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HIGH-PERFORMANCE WOOD SPARS
WIND-FARM TENDERS FROM AMC
DRILLING FOR ROD HOLDERS
REMOVING A FAILED ENGINE

To Carry

by Stephen Olson

ALISON LANGLEY

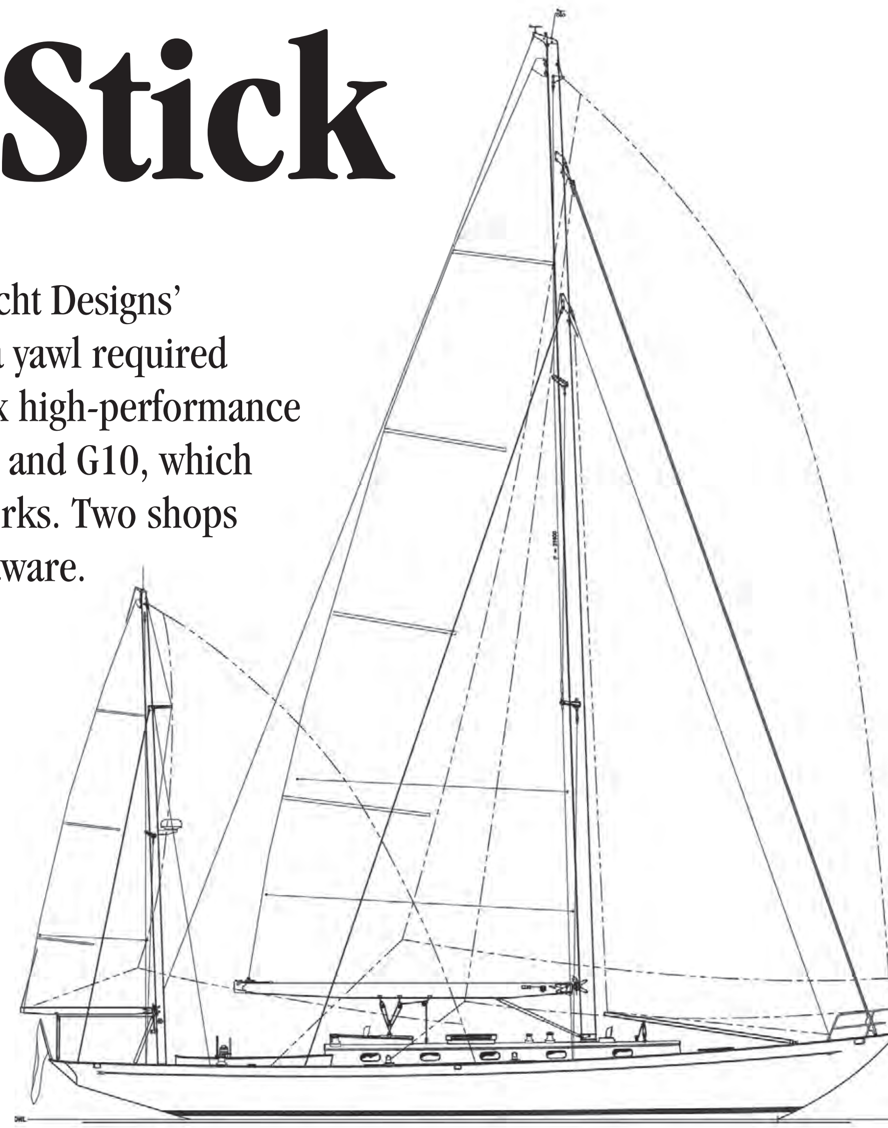
This 84.3' (25.7m) wood, metal, and FRP mainmast was built by Artisan Boatworks (Rockport, Maine) for a new Pedrick 65 Classic Yawl, designed by Pedrick Yacht Designs Inc. (Newport, Rhode Island). Tight mechanical, engineering, and construction protocols were essential in creating wood spars able to tolerate the high loads of the yacht's modern rig comprising rod rigging, Kevlar backstays, and hydraulic tensioning. The hull, deck, and interior were built by Hodgdon Yachts of East Boothbay, Maine.

On a fall day in 2015 when I stopped by Alec Brainerd's Artisan Boatworks, in Rockport, Maine, I found the builder deep in discussion with yacht designer David Pedrick, president of Pedrick Yacht Designs Inc. (PYD), in Newport, Rhode Island. They shared with me the subject of their exchange—drawings of PYD's current project: a 65′ (19.8m) reinterpretation of the classic yawls that dominated ocean racing when the Cruising Club of America (CCA) rating rule produced boats still admired for their balance of speed, seaworthiness, and beauty. PYD's new design was an apt update of classic CCA models like *Black Watch*, *Argyll*, and *Finisterre*. No surprise, given that as a student at Webb Institute's Naval Architecture program, Pedrick did an internship at Sparkman and Stephens (S&S), the New York City firm responsible for many of those classic designs.

"It was a change of direction for me," he said, "working on yachts instead of ship design that most Webb graduates do." There was no better place than S&S to develop a deep understanding of and appreciation for the classic look and feel of the CCA type. Indeed, the S&S reputation had been forged in successful campaigns of ocean racing yachts like *Dorade* and *Stormy Weather*, and also in an almost unbroken string of *America*'s Cup defenders.

a Big Stick

The aesthetics of Pedrick Yacht Designs' reinterpretation of a CCA-era yawl required the firm to engineer complex high-performance spars of wood, carbon fiber, and G10, which were built by Artisan Boatworks. Two shops made the custom metal hardware.



PEDRICK YACHT DESIGNS INC.

The Pedrick 65 Classic Yawl's profile and sail plan are faithful to the New England–style yawls built during the pre- and post-World War II era to the Cruising Club of America (CCA) rating rule. Rig proportions closely match historical references, although the use of headsails is different (see page 54).

After graduation in 1970, Pedrick took a job at S&S, and has been designing yachts ever since. He has worked on eight *America*'s Cup campaigns, including two successful defenses during the 12-Meter era. He has also consulted on the near-total rebuild of the 1937 Camper & Nicholsons 12-Meter *Blue Marlin* (ex-*Alanna*), as well as reconfigurations of the 12-Meters *Courageous, Hissar,* and *New Zealand (KZ-3)*. He designed, as well, the remarkable 90′ (27.4m) neoclassic carbon fiber sloop *Savannah*, a modern build with much of the look of a classic J-boat. (See "The Pedrick Profile," *Professional BoatBuilder* No. 86.)

In short, Pedrick has the experience to comfortably draw a vessel that would blend traditional aesthetics with modern performance. The Pedrick 65 embodies the classic profile of a CCA yawl above water with a canoe hull, fin keel and spade rudder below. Contemporary updates include a cold-molded wood composite hull and a spacious cockpit, while wood spars enhance the yacht's classic character. With a ballast ratio higher than CCA classics, the new hull would possess increased stability, standing up to the rig, rather than heeling over and dumping wind and power out of the top of the sail. That, along with modern sails, rod rigging, and a hydraulic backstay, boom vang, and jack under the mast butt, would result in much higher rig loads than those on an early CCA boat.

A significant improvement over conventional wooden yachts was compliance with 21st-century structural engineering. The Pedrick 65's hull was engineered to meet and exceed the new, European-based codes of the International Organization for Standardization—the primary code being ISO 12215 for "Small Craft—Hull Construction and Scantlings." PYD applied this code to the particular characteristics of cold-molded wood

PEDRICK YACHT DESIGNS INC.

The Pedrick 65's classic character above the waterline has only a few subtle contemporary concessions to facilitate sail handling. Concealed below the waterline are a high-performance cruising keel and rudder that deliver uncharacteristically fast performance and agile handling.

construction, assuring an indefinitely long lifetime for this yacht. Aside from Pedrick's commitment to using best engineering practices, his other reasoning for complying with ISO 12215 was straightforward: "Where a structural standard exists, we could be liable if something we designed that didn't comply with the standard were to fail."

Hodgdon Yachts, based in East Boothbay, Maine, was chosen as principal builder of the new yacht. The family-owned boatyard has been in business since 1812, but a glance at the performance of recent builds such as the 155′ (47.2m) ketch *Scheherazade* (2003) and the 100′ (30.5m) sloop *Comanche* (2014) confirms that the builder is still at the top of its game. In July 2016 *Comanche* set the record for the fastest transatlantic sailing passage: 5 days, 14 hours, 21 minutes, 25 seconds from Ambrose Light (New York), to the Lizard Light (Cornwall, U.K.), averaging 21.44 knots. A seriously fast sailboat. (For more on *Scheherazade*, see PBB No. 86, page 88; and for *Comanche*, see "0 to 60," PBB No. 153.)

In the annals of Maine boatbuilding, there are certainly precedents for putting wooden masts in modern reproductions. In 1978 Ø. Lie-Nielsen built the ketch *Whitehawk*, a 93′ (28.3) Bruce King–designed adaptation of L. Francis Herreshoff's *Ticonderoga*, one of the world's most famous yachts. *Whitehawk*'s 120′ (36.6m) mainmast, and mizzenmast, bowsprit, and booms were all built of wood by Basil Burns, an old-school sparbuilder in Thomaston, Maine.

ALISON LANGLEY (BOTH)

Above—*A series of custom-cut templates guided the Artisan Boatworks crew in hand-planing the internal shape of the hollow, glued Sitka spruce mainmast. Note: The mast cross section is not symmetrical fore and aft.*
Right—*Timo Foster finishes with a curved backing-out plane.*

Far left—*While the masts will look traditional, the complex interior structure of the main includes two conduits for wiring: one for electrical service to lights and electronic equipment, and another for a lightning-protection ground wire.*
Left—*The plan was to start building the smaller spars such as the mizzenmast to allow the crew to gain experience before tackling the mainmast.*

Extruded aluminum and carbon fiber are the common materials for building modern high-performance rigs. But in the design Pedrick and Brainerd showed me, aesthetic considerations mandated that the spars be made of Sitka spruce, impeccably varnished to a high shine. To expedite the build, Hodgdon turned the spars over to Artisan Boatworks.

Brainerd's shop is primarily known for major rebuilds of modestly sized classic boats like the Herreshoff Fish-class and 12½-class sloops, as well as new construction of exquisite reproductions. This involves a lot of mast building, although at a much smaller scale than the Pedrick 65. Going from building traditional wood spars for 20′–30′ boats to building an 84.3′ (25.7m) mast that only *looks* traditional is quite a jump. "It was daunting," Pedrick said, "but Artisan's crew are superb woodworkers, and I was fully confident that they could do it."

Because the project called for main- and mizzenmasts, two booms, and a jib boom, there was an opportunity to ramp up the process, starting with the smaller booms and mizzenmast as a warm-up before constructing the main boom and mainmast. That would allow Artisan's crew to work on progressively larger, more complex pieces. By the time they got to the mainmast, they'd be up to speed. In addition, the plan allowed for the four "little" spars to be built in the smaller, easily heated section of the shop before the weather got warm enough to glue up the mainmast in the larger shop space. Temperature is critical when putting together hollow masts that rely entirely on the integrity of epoxy glue joints.

ALISON LANGLEY (ALL)

The mainmast, glued up from a cross section of 10 select staves of clear Sitka spruce, required lengthening the shop space to accommodate the spar in a temporary shelter.

The first hollow wood masts were made possible with the development of water-resistant glues that met the requirement of forming glue joints stronger than the wood around them. Glue continued to improve with resorcinol, introduced in the 1940s, providing remarkable strength, water resistance, and durability. Today, epoxy, which doesn't require the heavy clamping pressure on glue joints that resorcinol does, is almost entirely the choice for sparmaking.

Glued wood spars developed during the period when the virgin forests of the Pacific Northwest were being cut, and long, clear lengths of Sitka spruce were cheap and readily available. While Douglas-fir was well thought of by illustrious designers such as L. Francis Herreshoff, Sitka spruce is the premium material for wooden spar building, and has been since ships first arrived in the Pacific Northwest, and sailors noted the light weight of the wood and the abundance and great length of their clear, sound trunks. Sitka spruce was used for ships' solid masts, and later for wing spars and other structural members of early aircraft. During World War I Sitka spruce was declared a strategic material, vital for producing aircraft for the American war effort. Troops were dispatched to the rainforests of Washington's Olympic Peninsula to protect the trees, railways, and sawmills from sabotage by enemy agents or the Industrial Workers of the World (IWW), a radical labor union powerful in the forests of the Pacific Northwest.

Today the virgin forests are pretty much gone, but Sitka spruce is still prized. The supplier for the Pedrick 65's masts and booms was Touchwood BV, a Dutch company that specializes in providing Sitka spruce and Alaskan yellow cedar for European classic yachts, wing spars for historic aircraft, and "tonewood" for musical instruments. Most premium-quality pianos, guitars, and indeed almost all stringed instruments have Sitka spruce soundboards. For a time, the company operated a sawmill in southeast Alaska, but problems getting enough timber prompted the company to shift milling to Terrace, British Columbia. The mill operates a pair of horizontal bandsaws and a dry kiln that can handle logs 40′ (12.2m) long. Some heating is necessary, since any softwood imported into the European Union must be certified to have been heated to 130°F (56°C) for at least 30 minutes as a disease control measure to prevent spreading pests and fungal diseases such as blue stain.

Because the wood for the Pedrick 65's mast was shipped first to Touchwood in Schijndel, The Netherlands, it was subject to the EU rules. There the lumber was finish-dried, re-sawed, planed, and then selected for grain

Above—*Crew laid the spruce staves, their vertical faces coated with wet epoxy, in the space between two fences of straight angle iron secured to the level skeleton table. To apply even pressure along the length of the spar as the glue joints cured, an 85' (25.9m) length of fire hose was inflated in the gap that remained.*
Right—*Perfectly aligning the individual staves was critical.*

and soundness. Individual boards were selected and labeled for the masts and booms. Brainerd: "The matches were amazing. The masts were made with ten staves, not six, the way you normally do it, so they're vertical grain all the way around."

A sparbuilding shop must be long enough to accommodate the total length of the spar, and it needs a full-length bench to allow the spar to be glued up perfectly straight. At Artisan, a lean-to on the side of the main building hall was the basis for a temporary spar shop. Primarily the space serves as a machinery room for the requisite stationary woodworking equipment: tablesaw, radial-arm saw, planer, and spindle shaper. It was extended with a temporary, lightly framed, plastic-covered shelter to accommodate the mainmast.

An 85′ (26m) skeleton table was built down the middle of the building, and leveled using a laser. The original plan was to glue up the spars in quick succession, and then move them so the machinery room would be usable once again. It didn't turn out that way.

ALISON LANGLEY (ALL)

Sitka spruce from the Dutch supplier Touchwood BV had been dried, re-sawed, planed, and selected for the specific area of the spar based on grain orientation. Each piece was labeled with part numbers from Touchwood's drawings.

Pedrick explained some of the factors in designing a boat of traditional appearance with modern performance. First, in comparison to a vintage CCA-rule boat, the modern version is lighter in weight, with a higher ballast ratio, and stiffer hull thanks to rigid cold-molded wood/epoxy construction. Altering the underbody to incorporate a fin keel with bulbous tip and a detached spade rudder reduces wetted surface and enhances stability. But none of these differences is apparent to a casual observer, who will see the traditional yawl rig and classic profile.

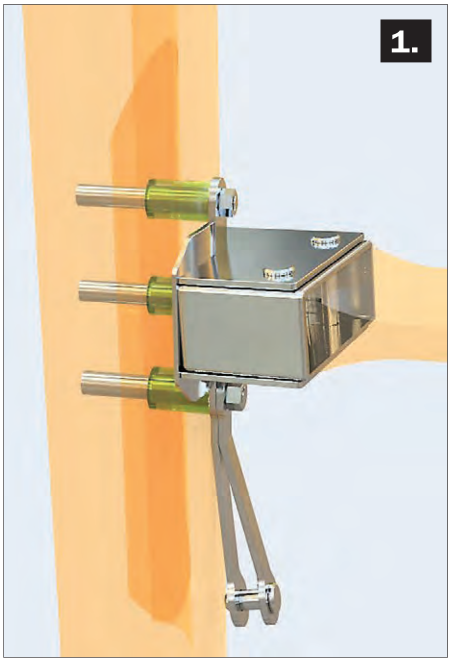
Pedrick Yacht Designs departed from conventional practice when it came to sheeting the main boom. The mainsheet tackle and traveler were located forward of the cockpit and companionway hatch to permit an unobstructed cockpit. But moving the sheet tackle forward on the boom greatly increases the bending loads on the spar and the loading on the mainsheet tackle. Pedrick described the load on the main traveler as being "equivalent to the weight of a big SUV [sport utility vehicle]."

The Pedrick 65's traveler is on top of the companionway hatch scuttle, which, in itself, is structurally weak. However, the scuttle provided internal space to create a substantial, carefully engineered stainless steel weldment, cantilevered and concealed inside it, to carry up to 3 tons of load from the mainsheet traveler forward of the hatchway to the fore-and-aft bulkheads alongside the companionway stairs.

The load in the boom would be easy enough to accommodate if it were aluminum, but not so easy when the material is spruce. Stiff and strong in the grain direction but weak perpendicular to the grain, it also has low compression strength for supporting concentrated loads at standing rigging tangs and other fasteners. The solution was to build what looks like a traditional hollow spruce boom of rectangular section, but inside the top and bottom is a massive reinforcement of 18′ (5.5m) staggered, carbon fiber/epoxy "planks." Invisible from outside, they "contribute two-thirds to the ultimate strength of the boom," according to Pedrick.

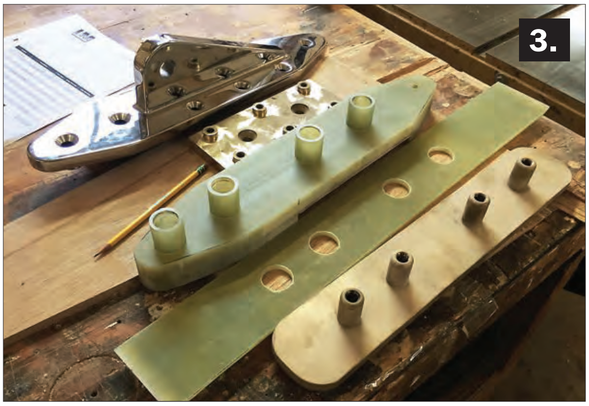
A cleverly designed foundation inside the boom, made of carbon fiber and G10—a high-density glass-fiber-and-epoxy composite—reinforces the boom against the loads imposed by a hydraulic boom vang, which can exert 10 tons of tension.

Top—*The deck arrangement is simple, belying some of the hidden engineering details that make it so. Mid-boom sheeting, the hydraulic boom vang, and some spar fittings shown represent modern departures from conventional CCA-period rigging technology.* ***Right—****Carbon fiber laminates are dry-fit inside the top and bottom face of the box-section spruce boom.*



PEDRICK YACHT DESIGNS INC.

ALISON LANGLEY



COURTESY ARTISAN BOATWORKS

__1__—Tang bolts for the D1 shrouds on both sides of the mast are supported by G10 bushings and locally thickened wall. Traditional dog-bone stainless steel tangs incorporate spreader clips, to which heel boxes for the spruce spreaders are pinned. __2__—G10 reinforced every screw in the spars. __3__—The stainless steel vang attachment for the boom will be secured by the extensive G10 foundation and backing hardware lying beside it.

G10 was also used for reinforced mounting points for every screw attached to the spars. Instead of simply driving a wood screw into the spruce, PYD specified tapped cylindrical G10 plugs for machine screws. For each fastener, Artisan's builders drilled an oversized hole, epoxy-glued a G10 plug into the hole, and then drilled and tapped the machine-screw threads into the plug. Machine screws mounted in G10 can carry much greater load than wood screws. Also, machine screws can be removed and replaced with no reduction in holding power; with wood screws, the whole assembly weakens each time a screw is removed and replaced.

Pedrick Yacht Designs specified more G10 in large (3″, or 76mm) circular bushings set into the mast in way of the cross-bolts for the shroud tangs and spreader brackets. The bushings distribute crushing loads from the shrouds to a larger area of the wooden mast, allowing a more compact tang design.

The approach is quite different from the conventional 20th-century use of sheet bronze for shroud tangs that distribute shear loads to the spar through a multitude of wood screws. The tangs for a big rig of that era relied on skilled workmanship, because each countersunk screw must fit perfectly in its countersunk bore in the tang, or the shrouds' loading won't be properly distributed to the spar. Another advantage of the big G10 bushings is that simply removing the cross-bolts exposes the entire varnished surface for refinishing. Renewing the varnish on an old-style mast is labor-intensive and expensive, and neglecting the finish allows water to get at the wood and weaken it.

COURTESY ARTISAN BOATWORKS

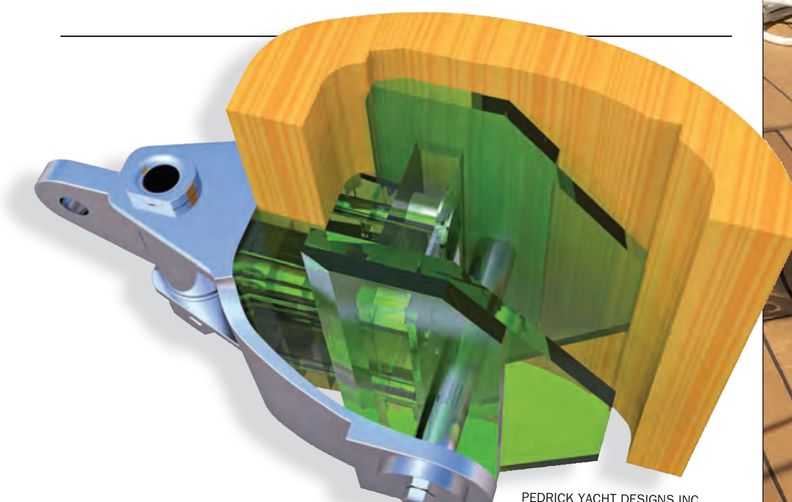
Large fittings, such as the gooseneck whose footprint is visible here, are backed with G10 bushings to resist crushing loads of cross bolts. Sail tracks are also backed by bronze splines in high-load areas where the headboard lands while under way with full or reefed sail.

The Pedrick 65 has an unusual fractional-rigged sail plan. It was conceived for easy daysailing with just a few crew, notwithstanding the challenge to achieve that in a moderately heavy yacht of this size. For sailing upwind, the sails used are an inner headsail, the main, and the mizzen, set up for short-handed operation. The yacht's sailing performance and sail-carrying ability have been designed for this combination. The inner headsail is the jib—a nonoverlapping, self-tacking sail on a jib boom for sailing to windward. Jibstay tension is applied by the directly opposing running backstays, led to cockpit winches near the helm. Tension is monitored by a load cell at the base of the stay. When tacking, no sail adjustments are necessary, just the transfer of running-backstay load from side to side on their winches. The outer headsail is a reacher, not to be used upwind except perhaps in light air. It rolls up with a Reckmann electric furler. Headstay tension is applied by a combination of the topmast backstay on a hydraulic cylinder, and a running backstay.

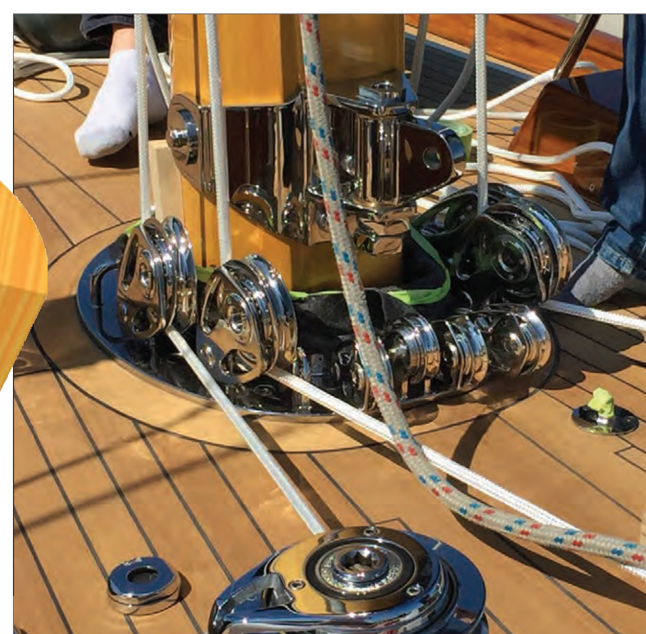
COURTESY ARTISAN BOATWORKS

The complex G10, Sitka spruce, bronze, and stainless steel boom-vang attachment is snugly fit to near machined tolerances into the spar.

To the extent that the Pedrick 65 is a reinterpretation of a 1950s-vintage CCA yawl, a hydraulic boom vang is an anomaly. In those days, a tackle

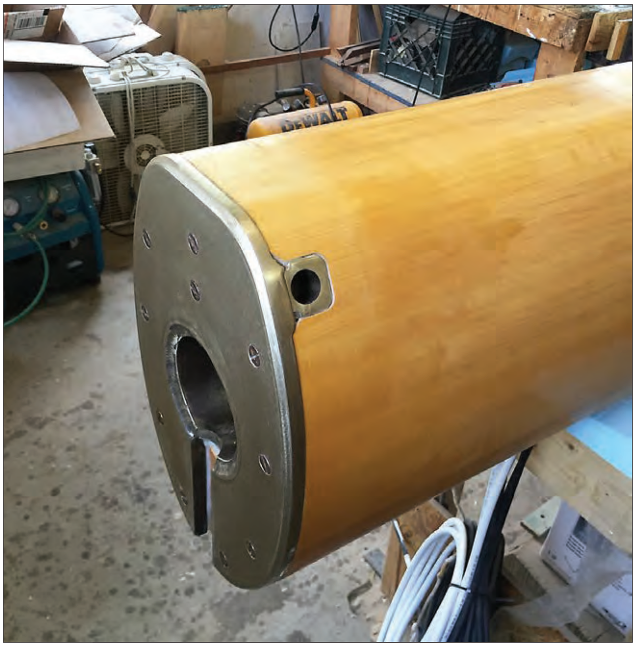


PEDRICK YACHT DESIGNS INC.



COURTESY ARTISAN BOATWORKS

Left—*The hydraulic boom vang can pull a 10-ton load aft, as well as nearly athwartships when running downwind. Because spruce has very low strength perpendicular to the grain, a complicated H-shaped assembly in G10 fiberglass (shown in green) was engineered to transfer the vang's horizontal and torsional loads into the spruce. The mast was filled solid in this area, with substantial area for direct compression of the G10 assembly. In addition to epoxy bonding the G10 and spruce, in the aft face of the stainless steel strap foundation five bolts thread into flanged bushings in the G10 assembly; and a large bronze compression rod passes through the mast athwartships, supported by G10 bushings in the mast wall. This arrangement is designed to spread the torsional load from the fitting into the spruce spar when the vang is at maximum load and the boom is athwartships for running.* ***Right***—*On the mainmast the finished vang-attachment point just above the mast partners deceptively appears to be a bit of simple stainless hardware.*



COURTESY ARTISAN BOATWORKS (BOTH)

Left—*The stainless heel plate at the butt of the mainmast was fabricated with a void in the middle to house a hydraulic jack that allows rig tension to be increased or decreased at will. The small fitting set in the side of the plate is one of multiple receptacles for retaining screws that secure the mast to the maststep.* ***Right***—*The complex maststep accommodates solid shims, slid between the heel plate and the step foundation to carry the load after the rig has been tensioned by the hydraulic jack.*

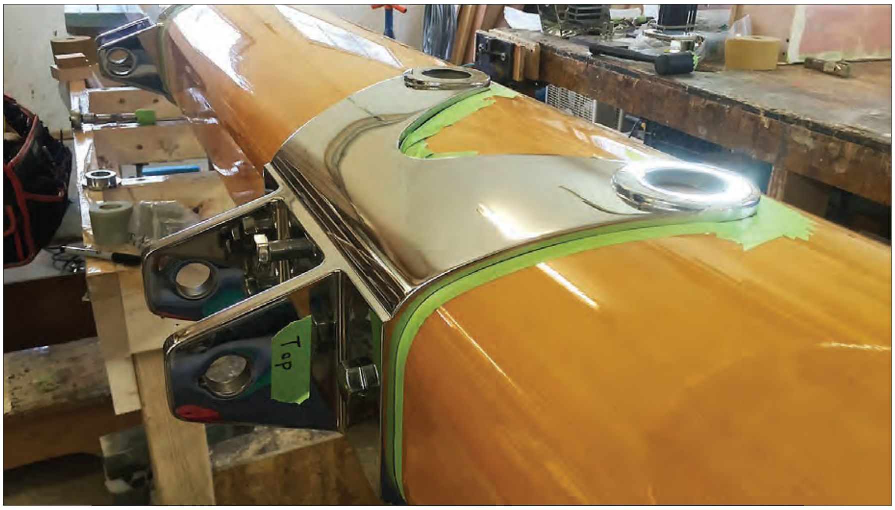
(often called a kicking strap) might be rigged to haul down on the boom to improve sail shape, but it would be rigged near the middle of the boom and attach to a strong attachment point on the deck. Changing course or jibing would require unrigging the kicking strap, and if a broach or a roll drove the end of the boom into the water, it could break the boom at the strap's attachment point.

On smaller one-design racing boats, the Lightning for example, a typical vang is a two- or three-part tackle rigged between the base of the mast and a point on the boom out far enough so the tackle makes about a 45° angle between mast and tackle. The boom is free to swing through its full range of lateral motion, even with the vang set up tight. Consequently, downwind maneuvering doesn't require constant shifting of the vang. It's a practical, convenient device as long as the boom and mast stand up to the high vang loads. On big boats, powerful vangs didn't appear until aluminum masts and booms became the norm. In the Pedrick 65, incorporating a hydraulic vang into her wooden rig required that the boom and lower mast conceal robust internal G10 and carbon fiber foundations that distribute the vang's high loads into the wood spars.

The only other piece of hydraulic equipment is the mast jack inside the butt of the mast. It permits putting relatively high initial tension in the shrouds, typical of modern performance rigs. The mast is jacked up tight, with hydraulic pressure corresponding to the targeted pre-tension load of the shrouds. Fore-and-aft rigging is eased for this operation. After slightly over-jacking, solid shim plates are slid between the heel plate of the mast and the maststep foundation. All hydraulic pressure is then eased off, leaving the shrouds tight. A great advantage of this system is for subsequent fine-tuning of shroud tension according to observing the mast's athwartships alignment under sail. As a dockside operation, the jacking process can be reversed to ease the shrouds, adjust the turns of individual stays' turnbuckles, and re-tension the rig. Secondarily, if the yacht is to be left without being sailed for a period of time, one shim plate can be removed to ease all the loads on the shrouds and mast.

The hydraulics of the vang, standing backstay, and mast jack are more recent rig technology but are basically simple mechanisms, first cousin to a hydraulic bottle jack.

One problem in building a modern wood spar is finding appropriate hardware strong enough to withstand the loads of a big rig while looking like traditional fittings. Because the number of wooden spars



COURTESY ARTISAN BOATWORKS

The main boom gooseneck, and much of the more complex hardware in the Pedrick 65 rig, was cast at New England Castings (NEC) in Standish, Maine.

built each year is a tiny segment of the overall market, there is little incentive for the few producers of yacht hardware to manufacture on a semi-custom basis. Aesthetics are an issue as well. Hardware that looks just right on a 1920s cruising boat might look glaringly out of place on a yacht that draws its visual cues from a postwar racing/cruising yacht. The builders of *Whitehawk* faced that problem, when they were trying to scale up a 1930s-era yacht. The solution was to custom-fabricate bronze hardware by scaling up the original hardware L. Francis Herreshoff designed for *Ticonderoga*.

Almost all of the Pedrick 65's rig hardware and significant amounts of her deck hardware were custom designed by Pedrick Yacht Designs. Most of these elegant metal components were made by two Maine shops, detailed below. The principal custom fabricator was Lyman-Morse (L-M) Fabrication. A reputable boatbuilder in its own right, L-M is spread between hull construction in Thomaston, and a prime waterfront service yard in Camden Harbor (the former Wayfarer Marine). Halfway between the two, it does metalwork at the former Steele and Marshall shop in Rockland.

The second contractor, responsible for cast hardware, was New England

Castings (NEC), a specialty foundry in Standish, Maine.

Lyman-Morse Fabrication

The first impression upon entering the building is one of scale. Its enormous space—150′ x 100′ (46m x 31m) with high overheads and big doors—makes a 24′-long (7.3m) metal brake look incidental. The manager is Jonathan Egan, a former British Royal Marine, polished, polite, and almost certainly tough as nails.

While metal fabrication may seem ordinary—nothing but shears and brakes, welders and grinders—the welding I saw in this shop was perfect. You expect that when an experienced welder uses the latest pulsed-arc MIG (metal inert gas) welding equipment, but here plain stainless steel stock is transformed into fluid shapes with no trace of a telltale weld bead anywhere.

COURTESY ARTISAN BOATWORKS

On this project the tolerances for components, including the interfaces between metal fittings and wood components, were to be within the designed millimeter. This fabricated sheave box is test-fit to a mock section of the mainmast head.

Once the welding and grinding are finished, the part is polished to a mirror finish. Egan referred to it as a "No. 8 finish." The American Society for Testing and Materials (ASTM) publishes specifications for finishes on stainless steel. No. 8 is: "the most reflective polished finish that is covered by the ASTM standards. . . . In comparison to a No. 7 finish, the grit lines are much less visible, but they can be seen if the finish is examined closely. The resulting finish is mirror-like but not a perfect mirror."

COURTESY ARTISAN BOATWORKS

Built by Lyman-Morse Fabrication (Thomaston, Maine), this mainsheet attachment for the main boom includes the G10 plugs that will be let into the side of the spar. The G10 backing plate will rest on top of the carbon fiber stack inside the boom.

Well, that's the technical description. Looking carefully at L-M and NEC work on this project, I never saw anything less than a perfect mirror finish. Maybe the most impressive fabricated part is the complex mast cap fitting, where headstay and backstay cap shrouds all terminate, and the various halyards and lifts run through turning blocks. Only problem is it's more than 75′ (22.8m) above the deck. Hopefully the seagulls are impressed.

Egan pointed out that there's more than aesthetics involved here. "Stainless steel welded parts usually start to corrode at the edges of the weld beads," he said. "When they're finished and polished out like this, corrosion isn't a problem."

L-M's finishers start with rotary abrasives, working through the grits until they end with 15-micron wet/dry paper from 3M, and then finish with rouge paste and a polishing cloth.

New England Castings

This modest foundry specializes in low-volume, high-precision casting using the "lost-wax" process. Said to be the oldest known method of casting metal, with some examples dating back 5,700 years, in its modern industrial form it's known as "investment casting." According to Walter Butler, president of NEC, the process allows casting parts that have a much smoother finish as they come out of the mold than could be achieved with sand casting, the other major method to cast bronze/brass, iron, steel, stainless steel, and hardened steels. Investment casting can also yield more complicated parts than is possible with sand casting.

In a traditional lost-wax foundry, the pattern is made of paraffin wax, which is easy to shape and carve. Then the pattern is dipped alternately in a silica fluid and a sand (silica) grit, and allowed to dry until the pattern is encased in a ½″-thick (13mm) layer of dried silica. This is the mold, which is placed in an oven, where the silica hardens into a solid, and the wax melts and runs out, leaving a void in the exact shape of the pattern. In this process, called the "burnout," the heat also hardens the mold so it can withstand being filled with molten metal, which is poured into the mold and allowed to solidify as it cools. When the foundrymen break the silica mold away from the part, an exact copy of the pattern remains.

Making patterns of wood or wax is a highly skilled occupation. A pattern must not only be shaped correctly, it has to be shaped "wrong" in order to be right. That's because molten metal shrinks as it solidifies; how much depends on the metal. So the traditional patternmaker lays out the work with special rulers that compensate for shrinkage, and if it's all done right, the intentionally distorted pattern—which is not an exact copy of the desired finished casting—yields parts of the intended shape and dimensions.

A company like NEC doesn't make many molds by hand anymore. The functions of designer, draftsman, and patternmaker are combined in a computer process: the designer runs a three-dimensional (3D) drafting program (Solidworks 3D CAD), which is set up to alter measurements to compensate for shrinkage. Once the design is complete, the digital file is sent to Stratasys Direct Manufacturing (Valencia, California), where the file is "printed" on a 3D printer, yielding a plastic pattern of the part. Because the drafting program has already compensated for shrinkage during casting, the plastic printed pattern is dipped in silica slurry, as with a wax pattern, and then burned out, where the plastic burns, instead of melting like wax.

STEPHEN OLSON

Investment casting is an art at NEC. Employing an optical emission spectrometer, the crew can fine-tune alloys by adding scoops of crushed elements, including chromium, manganese, cobalt, and nickel.

A significant advantage of this approach is that the digital file of the pattern design can be easily adjusted so the printer produces an exact plastic prototype of the cast part, and the prototype can be tried on for fit and function before casting the part in metal. This can save a lot of time and money.

Walter Butler has an industrial technology education and knows a market when he sees one. He originally came to NEC as an employee, but when the former owners lost a contract to make military firearms parts they despaired of finding other work. Butler did not. "I thought there were other things we could do," he said. Today the company employs a crew of around 40, casting everything from parts for the U.S. Army's Abrams tank, to precision high-temperature parts for industrial gas turbines used to generate electricity.

The foundry setup at NEC shows that the company can meet high standards. In a room adjacent to the foundry, a peculiar machine stares through big windows into the foundry. This optical emission spectrometer can look with its electronic eye at the flash of an electric arc and quickly identify and quantify all the elements of an alloy. Next to the spectrometer is a rack of bins built against the wall, each bin with a scoop like one used for bulk food at a pet store, except these bins hold what looks like crushed

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Above—*All the custom turning blocks seen on page 54, as well as the outhaul cars, were made by Harken (Pewaukee, Wisconsin).* ***Right***—*Shown here is a mix of cast, machined, and welded rig components for the Pedrick 65.*

rock, labeled Chromium, Manganese, Cobalt, Nickel, Iron, Copper, and so on. Butler explained that if a company wants to be in the business of casting parts like turbine blades, which must survive inside the high temperatures and loading environment of a gas-fired geared shaft turbine, the foundry must be able to ensure that the metal poured into the mold conforms exactly to the turbine builder's specification. The spectrometer can do that, and the alloy of the molten charge can be corrected by adding precisely measured ore from the bins on the wall.

For the Pedrick 65's castings, the specification was Duplex 2205, a fairly recent alloy with greater strength and corrosion-resistance than 316L. (See "The Power and Peril of Stainless," PBB No. 146, specifically page 52.) Chemical composition as percentage of weight includes:

22% chromium (CR)
5.7% nickel (NI)
3.1% molybdenum (MO)
0.02% carbon (C)
0.17% nitrogen (N)

For casting work, the metal's designation is ASTM A890-4A.

After the molten metal has cooled, the mold is broken and the casting inspected. If it passes, it goes to the machine shop for any necessary work, and finally to the finishers. In a conventional metal shop you might call these guys "grinders," because that's the primary tool in use. But here they sometimes only start with grinders, followed by abrasive paper in finer and finer grits. Before writing this article, I was not aware that the 3M company makes 15,000-grit sandpaper.

"The toaster," the main boom cap fitting, accommodates sheaves for topping lift, outhaul, and reefing clew lines. Cast by NEC, it includes fabricated elements from Lyman-Morse.

COURTESY ARTISAN BOATWORKS

An interesting aspect of this joint metalworking project is illustrated by what came to be known as "the toaster," which is the aft cap of the main boom. Because the spar is rectangular in section, so too is the cap casting, with three slots cast in the top for the sheaves for topping lift, clew outhaul, and reefing clew lines. It's a big, shiny box, and with the slots in the top it looks a lot like that humble kitchen appliance. But the interesting thing to me was that even though NEC did the base casting, and L-M did the machine work, it is impossible to tell where one shop's work leaves off and the other's begins. This is true throughout.

COURTESY ARTISAN BOATWORKS

Before the mainmast's two halves are epoxied together, the conduit is secured inside, and tag-lines to run the multiple halyards in the mast are kept free of all constrictions. The smooth bronze deflector plate in the center will limit halyard chafe when the mast is tensioned and bent while sailing.

As the bits and pieces of hardware were finished, they were delivered to Artisan. Construction of the smaller spars, beginning with the mizzenmast, had begun in March 2015. The main boom was under way in the late summer. The mainmast had been partially glued up during this time, creating an 84′-long obstacle right through the machinery room. Conduits for mast electrical wiring and blocking for the spreader mounts and shroud tangs had been fitted, but final details of mast fittings had been postponed until all fittings for the other spars had been completed. Pending the design of remaining mast details, the two halves of the spar couldn't be glued together, so they were hoisted overhead and lashed to the rafters as Artisan's crew shifted to other projects.

COURTESY ARTISAN BOATWORKS (BOTH)

Reasons for the delay? These spars and their fittings are highly customized. Normally, according to Pedrick, if a boat is to be fitted with a conventional aluminum or carbon fiber mast, the spar company contracting to build the rig has a design staff to choose the appropriate parts from the company's stock, or to design custom hardware. In contrast, the entire design and engineering project for the Pedrick

Sanding the outside of the completed spar was as obsessively meticulous as the rest of the build. It required a series of custom-cut hard-foam sanding blocks shaped to the specifically designed sectional curvatures of the spar at various points along its tapered length.

65's spar package started with a blank sheet of paper. The calculations for every part had to be done from scratch, and Pedrick Yacht Designs was assigned, as well, to produce the associated shop-level detailed drawings. Such expanded scope of work is a peril of specialized, custom projects, and puts pressure on all their participants.

As plans finally arrived at the shop, the Artisan crew finished the internal mast structures and closed the two halves to make a complete spar at last. On April 15, 2016, it was loaded onto a semi-trailer rig and shipped to East Boothbay, where the hull was nearing completion. On May 11, before a moderate crowd of onlookers, a crane picked the mast up and, with a full gang of yard workers and riggers in attendance, stepped the spar before the shrouds and stays were tightened to their preliminary tension. As they tightened up, the mast began to bend, alarmingly. "I thought it was going to snap," said Brainerd. Something was clearly wrong, and the first line of discovery was to get the mast out of the boat and lay it over a pair of mast stands. Then, to check stiffness, riggers suspended a weight from the midpoint of the mast. "It was maybe a thousand pounds [454 kg]," Brainerd said. "I was amazed the mast didn't break."

In fact, crunching the numbers on the amount of bend in the mast due to the applied weight showed that the mast was actually stiffer than expected. This led to searching for other causes of the excessive bend. Attention turned to the spreaders. On this rig, the spreaders have a fair amount of sweepback, as opposed to just sticking out perpendicular to the centerline. This is a modern development, and in this regard the rig in the Pedrick 65 is quite modern, even though the spars are built of wood. Swept spreaders, Kevlar running backstays, rod rigging, and hydraulic stay-tensioning are all rig elements unknown or very rare in the CCA era.

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Stepping the mast, varnished to a high shine, in the completed hull. The swept spreaders, fully rigged here, presented a problem when the rig was initially tensioned. Testing determined that the spreaders were out of plane with the masthead tang and chainplates. Correcting the sweep angle remedied the error.

Swept spreaders simplify a rig, eliminating the need for double lower-shrouds to stabilize the mast at the lower spreaders, and reducing or possibly eliminating the need for checkstays. However, it is critical that the spreader tips be in the same plane as the cap-shroud-masthead tang and chainplates. If they aren't, tightening up the rig will over-bend the mast and risk breaking it.

The solution involved machining the spreader mounts to correct the sweep angle, bringing the spreader ends into plane. Not rocket science, but any process that involves big truck cranes, rigging gangs, relaunching, and copious amounts of engineering and consultant time does not come cheap.

In the end, the rig stood up straight, the vessel passed her builder's trial, and she was delivered to her new home in midcoast Maine, where her bright finished spruce mast stands out among the forest of production aluminum and carbon spars that surround her. PBB

***About the Author:** Stephen Olson is a certified marine surveyor with 30 years of experience. Based in Belfast, Maine, he surveys yachts and workboats, sail and power. He has sailed as engineer and licensed master on tugboats, as bosun on oceangoing tankers, and as licensed master on schooners in semester-at-sea programs.*