of which can have separate addresses but with one connection to the network. In terms of power distribution, a number of circuit breakers may be clustered together, each with its own address, but with a single connection to the network. If more than 50 physical connections, or 252 nodes, are needed, a second network can be added with a "bridge" between the two.

The messages themselves are short, being limited to 8 bytes (64 bits; 1 byte = 8 bits), with the actual data content being less than 50% of the message. The rest consists of the identifier and various error-checking mechanisms. With NMEA 2000, messages larger than 8 bytes, but less than 256 bytes, are broken up and sent sequentially, using something known as a *fast packet transmission.* Longer messages (the limit is 1,785 bytes) are sent in blocks, when there is available time on the bus, and reassembled in an "envelope" that is "opened" once the message is complete—what's known as *transport protocol.* Currently, all NMEA 2000 messages greater than 8 bytes have been designed to use the fast packet transmission. There are two types of messages: status messages, which are sent at some periodic rate to update any device that cares about that particular information; and control messages, which are sent only when needed—for example, to turn a breaker on or off.

CAN-based systems are not designed to carry large streams of data such as video. For large-volume data, some other approach is needed. Ethernet is rapidly becoming the dominant technology (see the sidebar on page 66). With Ethernet, our three-cable boat actually becomes a four-cable boat consisting of the negative and positive power cables, a relatively low-volume CAN-based messaging system (or a rival system), and a high-volume Ethernet-based data-transfer system.

Benefits of CAN

A CAN-based network allows multiple electronic devices to be connected together, via a single cable connection, in order to share information. Its message-sending and -receiving protocols, and the physical layer, have been well tested in literally millions of vehicles and thousands of industrial applications, and have proven to be reliable, rugged, and error-free. The content-based nature of CAN allows users to define messages appropriate to their application, making it extremely flexible.

The fact that CAN-based systems are now so widespread means that there are numerous chip manufacturers producing the necessary transceiver (transmitting and receiving) chips for any device in a CAN-based system. Once a set of messages has been devised, it's easy for a chip manufacturer to program them into a chip, allowing any device with this chip to be added to a network and immediately begin sending and receiving messages to and from all other devices on the network. The existing mass market for CAN chips means that the cost is relatively low; the wholesale price ranges from $2 to $5.

As for the physical layer, a number of manufacturers are already supplying to industry the DeviceNet type of hardware specified by NMEA. (Maretron is the first to have had NMEA 2000–certified products.) This, too, helps keep the cost down, although, as noted, the high quality of the hardware in the backbone required by NMEA 2000 does drive the cost up over that of some competing hardware. Manufacturers getting on the SmartCraft bus work with MotoTron to establish a suitable physical layer.

From a device manufacturer's standpoint, the R&D that has already been put into a CAN-based system such as NMEA 2000 or SmartCraft, and the availability of the necessary chips, can significantly reduce design

Open vs. Proprietary Standards

NMEA 2000 is an open standard for marine electronics and engine data in the sense that it has been developed by a broad range of organizations over a period of nine years. NMEA grants certification to any manufacturer who purchases and meets the requirements of the NMEA 2000 standard. These requirements are a result of the efforts and input of NMEA members, including manufacturers, installers, and the U.S. Coast Guard. NMEA has also been working with international standards-setting bodies such as the International Maritime Organization (IMO), the International Electrotechnical Commission (IEC), and the International Organization for Standardization (ISO), as a result of which NMEA 2000 will likely be adopted as a worldwide standard.

NMEA's automatic dynamic addressing approach requires every product to be capable of negotiating its address and position in the hierarchy, enabling devices to be added and removed at any time, and enabling the system to function regardless of the state of any

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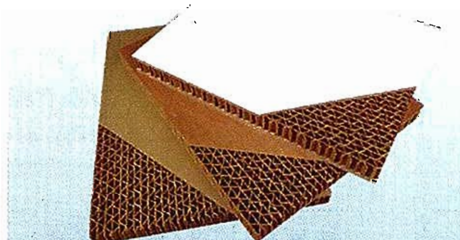

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time for new products. From a boatbuilder's and installer's perspective, the single-cable installation and compatibility of all devices programmed for a particular CAN-based system greatly reduce installation complexity, time, and cost, as well as the likelihood of post-installation problems. From a boat owner's perspective, the considerable reduction in cabling and connections is almost certain to result in greater reliability. If the system permits any compatible device to be plugged in and unplugged without having to reconfigure the system or the device (what is commonly known as "plug and play"), the boat owner can buy best-in-class devices from any manufacturer, rather than being locked into one manufacturer's proprietary system. NMEA 2000 is configured this way; SmartCraft is not (see the sidebar on page 58).

Non-CAN Approaches: ED&D's E-Plex

Although CAN-based systems have received the lion's share of publicity to date, there are a couple of non-CAN networking systems that have entered the marine world from left field, and that have considerable potential. These are ED&D's E-Plex, and Victron's VE.Net. Both focus on power distribution rather than propulsion monitoring and control or navigation, although both have interfaces with just about any other conceivable system. (In May 2005, ED&D was acquired by Airpax Corporation, a manufacturer of circuit breakers and engine sensors.)

E-Plex utilizes a relatively slow (20 Kb per second, Kbps) master/slave messaging protocol. In essence, the master (which ED&D calls a *clock*, or *E-Plex Control Module* [ECM]) samples all the nodes sequentially. The nodes use the position of the data in the sequence to determine if it is directed at them. This dramatically reduces the amount of activity on the bus as compared to a CAN-based system. For example, a simple "on" or "off" instruction with CAN requires the 29-bit identifier in a 64-bit message, as opposed to a single bit at a particular point in the sequence with E-Plex. At 250 Kbps, a 64-bit CAN message will take 256 microseconds, whereas a single E-Plex bit at 20 Kbps will take 50 microseconds. Despite the slower bus speed, E-Plex is five times faster in this instance! Most E-Plex messages are, in fact, only 1 bit in length, although some may be 8, 10, or 16 (for example, engine rpm is 16). A 16-bit E-Plex message will take 800 microseconds, as opposed to 256 microseconds for the equivalent CAN message (E-Plex is more than three times slower), but, asks David Bateman, president and lead designer at ED&D, "how many engines outputting rpm do you have?"

The nature of the E-Plex protocol is such that there are no collisions; the clock controls the messaging sequence. But, there can be no prioritizing of messages. Some messages are not particularly time sensitive. Depth information, for example, is not needed in most situations more than once every second, maybe much less. Others are time sensitive—throttle, transmission shifting, and steering individual device. If a manufacturer has a device for which there are not currently appropriate messages built into the system, the manufacturer can approach the regulatory committee (NMEA's standards committee) and work with it to devise the necessary messages, according them an appropriate priority level within the priority hierarchy.

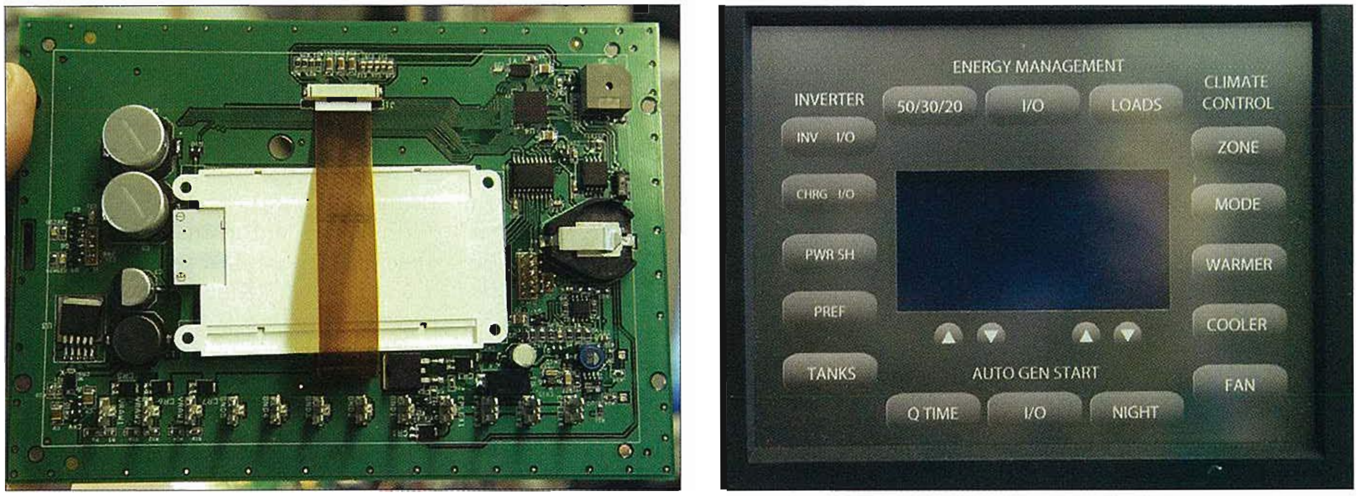
In order to obtain NMEA 2000 certification, a device is tested by its manufacturer to ensure that it will communicate and behave properly on the NMEA 2000 bus and that it has the necessary self-configuring capabilities to meet the plug-and-play characteristics of NMEA 2000. The device manufacturer purchases both hardware and software from NMEA to carry out all the required tests. These generate an encrypted test-data base file that is sent to NMEA for validation.

To avoid unnecessary development costs, the NMEA has two levels of certification: "A" and "B." Simple devices, such as a speed sensor that needs to output only a simple message, do not require the capabilities of sophisticated devices such as an autopilot, which will be receiving and processing information from several sensors, and then outputting messages to a chart plotter and other devices. The speed sensor can be certified to level-B compliance; the autopilot will need to be certified to level-A compliance.

A consumer should be able to buy any NMEA 2000–certified product and plug it into an existing NMEA 2000 system—true plug-and-play versatility, allowing the consumer access to an ever-widening range of mutually compatible electronic devices. And the more information there is on the system, the more powerful the uses to which this information can be put. One of the things an open standard tends to do is release the creative juices of software writers and engineers, resulting in novel and unforeseen applications of the available data. A list of NMEA 2000 Certified Manufacturers/Suppliers/equipment can be found at www.nmea.org/about/news.cgi?article_id=177.

SmartCraft, by contrast, is a proprietary system controlled by the Brunswick Corporation, via MotoTron. In developing the system, MotoTron has worked with Kvaser AB, a leading CAN Kingdom developer, as well as the U.S. Navy.

MotoTron is primarily responsible for developing the messages on the SmartCraft system, determining message priority, and so on. If a manufacturer wants to get on the bus (CAN X, P, or V) there is a process by which the manufacturer and MotoTron define the project, develop the messages and the necessary hardware, and test and validate the application, at which point the product becomes certified. As with NMEA, MotoTron sells hardware and software to the manufacturer to help with the development and validation process. Unlike NMEA, MotoTron is much more actively involved at every step, including bench-testing



Left—*An E-Plex "clock" or "control module" is the center of ED&D's system, which employs a master/slave messaging protocol.*
Right—*The company provides a variety of screen sizes and layouts for its clock face.*

commands. When it comes to distributed power, signals such as switching lights on and off are time sensitive: if there is a delay, the operator is likely to think the switch is not operating, and will try switching again.

ED&D's goal is to ensure that all address points on the system are sampled at least 10 times a second. Doing a little simple arithmetic, if we assume all messages are 1 bit long, at 20 Kbps (20,000 bits per second), sampling 10 times a second, the system can handle 2,000 messages per second (20,000/[10 x 1]); this would be more than adequate for even a superyacht. However, if we assume the average message is 10 bits long, at 20 Kbps, sampling 10 times a second, the system can handle 200 messages per second (20,000/[10 x 10]), which would significantly limit the number of devices on the bus.

As noted, most messages are 1 bit

of models and validating the application in real-life boat tests. MotoTron charges for its time by the hour, and then collects a royalty fee for every validated device that is sold.

Given the CAN Kingdom nature of SmartCraft and the lack of automatic dynamic addressing, an applications engineer is needed to add or remove devices to an existing network. The infrastructure for this is provided by Brunswick Corporation builders, distributors, and field technicians. As the message base becomes more fully developed, and recognition of more certified nodes is built into the King (the controller), it will be possible to add or remove, in a plug-and-play fashion, many devices for which messages have already been developed.

MotoTron's approach is more restrictive and more tightly controlled than that of NMEA. Phil Gaynor, business manager at MotoTron, argues in favor of it as follows: "A free and open network [such as NMEA 2000] is, by definition, not a field-supported or 100% pre-tested network like SmartCraft. Without management, it's very difficult to create the consumer benefits that an 'integrated' network system of products should deliver.... When issues arise from connecting devices together, members of the free network are only responsible for verifying that their products are transmitting/receiving messages successfully. Without management over how each company displays and controls another company's products, quality to the customer is at risk. A very likely result is that product warranties, such as those for complex digitally controlled engines, will have limitations placed on them because of the risk an unmanaged network imposes." NMEA 2000 advocates challenge those statements.

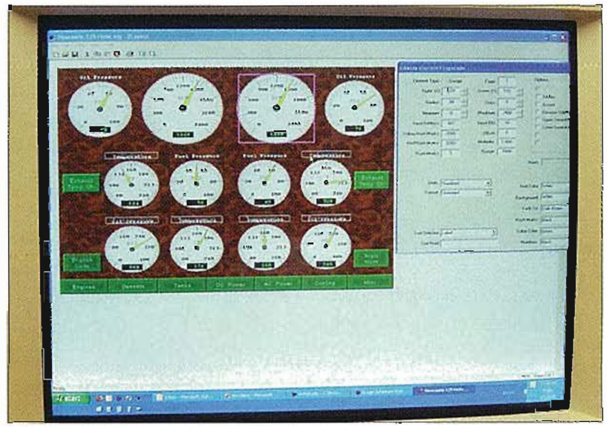
Gaynor notes that "management costs money, and even though royalties are generally viewed with skepticism, without them the databus management and implementation responsibilities will fall mainly on the customer.... Both Mercury and Cummins MerCruiser customers expect more from us than that, and so we are providing SmartCraft in this way to them."

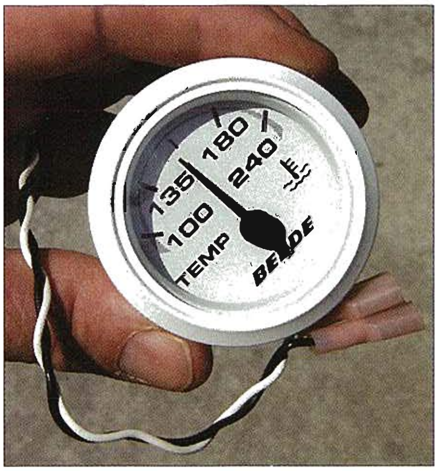
There are clearly some deep-seated philosophical differences between NMEA and the Brunswick Corporation in terms of how accessible to make the bus, and how to provide protection to mission-critical functions (bus redundancy and strictly controlled access versus a "bulletproof" physical layer). Given the lack of real-world experience with any of these systems, it remains to be seen how serious those differences may be.

As with NMEA 2000, SmartCraft has two levels of licensing. Certified manufacturers can be found at www.smartcraftnetworked.com.

—Nigel Calder

Right—*An E-Plex tank-level sensor has a "core" or circuit board inside it that communicates the information from the tank to the "clock."*
Far right, top—*A second type of tank-level probe with an embedded E-Plex core.*
Bottom—*An E-Plex system displayed on a computer monitor. Most additions to an E-Plex bus require reprogramming through a personal computer with a simple software package called E-Logic.*





A temperature gauge converted to operate on an E-Plex system. The twisted wires will be the only connection.

Wireless Technology

We have recently seen some marine wireless entries into the low-volume/data-transfer field, including Bluetooth, using short-range radio to communicate between compatible devices (each of which must include the necessary chip). Bluetooth has become popular enough to be incorporated into an international standard. It connects a wireless mouse and keyboard to a computer, wireless headphones to a stereo system, and so on.

A similar technology has been developed by Tacktick for a range of wireless, solar-powered boat instruments—for example, a masthead-mounted wind-speed and -direction sending unit that communicates wirelessly with a display device in the cockpit. It draws significantly less power than Bluetooth, while operating 16 times faster than NMEA 0183.

There is also WiFi and similar broadband (high-speed) wireless technologies found ashore that enable huge amounts of data to be transferred wirelessly over relatively short distances.

It remains to be seen whether or not wireless technology will become popular for transmission of critical data such as steering commands. There is always the fear that powerful outside interference, or other problems, will drown out the signals. —*N.C.*

in length. Analog sensors, such as voltage, current, or frequency, typically require 10 bits, or "addresses"; each bit constitutes an address. A recent installation on a 41′ (12.5m) powerboat uses about 600 address spaces, and, as a result, updates over 30 times a second. That includes AC and DC power monitoring, engine start and stop, an engine monitoring system, bilge controls, trim tabs, lighting, wipers, and other distributed-power functions.

It would be an interesting exercise to take the entire electrical system on a large yacht and see what the sample rate would be if it were fully configured to run on E-Plex. Bateman is confident that E-Plex can handle just about any boat. Julian Potter, manufacturing and engineering supervisor at Sealine, a British boatbuilder implementing E-Plex on the production line (Sealine calls it "SeaPlex"), noted that as boats get larger the number of devices does not go up exponentially. The engine bay, for example, has more or less the same number of "modules" over a broad range of boat sizes.

With NMEA 2000 and SmartCraft, the number of addresses is limited by the possible permutations of the address portion of the 29-bit identifier. With E-Plex there is no theoretical limit—it's just a matter of adding another address to the clock's address list. But, there is a practical limit inasmuch as each new address lengthens the time it takes the clock to cycle through all the addresses, and as such slows down the sampling rate.

The ED&D approach is proprietary, including the design of the clock, the software that runs the system, and the transceivers, which ED&D calls a "core." At the time of this writing,

Ethernet

When we get to really large data requirements, such as video, we are into the realm of Ethernet-based systems such as Furuno's NavNet, Northstar's N2, Garmin's MarineNet, and Raymarine's HSB2.

Ethernet, a protocol for high-speed communication, was invented by Robert Metcalfe at Xerox in 1976, but subsequently has become so popular that it is now an internationally regulated network technology. Data can be transmitted and received at a rate of 1,000 megabits per second through a network of up to 300′ (91m) between nodes/switches. NMEA 2000 can transmit and receive 250 Kb per second over 656′ (200m); SmartCraft, over 130′ (40m). Ethernet is 4,000 times faster. Ethernet does not have a distance limitation—provided there are hubs/switches every 300′, which is an advantage over CAN on large yachts and ships.

A major difference between CAN and Ethernet is the size of data packets. On CAN the data packets are relatively small, primarily the data from one sensor at a time, whereas Ethernet packets can contain hundreds or thousands of sensor data all within one packet. The result is greater efficiencies of transmission, with only one interrupt per packet of multiple data. In addition, the large packet sizes allow Ethernet to be less restrictive in terms of data format.

Ethernet also wins over CAN in the number of nodes it can support. A large yacht can have thousands of sensor points, while a large ship might have up to 50,000 sensor points. The large number of nodes and data packets fit easily within an Ethernet framework; however, the cost of adding the Ethernet chip at each device is higher.

As with NMEA 0183, Ethernet is *point to point* (see Part 1 of this series), which means a separate cable must be run from each sensor or device to the control panels. This returns us to the existing system of multiple parallel cables in a boat and consequent large wiring harnesses. These cables can be consolidated by running them into an intermediate hub, with one wire connecting the hub back to the panels, but that adds another device and more cost. Standard Ethernet hubs start at $20.

As with CAN-based messages, Ethernet protocol specifies a set of rules for constructing and sending messages. Ethernet has two forms of transmission: Universal Datagram Protocol, or UDP; and Transmission Control Protocol, or TCP. UDP messages are sent in a broadcast mode to all nodes, while TCP uses a specific address for transmission. With CAN, the microcontroller at each device interrogates the message to determine if it has data for its processor. With Ethernet, employing TCP communications, two devices form a direct peer-to-peer connection that guarantees data delivery.

In the event of a collision between two Ethernet messages, the two sending nodes back off and then retransmit the data after a randomly chosen delay period. The messages may collide again, or collide with another message, in which case the process is repeated. In theory, given the randomly generated delay periods, sooner or later (we are talking nanoseconds here) the messages will be timed such that no collisions occur and all get through. In UDP there is the potential for one or more messages to get lost, but not in TCP. However, Ethernet can sustain a maximum continuing utilization of only 30% before the performance of the network will begin to degrade. CAN, though, continues to operate flawlessly at 100% utilization.

Ethernet does not have the same capability as CAN to take offline a defective node that is outputting junk. In fact, a node can send a stream of junk that will block all other nodes from sending and receiving messages. As with CAN, the physical layer is highly variable from application to application. In a home office, it is not very rugged. But, cables and connectors can be purchased to meet very demanding physical needs, including waterproof connections and waterproof hubs/switches. Ethernet has been used quite successfully in manufacturing facilities that are wet, dirty, and electrically noisy.

When it comes to high-volume data flows, such as those generated by many modern radars and chart plotters, or by high-resolution video (such as from closed-circuit TV), Ethernet provides an extremely cost-effective network. On larger boats and superyachts, which may have full-scale office-style networks that integrate several computers, printers, scanners, and other devices with shipboard electronics and a mass of data input sensors, Ethernet has become the predominant networking technology, including for relatively low-volume, monitoring, alarm, and control circuits. A good example is provided by the SiMON (Ship's Information Monitoring System) from Palladium Technologies.

—*N.C.*

the transceivers had not yet been miniaturized into a chip [ASIC], but instead are built on a printed circuit board. Once a system is set up and the clock programmed, if any module fails and is replaced, the clock will program a replacement module for the specific application. In other words, in terms of switching-out parts, this is plug and play. At the planning stage for a given system, if future needs can be identified, these needs can be built into the software, which will require no further adjustment when the additional equipment is installed. Otherwise, additions to, or deletions from, the bus require reprogramming via a personal computer. E-Plex includes a highly intuitive software package called "E-Logic" that greatly simplifies this process and that adds considerable value in terms of the ability of an end user to customize a system (more on this in Part 3 of the series). Nevertheless, it is not a fully plug-and-play system in the sense of NMEA 2000.

In terms of the physical layer, E-Plex uses a single twisted-pair bus with the data signals running on the power cables (in contrast to NMEA 2000, with its five cables, and SmartCraft, with its up to three twisted-pair buses plus power cables). As opposed to a CAN-based system, in which the backbone must be installed in a linear fashion with a resistor at each end, the E-Plex backbone can be installed in any fashion—a linear and/or a "star" pattern (a central connection point with cables branching out)—with a single resistor somewhere in the system, and individual "branches" up to 500′ (152m) in length. Sealine's "clock" has connections for four branches; the company uses three of these at the present time, with one bus going forward, one aft, and one to the bridge.

ED&D exercises no control over the physical layer, its installation, or connections to it. Connections can be made by splicing in at any point. That makes the installation side much more economical than NMEA 2000 (and also more economical than SmartCraft) but makes it more likely that poor installations will result in poor performance that negatively impact the system. It's up to the installer to see that the job is done right.

The data bus on CAN-based systems is typically operating on plus or minus 1.5V, resulting in a 3.0V swing (from 1.5V to –1.5V); since ED&D is sending the data signals down the power bus, it is operating at battery voltage—that is, a 12.0V swing (from 0.0V to +12.0V) on a 12V system, and a 24.0V swing on a 24V system. The greater the swing, the easier it is for devices on the bus to distinguish between a true signal and "noise" or interference of various kinds. Dave Bateman claims that the high swing on the E-Plex bus makes it possible to achieve reliable communications with less RFI suppression, and therefore lower cost.

Individual physical connections to the bus will draw from a low of 15 mA to a high of 1 amp. The E-Plex clock is current-limited to 3 amps, which means the maximum number of physical connections is 200 (3 amps/15 mA), and will likely be considerably lower than this. But, as

Networking Technology and the ABYC

Over the past 50 years, the American Boat & Yacht Council (Edgewater, Maryland) has carved out a preeminent role for itself as the principal standards-writing body for the recreational boating industry. Its standards-writing process is based upon Project Technical Committees, or PTCs—composed of dedicated volunteers, and coordinated by ABYC staff. It is these committees that have dealt with evolving technology, and changing public concerns regarding safety, in a manner that has served both the industry and the boating public well. Perhaps the best testament to this is that when the Europeans decided, not long ago, to get into the recreational-boating standards-writing business themselves, the ABYC's standards were selected as the model and starting point.

Right now, the rapid introduction of three new technologies is confronting the Electrical PTC:

1. Cogeneration, meaning the ability of inverters and other AC power-supply and conditioning devices to parallel themselves with shore power or onboard generators. (Parallel operation is presently not allowed under ABYC standards.)

2. The introduction of high-voltage DC electric motors and propulsion systems. Some will operate on DC voltages up to 800 volts. (The present DC standard covers applications only to 50 volts.)

3. The use of electronic devices for DC and AC power distribution and circuit overload protection. (The existing standards presuppose traditional air-gap-type technology.)

The third item on the list above is especially challenging. Why? Because it is now possible to combine traditional fuse and circuit-breaker technology with electronic circuit-control devices in a way that passes all present ABYC standards for branch-circuit protection—and yet the equipment is vulnerable to failures from sources never envisioned by the ABYC. Consider that, in one case, the electronic circuit breakers on a boat were randomly turning on and off at erratic intervals. It was eventually determined that a defective battery installation kept intermittently dropping the voltage on the DC system below the minimum 5.0 volts required to keep the electronic circuits functional. In another case, random operation of circuit control devices was attributed to high radio-frequency interference from a radar and single-sideband installation.

The latter situation ties directly into the intense debate over what kind of shielding is required for data cables (control cables) in networked electronics and power distribution systems. Based on assumptions derived from the automotive field, and other assumptions about boat usage, plus some testing, under the NMEA 2000 protocol, of unshielded cable (and bombarding it with electric field strengths of 50 volts per meter), Rich Gauer of Maretron—a proponent of the NMEA's conservative physical layer—writes: "Once we have a hundred thousand boats with these systems using unshielded cable, then every seven minutes a boat somewhere will experience an undetected error: inadvertent transmission shift, a breaker turning 'on' or 'off,' a windlass or winch turning 'on' or 'off,' an inadvertent alarm, a throttle glitch, a steering glitch, and the like. Is this acceptable?"

Gauer's comments raise a number of complex issues for a standards-writing organization such as the ABYC. For instance, do electric fields of this strength occur on boats? What is an acceptable undetected error rate? How is it calculated? Does the acceptable error rate vary according to how safety-critical an application is? What, if any, language and/or test requirements in the ABYC standards are necessary to address these issues? Gauer reports that the automotive industry requires safety-critical systems (throttle controls, say) to be tested to 60 volts per meter, while some applications are routinely tested to 100 volts per meter. Perhaps the ABYC should adopt similar language.

This is just one example of several emerging areas of concern, raised by the new technologies, that need to be addressed. The challenge is to adapt existing ABYC standards in a way that will continue to protect and enhance the safety of the boating public without creating unnecessary obstacles to the development and implementation of those very technologies, and to do so in a timely manner. It will take the active participation of industry professionals in the standards-writing process—precisely when most of them are working long hours to refine their own products while battling for market share.

The ABYC Electrical PTC recently created several ad-hoc subcommittees to look into these matters and bring proposals back to the PTC. Those companies in the forefront of product development must get involved to ensure that the necessary questions get asked. In so doing, they will help establish a level and consistent standards-based playing field for the introduction of these critical new technologies, which can only benefit manufacturers and consumers alike.

Having personally observed the Electrical PTC for more than 15 years, I know it can rise to the occasion. And when it does, the recreational marine industry as a whole should give the committee the technical support and resources it needs to fulfill its mission.

—N.C.

with CAN, each connection can include multiple addresses.

E-Plex has several layers of error protection. Matt Bush, ED&D's lead programmer, reports, "Given the bus's high degree of noise immunity [as a result of the high voltage swing], a typical system will run for hours without generating a single data error. Any time an error is generated, all modules throw away the data just received and prepare to retransmit. Even if the bus was generating one data error a second, if the update rate was 30 times a second, this would just drop to 29 times a second."

Non-CAN Approaches: Victron's VE.Net

As with ED&D, Victron's focus is on power distribution rather than engine control or navigation. Additionally, Reinout Vader, the founder of Victron, is a sailboat owner who is particularly interested in boats with intermittent generating sources, and which therefore need to minimize the load on the DC system. Matthijs Vader, Victron's principal systems designer, notes that although "CAN is a beautiful network...that is very suitable for navigational integration," it requires more power to operate than is necessary for a distributed-power system. "Since CAN is a network that has been designed for cars, which have short cable runs and power from an alternator always available, this is not a real surprise."

On a boat, the power-distribution network will often be in use when there is no generating source online, including when the boat is anchored or in harbor. So, the network must be designed to minimize energy overhead. As opposed to a navigational system, which will have a limited number of devices, the power distribution system will include a large number of sensors and devices—quite possibly hundreds on a larger boat. As the number of devices on a network rises, and thus the total electrical load, the network cabling must be increased in size to handle the load, which drives up the cost. A difference of a few milliamps per connection can make a significant difference in both the overall energy consumption *and* the cost of installation.

All of which raises some interesting considerations that do not seem to have caught the attention of other systems designers. Traditional circuit-breaker and fuse technology imposes no energy overhead on a boat, except in cases where distribution panels include LED annunciators. Distributed-power systems, however, require energy to power up the chips at each node, and to operate the display screen if this is the mechanism used to control the system. (Some low-end systems employ keypads with minimal energy consumption.) The load occurs whether or not a device is turned "on" or "off"; it is a constant parasitic load that comes with the technology. When a traditional circuit breaker is in the "on" state, there is still no energy cost in terms of operating the breaker (assuming no voltage drop through the breaker), whereas the switching devices used in electronic circuit breakers create some power loss that is dissipated as heat. All in all, a distributed-power system on a moderately complex boat could easily draw 1 to 3 amps at 12V continuously. For an energy-conscious boat owner, those values represent a significant overhead.

Victron's VE.Net starts from the following premises: power consumption is related to data speed of transmission; and mission-critical data need to move in near real-time, but some, such as voltage displays, do not. Victron's approach is to use the lowest data speed possible, combined with the ability to send data at different speeds so that where high speed is necessary it can be accommodated, albeit with higher energy consumption. To this end, Victron has developed a variable-speed system that ranges from 9,600 bps to 115 Kbps.

This is a master/slave system. On startup, if two or more nodes transmit at the same time, resulting in collisions, then each backs off and retransmits at a random interval until no collision occurs. (Ethernet transmits in a similar fashion—see the sidebar on page 66.) The node with the highest processing power now becomes the master. After the initial exchange, the master takes over, sampling all the nodes in a sequence that varies according to priority needs (some nodes get sampled more often than others), and with the speed varying according to the speed of the node being sampled. This avoids further collisions. Nodes can communicate directly with one another, with the master controlling their time on the bus, but to do so an addressing system is needed based on a 32-bit identifier. The addressing system drives up the content of messages during the initial contact phase and, as a result, slows down the message rate. However, messages are sent only on an as-needed basis, which keeps down the message volume—as opposed to E-Plex's cycling through all addresses at each cycle. There is no message prioritization.

As with CAN-based systems, the backbone has two power cables and two data cables. When the voltage on one data cable is higher than the other, it signifies a "1," and when the second is higher, a "0." (This is also how CAN operates.) The microprocessors in the nodes synchronize on the slopes—that is, when the voltages cross. Any transient voltage spikes tend to occur on both cables, so the higher one remains higher, making the system relatively immune to interference.

Up to 256 nodes can be connected to the net. The maximum length of the net is 500m (1,600′).

Aside from the chips at each node, the single biggest load on a distributed-power system is likely to be the screen (or screens) used for command and control. This load will vary according to screen size and display technology. Victron minimizes it by the inclusion of a "sleep" mode that kicks in if no activity takes place for a given length of time.

Victron has concentrated on minimizing the installation cost by utilizing commonly available RJ 45 connectors, and—as with NMEA 2000 and E-Plex—ensuring that the installation can be done by regular boatyard workers rather than requiring expensive networking professionals. VE.Net has interfaces to NMEA 2000, Ethernet, and other systems in order to be able to create a fully integrated "tiered" networking approach on boats of any size.

A phased rollout of components necessary for a whole-boat VE.Net began in 2005.

The Tiered Approach

It would seem that in a perfect world the entire marine industry would embrace a single networking standard with a plug-and-play capability, such as NMEA 2000. Boatbuilders and boat owners would be able to buy any networked electronic equipment or digital-switching (power distribution) device they wanted and simply plug it into the system via a drop cable and network T.

But, because of the different benefits and drawbacks of one approach over another—cost, bandwidth, power consumption, reliability, ease of installation, redundancy, protection for mission-critical functions—a case can be made for what is known as a tiered approach. The most cost-effective setup is applied to a given subsystem—for example, a CAN-based propulsion control system, Ethernet for large-volume navigational data, and a non-CAN-based distributed-power system—and then the various systems are interfaced such that data can be shared, and command and control can take place from common display screens.

We are already seeing the development of interface boxes (referred to as "bridges" and "gateways") that can take the messages and data streams created by one system and translate them into the language of another system, enabling a fair amount of communication between systems. For example, an engine and its controls can be operating on the SmartCraft system, with the boat's navigational electronics using both NMEA 2000 and Ethernet, and the remotely operated circuit switches controlled by E-Plex (or perhaps the EmpirBus variant of CAN that is now being installed by a number of boatbuilders in Europe, or the Carling/Moritz variant that is starting to be deployed in the U.S.). Among them, these four systems will have literally dozens of sensors providing data that is initially inaccessible between systems. With appropriate bridges and gateways, most of the information can be made accessible to all four systems. With careful design, the redundant cabling and redundant systems can be minimized.

One way or another, the three- (or four- or five-) cable boat is close to being a reality, although it is not at all clear which particular networking variants are likely to come out on top in the shakeout that is just beginning to occur. PBB

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See* SOURCE LIST *on the following pages.

Source List of Companies Mentioned in the Text

Bluetooth SIG
7300 College Blvd., Suite 200
Overland Park, KS 66210 USA
Tel. 913-317-4700
www.bluetooth.com

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DSS
(Digital Switching Systems)
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www.dnagroup.com

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Lisle, IL 60532-1682 USA
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www.motc[illegible]on.com

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Acton, MA 01720 USA
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SmartCraft. See **Mercury Marine**

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Steering System Fundamentals

Part 1: Design and installation considerations for determining rudder shape, area, aspect ratio, and thickness.

Text, photos, and drawings by Dave Gerr
(except where noted)

Rudders, and the steering systems that control them, literally enable a boat to get where it's going. Crisp, responsive steering in all conditions and at all speeds makes a vessel a pleasure to operate. Poor steering response (or, worse, a broken steering system) is not merely unpleasant; it's potentially dangerous. Here, we'll discuss the basics of rudders and steering systems for inboard-powered boats, both power and sail. We'll also review some important considerations that are often neglected. And, we'll look at a few special, or unusual, rudders.

Putting the Rudder to Work

Fundamentally, a rudder is no more than a board hung aft on the centerline of a boat and free to pivot on hinges, called **gudgeons** and **pintles**, along the leading edge; or around a roughly vertical shaft, called the **rudderpost** or **rudderstock**. (On modern twin-screw craft, the rudders are hung on rudderstocks just aft of each propeller.)

If we deflect the rudder blade of a boat to one side—to port, say—we increase the force of the water hitting the port, or left, side of the rudder, which in turn swings the boat's entire stern in the opposite direction, to the right, or starboard. Since we've used the force of water flowing past the rudder to kick the stern around to starboard, the bow has now been swung to port, and off we'll go to port—presumably what we had in mind when we put the helm over in the first place.

Describing the Rudder and Aspect Ratio

Since rudders come in many shapes and sizes, designers have adopted some airplane terminology to help describe them accurately (**Figure 1**). The depth, or vertical height, of a rudder is called its **span**. (Span is always measured vertically, not along the length of an angled, or swept-back, rudder.) The fore-and-aft length of the rudder is referred to as its **chord**. Designers tend to visualize airplane wings (or hydrofoils—like rudders or keels)—as growing out of the fuselage (or hull); this is, after all, where they are attached. Accordingly,

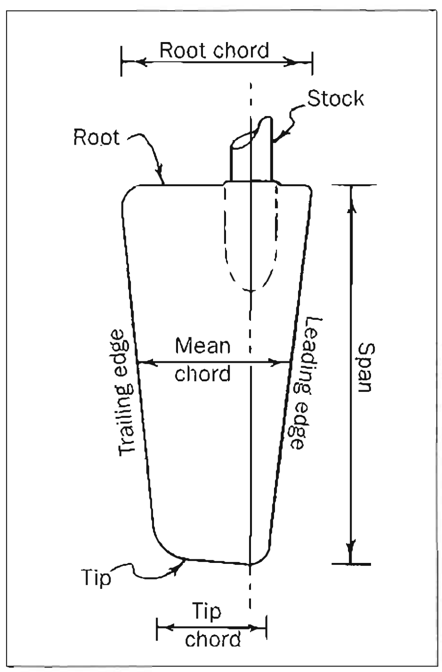

***Figure 1**—Rudder plan geometry.*

the top of the rudder, near the hull underbody, is known as the **root**; and the fore-and-aft length here is the **root chord**. Similarly, the bottom end of the rudder—farthest from the hull—is named the **tip**; and the fore-and-aft length at this location is the **tip chord**. The average rudder length, fore and aft, is called the **mean chord,** or the **midchord**, as it's usually at or near midspan (mid-height).

All hydrofoils (and rudders are really hydrofoils, not simply boards) are more efficient if they are long and narrow rather than short and squat. It's important to be able to describe this feature clearly; the measurement is **aspect ratio**.

$$\text{Aspect Ratio} = \frac{(\text{Span})^2}{\text{Area}}$$

Where:
Span = vertical height of rudder blade in feet or meters
Area = area of rudder blade in square feet or square meters

(Note: this is sometimes referred to as the "geometric aspect ratio"; in many cases, the "mirroring" effect of the hull above the rudder roughly doubles the "effective aspect ratio.")

The higher the aspect ratio, the deeper and narrower the rudder. To quickly estimate the area of the rudder, just measure its chord (fore-and-aft length) at midspan (height), and multiply by the span at midchord (the average height).

If a boat's rudder has an area of 1.9 sq ft ($0.176m^2$) and an average height, or span, of 2.1′ (0.64m), its aspect ratio would be 2.32 to 1, or simply 2.32 (2.1′ x 2.1′ ÷ 1.9 sq ft = 2.32:1, or 0.64m x 0.64m ÷ $0.176m^2$ = 2.32:1). This is a good, deep, narrow rudder for a powerboat. An aspect ratio higher than 2.4 or so gives a still more efficient rudder blade, but adds excessive bending strain on the rudderstock. Such very high aspect ratios should generally be avoided on powerboats.

Sailboat Rudder Aspect Ratio

Aspect ratios on sailboats are somewhat higher than those on powerboats. An aspect ratio between 2.2 and 3.5 is normal, tending higher for spade rudders on fin-keel boats. Very high aspect rudders are becoming common on performance sailboats with high aspect fin keels. Such craft often have rudders with aspect ratios between 3.5 and 4.5. Higher aspect rudders are found on certain all-out raceboats. Generally, I don't recommend aspect ratios over 4.5 as good practice, because the bending loads on the deep rudder's stock are so much higher, with increasingly less improvement in rudder response.

Rudder and Hull Work Together

In turning, a boat essentially pivots around its combined center of gravity and the center of water pressure on the hull forward. The greater the distance the rudder is aft of this combined center, the greater the lever arm it has with which to twist the boat around. For the same steering effect, a smaller rudder can be used, provided it is farther aft. Similarly, a boat with a deep forefoot or a steering fin forward responds more quickly to the helm than a boat without those features. That isn't of much importance on average craft, which generally have fairly good proportions for the purpose. However, long, shallow hulls and/or very high-speed, shallow-bodied planing hulls sometimes benefit from the addition of a small, fixed steering (or so-called skid) fin forward, about amidships.

Sizing and Locating the Skid Fin

The designer has to be very careful not to overdo the size of a skid fin, as too much area forward makes a boat too quick on the helm. In rough seas, such a fin could broach a boat or cause it to trip over the forward fin and capsize. A rule of thumb is that the skid fin—when one is required at all—should be placed about 10% to 15% of the length of the waterline forward of the center of gravity, and that the area of the skid fin should be about 80% of the rudder area. (If you have no exact information, you can assume that the center of gravity of a high-speed planing hull is about 60% of the waterline length aft of the bow at the waterline.)

Aspect Ratio, Rudder Area, and Banking

A less well-known consideration of rudder design is that rudder aspect ratio affects how a boat banks in a turn. When you put the helm over for a hard turn at high speed, centrifugal force acts on the boat's center of gravity, pulling outward. Because the center of gravity of almost all planing hulls—in fact, of most boats of any type—is well above the waterline, the boat tends to heel outward in a turn. The outward bank is uncomfortable, and decreasing it or getting an inward bank is ideal. The force of water pressure on the underside of a planing hull's outboard chine counteracts outward heel considerably, but the water force acting on the rudder helps as well (**Figure 2**). The deeper the rudder, the greater its aspect ratio; and the more area it has, the more effective it is in generating a sure-footed inward bank.

Types of Rudders

Rudders come in two basic types: inboard rudders that are mounted entirely under the hull, and outboard rudders (**Figure 3**) that are hung on the transom and thus project aft of the hull proper. These may each be divided again into balanced and unbalanced rudders. A balanced rudder has some of its area forward of its

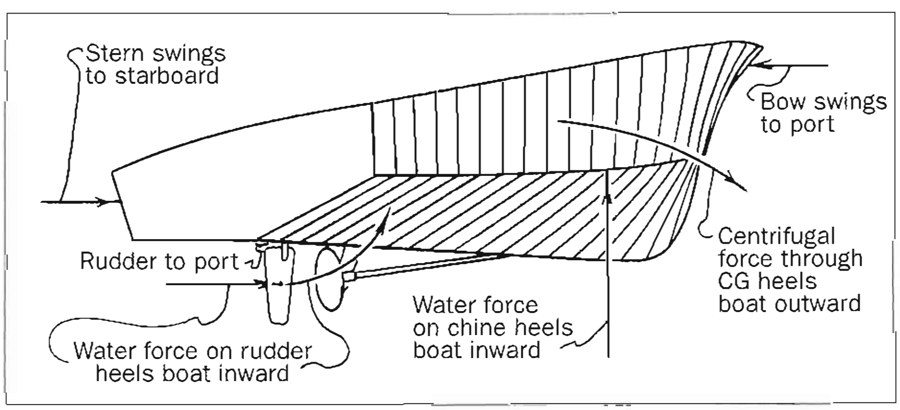

***Figure 2**—Forces from a turn to port.*

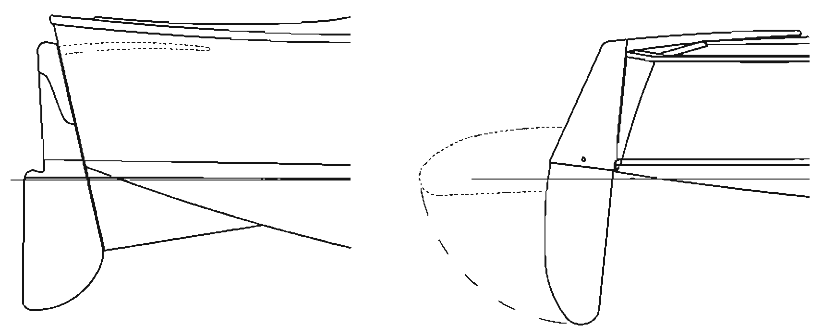

***Figure 3**—Sailboat outboard rudders.*

pivot, or turning axis, point, whereas an unbalanced rudder pivots, or hinges, entirely at its leading edge, with no area projecting forward at all. Finally, rudders may be spade rudders, with no bearing or support below the bottom of the rudder blade, or they may be rudders with bearings above and below the rudder blade.

Inboard vs. Outboard Rudders

For the same rudder shape and area, an inboard rudder is almost always more efficient than an outboard rudder. The hull traps the water rushing over the top portion of the blade, guiding the entire flow aft and forcing that water to do useful steering work. This is the important endplate effect, and it reduces induced drag, which is nothing more than the wasted energy caused by water roiling around the top or bottom edges of a hydrofoil. Often, high-speed craft fitted with outboard rudders will have endplates (sometimes incorrectly called cavitation plates) fastened to them at the waterline, or at the rudder's top. The proper term is either *endplate* or *ventilation plate*. These plates help noticeably, but such rudders are still not quite as efficient as a true inboard rudder.

The great advantage of outboard rudders—at least for larger rudders in low- to medium-speed craft—is their simplicity. It's comparatively inexpensive to attach the gudgeons and pintles outside the hull on the transom, and to run the tiller to steering gear far above the waterline, where watertightness isn't a big consideration. By contrast, an inboard rudder usually requires a rudderport and stuffing box through the bottom of the hull—a potential source of leaks that should be inspected at the beginning and end of each season, and before and after any major passage. Moreover, the outboard rudder allows the propeller to be installed farther aft, which permits the shaft angle to be slightly lower (closer to parallel with the waterline) for slightly more efficient thrust. Outboard rudders on smaller planing hulls are available with premanufactured housings containing the tiller arm. The entire housing bolts to the bottom of the transom, with the tiller projecting through a hole forward into the hull.

Balance and the Rudder

Balanced rudders move the center of water pressure—the force of the water striking the rudder blade itself—closer to the rudder's pivot axis than it would be on an unbalanced blade. Maximum water pressure occurs at maximum helm, or rudder, angle, which is about 35° to either side of dead center—70° hard over to hard over. (At greater angles, ordinary rudders stall, lose effectiveness, and are strained by excessive water pressure. Internal stops should be fitted to keep rudders from turning farther.)

Because the water is striking the rudder blade from ahead, the leading edge does more work than the trailing edge. (This is true of all hydrofoils and of airfoils as well.) Accordingly, the center of water pressure doesn't fall at the geometric center of the rudder blade as viewed from the side, but at some point forward of this. In fact, although the position of the center of pressure moves around with changes of rudder angle, it usually falls somewhere between 30% to 40% of the fore-and-aft length of the rudder—the chord—aft of the leading edge, at a maximum 35° of helm.

If you're working on a project where you need to estimate the location of the center of pressure at angles other than the maximum 35°, you can use the following approximate formula:

Pressure Location in % of Mean Chord Aft of Leading Edge = 0.18 + 0.305 sine (rudder angle, degrees)

That will give you a passable approximation for rudders of normal airfoil section shape for angles up to 40%. For wedge-section and parabolic rudders, add 14% to the result above.

If the boat's rudder has a span—vertical height—of, say, 2.1′ (0.64m) and a mean chord of 0.9′ (274mm), then the center of water pressure would fall about 35% of the chord aft of the leading edge, or 0.31′ (96mm) aft. The unbalanced rudder—at a water pressure of 985 lbs (447 kg)—would thus generate a torque (a force times a lever arm) of 305 ft lbs—0.31′ x 985 lbs = 305 ft lbs, or 0.096m x 447 kg = 42.9 kgm.

If we fit this boat with a rudder of the same area and proportions, but with a 17% balance (**Figure 4**), then the pivot point will be farther aft and closer to the center of pressure. In this case, just about 0.07′ (21mm) away. The balanced rudder will generate a torque of just 69 ft lbs (9.4 kgm)—440% less! That results in much

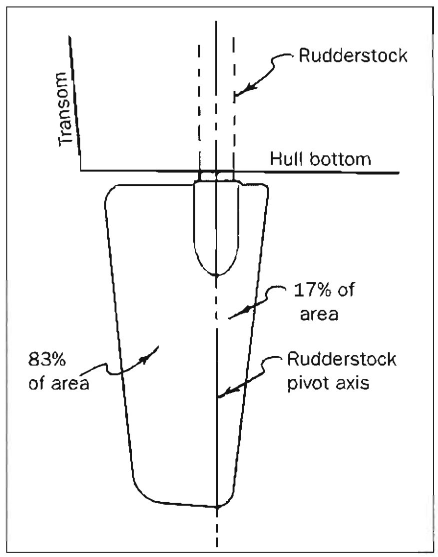

***Figure 4**—Sailboat rudder with 17% balance and 2.32:1 aspect ratio.*

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easier steering and lighter loads on the steering gear, autopilot, and—not incidentally—on the helmsman.

Balance is determined by the percentage of rudder area forward and aft of the rudderpost axis. The drawing shows a rudder with 17% balance, which years of trial and error have demonstrated to be about ideal. Twenty-percent balance is usually the absolute maximum. More balance than this can move the center of water pressure ahead of the pivot axis, making the rudder shear wildly or lock up at hard over, causing uncomfortable (or even dangerous) steering.

Balanced rudders should not be installed directly behind a skeg or keel. Since the leading edge projects out from the hull centerline when the rudder is turned, such a balanced rudder would catch the water flow on the leading-edge side. That creates unwanted turbulence. For powerboats and for racing sailboats with spade rudders, the advantage of a lighter and more responsive helm makes the balanced rudder hard to beat. For cruising sailboats, though, an unbalanced rudder with a skeg or keel immediately ahead of it offers less resistance and smoother water flow to the rudder.

Real-World Problem With Too Much Balance

An interesting example of a real problem created by too much balance is depicted in **Figure 5**. This boat came into the service yard for repairs to the running gear after grounding; the yard noted the sizable trim tab you see bolted to the rudder. The owner was asked: Was the tab bent, or straight? The owner thought it had been straight. Once repaired and relaunched, this boat steered so strongly to port that it was unmanageable. Hauling the boat again (and with a bit of experimentation), the yard bent the trim tab 10° to port—and then the steering was fine. The boat's builder, not the service yard, had built in the steering problem, and had "corrected" for it by adding the tab and bending it over.

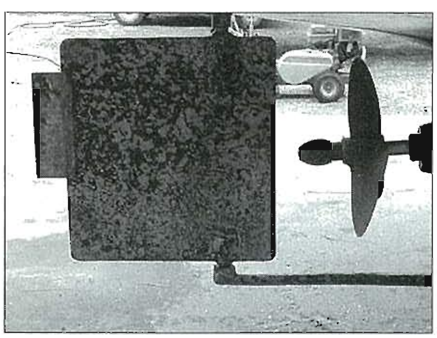

***Figure 5**—After a grounding, the trim tab on this rudder was set straight, causing the boat to steer strongly to port. The boat was hauled, and the problem solved by bending the trim tab 10° to port.*

Looking at the photo, you can see the reason: there's too much balance (about 25%). A portion of the slipstream from the prop was catching the leading edge of the rudder in such a way that it swung the blade to port, which would have made the boat turn to port. Bending the tab to port counteracts the turning effect on the rudder, forcing the blade to starboard—back to center, or neutral. In theory, you could also correct this effect through fairing away the leading edge by grinding down some of the starboard side of the rudder at the leading edge, or bending the leading edge of the rudder blade to starboard slightly. In any case, you can see why it's important not to have too much balance, and how you might correct the problem if faced with it.

(Incidentally, note also that there's too much shaft overhang between the propeller and the stern bearing, and that the propeller-nut zinc is too big, which can cause turbulence. There's also no shaft-pulling hole in the rudder, so the entire rudder, and probably the skeg below it, would have to be unshipped to remove the propeller shaft.)

Sizing Up the Rudder

The big question regarding rudders is just how big they should be. The smaller the rudder, the less drag it creates and the faster the boat can go. Also, smaller rudders require less steering force and are easier to manage. If the rudder is too small, though, you'll end up with insufficient steering control. Somehow, a happy medium has to be found.

Rule-of-Thumb Rudder Area

Basic rule-of-thumb rudder area formulas are as follows:

Average Planing Boat Rudder Area = 0.018 x Waterline Length x Draft (hull only)

Semidisplacement Boat Rudder Area = 0.04 x Waterline Length x Draft (hull only)

Displacement Boat Rudder Area = 0.08 x Waterline Length x Draft (hull and skeg or keel)

Sailboats With Deep, Narrow Fin-Keels = 0.045 x Waterline Length x Draft (including keel)

Sailboats With Moderate (Modern, Long) Keels = 0.058 x Waterline Length x Draft (including keel)

Sailboats With Traditional Full, Long Keels = 0.068 x Waterline Length x Draft (including keel)

Powerboat Rudder Area Formula

For powerboats, rudder area is more accurately found from a variation of Skene's formula:

Total Rudder Area:

$$K = (\text{WL, ft})^{1.5} \div 50$$

$$\text{Area} = K\sqrt{\frac{\sqrt{\text{WL, ft}} \times \text{Disp., tons}}{100 \times \text{kts} \times (0.01\ \text{WL, ft})^3}}$$

or

$$Km = (\text{WL, m})^{1.5} \div 90.56$$

$$\text{Area} = Km\sqrt{\frac{\sqrt{\text{WL, m}} \times \text{Disp., tons}}{55.2 \times \text{kts} \times (0.0328\ \text{WL, m})^3}}$$

Where:

kts = maximum speed in knots

A twin-screw planing 75′ (22.8m) motoryacht, 66.34′ (20.22m) WL and 77.86 tons, would work out as shown in the boxed formulas below:

$$K = (66.34'\ \text{WL})^{1.5} \div 50 = 10.81$$

$$\text{Area} = 10.81\sqrt{\frac{\sqrt{66.34'\ \text{WL}} \times 77.85\ \text{tons, Disp.}}{100 \times 28\ \text{kts} \times (0.01 \times 66.34'\ \text{WL})^3}} = 9.52\ \text{sq ft}$$

$$Km = (20.22\text{m WL})^{1.5} \div 90.56 = 1.004$$

$$\text{Area} = 1.004\sqrt{\frac{\sqrt{20.22\text{m}}\ \text{WL} \times 77.85\ \text{tons, Disp.}}{55.2 \times 28\ \text{kts} \times (0.0328 \times 20.22\text{m WL})^3}} = 0.885\text{m}^2$$

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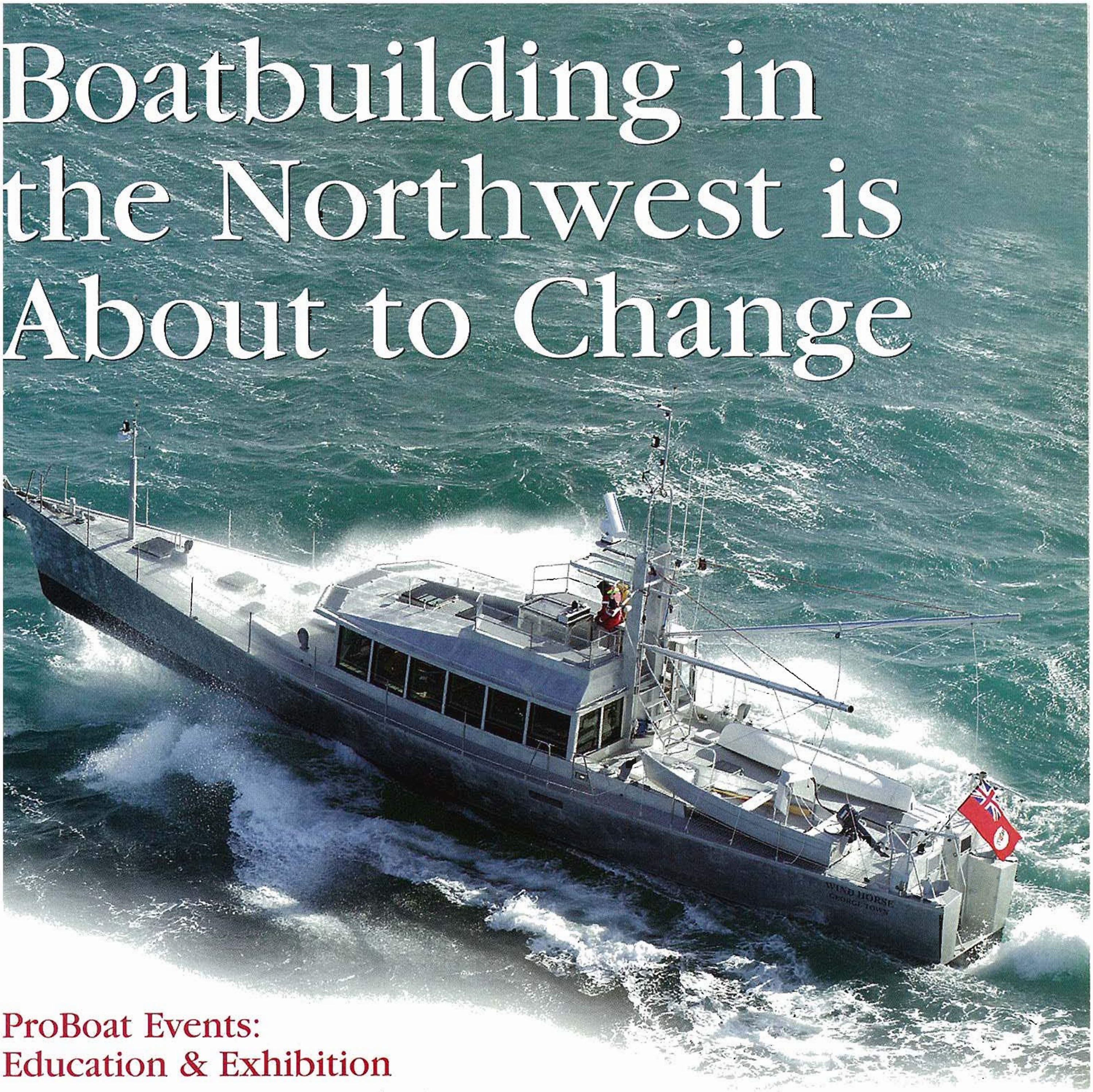

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Because this is a twin-screw boat, it has two rudders (one behind each prop), and each rudder would have 4.76 sq ft (44.25m^2) area, or a bit more.

The rule of thumb for planing hulls is that the total rudder area (all rudders) should be 2% of lateral plane.

For displacement motor cruisers, the rule of thumb is between 3% and 4% of lateral plane.

These rules of thumb should be used only as a check against your calculations, so apply the formula.

Note that additional rudder area doesn't harm maneuvering, but it does add extra appendage drag and extra cost in bigger steering gear. It doesn't make sense to use rudders much larger than required; however, boats that will do a lot of low-speed maneuvering would do well with 10% to 15% more area than indicated in the formula. Sportfishing boats and ferries fall into this category. For such craft there's some penalty in extra drag, but the quicker helm response at low speed will be worth it.

Sailboat Rudder Area

For sailboats, rudder area should be between 8% and 10% of total lateral plane, or LP. The higher the aspect ratio and the farther aft the rudder, the lower the required area. Thus, if the rudderpost is at, say, station 10 (at the aft end of the waterline) and the rudder is deep and high aspect, you could even get sufficient steering response with 6% or 7% of lateral plane area (on a fin-keel boat).

Sailboat Rudders as Directional Stabilizing Fins

Though reducing the wetted surface with such a high aspect rudder well aft would seem to make sense, it's seldom a good idea. This is because rudders on fin-keel sailboats perform a second function: they act as directional stabilizer fins, similar to the feathers on the trailing end of an arrow.

Common belief has it that sailboats with deep, narrow (high aspect) fin keels don't hold course well, and that longer keels are needed for good directional stability. In fact, a high-aspect balanced spade rudder of sufficient area damps out, or stabilizes, directional oscillations well, and can make a high-aspect fin-keel boat quite steady on the helm (though not as steady as a traditional long-keel design would be). For this reason, I usually use 9% of total lateral plane on all sailboats.

Indeed, with very high-aspect fin keels, the rudder plays an additional, critical role in resisting leeway; a rudder area of 10% of LP can give better upwind performance and better directional stability. The result: a steadier helm.

Skegs on Sailboat Rudders

Sailboats with separate fin keels can have balanced spade rudders or unbalanced rudders on skegs. If the rudder is on a skeg, up to 12% of the rudder area can be assumed to be in the skeg. Thus, if you need 10 sq ft (0.9m^2) of rudder area (to get 9% of lateral plane), 12% of that 10 sq ft (1.2 sq ft or 0.1m^2) could be counted as being in the skeg. If the skeg is larger, that's fine. The skeg will improve directional stability and further protect and strengthen the rudder. But the additional area (over 12% of the desired rudder area) should not be counted toward the effective rudder area.

If the skeg gets very large—80% of rudder area or more—then this is closer to a rudder hung off the back of a traditional long keel, and none of the skeg area should be counted as rudder area.

The Rudder in Cross-Section

There's a tendency to think of the rudder cross-section (rudder sections) as being a classic airfoil shape—a rounded entry, maximum width about 30% of chord abaft the leading edge, and a gently convex trailing section terminating at a point. In fact, for sailboats and for displacement power cruisers, this is the ideal standard section shape. As vessels become faster, though, that section becomes less effective. Above 25 or 30 knots, the blunt, rounded leading edge of traditional airfoil sections causes too much turbulence in front of the rudder.

At high speed, when the rudder is put over, the blunt leading edge virtually tears the water flow away from the blade, leaving a swirl of eddies along the blade surface. Such turbulent flow generates very little force or lift, and is, in fact, a stall, just like the stalling of an airplane wing in too steep a climb. Accordingly, as boat speed increases, the leading edge of the rudder should be made sharper and sharper, and the point of maximum section width moved aft.

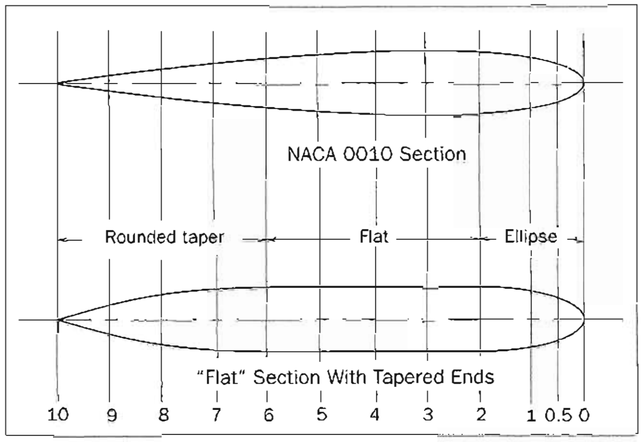


***Figure 6**—Low-speed rudder sections.*

Airfoil Rudder Sections—Low to Medium Speed

Typical sections that perform well for rudders on sailboats and on displacement and medium-speed powerboats (up to about 18 knots) are shown in **Figure 6**.

There is a variety of suitable airfoil sections for rudders, but the NACA 0010 section, pictured, works well. (The table "Foil-Thickness Form Dimensions," page 87, gives the proportionate half-breadths at various locations along the length—i.e., along the section's chord.) Such a section has the theoretical minimum drag and

NACA Foil Sections

Objects designed to optimize lift in fluid flow (a gas or a liquid) are termed *foils*. This is the same as for an airplane wing, and the standard source for rudder- and keel-foil section shapes is the work of NACA—the National Advisory Committee for Aeronautics. (NACA was subsequently replaced by NASA.) The complete selection of NACA foils can be found in *Theory of Wing Sections*, by Ira H. Abbott and Albert E. von Doenhoff, published by McGraw-Hill (1949, 1959) and later reissued by Dover Publications (1980).

—*Dave Gerr*

highest lift in this type of application. Because these rudders are used on low-speed craft, the additional drag of a fat rudderstock (wider than the rudder-blade section) would be unacceptable. Accordingly, if the rudderstock has to be thicker than you can fit inside the 0010 section, make the section proportionally thicker by multiplying the widths at each station, by the required factor. For instance, if the 0010 section was 30″ (76cm) long (chord), the maximum width (thickness) at 17% chord would be about 2.76″ (69mm). The rudderstock, to be completely inside the blade, would have to be no more than about 2.25″ (55mm) diameter. You may, however, need a larger diameter. For example, say your calculations (see below) indicate you need a 2¾″ (70mm) stock; then the rudder blade should be about 3¼″ (81mm) thick at the stock—at 17% chord.

3.25″ ÷ 2.76″ chord = 1.17
or
81mm ÷ 69mm chord = 1.17
and
10% x 1.17 = 11.7%

Thus, you need to multiply all the section half-breadths (and the tip radius) by 1.17. The "10" in the "0010" means the basic section is a 10% width section. You'd end up, in this case, with an 11.7% width section, or a NACA 10-11.7 section. The fatter section will have more form drag than the 10% section; however, it will have less drag than the 10% section with a rudderstock projecting outside of it.

Flat Sections With Tapered Ends

Much is made of the "optimum" airfoil section. Such airfoil sections are best when budget and construction method permit. The fact is, a simple flat section (wide or thick enough to completely house the rudderstock) with the forward end rounded in an ellipse and the trailing edge tapered (as shown in Figure 6) works quite acceptably. The increased drag is slight, and there's little practical difference in steering response. Such rudders are easier to fabricate of laminated ply (or laminated ply and foam), glassed on the outside. I've specified this section on many designs.

Intermediate-Speed Rudders

As speeds increase to more than 18 knots, at modest helm angles the airfoil

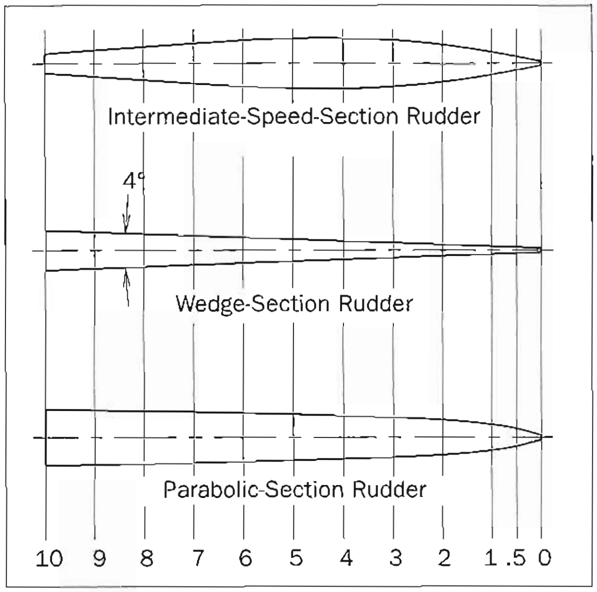


***Figure 7**—High-speed rudder sections.*

section or flat section with tapered ends begins to stall too soon. The effect is acceptable up to about 25 knots, but between 10 and 30 knots the intermediate-speed rudder section is optimum (**Figure 7**). The sharp leading edge, with the maximum thickness farther aft, and the square and wide trailing edge make the rudder work when cavitating at these higher speeds. This rudder shape is hard to find today, and would probably have to be custom fabricated.

Wedge-Section Rudders for High Speed

Huckins Yacht Corp. (builder of the famous Huckins PT boats) found that a true wedge-section rudder gave the most reliable steering on most planing vessels cruising at 25 to 30 knots and above. Such rudders come nearly to a true point at the leading edge (there's a very slight width here for strength), with a wide, squared-off trailing edge. A wedge angle of about 4° generally works best. Such wedge-section rudders do have somewhat more drag trailing at dead center (going straight ahead) than do airfoil-section rudders, but they are much less prone to stalling, and offer more positive steering control at high speed. Also, assume the center of pressure is at 40% of mean chord aft of the leading edge (at hard over).

Parabolic-Section Rudders for High Speed and Minimum Drag

The modern variant of the wedge-section rudder is the parabolic-section rudder. You can see in Figure 7 that it is similar in concept to the wedge-section rudder; however, instead of having straight sides in section, its sides are curved out somewhat in a gentle parabola. Parabolic-section rudders have all the advantages of wedge-section rudders, but the parabolic-section rudder creates less drag. The difference isn't large, but is enough to be worth installing where top speed or fuel economy is an important factor.

Real-World Comparison of Intermediate-Section and Parabolic-Section Rudders

Designer David Pugh reported to me the following real-world results comparing intermediate-section and parabolic-section rudder shapes:

> *I printed the page from your rudder drawings and enlarged it to the proper scale for our rudders. Then I went out in the shop and had some extra blades modified. We started with a simple wedge-shaped, transom-hung rudder from Marine Hardware. It is a stock rudder (OBRI 1.375-B). We simply added fairing putty to one set of blades to achieve your parabolic section. On a second section, we ground down the trailing edge slightly and used fairing putty to achieve your intermediate section. The boat (our new 34'/10.4m inboard, powered by twin 380 Cummins) topped out at 34.5 mph. There may have been a very slight improvement in speed with the parabolic section (0.1 mph). The intermediate section was equal to the parabolic section, or perhaps slightly better (0.1 mph again). I say "perhaps" because I have found that even with a GPS, a 0.1-mph change in speed is usually not worth noting since so many variables can alter speed on each run. Load conditions, wind, and wave height were similar on each run. Most interesting to me is that I could hardly detect any difference in handling. The only difference was that the intermediate-speed rudder did have a very slight tendency to burble or cavitate at high angles at high speed, but this was negligible.*

Though intermediate-section rudders seem to be overlooked, the above report indicates to me that they are preferable at speeds up to about 30–32 knots.

Rudders for High-Speed Multihull Sailboats

The above wedge-section and parabolic-section rudders are for use on powerboats. Such rudders create too much drag for racing or high-performance multihulls under sail, yet these boats can reach 30 knots or more. For such craft, airfoil-section rudders with the maximum thickness farther aft, and with the minimum thickness practically achievable, are best.

Skeg- or Keel-Hung Sailboat Rudders

On traditional sailboats, the rudder is fastened to the trailing edge of the keel. More modern sailboats may have the rudder running along the aft end of a skeg. In either case, the optimum rudder section is the trailing portion of the standard airfoil section, starting with maximum thickness at the rudderstock, just aft of the keel or skeg. You can see this in **Figure 8**.

As with airfoil-section spade rudders, such skeg- or keel-hung rudders will be nearly as effective, with nearly as

Foil-Thickness Form Dimensions Y as a Percent of Chord Foil Designation			
% Chord	0010	Intermediate	Parabolic
Tip Radius	1.100	NA	NA
0.00	0.000	0.410	0.410
1.25	1.578	—	—
2.50	2.178	—	—
5.00	2.962	0.133	1.727
7.50	3.500	—	—
10.00	3.902	2.212	2.519
15.00	4.455	2.986	3.043
20.00	4.782	3.641	3.421
25.00	4.952	4.167	3.691
30.00	5.002	4.554	3.892
35.00	4.920	4.803	4.056
40.00	4.837	4.930	4.205
45.00	4.625	4.948	4.350
50.00	4.412	4.871	4.492
55.00	4.108	4.715	4.628
60.00	3.803	4.493	4.754
65.00	3.428	4.220	4.867
70.00	3.053	3.911	4.968
75.00	2.620	3.580	5.062
80.00	2.187	3.242	5.152
85.00	1.697	2.906	5.238
90.00	1.207	2.572	5.324
95.00	0.672	2.240	5.408
100.00	0.105	1.908	5.492
Boxes Indicate Region of Maximum Thickness			

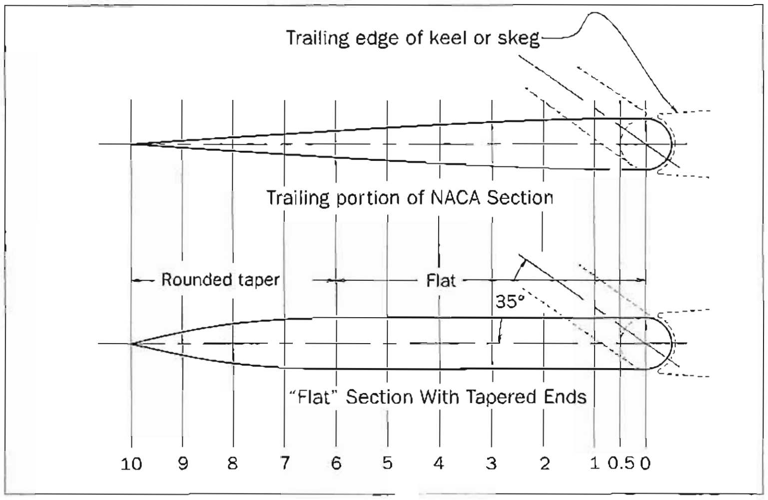


***Figure 8**—Skeg- or keel-hung sailboat rudder sections.*

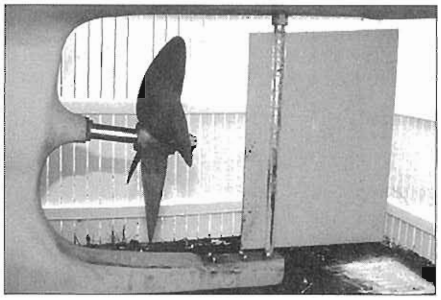
little drag, if made flat with a rounded taper to the trailing edge, as shown.

Rudder-Section Offsets

The table "Foil-Thickness Form Dimensions" gives the offsets for foil sections in Figures 6 and 7. Note that the section widths are half-breadths.

Metal Flat-Plate Rudders

Many commercial vessels and some displacement motor cruisers are fitted with metal flat-plate rudders. Although these can work acceptably



COURTESY WASHBURN'S BOATYARD

Figure 9—The small stainless steel flat-plate rudder on this lobster yacht gave poor response. Note the erosion of paint around the rudderstock.

at low speed, I recommend against them. Flat plates have the lowest effectiveness for generating lift (turning force) at all angles and at all speeds. This means more rudder angle for the same turn. It also means slower helm response, and possibly larger steering gear.

In addition, the round rudderstock runs outside down all or most of the height of the flat-plate rudder blade, thereby causing additional turbulence and loss of steering effect.

Figure 9 shows a small, rather crude stainless-steel flat-plate rudder (without stiffeners) on a single-screw lobster yacht. You can clearly see the erosion of paint caused by turbulence around the rudderstock. This rudder, though of adequate size, gave very unsatisfactory steering response. (Note also that there is too much overhang from the propeller hub to the stern bearing, and that the trailing edge of the rudder aperture isn't well faired; both can cause vibration and turbulence.)

The sole advantage of flat-plate rudders is that they're cheap and easy to build. That's why they're so common on workboats. To my mind, it is false economy, since steering control is integral to the crew's experience of a boat. Regardless, flat-plate rudders do work and are acceptable if cost-savings is paramount.

Rudder blade thickness should be:

$$\text{Plate thickness, inches} = 0.1 + \frac{S \times kts}{666}$$

or

$$\text{Plate thickness, mm} = 2.54 + \frac{S \times kts}{666}$$

Where:

S = stiffener spacing, in inches or millimeters
kts = boat speed, in knots

Maximum stiffener spacing (inches) steel or stainless = 6 + (plate thickness, inches x 48), or

Maximum stiffener spacing (mm) steel or stainless = 152.4 + (plate thickness, mm x 48)

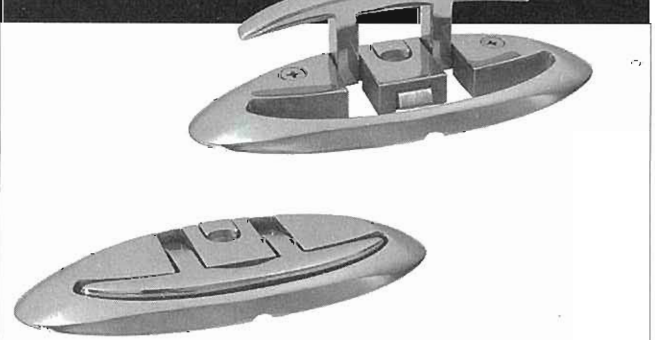
Maximum stiffener spacing, inches, aluminum = 4 + (plate thickness, inches x 32), or

Maximum stiffener spacing, mm, aluminum = 101.6 + (plate thickness, mm x 32)

Let's say we have an 18-knot boat, with a steel flat-plate rudder:

Try ⅜" (10mm) plate. Then:

6 + (0.375" x 48) = 24" maximum spacing, or
152.4 + (10mm x 48) = 632mm maximum spacing.



Try 10" (260mm) stiffener spacing:

Plate thickness, inches =

$$0.1 + \frac{10'' \times 18\text{ kts}}{666} = 0.37\text{, use } \tfrac{3}{8}''\text{, OK}$$

or

Plate thickness, mm =

$$2.54 + \frac{260\text{mm} \times 18\text{ kts}}{666} = 9.56\text{mm, use 10mm, OK}$$

Stiffener thickness should be the same as the rudder-blade plate thickness.

Stiffener height (or width athwartships) on either side of the rudder blade should be:

0.6 x diameter of the rudderstock, or

0.06 x mean rudder chord, whichever is greater.

Though the stiffeners are commonly of constant height from leading edge to trailing edge (rounded at the ends), they can be tapered. If tapered, then the maximum height is centered at the rudderstock and continues for 15% of mean chord fore and aft. Stiffeners can taper to 60% of maximum height at the leading and trailing edges.

Wood Outboard-Rudder Thickness

Some traditional sailboats have what are essentially wooden flat-plate rudders hung on gudgeons and pintles on the transom or behind the keel. Such rudders, called outboard rudders, were traditionally made of bolted-up solid timber. Modern wooden construction calls for epoxy laminated plywood, sheathed in glass. Either way, the standard thickness is:

Thickness, inches = 0.12 x immersed area, sq ft, or
Thickness, mm = 32.8 x immersed area, m^2

Thickness, inches =

$$\frac{\sqrt{\text{LOA, ft} + \text{beam, ft}}}{12.66}$$

or

Thickness, mm =

$$3.63\sqrt{\text{LOA, m} + (6.58 \times \text{beam, m})}$$

Use whichever value is larger.

Thus, if we had a 26′ (7.9m) catboat, with 9.5′ (2.89m) beam and 5.5 sq ft ($0.51m^2$) immersed rudder on the transom, thickness would be:

Thickness, inches = 0.12 x 5.5 sq ft = 0.66", or
Thickness, mm = 32.8 x $0.51m^2$ = 16.8mm, or

Thickness, inches =

$$\frac{\sqrt{26'\text{ LOA} + 9.5'\text{ beam}}}{12.66} = 1.15''$$

or

Thickness, mm =

$$3.63\sqrt{7.9\text{m LOA}} + (6.58 \times 2.89\text{m beam}) = 29.2\text{mm}$$

Use the thicker value and round to a standard size; here, 1¼" or 30mm.

Cored Fiberglass Shell Thickness

Many modern fiberglass rudders are surfaced with a fiberglass shell and filled with foam core. (In metal construction, this is often termed a "double plate" rudder, though such rudders are empty inside, not filled with foam.) The FRP shell must be strong enough to resist the water pressure and must also resist impact from debris. For standard polyester laminates of woven roving and mat, with a tensile strength of 26,000 psi (180 MPa) or greater, the FRP shell thickness should be equal to:

$$\text{Thickness, inches or mm} = \frac{\text{kts} \times \text{width, inches or mm}}{1{,}290}$$

Where:
kts = boat speed in knots, but never less than 5 knots
Width = maximum fore-and-aft width of the rudder blade, in inches or mm, but not less than 0.09″ (2.28mm) thick.

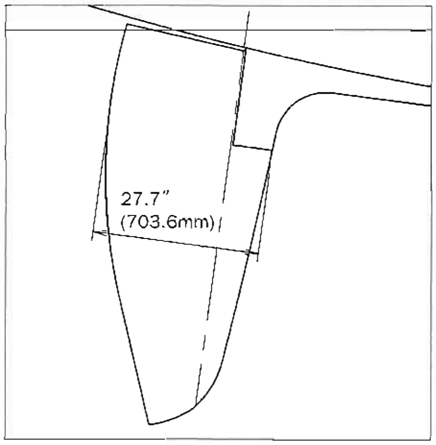


Figure 10—Rudder width.

If we had a spade rudder that was 27.7″ (703.6mm) maximum width from the leading to the trailing edge (**Figure 10**), with a maximum speed of 8.72 knots, then the rudder laminate shell thickness should be:

$$\text{Thickness, inches} = \frac{8.72 \text{ kts} \times 27.7''}{1{,}290} = 0.187''$$

or

$$\text{Thickness, mm} = \frac{8.72 \text{ kts} \times 703.6\text{mm}}{1{,}290} = 4.76\text{mm}$$

The foam core at the central portion of the rudder blade—where the foam is between the rudder-frame support arms coming off the rudderstock, and the inside of the FRP shell—should be at least 8 lbs/cu ft (128 kg/m^3) density.

Rudder Planform

The rudder profile, or planform, is the shape of the rudder viewed from the side. There has been an incredible variation in opinion regarding the planform shape that works best for different types of boats. To this day, there isn't wide agreement; however, certain fundamentals are recognized as important.

Sailboat-Rudder Planform

Earlier, we discussed what aspect ratio is and how it's calculated. On sailboats, the higher the aspect ratio (the longer/deeper and narrower the rudder), the more effective it is—within reason.

In **Figure 11**, rudder A is a 20-sq-ft (1.86m^2) rudder with a span of 9.73′ (2.96m). It has an aspect ratio of 4.73.

The trade-off for higher aspect ratio is that the bending moment on the rudder is greater and the stock, longer. This requires a heavier, stronger stock and bearings, and the rudder blade itself is rather slender—hard to make really strong.

Aspect ratios of 4 and over are

high, and aspect ratios over 5 should generally be avoided.

Aspect ratios between 3 and 3.5 are moderately high, and are a good choice for most performance-oriented boats. Rudders B and C have aspect ratios of 3.2.

Aspect ratios between 2.4 and 3 are moderate, and work well on almost all normal sailboats. Rudder D has an aspect ratio of 2.6.

For the same rudder area and rudderstock location, the higher the aspect ratio, the greater the turning force for a given helm angle. The difference, though, is not large. Identical boats fitted with rudder A and rudder B would have nearly the same steering response. Also, high aspect rudders tend to stall more easily at high rudder angles.

Very high aspect rudders, such as A, are appropriate only for sailboats with very high-aspect-ratio fin keels, which have been reduced to the minimum acceptable keel area. The deep, high-aspect-ratio rudder provides somewhat more resistance to leeway; it will be more effective as lateral

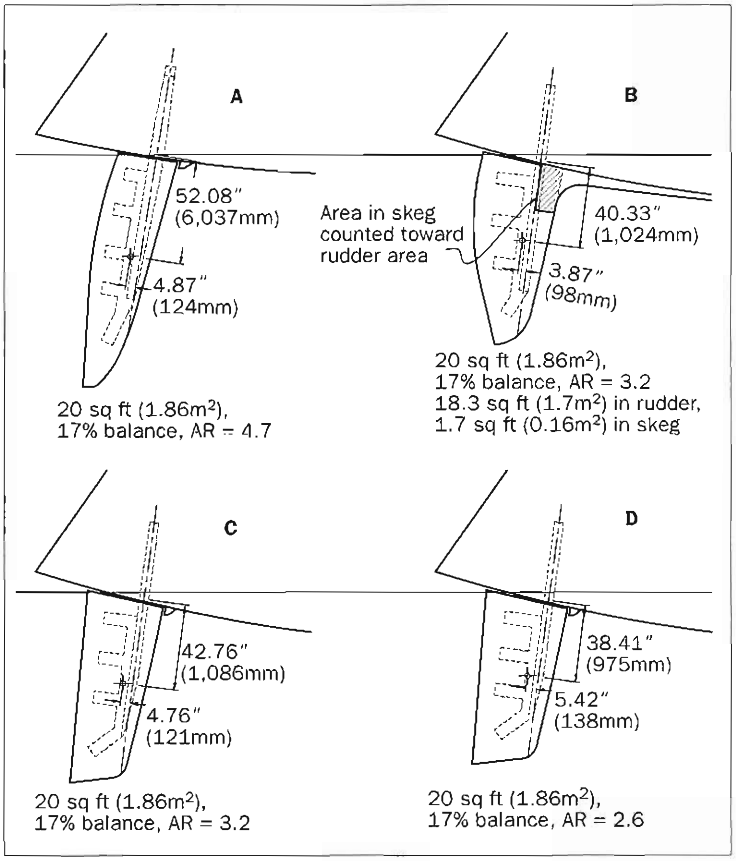


Figure 11—*Sailboat spade rudders.*

plane generating lift. Such very high aspect rudders thus effectively do double duty as some additional keel area.

Rudders B and C have the same area and aspect ratio; however, B is curved, and formed to have minimum area in the tip. This is to approximate the theoretical optimum elliptical planform—for minimum induced drag at the rudder tip. Rudder B would thus have slightly less drag than rudder C; otherwise, the steering response of the two will be virtually identical. Rudder C is simpler and less expensive to build.

Rudder D will work quite well even though it has the lowest aspect ratio of all four and is roughly rectangular in section. As a practical matter, the difference in steering response between C and D won't be great. Rudder D will be the least expensive to build.

In the real world, my first choice for optimum performance would be rudder B. That's because it will have slightly less induced drag than all the other rudders pictured, except for the extreme A. At the same time, rudder B is faired into the keel/skeg ahead of it. This makes for good tracking, and the area of the skeg immediately in front of rudder B counts as rudder area. So the rudder blade itself is of slightly less area to equal the total 20 sq ft/1.86m^2. That gives rudder B a lighter helm feel—by a small margin.

Both the shape for rudder B and the faired-in skeg are more expensive than rudder C, however. And rudder C will give quite satisfactory results.

Spade rudders should have their leading edges angled slightly aft to shed debris—line, plastic bags, kelp, seaweed, nets, and the like. The forward lower corner should be somewhat rounded, not only to help shed debris, but also to reduce damage from minor impacts.

Antifouling Skeg

Note that the sailboat spade rudders shown all have a small antifouling skeg fastened to the hull just forward of the rudder's leading edge. This helps avoid line, plastic bags, and seaweed from catching and jamming between the top of the rudder and the hull.

Traditional Sailboat Rudders

Traditional sailboat rudders are hung on the back of the keel. Another version is shown in the sailboat outboard rudder with skeg (Figure 3). On traditional and/or trailerable small craft, the outboard rudder is often made to kick up (as shown in the kick-up rudder drawing, also in Figure 3). The kick-up rudder blade is typically made of aluminum plate.

Powerboat Rudder Planforms

Single-screw displacement powerboats usually have balanced rudders on skegs immediately aft of the propeller. The "skeg" in this usage is the support for the lower rudder bearing projecting aft from the bottom of the keel, not a lateral-plane appendage forward of the rudder, as on sailboats.

Generally, aspect ratios between 0.8 and 2.3 work well. The higher aspect ratio—as with sailboat rudders—

improves response, but this is controlled by draft restrictions and propeller diameter. On some particularly shoal boats, I've used rudders with aspect ratios as low as 0.6.

Usually, such rudders are better made roughly rectangular in planform. Over the years, though, almost every imaginable shape has been tried, and all seem to work acceptably—as long as the area and balance are correct and the aspect ratio is reasonable.

Sometimes single-screw powerboat rudders are spade rudders (with no bearing at the bottom of the rudder blade). In this case, the rudder is better formed like a planing powerboat rudder, but no consideration has to be made for cropping the top corners for deadrise angle.

Planing powerboat rudders are a bit different. Such rudders are almost always spade rudders. **Figure 12** shows standard, stock, cast-bronze powerboat rudders. Current practice is to use trapezoidal-shaped rudders with sharp corners on high-speed boats; and round-corner, more square rudders on medium- to low-speed boats. It's not clear that there's really a great deal of difference in real-world steering response between these two planforms. Both will work well as long as the area and balance are correct and the rudder section shape is appropriate for the boat's speed.

Spade rudders for twin-screw boats, with out-turning wheels, are installed outboard of the shaft, aft of each propeller. Since almost all planing hulls have considerable deadrise, the top of the rudder (forward and aft of the rudderstock) is cropped away downward at an angle, so that the top corners don't hit the underside of the V-bottom hull when swung over. Out-turning propellers (viewed from aft, the starboard prop turns clockwise; the port prop, counterclockwise) are standard. If the props turn in the opposite direction, then the rudders are installed inboard of the shaft.

As with all spade rudders, the leading edge of the rudder blade should be angled slightly aft to shed debris.

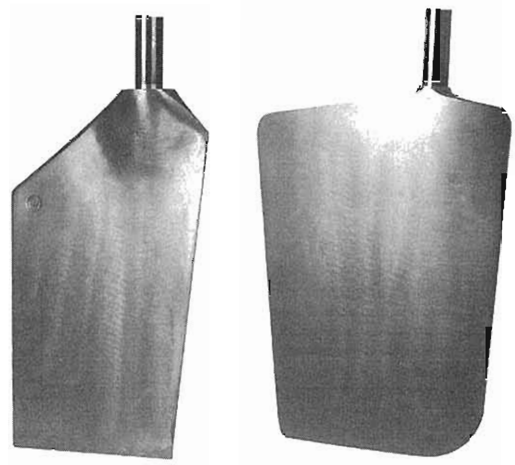
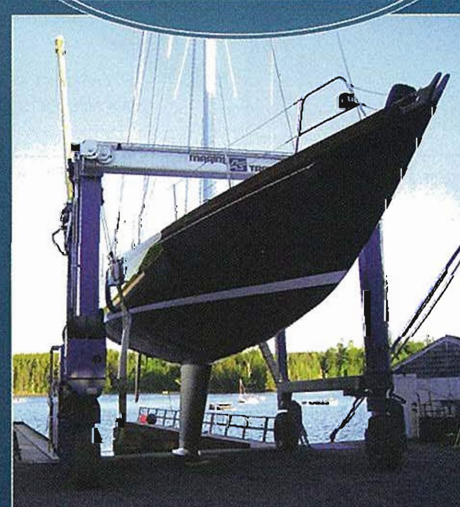


Figure 12*—Stock cast rudders.*



Boat Behavior in Turns

At the start of this article, we said rudders act like simple boards angled to the water flow, and then, more accurately, described rudders as hydrofoils that generate hydrodynamic lift to create side force. Some references wax eloquent on determining the coefficient of lift (C_L) for a particular rudder foil section shape and then calculating the resultant "normal force" (the force at right angles to the rudder blade) at the predicted angle of attack, based on the value for C_L. Though these calculations give some engineers a feeling of comfort, it isn't any more accurate than the method that follows. That's because there are so many unknowns:

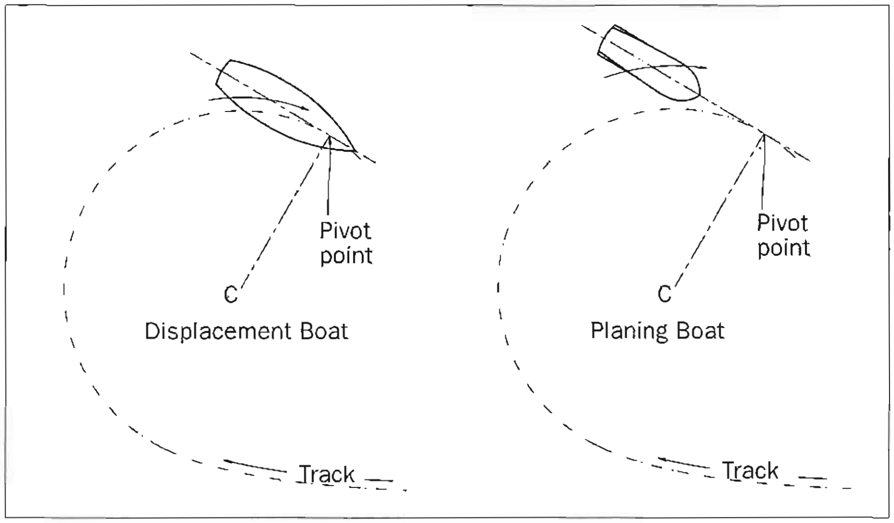


***Figure 13**—Boats skid through turns.*

- The water speed the rudder "sees" is difficult to calculate accurately, since the rudder is partially in the wake of the hull, which reduces the apparent speed at the rudder. At the same time, the rudder is also in the slipstream of the propeller, which increases the apparent water speed at the rudder. Working out exactly how this balances out is impractical for most applications.
- The angle of attack that the water actually makes with the rudder is almost always less than the rudder angle—because the boat skids sideways as it turns, and the entire hull turns as the rudder turns. The magnitude of these effects will differ among boats, at different speeds on the same boat, with different loading and trim conditions, and in different sea conditions.
- Boat speed decreases during a turn. **Figure 13** shows the skidding

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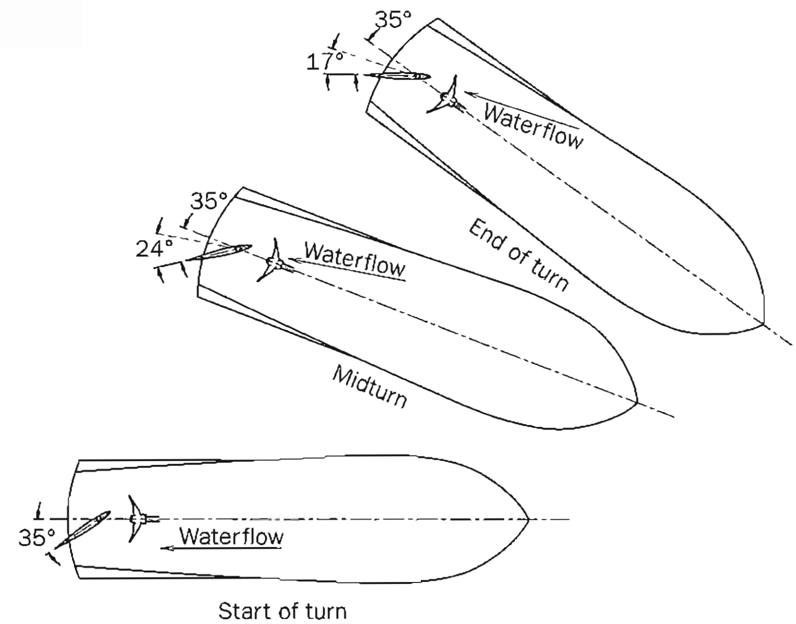


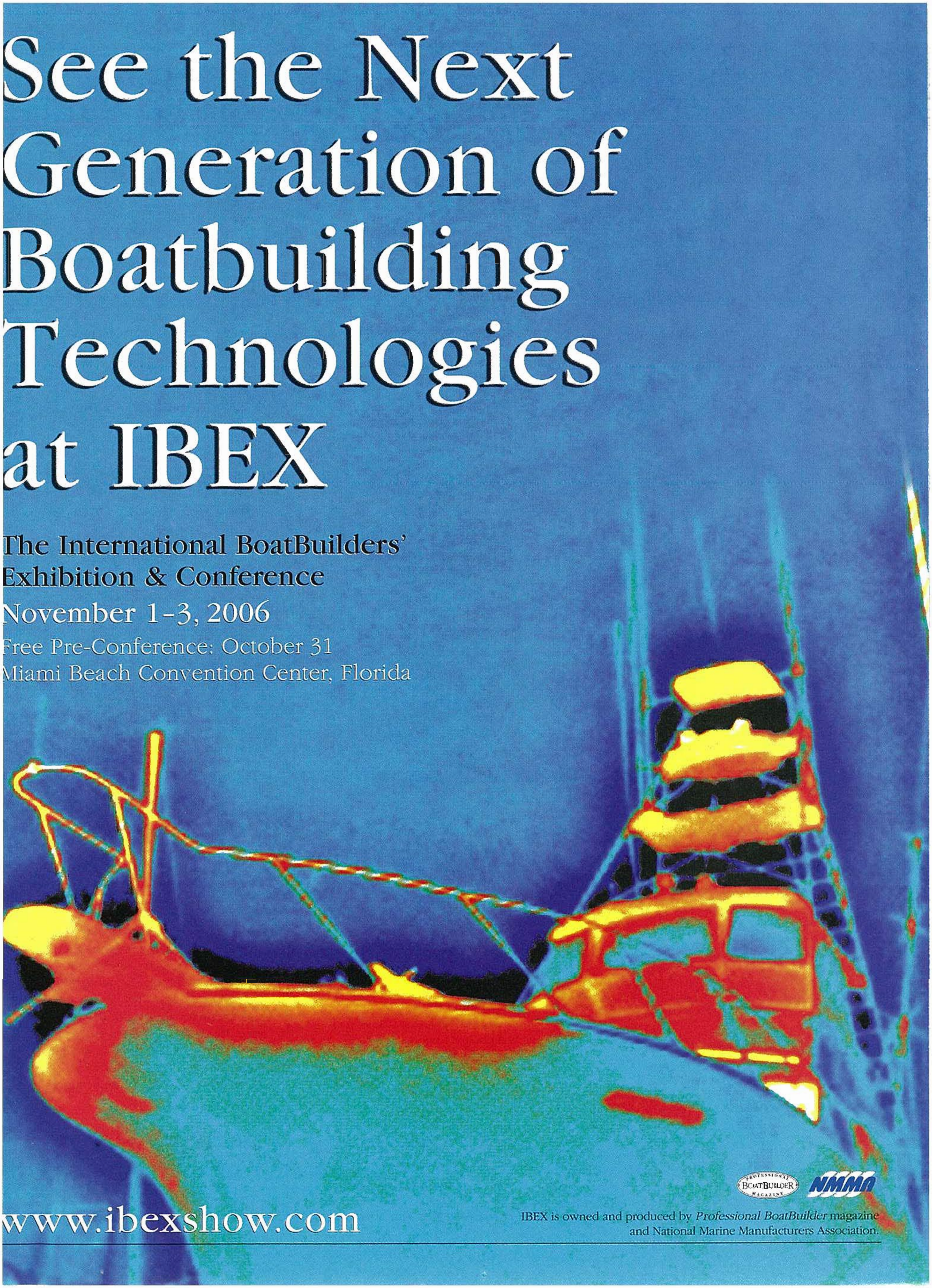
***Figure 14**—Effective rudder angles as a boat skids through a turn.*

effect and how it differs among different boats and at different speeds. In every case—as we discussed earlier—the rudder kicks the stern outboard (to make the turn) and the boat effectively pivots about the pivot point that is well ahead of the boat's center. Indeed, on fast planing craft, the effective pivot point may be ahead of the boat itself. This puts the entire boat outside the nominal turning circle.

Figure 14 shows how the skid changes the effective rudder angle, even with the rudder actually held at the same absolute angle (in the case of the drawing, at hard over, 35°).

Given these realities, the standard methods for calculating water pressure on the rudder, which we'll present in Part 2 of the series, are simply good practice. And, they give conservative results. PBB

***About the Author:** Dave Gerr is director of the Westlawn Institute of Marine Technology, and a practicing designer in New York City. His firm, Gerr Marine, has handled projects ranging from yachts to commercial vessels—monohull and multihull, sail and power. He is the author of* Propeller Handbook, The Elements of Boat Strength, *and* The Nature of Boats.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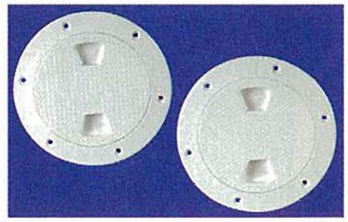

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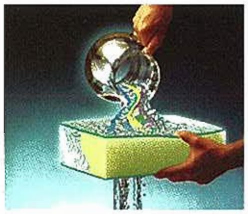

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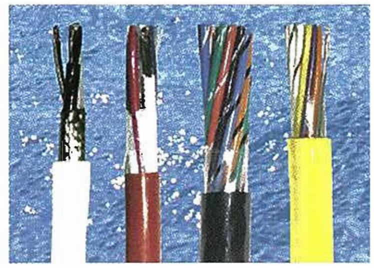

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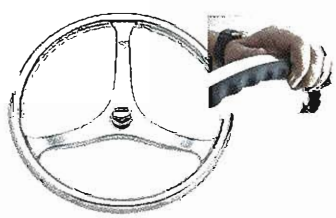

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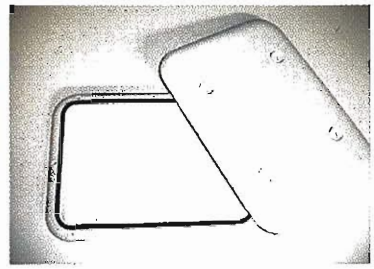

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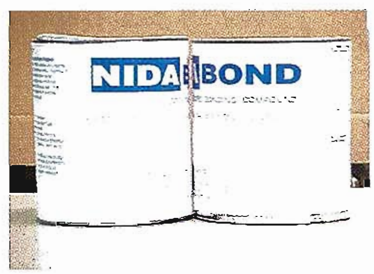

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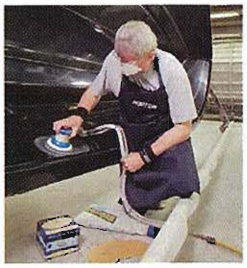

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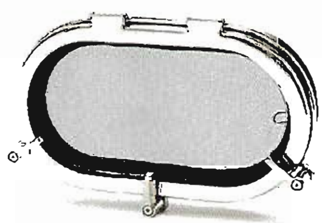

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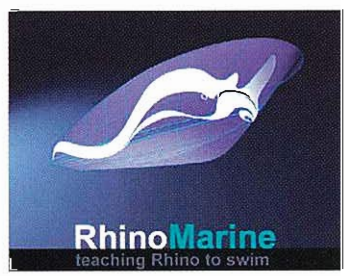

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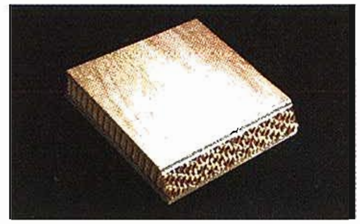

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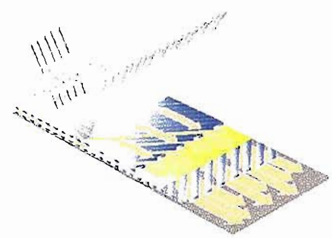

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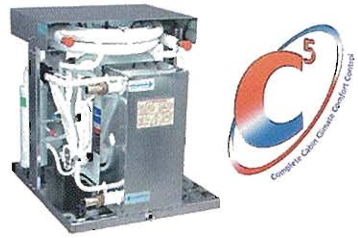

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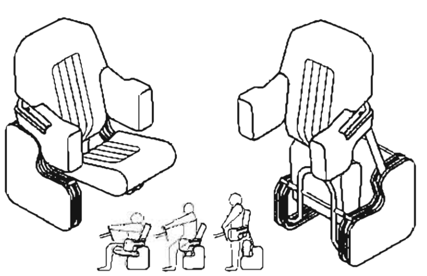

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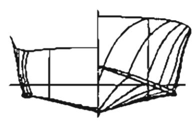

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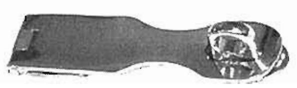

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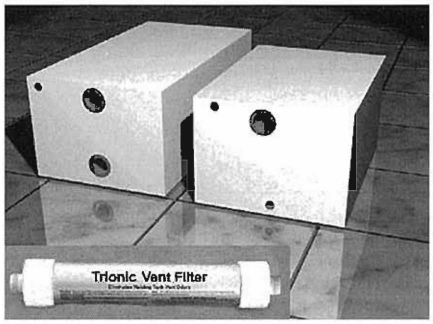

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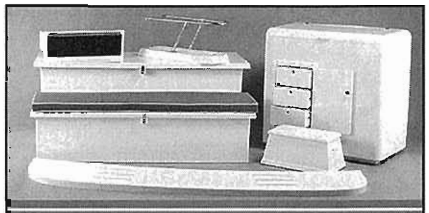

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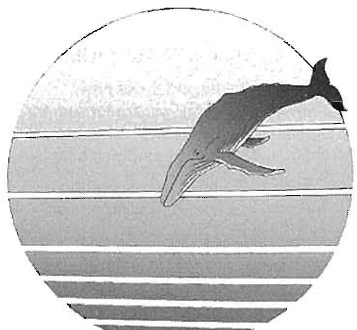

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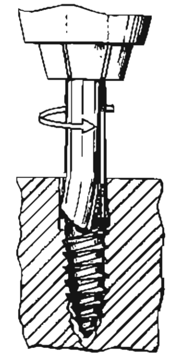

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Lower-Tier Licensure

by Lee Dana

As I write this, it's hurricane season again in the Southeast and along the Gulf Coast. Having survived two direct hits by the hurricanes that swept Florida last year, in a house that was built to meet Miami-Dade County's building code, I now have a better appreciation of the position that insurance companies take when a homeowner tries to purchase a policy that covers 140-mph (225.3-kmh) winds. In order to qualify for that coverage at minimum cost, the homeowner must present all documents of inspection regarding construction of exterior walls, and the type of roof and its construction. Moreover, window and door protection must be certified for 140-mph winds, as well as for wind-driven projectiles. All this in addition to an on-site inspection.

How does any of the above relate to boatbuilding? Well, to my way of thinking, a parallel set of circumstances would involve oversight of small-vessel construction and repair *not* covered by a classification society. Should insurance companies be the authority having jurisdiction (as they are in the case of my house)? If so, then the problem would be handed over to a contracted marine surveyor, who depends on the American Boat & Yacht Council, the National Marine Manufacturers Association, the U.S. Coast Guard, the National Fire Protection Association, and his or her cumulative experience for sufficient guidance. In my opinion, however, that arrangement is not acceptable. Why? Because the ABYC and NMMA are unduly influenced by industry; the NFPA is limited in scope; and the USCG is not really interested in recreational small craft (the service has higher priorities since 9/11). True, a surveyor's experience can be a fine asset, but the surveyor's only written guide, as things stand now, is the ABYC's book of standards and recommendations.

Meanwhile, Florida's very active—and economically important—small-vessel design-and-repair community is in a state of crisis, thanks to the Society of Naval Architects and Marine Engineers. SNAME has put forth the notion that to be an effective NA or ME, even for small vessels, you must be a licensed professional engineer, or PE. The rigid qualifications for becoming a PE in Florida would virtually eliminate a large percentage of what I consider very capable *small-craft engineers*, many of whom have been in business for years.

The test for a PE license specific to marine engineering and naval architecture, while technically administered by the National Council of Examiners for Engineering and Surveying, or NCEES, was actually developed by SNAME. A sample set of 15 study problems appears on the Society's Web site. As problems go, they're not that difficult; the questions deal with fluids, strength of materials, hydrostatics, ship dynamics, and machine design. Nevertheless, there is nothing in the study set that would invoke a mental image of a yacht, crew boat, patrol craft, or any other small-vessel-related technical problem that one might be trying to solve.

In this day and age, it seems a person must have a license for just about all business operations. For example, where I live, our neighborhood's steps to the beach, destroyed by hurricane, had to be replaced by a licensed marine contractor—even though any good carpenter could have done the job.

I think the State of Florida should, with the support of the state's marine professionals, take the lead and develop a program that would license those individuals who currently perform engineering on vessels under 200' (61m). Such licensure would require a minimum of five years' practical experience and the ability to pass a written test. The test could be designed to focus on the level of engineering work that is now being performed by many of our current practitioners, who, for a multitude of very good reasons, will not opt to take the state's PE exam as developed by SNAME.

Small-craft practitioners in Florida come from a variety of educational backgrounds: engineering programs (two- and four-year post-secondary schools), Westlawn Institute of Marine Technology, and some even self-taught. So let's start with the PE study problems put forth by SNAME. If a practitioner could pass those, would he or she be qualified to perform small-vessel engineering? Sure. One definition of engineering is "the practical application of math and science." My proposal would not diminish the PE status of naval architects and marine engineers. It would, however, provide technical status for the state's bona fide small-craft practitioners, and eliminate the less qualified. It could also motivate many more individuals to become *more* qualified.

There is some legal precedent here: the Land Surveyor's exam, which has a lower educational requirement. I might note that Melbourne, Florida–based naval architect Rob Schofield drafted a proposal that was presented in October to the Florida State legislature. The language of his draft is modeled after the law exempting aircraft personnel from a PE requirement.

The biggest hurdle for a lower-tier license, in Florida at least, is the title "engineer," which is reserved only for those who pass the PE test. PBB

About the Author: *A graduate marine engineer (and longtime SNAME member), Lee Dana spent nearly four decades at Bertram Yachts in Miami, completing his tenure there as the company's chief technical officer. He's now a marine consultant, based in Vero Beach, Florida.*

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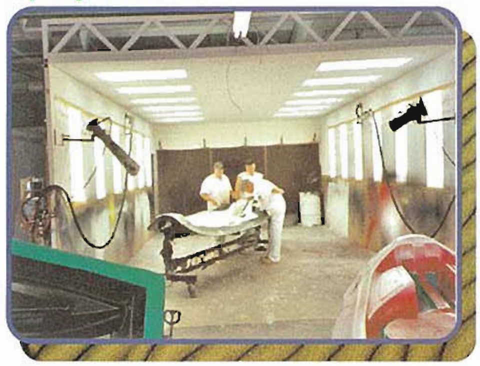

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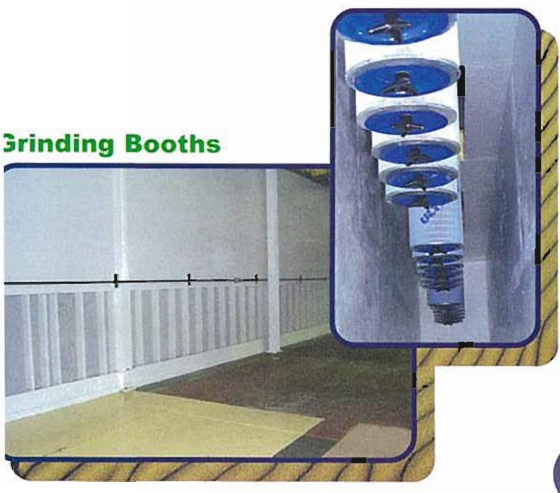

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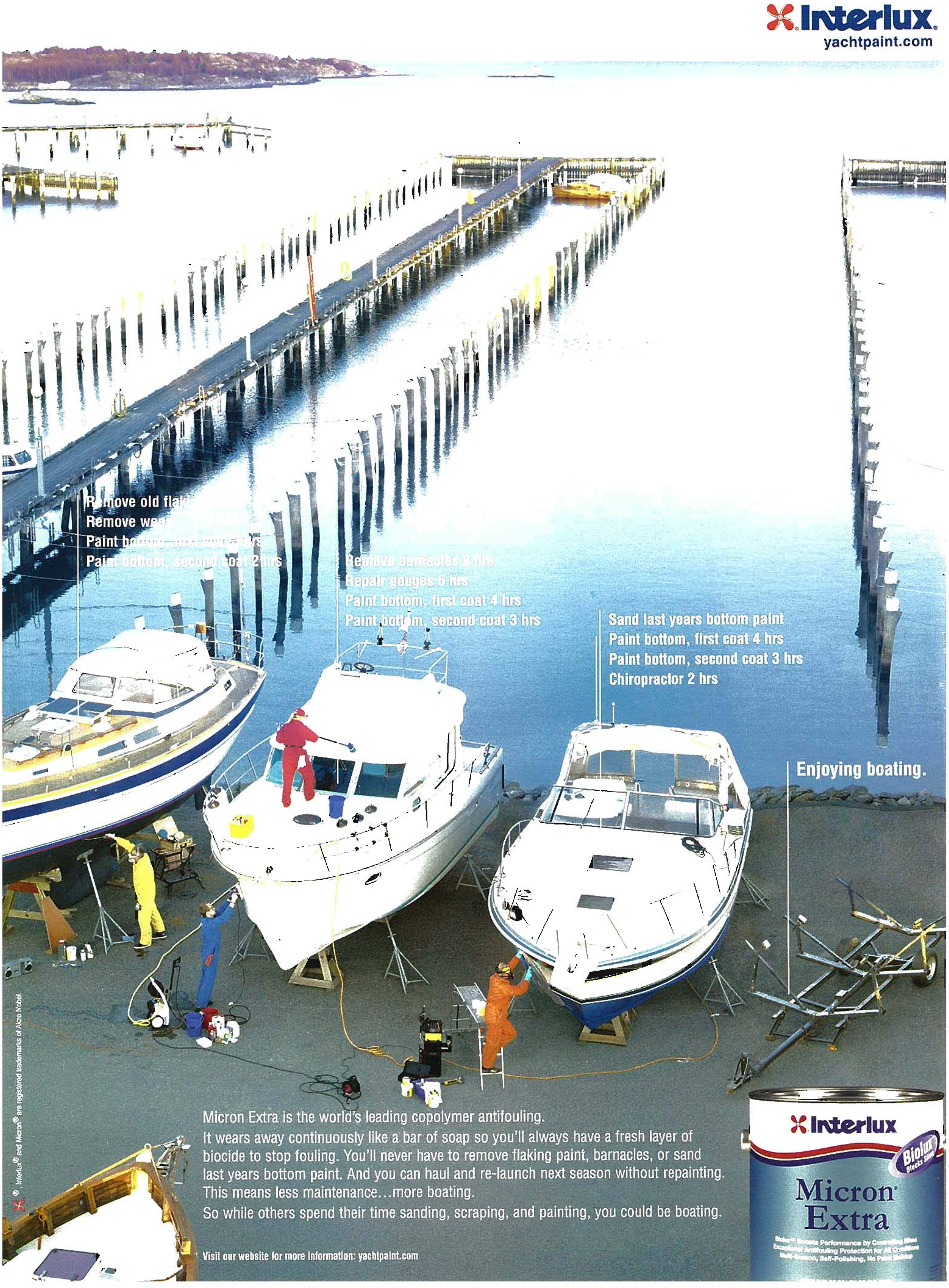
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