

If you've lost your balance and are careening toward the leeward rail, your boat's lifelines are all that stand between "onboard" and "overboard."

Make sure your "safety net" is up to the task!

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Between The Deck And A Wet Place

In order to better understand the forces involved and the failures experienced in lifeline systems, I organized a joint U.S. Naval Academy/ US Sailing multiphase research project that was partially funded by the Cruising Club of America. Our goal was to quantify the loads imposed upon lifeline components and determine when and how failures occur.

USNA mechanical-engineering majors first designed a full-scale replica of the deck perimeter of a Navy 44, the academy training boat. Its lifeline system is considered to be structurally sound. Next, skilled welders fashioned a testing jig from hefty mild-steel box beams and I-beams. Stanchion-base sockets were welded to the jig itself under the assumption that the vessel's deck could withstand the point loads imposed and that stanchion failure due to a light laminate would not be an issue. Once the jig was completed, the stanchions and lifeline rigging were installed using uncoated 1/4-inch 1x19 wire for the upper line and uncoated 3/16-inch 1x19 wire for the lower line (the same wire used on the 44). Navtec provided the hardware and loaned the project an in-line strain gauge. After rigging the jig, the midshipmen installed strain gauges and rigged a tensioning device that could apply up to 12,000 pounds of static load. Although most failures arise from dynamic forces — such as the loads imposed by a crewmember who is thrown across the deck — these forces can be converted to and compared with a static load. As the jig was being readied, riggers swaged short sections of wire and end fittings that were tested to destruction in a powerful INSTRON tensioning machine. This data was later compared with the loads recorded in the full system test, and helped to define where the Achilles heel of a lifeline system lay. To insure validity the test process was repeated several times and compared with previous findings. These phase-one results showed us how a lifeline system spreads loads and what components are most prone to failure.

The first surprise was that lifelines and hardware (at least the heavy-duty selection employed aboard the Navy 44s) usually don't fail. The critical point of failure occurs in the pulpit and tubular stanchions, which in turn slackens the wire and permits it to deflect outboard. As this deflection is gradual rather than instantaneous and may still prevent a crewmember from going overboard, this mode of failure is less cataclysmic than if the wire actually parted. An outward load that translates into wire tension puts extreme loads on the bow and stern pulpits and, in some cases, leads to failure of their welds. Tubular stanchions can withstand heavy compression loads but cope poorly with side loads. This bending moment results in a crimp of the tube wall where the stanchion exits the base, allowing the vertical support to fail rather than bend like a palm tree in a hurricane. Surprisingly, the system began to fail at just over 1,000 pounds even though the wire could handle many times that load. In follow-up testing, bow and stern pulpits were replaced by a weldment that could handle several thousand pounds of tensile loading without any significant deflection. In these tests, the same wire and stanchions withstood almost three times the load imposed in the first round of testing. When failure did occur, the cause was a wire pulling out of a swage fitting. The lesson learned? Every skipper should regularly inspect his boat's lifeline system, especially bow and stern pulpits, which should be configured to effectively oppose loads coming from opposite ends of the boat. Stern pulpits are often fabricated without the angled tube sections that can better withstand the tension transmitted by lifelines. Often, these stern rails have only four tubular upright supports, none of which is situated at an after corner of the stern deck. During the off season, pulpits can be removed and taken to a tube-steel fabricator who can weld on an additional reinforcing structure. An extra set of support legs can also be a worthwhile addition.

Lifeline Test

Lifelines and stanchions must work together. In a worst-case scenario, they can mean the difference between life and death. But they're also used as weather-cloth attachment points, as lashing arms for an array of gear, and by dockside

hands trying to stop a boat that's coming alongside. Until they're really needed, lifelines are generally abused and taken for granted.

Understanding The Components

In any onboard system made up of many components, one weak link can precipitate a major failure. Because many lifeline fittings are shackled, pinned, screwed, or even lashed together, it takes only one "undoing" to spell disaster. Wear and tear take their toll, so it's vital each part is appropriately sized and regularly inspected. Firsthand reports on lifeline failure reveal two things: quality U.S.- and European-made wire rope rarely breaks, and top-of-the-line terminals offer visual warning signs of deterioration prior to failing. Failure is often caused by a lost clevis pin (after the ring pin is accidentally yanked out by a snagged jib sheet), or a loose turnbuckle nut that allows the barrel to unwind. Gate hardware and some imported plastic-coated 7x7 wire are also prone to failure. So it makes sense to eliminate gates when possible and to replace coated, uninspectable rigging wire with conventional 1x19 wire. If you require a lifeline gate, don't skimp on the hardware, especially the gate clips. Like opposing teams in a tug-of-war, the bow and stern pulpits have to resist the loads transmitted through the connecting wire. To withstand the extreme force of a heavy crewmember pitched into a lifeline, these tubular rails must be well constructed and securely anchored to the deck. The growing use of open bow pulpits, once found on a few one-design racing boats but now fitted to many new production cruisers, is disturbing. Omitting the pulpit's continuing upper tube further destabilizes an already weak link in the lifeline system.

Ironically, some lifeline failures stem not from broken hardware, but from modern sandwich core deck-construction techniques. On some decks built in this manner, the core is eliminated near the hull/deck joint and the laminate is fairly thin. Particularly around the stanchion bases, there often isn't enough point-load resistance to handle routine tension and compression strains caused by leverage exerted on stanchion bases. Backing and topping plates and additional fiberglass in the area of the hull-deck joint may be needed to prevent the deck from failing. It's easy to determine whether this is a strong or weak link on your boat. When you re-bed your stanchion bases, measure the laminate thickness and check for the presence of backing plates. To continue the inspection, examine the bow- and stern-pulpit welds closely. Let an experienced rigger inspect any hairline cracks or excessive rust-colored residue. Be very attentive also to where the eye straps are welded to the rail. Toggles and turnbuckles are attached to these fittings, thus they are vital components. Lifeline stanchions need to stay in column, but due to the geometry of the system the lifelines transmit bending loads to the stanchions. The result can be considerable deflection and early failure, especially if the lifelines are loose and sloppy.

On many cruising boats, stern rails take on the appearance of an offshore drilling platform. In addition to anchoring the lifelines, they serve as mounts for solar panels, wind generators, biminis, and dinghy davits. The additional loads imposed by these components may impact the entire fabrication's structural integrity. When a big dinghy hangs in light davits attached to a stern arch that's loaded down with heavy, high-windage gear and is then tied off to the stern pulpit, there is cause for concern — especially when the boat to which it's affixed is heading offshore. Deck-sweeping seas are much heavier than the breeze blowing across the deck and can subject the tube fabrications, and the deck itself, to tremendously destructive forces. Most designers do not factor in the reinforcement required by these intricate struts; such retrofits need to be properly engineered. Radar pedestals or arches should be independent structures that do not compromise the integrity of the pulpits or lifelines.

Improving Your Lifeline System

To begin a lifeline upgrade, make sure your system meets the ISAF Special Regulations for Offshore Sailing. Though these rules have been drafted by the international racing community, they are equally appropriate for cruising sailors. In addition to setting minimum standards for stanchion height and placement, wire size, and hardware specifications, the regulations explain how to determine if your lifelines are properly tensioned. If your system fails to meet the specifications or seems flimsy, an off-season upgrade is a worthwhile winter project. First remove all wire and hardware while looking closely for signs of wear. Polish away stains, and with a jeweler's loupe hunt for stress cracks. Replace fittings that show significant signs of corrosion, distortion, or friction damage. Plastic-coated wire is impossible to inspect and quality varies — it can last 20 years, or fail in less than 10. It's wiser to replace 10-year-old wire that's had a hard life than it is to worry about it. Once all the wire is released, wiggle each stanchion, and note whether tip movement is due to a sloppy stanchion-to-socket fit or to a flexing deck near

the stanchion base. If movement is not excessive and the sockets seem substantial, you can ignore the former — but you must address the latter. Thin, weak, and poorly reinforced decks often show serious stress cracks in the gelcoat and in the laminate around the stanchion bases. Add stainless steel or FRP top and bottom plates to rectify this problem ("A Strong Stanchion To Save Your Life," *Cruising World*, Dec. '96). Simple hand tools can normally be used to remove stanchions and pulpits. The stainless steel stanchion is often inserted into a through-bolted base and pinned in place with a machine screw. Other stanchions are one-piece fabrications incorporating both the base and tube. While these are more rigid, several fasteners may need to be unscrewed for complete removal. Whatever the style, once they're off it's important to evaluate the condition of the deck around the installation points. Holes that penetrate the deck are susceptible to leaks. If the deck is cored with balsa or plywood there's a good chance that some repair work will be required.

A research project carried out by U.S. Naval Academy midshipmen revealed that the weak links in a lifeline system are the pulpits, and that the entire system could be improved by structural reinforcement. The objective in such an upgrade is to add tubular bracing to support lifeline tension and prevent structural collapse. It doesn't take a mechanical engineer to beef up a poorly reinforced pulpit. You can add tubing to oppose the loads induced by a tensioned lifeline. To accomplish this, take some 1-inch softwood dowel stock and a coping saw, and with duct tape mock-up a set of new support struts on your boat's bow and stern pulpit. Bring the assembly to a stainless steel fabricator with instructions to cut, fit, and weld the additional tubular reinforcement exactly where the dowels have been placed. Diagonal struts, extra legs, and reinforced lifeline attachment points are all alterations that can be done in the welding shop. Remember, your deck has a different camber than the welder's work table. If you're adding legs, it's vital that the mock-up accurately reflect their base-plate shape and angles. Do this before you disassemble the system. Many fabricators prefer to tack-weld new components in place and then return them to the boat to check the fit before welding them permanently.

With the hardware stripped, carefully inspect the bolt holes from above and below the deck. Look for any evidence of leaks, and make sure the bolt holes are free of core material. In many cases stanchion bases span the overlapped solid-glass region of the hull/deck joint and penetrate the deck at the point where the core begins and where there are often voids. If you find such a problem in your own boat, invest a little time and epoxy to plug the voids and seal those frustrating leaks. Here's how: Using a bent, headless nail or similar tool chucked into a power drill, remove all the soft wet core from around the bolt holes, then vacuum any residue from the holes. Cut back 1 inch of core around the fastener holes. Next, place a 1/4-inch bung in the bottom hole, and using West System 105/205 resin and 403 filler, make up a paste to inject into the cavity from above. I mix small amounts of filler at a time and use a plastic syringe to fill the holes. Keep in mind that you must let air escape through the injection hole. If it can't purge, pressure will build and the deck may be damaged. Once the filler has cured, redrill the holes, then bed and replace the stanchions. The result will be fewer leaks and a stronger deck at reinstallation time, remember the weak-link theory. Use new cotter pins, carefully seize all shackles, and pin or lock-nut the turnbuckles. During the season, note lifeline tension and avoid misuse whenever possible. That thin wire line, after all, may ultimately make the difference between a lovely sail and a very bad day.

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Photos

Midshipmen at the US Naval Academy are taught that sailboat lifelines are a grab-rail of last resort. They learn that these systems need to be carefully maintained and regularly checked for wear and tear.

1. Now that lower lifelines also play a key role in keeping movable "crew" ballast from going over-the-side, the safety ante has been raised, and it made sense for Navy Sailing and US Sailing to team up and take a closer look at what's involved. Analyzing the bits and pieces of hardware, stainless steel wire, and tubular stanchions that help keep crews on deck proved to be a significant challenge .

2. Mechanical Engineering majors at the Naval Academy developed a senior research project to analyze the lifeline system found aboard Navy 44's. They designed and oversaw the fabrication of a full scale jig that would be used as

a base upon which to erect a life line system identical to what's found aboard the Navy sloops. The mids devised a tension loading system that replicated crew weight hiking against a lower lifeline, and installed instrumentation that measured the loads being imposed at numerous points around the jig.

3. Their initial findings indicated that lifeline wire, especially the 1X19 non coated rigging used on the academy boats, and the swages and hardware stood up well to the loads imposed. Surprisingly, the weak link in the system was the stern pulpit which was the first structure to give way under load.

4. Individual stanchions, swage fittings and other hardware were also tested to failure. Stanchions failed near their base as the tubing was crimped by the socket itself. These deflection failures were gradual, and in an actual sailing context they might prove to be less of a danger than an abrupt parting of the wire itself. Even so, the resulting slack in the lifeline could easily allow a crew member to be swept overboard.

5. During the testing process data was carefully recorded, and after repeated measurements the midshipmen wrote up their results presenting their findings to the academic staff of the Mechanical Engineering Department. The peer review process provided an opportunity to evaluate the results as well as the test protocol itself. It also helped define additional areas that phase two of this project would look into.