PROFESSIONAL BOATBUILDER

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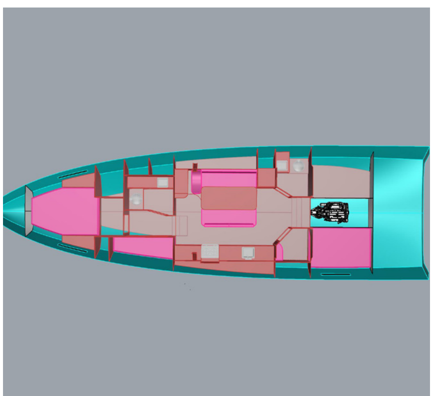
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On the cover: A grid of masts and fixed yards comprise the complex carbon fiber DynaRig structure on the superyacht *Maltese Falcon*, a modern variation on a traditional square rigger built by Italian builder Perini Navi in 2006. Story on page 38.

Photograph Courtesy of Dykstra Naval Architects.

Return Engagement

It's been a minute since we last spoke—half a year in fact—and a lot has happened: The magazine was shuttered in the fall; IBEX bought what assets remained and hired me to help take stock and plan the future; and I worked with IBEX staff to restructure and reanimate *Professional BoatBuilder* and proboat.com over the winter. Now we're back with this first issue produced under new ownership. Thank you to so many subscribers and advertisers for your kind notes of inquiry and encouragement during our hiatus from publishing, and thanks to all readers, writers, and supporters for your patience and faith that we would revive ProBoat to serve our beloved industry again. Change takes time, and while our ambition in reviving the periodical as an IBEX Technical Journal has been to keep our 36-year editorial mission intact, with this new edition, you'll undoubtedly notice more than a few alterations.

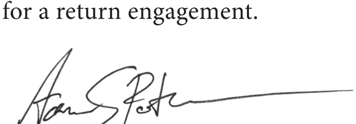
First, you're not holding this page in a bound volume delivered in a plastic envelope by the postal service. With PBB No. 212, all subscribers join the nearly 1 out of 3 who previous received the magazine as a digital issue only. The convenience of reading and storing your technical journal on a digital device that's readily referenced from office or engineroom appeals to a growing demographic of boatbuilders and technicians. We want to get information from our pages into your hands with as little friction as possible—that means landing it in whatever device is already in your hands and in front of your eyes for hours every day.

We also know that paper, printing, and postage costs are on unpredictable upward trajectories. Strategically, it makes more sense to control publishing and delivery costs than it does to cut investment in timely, credible, independently sourced editorial content. That's why we've committed to delivering additional original boatbuilding information at ProBoat.com, IBEX 365, and in email news bulletins released between the digital issues of our conventional journal going forward.

As for what remains the same, ProBoat's second act will continue to deliver far more than the rewritten press releases, vendor submitted advertorial, and lashings of AI slop and click bait that have swollen the internet's trove of marine industry misinformation. We'll focus on our signature mix of core skills for boat designers, builders, and service techs, as well as the promise and complexity of emerging technologies and materials. As you can see from this issue's table of contents, our stable of trusted contributing technical writers and professional correspondents is intact and fully engaged.

Our doors and minds stand open to ideas for diverse marine industry editorial topics, from the proven and practical to the innovative and inspirational. As a boatbuilding professional, be assured that articles we publish in these pages and posts will continue to be original, independently sourced material of our own inspiration and creation—you will always know who to call with praise, blame, or questions.

It's our honor and pleasure to be back for a return engagement.



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FROM IBEX EXECUTIVE DIRECTOR ANNE DUNBAR

An New Issue, A New Owner, A New Chapter

Dear *Professional BoatBuilder* Reader,

Thank you for being here. I'm pleased to welcome you to the first digital edition of *Professional BoatBuilder* magazine under its new ownership.

We are proud to bring *Professional BoatBuilder* back as an IBEX Technical Journal. Reuniting these two trusted industry brands strengthens our shared mission: to support and advance the professional boatbuilding community.

This edition marks a new chapter as we transition *Professional BoatBuilder* to a fully digital periodical, with one special print issue each year, distributed at IBEX and METSTRADE. This approach allows us to provide timely, in-depth content to readers worldwide—while also supporting IBEX's corporate sustainability goals by reducing our environmental impact.

In addition to our digital issues, we publish bimonthly editorial posts on the proboat.com website and accompanying email newsletters featuring shorter, but always substantive, technical content. These pieces reflect the same high standards and trusted voice you've come to expect from *Professional BoatBuilder*, delivered right to your inbox to keep you informed between issues.

We appreciate your patience over the past several months as we worked through this transition. Our editorial team remains deeply committed to continuing *Professional BoatBuilder*'s legacy as the leading technical resource for boatbuilders, designers, and marine professionals around the world.

We're excited about what's ahead and grateful for your continued support.

Enjoy the issue.

Sincerely,

Anne Dunbar

Anne Dunbar
Executive Director
IBEX – International BoatBuilders' Exhibition & Conference


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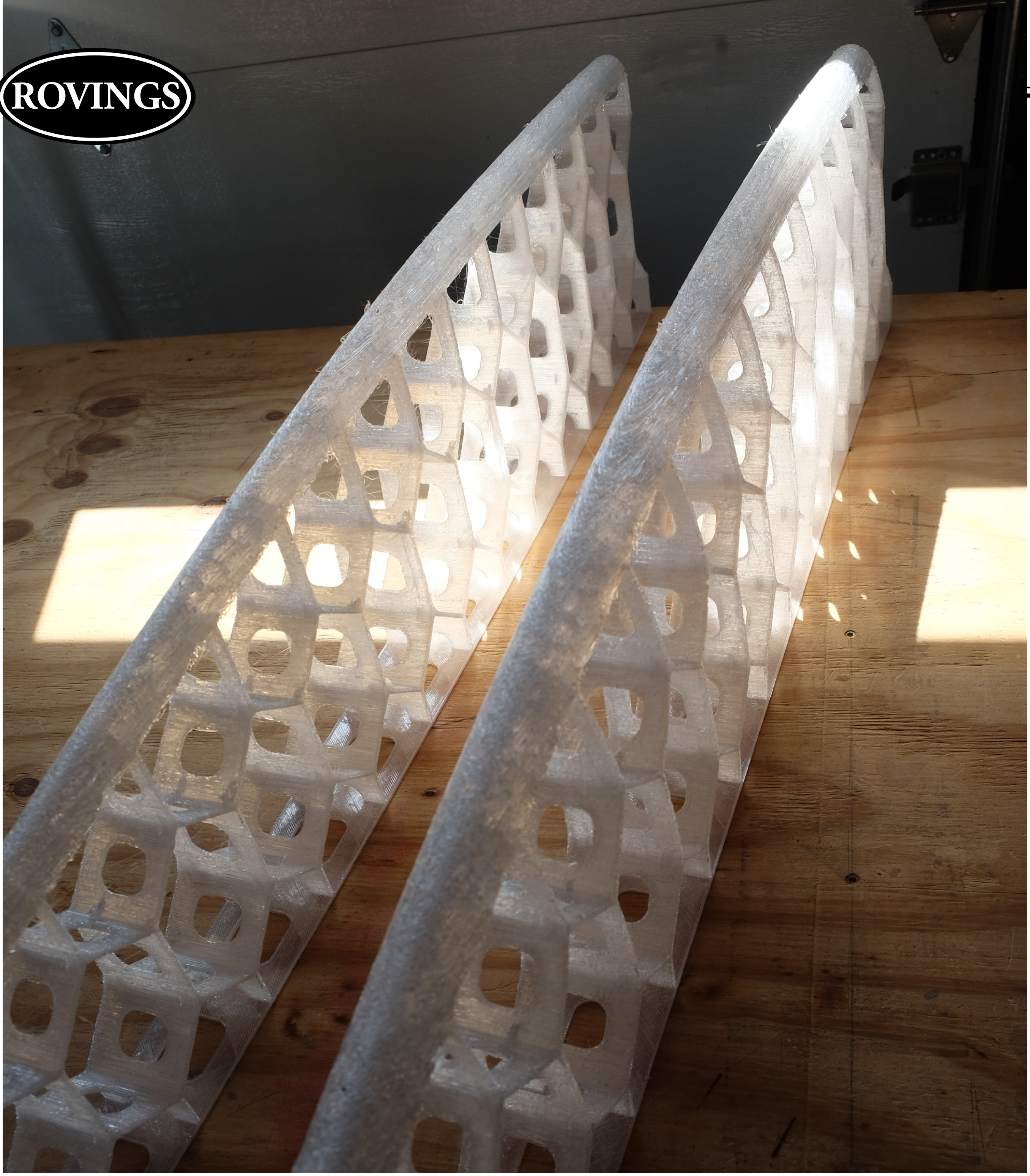


AARON PORTER (BOTH)

Reading the Small Print

Easily stored in a garage or closet and transportable on a bicycle, surfboards are some of the simplest buoyant watercraft on the market today. But as any haiku poet or headline writer can attest, it's a mistake to equate simple with easy. Getting the little things right can be just as challenging and gratifying as solving the complex equations. The advantage simplicity of form and scale offers the creative mind is an opportunity to try out new ideas in design and construction with minimal risk given the modest investment in time and materials. You also know pretty quickly whether your latest notion is a success or failure.

No surprise then that surfboards offer a promising experimental platform for boatbuilding industry innovators trying out new construction materials and methods. While searching for boatbuilders who use 3D printing for structural

Two halves of a 3D-printed surfboard core structure before initial fairing, attachment to a wood spine, and installation of GRP skin laminates.

components, I found a case in point in my seasonal hometown (Portland, Maine): Blueprint Surf Co. has been printing the core structure of their innovative custom surfboards as a startup business since 2022.

Co-founders Mike Ballin and Luke Diehl don't claim to be the first to try it, but they may be among the most persistent, having printed and tested dozens of boards in their quest to get it right. Diehl's background is in medical devices, including some 3D-printed titanium products. Ballin's experience is in environmental consulting. They met seven years ago surfing the cold waters of southern Maine. Their shared passion and diverse skills led them to start Blueprint.

Ballin's priority is to minimize environmental impact of the boards they build by using recycled and renewable materials wherever possible. Diehl brought his 3D-printing and business experience to the table.

Currently the boards' core lattice structures are printed at a rate of one per week on a modest machine with a 2′ x 6′ (.6m x 1.8m) bed at Northeastern University's Roux Institute in Portland. Ballin said the Roux partnership has also helped with engineering and adjusting print materials as the build process has evolved. Ballin does the laminating and finish work in his shop.

In the rafters of the unassuming South Portland garage where Ballin fairs and applies fiberglass and Entropy bio-based epoxy resin to the printed cores, there's a collection of broken boards that chart Blueprint's evolution. They're not pretty to look at, but they reveal many of the lessons learned.

The first board they built was strong and very heavy Balin said. "You couldn't sell anything like a third of its weight." The printed structural lattice of the early boards comprised a roughly square horizontal grid with round holes printed into the vertical structure. The failure mode was obvious—the grid would crack along the lines of the fine 3D-printed plastic layers applied by the printer in a stack from the bottom of the board to the top.

Builder Mike Ballin inspecting a Screaming Gull model board from Blueprint's line. Note the core vent and tether attachment points at the aft end of the board.

Like any lightly built boat, each board is a kinetic structure subject to many interacting forces and movements. The greatest force the board would be subjected to in common use is a surfer's heel driving into the deck. "The lattice

Left—*Early Blueprint prototypes tested on the water suffered from shear failures in the printed core.* ***Inset***—*With a shift to printing recycled polypropylene material from fishing nets, Ballin also optimized printer orientation, laying individual beads of plastic down horizontally but installing them vertically between skins in the board structure.*

structure needed to be able to dissipate that energy quickly and efficiently," Ballin said.

To avoid the pillar failure of the earliest boards, they changed printer orientation so that the layers of printed plastic were laid down with each half of the board standing on edge. In addition, they changed the lattice to more complex polygonal forms and installed a longitudinal wood spine between the two halves of some boards. Ballin noted that the lattice structure is also limited by the maximum void span he's confident he can bridge with his proprietary method of applying the first layer of glass to the printed core. On the newest boards, the polygons visible through the deck (it's an appealing signature look) vary in size based on the designed use of the board.

Another structural challenge familiar to composite boatbuilders is the bond between the core and the fiberglass skin. When glassing to the printed lattice "you have such a small surface area to bond to, whatever you're bonding has to be really strong," Ballin said. The early boards reveal a few failures and imaginative attempts to increase bond strength and prevent sagging of the skins.

The current solution for bonding the core and skin is the one element of the Blueprint's build method Ballin won't share for publication. But the rest of his glassing routine is simple fairing of the printed core structure and multiple hand-laid glass laminates finished with sealer and a couple of hot coats of epoxy faired with 300-grit sandpaper. So, while the cores may be 3D printed, these boards depend on refined hand skills and craftsmanship for their buoyancy, structure, and final finish.

Ballin said after building 50 boards, he feels like his fiberglass skills are getting to be where he wants them to be. Similarly, the printed cores are finally reliably repeatable and consistent. (They had to switch between polypropylene from recycled fish nets and more common recycled PETG in 2024 when a Dutch supplier of the former went out of business.) He sees room for more improvement. "I still want to get a kilogram and a half off the boards right now," he said.

Structure aside, the business model is equally challenging for these custom-built, environmentally optimized boards. "What we're looking to replace is the foam core, and that is already so cheap that with all our material costs and printing time, we're working with a pretty small margin," Ballin said. His current turnaround time for a board (including six days printing) is two weeks.

Keeping labor to a minimum is essential, as is marketing the customizability of a Blueprint board to consumers willing to pay more for a tailored fit. Ballin said to that end, he's working with reputable board shapers like Australian Alan Emery to be able to build their designs with Blueprint technique. Offering a variety of boards from diverse designers would be hard to do with series-built injection-molded boards, but with 3D printing you aren't tied to a single mold shape that determines the exact form of every board (or boat) you build. The versatility of the technology encourages refinement of shapes informed by use and on-water performance.

Blueprint Surf Co., Portland, Maine.

—Aaron Porter

AARON PORTER (ALL)

The range of shapes and sizes in Ballin's library of surfboards speaks to the experimentation and innovation in shapes and structures that custom printing invites.

Panel Discussion

Manufactured sheet goods are essential to modern construction practices. Few residential or commercial structures built today are completed without a significant investment in plywood, OSB, MDF, sheetrock, melamine board, etc. While the compound curves and oblique angles that define boats make flat 4′ x 8′ (1.2m x 2.4m) panels a little less useful than they are in square-cornered terrestrial buildings, a refined menu of sheet good offerings have become indispensable to boatbuilders. Starting with plywood in the 1930s, sheet goods have served in myriad marine applications from structural members to hull, cabin, and deck sheathing, core material, and interior panels and components. Indeed, easing construction of hulls from plywood sheets informed a shift in boat design through the mid-20th century to embrace the cylindrical and conical curves coupled with hard chines that are all easily formed from developable surfaces.

Even as molded glass reinforced plastic (GRP) came to dominate recreational boatbuilding starting in the 1960s, marine-grade plywood remained essential. But as the quality of available plywood has diminished and the price has risen, many builders have been casting about for alternative sheet goods to build with. As the fleet ages, service yards—challenged by the need to replace plywood core and reinforcements in composite hulls and deck (especially in transoms) with rot-resistant structural material—have turned to fiberglass reinforced closed-cell foam alternatives like Koosa board, which has admirable material properties but a price that makes it impractical for some applications.

At IBEX 2024, Arizona-based Supersede introduced a new option for boatbuilders. According to company co-founder Sean Patterson, the genesis of the product was this question: "How do we replace plywood with something that's a little more sustainable and make it a little better performing?"

Focusing on sustainability first, the team looked to recycled plastics, of which there is an abundance in raw form. They chose polypropylene for availability, affordability, and its capacity to be extruded into uniform sheets of any length, which means custom lengths of 4′ wide material are available at the same price per square foot as stock 4′ x 8′ sheets. And "because it's made out of recycled polypropylene, it's going to be 100% waterproof," Patterson said. The design and market goal was to create "a drop-in replacement for where you're using marine ply today," he said.

During product development in 2023, the team talked to boat builders, repairers, and sales teams and were surprised at how much all players knew about the plywood and other sheet goods they were using. Patterson read the broad knowledge about the flexural modulus, fastener retention, water absorption rates, density, and impact strength as symptomatic of "an industry looking for solutions."

To match weight and other material properties of marine plywood, the cross section of a sheet of supersede is a grid of extruded plastic with smooth surface sheets on top and bottom connected by pillars or web sections, like a series of closely spaced I-beams set at slight angles to enhance shear properties. Each panel is shot through with roughly triangular void space that Patterson said can be sealed on the ends or on cutouts with banding machines or tape, especially if you plan to vacuum bag it as a core material in a composite structure like a deck or transom.

COURTESY SUPERSEDE

Panels extruded from rot-resistant recycled polypropylene are redefining practicality and expectations for structural sheet goods among boatbuilders.

He said the compression strength of Supersede is twice that of most marine plywood, and fastener retention is 1.7 times that of wood. He noted that metal screws winding through the extruded polypropylene tend to seal tightly with the material, limiting water intrusion. But if water gets into some of the voids, he said there's no structural penalty as there's nothing to rot, and freeze-thaw cycles do not compromise panel integrity.

Patterson said additional measures need to be taken to optimize the plastic panels for adhesion of coatings, carpet, decking materials, wood veneers, or composite laminates. Builders can specify corona treatment (a process Patterson describes as shooting the panel with a storm of tiny lightning bolts) on one or both faces of a panel. The result is a respectable dyne rating of about 50, which allows for good surface adhesion, according to Patterson.

The alternative that's not possible with plywood is to leave Supersede panel uncoated. It is rot resistant and UV stable, so with a hot roller treatment that can texture the panel with a nonskid grit pattern or faux wood grain, the raw surface can serve as a deck or cockpit sole.

Patterson noted that the material is easy to work with, generating little dust, never splintering, and yielding fully recyclable production waste. "You take your offcuts, put them in a bin, then on the next truck on the way back here. We'll weigh it and give you a discount on your next order," Patterson said.

Product consistency is maintained through consistent lab testing of every batch of polypropylene material that comes in for production use. He noted that because sources of production waste vary, Supersede tests each batch for material properties and adjusts the content with their own amendment materials to get it into specification before generating the pellets for extruding the panels.

Currently the Marine Board is available in ½″ and ¾″ thicknesses, but Patterson said thinner options are in development.

Following Supersede's introduction to the marine market in 2024, Patterson said they are working with upward of 30 marine companies (mostly OEMs) and have distributors in North America, the Caribbean, and Europe.

Supersede, 21500 N. 8th Way, Suite 140, Phoenix, AZ 85024, USA, tel. +1-631-903-4965, info@supersede.build

—A.P.

The Unsinkable Allan Brown, 1935-2025

COURTESY ALLAN BROWN/PBB ARCHIVE

Allan Brown at the helm of Super Nova *during his last race in October 1968. He went on to lead development for other iconic high-speed powerboat brands.*

After living at full throttle for nearly 90 years, **Allan "Brownie" Brown** could not straighten his head because of neck injuries and had two knees replaced, but what he had survived in a career of boat racing would have killed lesser men. And that's before factoring in his pre- and post-race antics. Fellow 92-year-old racer Odell Lewis remarked at the last OFF (Old Friends Forever) racer reunion, "Hell, the rough water was nothing—we ran in that all day! It was the partying that was tougher!"

Brown died May 28 in Sabastian, Florida, at 89. He described his life as "racing, developing, designing, drinking, and playing gin rummy." A lover of speed, beer, women, and adrenaline, he fled Terre Haute, Indiana, in 1956 to escape life as a teacher, for which his Indiana State education had prepared him. He left his loves of fishing, hunting, and freshwater boating to seek adventure in Miami as a boat mechanic. "Coincidentally," as he often repeats in his irreverent, sarcastic, and historical book, *Tales from Thunderboat Row*, 1956 was the year boat racing started in Miami. Perhaps fate—Brownie found his place among daredevils experimenting in powerboat and engine building, innovation, and racing.

He became general manager at Challenger Marine, a large boat dealer and service center on 135th Street in North Miami, as nearby 188th Street evolved into the notorious Thunderboat Row—and his future. Living well with a strong company, new house, wife, and kids, he bought a Formula 233 race boat from Don Aronow, telling the notorious builder it was a "lousy name for a boat" and wouldn't catch on.

When Aronow sold Formula to Thunderbird and started Donzi, he promised, as Brown recalled, "money, fame, loose women, booze… but he forgot to tell me all those things were for him." Brown bit, leaving the solid dealer job for the next adventure. He was grateful to Aronow. While creating the new company demanded hard work and long hours, it bestowed the fringe benefit of racing Donzis.

Bertram had dominated offshore racing, but when the Ray Hunt/Walt Walters designed Donzi came on the scene, focus shifted. Brown shone as the Donzi boss—though he thought it was another "stupid boat name"—but when Aronow sold Donzi to the Canadian Teleflex corporation, Brown was part of the deal. He stayed for four years before moving on to new adventures.

Among the notable boat companies he headed were Cary, Magnum, Cougar, and Cigarette, plus some less storied brands like his brainchild, Nova Marine. Stints with companies like Holman Moody, Ford, Stainless Marine, and Gentry Transcontinental led to other innovations, experiences, and inevitably, more stories as he kept moving. Brown said that after about five years, "I'd get sick of them, or they'd get sick of me."

His friends and contemporaries were the who's who of the era—Jim Wynn, Sam Griffith, Don Aronow, Forrest Johnson, Clive Curtis, and Dick Bertram—but his idol was revolutionary Italian powerboat designer Renato "Sonny" Levi. "No one was smarter, handsomer, or more competitive," said

Brown, and in his book, he relays a reverently hilarious story about the late great racer.

Tales from Thunderboat Row is a witty insider's account of offshore racing from the 1950s-90s, but the working side of Brown was an equally compelling story, one of focus and achievement behind the mischievous gleam in his eye and his wry smile.

English boatbuilder, Clive Curtis, brought Brown on to head Cougar USA. His son Steve Curtis remembers Brown as, "a friend and mentor—I was the age of his son, so he guided me, but he was also fun. I wanted to drive, so he used me like a test dummy. But I could talk to him, not just about boats but about girls, about life." Curtis described Cougar in Miami during the 1980s as an exciting "social club" where racers—including Formula 1 car racing teams, owned by investor Ted Toleman—"hung out" just soaking in the adrenaline of powerboat racing.

Brown said that Cougar became the "Big Cat Guys" and attracted the military, smugglers, and eventually, Richard Branson, who commissioned a 67′ (20.4m) Cougar as the *Virgin Atlantic Challenger* to take the transatlantic record. Though that boat sunk 116 miles (267 km) from the finish line, Branson stole Brown's right-hand man at Cougar, Steve Ridgeway, to become Virgin Atlantic Airway's CEO, and Brown went on to join Gentry Transatlantic at the invitation of John Connor.

Connor, best known as Betty Cook's KAAMA team throttleman when she became the first American woman to win the Cowes-Torquay race in 1967, headed the company, as powerboat racer Tom Gentry looked to convert his *Gentry Eagle* race boat into a yacht and then decided to break the transatlantic record. Connor brought Brown on to help configure the new vessels. "He was a great idea guy, but he also created a positive atmosphere for the crew. His attitude was always, 'Hey! This is a fun job!' He got the work done and never seemed to have a bad day," Connor stated.

Brown and the design team struggled for four years to perfectly size a model that could carry the fuel and maintain power for a transatlantic crossing. Just as they were ready to build, Tom Gentry was killed in 1994 at the Key West World Championship races, ending that dream and company.

Then Val Jenkins, a long-time friend who had come from Rybovich to Mako to Cigarette, brought Brown in to help with the iconic brand. Jenkins said, "Brownie carried a lot of weight, but he never threw his weight around. When he made a suggestion, it was like a command." But Brown was not a "commander" Jenkins insists. He'd walk around the factory and watch what was being done. If he didn't like the direction, he'd make a "suggestion. Brownie was very free with his knowledge," Jenkins added.

Brown described early boatbuilding in Miami before fiberglass as "more craft than business." He then updated his description observing, "Computers have sucked the knowledge out of the technical end of boating. Nobody builds their own molds, and many 'builders' don't even lay up their own boats. It seems that when this generation of boatbuilding geezers dies, there won't be any more Howard Abbeys or Forrest Johnsons or Sam Griffiths." He concocted a *2001: A Space Odyssey* scenario around the subject of computer-assisted design when Hal can't disobey an order to build an 8-engined, 40′(12.2m) outboard. Brown concluded, "Humans don't know how to build boats anymore!"

In the early 2000s, with boatbuilding in his wake—except for his personal projects—another challenge opened as technophile **Harry Schoell** asked for help pursuing his latest inventions. Brown joined a talented team on the cusp of major innovations contributing to sustainable transport and robotics. One of the bright young guns, Travis Love, now Senior Engineer at Yamaha Outboard Division, related, "Brownie was like having a fun uncle at work, and I had a front-row seat to the reminiscing of past projects, inappropriate jokes, thick sarcasm, and banter that resulted in plenty of uncontrollable laughter."

All who knew Brownie are now shaking our heads, wondering who to call with boating questions. Michael Peters laughingly contemplated the need to become an historian. "Without Brownie, who else knows this information?!"

It is impossible to describe or define the man. He was so much to so many, contributing to our knowledge base, our industry, and entertainment. I savor many conversations over many Heinekens and miss that twinkle in his eye as he relayed a "slightly" off-color story. I miss calling to ask historical questions, which he answered quickly without a second thought. Curtis said he had a photographic memory, and Jenkins added, "Brownie didn't need to concentrate, he'd say, 'I just think about it and the answer is there.'"

Perhaps instantly accessed knowledge was part of his talent, but the other part was just making people around him feel important and appreciated.

As Love summarized, "I don't think the cleverest author could dream up a story as good as the life Brownie lived. He is a true legend of a bygone age that paved the way for so many and so much of what the marine industry is today."

Godspeed my friend—but you are probably teaching God about speed now. PBB

—Marilyn DeMartini

TASK SHEET Antifouling: Taming Bottom Growth

by Eric Renshaw

Photographs by Aaron Porter (except where noted)

Painters should wear full personal protective equipment when applying most antifouling paints.

INTRODUCTION

Boats demand constant maintenance, but one of the most persistent predictable needs, even for boats that never leave the dock, is the prevention and removal of biological growth on the bottom. Any part of the boat in constant contact with the water the boat floats in is susceptible to marine growth. Depending on the water's warmth, salinity, and nutrient loading, that growth can range from a light algae layer on a biological film of microorganisms to heavy biofouling of marine plants and animals like mussels and barnacles that feed on plankton in the water. Their accumulation can have all kinds of detrimental effects on a boat—reduced speeds, excessive fuel consumption, or in the case of the dreaded shipworm, catastrophic structural failures. Any surface not coated in a protective paint with antifouling properties requires frequent scrubbing to prevent unsightly stains and biological growth.

In most waters, manual removal is impractical, so seafarers have treated hull bottoms for many hundreds of years with a range of coatings from tar, tallow, and hot pepper to mercury, arsenic, and tin paints, with varying degrees of success. One of the more effective antifouling coatings discovered was copper, applied in the form of thin sheets affixed to a ship's bottom or as powder mixed with paint. (For more on antifouling see Steve D'Antonio's "***Antifouling Tactics***" on ProBoat.com.)

Enter the modern era of antifouling coatings. Meant to be efficient and relatively economical, bottom painting has become one of the most dreaded annual maintenance rituals, sometimes requiring bi- or tri-annual replenishment depending on the coating, environment, and vessel use.

This article is intended as a practical guide to this essential maintenance task for professional boatyard technicians and any fastidious or parsimonious boatowners who prefer to paint their own bottoms.

PREPARATION

Let's start at the beginning, with forethought and essential planning. We want to focus on the who, where, what, when, and how of antifouling.

The first of these calls for some self-awareness about your experience level. As a seasoned professional, you may

A coat or two of copper-based bottom paint is a standard annual maintenance measure, especially on traditional wood hulls.

have developed some complacency and think you can skip certain steps. As a new employee or boat owner, you may not even know what steps you are at risk of skipping. In either case, be honest with yourself about your knowledge and abilities as you plan the project.

You should know your yard's policies, as well as relevant state and local regulations. If you don't, look them up and remember that location matters whether it is your back yard or your boatyard. Some states may require the painter to have a pesticide applicator's license, some locales don't allow sanding of antifouling paints due to environmental regulations, and in others there are special containment requirements should the hull need sanding or stripping below the waterline. Be familiar with these requirements before getting started as an EPA fine for violations can be significant. Keep in mind that removal of old paint may not be required if the boat was coated with an ablative that wears off with use, preventing buildup of old paint.

Indeed, the paint specified dictates much of the process. The best antifouling option is dictated by a boat's use profile, location, and hull material. That means doing some research. Perhaps you have a houseboat that lives at the dock in the brackish tidal waters of a river delta, and you only get under way once a month. Or maybe you own a charter boat that takes people out fishing daily. Remember the ablative paint? It's not ideal for the sedentary houseboat but would likely perform well on the charter boat. Consult manufacturer's recommendations and consider any client preferences as you choose the paint.

The following variables should factor into your choice:

A. Type of use: Is the boat sitting relatively still most or all year, is it a race boat, does it live on a trailer year round, or is it docked in a marina or at a mooring?

B. Type of water: Salt, brackish, or fresh?

C. Hull material: Fiberglass, wood, steel, aluminum, or exotic composites like carbon fiber and Kevlar.

It's a practical reality that often your paint choice depends on what was selected years before when the first antifouling coat was applied. The standard yard task, barring a change in boat owner or location, is to apply the same bottom paint that has been used on the boat before. If switching paint brands or systems, be sure the new coating is compatible with the underlying residual paint, or that the surface is prepped and primed to accept the new chemistry.

Before making your final antifouling selection, consult the coating manufacturer's published Technical Data Sheet (TDS) for the product, which includes details such as time to cure before launch, solvents and thinners, pre-application prep, and optimal atmospheric conditions. It's important to know whether your coating must be immersed in water after two days of cure time or if it can sit two months before launch day. If the paint requires immersion within a set period, this is the time to reserve the Travelift to make certain of the launch schedule.

The TDS will also tell you how to prep and prime the surface for painting depending on whether the hull is bare or has some coatings applied already. In the latter case, it's important to determine what the previous coatings are to check paint compatibility. Most coatings manufacturers have great tech support, so give them a call to confirm compatibility if you have any doubt.

One last point to consider before starting the real work is personal protective equipment (PPE). Remember, most of this paint is toxic; even the most "environmentally friendly" types of antifouling coatings can cause health issues. Especially for professionals who are exposed daily, the health risks are real. Consult the product's Material Safety Data Sheet (MSD, MSDS) and follow the listed recommendations. This information will be found on the manufacturer's website for your product of choice. In general, disposable protective suits, organic compound respirators, nitrile gloves, and chemical-rated goggles should be worn when working with this stuff.

ERIC RENSHAW

The essential tools and equipment for applying antifouling paint are neither expensive nor exotic, but it's good practice to be sure you have them all at hand before starting the job.

TOOLS & MATERIALS

Let's look at a basic equipment/materials list, which will need to be adjusted depending on your specific situation and plans. Make sure you have everything on your completed list handy before starting the job.

1. The antifouling coating appropriate to your project boat, along with the recommended solvents and primers.

How much? Everyone has their own, but this is my formula:

0.85 (X)(LOA) x 2

where **X** = distance from the keel to the widest point at the chine in feet, and **LOA** = length overall of the vessel in feet.

This gives you a fair estimate of the square footage of surface to be painted. The TDS will give you the square foot coverage per unit the material is sold by (quart, liter, gallon, etc.). For deep fin-keel boats, calculate the keel separately as a rectangle (average width x height) x 2 for both sides.

2. Surface prep materials, per the TDS.

3. Assorted tape—strapping tape for adhesion test, painter's, and fine-line tape for masking off the waterline (see Jim Moores's "Tape Technique" Task Sheet in *Professional Boat-Builder* No. 210, page 54).

4. Plastic or canvas tarps for containing dust, debris, and paint drips.

5. Stiff scraper (and a file to sharpen it) and a heat gun if the paint needs to be stripped.

6. A water supply and garden hose with spray head or a pressure washer.

7. Appropriate brushes, roller covers, and frames, per the TDS.

8. An abundance of paint rags, paint mixer, mixing cups, and roller pans.

PROCEDURE

Surface preparation is the most important part of the job. If the hull has old paint on it, start with an adhesion test; if the old paint doesn't stay on the boat, neither will the new. To do this, select an unobtrusive area or an area that looks doubtful and mark off a 3″ x 3″ (75 x 75mm) area with pencil. Then score it carefully in 1″ (25mm) squares through the paint but not into the hull itself. Cover the area marked with strapping tape, rubbing with firm pressure for best adhesion. Peel off the tape, pulling 90° to the surface. If the paint comes off with the tape in layers or down to the hull, it is time to strip.

Before you start serious surface prep, make sure the boat is firmly blocked and stable on solid ground. (Note that blocking and stands will need to be moved and the paint patched where they interfered with the initial coating.) Don't work on any vessel while it hangs in slings. Trailer boats should be removed from the trailer.

There are many ways to strip a bottom but the most efficient is to sandblast with a corn cob or walnut shell medium. Corn cob is the softer and works great on wood hulls. It has the added benefit of revealing soft planks that should be replaced. I used to subcontract the paint stripping to a mobile sandblaster who dealt with all the mess.

For manual stripping, first check the bootstripe or waterline for paint

Be sure the boat is correctly blocked and supported before getting under it to prep the bottom. Remember, you will need to move the stands to paint the entire surface.

adhesion issues, and tape it off with a good painter's tape in preparation for manual scraping below. Suit up in the appropriate PPE, then I go to a heat gun and scraper on wood hulls. This method is surprisingly fast, but I don't recommend it for FRP/GRP or wood-composite hulls where the heat can damage resin in the structural laminate. For those composite hulls, the manual solution is insane amounts of sanding. Wet-sanding here is nice as it keeps the dust under control, but it requires a filtered floor drain to catch the debris. (You may want to add cheap rain gear to your materials list should you choose that route.)

Finish sanding the hull surface in the grits recommended in the TDS for the first coating to be applied, be it primer, barrier coat, or antifouling.

Mercifully, in most cases, stripping a hull isn't necessary, especially when the boat is hauled at least annually and thoroughly cleaned using a power washer that knocks off biofouling and much of the loose paint. So, if you passed the adhesion test, life is good, and all you need to do is prep the hull according to the TDS, making sure there are no hard edges or chips in the remaining bottom paint for water to get a hold of under way.

Some paints require a light scuff with a specific grit. I like to use a drywall sanding stick and the mesh sandpaper for sanding drywall mud. To limit dust, you can wet-sand, just remember to rinse and wipe frequently. Don't let the slurry dry; it will glue itself back to the hull and be very difficult to remove.

Clean up thoroughly, recycling your plastic and washing off canvas tarps and drop clothes. Vacuum up the area to remove dust and dispose of the debris according to your local regulations. Remember, even the dust is toxic. Remove any remaining tape.

Some areas of caution during bottom preparation and painting are the ground plate and other sacrificial anodes (zincs). Many boats equipped with a bonded ground system to deal with stray electrical currents and lightning strikes have a bronze ground plate on the hull exposed to the water well below the waterline. The metal terminal should not be painted as the coating will lessen the fitting's conductivity to the water. This is especially critical for a ground plate intended for lightning protection. In addition, sharp corners and edges are the best points of conduction for the plate, so try not to sand them round. Similarly, sacrificial zincs should never be painted.

Next comes the fun part: painting the hull. I always paint the bootstripe first, so I have a smooth surface to tape to and get a crisp line between antifouling and topside finishes. This requires taping off again with a two-tape system. Wipe the surface down with an appropriate solvent per the TDS and apply the painter's tape or other safe-release tape about ¼″ (6mm) from the edge of the line. Then, apply the fine-line tape (I prefer 3M brand there) to the line and overlapping the safe release tape. Rub it all down with firm pressure. This technique assures the fine-line tape, which has superior adhesion qualities and resistance to some of the chemicals common in marine finishes, does not peel off any paint.

Once you've taped you bootstripe, you can immediately apply primer or paint. Do not leave the tape on any longer than about three days for successive coats. Hot coats (paint dry but not fully cured) can be applied per the TDS of your bootstripe paint. I tend to use 1″ (25mm) foam brushes for this, but a good bristle brush is fine. I have even sprayed bootstripes with a touch up HVLP spry gun. After applying the final coat, immediately remove the tape by pulling away from the still-wet paint at an acute angle. This prevents paint chips along the tape edge.

Wait until the paint has fully cured, usually a couple of days, before taping off for the antifouling, barrier, or prime coats. Tape the waterline again using the same technique in the previous step and suit up in full PPE. Apply the paint according to the TDS.

With most antifouling paints, you have to really move to maintain a wet edge; they dry quickly. The paint, which should be thoroughly mixed at the outset, will also require frequent stirring in the pan to keep the heavy solids from settling.

Stir the paint thoroughly using a mixing attachment on a drill or a stationary paint mixer, and pour it promptly into a roller pan before solids start to settle out.

Most commonly, you apply bottom paint by rolling it on perpendicular to the waterline, usually from waterline to keel unless you're applying a hard shell (racing) type paint. It must be applied swiftly, keeping a wet edge between working areas. It helps to keep those areas small and overlapping so the paint does not dry before you get to the next one. Also, apply more pressure on the roller toward the dry side of the application area. This helps reduce lines from the edge of the roller that overlaps with areas already painted. Also, flip the roller between strokes to keep the paint more evenly loaded on the roller.

Use a small brush to "cut in" around zincs, transducers, and other things not getting painted. It's best to brush those edges first, then roll to the brushed coating. If your hull is lapstrake planked or molded, you will have to use a 3″ (76mm) roller running fore and aft following the planking and painting the edges with a small brush.

If you are using a hard racing finish, you may want one person rolling and one person tipping to assure a uniformly smooth brushed finish textured fore and aft. In addition to race-boat owners, some customers with classic runabouts or dry sailed boats that spend most of their time on trailers, demand a brushed finish on the hull bottom. If you need

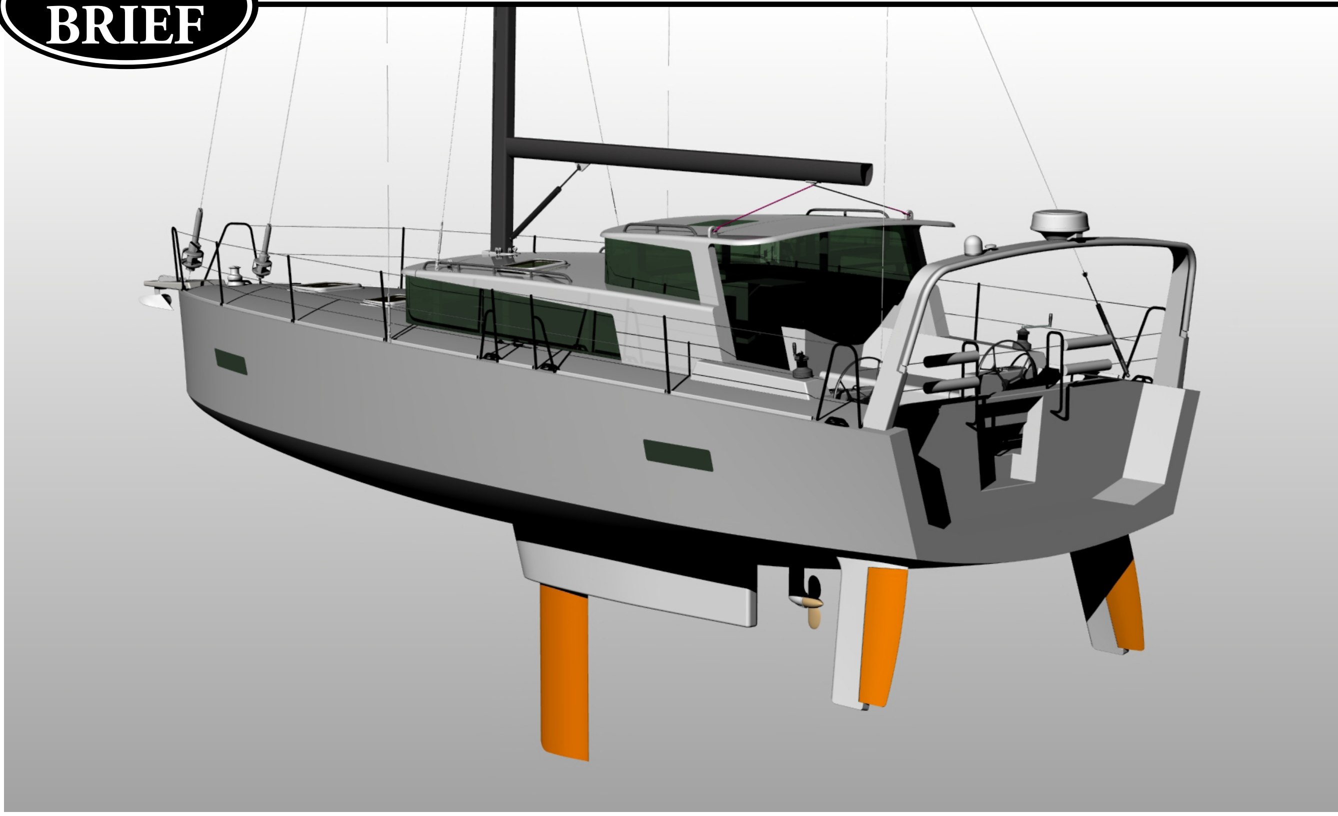
Taping the waterline assures a sharp line of transition between bottom and topside paints.

Left—*Roll the paint on in steady even passes from the keel to the waterline overlapping slightly with the last pass to assure coverage.* ***Inset***—*First, cut in at the waterline and around hardware with a brush, then roll on paint to meld with the brushed areas.*

a second coat per the TDS, or the first looks a bit translucent, wait the TDS recommended time before overcoating. (Note that water-based formulations tend to need an overcoat.) Then, immediately remove any tape in the same manner used for the bootstripe.

The next day, you will need to move the stands and blocking to prep/paint those areas. Keep a piece of cardboard, foam, or carpet between the blocks and your fresh paint. Let those patches dry as you do one more thorough cleanup and you're ready to launch. PBB

About the Author: *Eric Renshaw grew up on the Great Lakes working on his father's sportfishing charter boat. He started his boatbuilding and restoration business at age 19 and has built over 40 new vessels and restored more than 300 to date. Since 2020, he has been an instructor at Great Lakes Boat Building School (now the Marine Trades Institute) where he builds boatbuilders instead of boats. He continues to maintain boats in his home workshop and fish around the Straits of Mackinaw. He is a USCG certified boatbuilder and ABYC master technician.*

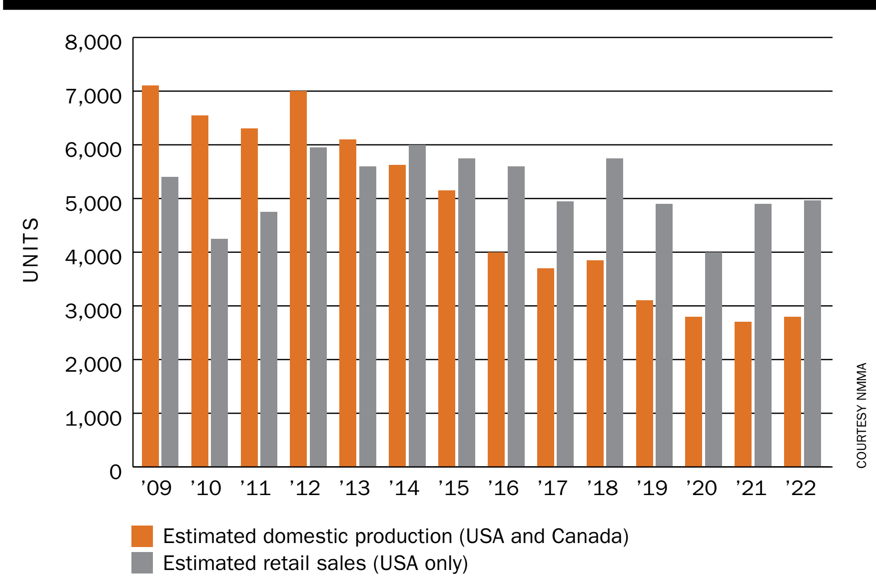


EXP44

Creating a cruising sailboat for a new economy.

Text and graphics by Geoff Van Gorkom
(except where noted)

Sailboat Production and Retail Sales Estimates



The "Made in the U.S.A." badge has been a consistent stamp of quality in the global boatbuilding industry. Unfortunately, in response to economic pressure over the past 30 years, many U.S. manufacturing companies have closed their doors or relocated their construction operations abroad in a bid to remain competitive. So, it should come as no surprise to anyone in the recreational marine sector that sailboat production in the United States is at an all-time low. Meanwhile, most new production and semi-production sailboats being sold in the U.S. are being built offshore in Europe and Asia.

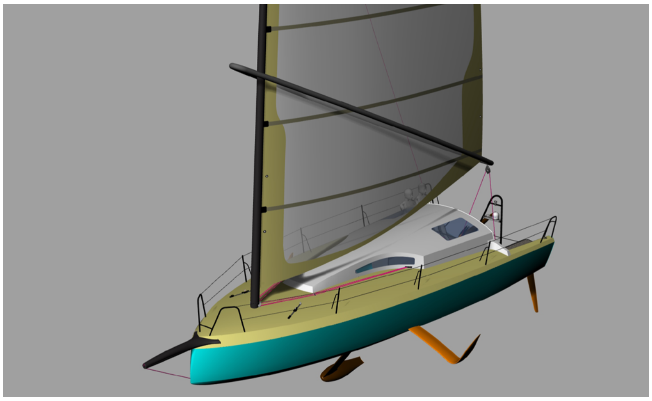
I'm heartened by some recent signs that this trend may be heading in the other direction, providing a real opportunity to inject some life back into our industry. For example, material costs and labor rates for many of the dominant European and Asian manufacturers have steadily increased over the last several years, not to mention the U.S. tariffs recently imposed in almost all trading nations,

A new performance cruiser from Van Gorkom Yacht Design anticipates a revival of sailboat construction in North America.

should they remain in place. In the face of that trend, U.S. boatbuilders, powered by a skilled domestic workforce, have started to look more affordable and a lot more convenient for the North American market. I've seen real interest out there among buyers, and that translates to design commissions in my office.

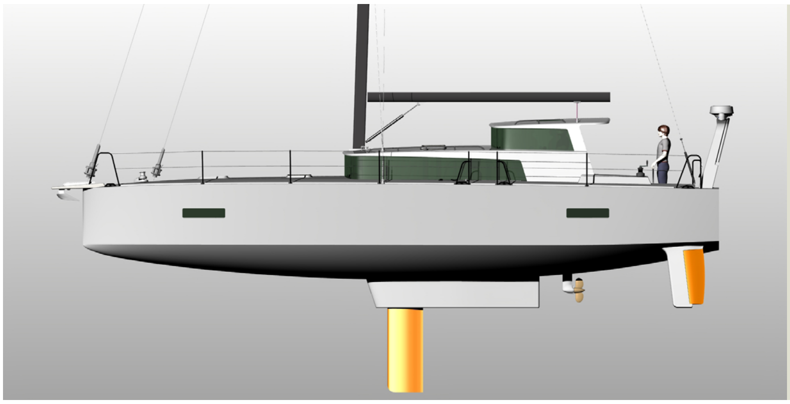
A case in point: I recently had a custom cruising sailboat project come through the office that unfortunately didn't get to the build stage with the initiating client. However, it alerted me to the fact that there's a viable market for expedition-focused sailboats out there that's new to U.S. builders. It's a niche sector that French and Dutch boatbuilders, such as Alubat and KM Yachts, have been successfully capitalizing on for years, to the point that these manufactures currently have orders extending out to 2028.

While the commission vaporized, I couldn't ignore the preliminary design study for the custom pilothouse cutter. It became the genesis for the Van Gorkom Yacht Design EXP44. Conceived of for the cruising sailor who wants to explore some off-the-grid corners of the world, it's a 44-footer (13.4m) with blue-water capabilities. The base hull and deck arrangement with a quasi-customizable interior makes this boat the ideal vehicle for an established U.S.-based boatbuilder, or a startup enterprise, to produce a quality boat on a semi-production basis. To be clear, this opportunity is not about repeating the pattern of cutting corners to yield an inexpensive production model—the mistakes that drove so much business offshore. To establish a credible brand, this cruising yacht will need to be built to a high standard and be tough enough to safely withstand the rigors of open-ocean sailing.



*The EXP44 carries some of the hull shape and performance DNA from Van Gorkom's recent competitive offshore models, the Mini 6.5 2G, **top**, and 2xS-30, **bottom**.*

As with all design projects, I had to make compromises when balancing form and function, particularly when considering the mission statement of an "expedition" yacht. Aluminum was chosen as the base building material, not only for its robust properties, but for ease of construction. I've specified that all structural elements will be fabricated in 5086 aluminum for plating and 6061 for extrusions. The "Erector Set" type of assembly, made up of precise waterjet-cut parts, makes for cost-effective boatbuilding by guaranteeing repeatability



EXP44 Particulars

LOA (hull):	13.41m (44′)
LWL:	13.27m (43′ 6″)
Max Beam:	4.03m (13′ 3″)
Draft (up):	1.22m (4′)
Draft (dn):	3.00m (9′ 10″)
DSPL (sailing):	11,340 kg (25,000 lb)
Ballast:	4,082 kg (9,000 lb)
SA (upwind):	106m^2 (1143 ft^2)
SA (downwind):	163m^2 (1753 ft^2)

The EXP44 rig is a compromise between high performance and manageability for a small crew in challenging sailing conditions.

and reducing construction time. The hull, deck, and internal structures are all engineered to ABS and ISO standards.

Hull & Appendages

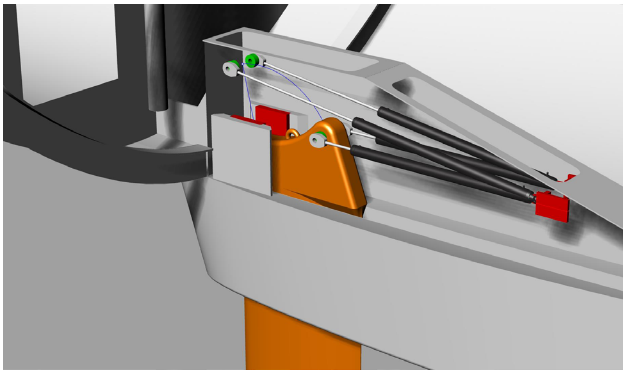
The chined hullform and slightly reversed sheer of the EXP44 is a development of VGYD's second generation go-fast boats. The hull designs of our Mini 6.5 2G and the 2XS-30 incorporate the latest proven trends in hydrodynamic efficiency. These models carry a generous amount of reserve buoyancy, a moderate prismatic, and there's a concerted effort to reduce the pitch moment. This philosophy, along with an additional emphasis on maximizing the waterline and interior volume, will result in a sea-kindly and comfortable yacht that I predict will be quick and efficient through the water.

The EXP44 has a minimum shoal draft of only 4 feet (1.22m), allowing it to comfortably anchor in most of the planet's cruising grounds. However, sailing performance has not been neglected as is common among some of its expedition yacht counterparts. The boat is fitted with a high aspect ratio, hydraulically controlled, solid steel, rotating centerboard arrangement that projects from a ventral keel fin to a maximum draft of 9′10″ (3m). To optimize the vessel's righting moment, the primary fixed ballast will be made up of preformed lead ingots sealed into the fin. I considered bilge keels for this design, but the emphasis on performance outweighed the practicality of beaching the boat. This issue was resolved via the twin aluminum skeg rudders that complete the shallow draft appendage package. The integral structure of the skegs, along with the keel fin, form a tripod allowing the boat to be sit level on the hard. The skegs also provide damage protection for the rudder blades. The option of composite spade rudders is available for the cruiser looking for a little more performance.

Rig

The sail plan and rig configuration of the EXP44 are optimized to balancing performance and user friendliness. In terms of raw performance, the EXP44 has a Dspl/LWL ratio of 135, a SA/Dspl ratio of 21.4, and a Dellenbaugh angle of 12. In short, the boat will not disappoint under sail, and its motion should be neither too stiff nor too tender. Controlling the sail plan will be relatively easy in most wind conditions as it is broken down into three working sails—a 95% jib, a staysail, and a main. The mainsheet leads back through the boom, then below to a Harken captive reel winch, giving the helmsperson push-button control of mainsail trim. The jib and staysail have Harken roller-furling systems for user-friendly control of the headsails. The asymmetric gennaker deploys from the bowsprit on a roller furler for easy sets and douses. All control lines lead back to the cockpit, ensuring the crew rarely need to go forward in heavy conditions. The rig is centered around a deck-stepped aluminum mast with swept-back upper and lower spreaders, and an alloy boom (carbon fiber spars are an option). The bridled backstay is controlled with a hydraulic, single-acting ram.

The contemporary raised salon and pilothouse not only complement the aesthetics of the hull and rig design, they allow for an unobstructed view of the outside world. The superstructure interacts seamlessly with the partially enclosed working cockpit, which provides heavy-weather protection for the crew, yet is expansive enough for entertaining or solitary relaxation. The cockpit opens to twin helm stations aft and a walk-through to the transom steps that allows easy boarding access and doubles as a swim platform. The radar arch accommodates an array of antenna, and its integrated lifting arm allows it to serve double duty as a dinghy davit.



The complex hydraulically controlled, rotating steel centerboard is an instance of Van Gorkom choosing performance over the practicality of simple bilge keels.

Accommodations

Within physical limits, the voluminous interior can be customized to suit different use profiles as envisaged by the range of owners the EXP44 is likely to attract. In the standard version, there's a roomy stateroom forward and one to starboard and aft. There are two heads with showers, the fully equipped galley is to the port side of the saloon, and there's a raised dining area to starboard

with panoramic views. The table and bench seats can be converted to a spacious double bunk. The navigator sits forward of the dining area with clear sightlines ahead. There's plenty of stowage, as well as a day bunk on the port side forward of the saloon. This area could also accommodate a washer/dryer unit and storage, or perhaps a work bench area. With generous standing headroom throughout the boat, there are many possible interior layouts.

Drivetrain & Systems

The EXP44 is powered by a Yanmar 80-hp diesel engine through a sail drive, giving the boat a cruising speed of 8+ knots. There is good access to the engine, port and starboard, by removing interior paneling. There's also a soft patch in the cockpit sole in case the engine needs to be pulled. The two 95-gallon (360 l) fuel tanks and a 10-gallon (37.8 l) day tank give the boat a motoring range of approximately 600 miles at cruising RPMs.

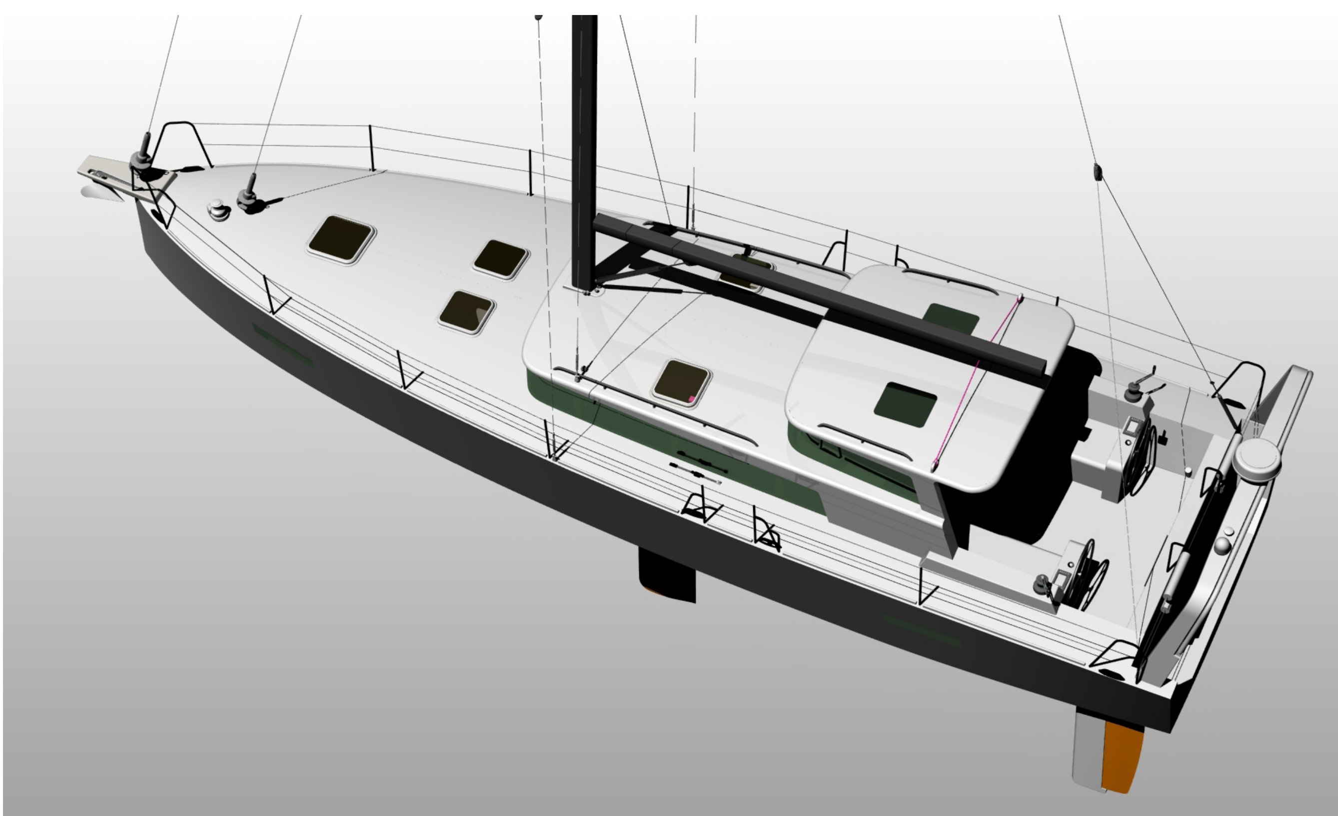
The sail drive is positioned with its lower unit up behind the keel where it is naturally protected from impact with flotsam and jetsam. For maneuvering in tight places, the boat is fitted with a retractable bow thruster.

The contemporary raised salon and pilothouse not only complement the aesthetics of the hull and rig design, they also allow for an unobstructed view of the outside world.

House electricity demands can be met by the 9.5-kW diesel generator, with supplementary voltage coming from a solar panel array mounted on top of the pilot house. There is a 500-Ah lithium-iron-phosphate battery bank with a backup AGM battery. Double-pole switching throughout the boat will eliminate the potential for stray current—an important consideration on an aluminum boat.

The boat will carry 120 gallons (454.2 l) of potable water, although lesser tankage backed up by a water maker is an option.

__About the Author:__ Geoff Van Gorkom is a degreed naval architect/marine engineer and the principal designer at Van Gorkom Yacht Design (Portsmouth, Rhode Island), which he founded in 1994. He has extensive experience designing sailing yachts, from Maxi boats to Mini Transat 6.5s. He has also designed a series of power boats and super yachts, and has experience engineering metal and composite marine structures. (vgyd.com)



A practical deck layout marries an uncluttered working foredeck with a sheltered cockpit housing twin helm stations.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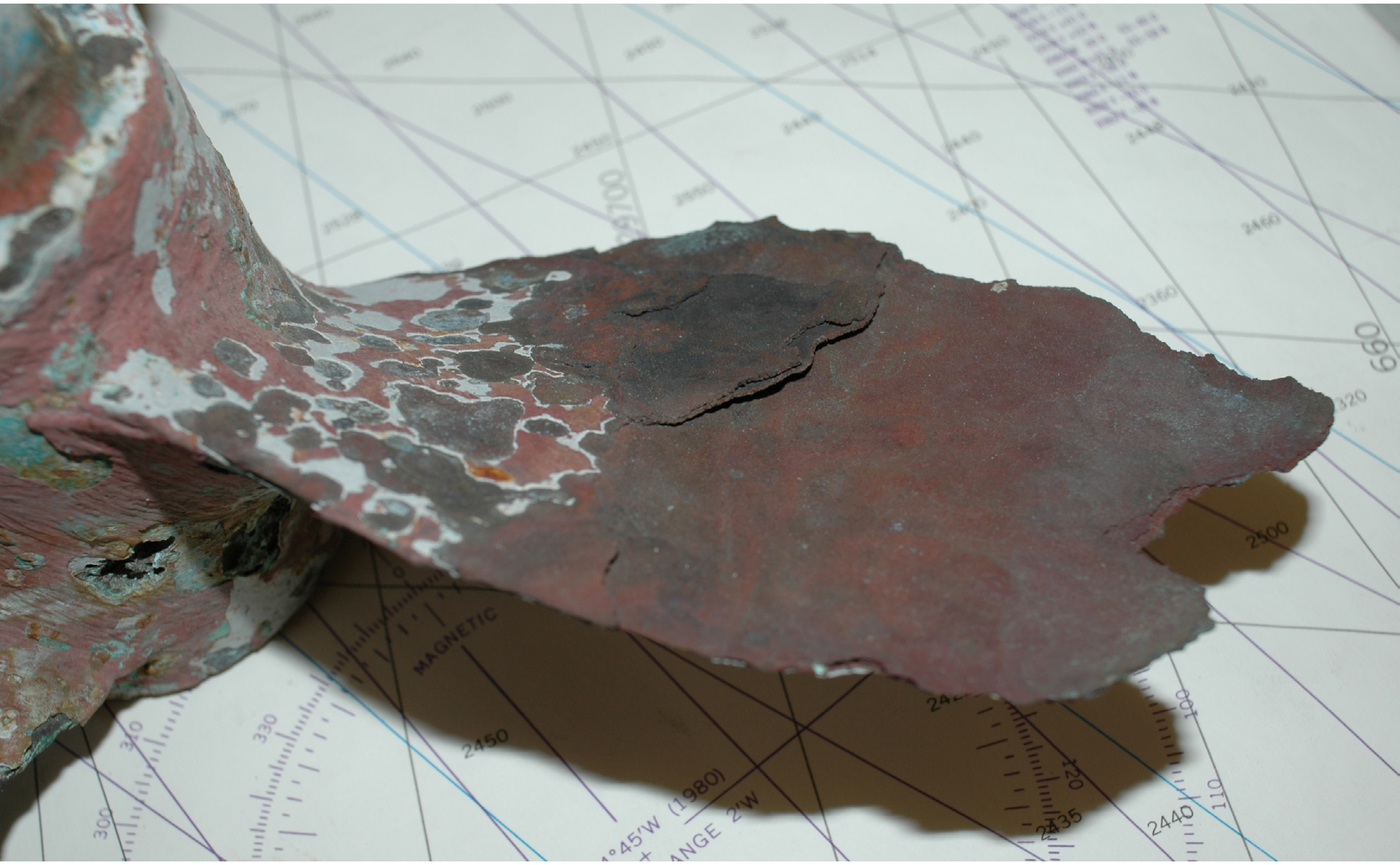
Corrosion Evasion: Part 1

Preventing galvanic, stray-current corrosion.

Text and photographs by Steve D'Antonio



There's a conversation I find myself having on too many occasions that goes something like this:

Jim: "Hey Steve, I'm interested in purchasing/building this vessel. It's XX feet, does XX knots with a range of XXXX miles…Oh, and it's aluminum/steel."

Me: "That sounds great Jim. Have you ever owned a metal boat before?"

Jim: "No. Why, is that a problem? What do I need to know?"

Me: "You need to know everything. When it comes to corrosion, you've got to educate yourself to be your own expert, because the guidance you get from other boatowners, and even industry professionals, is almost always incorrect."

While that advice to owners is intended to steer them on a path to technical education and self-reliance, I worry that often they turn directly to the internet where the volume of corrosion misinformation available seems infinite. My intent with this two-part article is to provide a solid primer for boatyard technicians and boat owners who should know the essentials of corrosion prevention. —Steve D'Antonio

Stray-current corrosion can destroy metal components like this propeller in a brief exposure period.

It's a rare day when I don't hear from someone trying to solve some vexing corrosion problem. No surprise: Almost every modern boat includes a wide range of metallic, corrosion-prone components—bronze seacocks, iron engine blocks, stainless steel and aluminum deck hardware, and copper wiring. Add water or electricity or both to this mix, and the results can be crippling and costly.

While there are scores of different corrosion variations specific to different metals—poultice corrosion in aluminum, crevice corrosion in stainless steel—there are just two overarching mechanisms that cause most corrosion on small craft: galvanic or dissimilar-metal, and stray-current corrosion.

Galvanic

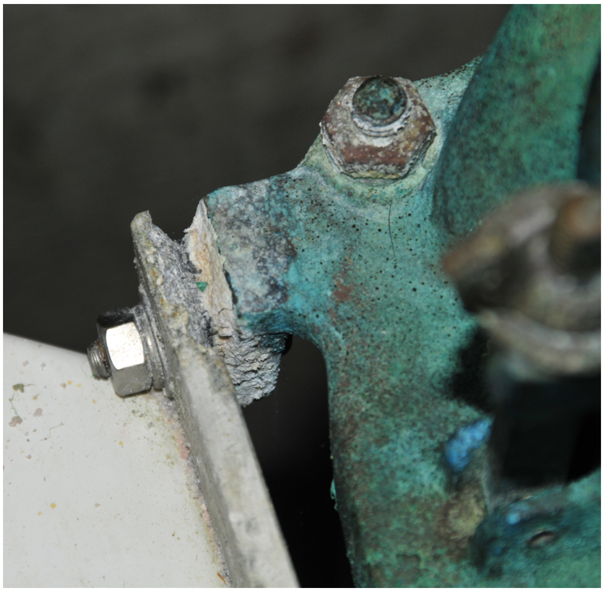
Galvanic corrosion is electrical in nature, occurring when dissimilar metals are placed in direct contact with each other, or are electrically connected via a wire or other conductor, while simultaneously exposed to an electrolyte such as fresh or seawater, or even high humidity. (Note that seawater's enhanced conductivity accelerates the process.) In this case, electricity is created by the dissimilar metals sharing an electrolyte. It functions much like a battery, albeit at a very low rate typically measured in millivolts.

While virtually any two metals will interact with each other in these conditions, the farther apart they are on the galvanic series or scale (see accompanying chart), the more dramatic their encounter will be. Metals located at the most noble and most corrosion-resistant end of the galvanic series include exotics such as graphite (including carbon fiber), gold, and titanium as well as more pedestrian 316 stainless steel, and nickel-chrome alloys used for propeller shafts. Those at the least noble end of the series, such as magnesium, zinc, and aluminum alloys, are significantly less corrosion resistant.

Some especially problematic combinations of dissimilar metals include copper (and copper alloys such as bronze and brass)and aluminum alloys, and to a lesser degree, stainless steel and aluminum. Because of its extreme location on the galvanic scale, virtually any metal placed into contact with aluminum in the presence of moisture, will cause the latter

Table 1. Galvanic Series I

	Ag/AgCI REFERENCE CELL POTENTIAL (mVDC)	Zn REFERENCE CELL POTENTIAL (mVDC)
ANODIC OR LEAST NOBLE		
Magnesium and Magnesium Alloys	-1600 to -1630	-600 to -630
Zinc	-980 to -1030	-30 to +20
Aluminum Alloys	-760 to-1000	0 to +240
Cadmium	-700 to -730	+270 to +300
Mild Steel	-600 to -710	+290 to +400
Wrought Iron	-600 to -710	+290 to +400
Cast Iron	-600 to -710	+290 to +400
13% Chromium Stainless Steel, Type 410 (active in still water)	-460 to -580	+420 to +540
18-8 Stainless Steel, Type 304 (active in stil water)	-460 to -580	+420 to +540
Ni-Resist	-460 to -580	+420 to +540
18-8, 3% Mo Stainless Steel, Type 316 (active in still water)	-430 to -540	+460 to +570
Inconel (78% Ni, 13.5% Cr, 6% Fe) (active in still water)	-350 to -460	+540 to +650
Aluminum Bronze (92% Cu, 8% Al)	-310 to -420	+570 to +690
Nibral (81.2% Cu, 4% Fe, 4.5% Ni, 9% Al, 1.3% Mg)	-310 to -420	+570 to +690
Naval Brass (60% Cu, 39% Zn)	-300 to -400	+600 to +700
Yellow Brass (65% Cu, 35% Zn)	-300 to -400	+600 to +700
Red Brass (85% Cu, 15% Zn)	-300 to -400	+600 to +700
Muntz Metal (60% Cu, 40% Zn)	-300 to -400	+600 to +700
Tin	-310 to -330	+670 to +690
Copper	-300 to -570	+430 to +700
50-50 Lead- Tin Solder	-280 to -370	+630 to +720
Admiralty Brass (71% Cu, 28% Zn. 1% Sn)	-280 to -360	+640 to +720
Aluminum Brass (76% Cu, 22% Zn, 2% Al)|	-280 to -360	+640 to +720
Manganese Bronze (58.8% Cu,39%Zn, 1%Sn, 1%Fe, 0.3%Mn)	-270 to -340	+660 to +730
Silicon Bronze (96% Cu Max, 0.80% Fe, 1.50% Zn, 2.00% Si. 0.75% Mn, 1.60% Sn)	-260 to -290	+710 to +740
Bronze-Composition G (88% Cu, 2% Zn, 10% Sn)	-240 to -310	+690 to +760
Bronze ASTM B62 (thru-hull) (85% Cu, 5% Pb. 5% Sn. 5% Zn)	-240 to -310	+690 to +760
Bronze Composition M (88% Cu, 3% Zn. 6.5% Sn. 1.5% Pb)	-240 to -310	+690 to +760
13% Chromium Stainless Steel, Type 410 (passive)	-260 to -350	+650 to +740
Copper Nickel (70% Cu, 10% Ni)	-210 to -280	+720 to +790
Copper Nickel (75% Cu, 20% Ni, 5% Zn)	-190 to -250	+750 to +810
Lead	-190 to -250	+750 to +810
Copper Nickel (70% Cu, 30% Ni)	-180 to -230	+770 to +820
Inconel (78% Ni, 13.5% Cr, 6% Fe) (passive)	-140 to -170	+830 to +860
Nickel 200	-100 to -200	+800 to +900
18-8 Stainless Steel, Type 304 (passive)	-50 to -100	+900 to +950
Monel 400, K-500 (70% Ni. 30% Cu)	-40 to -140	+860 to +960
Stainless Steel Propeller Shaft (ASTM 830:#17 & ASTM 584: # 19)	-30 to +130	+970 to +1130
18-8 Stainless Steel, Type 318 (passive) 3% Mo	0.0 to -100	+900 to +1000
Titanium	-50 to +60	+950 to +1060



Textbook galvanic corrosion scenario with this mix of a bronze seawater strainer, an aluminum bracket, and a stainless bolt.

to corrode. In 1895, before this phenomenon was thoroughly understood from a boatbuilding perspective, the Herreshoff-designed and built America's Cup contender *Defender*, was assembled using nickel-aluminum alloy hull plating above the waterline and bronze plate below the waterline, all built over steel frames and attached with bronze rivets throughout. The result was a battery-like hotbed of galvanic activity. Predictably, the victorious sailing yacht was short lived. By 1901, the hull plating had pitted so heavily the boat was no longer seaworthy and had to be scrapped, but she had already fulfilled her successful Cup defense exactly as intended by her designer and builder who knew she wouldn't last.

Examples of common onboard combinations prone to galvanic corrosion include brass hydraulic steering cylinders or bronze seawater strainers supported by aluminum brackets, bronze sail track installed on aluminum spars, aluminum hydraulic cylinders that utilize brass hydraulic fittings, and stainless fasteners married to aluminum substrates such as spars, cranes, arches, radar masts, etc.

The best examples of galvanic corrosion on a boat are intentional: sacrificial anodes attached to underwater metals such as propeller shafts, through-hull fittings, struts, rudders, and heat exchangers. Known as cathodic protection, the generic "zinc" anode is commonly made of one of three possible sacrificial metals well suited to the purpose: zinc, aluminum, and magnesium. Zinc should only be used in seawater, magnesium is suited exclusively for fresh water, while aluminum can be used in fresh, brackish, or sea water (see the accompanying ABYC anode chart). Whatever its material, the anode's function is to corrode, while protecting the metal to which it's attached.

Aluminum sail and turning-block track on masts and deck are frequently attached with stainless fasteners, leading to mild galvanic corrosion.

Table 2. Anode Options

	SALT WATER	BRACKISH WATER	FRESH WATER
Zn	✓		
Al	✓	✓	✓
Mg			✓

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The most effective means of preventing galvanic corrosion is to avoid using dissimilar metals in applications where they will be in direct contact with each other or be otherwise electrically connected. The practical definition of dissimilar in this context is any two metals whose resting voltage differ by more than 200 mV in the galvanic series. Where this is unavoidable, another effective method of corrosion protection is to insert a layer of non-conductive material (or in some cases such as aluminum fuel tanks, a metal that is benign to both) as insulation between them. Appropriate nonconductive materials include prefabricated fiberglass or epoxy-based sheet, also known as GPO3 or G10, but you should avoid using non-reinforced plastics such as UHMW or rubber sheeting in highly loaded structural applications—under cleats, sail tracks, and steering rams for instance. Stainless steel is often installed as an insulator between aluminum and copper-based alloys—aluminum fuel tanks and brass (a copper alloy) plumbing fittings and valves for instance. In this assembly, the dissimilar materials are technically still connected, but the stainless-steel bushing provides the necessary degree of isolation to inhibit galvanic corrosion. This approach, which works only because the fuel tank is not immersed in water, would not be acceptable for submerged, or continuously wetted components.

While galvanic corrosion is typically a localized phenomenon caused by interaction between the dissimilar metals on a single vessel, it can also occur between vessels. This interaction can be confusing and is undoubtedly the source of a great deal of misinformation, including most "hot marina" myths. Inter-vessel galvanic corrosion occurs when, for instance, two or more nearby vessels plug into shore power, and the green AC safety grounding wiring on each vessel common with its bonded underwater metals—seacocks, struts, shafts, and anodes—becomes connected whether or not the shore power is energized. In short, the moment a shore-power cord is plugged in, the AC safety grounds and bonding systems on the vessels are interconnected. When this occurs, intact sacrificial anodes, or less noble underwater metals such as aluminum stern drives, on one vessel may begin protecting underwater metals on other connected vessels, ones whose anodes are depleted. Except for the fact that the shore-power cord must be connected, this phenomenon has little if anything to do with the marina, or AC shore power per se. It remains a galvanic, and hence DC rather than AC, interaction.

Such multi-vessel galvanic action is easily thwarted with either a galvanic isolator, or an isolation transformer. The former block, up to 1.4V (above the typical galvanic corrosion voltage threshold) of DC voltage on the AC shore-power safety grounding wire, while still allowing AC fault current to flow freely, as it is critical to safety. Because galvanic corrosion is DC in nature, the electrical interconnection of adjacent vessels is prevented by the galvanic isolator.

Isolation transformers take this a step further, by isolating all direct shore-power connections to the vessel, including the AC safety ground, between the vessel and dock power, thereby blocking any level of inter-vessel interaction.

Every boat equipped with a shore-power system should utilize one of these devices to prevent corrosion induced by connection through the shore-power safety ground. Galvanic isolators are relatively affordable, while transformers are more costly, the latter, however, offer benefits in addition to absolute isolation. (For more on isolation transformers and galvanic isolators see "**The Complexity of Plugging In**" in Professional BoatBuilder No. 181, page 100.)

While it is a potentially serious and costly phenomenon, galvanic corrosion occurs at a stately pace, typically over the course of weeks, if not months and years. With proper alloy selection, isolation, and cathodic protection, it can be minimized if not eliminated.

Stray Current

This form of corrosion differs from the galvanic variety in that it only occurs in the presence of an outside source of electricity, usually a vessel's own DC electrical system, typically a battery or battery charger. AC voltage from shore power doesn't cause stray-current corrosion except in some very rare circumstances. If it did, the DC voltage blocking ability of a galvanic isolator would be ineffective. In those few instances where AC-induced stray-current corrosion does occur, it is of greatest concern to aluminum-hulled vessels or those equipped with aluminum drives.

The typical stray-current corrosion scenario involves a faulty electrical connection located in, or close to, bilge water or that makes contact with submerged metal. Contrary to popular belief, electricity does not seek ground; it seeks a return path to its source. In the case of stray current corrosion, that's usually the vessel's battery. Current leaking into bilge water can travel to a through-hull fitting, into the surrounding water and then to the propeller and shaft, which are grounded to the DC negative system via the engine block (often shafts/props do not represent a low-resistance connection to the vessel's DC negative or grounding/bonding system because the oil-filled transmission is a poor conductor, however, a bonded stuffing box can provide this path.), providing a route back to the battery. In this example, the propeller will almost certainly suffer from severe and rapid corrosion. Unlike galvanic corrosion, which occurs comparatively slowly, stray-current corrosion often moves with startling rapidity, potentially destroying a propeller, shaft, or sterndrive in a matter of days.

Sacrificial anodes, galvanic isolators, and isolation transformers offer little if any protection against this electrical scourge. Note that isolation transformers can be beneficial for preventing stray-current corrosion that originates on other vessels.

The most effective means of preventing stray-current corrosion is observing sound wiring practices and adhering to American Boat and Yacht Council (ABYC) standards everywhere onboard, particularly in and around bilge areas.

A common source of corrosive stray current in the bilge is pump wiring connections that are too close to the water and unprotected by waterproof heat-shrink tubing.

To that end, I insist that electrical connections to bilge pumps and float switches be made no less than 18″ (457mm) above the base of the pump (my personal standard, not ABYC's). The primary reason is to improve reliability, but this approach also reduces the likelihood of stray current leaking into bilge water and avoids the resulting corrosion. In applications where these connection geometries are impractical, connections should be made completely waterproof using heat-shrink butt splices or simple heat-shrink tubing and, if necessary, application of silicone sealant.

No electrical connections should ever be allowed to lay in bilge water, regardless of secondary waterproofing measures. A detail as seemingly innocuous as improperly crimping, and thereby piercing a heat-shrink butt splice, can create a path through bilge water for stray current. I routinely encounter pierced heat-shrink insulation on a range of boats. It's usually caused by a technician selecting a crimping die for uninsulated terminals and applying it to the insulated variety, but it can also occur when overaggressively using the correct insulated-terminal die. Check your connections closely, and seal them with silicone or polyurethane sealant if they are breached.

Aluminum lower units, common on stern, pod, and sail drives, are particularly vulnerable stray-current corrosion.

A bonding system is another strategy to prevent or diminish the effects of stray-current corrosion. Performing as one segment of a vessel's overall grounding system, it encompasses the DC negative, AC safety ground, and lightning-ground systems, all of which are interconnected in an ABYC-compliant design.

In brief, a bonding system electrically connects underwater metals and many metallic hardware and machinery components, including through-hull fittings, seacocks, rudders, propeller shafts, struts, and strainers. Note that bonding of shafts must be via shaft brushes capable of achieving the ABYC-mandated 1 ohm or less of resistance between shaft and anode, which is typically only achievable using silver slip-ring brush assemblies. Common and inexpensive wand/carbon or bronze brush styles will not meet the maximum resistance standard.

There are two primary benefits to bonding. The first is mitigation of stray-current corrosion. In the scenario I described above—voltage leaking into bilge water from a defective bilge pump connection—if the seacock through which the fault current flowed was bonded, all or most of the current would return through the bonding system directly to its source, the battery. It would not run through the water the vessel is floating in, thereby eliminating or minimizing stray-current damage to the propeller.

A bonding system connected to all underwater metal hardware and machinery protects them from stray-current corrosion by returning any fault current from onboard systems directly back to the battery.


On a planing hull, the anode for an onboard bonding system mounts to the transom below the waterline.

The second benefit of a bonding system relates back to galvanic corrosion. The metals that comprise a bonded system are nearly always dissimilar—silicon bronze seacocks, stainless-steel alloy shafts, and manganese-bronze propellers for instance. This necessary mix of metals with different potentials violates the guidelines on galvanic corrosion. Bonding systems provide an exception to the rule because they contain one additional ingredient in the seawater-metal cocktail: a sacrificial hull-mounted anode. These are commonly installed on the transom of a planing vessel, and on the bottom of a displacement hull. Connecting underwater metals to each other, then to an anode, follows the bond-and-protect protocol, a proven approach so long as you follow a handful of guidelines. Chief among these is ensuring low-resistance connections are made between all bonded components and hull anodes. ABYC's resistance standard for all these connections is a demanding 1 ohm maximum.

Where fiberglass vessels are concerned, bonding systems are strongly recommended but not mandatory for compliance. Their installation guidelines are detailed in ABYC Standard E-2, "Cathodic Protection."

On most of the boats I inspect, bonding systems and their connections are in abominable condition—green, crusty, loose, or broken all together. They are a reminder that bonding systems need to be periodically inspected and maintained. Corroded or otherwise poor connections should be cleaned or replaced. If you have doubts about the integrity of the system, check resistance between components using an ohm meter, while the vessel is hauled. (For more on bonding systems see "**Bonding Basics**" in PBB No. 138, page 18.)

Corrosion Subsets

With a firm understanding of the most common forms of metal corrosion on boats, it's time to look closely at some of the applications, behaviors, and peculiarities of different metals you're likely to encounter.

Copper Alloys: While copper is naturally corrosion resistant, it has been best known to boatbuilders for centuries applied in sheets as metal cladding on hull bottoms to prevent teredo worms from digesting timbers. A natural antifoulant, copper is still the active additive in many modern bottom paints. Because it is an excellent biocide, on many vessels it is used in domestic water systems. Copper alloy tube is also used by many engine manufacturers for conveyance of seawater, for heat exchangers and wet-exhaust systems.

As corrosion resistant as good copper hardware can be, it is susceptible to two forms of corrosion: impingement attack, or "erosion corrosion," caused by fast-moving water in a copper pipe or tube. Because copper is relatively soft, it can literally be worn away by swiftly moving seawater. This is especially true at 90° turns and restrictions where turbulence and velocity are greater.

Copper can also fall prey to decay by exposure to hydrogen sulfide, a common constituent of polluted or onboard "black" water.

The terms brass and bronze comprise numerous copper alloys, the primary defining element of which is zinc. Located low on the galvanic scale, it corrodes very easily in the presence of other metals and an electrolyte, such as seawater, which is why it's used in sacrificial anodes. Zinc also imparts strength to copper. Mixing the two, often in about a 40:60 ratio, yields brass suitable for clocks, lamps, and cabin hardware, but most definitely not, with few exceptions, for seawater plumbing.

Brass is often inadvertently installed in pipe-to-hose adapters and pipe plugs in raw-water systems where it is vulnerable to dezincification.

Brass: It's a metal that is almost synonymous with the sea, resides in the family of copper alloys whose primary ingredients, in varying ratios, are copper and zinc. Some brasses are composed of as much as 50% zinc. The more common rough formulations are; red brass (85% copper, 15% zinc); leaded red brass (85% copper, 5% zinc, 5% lead, 5% silicon); cartridge brass (70% copper, 30% zinc); Muntz metal (60% copper, 40% zinc); admiralty brass (70 copper, 30% zinc); naval brass (60%copper, 40% zinc); aluminum brass (76% copper, 22% zinc, 2% aluminum); Tobin "bronze" (60% copper, 39% zinc and 1% tin); and manganese "bronze" (67% copper, 25% zinc, 3% Aluminum, 2.5% manganese, 2% iron). The last two in the list are called "bronze" but because of their high zinc content, they are in the brass family. In order to be considered a true bronze, a copper alloy must contain little (typically single percentage points) or no zinc.

While brass has many familiar uses aboard, from clocks and joiner work trim to lamps and electrical components, it must be avoided for use below the waterline or in raw-water plumbing. It is worth noting that many small (¼″-⅜″ NPT) plumbing fittings, such as pipe-to-hose adaptors, pipe plugs, and bushings are made of brass, while their larger cousins are commonly bronze. Most seacock and sea-strainer drains are fitted with ⅛″ or ¼″ NPT plugs. Under no circumstances should these be replaced with brass. Where replacements are needed, ⅛″ bronze plugs can often be obtained from the equipment manufacturer.

If you are unsure of a plug's material, avoid using it below the waterline or for raw seawater. In my experience, you shouldn't rely on chandlery clerks and many marine equipment vendors to provide accurate alloy information. Many are unaware of the important distinction between brass and bronze and the prohibitions for use of the former.

Brass is often inadvertently substituted for bronze in water-injection ports on stuffing boxes, which call for a threaded pipe-to-hose adaptor of ¼″ or ⅜″. I've seen this error lead to vessel loss.

If its primary constituent is copper, why is brass so susceptible to corrosion? It's because most of the brass alloys also contain a substantial amount of zinc, which leaves them especially susceptible to a type of corrosion referred to as

The telltale pink hue of dezincification in this propeller suggests a need for replacement or addition of sacrificial shaft anodes (zincs).

dezincification. This is a process whereby the zinc selectively corrodes from the alloy, leaving a porous copper shell that retains its shape but little strength.

Dezincified components can often be identified by splotchy reddish or pink coloring. A common example involves propellers, many of which are fabricated from a Manganese bronze, a brass alloy that's especially susceptible to dezincification. It's imperative to protect this often-substantial investment in essential propulsion hardware by monitoring the condition of sacrificial shaft anodes and renewing them when necessary. An anode is considered "depleted" when diminished to 50% of its original dimensions. In a conventional combination of proprietary shaft alloy and brass propeller, once the anode is gone, the next least-noble metal (or metal most likely to corrode) is the prop, which will begin to corrode, sacrificing itself for the shaft, which is more noble.

Brasses are susceptible to other forms of corrosion in addition to dezincification. A common ingredient of household cleaners, ammonia, will readily attack brass, causing it to weaken and crack. Mercury is also corrosive to brass, as is the hydrogen-sulfide rich polluted water mentioned above.

Corrosion resistance requirements limit the range of materials from which seacocks and related components should be made. Only bronze, DZR brass, glass-reinforced plastic, and in some cases, stainless steel may be used.

While copper-zinc alloys used below the waterline are vulnerable to dezincification, that's not true of true bronze alloys with primary elements of copper and tin. Other common alloying elements include silicon and nickel, technically making these alloys something other than bronze, but still acceptable for use in seawater plumbing.

Unfortunately, there's a broad array of alloys between true bronze with no, or very little, zinc and true brass, which contains a high percentage of zinc. Two common alloys often used in marine applications are 85-5-5 and DZR. 85-5-5 contains 85% copper, 5% zinc, 5% lead, and 5% silicon, and can be used below the waterline in seawater applications.

Some European manufacturers use DZR brass, a dezincification-resistant brass alloy with a higher zinc composition than many other copper alloys (30% or more). But it also includes trace amounts of other metals meant to retard zinc corrosion or leaching. To be used with confidence, DZR brass hardware must be embossed or de-bossed with the letters DZR, rather than simply a packaging description.

Leaded red brass is another copper alloy sometimes used in marine applications. Composed of copper, zinc, and lead, it is commonly used for the manufacture of pipe nipples and may be used in seawater applications provided the zinc content does not exceed 15%. (Note: I have never seen a pipe nipple marked with its alloy makeup, making it challenging to know whether a part is suitable or not.)

None of these alloys resists dezincification nearly as well as the zinc-free, or near-zinc-free, bronze alternatives. Because they are less expensive and unlikely to become a problem in the early years of a boat's life, they can be an attractive alternative for more cost-conscious builders.

Bronze: Although it is a copper alloy, because bronze is free of any appreciable amount of zinc, it is not susceptible to dezincification. Its parent element is copper, its alloying element is tin, and possible trace amounts of zinc may be added to improve machinability. Pound for pound, it is often more expensive than brass, which contains less costly zinc.

Gunmetal is a bronze alloy commonly found in marine applications, although, as its name suggests, it was historically used for firearms manufacture. It is a bronze alloy consisting of 88% copper, 10% tin, and 2% zinc. While not especially strong, it is corrosion resistant and perfectly acceptable for below-the-waterline use. Gunmetal is often used to cast cleats, chocks, and shaft logs.

Another useful bronze alloy, aluminum bronze, is strong but can be susceptible to de-aluminumification. This phenomenon is prevented with the addition of nickel to form an alloy commonly referred to as NI-BR-AL (nickel, bronze, aluminum). This strong corrosion-resistant bronze is often used for propellers and struts. Manganese is sometimes added to this already mixed soup of metals to increase strength. Prop repair shops sometimes charge a premium for reworking NIBRAL props due to their tendency to take on a set or memory. This alloy should not be confused with the manganese bronze.

Silicon bronze is by far the most popular alloy for the fabrication of underwater hardware. Most quality seacocks are made of this extremely resilient metal. Its common formulation is 96% copper, with the remaining 4% being silicon and other trace elements, sometimes including very small amounts of zinc. Bronze hardware such as nuts, bolts, and screws are often made of this alloy and can be expected to give long, corrosion-resistant service.

Phosphor bronze is typically made up of 85-95% copper and 5-10% tin, with the addition of a small amount of phosphorous, which improves hardening characteristics. It is a choice material for bearings and springs.

While the varieties of copper alloys tailored to very specific applications are so numerous that I haven't the space to addressed them exhaustively here, the most important thing to remember on a boat is that most brass is ill-suited for most application where it's called upon to convey or stem the flow of seawater, regardless of whether it's above or below the waterline. This includes plumbing associated with raw-water strainers, stuffing boxes, seacocks, sanitation, and air-conditioning systems. Bronze alloys, on the other hand, are well suited to demanding service below the waterline.

In Part 2, we'll continue our primer on corrosion prevention at sea by looking in depth at stainless steel and aluminum. PBB

About the Author: *For many years a full-service yard manager, Steve now works with boatbuilders and owners and others in the industry as Steve D'Antonio Marine Consulting. He is an ABYC-certified Master Technician and sits on that organization's Engine and Powertrain, Electrical, and Hull Piping Project Technical Committees. He is also technical editor of* Professional BoatBuilder.

Sailing's Square Future

Maltese Falcon *under way*

Tracking the renewed passion for DynaRig efficiency.

by Nic Compton

The 88-meter (289′) sailing yacht *Maltese Falcon* was the standout boat of 2006. Even those of us not much interested in superyachts couldn't help but be intrigued by her spectacular three-masted DynaRig, which presents as a modern rendition of a traditional square-rigger, only created with carbon fiber spars and stripped of standing rigging. It was a fascinating and imaginative mix of old and new technologies, so it was no surprise to learn that owner Tom Perkins's other boats were the 1915 Herreshoff schooner *Mariette* and the 1930 classic motoryacht *Atlantide*.

Maltese Falcon wowed traditionalists and modernists alike, winning multiple awards from Boat International, Showboats International, and the International Superyachts Society. Perkins clocked upwards of 60,000 miles (96,560 km) on the boat, including a 10-day Atlantic crossing, before selling her for a reported $60 million in 2009.

Ten years after *Maltese Falcon* took the yachting world by storm, the 107m (351′) *Black Pearl* was built sporting the same rig but scaled up by 25%. When launched in 2016, she was the largest sailing yacht in the world, and arguably one of the most eco-friendly, with a sophisticated energy storage system and advanced waste recycling. When her owner died of COVID-19 in 2021, she went into a state of limbo while estate claims were sorted out. She finally completed her first Atlantic crossing in 2023.

And that, it seemed, was that for the DynaRig. Another good idea ahead of its time that didn't find an enduring application.

Until now. In June 2021, Damon Roberts, the man in charge of building the rigs for *Maltese Falcon* and *Black Pearl,* joined Auckland-based Southern Spars as their DynaRig authority. The result seems to be a revival of interest in the rig with a surge of confirmed orders, including three projects currently in progress and several more on drawing boards. One of the renowned rig company's latest clients is Greenpeace, which has commissioned the construction of a new 75m (246′) flagship fitted with a DynaRig, and several cargo ship-owners are interested in the system's fuel-saving potential. Suddenly, it seems, everyone is catching on to the practical application of this esoteric rig for powering large vessels safely with minimal crew and maximum green credentials.

G. SARGENTINI/PERINI NAVI, COURTESY DYKSTRA NAVAL ARCHITECTS

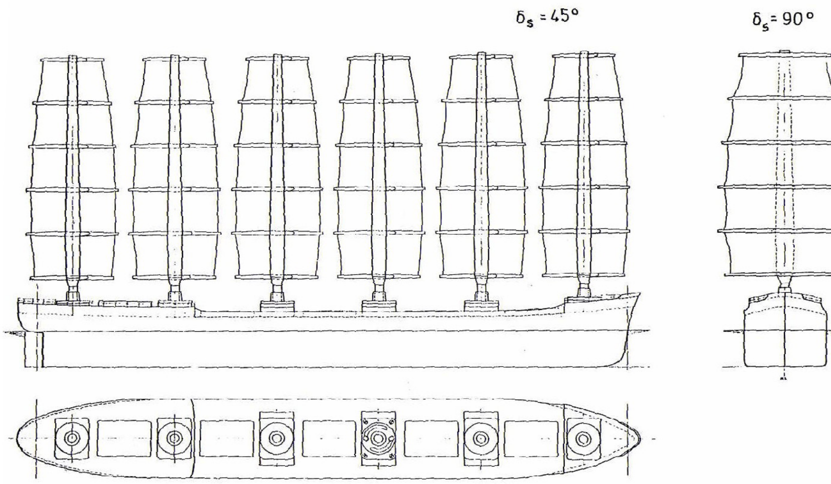
Dawn and Development

The DynaRig system was first devised in the 1960s by German hydraulics engineer Wilhelm Prölss. His idea was to use a modern square rig to power cargo ships on long-distance passages. Prölss envisaged craft of up to 60,000 tons carrying up to 12,000m^2 (129,167 sq ft) of sail on six masts, charging around the world at speeds of 16-18 knots. He calculated this would yield fuel savings of 40-60% compared to conventional diesel-powered vessels.

With the advent of the 1970s oil crisis, his ideas gained currency, and he received substantial government funding to develop the concept. The main drawback of his design was that he planned to build the masts in steel, with stays going down to a circular track that moved around as the masts rotated. This was particularly problematic when it came to the slot down the front edge of the mast for the sails to furl into, which was almost impossible to build out of steel. That problem was never satisfactorily resolved.

Prölss's ideas were quite simply ahead of the available technology and, as the price of oil dropped and the world resumed its fuel-guzzling ways, his visionary scheme was abandoned.

Fast forward to 2001, when venture capitalist Tom Perkins was looking for a large, comfortable yacht to sail around the world with minimum crew. He had already owned two yachts, both called *Andromeda la Dea*, built by Perini Navi, and became interested in a hull the company had built on spec in Turkey in 1989-90. The project had ground to a



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The DynaSchiff, designed by Wilhelm Prölss during the 1970s oil crisis, was a 6-mast, auxiliary-powered, sailing cargo ship. It was never built.

halt in the wake of the Gulf War, but Perkins could see the potential of the unfinished boat and approached naval architect Gerard Dykstra to design a rig that would make the boat suitable for the round-the-world voyage he envisaged.

Although best known for designing luxury sailing yachts, Dykstra has a passion for traditional craft and has been at the forefront of the modern classic yacht movement. He has also designed several sail-training ships, including the square-rigged *Cisne Branco* and *Stad Amsterdam*. He first came across the DynaRig concept in a journal produced by the Amateur Yacht Research Society in the 1960s and stored the idea in a "recess of my mind" until it found an application.

Dykstra Naval Architects (DNA) produced four possible rigs for the Perini hull: a three-masted gaff schooner with semi-automated sails; a traditional three-masted barque with furling sails; a "modern" three-masted barque with yards fitted to the bottom of the lower sails; and a three-masted DynaRig. The first three were all imagined with clipper bows, bowsprits, and traditionally styled deckhouses. Only the DynaRig version kept the existing, raked stem and featured a more modern cabin structure and wheelhouse design.

According to a paper submitted by the *Maltese Falcon* team (including Perkins, Dykstra, and Roberts) to the 2004 HISWA Symposium on Yacht Design and Yacht Construction, the owner quickly selected the DynaRig version. It was the "logical choice" the authors wrote, because:

"With modern technology the sail handling potential is excellent, and the windward performance is good. The large sail area required for large sailing ships can be split over many masts and yards. The DynaRig is ideal for single instrument panel operation. One [person] can control all functions. The square rig allows precise manoeuvring under sail. The rig looks aesthetically pleasing and matches the styling of the Perini Navi hull. But most important; the square rig allows safe and high average speeds in ocean conditions."

The next consideration: Would it be possible to build a 60m (196.8′) freestanding rig using modern technology, particularly with the requirement for a front-facing cavity, which the two halves of the butterfly-like sail furl into?

There was one man who would know the answer. Like Dykstra, Roberts has a background in modern and traditional boats. As the founder of Carbospars, he had built dozens of freestanding carbon fiber rigs based on Ian Howlett's modern balestron concept, the Aerorig, whereby the mainsail and jib both set on booms fixed to the mast, and the whole rig rotates as a single unit. At the time, Carbospars was one of the few companies making carbon fiber spars, and they were soon hired to make masts for other boats, such as Loick Peyron's trimaran *Fujicolor*, Mike Birch's trimaran *Biscuits la Trinitaine*, and Peter Blake's record-breaking *ENZA New Zealand*.

It was while working on more classic projects such the J-Class *Velsheda*, *Windrose*, *Adix*, and *Adela*, that Dykstra and Roberts teamed up, with Carbospars supplying carbon fiber spars, sometimes covered with a layer of wood to look more traditional. Roberts had helped design the rig for the sail training ship *Tenacious*, so he was an obvious candidate to look at the feasibility of building a modern DynaRig. It took him two days to work out whether such a thing was possible, and his analysis came to a surprising conclusion.

"When I worked on *Tenacious*' rig, I used a program we'd developed to analyze the size of the masts, and it came out not dissimilar to the figures for a freestanding mast. Initially, I thought that was really odd, but when you analyze it, it's quite obvious that a square rig is effectively a freestanding mast, because although it has a cloud of rigging, the rigging there primarily to get guys aloft to handle the sails. Look at the side rigging on any square rigger and you'll see it goes straight up, so the angles are small, and the stretch in the rigging means it's giving very little support to the mast. The top two-thirds of the mast is a freestanding mast sideways. You see that immediately when you start analyzing the rig using more sophisticated modern techniques."

Computer analyses performed by DNA produced similar results. As for that tricky gap down the front of the

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Testing a single-sail version of the fixed camber DynaRig installed on a wooden rowboat in Amsterdam.

masts, some clever carbon fiber reinforcement would allow them to create spars of such strength and elegance that Prölss could only have dreamed of.

Before construction could begin, an extensive testing program was conducted, including simulations using ⅙th scale models in a towing tank at Delft University and a wind tunnel at the Wolfson Unit at Southampton University, as well as full-size sail tests on site. At one point, a panel was fitted to a wooden rowing boat and sailed around the waters of Amsterdam, yielding useful information about how to handle a square rig.

One of the main areas of inquiry was the amount of camber to build into the 18 yards: The flatter the camber, the better the boat's performance upwind, while greater camber would create a fuller sail that would be better downwind. Prölss tried out two types: a straight version with curved ends and one with a built-in 12% camber. The *Maltese Falcon* team soon homed in on the second option as the best all-rounder. As they wrote in their symposium paper: "Yards with adjustable camber are something for the future. It would have stretched our collective imagination too far at this stage."

The tests also showed that the DynaRig was about twice as efficient as the traditional square rig and that "much higher average speeds could be maintained over selected ocean routes."

Early wind-tunnel testing of the DynaRig's furling and sail-control system.

Perhaps not surprisingly given how much work went into testing Prölss's original design, the actual shape of the sails needed very little adjustment. "We found lots of opportunity to improve the structural components to make the rig operational with new materials like carbon fiber, but the geometry of the rig did not change all that much," says Dykstra.

True to Prölss's original concept, the new rig was devised so that each sail furls into a central mandrel, one side furling on top of the other so that they are doubled. To set the sail, the mandrel is released, and the four corners of the sail are pulled out by outhauls run through sheaves at the yard ends. The head and foot of the sails are fitted with bolt ropes that run through grooves in the yards above and below, eliminating the gap between the sails on a conventional square-rigger. Unlike the Prölss design, which envisaged a single motor operating the mandrel and outhauls of each sail (see **Figure 1.**), *Maltese Falcon*'s rig has one electric motor to operate each mandrel and four others to operate the outhauls at the corner of every sail (see **Figure 2.**). In the event of a systems failure, the mandrels can be operated manually to furl (or unfurl) the sails.

The entire complex rig can be operated by one person through a networked custom control panel built around an image of the vessel showing all 15 sails. The sails can only be set one at a time on each mast, partly because it's deemed to be more seamanlike, but also because of the power required for unfurling and sheeting. To set the sails, you simply tap the order of unfurling. Once you've made your selection, you tap "Go," and the sails set automatically in the chosen sequence. It takes up to 70 seconds to set the biggest sail and about 6-7 minutes to set all 15 sails. As the yards are fixed to the masts, the sail angle to the wind is adjusted by rotating each mast individually through the control panel.

Each mast deck bearing weighs about 900 kg (1,984.2 lbs) and the heel bearing and mast rotation mechanism is in the order of 9 tons. Four hydraulic motors mounted in a housing fitted to the mast base, not to the ship, drive mast rotation.

COURTESY DYKSTRA NAVAL ARCHITECTS (BOTH)

Full-size test of DynaRig mast, yards, sail, and control mechanism for Maltese Falcon *in Turkey.*

Figure 1. Initial Design Study for Furling and Sheeting

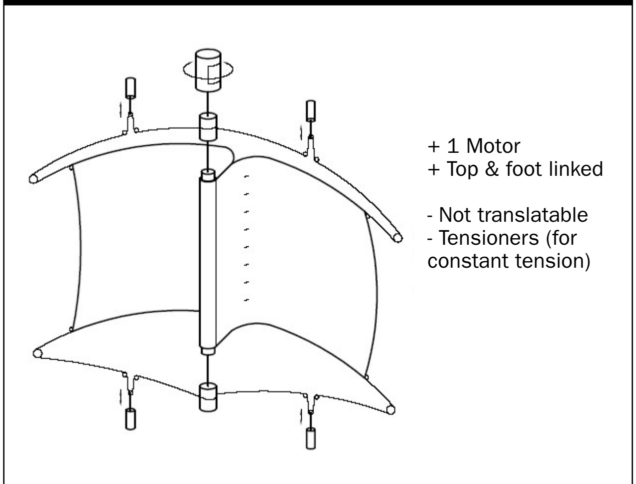
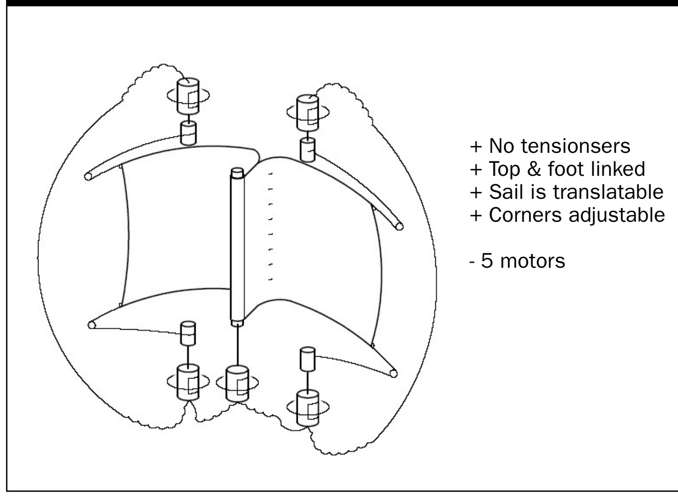


Figure 2. Selected Proposal for Furling and Sheeting Controls



This means tolerance between mast gear and motor gears remains independent of the mast's bending-induced displacements. To prevent the hydraulic motors rotating with the mast, there are two anti-torque bars anchoring the rotation mechanism to the ship's structure. The system is specified at 1,000 kilonewton meter (Knm) torque.

In a significant nod to tradition, the sails have the same names as on a traditional square-rigger, with the royal at the top, followed down by the topgallant, the upper topsail, the lower topsail, and the course. The masts also have the same names and are called, from bow to stern, the fore mast, the main mast, and the mizzen mast.

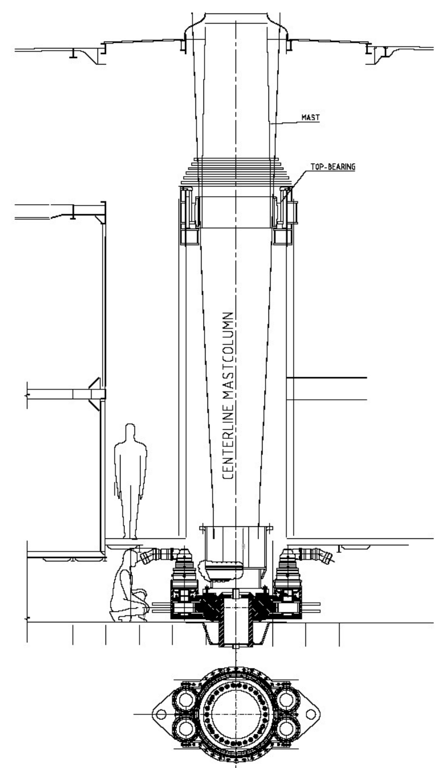
Just like on those square-riggers, shortening sail is a matter of furling sails to reduce sail area, starting from the top down and from aft forward—the first sail to go is the mizzen royal, and the last to go is the fore course. In heavy weather, the courses are furled before the lower topsails to prevent the sails catching in the water. In extremis, the royals are made from a lighter canvas, so if the vessel is hit by a sudden overwhelming gust of wind, they will be torn to shreds, though this has yet to be put into practice.

Astonishingly, the sails are made from ordinary Dacron sailcloth. Similar to traditional square rigs, the relatively small individual expanses of canvas, coupled with the support of the head (and in the DynaRig the foot as well) by the yards, make the working loads on the sailcloth modest. There is no need for the exotic sail material common on most modern sailing yachts. And, because the rig is most efficient downwind, there's no need for any costly and troublesome extra downwind sails, such as spinnakers. Indeed, Damon estimates the cost of *Maltese Falcon*'s entire sail wardrobe is less than half the price of the mainsail alone of a conventional large modern yacht.

It should be noted that Perkins was a serious sailor and wanted a rig that would perform well in all conditions—with an emphasis on the downwind sailing he anticipated doing on long global passages. Indeed, the symposium paper notes that he "always [opposed] any ideas to reduce sail on paper," arguing that "one can always reduce sail when sailing".

The hull he chose, however, was originally designed as an easily driven shape with relatively shallow draft and small sail area. To stand up to the 2,300m^2 (24,757 sq ft) of sail that was now being proposed, an extra 100 tons of ballast was added, increasing the boat's draft from 4.3m (14.1′) to 6m (19.7′). The team designed and tested a daggerboard to improve upwind performance. It was eventually ruled out on grounds of cost and practicality.

Maltese Falcon made an unforgettable sight when she burst onto the scene in 2006. Her lavish art deco interior clearly



COURTESY DYKSTRA NAVAL ARCHITECTS (ALL)

Each unstayed carbon fiber mast can be rotated independently to change the angle to wind of all the sails set on it. The adjustment mechanism is driven by four hydraulic motors a the base of the mast.

put her into the luxury superyacht bracket, yet her unusual slightly retro rig set her apart from other modern sailing yachts, with their huge white sails and shiny hardware. Here was a yacht that mixed tradition (it doesn't get much more old-fashioned than a square-

COURTESY DYKSTRA NAVAL ARCHITECTS

The 107m (351') Black Pearl*, built by Oceanco in 2016, is driven by a Dykstra-designed DynaRig 25% larger than* Maltese Falcon*'s.*

rigger) with modernity (all that carbon fiber) and a huge amount of style (not least Ken Freivokh's interior).

One of the most notable aspects of the rig was its clean look and visual simplicity. All the running rigging components are contained within the spars—including the 75 motors to operate the 15 sails—which leaves the deck free of the usual clutter of hardware to handle a large rig. There are no creaking winches and straining lines on deck; everything happens above your head.

"The rig is easy to handle because of the automation," says Roberts. "None of the ropes comes down to the deck, and none of it is highly loaded, which gives massive safety. It's much less complex than handling a massive rig on a modern yacht, where you've got highly loaded kit with 20 tons of load in a rope, and you need additional sail plan to go downwind. With the DynaRig, you have all sails set so downwind sailing and gybing is easy. You don't even need to tell your guests when you're gybing because there's no risk. It's like sailing a dinghy, where you get pure enjoyment out of sailing. A few times during regattas we raced *Maltese Falcon* with only three people sailing the boat—one trimming, one steering, and one on tactics/navigation."

Prölss would have been delighted with the performance of the world's first full-size DynaRig vessel. Off the wind, she quickly reached 18 knots, while in a blow she flew along comfortably at over 20 knots. Even upwind, her performance was surprisingly good, tacking at up to 45° to the wind (as Prölss had predicted), though 50-55° was more efficient in terms of leeway, given her lack of daggerboard. So pleased was Perkins with her performance that he decided to race her against other superyachts, despite having expressly said that wasn't his intention. And it wasn't just in a blow that the boat performed above expectations.

"In light winds, *Maltese Falcon* performs really well, considering the measure of sail-power-to-displacement ratio, because the sails are held rigidly into a decent shape," says Roberts. "She is much faster downwind racing against other superyachts, even though they have spinnakers, because the sails sit there in ghosting conditions—in 3-4 knots of wind—and create drive. If there's any swell, the sails on a conventional rig slap around hopelessly and the spinnakers don't fill properly. She won a number of races in light airs.

"I've been on *Maltese Falcon* when she's hit 24 knots, which is way above any speed she can achieve under motor. Like any square-rigger, the boat is a serious weapon going downwind in strong weather conditions. In near gale winds, Force 7, reefed down, she's just a joy."

Black Pearl & Beyond

Despite the evident success of such a convincing DynaRig prototype, follow-up orders proved elusive. It seemed luxury yacht owners were inherently conservative and just weren't ready to adopt such a novel rig. Or perhaps they

COURTESY DYKSTRA NAVAL ARCHITECTS (BOTH)

An as-yet-to-be-named 88m (288.7′) DynaRig superyacht with two masts promises improved upwind performance compared to its three-masted antecedents.

didn't like the idea of appearing to copy such a recognizable rig, opting instead to mimic every other superyacht's predictable fore-and-aft configuration.

Whatever the reason, it took 10 years for another DynaRig vessel to be built. This time the commission was for a 107m (351′) new build with modern styling by Ken Freivokh. *Black Pearl*'s rig was an almost direct copy of her predecessor's, with some minor adjustments. A decade of equipment service and testing left no doubt that the electric motors were completely reliable, which led to substitution of the hydraulic mast rotation devices on *Maltese Falcon* with electrically driven ones. The yard curvature on the main and the mizzen masts were slightly flattened to improve windward performance. And the yards were restyled to look a bit more angular, at the owner's request.

It would be another eight years before another DynaRig order came in, and by

A commissioned 57m (187′) DynaRigged catamaran promises to be the largest sailing cat in the world when it launches.

that time the world was a very different place. With more and more millionaires and billionaires, luxury yachts are increasing in size and number. At the same time there is an increasing awareness of environmental impacts and interest in measuring carbon footprints. The DynaRig addresses both issues, requiring much smaller crews to handle it and offering huge savings in fuel consumption, without inconveniencing the ship's guests. Indeed, according to Roberts, the DynaRig is considerably cheaper to install on any yachts over 60m (196.8′) than its conventional fore-and-aft equivalent.

"Sailing yachts have got bigger, and bigger and conventional rigs are not suitable for that type of cruising yacht—a mainsail of 1,000m^2 (10,763 sq ft) doesn't make sense," says Dykstra. "In this case, the Dynarig is very efficient, as the individual sails have very small area and are easy to manage."

Predictably perhaps, the next DynaRig yacht (as yet unnamed), started in 2019, will be the biggest to date: longer than *Black Pearl* and with 80m (262.5′) masts, compared to 60m on previous boats. This newest incarnation of the rig is with just a pair of masts, which Roberts says allows for more separation between the two and means there isn't a mizzen sitting in the dirty air behind the mainmast and foremast. One result should be better upwind performance, though with a slight penalty in performance downwind.

It's not just millionaires and billionaires who are embracing the benefits of the DynaRig. None other than the original eco-warriors (now multinational corporation) Greenpeace have chosen the rig for their next flagship, *Rainbow Warrior IV*. The organization had considered the rig for their previous vessel, the 58m (190.3′) *Rainbow Warrior III* built in 2011 and designed by Dykstra, but at that time opted for a staysail schooner with A-frame masts.

The new 75m (246.1′) vessel, also designed by Dykstra, is described as "Greenpeace's most sustainable sailing vessel to date," and features two DynaRig masts, and a host of alternative power systems—hydrogen, solar panels, and battery packs. The boat is at what Roberts calls a "sweet spot" for the rig, where the two masts will give maximum efficiency while staying below the maximum height for the Panama Canal, sometimes referred to as the Panamax size. A similar rig is being built for a 57m (187′) catamaran which, when launched, will be the biggest sailing catamaran in the world.

Going Commercial

But perhaps the greatest potential for the rig is exactly as Prölss originally intended back in the 1960s: powering long-distance cargo ships. Dykstra has fielded several enquiries from shipowners ("in the tens," he says) interested in the energy-saving possibilities of the rig and, as environmental regulations become more stringent, its eco-credentials.

"So far, the fuel crisis is too low, and emissions are not taxed sufficiently," says Dykstra, who has a lifelong interest in Wind-Assisted Ship Propulsion (WASP). "As soon as the regulations change and ships can't use low-price fuels anymore, then we will have a case. For the moment, it is still too big a question mark for shipowners. But things are changing quite quickly. There are more and more regulations—like you can't use dirty oil on coastal routes anymore—so, I have good hope we are at a turning point."

The sudden interest in emissions is partly driven by new IMO regulations which require commercial vessels to reduce exhaust emissions by 2030. "For some ships this will amount up to 40%," says Dyna & AeroRig Head of Sales Rudy Jurg, "hence the huge interest in wind-driven propulsion technologies such as the DynaRig and AeroRig to meet these targets. There are now approximately 105 wind propulsion installations (rotor, suction sail, kite, wing sail, soft sail/hybrid) which is expected to grow to over 10,000 units by 2030."

Ironically, a possible objection to the DynaRig for commercial shipowners is that it currently requires at least one extra specialist crew member—a sailing master—to operate the sails. What is a staff-reducing technology on a sailing superyacht becomes a staffing burden on a ship with no absolute requirement for a rig.

One of the leaders in this drive for cleaner global transport is Veer. The company is headed by Danielle Southcott (née Doggett), who helped set up the SailCargo project to build a wooden sail cargo ship in Costa Rica. Her new vision is a 100m (328.1′) modern containership powered by a three-masted DynaRig and hydrogen engines. In August 2024, the company was reported to have signed a letter of intent with Norway's Fosen shipyard to build the first two of these zero-emissions ships.

"There is an ever-increasing awareness of the desirability of sail in terms of greenness," adds Roberts. "We now have much better weather predicting programs, so suddenly weather routing becomes much better. You don't have to follow the traditional trade routes; you can really optimize your routes continually. You see that in the round-the-world races such as the Vendée Globe. That's a massive gain."

With so much interest from the commercial sector, the pressure now is to

create a rig that is not just a rich person's plaything but an affordable product for general use.

"The changes to the new generation of DynaRigs are aimed at making the manufacturing process simpler and more cost-effective, rather than being aimed at speed or reliability," says Roberts. "The rig's reliability is really good, and it has proven performance. We've got the benefit of thousands of sea miles and data from every second the rig has been up from embedded optical fiber load-monitoring systems. So, we've got unparalleled real-time data of the rig in use in a wide range of conditions.

"We are now working on simplifying the way we manufacture the rig. When we started building carbon masts, carbon was very expensive and labor rates were very cheap, so most of the cost of the rigs related to materials. Today, it's the other way round—carbon fiber is cheap, and labor is very expensive. So, we are focused on removing labor hours."

Suddenly, after 60 years of relative obscurity, the DynaRig is in greater demand than ever before. A combination of factors, not least the health of the planet, means that it is now more relevant than ever. The technology and construction of prototype boats to help refine it have finally caught up with Prölss's vision of 60 years ago and his ambitious concept can not only be built but, with some fine tuning, can be built relatively cheaply. The future is bright, and it seems more than likely the future is square. PBB

About the Author: *Nic Compton is a freelance writer/photographer based in Devon, U.K. He lived on boats in the Mediterranean until the age of 15 and worked as a boatbuilder for many years before swapping his chisel for a pen and his router for a computer. He sails a Rhode Island–built Freedom 33, currently based in Greece.*

Wind-assisted propulsion for commercial cargo operations has been a passion of Dykstra's since he was introduced to Prölss's work from the 1960s. He has multiple designs for commercial cargo carriers in the works.

COMPOSITE MATERIALS

THREESIXFIVE MEDIA

Breaking it Down

Tank-free solvolysis technology reclaims glass and carbon laminate material from large parts for reuse in new boats.

by Aaron Porter (Photos courtesy of Resolve Composites)

I first visited Tern Boatworks (Lahave, Nova Scotia) in the spring of 2022. At that time, the two-campus boatyard with a crew of about 12 was focused on readying the storage and service fleet for the looming summer season, while simultaneously restoring a locally built wooden Cape Island boat, an historic 40′ (12.2m) Nova Scotia schooner yacht, and retrofitting electric auxiliary propulsion in a fiberglass daysailer. An admirably diverse portfolio—even by the inclusive standards of the average small full-service boatyard—I quickly found myself deep in discussions about Tern's

Nick Bigeau and Amy Russell of Resolve Composites inspect reclaimed fiberglass laminate material they stripped of resin using their solvent-based composite materials recycling process.

Tern Boatworks owner Bruce Thompson and Bigeau review the plans for a center console skiff they are building with laminates reclaimed from a discarded wind turbine blade.

more cutting-edge experimentation with natural-fiber composites. (For more on Tern Boatworks, see Melissa Woods's "**Young Canadians**" in Professional BoatBuilder No. 171, page 60.)

At that time, the notion of applying flax or hemp as laminate material in marine composites was very outside the norm and, in my experience, limited to some forward-looking European boatbuilders with climate-driven regulatory changes and research funding spurring them on. It wasn't an area of inquiry I'd expected to encounter at the core of a modest Nova Scotia boatyard, but I was quickly swept up in the enthusiasm of Tern owner Bruce Thompson and his composites expert Nick Bigeau. As they made their earnestly pragmatic case for building boats with renewable composites, our discussions of carbon footprints, thermoplastic vs. thermoset resins, recycled PET core materials, and peculiarities of vacuum infusing natural-fiber laminates returned to the frustrating reality that no build option was truly recyclable as production waste or at the end of a boat's useful life. Numerous materials promised recyclability, renewability, and "greener" composites, but the best options at the time were to grind up the composite waste for incineration or use as filler in lower-grade materials. Thompson and Bigeau had innovative ideas and some specific plans to build a prototype boat of natural laminates, but we agreed that there wasn't anything conclusive to report out yet. They'd be in touch when they had something to share.

Two-and-a-half years later, I got the call I had been only half expecting. They had a new spinoff composite technology company (Resolve Composites), a solvent-based process to pull cured thermoplastic or thermoset resins from discarded composites (ReceTT) and were building a small boat out of fully reclaimed fiberglass laminates.

"We were initially going to build a boat with flax fibers and Elium (thermoplastic resin), but it was bugging us thinking, 'How do we know that this is going to get recycled?'" Bigeau said, when I visited their snow-bound boat shop in Gold River, N.S., the last week of 2024. Knowing that only 8% of plastics get recycled, he and Thompson realized there were slim odds that an Elium hull would be responsibly disposed of just because it was theoretically more recyclable than a polyester or conventional epoxy structure. The leading issue for them had become the practicality of composites recycling for boatbuilders and service yards.

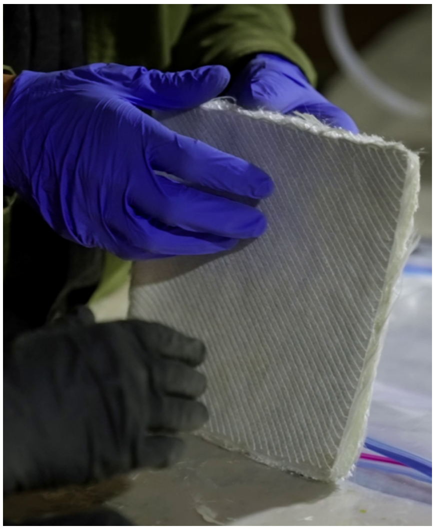
"We thought we'd engineer a boat so it could be recycled," Thompson said. "Basically, we'd build a boat, then recycle the boat and try to reuse the materials and rebuild the boat," Bigeau explained. Thinking of the boat as a matrix of components that ideally could be disassembled and reused without changing their form or basic properties, pushed the team to prioritize the reusability of materials. In that context natural fibers offered few benefits, but robust glass or carbon fibers that could be reclaimed and reused multiple times held great promise.

Bigeau's research started with Elium resin, which he says is most promising when it comes to reclamation of the resin particularly through thermolysis, but requires volatile, expensive, and tricky-to-handle solvents to clean it from fibers you hope to reuse. (For more on Elium thermolysis, see "**Building In Circles.**") In Tern's working boatyard environment, those qualities presented significant liabilities, but Bigeau's next discovery, Recyclamine from Aditya Birla Advanced Materials, was a good fit. It's a thermoset epoxy with an active ingredient in the hardener that makes it recyclable. It can be stripped from the laminate using a relatively mild acetic acid solvent and without high-temperature treatment.

Bigeau and Thompson had been thinking they might have to send the boat they were planning to build and then recycle, to a specialized contractor for the solvolysis. However, after talking with the Recyclamine technical staff, they realized it would be possible to process the end-of-life composites in house with relatively accessible materials, equipment, and facilities.

Test Panels

The first step in proving feasibility was to build 1 sq ft (.09m^2) composite test panels with fiberglass laminates and Recyclamine resin, break some of them down in a bath of the acid solvent, reclaim the fiber, and create new panels from the recovered material. At that scale, the process went smoothly for the boatbuilders accustomed to much larger



THREESIXFIVE MEDIA (ALL)

Composite test panels were infused, cured, and broken down through solvolysis. The laminate material was then reused to create new panels.

projects. Their sample panels of virgin and recycled fiberglass are largely indistinguishable to the casual observer.

To delve deeper, Bigeau sent coupons to the Composites Research Network at the University of British Columbia for tensile, flexural, and facesheet testing. Lab results indicated that tensile properties reduced on average 10% in the second-generation panels, which makes them completely adequate for boatbuilding. Likely contributors to the difference are fiber misalignment and the absence of sizing (a resin adhesion enhancer) on the reused fibers. Bigeau noted, with some surprise, that the facesheet and flexural properties had improved in the reused-fiber test panels. He speculated that these gains were due to the recycled fibers being compacted or debulked repeatedly under vacuum, resulting in a higher fiber-to-resin ratio. There's more testing to come on this subject.

Next, the Resolve team built a bow section splashed from an outboard skiff in the yard to check the practical challenges of subjecting a larger composite structure to solvolysis without cutting it up. This step was essential to their ambition of reclaiming large sections of laminate material that could be reused in a new structure.

The bow was built of two layers of biaxial 1708 fiberglass infused on either side of a foam core—essentially the layup for the prototype boat they were planning, Thompson said. But it was far bulkier than anything they had previously processed.

With the small test panels, Bigeau said, "We put the solvent in a beaker, we broke it down, and we reused the materials, but we didn't have a process yet." Following the same model, the approximately 4′(1.2m) bow section would require a big tank of solvent to break it down. Bigeau estimated they'd need 1,400 liters (317.8 gallons) of solvent, which was really a deal killer. It was just too much solvent to conveniently handle, store, and process at the boatyard. "I was thinking we'd need big tanks and to clear the shop out for a week to do this," Bigeau said. "It starts to become problematic."

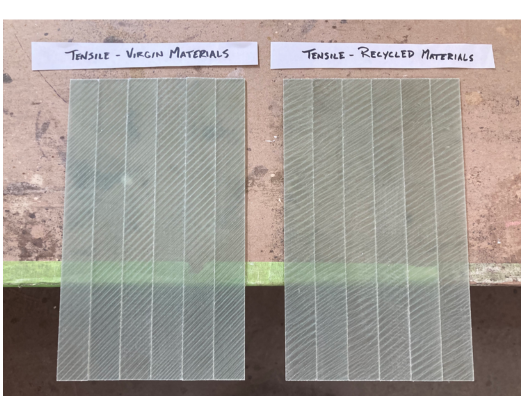
At this critical point the Resolve team improvised an entirely new approach that cut the solvent volume to a scant 144 l (32.7 gal). Now patent pending, their "ReceTT" process is basically a reversal of resin infusion, "circulating solvent over the surface area of the part," Bigeau explained. It allowed them to break down the chunky bow section in eight hours without cutting it up and to reclaim all the laminate materials in their full assembled dimensions, and the thermoplastic material from the Recyclamine resin. The circulating pump and heater consumed roughly 37 kilowatt hours (kWh).

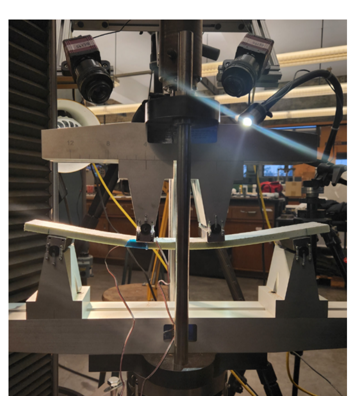
Top—*The process was tested on a foam-cored bow section built for testing.* ***Bottom***—*The reclaimed PET foam and glass laminates.*

Mission accomplished as far as securing the materials that could be reused to build a new boat as originally planned. But on the way, they'd stumbled on a fortuitous distraction—discarded wind turbine blades—that would reroute the boatbuilding project.

Wind Shift

In researching Recylamine, Bigeau learned that Siemens Gamesa, a Danish wind turbine builder, was producing full-size blades with the resin in expectation that they could be fully recyclable at the





Far left—*Coupons of virgin and recycled laminates underwent tensile testing at the University of British Columbia.* ***Left***—*The lab also performed flexural testing on cored composite panels.*

end of their service life. The effort won an innovation award at the 2022 JEC World composites show in Paris, but many practical details of how the big blades would be broken down for reuse had yet to be worked out. Bigeau saw a potential source of large composite structures built with Recylamine that could yield high-quality laminates for his boat project. The possibility of using an existing discarded blade rather than building a boat, breaking it down again, then reusing the salvaged laminates to build a new boat, was appealing. Siemens Gamesa was interested. They agreed to collaborate with Resolve on the Second Wind Project, to build the 17.9′ (5.5m) skiff Thompson and Bigeau had been planning as a technology demonstrator.

They shipped a portion of the blade's spar cap (a highly reinforced strip located at the top and bottom of the blade's airfoil section) to Nova Scotia for testing. "It was hard to convince them to keep it in 20′ (6.1m) lengths," Bigeau said, "but I wanted to demonstrate we could do full-length composites."

What arrived was a 240-kg (529.1-lb) 1m x 6m x 57mm (39.3″ x 236.2″ x 2.2″) section of blade surface laminate comprising multiple layers of stitched unidirectional fiberglass skinned with 12-oz biaxial cloth. The crew set up the blade fragment on a shop bench and subjected it to the reverse-infusion process they'd practiced on test coupons and the bow section. It was all done at 80°C (176°F), while sharing the shop space with other boatbuilding projects, Bigeau said. So, not too precious or unapproachable for a standard boatyard. The only glitch he reported was the need to upgrade equipment including the pump to address changes in solvent viscosity with resin saturation. This first project involved experimentation over a couple of months, but Bigeau projected it would take about a week under more normal shop conditions with standardized processes and gear. The results were all that Thompson and Bigeau were hoping for: clean, large-scale laminates that looked like new fiberglass material that has been re-rolled and stored on the rack.

THREESIXFIVE MEDIA

Amy Russell cuts some of the recovered fiberglass cloth on the shop floor to use in building the prototype Bantam Bay skiff.

Rolls of glass reclaimed from a 20' (6.1m) section of wind turbine blade spar cap and the barrels containing the acetic acid solvent that dissolved the Recyclamine resin from the laminate.

"It validates Siemen's choice in the resin, and it validates the Recyclamine technology" Bigeau said. "Where our technology comes in is that we were able to do it at this scale."

While most composites recycling and reuse efforts rely on chopping and grinding materials before including them in a new structure, Resolve's approach is to keep the laminate material intact and in usable dimensions, thereby minimizing energy and labor demands of the process and maintaining material properties consistent with those of original laminates.

"Why chop up materials when you can do it like this?" Bigeau asked, as we unrolled some long samples of unidirectional and biaxial glass on the bench. Rinsed in warm water following solvolysis, the dried reclaimed materials, including some carbon fiber they had processed, preserved the drape and handling qualities of the originals, though Bigeau confirmed that the glass would not have the sizing of the virgin cloth. They salvaged 170 kg (374.8 lbs) of usable glass from the blade fragment, most of it destined for the boatbuilding project and additional testing.

As proud as the Resolve team is of the quality and quantity of reclaimed fiberglass, and the minimal energy input required, Bigeau is clear that this isn't a waste-free process. At the end of their project, the extracted resin was suspended in 908 l (206.1 gal) of 25% acetic-acid solution. By raising the Ph, the resin can be forced to precipitate out and be separated as a crumbly material that Bigeau said he isn't sure what to do with… yet. He's hopeful the Recyclamine chemists will be able to reuse it in formulating new resin in much the same way that elements of thermoplastic Elium resin extracted during thermolysis of composite production waste can be reused.

Beyond Thermoplastics & Recyclables

Having developed the promising solvent-saving ReceTT process, the Resolve team took a detour from the boatbuilding project to explore whether it could be applied to composites made with conventional epoxy (non-Recyclamine) resins. Samples of the resulting reclaimed laminate materials were pliable but stiff with lingering resin. You'd never mistake them for new material, but yielded properties attractive to commercial boatbuilders for low-stakes applications like interior panels. They haven't done lab testing of the samples yet.

By testing different solvents, the team looked to maximize resin-stripping while avoiding damage to the fiber material. In one test, the solvent dissolved resin but also the polyester stitching that held the layers of unidirectional fibers of the original cloth in place. Bigeau had a sample of new material restitched with nylon by a neighboring sailmaker for the next test panel, and the nylon survived the solvolysis. Of course there isn't a material producer stitching with nylon, but the proof of concept means there could be if there appears to be a scaled market demand for it in the future.

Other experiments confirmed that a builder's material choices might have to change to meet the needs of evolving recycling technologies. For instance, Bigeau explained how foam core from recycled polyethylene terephthalate (PET) has a low installed carbon footprint, but it

Above—*All the components recovered from another blade section, this one built with nonrecyclable thermoset epoxy resin, using Resolve's ReceTT process.*
Left—*The original section of laminate.*

breaks down in some solvolysis processes, contaminating the resin you are trying to recover. In that context, using styrene acrylonitrile (SAN) foam, which may not be readily recyclable but can be separated through solvolysis, could be a greater environmental benefit. It all points to the need for careful deliberation before choosing the technology to best breakdown legacy composites or to build new composite structures.

As a worst-case, real-world test, Bigeau sourced a section of nonrecyclable wind turbine blade comprising PVC core, thermoset resin, bonding putty, balsa core, fiberglass cloth, and polyethylene coating. Running the ReceTT process at room temperature, they were able to separate the fiberglass, coating, resin, foam, and balsa. While most elements were left moderately contaminated by the process, the disassembly allows for separation of material types for further processing or disposal. For instance, glass or carbon fibers are left at usable lengths and uncontaminated by the chlorine and bromine that would have resulted from pyrolysis of PVC core material.

That potential to pull apart the components of a composite structure without grinding them up into a slurry of incompatible materials sets the ReceTT process apart from conventional recycling efforts. "Mechanical grinding was meant for paper, cardboard, and metals. It wasn't really meant for composites," Bigeau said. He's committed to identifying the methods and virtues of separating various composite materials and maintaining them in their most useful forms or dimensions for reuse or disposal. That includes the possibility of subjecting some of the materials to additional processes like pyrolysis following initial solvolysis treatment.

Bigeau said he found strong interest in ReceTT solvolysis at the March 2025 JEC World show, where European composites manufacturers facing legislative requirements for recycled content in new structures have an open-minded approach to reused materials.

The Boat

Back at the boatyard, Thompson and Bigeau had removed the long-awaited 17.9′ (5.5m) Bantam Bay skiff to a storage space to accommodate a large yacht restoration in the main shop over the winter. Built in a split mold to accommodate an attractive measure of tumblehome, I could see the two halves of the V-bottom skiff in differing stages of completion, one infused and the other with laminate materials still being loaded. If you didn't know better, it looked like an ordinary build.

"It's all unidirectionals except for the two skin pieces which are biax," Bigeau

Above—*Reclaimed unidirectional and biaxial fiberglass fabric is placed in the skiff mold with recycled PET foam core prior to resin infusion.* ***Inset***—*The unidirectionals, shot through with striped longitudinal stiffeners that were part of the custom wind-blade laminate material, were layered and oriented carefully at 90 degrees to yield a biaxial equivalent structure upon infusion.*

said. The only clue that the laminates were out of the ordinary was the series of thermoset stiffeners visible in the 24-oz unidirectionals. They were in the original specialized wind-blade laminate material and weren't broken down by the solvent during processing. They made it challenging to drape the glass around tight corners at the skiff chines. Some judicious trimming and pairing of the unis to create a +/- 45° laminate on either side of the ½″ recycled PET foam core, coupled with taping and 12-oz biaxial skins, delivered an overbuilt hull laminate for what will be an able workboat for the yard.

The completed skiff will be a very different vessel than the one they discussed with designer Laurie McGowan when he drew up the lines for a boat to test natural-fiber laminates in 2022. The lessons the Tern Boatworks team learned along the way have spun off a separate company with patents, international partners, and a growing reputation as part of the solution to the composites recycling challenge. Bigeau insists their solvolysis process isn't a solitary answer to the need for a change in end-of-life processing of composite boats. Adding it to the growing toolbox designers and builders confronting shifts in regulatory requirements and market demands can work from is what he sees as the best hope for the future of boatbuilding and the broader composites industry.

Planning for how structures come apart and what you can create with their reclaimed materials involves complex, long-range thinking, but it holds the potential to keep old boats and wind turbine blades out of landfills and can lower the carbon footprints of numerous sectors that might be included in the equation. PBB

About the Author: *Aaron Porter is editor of* Professional BoatBuilder *magazine.*

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PARTING SHOT

Boatbuilding's Best Friend, Carl Cramer, 1946-2025

by Aaron Porter

The death of *Professional BoatBuilder* founder Carl Cramer on April 10 brought a flood of calls and messages from friends and readers around the world to the magazine's editorial desk. Carl was every boatbuilder's best friend, whether they knew it or not. A passionate sailor and boat owner, a brilliant publisher, and a relentless boating-industry impresario, he founded multiple new business ventures for Maine-based WoodenBoat Publications during his 27-year tenure—a wood one-design regatta, ahead-of-its-time online training for marine technicians, an online tradeshow, *Professional BoatBuilder*, and the International Boatbuilder's Exhibition and Conference (IBEX), which he claims to have started as an excuse to meet the designers, builders, and writers who were his heroes.

His admiration for the work of boatbuilding was broad and generous, ranging from the composites shop, paint booth, and rigging loft to the design office and marketing department. The trade returned his genuine enthusiasm with respect, friendship, and unending fodder for his new ideas and passions. No surprise then that he owned dozens of boats, from wetsuit-mandatory, trapeze-equipped sailing dinghies, and Uffa Fox's only outboard skiff to a couple of graceful Herreshoff ketches and a pint-sized Whiticar sportfisherman. And no shock again that he gave many of them away when the next boat idea caught his fancy.

Born on July 14, 1946, in Hollywood, California, Carl grew up in Santa Barbara, moving to Maine to attend Bowdoin College in 1964. Excepting protracted adventures in Vietnam, Sweden, the Netherlands, and Nova Scotia, the rest of his life was centered in Maine around boats and publishing offices.

Early careers included yacht designer, boatyard worker, bookstore owner, and during the record-breaking blizzard of 1978, the last taxi driver taking fares in Portland. In the 1980s, he worked for Downeast Magazine, then co-founded multiple computer publications.

In 1987, Carl was hired to work at WoodenBoat magazine where he became publisher in 1989, a position he held until his retirement in 2014. During those decades, the Brooklin, Maine-based magazine and its associated school, shows, and other marine publications flourished in no small part because of Carl.

In 1989, he launched this magazine followed by the immensely successful IBEX. More pied piper than field marshal in command style, he often stood in the background of his own achievements, lavishing credit on the people who brought his ideas to fruition.

An enthusiastic sailor, Carl was passionate about boats. He delighted in a cockpit full of friends, chatter, and sunshine.

KATE HOLDEN

But Carl's true expertise was people. He relished talking to strangers and made fast friends despite language and cultural barriers. Carl was also a pathological reader, who consumed multiple books every week, then passed them on to friends with pithy praise or condemnation.

In person, he was a fearless iconoclast and a gentleman. Carl loved to argue morality, literature, and naval architecture, but with a twinkle in his eye and a Heineken in hand. His formal attire was a suit paired with Crocs. His manners were gracious. He always stood when a woman entered or retired from the room, and he eschewed trash talk. Carl remained gallant in an age when chivalry was long dead.

Carl often explained to waiters as he ordered an appetizer for dinner, "I'm just a little guy." And he was. Indifferent to food, he appeared to derive all the nourishment to maintain his modest frame and fast pace from the company he kept. He was light and moved lightly through the world like a feather or a laugh lofted on the wind and gone.

Openminded, openhearted, and always out in front of the fleet is how the industry will remember Carl. Our condolences to his wife Melissa Wood, a beloved colleague and former editor at *Professional BoatBuilder*. PBB

About the Author: *Aaron Porter is editor of* Professional BoatBuilder *magazine.*

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